COLORADO

Air Pollution Control Division

Department of Public Health & Environment

Technical Services Program

2023 Air Quality Data Report

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COLORADO AIR QUALITY DATA REPORT

2023

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October 24, 2024

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Glossary of Terms

AADT	Annual Average Daily Traffic
APCD	Air Pollution Control Division
AQS	Air Quality System (EPA database)
BLM	Bureau of Land Management
CAMP	Continuous Air Monitoring Program
CAQCC	Colorado Air Quality Control Commission
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CO	Carbon monoxide
CV	Coefficient of Variation
DQO	Data Quality Objective
EPA	U.S. Environmental Protection Agency
IMPROVE	Interagency Monitoring of Protected Visual Environments
MSA	Metropolitan Statistical Area
NAAQS	National Ambient Air Quality Standards
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_x	Oxides of nitrogen
NO_y	Total reactive nitrogen
NPS	National Park Service
O_3	Ozone
Pb	Lead
$PM_{2.5}$	Particulate matter with an equivalent diameter less than or equal to 2.5 micrometers
PM_{10}	Particulate matter with an equivalent diameter less than or equal to 10 micrometers
ppb	Parts per billion (one part in 10^9)
ppm	Parts per million (one part in 10^6)
PM	Particulate Matter
QA/QC	Quality Assurance/Quality Control
RAQC	Regional Air Quality Council
RAVI	Reasonably Attributable Visibility Impairment
SIP	State Implementation Plan
SLAMS	State or Local Air Monitoring Stations
SO_2	Sulfur dioxide
SPM	Special Purpose Monitor
STN	Speciation Trends Network
TSP	Total Suspended Particulates
µg	Microgram (10^{-6} grams)
USFS	U.S. Forest Service
VOC	Volatile Organic Compound

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Introduction

The Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE) has prepared the 2023 Air Quality Data Report as a companion document to the Colorado Air Quality Control Commission Report to the Public. The Air Quality Data Report addresses historical trends in air quality and includes a detailed examination of the monitoring data collected by APCD in 2023. The Report to the Public discusses the policies and programs designed to improve and protect Colorado's air quality.

1.1 Overview of the Colorado Air Monitoring Network

APCD conducted air quality and meteorological monitoring operations at 45 locations statewide during 2023. Ozone (O_3) and particulate matter (PM) monitors, including those for particulate matter less than 10 μm in diameter (PM_{10}) and particulate matter less than 2.5 μm in diameter ($PM_{2.5}$), are the most abundant and widespread monitors in the network. During 2023, there were PM_{10} monitors at 17 locations, $PM_{2.5}$ monitors at 19 locations, O_3 monitors at 22 locations, carbon monoxide (CO) monitors at seven locations, nitrogen dioxide (NO_2) monitors at seven locations, and sulfur dioxide (SO_2) monitors at four locations. APCD also operated 19 meteorological sites statewide for the continuous measurement of wind speed, wind direction, temperature, and other various meteorological parameters.

A map of APCD air quality stations is shown in Figure 1.2 and the parameters monitored at each location are given in Table 1.1.

1.1.1 APCD Monitoring History

The State of Colorado has been monitoring air quality statewide since the mid-1960s when high volume and tape particulate samplers, dustfall buckets, and sulfation candles were the state of the art for defining the magnitude and extent of the very visible air pollution problem. Monitoring for gaseous pollutants (CO, SO_2, NO_2, and O_3) began in 1965 when the federal government established the CAMP monitoring station in downtown Denver at the intersection of 21st Street and Broadway, which was the area that was thought at the time to represent the best site for detecting maximum levels of most of the pollutants of concern. Instruments were primitive by comparison with those of today and were frequently out of service.

Under provisions of the original Federal Clean Air Act of 1970, the Administrator of the U.S. EPA established National Ambient Air Quality Standards (NAAQS) designed to protect the public's health and welfare. Standards were set for total suspended particulates (TSP), CO, SO_2, NO_2, and O_3. In 1972, the first State Implementation Plan (SIP) was submitted to the EPA. It included an air quality surveillance system in accordance with EPA regulations of August 1971. That plan proposed a monitoring network of 100 monitors (particulate and gaseous) statewide. The system established as a result of that plan and subsequent modifications consisted of 106 monitors.

The 1977 Clean Air Act Amendments required States to submit revised SIPs to the EPA by January 1, 1979. The portion of the Colorado SIP pertaining to air monitoring was submitted separately on December 14, 1979, after a comprehensive review, and upon approval by the Colorado Air Quality Control Commission. The 1979 EPA requirements as set forth in 40 CFR 58.20 have resulted in considerable modification to the network. These and subsequent modifications were made to ensure consistency and compliance with Federal monitoring requirements. Station location, probe siting, sampling methodology, quality assurance practices, and data handling procedures are all maintained throughout any changes made to the network.

1.1.2 Description of Monitoring Regions in Colorado

The state has been divided into eight multi-county areas that are generally based on topography and have similar airshed characteristics. These areas are the Central Mountains, Denver Metro/North Front Range, Eastern High Plains, Pikes Peak, San Luis Valley, South Central, Southwestern, and Western Slope regions. Figure 1.1 shows the approximate boundaries of these regions.

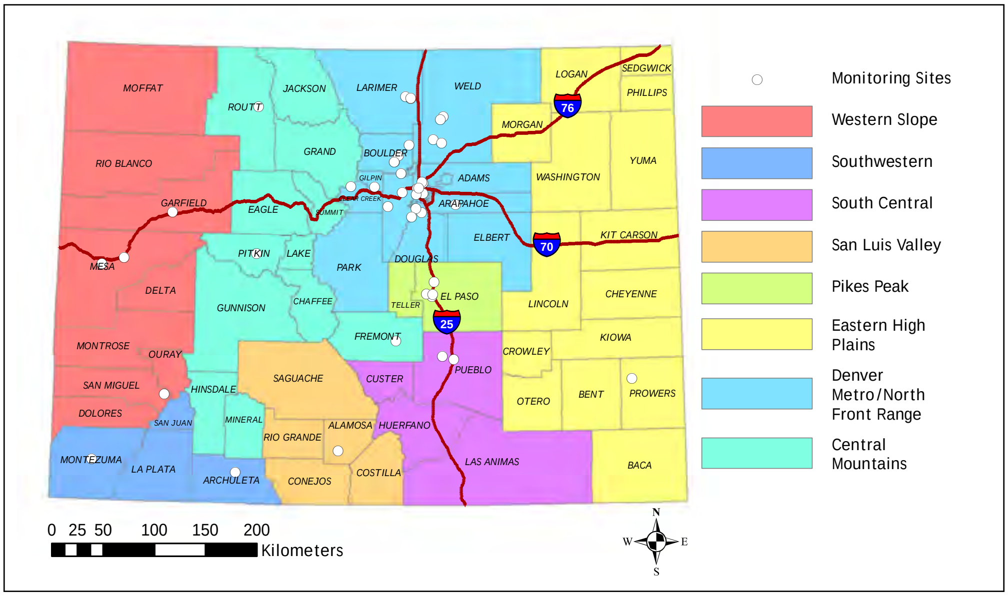

Figure 1.1: Counties and multi-county monitoring regions discussed in this report.

1.1.2.1 Central Mountains Region

The Central Mountains region consists of 12 counties in the central area of the state. The Continental Divide passes through much of this region. Mountains and mountain valleys are the dominant landscape features. Leadville, Steamboat Springs, Cañon City, Salida, Buena Vista, and Aspen represent the larger communities. The population of this region is approximately 245,763, according to the 2020 U.S. Census. Skiing, tourism, ranching, mining, and correctional facilities are the primary industries. The Black Canyon of the Gunnison National Park is located in this region.

The primary monitoring concern in this region is centered around particulate pollution from wood burning and road dust. During 2023, there were three particulate monitoring sites operated by APCD in the Central Mountains region. APCD also operates an O_3 monitor in this region, at the high-elevation Mines Peak monitoring site. This site is not considered a regulatory site for O_3 due to difficulties controlling the internal temperature of the shelter. All of this region complies with federal air quality standards.

1.1.2.2 Denver Metro / North Front Range Region

The Denver Metro/North Front Range region includes Adams, Arapahoe, Boulder, Broomfield, Clear Creek, Denver, Douglas, Elbert, Gilpin, Jefferson, Larimer, Park, and Weld counties. This 13 county region comprises the largest population base in the state of Colorado with approximately 4,143,171 people living in the area, according to the 2020 U.S. Census. This region includes Rocky Mountain National Park and several other wilderness areas. Since 2002, the region has complied with all National Ambient Air Quality Standards, except for ozone. The area has been exceeding the EPA's ozone standards since the early 2000s, and in 2007 was formally designated as a "nonattainment" area. This designation was re-affirmed in 2012 when the EPA designated the region as a "marginal" nonattainment area after a more stringent ozone standard was adopted in 2008. In 2015, the EPA reviewed criteria for ozone and related photochemical oxidants and revised the primary and secondary 8 hour ozone standards further downward to a level of 0.070 parts per million (ppm). In June 2018, EPA classified the region as a "marginal" nonattainment area for the 2015 8-hour ozone standard, effective August 3, 2018. The attainment deadline for the 2015 standard was August 3, 2021, based on 2018-2020 ozone season data. In January 2020, EPA classified the region as a "serious" nonattainment area under the 2008 ozone standard. The attainment deadline for the 2008 standard was July 20, 2021, based on 2018-2020 ozone season data. In 2022, EPA classified the region as a "severe" nonattainment area for the 2008 8-hour O_3 standard.

In the past, the Denver-metropolitan area has violated health-based air quality standards for carbon monoxide and fine particles. In response, the Regional Air Quality Council (RAQC), the Colorado Air Quality Control Commission (CAQCC), and APCD developed, adopted, and implemented air quality improvement plans to reduce each of these pollutants. For the rest of the Northern Front Range, Fort Collins, Longmont, and Greeley were nonattainment areas for carbon monoxide in the 1980s and early 1990s, but have met the federal standards since 1995. Air quality improvement plans have been implemented for each of these communities.

During 2023, there were 53 air quality and meteorological monitors at 27 individual sites in the Northern Front Range Region. There were six CO monitors, 16 O_3 monitors, seven NO_2 monitors, three SO_2 monitors, as well as seven PM_{10} monitors, 14 $PM_{2.5}$ monitors, and 15 meteorological towers. There were also two air toxics monitoring sites, one located at CAMP, and one at Platteville. The CAMP site monitors urban air toxics, while the Platteville site monitors air toxics in a region of oil and gas development.

1.1.2.3 Eastern High Plains Region

The Eastern High Plains region encompasses the fifteen counties on the plains of eastern Colorado. The area is semiarid and often windy. The area's population is approximately 134,688, according to the 2020 U.S. Census. Its major population centers have developed around farming, ranching, and trade centers such as Sterling, Fort Morgan, Limon, La Junta, and Lamar. The agricultural base includes both irrigated and dry land farming.

Historically, there have been a number of communities in the Eastern High Plains Region that were monitored for particulates and meteorology but not for any of the gaseous pollutants. In the northeast along the I-76 corridor, the communities of Sterling, Brush, and Fort Morgan have been monitored. Along the I-70 corridor, only the community of Limon has been monitored for particulates. Along the US-50/Arkansas River corridor, the Division has monitored for particulates in the communities of La Junta and Rocky Ford. These monitoring sites were all discontinued in the late 1970s through early 1990s after a review showed that the concentrations were well below the standards and trending downward. The only sampling site left in operation in this region is a PM_{10} monitoring site located in Lamar.

1.1.2.4 Pikes Peak Region

The Pikes Peak region includes El Paso and Teller counties. The area has a population of approximately 783,027, according to the 2020 U.S. Census. Eastern El Paso County is rural prairie, while the western part of the region is mountainous. The U.S. Government is the largest employer in the area, and major industries include Fort Carson and the U.S. Air Force Academy in Colorado Springs, which are both military installations. Aerospace and technology are also large employers in the area. All of the area is currently in compliance with federal air quality standards. However, two exceedances of the level of the SO_2 standard were observed at the Highway 24 site during 2014-2015. These elevated values have not resulted in a violation of the NAAQS and SO_2 concentrations have been trending downward at the Highway 24 site since 2016 (see subsection 4.4.4).

During 2023, there was one CO monitor, one SO_2 monitor, and two O_3 monitors in the Pikes Peak region, as well as one PM_{10} monitor and one $PM_{2.5}$ monitor. Most of these monitors are located in the populous city of Colorado Springs.

1.1.2.5 San Luis Valley Region

Colorado's San Luis Valley region is located in the south central portion of Colorado and is comprised of a broad alpine valley situated between the Sangre de Cristo Mountains on the northeast and the San Juan Mountains of the Continental Divide to the west. The valley is some 114 km wide and 196 km long, extending south into New Mexico. The average elevation is 2290 meters. Principal towns include Alamosa, Monte Vista, and Del Norte. The population of this area is approximately 46,495, according to the 2020 U.S. Census. Agriculture and tourism are the primary industries. The valley is semiarid and croplands of potatoes, head lettuce, and barley are typically irrigated. The valley is home to Great Sand Dunes National Park.

In 2023, CDPHE operated a single monitoring site in this region, which serves as both a PM_{10} and $PM_{2.5}$ site located in Alamosa. This site began operation on 10/26/2023.

1.1.2.6 South Central Region

The South Central region is comprised of Pueblo, Huerfano, Las Animas, and Custer counties. Its population is approximately 196,119, according to the 2020 U.S. Census. Population centers include Pueblo, Trinidad, and Walsenburg. The region has rolling semiarid plains to the east and is mountainous to the west. All of the area complies with federal air quality standards. In the past APCD has conducted particulate monitoring in both Walsenburg and Trinidad, but that monitoring was discontinued in 1979 and 1985, respectively, due to low concentrations.

During 2023, there were two particulate monitors (one PM_{10} monitor and one $PM_{2.5}$ monitor) operated in the South Central Region, both at a site located in the city of Pueblo. There was also one O_3 monitor and one meteorological tower located in this region during 2023.

1.1.2.7 Southwestern Region

The Southwestern region includes the Four Corners area counties of Montezuma, La Plata, Archuleta, and San Juan. The population of this region is approximately 101,595, according to the 2020 U.S. Census. The landscape includes mountains, plateaus, high valleys, and canyons. Durango and Cortez are the largest towns, while lands of the Southern Ute and Ute Mountain Ute tribes make up large parts of this region. The region is home to Mesa Verde National Park. Tourism and agriculture are the dominant industries, although the oil and gas industry is becoming increasingly important. All of the area complies with federal air quality standards.

During 2023, there was one O_3 monitor located in Cortez and one PM_{10} monitor located in Pagosa Springs.

1.1.2.8 Western Slope Region

The Western Slope region includes nine counties on the far western border of Colorado. A mix of mountains on the east, and mesas, plateaus, valleys, and canyons to the west form the landscape of this region. Grand Junction is the largest urban area, and other cities include Telluride, Montrose, Delta, Rifle, Glenwood Springs, Meeker, Rangely, and Craig. The population of this region is approximately 332,293, according to the 2020 U.S. Census. Primary industries include ranching, agriculture, mining, energy development, and tourism. Dinosaur and Colorado National Monuments are located in this region.

During 2023, there was one O_3 monitor in Rifle, one O_3 monitor and a meteorological tower in Palisade, PM_{10} monitoring in Telluride, and PM_{10} and $PM_{2.5}$ monitoring in Grand Junction. The Grand Junction Pitkin site is equipped with meteorological instrumentation. All of the area complied with federal air quality standards during 2023.

1.1.3 Monitoring Site Locations and Parameters Monitored

Table 1.1: Summary of parameters monitored at APCD monitoring sites discussed in this report. Detailed site descriptions can be found in Appendix A.

AQS Site Number	Site Name	County	Parameters Monitored						
			O_3	CO	NO_2	SO_2	PM_{10}	$PM_{2.5}$	Met
08-001-0010	Birch Street	Adams					X	X	
08-001-3001	Welby	Adams	X	X	X	X	X		X
08-003-0001	Alamosa - ASC	Alamosa					X	X	
08-005-0002	Highland Reservoir	Arapahoe	X						X
08-005-0005	Arapaho Community College (ACC)	Arapahoe						X	
08-005-0006	Aurora - East	Arapahoe	X						X
08-007-0001	Pagosa Springs School	Archuleta					X		
08-013-0003	Longmont - Municipal Bldg.	Boulder					X	X	
08-013-0012	Boulder Chamber of Commerce (CC)	Boulder					X	X	
08-013-0014	Boulder Reservoir	Boulder	X						X
08-013-1001	Boulder - CU	Boulder					X	X	
08-019-0006	Mines Peak	Clear Creek	X						
08-031-0002	CAMP	Denver	X	X	X	X	X	X	X
08-031-0013	National Jewish Health (NJH)	Denver						X	
08-031-0026	La Casa	Denver	X	X	X	X	X	X	X
08-031-0027	I-25: Denver	Denver		X	X			X	X
08-031-0028	I-25: Globeville	Denver			X			X	X
08-035-0004	Chatfield State Park	Douglas	X					X	X
08-041-0013	U.S. Air Force Academy (USAFA)	El Paso	X						
08-041-0015	Highway 24	El Paso		X		X			X
08-041-0016	Manitou Springs	El Paso	X						
08-041-0017	Colorado College	El Paso					X	X	
08-043-0003	Cañon City - City Hall	Fremont					X		
08-045-0012	Rifle - Health Dept.	Garfield	X						
08-047-0003	Black Hawk	Gilpin	X						
08-059-0006	Rocky Flats - N.	Jefferson	X		X				X
08-059-0011	NREL	Jefferson	X						
08-059-0014	Evergreen	Jefferson	X						X
08-069-0009	Fort Collins - CSU	Larimer						X	
08-069-0011	Fort Collins - West	Larimer	X						X
08-069-1004	Fort Collins - Mason	Larimer	X	X					X
08-077-0017	Grand Junction - Powell Bldg.	Mesa					X	X	
08-077-0018	Grand Junction - Pitkin	Mesa							X
08-077-0020	Palisade Water Treatment	Mesa	X						X
08-083-0006	Cortez - Health Dept.	Montezuma	X						
08-097-0008	Aspen	Pitkin					X		
08-099-0002	Lamar - Municipal Bldg.	Prowers					X	X	
08-101-0015	Pueblo - Fountain School	Pueblo					X	X	
08-101-0016	Pueblo West	Pueblo	X						X
08-107-0003	Steamboat Springs	Routt					X		
08-113-0004	Telluride	San Miguel					X		
08-123-0006	Greeley - Hospital	Weld						X	
08-123-0008	Platteville - Middle School	Weld						X	
08-123-0009	Greeley - Weld County Tower	Weld	X	X					X
08-123-0013	Platteville Atmospheric Observatory (PAO)	Weld	X		X				X

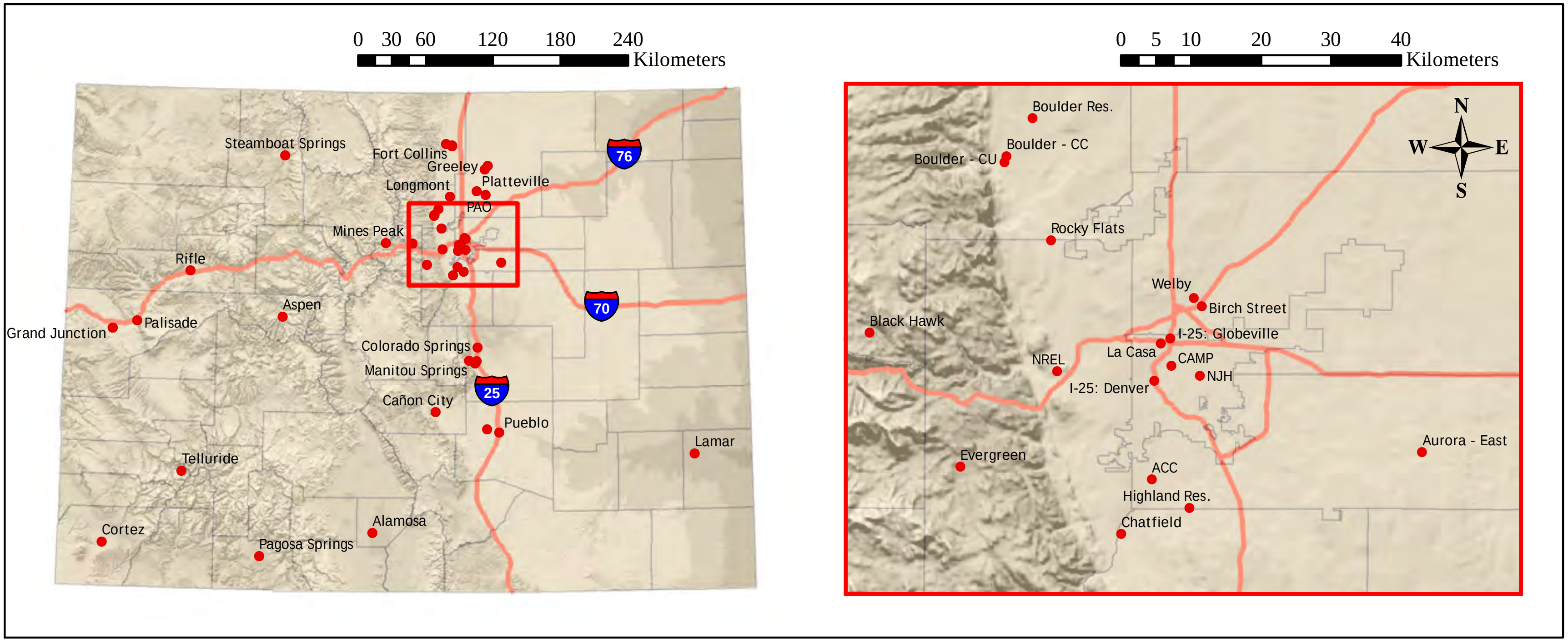

Figure 1.2: Map of Colorado with an inset map of the Denver metropolitan area showing the location of all monitoring sites operated by APCD and listed in Table 1.1. For the purpose of improving the readability of the map, labels for monitoring sites in Fort Collins, Grand Junction, Pueblo, and Colorado Springs have been combined under a single label. Detailed site information, including AQS identification numbers, site descriptions and histories, addresses and coordinates, monitoring start dates, site elevations, site orientation/scale designations, etc., can be found in Appendix A.

2

Criteria Pollutants

Criteria pollutants are those for which the federal government has established National Ambient Air Quality Standards in the Federal Clean Air Act and its amendments. There are six criteria pollutants: carbon monoxide (CO), ozone (O_3), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), lead, and particulate matter, which is currently split into PM_{10} and $PM_{2.5}$ size fractions. Standards for criteria pollutants are established to protect the most sensitive members of society. These are usually defined as those with heart and/or respiratory problems, the very young, and the elderly. The standards for each of the criteria pollutants are discussed in the following sections. A summary of these levels are presented in Table 2.1. The primary standards are set to protect human health. The secondary standards are set to protect public welfare, and take into consideration such factors as crop damage, architectural damage, damage to ecosystems, and visibility in scenic areas.

In 2015, based on an EPA review of O_3 health effects studies, EPA revised the level of both the primary and secondary standards. EPA revised the primary and secondary ozone standard levels to 0.070 parts per million (ppm), and retained their forms (fourth-highest daily maximum, averaged across three consecutive years) and averaging times (eight hours). The final rule making was effective on October 26th 2015.

Due to low measured concentrations over the last decade, the APCD has not operated lead monitors in recent years. Historic trends data are available in data reports from previous years. [1]

2.1 Summary of Exceedances

Table 2.2 is a summary of those APCD sites that have recorded exceedances of the ambient air quality standards in the last two years, with the number of days in exceedance listed. An exceedance of a NAAQS is defined in 40 CFR 50.1 as "one occurrence of a measured or modeled concentration that exceeds the specified concentration level of such standard for the averaging period specified by the standard." A violation of the NAAQS consists of one or more exceedances of a NAAQS. The precise number of exceedances necessary to cause a violation depend on the form of the standard and other factors, including data quality, defined in federal rules such as 40 CFR 50. Exceedances that have been flagged by the Division as exceptional events are shown in parentheses in Table 2.2. See subsubsection 2.2.5.4 for an explanation of exceptional events.

[1] https://www.colorado.gov/airquality/tech_doc_repository.aspx

Table 2.1: National Ambient Air Quality Standards (NAAQS) for criteria pollutants.

Pollutant	Primary / Secondary	Averaging Time	Level	Form
Carbon Monoxide (CO)	Primary	8-hr	9 ppm	Not to be exceeded more than once per year
		1-hr	35 ppm	
Nitrogen Dioxide (NO_2)	Primary	1-hr	100 ppb	98^{th} percentile of 1-hour daily maximum concentrations, averaged over three years
	Primary and Secondary	Annual	53 ppb	Annual mean
Sulfur Dioxide (SO_2)	Primary	1-hr	75 ppb	99^{th} percentile of 1-hour daily maximum concentrations, averaged over three years
	Secondary	3-hr	500 ppb	Not to be exceeded more than once per year
Ozone (O_3)	Primary and Secondary	8-hr	0.070 ppm	Annual fourth-highest daily maximum 8-hr concentration, averaged over three years
PM_{10}	Primary and Secondary	24-hr	150 µg m^{-3}	Not to be exceeded more than once per year on average over three years
$PM_{2.5}$	Primary	Annual	12 µg m^{-3}	Annual mean, averaged over three years
	Secondary	Annual	15 µg m^{-3}	Annual mean, averaged over three years
	Primary and Secondary	24-hr	35 µg m^{-3}	98^{th} percentile, averaged over three years

Table 2.2: Exceedance summary table for APCD monitoring sites showing the number of days in exceedance for O_3, PM_{10}, and $PM_{2.5}$ in 2022 and 2023. Data in the table may include exceptional events. Exceptional events are periods of high pollutant concentrations that cannot reasonably be prevented using typical air pollution control strategies.

AQS Site Number	Site Name	2022			2023		
		O_3	PM_{10}	$PM_{2.5}$	O_3	PM_{10}	$PM_{2.5}$
08-001-3001	Welby	14			2		
08-005-0002	Highland Reservoir	12			8		
08-005-0006	Aurora - East	3			4		
08-007-0001	Pagosa Springs School		4			1	
08-013-0014	Boulder Reservoir	7			4		
08-031-0002	CAMP	4			3		
08-031-0026	La Casa	6			3		
08-035-0004	Chatfield State Park	18			13		
08-041-0013	U.S. Air Force Academy (USAFA)	2					
08-041-0016	Manitou Springs	2					
08-047-0003	Black Hawk	4			4		
08-059-0006	Rocky Flats - N.	21			10		
08-059-0011	NREL	22			11		
08-059-0014	Evergreen	13			8		
08-069-0011	Fort Collins - West	8			5		
08-069-1004	Fort Collins - Mason	3			1		
08-099-0002	Lamar - Municipal Bldg.		2			1	
08-101-0015	Pueblo - Fountain School		3				
08-101-0016	Pueblo West				1		
08-123-0009	Greeley - Weld County Tower	2			1		
08-123-0013	Platteville Atmospheric Observatory (PAO)	10					

2.2 General Statistics for Criteria Pollutants

In this section, historical trends in ambient pollutant concentrations are illustrated using NAAQS standard values measured throughout Colorado in each year. This comparison is for reference only as the NAAQS apply only over the averaging periods shown in Table 2.1 (typically a three-year period). Subsequent sections of this report include an evaluation of the concentrations of each pollutant in a manner directly comparable to the NAAQS.

2.2.1 Carbon Monoxide

CO is a colorless and odorless gas formed when carbon compounds in fuel undergo incomplete combustion. The majority of CO emissions to ambient air originate from mobile sources (i.e., transportation), particularly in urban areas, where as much as 85% of all CO emissions may come from automobile exhaust. CO can cause harmful health effects by reducing oxygen delivery to the body's organs and tissues. High concentrations of CO generally occur in areas with heavy traffic congestion. In Colorado, peak CO concentrations typically occur during the colder months of the year when CO automotive emissions are highest and nighttime temperature inversions are more frequent.[2]

The National Emissions Inventory[3] estimates that 31% of CO emissions are from highway vehicle sources. They also estimate that off-highway transportation sources, including all off-road mobile sources that use gasoline, diesel, and other fuels, contribute an additional 22% of emissions, making transportation approximately 53% of the total CO emissions nationwide. Figure 2.1 illustrates the trend of national CO emissions from 1970 through 2023.

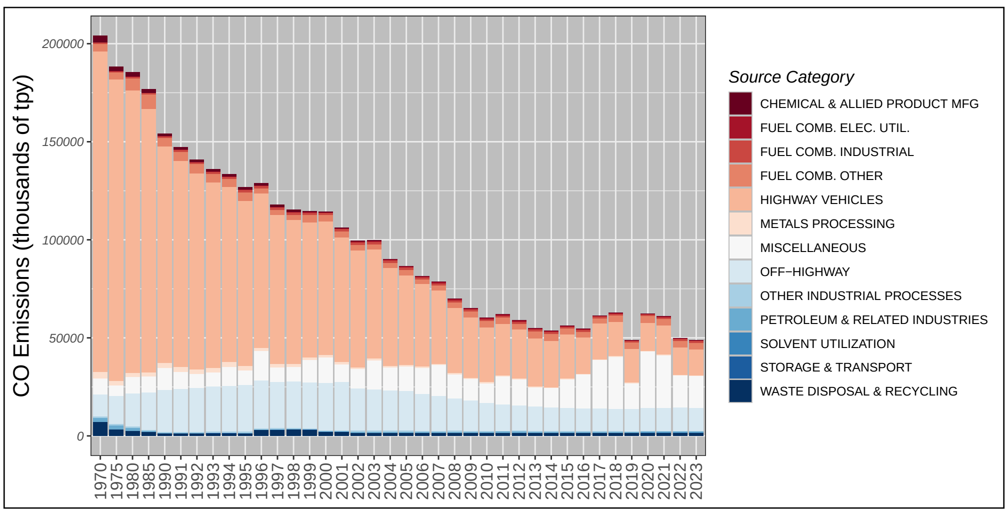

Figure 2.1: Trends in national carbon monoxide emissions from 1970 to 2023. Data was sourced from the 2020 National Emissions Inventory.

2.2.1.1 Standards

The EPA first set air quality standards for CO in 1971. For protection of both public health and welfare, EPA set an eight-hour primary standard at 9 parts per million (ppm) and a one-hour primary standard at 35 ppm. In a review of the standards completed in 1985, the EPA revoked the secondary standards (for public welfare) due to a lack of evidence of adverse effects on public welfare at or near ambient concentrations. The last review of the CO NAAQS was completed in 2011 and the EPA chose not to revise the standards at that time.

The one-hour and eight-hour NAAQS standards are not to be exceeded more than once in a year at the same location. A site will violate the standard with a second exceedance of either the one-hour or eight-hour standard in the same calendar year. An EPA directive states that the comparison with the CO standards will be made in integers. Fractions

[2] Reddy, P. J., Barbarick, D. E., & Osterburg, R. D. (1995). Development of a statistical model for forecasting episodes of visibility degradation in the Denver metropolitan area. Journal of Applied Meteorology, 34(3), 616-625

[3] https://www.epa.gov/air-emissions-inventories/

of 0.5 or greater are rounded up; therefore, actual concentrations of 9.5 ppm and 35.5 ppm or greater are necessary to exceed the eight-hour and one-hour standards, respectively.

The seven CO monitors currently operated by APCD are associated with both State Maintenance Plan requirements and federal regulatory requirements. Recently, the EPA has revised the minimum requirements for CO monitoring by requiring CO monitors to be sited near roads in certain urban areas. EPA has also specified that monitors required in metropolitan areas of 2.5 million or more persons are to be operational by January 1, 2015, and that monitors required in CBSAs of one million or more persons are required to be operational by January 1, 2017. Monitors have been installed at a near roadway NO_2 site (I-25 Denver) to satisfy these requirements.

2.2.1.2 Health Effects

CO affects the central nervous system by depriving the body of oxygen. It enters the body through the lungs, where it combines with hemoglobin in the red blood cells, forming carboxyhemoglobin. Normally, hemoglobin carries oxygen from the lungs to the cells. The oxygen attached to the hemoglobin is exchanged for the carbon dioxide generated by the cell's metabolism. The carbon dioxide is then carried back to the lungs where it is exhaled from the body. Hemoglobin binds approximately 240 times more readily with CO than with oxygen. How quickly the carboxyhemoglobin builds up is a factor of the concentration of the gas being inhaled and the duration of the exposure. Compounding the effects of the exposure is the long half-life (approximately 5 hours) of carboxyhemoglobin in the blood. Half-life is a measure of how quickly levels return to normal. This means that for a given exposure level, it will take about 5 hours for the level of carboxyhemoglobin in the blood to drop to half its current level after the exposure is terminated.

The health effects of CO vary with concentration. At low concentrations, effects include fatigue in healthy people and chest pain in people with heart disease. At moderate concentrations, angina, impaired vision, and reduced brain function may result. At higher concentrations, effects include impaired vision and coordination, headaches, dizziness, confusion, and nausea. It can cause flu-like symptoms that clear up after leaving the polluted area. CO is fatal at very high concentrations. The EPA has concluded that the following groups may be particularly sensitive to CO exposures: angina patients, individuals with other types of cardiovascular disease, persons with chronic obstructive pulmonary disease, anemic individuals, fetuses, and pregnant women. Concern also exists for healthy children because of increased oxygen requirements that result from their higher metabolic rate.

2.2.1.3 Statewide Summaries

CO concentrations have dropped dramatically since the early 1970s. This change is evident in both the concentrations measured and the number of monitors that have exceeded the level of the eight-hour standard. In 1975, 9 of 11 (81%) state-operated monitors exceeded the eight-hour standard. In 1980, 13 of 17 (77%) state-operated monitors exceeded the eight-hour standard. Since 1996, no state-operated monitors have recorded a violation of the eight-hour standard. In 2023, the highest statewide second maximum eight-hour concentration was 1.8 ppm as recorded at the I-25 Denver station. Historical trends in CO NAAQS values for the CAMP and Welby stations are shown in Figure 2.2 and Figure 2.3 for illustration purposes.

Figure 2.4 shows the trend in maximum one-hour CO values recorded statewide between 1965 and 2023. The highest one-hour concentration ever recorded at any of the state-operated monitors was 79.0 ppm, which was recorded at the Denver CAMP monitor in 1968. In 2023 the highest one-hour concentration was 2.5 ppm, a value recorded at the I-25 Denver station. The one-hour annual maximum concentrations have declined from more than twice the standard in the late 1960s to about one quarter of the standard today. Table 2.3 presents the historical maximum values recorded in Colorado.

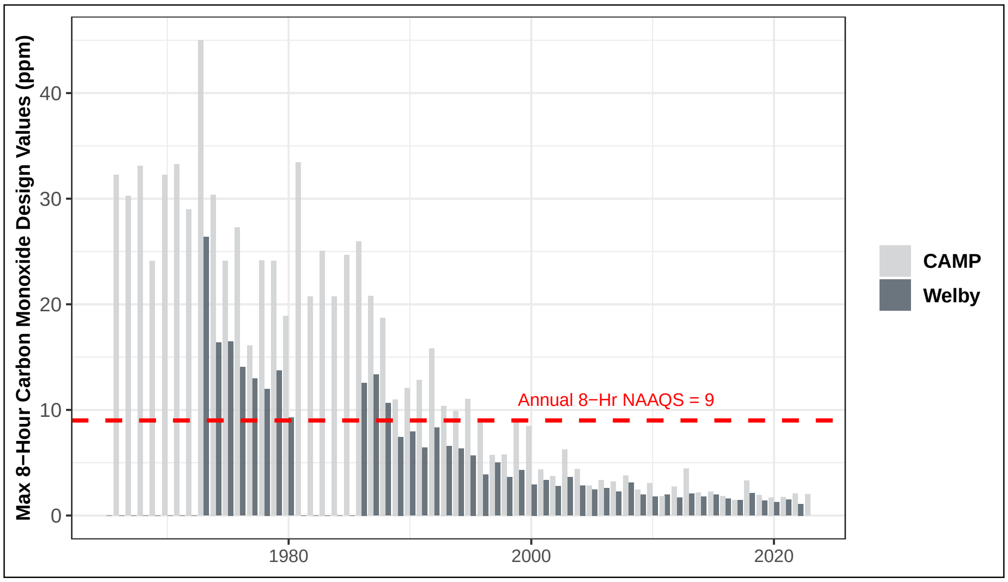

Figure 2.2: Historical record of maximum eight-hour carbon monoxide values at the CAMP and Welby stations.

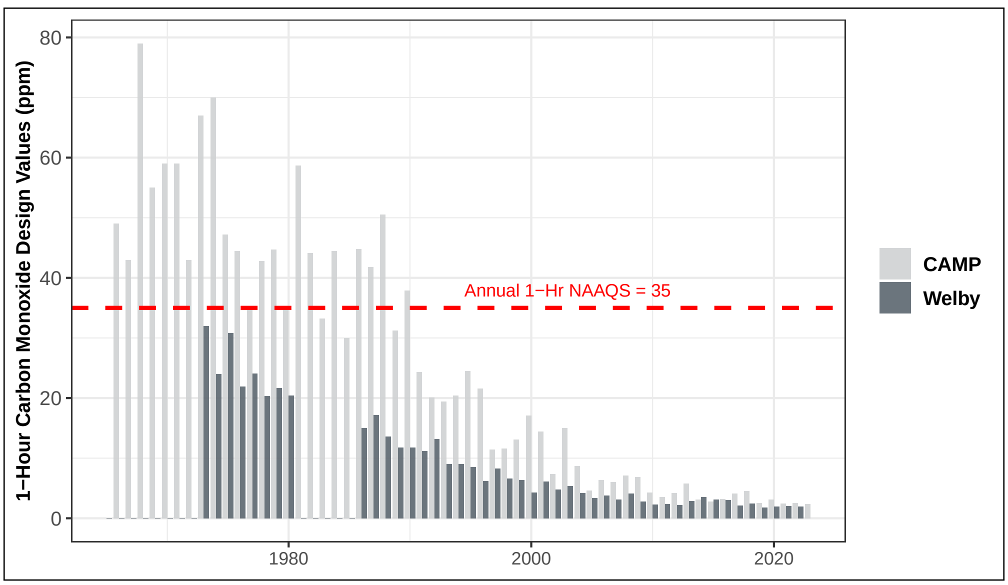

Figure 2.3: Historical record of maximum one-hour carbon monoxide values at the CAMP and Welby stations.

Table 2.3: Historical maximum one-hour CO concentrations in Colorado

Site	Max 1-Hour CO (ppm)	Year
CAMP	79.0	1968
CAMP	70.0	1974
CAMP	67.0	1973
Denver	64.9	1979
CAMP	59	1970
2023 Maximum		
I-25 Denver	2.5	2023

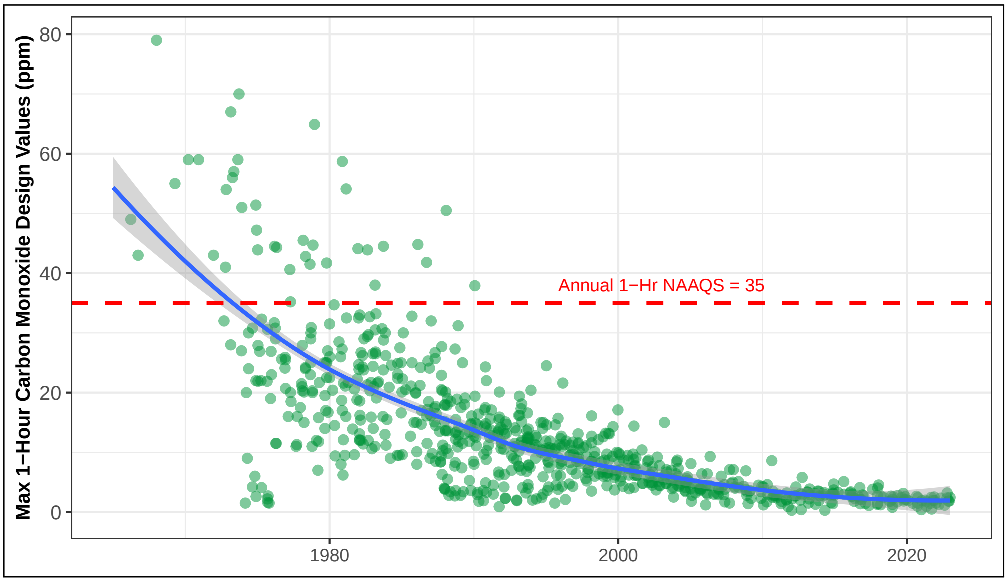

Figure 2.4: Statewide historical record of maximum one-hour carbon monoxide values. The mean trend obtained using a generalized additive model is shown as a blue line.

2.2.2 Sulfur Dioxide

Sulfur dioxide (SO_2) is one of a group of highly reactive gasses known as "oxides of sulfur," or sulfur oxides (SO_x). The largest sources of SO_2 emissions are from fossil fuel combustion at power plants (73%) and other industrial facilities (20%), as shown in Figure 2.5. Smaller sources of SO_2 emissions include industrial processes such as extracting metal from ore, and the burning of high sulfur containing fuels by locomotives, large ships, and non-road equipment. SO_2 is linked with a number of adverse effects on the respiratory system.[4] Furthermore, SO_2 dissolves in water and is oxidized to form sulfuric acid, which is a major contributor to acid rain, as well as fine sulfate particles in the $PM_{2.5}$ fraction, which degrade visibility and represent a human health hazard.

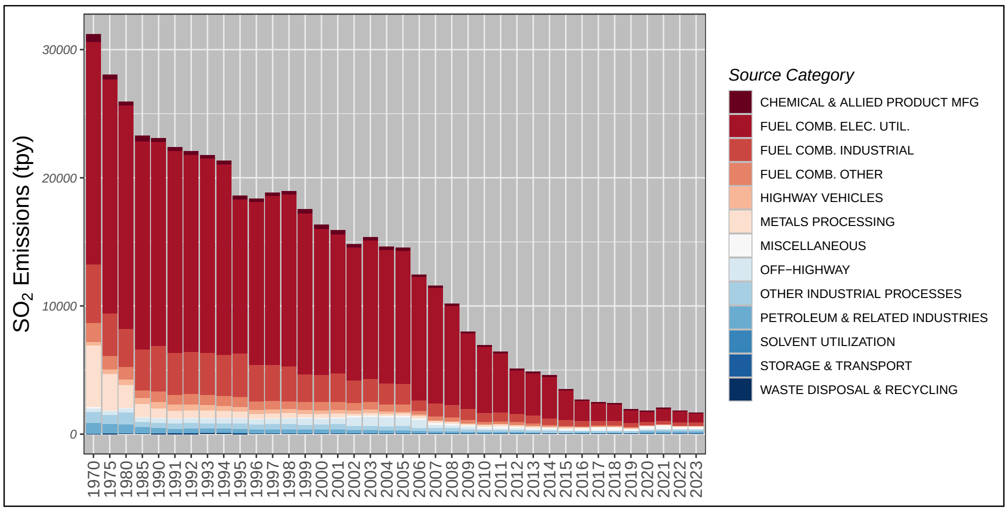

Figure 2.5: Trends in national sulfur dioxide emissions from 1970 to 2023. Data was sourced from the 2020 National Emissions Inventory.

2.2.2.1 Standards

The EPA first promulgated standards for SO_2 in 1971, setting a 24-hour primary standard at 140 ppb and an annual average standard at 30 ppb (to protect health). A three-hour average secondary standard at 500 ppb was also adopted to protect the public welfare. In 1996, the EPA reviewed the SO_2 NAAQS and chose not to revise the standards. However, in 2010, the EPA revised the primary SO_2 NAAQS by establishing a new one-hour standard at a level of 75 parts per billion (ppb). The two existing primary standards were revoked because they were deemed inadequate to provide additional public health protection given a one-hour standard at 75 ppb.

APCD has monitored SO_2 at eight locations in Colorado in the past. Currently, there are four SO_2 monitoring sites in operation. No area of the country has been found to be out of compliance with the current SO_2 standards. There were two exceedances of the one-hour standard at the Highway 24 (Colorado Springs) site during the 2014-2015 period; however, there was no exceedance recorded at any site in 2023.

2.2.2.2 Health Effects

High concentrations of sulfur dioxide can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated sulfur dioxide levels during moderate activity may result in breathing difficulties that can be accompanied by symptoms such as wheezing, chest tightness, or shortness of breath. Other effects that have been associated with longer-term exposures to high concentrations of sulfur dioxide, in conjunction with high levels of particulate matter, include aggravation of existing cardiovascular disease, respiratory illness, and alterations in the lungs' defenses. The subgroups of the population that may be affected under these conditions include individuals with heart or lung disease, as well as the elderly and children.

[4] Ware, J. H., Ferris Jr, B. G., Dockery, D. W., Spengler, J. D., Stram, D. O., & Speizer, F. E. (1986). Effects of ambient sulfur oxides and suspended particles on respiratory health of preadolescent children. The American Review of Respiratory Disease, 133(5), 834-842

2.2.2.3 Statewide Summaries

The concentrations of sulfur dioxide in Colorado have never been a major health concern as there are few industries that burn large amounts of coal in the state. Additionally, western coal that is mined or imported into Colorado is naturally low in sulfur. The concern in Colorado with sulfur dioxide has been associated with acid deposition and its effects on mountain lakes and streams, as well as the formation of fine aerosols. Ambient SO_2 levels have decreased significantly in the past forty years, with one-hour SO_2 annual 99^{th} percentile values at the CAMP station having declined from greater than 200 ppb in the late 1960s and early 1970s to 5 ppb in 2023, as shown in Figure 2.6. Figure 2.7 shows the declining trend in sulfur dioxide readings over the last several decades, with relatively low concentrations of sulfur dioxide recorded at APCD monitors. This same trend is evident, although not as pronounced, in the three-hour and 24-hour averages. Table 2.4 presents the historical maximum one-hour concentrations recorded in Colorado.

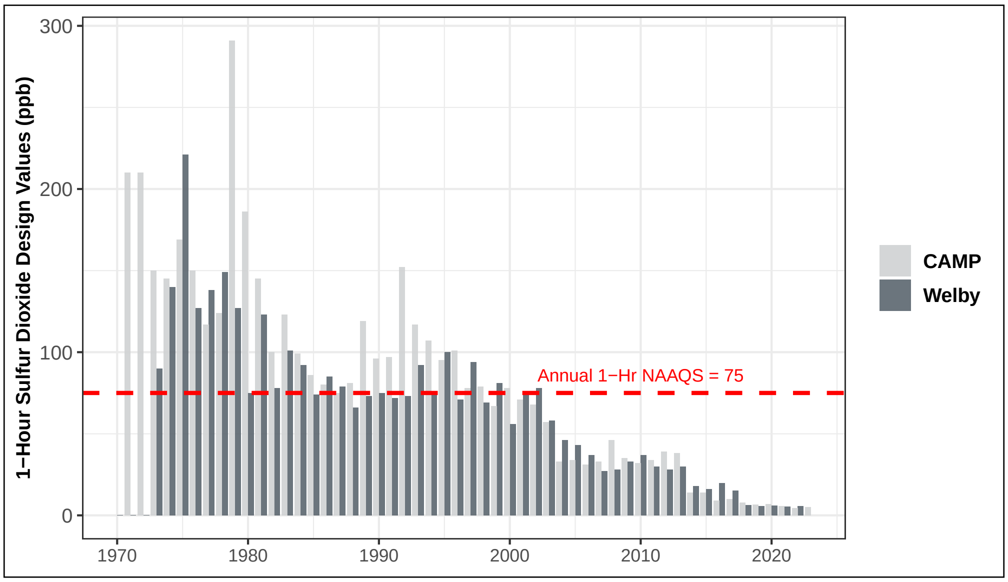

Figure 2.6: Historical record of one-hour sulfur dioxide annual 99^{th} percentile values at the CAMP and Welby stations.

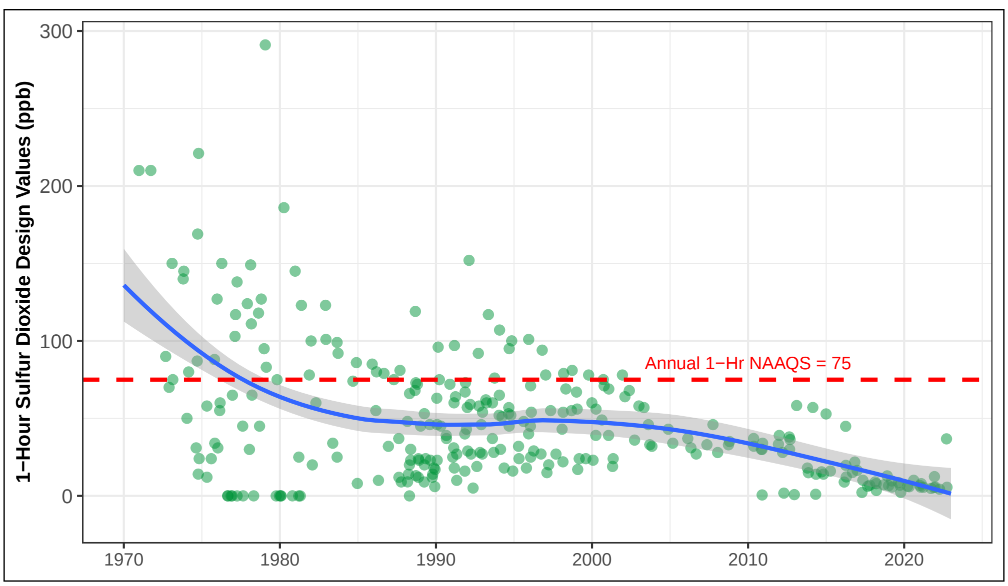

Figure 2.7: Statewide historical record of one-hour sulfur dioxide annual 99^{th} percentile values. The mean trend obtained using a generalized additive model is shown as a blue line.

Table 2.4: Historical maximum one-hour SO_2 concentrations in Colorado

Site	**Max 1-Hour SO_2 (ppb)**	**Year**
Rio Blanco	733	1976
Denver	550	1974
CAMP	490	1969
CAMP	360	1965
Denver	328	1976
2023 Maximum		
Welby	17	2023

2.2.3 Ozone

O_3 is an atmospheric oxidant composed of three oxygen atoms. It is not usually emitted directly into the air, but at ground-level is formed via photochemical reactions among NO_x and volatile organic compounds (VOCs) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources of NO_x and VOCs (see Figure 2.8 and Figure 2.10). Breathing ozone can trigger a variety of health problems, particularly for children, the elderly, and people of all ages who have lung diseases such as asthma.[5] Urban areas generally experience the highest ozone concentrations, but even rural areas may be subject to increased ozone levels because air masses can carry ozone and its precursors hundreds of miles away from their original source regions.

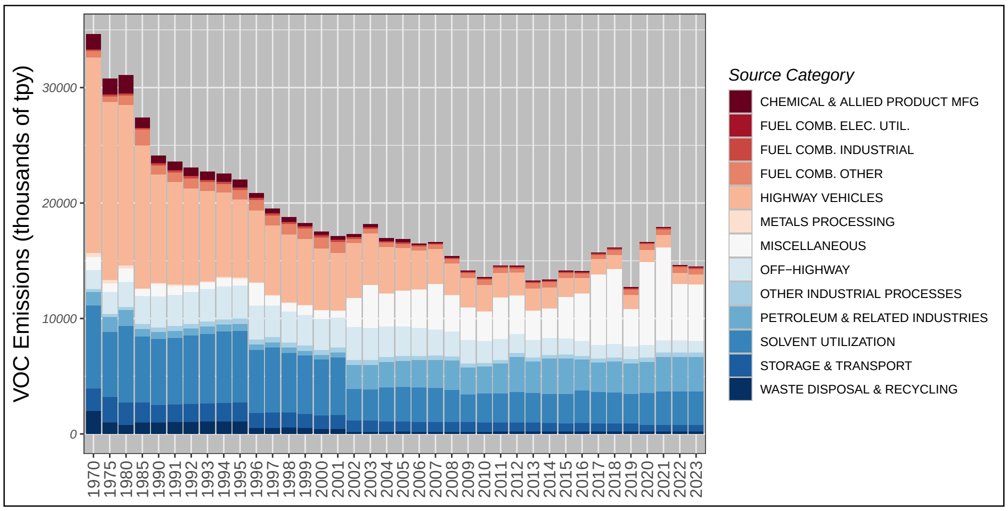

Figure 2.8: Trends in national VOC emissions from 1970 to 2023. Data was sourced from the 2020 National Emissions Inventory.

Sunlight and warm weather facilitate the ozone formation process and can lead to high concentrations. Ozone is therefore considered to be primarily a summertime pollutant and typically reaches maximum concentrations when hot summer days provide the conditions for the precursor chemicals to react and form ozone. However, ozone can also be a wintertime pollutant in some areas. Emerging science is indicating that snow-covered oil and gas-producing basins in the western U.S. can be subject to wintertime ozone concentrations well in excess of current air quality standards. High ozone concentrations in winter are thought to occur when stable atmospheric conditions allow for a build-up of precursor chemicals, and the reflectivity of the snow cover increases the rate of UV-driven reactions during the day. Ozone and its precursors are then effectively trapped under the inversion. The Upper Green River Basin in Wyoming has been studied to model such effects.[6]

2.2.3.1 Standards

In 1971, the EPA promulgated the first NAAQS for photochemical oxidants, setting a one-hour primary standard at 80 pbb (O_3 is one of a number of chemicals that are common atmospheric oxidants). The level of the primary standard was then revised in 1979 from 80 ppb to 120 ppb and the chemical designation of the standard was changed from "photochemical oxidants" to "ozone." In 1993, the EPA reviewed the O_3 NAAQS and chose not to revise the standards. However, in 1997, the EPA promulgated a new level of the NAAQS for O_3 of 80 ppb as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years. The O_3 NAAQS was then revised again in 2008 when the EPA set an eight-hour standard of 75 ppb. On November 26, 2014, the EPA again proposed lowering the O_3 NAAQS standard from 75 ppb to a level between 65 ppb and 70 ppb. In November 2015, the EPA set the standard at 70 ppb as an annual fourth-highest daily maximum eight-hour concentration, averaged over three years. To ensure

[5] Kampa, M., & Castanas, E. (2008). Human health effects of air pollution. Environmental pollution, 151(2), 362-367

[6] Carter, W. P., & Seinfeld, J. H. (2012). Winter ozone formation and VOC incremental reactivities in the Upper Green River Basin of Wyoming. Atmospheric Environment, 50, 255-266

compliance with the 2008 and 2015 O_3 standards, the EPA has extended the O_3 monitoring requirements for Colorado by 5 months, essentially redefining Colorado's ozone season as January through December. In 2023, 16 of 20 O_3 sites operated by APCD had three-year NAAQS values in excess of the current eight-hour O_3 standard of 70 ppb.

2.2.3.2 Health Effects

Exposure to ozone has been linked to a number of health effects, including significant decreases in lung function, inflammation of the airways, and increased respiratory symptoms, such as cough and pain when taking a deep breath.[7] Exposure can also aggravate lung diseases such as asthma, leading to increased medication use and increased hospital admissions and emergency room visits. Active children are the group at highest risk from ozone exposure because they often spend a large part of the summer playing outdoors. Children are also more likely to have asthma, which may be aggravated by ozone exposure. Other at-risk groups include adults who are active outdoors (e.g., some outdoor workers) and individuals with lung diseases such as asthma and chronic obstructive pulmonary disease. In addition, long-term exposure to moderate levels of ozone may cause permanent changes in lung structure, leading to premature aging of the lungs and worsening of chronic lung disease.

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather).[8] In long-lived species, these effects may become evident only after several years or even decades and may result in long-term effects on forest ecosystems. Ground level ozone injury to trees and plants can lead to a decrease in the natural beauty of our national parks and recreation areas.

2.2.3.3 Statewide Summaries

As illustrated in Figure 2.9, statewide average O_3 values have historically fluctuated around the standard. In recent years, the trend has been downward, but the averages seem to fluctuate within the amount of variance seen for the last several years.

Ozone monitoring began in 1972 at the Denver CAMP station, and eight exceedances of the then-applicable one-hour standard were recorded that year. Table 2.5 lists the five highest eight-hour concentrations recorded in Colorado. Note that all five maximum historical values were recorded within the first three years of ozone monitoring.

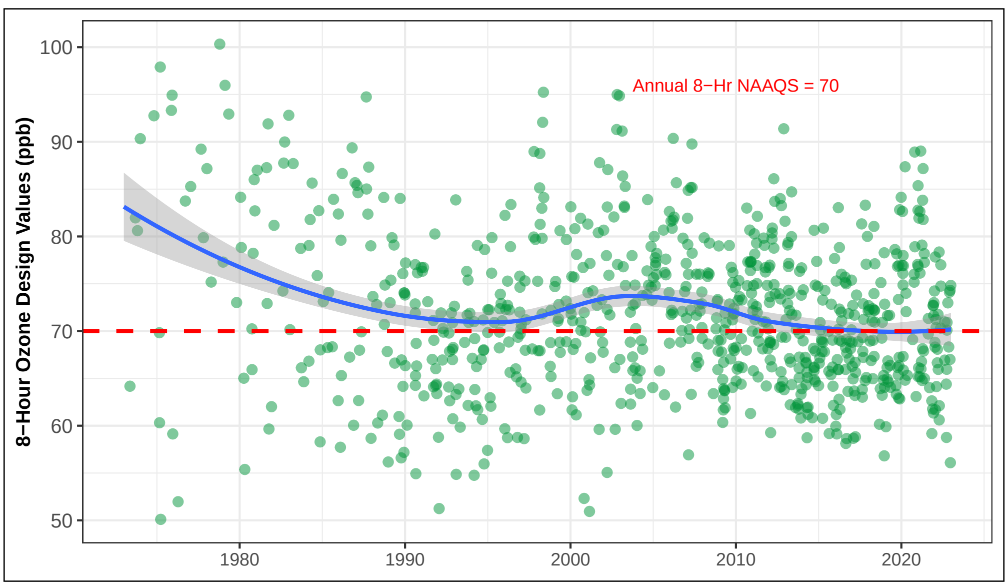

Figure 2.9: Statewide historical record of eight-hour ozone NAAQS values. The mean trend obtained using a generalized additive model is shown as a blue line.

[7]Lippmann, M. (1989). Health effects of ozone: a critical review. Journal of the Air Pollution Control Association, 39(5), 672-695.
[8]Ashmore, M. R. (2005). Assessing the future global impacts of ozone on vegetation. Plant, Cell & Environment, 28(8), 949-964.

Table 2.5: Historical maximum eight-hour O_3 concentrations in Colorado

Site	**Max 8-Hour O_3 (ppb)**	**Year**
CAMP	310	1972
CAMP	264	1973
Arvada	198	1973
Denver	194	1973
Welby	156	1974
	2023 Maximum	
Fort Collins - West	88	2023

2.2.4 Nitrogen Dioxide

NO_2 is one of a group of highly reactive gasses known as "oxides of nitrogen," or nitrogen oxides (NO_x). Other NO_x species include nitric oxide (NO), nitrous acid (HNO_2), and nitric acid (HNO_3). The EPA's National Ambient Air Quality Standard uses NO_2 as the indicator for the larger group of nitrogen oxides. NO_2 forms quickly from emissions from motor vehicles, power plants, and off-road equipment, with on and off-road vehicles accounting for over 50% of emissions nationally. In addition to contributing to the formation of ground-level ozone and fine particle pollution, NO_2 is linked with a number of adverse effects on the respiratory system.[9]

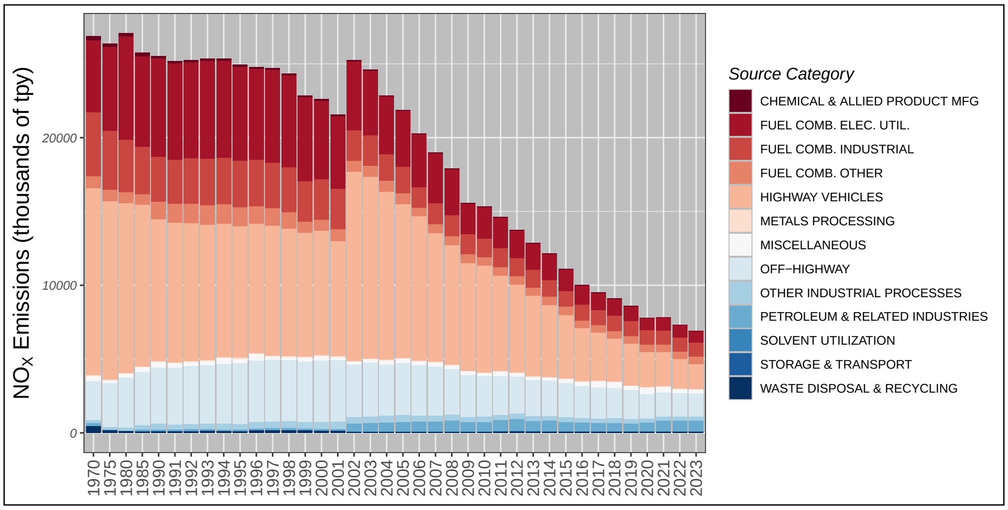

Figure 2.10: Trends in national NO_x emissions from 1970 to 2023. Data was sourced from the 2020 National Emissions Inventory.

2.2.4.1 Standards

The EPA first set standards for NO_2 in 1971, setting both a primary standard (to protect health) and a secondary standard (to protect the public welfare) at 0.053 parts per million (53 ppb), averaged annually. The Agency has reviewed the standards twice since that time, but chose not to revise the annual standards at the conclusion of each review. In January 2010, the EPA established an additional primary standard at 100 ppb, averaged over one hour. Together the primary standards protect public health, including the health of sensitive populations; i.e., people with asthma, children, and the elderly.

The EPA has established requirements for an NO_2 monitoring network that will include monitors at locations where maximum NO_2 concentrations are expected to occur, including within 50 meters of major roadways, as well as monitors sited to measure area-wide NO_2 concentrations that occur more broadly across communities. Per these requirements, at least one monitor must be located near a major road in any urban area with a population greater than or equal to 1,000,000 people. A second monitor is required near another major road in areas with either: (1) population greater than or equal to 2.5 million people, or (2) one or more road segments with an annual average daily traffic (AADT) count greater than or equal to 250,000 vehicles. Near-roadway monitoring is conducted at the I-25 Denver (installed in 2013) and I-25 Globeville (installed in 2015) sites. In addition to the near roadway monitoring, there must be one monitoring station in each metropolitan area with a population of 1 million or more persons to monitor a location of expected highest NO_2 concentrations representing the neighborhood or larger spatial scales. The CAMP site satisfies this requirement. Additionally, the Welby monitoring location serves as a an EPA Regional Administrated NO_2 site targeted at the characterization of NO_2 exposure for susceptible and vulnerable populations.

[9]Weinmayr, G., Romeo, E., De Sario, M., Weiland, S. K., & Forastiere, F. (2010). Short-term effects of PM_{10} and NO_2 on respiratory health among children with asthma or asthma-like symptoms: a systematic review and meta-analysis. Environmental Health Perspectives, 118(4), 449-57.

2.2.4.2 Health Effects

Elevated concentrations of nitrogen dioxide cause respiratory distress, degradation of vegetation, clothing, visibility, and increased acid deposition. Nitrogen dioxide also causes concern with the formation of fine aerosols. Nitrate aerosols, which result from NO and NO_2 combining with water vapor in the air, have been consistently linked to Denver's visibility problems.[10]

2.2.4.3 Statewide Summaries

Colorado exceeded the annual mean NO_2 standard of 53 ppb in 1977 at the Denver CAMP monitor, but concentrations have shown a gradual decline since this time. Figure 2.11 and Figure 2.12 show that levels have declined minimally but remained below the NAAQS at both the Welby and CAMP monitors over the past ten years in terms of both the annual mean and one-hour NAAQS values. The statewide historical trend is summarized in Figure 2.13. Table 2.6 presents the historical maximum one-hour NO_2 values recorded in Colorado.

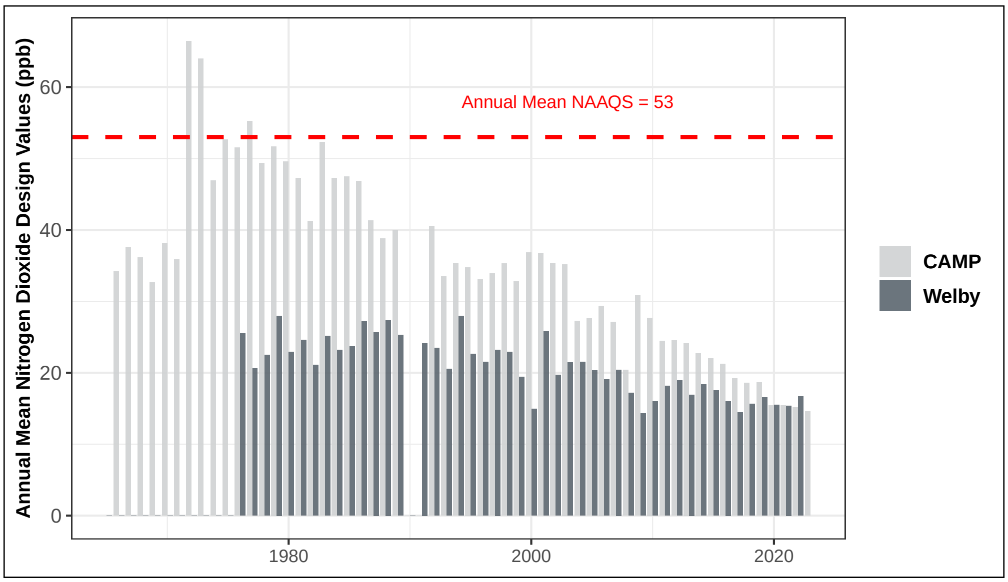

Figure 2.11: Historical record of annual mean nitrogen dioxide NAAQS values at the CAMP and Welby stations.

Table 2.6: Historical maximum one-hour NO_2 concentrations in Colorado

Site	Max 1-Hour NO_2 (ppb)	Year
Denver	639	1983
CAMP	620	1973
CAMP	462	1989
CAMP	448	1983
CAMP	420	1974
	2023 Maximum	
I-25 Globeville	75	2023

[10]Sloane, C. S., Watson, J., Chow, J., Pritchett, L., & Richards, L. W. (1991). Size-segregated fine particle measurements by chemical species and their impact on visibility impairment in Denver. Atmospheric Environment. Part A. General Topics, 25(5), 1013-1024.

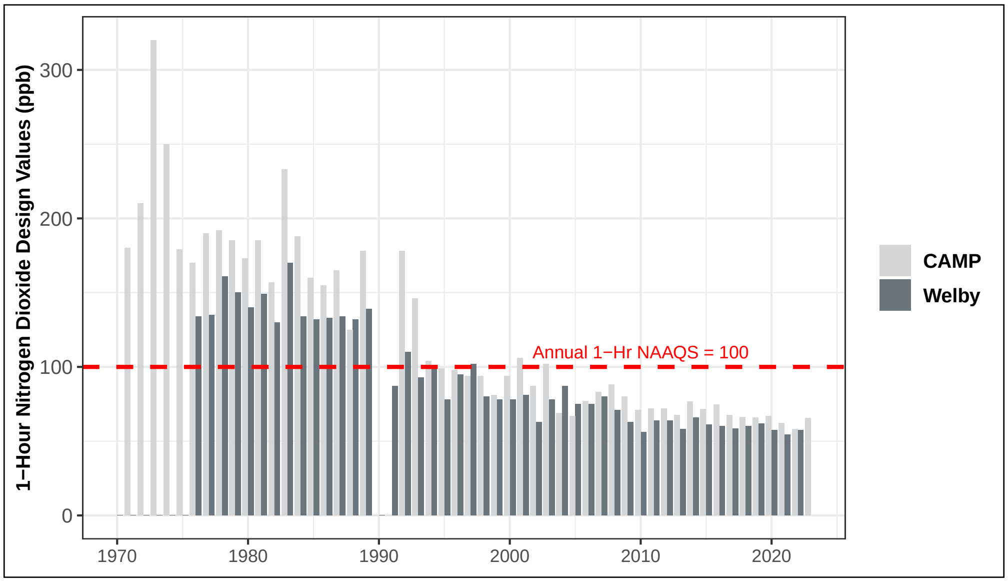

Figure 2.12: Historical record of one-hour nitrogen dioxide NAAQS values at the CAMP and Welby stations.

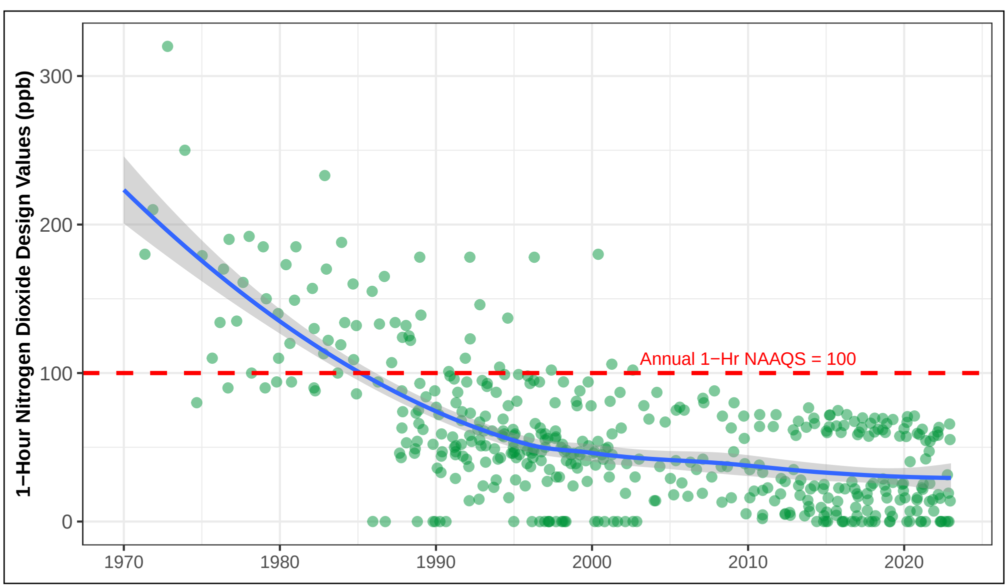

Figure 2.13: Statewide historical record of one-hour nitrogen dioxide NAAQS values. The mean trend obtained using a generalized additive model is shown as a blue line.

2.2.5 Particulate Matter

Atmospheric particulate matter (PM) consists of microscopic solid or liquid particles suspended in the air. PM can be made up of a number of different components, including acidic aerosols (e.g., nitrates and sulfates), organic carbon, metals, soil or dust particles, and allergens (such as fragments of pollen or mold spores). Some of these particles are carcinogenic and others have health effects due to their size, morphology, or composition.

2.2.5.1 Health Effects

Particle size is the factor most directly linked to the health impacts of atmospheric PM. Particles of less than 10 micrometers (μm) in aerodynamic diameter (PM_{10}) are inhalable and thus pose a health threat. Particles less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) can penetrate deeply into the alveoli in the lungs, while the smallest particles, such as those less than 0.1 μm in aerodynamic diameter (ultrafine particles), can penetrate all the way into the bloodstream. Exposure to such particles can affect the lungs, the heart, and the cardiovascular system. Particles with diameters between 2.5 μm and 10 μm ($PM_{10\text{-}2.5}$) represent less of a health concern, although they can irritate the eyes, nose, and throat, and cause serious harm due to inflammation in the airways of people with respiratory diseases such as asthma, chronic obstructive pulmonary disease, and pneumonia. Note that PM_{10} encompasses all particles smaller than 10 μm, including the $PM_{2.5}$ and ultrafine fractions.

The welfare effects of particulate exposure may be the most widespread of all the pollutants. No place on earth has been spared from the particulate pollution generated by urban and rural sources. This is due to the potential for extremely long-range transport of fine particles and chemical reactions that occur from gases in the atmosphere to create secondary particulate matter in the form of microscopic liquid droplets. The effects of particulates range from visibility degradation to climate changes and vegetation damage. General soiling, commonly thought to be just a nuisance, can have long-term adverse effects on building paints and other materials. Acid deposition as particulates can be detected in the most remote areas of the world.

2.2.5.2 Emissions and Sources

The majority of PM_{10} pollution comes from miscellaneous sources, which are mainly fugitive dust sources rather than stack emissions or combustion sources. Fugitive emissions are those not caught by a capture system and are often due to equipment leaks, earth moving equipment vehicles, and windblown disturbances. $PM_{2.5}$, on the other hand, is typically formed in the atmosphere via gas to particle conversion and consists primarily of nitrates, sulfates, and organic carbon (black carbon from combustion can be an important primary source of particles in the $PM_{2.5}$ size fraction). The historical trend in national PM emissions from 1990 to 2023 is shown in Figure 2.15 for illustration purposes.

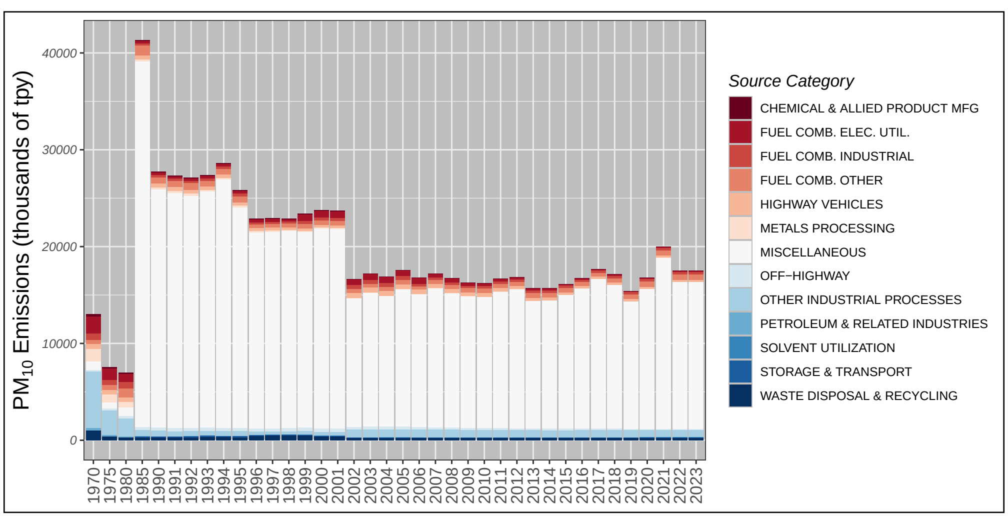

Figure 2.14: Trends in national PM_{10} emissions from 1970 to 2023. Data was sourced from the 2020 National Emissions Inventory.

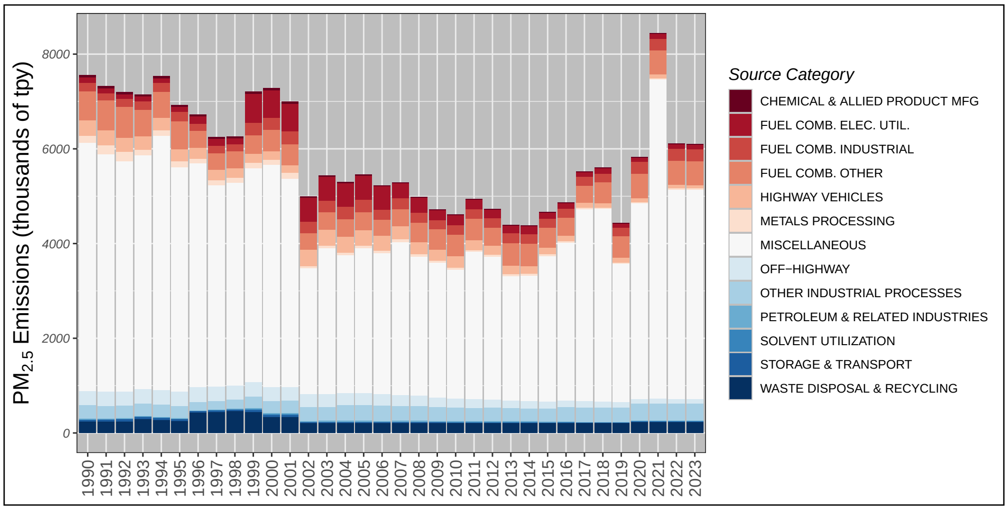

Figure 2.15: Trends in national $PM_{2.5}$ emissions from 1990 to 2023. Data was sourced from the 2020 National Emissions Inventory.

2.2.5.3 Standards

EPA first established standards for PM in 1971. The reference method specified for determining attainment of the original standards was the high-volume sampler, which collects PM up to a nominal size of 25 to 45 µm (referred to as total suspended particulates or TSP). The primary standards, as measured by the indicator TSP, were 260 µg m^{-3} (as a 24-hour average) not to be exceeded more than once per year, and 75 µg m^{-3} (as an annual geometric mean). In October 1979, the EPA announced the first periodic review of the air quality criteria and NAAQS for PM, and significant revisions to the original standards were promulgated in 1987. In that decision, the EPA changed the indicator for particles from TSP to PM_{10}. EPA also revised the level and form of the primary standards. The EPA promulgated significant revisions to the NAAQS again in 1997. In that decision, the EPA revised the PM NAAQS in several respects. While it was determined that the PM NAAQS should continue to focus on particles less than or equal to 10 µm in diameter (i.e., PM_{10}), the EPA also decided that the fine and coarse fractions of PM_{10} should be considered separately. The Agency's decision to modify the standards was based on evidence that serious health effects were associated with short- and long-term exposure to fine particles in areas that met the existing PM_{10} standards. The EPA added new standards, using $PM_{2.5}$ as the indicator for fine particles and using PM_{10} as the indicator for the $PM_{10\text{-}2.5}$ fraction. The EPA established two new $PM_{2.5}$ standards: an annual standard of 15 µg m^{-3}, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors, and a 24-hour standard of 65 µg m^{-3}, based on the 3-year average of the 98^{th} percentile of 24-hour $PM_{2.5}$ concentrations at each population-oriented monitor within an area. These standards were modified again in 2006 and 2012. The current NAAQS for PM_{10} is a primary 24-hour standard of 150 µg m^{-3} not to be exceeded more than once per year on average over three years. There are currently three NAAQS for $PM_{2.5}$: (1) a primary annual standard of 12 µg m^{-3}, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations, (2) a secondary annual standard of 15 µg m^{-3}, based on the 3-year average of annual arithmetic mean $PM_{2.5}$ concentrations, and (3) and a 24-hour standard of 35 µg m^{-3}, based on the 3-year average of the 98^{th} percentile of 24-hour $PM_{2.5}$ concentrations.

2.2.5.4 A Brief Explanation of Exceptional Events

Often times air pollution episodes originate from natural sources that are not preventable and cannot be reasonably controlled by humans. These include events like volcanic eruptions, large regional dust storms, and wildfires. If an exceedance of the NAAQS (PM_{10} concentrations greater than 150 µg m^{-3} in attainment areas and greater than 98 µg m^{-3} in PM_{10} non-attainment areas) can be shown to have resulted from a natural event and can be documented with scientific evidence, the event can be excluded from NAAQS calculations. For example, one such event was the large wind and dust storm that occurred on March 31, 1999 when monitors from Steamboat Springs to Telluride reported high PM_{10} concentrations. Similar exceptional events have been documented in Lamar, Alamosa, Crested Butte, Durango, Grand

Junction, Pagosa Springs, and Pueblo. These events are not included in NAAQS determinations, not because they are without any health risk but because they are naturally occurring events that cannot be reasonably prevented or controlled. The EPA may concur on events that APCD flags and documents as exceptional events in the EPA's AQS database. The Exceptional Events Rule was revised in 2016, with an effective date of September 30, 2016. The EPA has been much more restrictive on concurring natural events since the revision. Concentrations between 98 and 155 $\mu g\ m^{-3}$ that are located in State Implementation Plan maintenance areas are also allowed by the Exceptional Events Rule to be flagged and documented as exceptional events. More details can be found at `https://www.epa.gov/air-quality-analysis/treatment-air-quality-monitoring-data-influenced-exceptional-events`.

2.2.5.5 Statewide Summaries

PM_{10} PM_{10} data have been collected in Colorado since 1985. The samplers were subsequently modified to conform to the requirements of a new standard when it was established in July of 1987. Therefore, annual trends are only valid back to July 1987. Since 1988, at least one Colorado monitor has exceeded the level of the 24-hour PM_{10} standard (150 $\mu g\ m^{-3}$) every year except for 2004.

In cases other than exceptional events and more so than for other pollutants, PM_{10} pollution is a localized phenomenon and concentrations can vary considerably in Colorado on both spatial and temporal scales. Therefore, local averages and maximum concentrations of PM_{10} are more meaningful than averages covering large regions or the entire state. However, statewide values have been summarized in a box plot in Figure 2.16 for illustration purposes. The box plot shows the median PM_{10} NAAQS value statewide for each year as a horizontal black bar, as well as the first quartile (Q1, box bottom), the third quartile (Q3, box top), and the minimum and maximum values, which are represented by vertical black tick marks. For each year, outliers are considered to be those points with values greater than Q3 + 1.5*(Q3 - Q1) or less than Q1 - 1.5*(Q3 - Q1), and are represented by black points.

PM_{10} exceedances in Colorado are mainly due to large regional dust storms that usually begin in desert areas to the south and west of the state. These are natural or exceptional events for which the Division is currently analyzing the scientific data and may document as high wind/blown dust exceptional events. The data shown in Figure 2.16 include those concentrations that are the result of exceptional events (see subsubsection 2.2.5.4). There have been several of these events documented in Colorado since PM_{10} monitoring began in 1987, including the maximum 24-hour PM_{10} concentration of 1220 $\mu g\ m^{-3}$ recorded in Lamar in 2013 and the 635 $\mu g\ m^{-3}$ value recorded in Alamosa in 2011. Table 2.7 presents the historical maximum 24-hour PM_{10} concentrations recorded in Colorado.

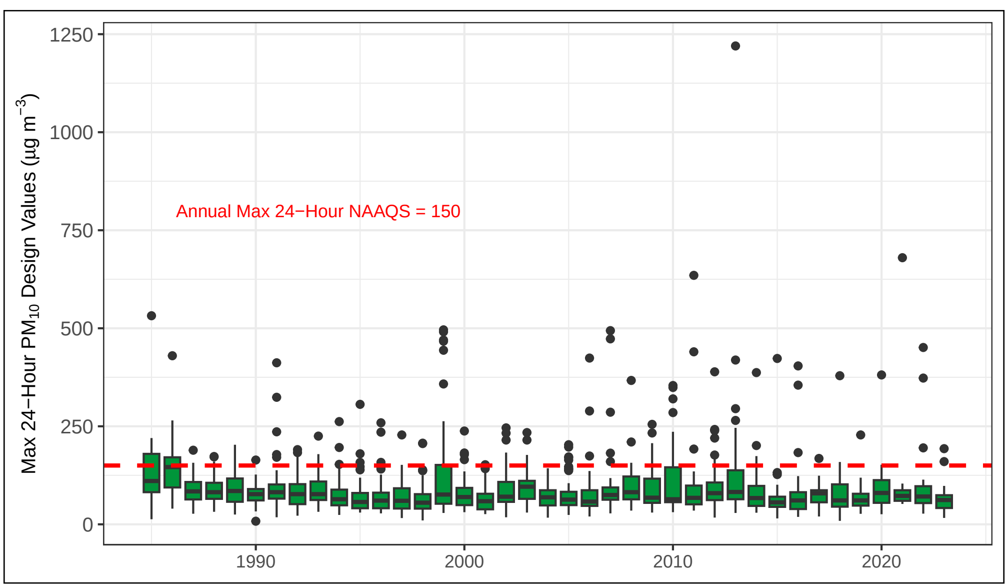

Figure 2.16: Statewide historical record of annual maximum 24-hour PM_{10} values. The box plot shows the median PM_{10} NAAQS value statewide for each year, as well as the interquartile range (box) of values observed at monitoring sites throughout the state and the minimum and maximum values. Outliers are indicated by black points.

Table 2.7: Historical maximum 24-hour PM_{10} concentrations in Colorado

Site	**Max 24-Hour PM_{10}** (µg m^{-3})	**Year**
Lamar	1,220	2013
Alamosa	635	2011
Denver	532	1985
Alamosa	494	2007
Montrose	491	1999
2023 Maximum		
Pagosa Springs	193	2023

$PM_{2.5}$ Monitoring for $PM_{2.5}$ in Colorado began in 1999 with the establishment of sites in Denver, Grand Junction, Steamboat Springs, Colorado Springs, Greeley, Fort Collins, Platteville, Boulder, Longmont, and Elbert County. Additional sites were established nearly every month until full implementation of the base network was achieved in July of 1999. In 2004, there were 20 $PM_{2.5}$ monitoring sites in Colorado. Thirteen of the 20 sites were selected based on the population of the metropolitan statistical areas. This is a federal selection criterion that was developed to protect the public health in the highest population centers. In addition, there were seven special-purpose-monitoring (SPM) sites. These sites were selected due to historically elevated concentrations of PM_{10} or because citizens or local governments had concerns about possible high $PM_{2.5}$ concentrations in their communities. A majority of the SPM sites were removed as of December 31, 2006 due to low concentrations and a lack of funding.

Figure 2.17 and Figure 2.18 show the historical trends in annual mean and 24-hour maximum $PM_{2.5}$ NAAQS values, respectively. Although data has only been collected for the past 12 years, the trend in the average levels of $PM_{2.5}$ appears to be essentially flat. Since the 35 μg m^{-3} standard is based on a three-year average of the 98^{th} percentile, the 24-hour standard has not been violated at any site, nor has the three-year average annual standard of 12 μg m^{-3}. Table 2.8 presents the historical maximum 24-hour $PM_{2.5}$ concentrations recorded in Colorado.

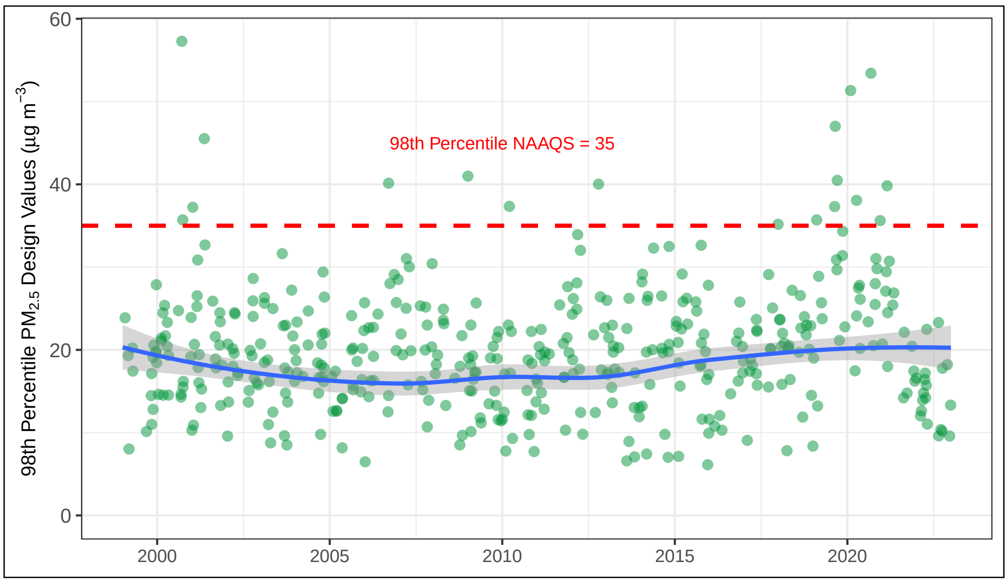

Figure 2.17: Statewide historical record of 24-hour $PM_{2.5}$ 98^{th} percentile values. The mean trend obtained using a generalized additive model is shown as a blue line.

Table 2.8: Historical maximum 24-hour $PM_{2.5}$ concentrations in Colorado. Data includes potential exceptional events.

Site	**Max 24-Hour $PM_{2.5}$** (μg m^{-3})	**Year**
Arapahoe Community College (ACC)	140	1999
Birch Street	87.6	2023
I-25 Globeville	87.2	2023
I-25 Denver	86.6	2023
CAMP	83.5	2023
2023 Maximum		
Longmont	96	2023

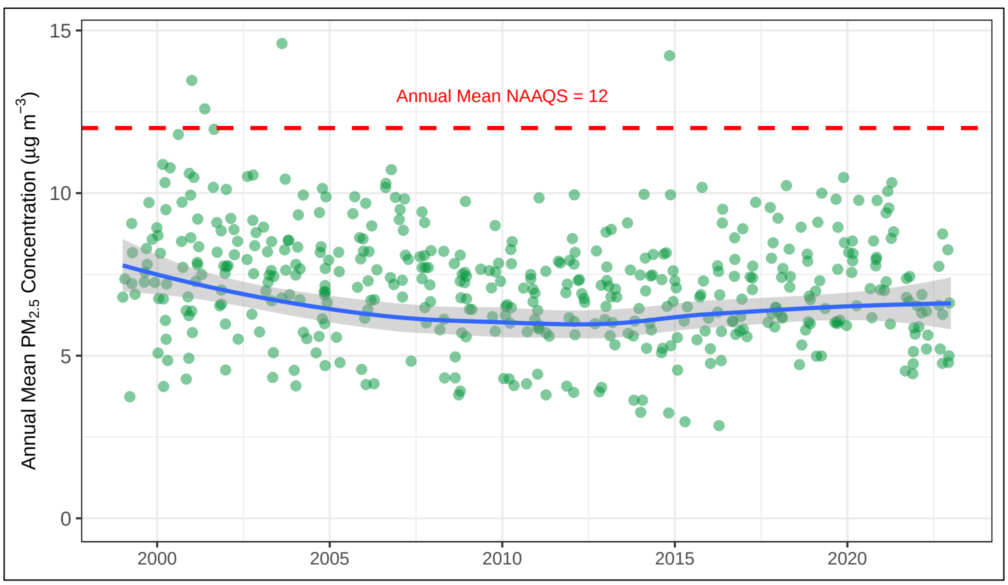

Figure 2.18: Statewide historical record of annual mean $PM_{2.5}$ values. The mean trend obtained using a generalized additive model is shown as a blue line.

3

Non-Criteria Pollutants

Non-criteria pollutants are those pollutants for which there are no current national ambient air quality standards. These include but are not limited to visibility, certain oxides of nitrogen species, total suspended particulates, some continuous particulate monitoring, and air toxics. Meteorological measurements of wind speed, wind direction, temperature, and humidity are also included in this group, as is chemical speciation of $PM_{2.5}$.

3.1 Visibility

Visibility is unique among air pollution effects in that it involves human perception and judgment. It has been described as the maximum distance that an object can be perceived against the background sky. Visibility also refers to the clarity with which the form and texture of distant, middle, and near details can be seen as well as the sense of the trueness of their apparent coloration. As a result, measures of visibility serve as surrogates of human perception. There are several ways to measure visibility but none of them tell the whole story or completely measure visibility as we experience it.

3.1.1 Standards

The Colorado Air Quality Control Commission established a visibility standard in 1990 for the Denver Metropolitan "AIR Program" area. The standard, an atmospheric extinction of 0.076 per inverse kilometer, was based on the public's definition of unacceptable amounts of haze as judged from slides of different haze levels taken in the Denver area. At the standard, 7.6% of the light is extinguished in each kilometer of air, and the standard is violated when the four-hour average extinction exceeds 7.6%. The standard applies from 8 A.M. to 4 P.M. each day, during those hours when the relative humidity is less than 70%. Visibility, along with meteorology and concentrations of other pollutants for which National Ambient Air Quality Standards exist, is used to determine the need for mandatory wood burning and voluntary driving restrictions.

There is no quantitative visibility standard for Colorado's pristine and scenic rural areas. However, in the 1977 amendments to the Federal Clean Air Act, Congress added Section 169a (Clean Air Act as amended in 1977, Section 169a 1977) and established a national visibility goal that created a qualitative standard of "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from man-made air pollution." The implementation of Section 169a has led to federal requirements to protect visual air quality in large national parks and wilderness areas (Visibility Protection for Federal Class 1 Areas n.d.). Twelve of these Class I areas are located in Colorado. Federal and state law prohibits visibility impairment in national parks and wildernesses due to large stationary sources of air pollution.

3.1.2 Impacts on Public Welfare

Visual air quality is an element of public welfare. Specifically, it is an important aesthetic, natural, and economic resource of the State of Colorado. EPA, the US Forest Service, and the US National Park Service have conducted studies that show that good visibility is something that people undeniably value. They have also shown that impaired visibility affects the enjoyment of a recreational visit to a scenic mountain area.

While the value of visibility is difficult to measure, APCD believes that people prefer to have clear views from their homes and offices. These concerns are reflected in residential property values and office rents. Any loss in visual air quality may contribute to corresponding losses in tourism and usually make an area less attractive to residents, potential newcomers, and industry. Researchers have found this link strongest with concentrations of fine particles, which are the main contributor to visibility impairment. In July 1997, the EPA developed a NAAQS for $PM_{2.5}$ (more details are in subsubsection 2.2.5.3). Any control strategies to lower ambient concentrations of fine particulate matter for health reasons will also improve visibility.

3.1.3 Sources

The cause of visibility impairment in Colorado is most often fine particles in the 0.1 to 2.5 μm size range. Light passing from a vista to an observer is either scattered away from the sight path or absorbed by the atmospheric fine particulates. Sunlight entering the pollution cloud may be scattered into the sight path adding brightness to the view and making it difficult to see elements of the vista. Sulfate, nitrate, elemental carbon, and organic carbon are the types of particulate matter most effective at scattering and/or absorbing light. The man-made sources of these particulates include wood burning, electric power generation, industrial combustion of coal or oil, and emissions from cars, trucks, and buses.

Visibility conditions vary considerably across the state. Usually, visibility in Colorado is among the best in the country. Our prized western vistas exist due to unique combinations of topography and scenic features. Air in much of the West contains low humidity and minimal levels of visibility-degrading pollution. Nevertheless, visibility problems occur periodically throughout the state. Wood burning haze is a concern in several mountain communities each winter and Denver has its "Brown Cloud" pollution episodes.[1] Even national parks, monuments, and wilderness areas experience pollution related visibility impairment on occasion due to regional haze, interstate traffic or even regional or global-scale transport of visibility-degrading pollution.[2] The visibility problems across the state have raised public concern and spurred research. The goal of Colorado's visibility program is to protect visual air quality where it is presently acceptable and improve visibility where it is degraded.

3.1.4 Class I Areas in Colorado

Phase 1 of the visibility program, also known as Reasonably Attributable Visibility Impairment (RAVI), addresses impacts in Class I areas by establishing a process to evaluate source specific visibility impacts, or plume blight, from individual sources or small groups of sources. Figure 3.1 illustrates these areas in Colorado.

Section 169B was added to the Clean Air Act Amendments of 1990 to address Regional Haze. Since Regional Haze and visibility problems do not respect state and tribal boundaries, the amendments authorized EPA to establish visibility transport regions as a way to combat regional haze.

Phase 2 of the visibility program addresses Regional Haze. This form of visibility impairment focuses on overall decreases in visual range, clarity, color, and ability to discern texture and details in Class I areas. The responsible air pollutants can be generated in the local vicinity or carried by the wind often many hundreds or even thousands of miles from where they originated.

APCD developed a Regional Haze State Implementation Plan (SIP) in 2010 illustrating how Colorado intends to meet the requirements of EPA's Regional rules for the period ending in 2018 (the first planning period in the rule), while also establishing enforceable controls that will help address the long term national visibility goals targeted to be achieved by the year 2064.

Colorado's Regional Haze SIP was approved by the Colorado Air Quality Control Commission on January 7, 2011. This plan will lead to less haze and improved visibility in some of Colorado's most treasured and scenic areas, including

[1] Neff, W. D. (1997). The Denver Brown Cloud studies from the perspective of model assessment needs and the role of meteorology. Journal of the Air & Waste Management Association, 47(3), 269-285

[2] Kavouras, I. G., Etyemezian, V., DuBois, D. W., Xu, J., & Pitchford, M. (2009). Source reconciliation of atmospheric dust causing visibility impairment in Class I areas of the western United States. Journal of Geophysical Research: Atmospheres (1984-2012), 114(D2)

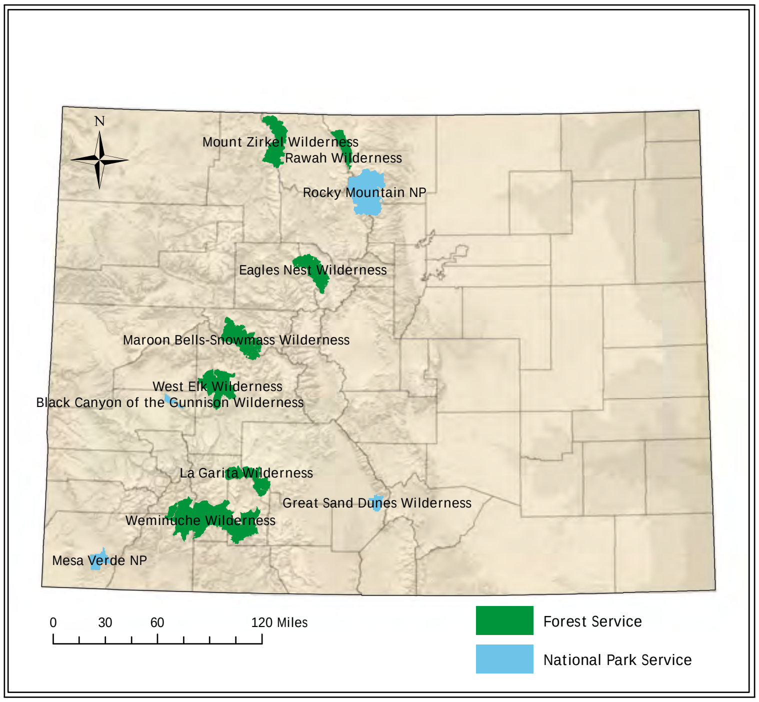

Figure 3.1: Class I areas in Colorado shown in green and blue. Blue indicates a National Park or Preserve, and green indicates a federally-protected wilderness area.

Rocky Mountain National Park, Mesa Verde, Maroon Bells, and the Great Sand Dunes [3].

3.1.5 Monitoring

There are several ways to measure visibility. APCD uses camera systems to provide qualitative visual documentation of a view. Transmissometers and nephelometers are used to measure the atmosphere's ability to attenuate light quantitatively.

A visibility site was installed in Denver in late 1990 using a long-path transmissometer. Visibility in the downtown area is monitored using a receiver located near Cheesman Park at 1901 E. 13th Avenue and a transmitter located on the roof of the Federal Building at 1929 Stout Street (Figure 3.2). This instrument directly measures light extinction, which is proportional to the ability of atmospheric particles and gases to attenuate image-forming light as it travels from an object to an observer. The visibility standard is stated in units of atmospheric extinction. Days when the visibility is affected by rain, snow, or relative humidity above 70% are termed "excluded" and are not counted as violations of the visibility standard.

Elsewhere in Colorado, several agencies of the federal government, in cooperation with regional and nationwide state air pollution organizations, also monitor visibility in a number of national parks and wilderness Class I areas, either individually or jointly through the Interagency Monitoring of Protected Visual Environments (IMPROVE) program. The goals of the monitoring programs are to establish background visibility levels, identify trends of deterioration or improvement, identify suspected sources of visibility impairment, and to track regional haze. Visibility and the atmospheric constituents that cause visibility degradation are characterized with camera systems, transmissometers, and extensive fine particle chemical composition measurements by the monitoring network. There are currently IMPROVE monitoring sites in Rocky Mountain National Park, Mesa Verde National Park, Weminuche Wilderness, Mount Zirkel Wilderness, Great Sand Dunes National Monument, White River National Forest, and San Juan National Forest. These data are not contained in this report, but are available at `https://vista.cira.colostate.edu/improve/`.

[3]`https://oitco.hylandcloud.com/POP/DocPop/DocPop.aspx?docid=3262052`

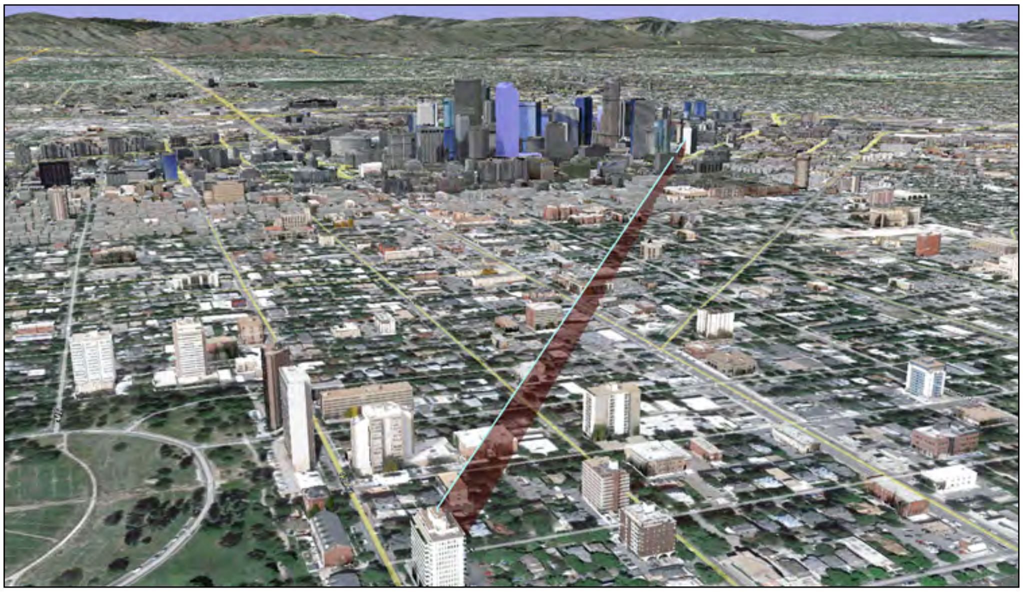

Figure 3.2: Denver transmissometer path (for illustration purposes only).

3.1.6 Denver Camera

APCD operates a web-based camera that can be viewed on the Live Image of Denver icon on the bottom left side of the screen at the APCD web site `https://www.colorado.gov/airquality`. There is a great deal of other information available from this site in addition to the image from the visibility camera, including the Front Range Air Quality Forecast, Air Quality Advisory, Monitoring Reports, this report, and the Open Burning Forecast.

The images in Figure 3.3 show the visibility on one of the best and one of the worst days for the year, October 21st and May 20th, respectively.

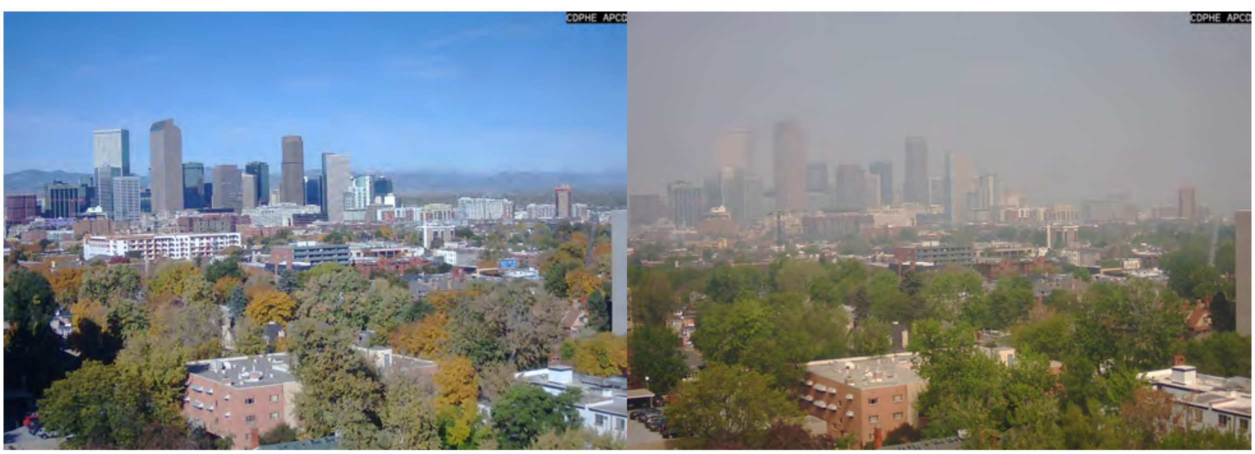

Figure 3.3: Denver Camera images of the best (left) and worst (right) visibility days in Denver during 2023.

These two pictures are images made by the web camera at the visibility monitor located at 1901 E. 13th Avenue in Denver, and are centered on the Federal Building at 1929 Stout Street (see Figure 3.2, the camera follows the transmissometer path). The difference in these two pictures is not just the brightness but the detail that can be seen between the two images. On the best day, buildings can be clearly resolved, and the Front Range is visible. On the worst day, however, contrast between buildings is lower, and the Front Range is obscured.

3.2 Nitric Oxide

Nitric oxide (NO) is the most abundant of the oxides of nitrogen emitted from combustion sources. There are no known adverse health effects at normal ambient concentrations. However, NO is a precursor to nitrogen dioxide, nitric acid, particulate nitrates, and ozone, all of which have demonstrated adverse health effects. There are no federal or state standards for nitric oxide.

Nitric oxide was measured simultaneously with NO_2 at the Welby, CAMP, La Casa, I-25 Globeville, I-25 Denver, Rocky Flats, and PAO sites. Table 3.1 shows the maximum and average NO concentrations measured in Colorado in 2023. Without national standards with which to compare these numbers, they are presented here for informational purposes only, and are considered by APCD to be consistent with recent historical nitric oxide concentrations (the I-25 site does not have long-term historical data to compare, as it was installed in June of 2013).

Table 3.1: Summary of average and maximum one-hour nitric oxide values measured at APCD monitoring sites in 2023.

Site Name	County	NO (ppb)	
		Annual Average	Maximum Value
Welby	Adams	10.6	222
CAMP	Denver	8.2	323
La Casa	Denver	7.6	200
I-25 Denver	Denver	22.0	240
I-25 Globeville	Denver	28.8	326
Rocky Flats - N.	Jefferson	0.4	71
PAO	Weld	1.4	81

3.3 Air Toxics

Toxic air pollutants, or air toxics, are those pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects. Air toxics may also cause adverse environmental and ecological effects. EPA is required to reduce air emissions of 188 air toxics listed in the Clean Air Act. Examples of air toxics include benzene (found in gasoline), perchloroethylene (emitted from some dry cleaning facilities), and methylene chloride (used as a solvent by a number of industries). Most air toxics originate from man-made sources, including mobile sources like cars, trucks, and construction equipment, and stationary sources like factories, refineries, and power plants, as well as indoor sources (some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires. [4]

People exposed to air toxics at sufficient concentrations may experience various health effects including cancer and damage to the immune system, as well as neurological, reproductive (including reduced fertility), developmental, respiratory, and other health problems. In addition to exposure from breathing air toxics, risks are also associated with the deposition of toxic pollutants onto soils or surface waters, where they are taken up by plants and ingested by animals and eventually magnified up through the food chain. Like humans, animals may experience health problems due to air toxics exposure.

Since 2004, APCD has monitored air toxics in Grand Junction as part of EPA's National Air Toxics Trend Stations project. Monitoring for ozone precursors, which are a subset of air toxics, began at CAMP and Platteville in December of 2011. The data from the Grand Junction study and the Ozone Precursor study are available in separate reports, available at `https://www.colorado.gov/airquality/tech.aspx`.

3.4 Meteorology

APCD takes a limited set of meteorological measurements at 19 locations around the state. These measurements include wind speed, wind direction, temperature, standard deviation of horizontal wind direction, and select monitoring of

[4] `https://www.epa.gov/haps/hazardous-air-pollutants-sources-and-exposure`

relative humidity and solar radiation. Relative humidity measurements are also taken in conjunction with the two visibility monitors. The humidity data are not summarized in this report since they are used primarily to validate the visibility measurements taken at the specific locations. The wind speed, wind direction, and temperature measurements are collected primarily for air quality forecasting and air quality modeling. These instruments are installed on ten-meter towers and the data are collected as hourly averages and sent along with other air quality data to be stored on the EPA's Air Quality System (AQS) database. The wind speed and wind direction data are shown as wind roses at the end of each monitoring area in chapter 4 below.

The wind roses displayed in this report (see chapter 4) are based on the direction that the wind is blowing from. Another way of visualizing a wind rose is to picture yourself standing in the center of the plot and facing into the wind. The wind direction is divided into 12 cardinal directions (ESE, for example). The wind speed is divided into six ranges: 0-2 ms^{-1}, 2-4 ms^{-1}, 4-6 ms^{-1}, 6-8 ms^{-1}, 8-10 ms^{-1}, and greater than 10 ms^{-1}. The length of each arm of the wind rose represents the percentage of time the wind was blowing from that direction at that speed. The longer the arm, the greater the percentage of time the wind is blowing from that direction.

3.5 Chemical Speciation of $PM_{2.5}$

Numerous health effects studies have correlated negative health effects to the total mass concentration of $PM_{2.5}$ in ambient air. However, it has not yet been completely determined if the health correlation is to total mass concentration, or to concentrations of specific chemical species in the $PM_{2.5}$ mix. When the EPA promulgated the NAAQS for $PM_{2.5}$ in 1997, a compliance monitoring network based on total $PM_{2.5}$ mass was established. Mass concentrations from the compliance network are used to determine attainment of the NAAQS. EPA soon supplemented the $PM_{2.5}$ network with the Speciation Trends Network (STN) monitoring to provide information on the chemical composition of $PM_{2.5}$. The main purpose of the STN is to identify sources, develop implementation plans to reduce $PM_{2.5}$ pollution, and support health effects research.

Colorado began chemical speciation monitoring at the Commerce City site in February 2001. Four other chemical speciation sites were established in 2001 in Colorado Springs, Durango, Grand Junction, and Platteville. The Durango site was closed in September 2003. The Colorado Springs site was closed in December 2006. These sites were eliminated when concentrations were found to trend low and when funding was reduced for the project. The Grand Junction site was closed in December 2009 and moved to DMAS NCore where it began sampling in January of 2010 to comply with the requirement from EPA to monitor $PM_{2.5}$ speciation at NCore sites. The DMAS NCore site was shut down due to redevelopment of the property and moved to the La Casa NCore monitoring site at 4545 Navajo Street in late 2012. APCD is currently monitoring for $PM_{2.5}$ speciation at the LaCasa, Platteville and Commerce City monitoring sites.

If $PM_{2.5}$ pollution is to be controlled, it is important to know the composition of $PM_{2.5}$ particles so that the appropriate sources can be targeted for reductions (see subsubsection 2.2.5.2 above for more information on $PM_{2.5}$ sources). Therefore, chemical speciation monitoring is conducted for 47 elemental metals, five ionic species, and elemental and organic carbon. Selected filters can also be analyzed for semi-volatile organics and microscopic analyses. The results of these samples can be obtained from APCD upon request. Some of these chemical species and compounds can cause serious health effects, premature death, visibility degradation, and regional haze. The chemical speciation data for $PM_{2.5}$ is used in many ways, such as to determine which general source categories are likely responsible for the $PM_{2.5}$ pollution at a given monitoring site on a given day, and how much pollution comes from each source category. There are two broad categories of $PM_{2.5}$ - primary and secondary particles. Primary $PM_{2.5}$ particles include those emitted directly to the air. Primary particles include carbonaceous particles from incomplete combustion in internal combustion engines, wood burning appliances, waste burning, and crushed geologic materials. Secondary $PM_{2.5}$ is formed from gases that combine in the atmosphere through chemical processes and form liquid aerosol droplets. Ammonium nitrates and ammonium sulfates are generally the two largest types of secondary $PM_{2.5}$ in Colorado.

4

Spatial Variability of Air Quality

In this section, concentration data covering the last fifteen years are summarized for each air quality monitor in the APCD network, which are grouped below by monitoring region and pollutant. The plots in this section show annual means and one-hour, eight-hour, or 24-hour values in the form of the NAAQS standards. The values recorded at individual sites are compared to statewide averages, which are shown in light blue in all plots. Please refer to subsection 1.1.2 for a brief description of the monitoring regions discussed below.

4.1 Central Mountains Region

4.1.1 Particulate Matter

The data below may include exceptional events. See subsubsection 2.2.5.4 for a description of exceptional events.

Table 4.1: Summary of PM_{10} values recorded at monitoring stations in the Central Mountains region during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Cañon City	Fremont	15.3	95	0
Aspen	Pitkin	15.8	56	0
Steamboat Springs	Routt	15.6	69	0

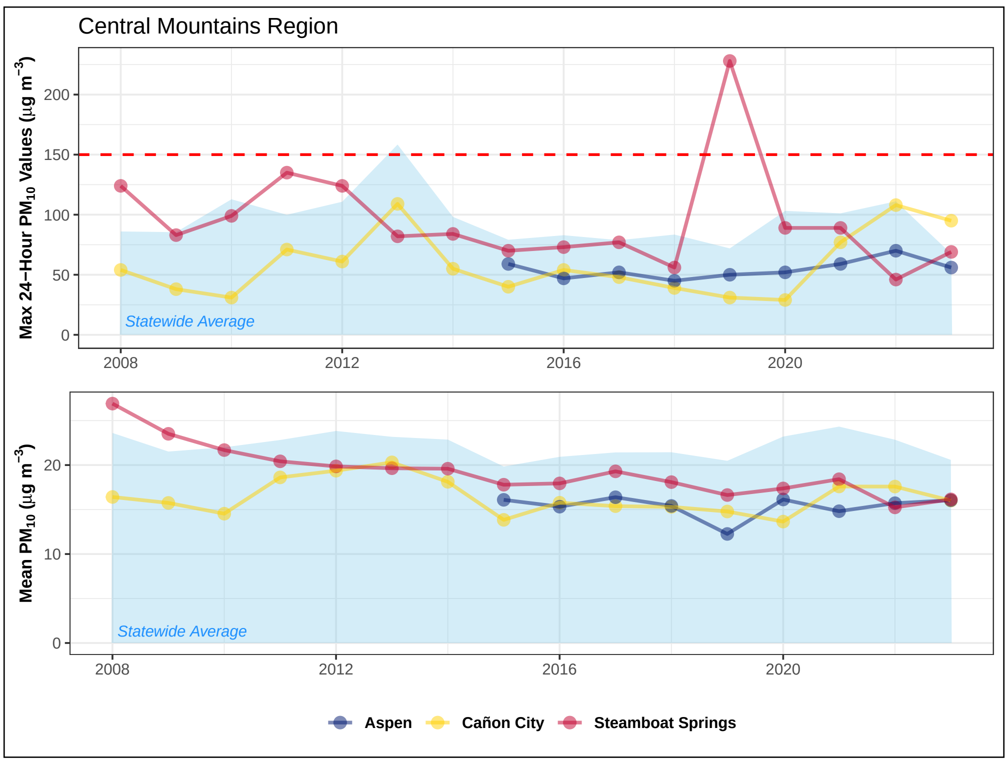

Figure 4.1: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Central Mountains region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

4.2 Denver Metro / North Front Range Region

4.2.1 Particulate Matter

There were no violations of the PM_{10} or $PM_{2.5}$ NAAQS in the Denver Metro/Northern Front Range counties in 2023. The Boulder - CU and CAMP monitors do not meet requirements for three consecutive years of operation; therefore, while the 2023 PM values are reported, the data from these sites cannot be compared to the NAAQS in terms of a three-year average. The $PM_{2.5}$ plots below show the 98^{th} percentile of the data collected during each year rather than the three-year average.

Table 4.2: Summary of PM_{10} values recorded at monitoring stations in the Denver Metro/Northern Front Range region during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Birch Street	Adams	30.3	98	0
Welby	Adams	28.5	95	0
Longmont	Boulder	19.3	41	0
Boulder Chamber of Comm.	Boulder	16.0	30	0
Boulder - CU	Boulder	14.8	35	0
CAMP	Denver	25.0	73	0
La Casa	Denver	20.7	49	0

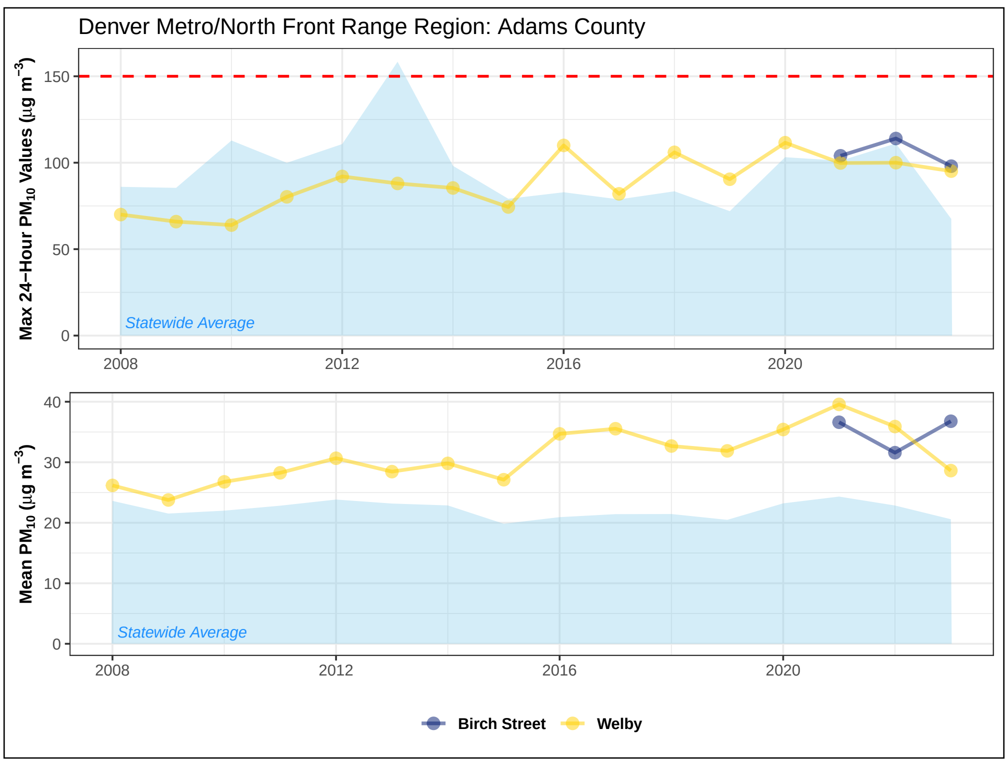

Figure 4.2: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Adams County. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

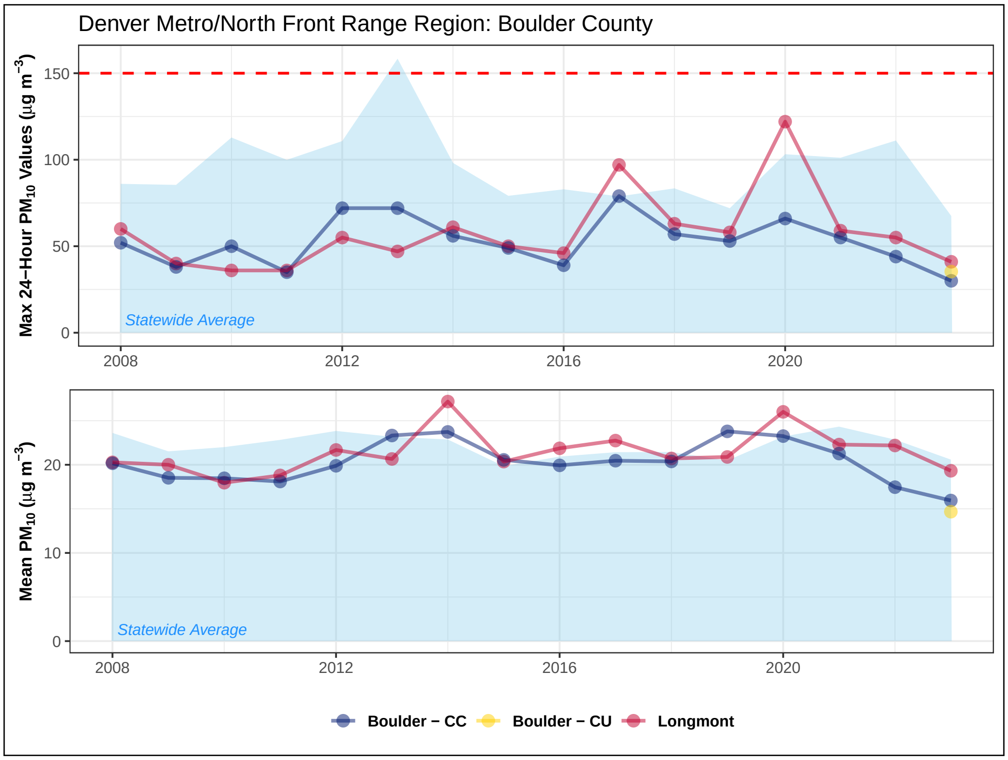

Figure 4.3: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Boulder County. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

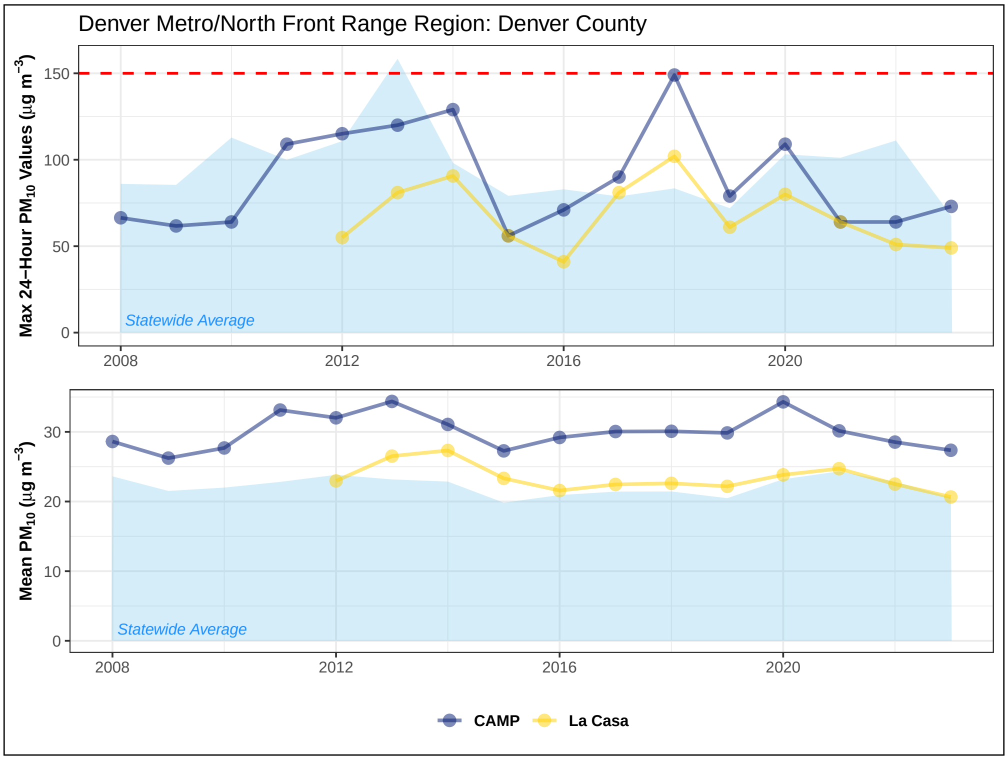

Figure 4.4: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in Denver County. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.3: Summary of $PM_{2.5}$ values recorded at monitoring stations in the Denver Metro/Northern Front Range region during 2023.

Site Name	County	$PM_{2.5}$ ($\mu g\ m^{-3}$)		
		Annual Average	Annual 98^{th} Percentile	3-Year Avg. of 98^{th} Percentile
Birch Street	Adams	8.4	24.1	-
Arapaho Comm. College	Arapahoe	5.4	16.0	17
Longmont	Boulder	6.6	17.8	23
Boulder Chamber of Comm.	Boulder	4.8	14.6	18
Boulder - CU	Boulder	4.1	12.3	-
CAMP	Denver	7.4	26.5	-
National Jewish Health	Denver	6.4	16.3	22
La Casa	Denver	6.4	16.2	19
I-25 Denver	Denver	7.7	19.2	18
I-25 Globeville	Denver	8.7	23.0	24
Chatfield State Park	Douglas	5.0	13.1	19
Fort Collins - CSU	Larimer	6.2	18.2	22
Greeley - Hospital	Weld	7.7	23.3	25
Platteville	Weld	7.7	21.9	23

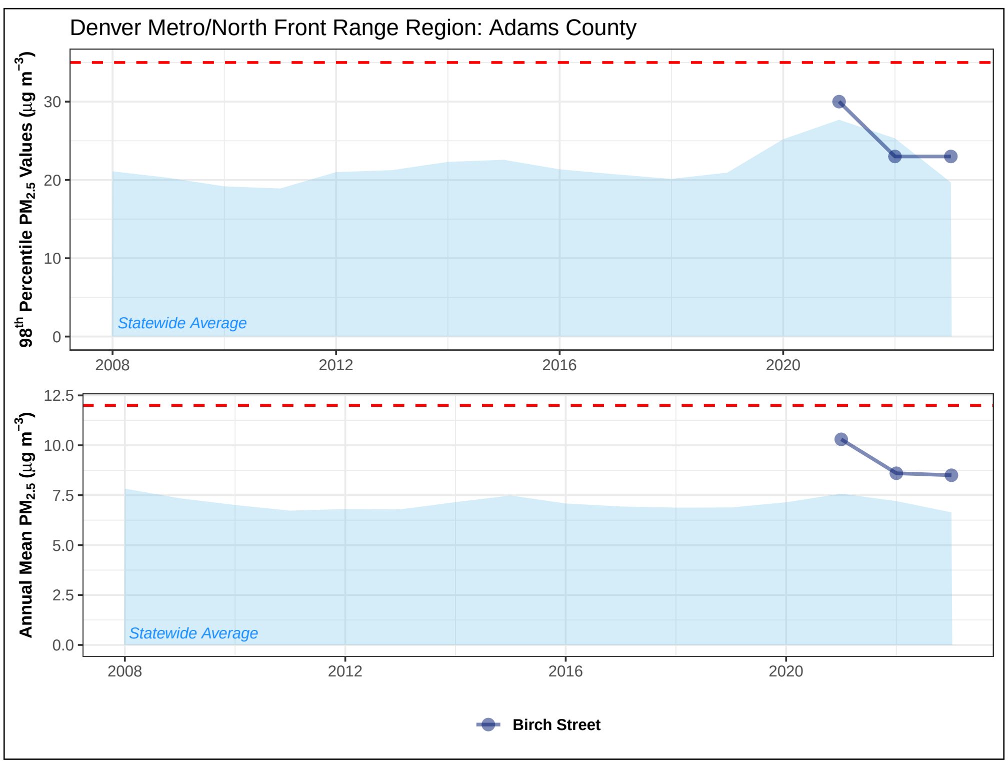

Figure 4.5: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Adams County. The 24-hour and annual mean NAAQS (35 $\mu g\ m^{-3}$ and 12 $\mu g\ m^{-3}$, respectively) are shown as dashed red lines.

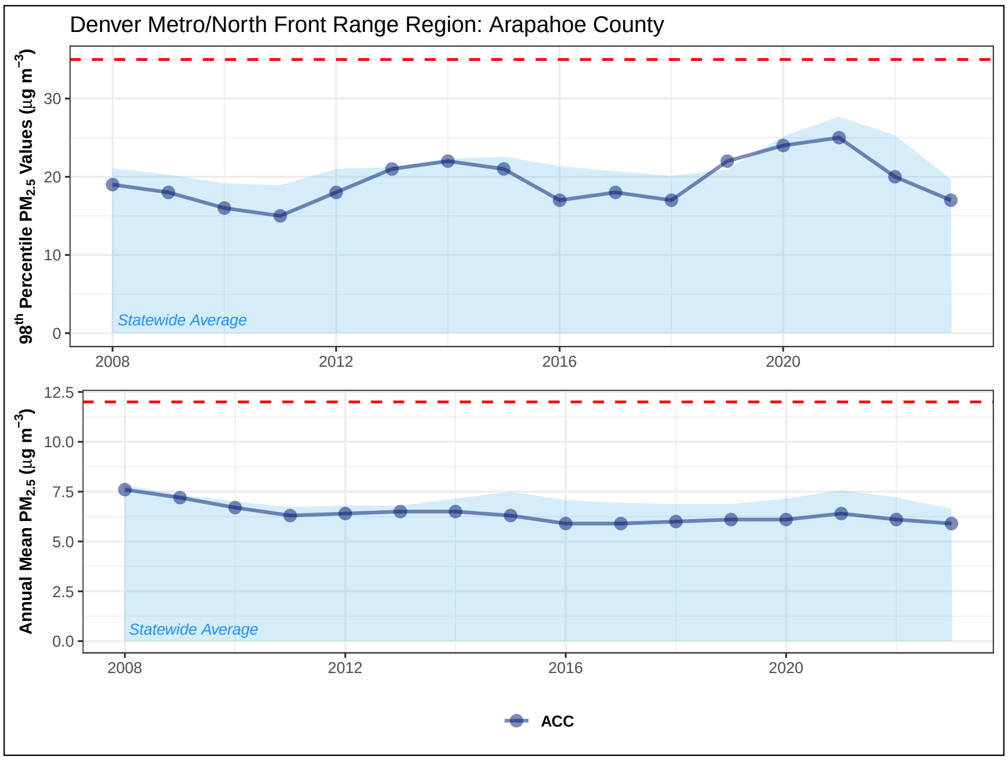

Figure 4.6: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Arapahoe County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

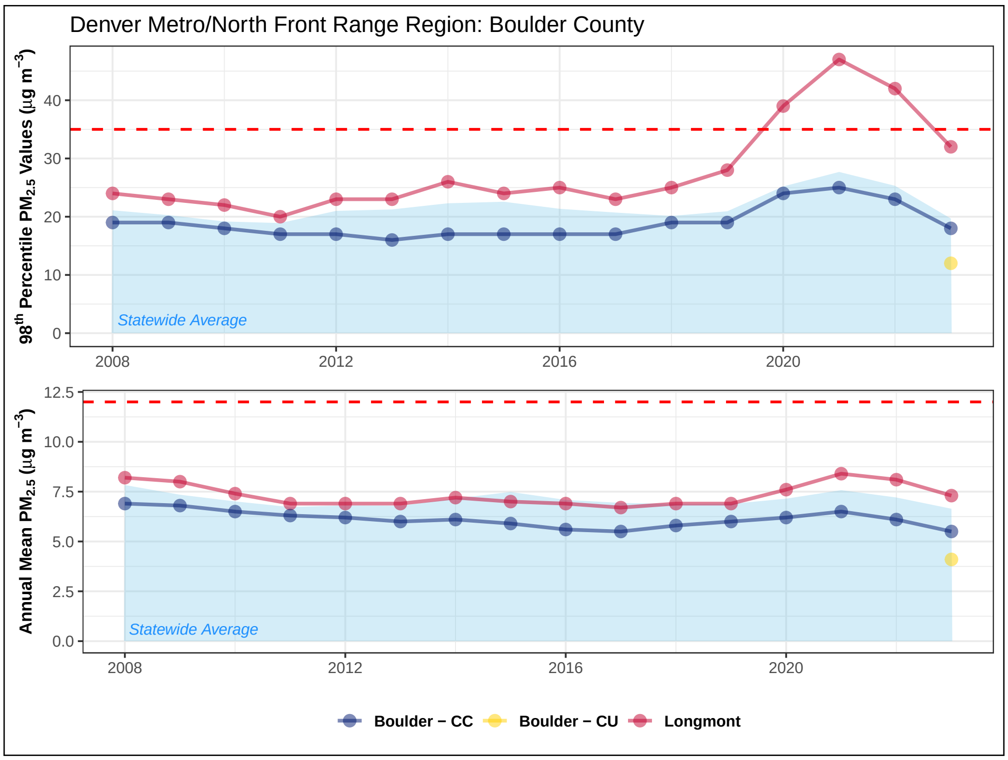

Figure 4.7: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Boulder County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

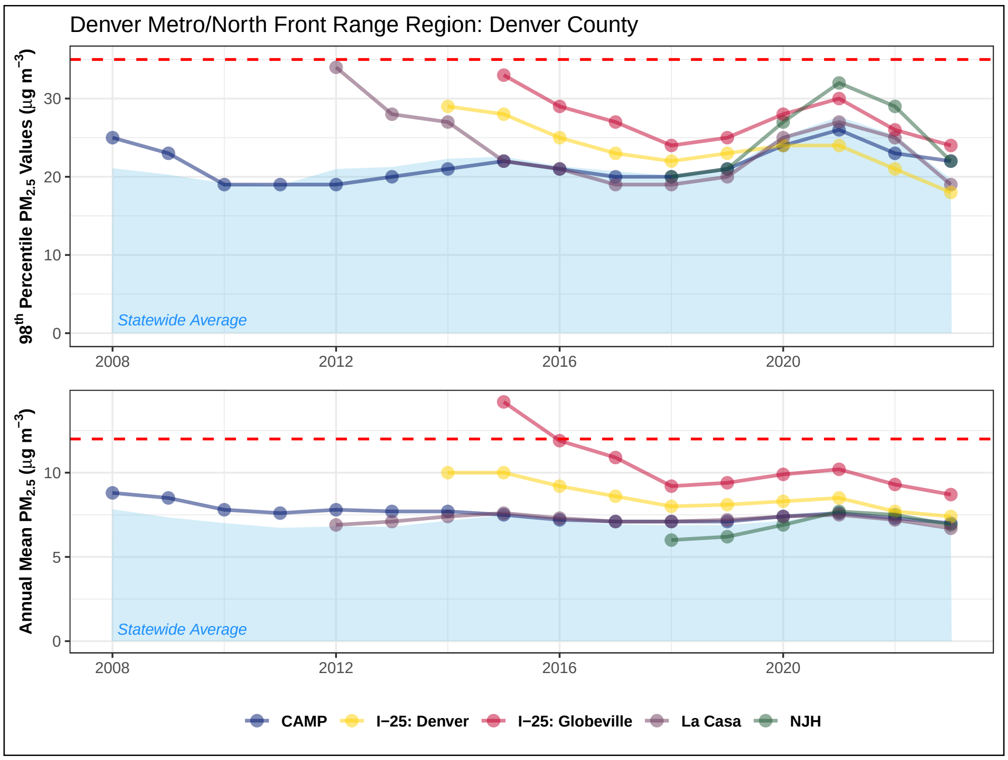

Figure 4.8: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Denver County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

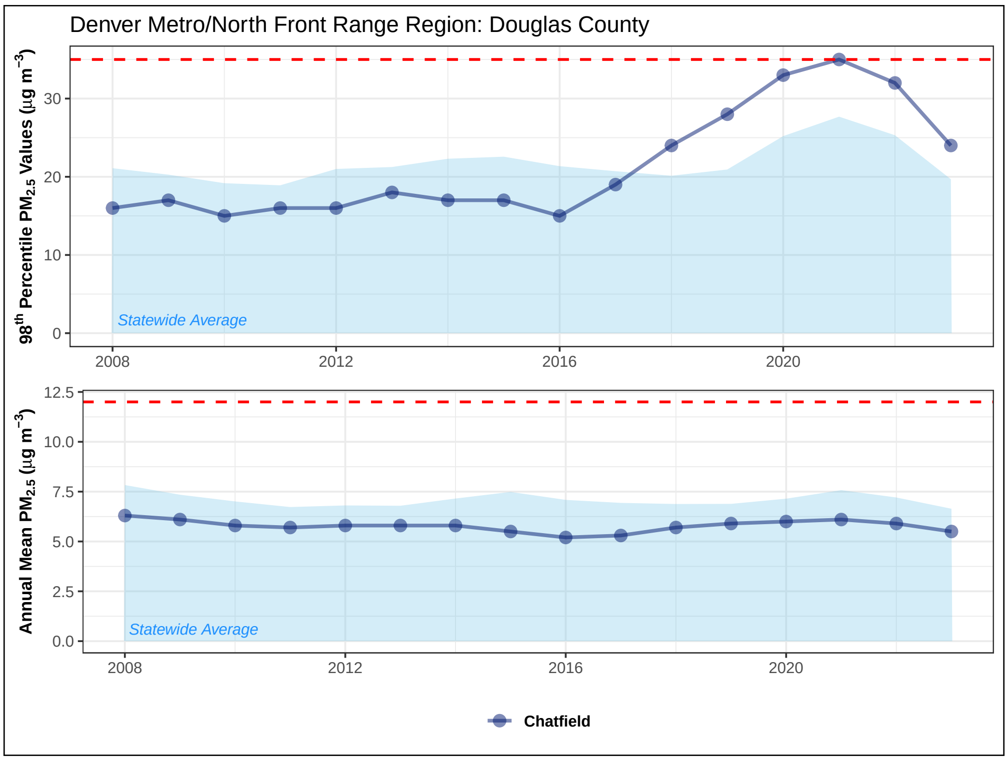

Figure 4.9: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Douglas County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

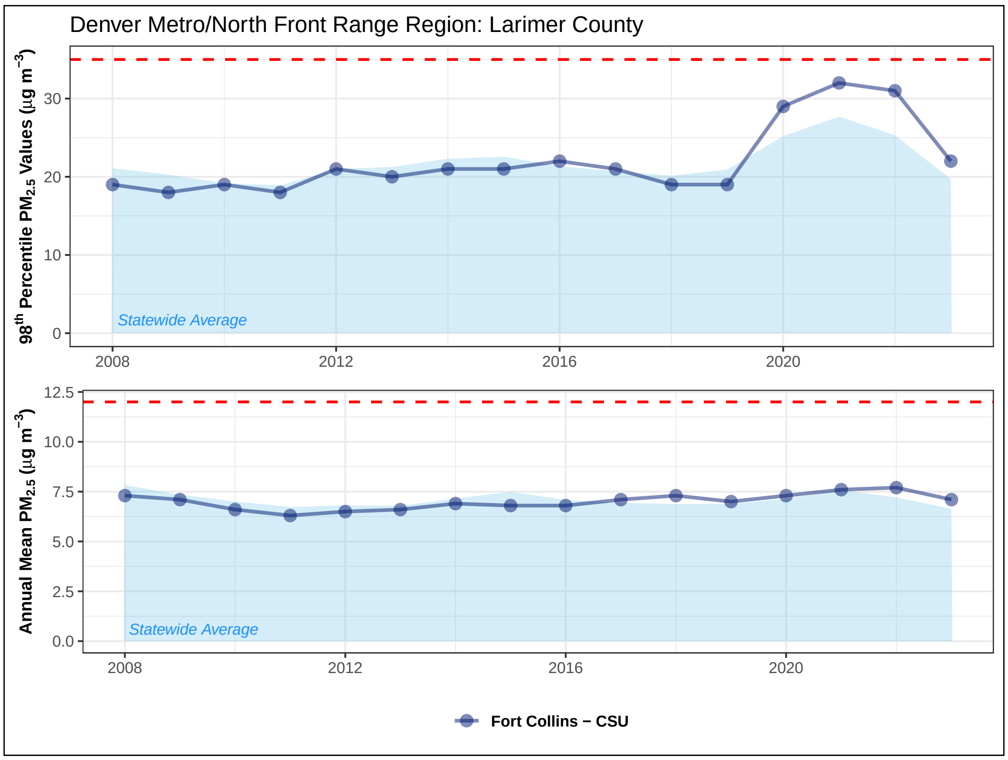

Figure 4.10: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Larimer County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

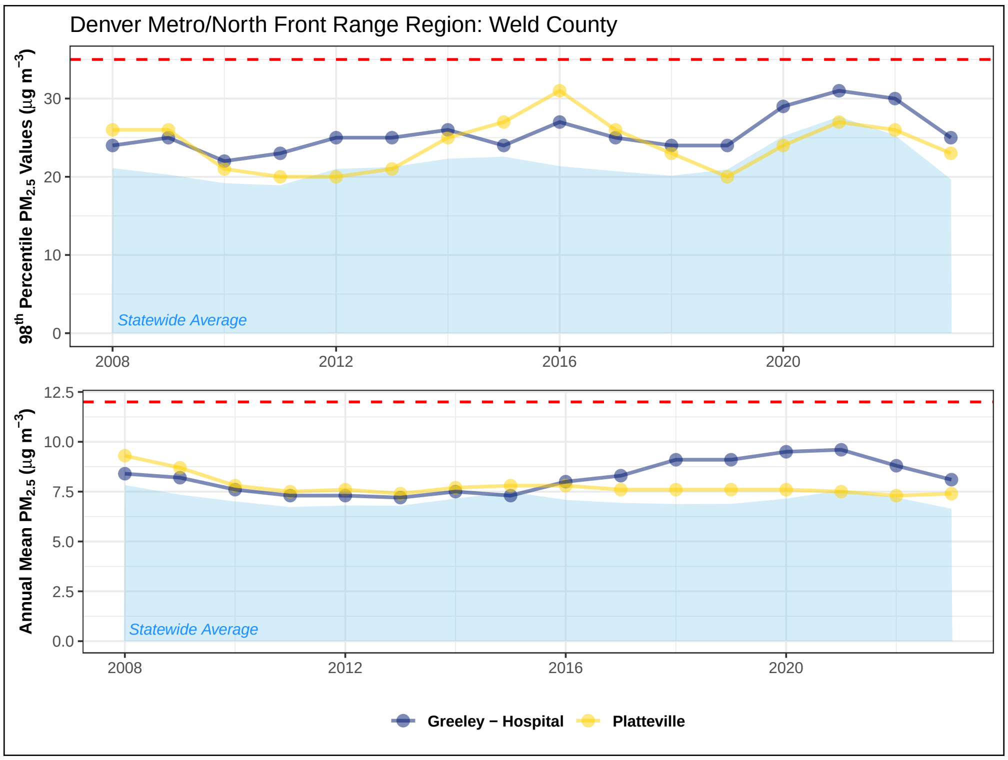

Figure 4.11: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in Weld County. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.2.2 Carbon Monoxide

Table 4.4: Summary of CO values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2023.

Site Name	County	CO 1-Hour Average (ppm)		CO 8-Hour Average (ppm)	
		1^{st} Max.	2^{nd} Max.	1^{st} Max.	2^{nd} Max.
Welby	Adams	1.8	1.6	1.3	1.2
CAMP	Denver	2.4	2.3	2.0	1.7
La Casa	Denver	2.1	1.8	1.5	1.4
I-25 Denver	Denver	2.5	2.4	1.8	1.8
Fort Collins - Mason	Larimer	1.8	1.7	1.1	1.1
Greeley - County Tower	Weld	1.2	1.1	0.8	0.7

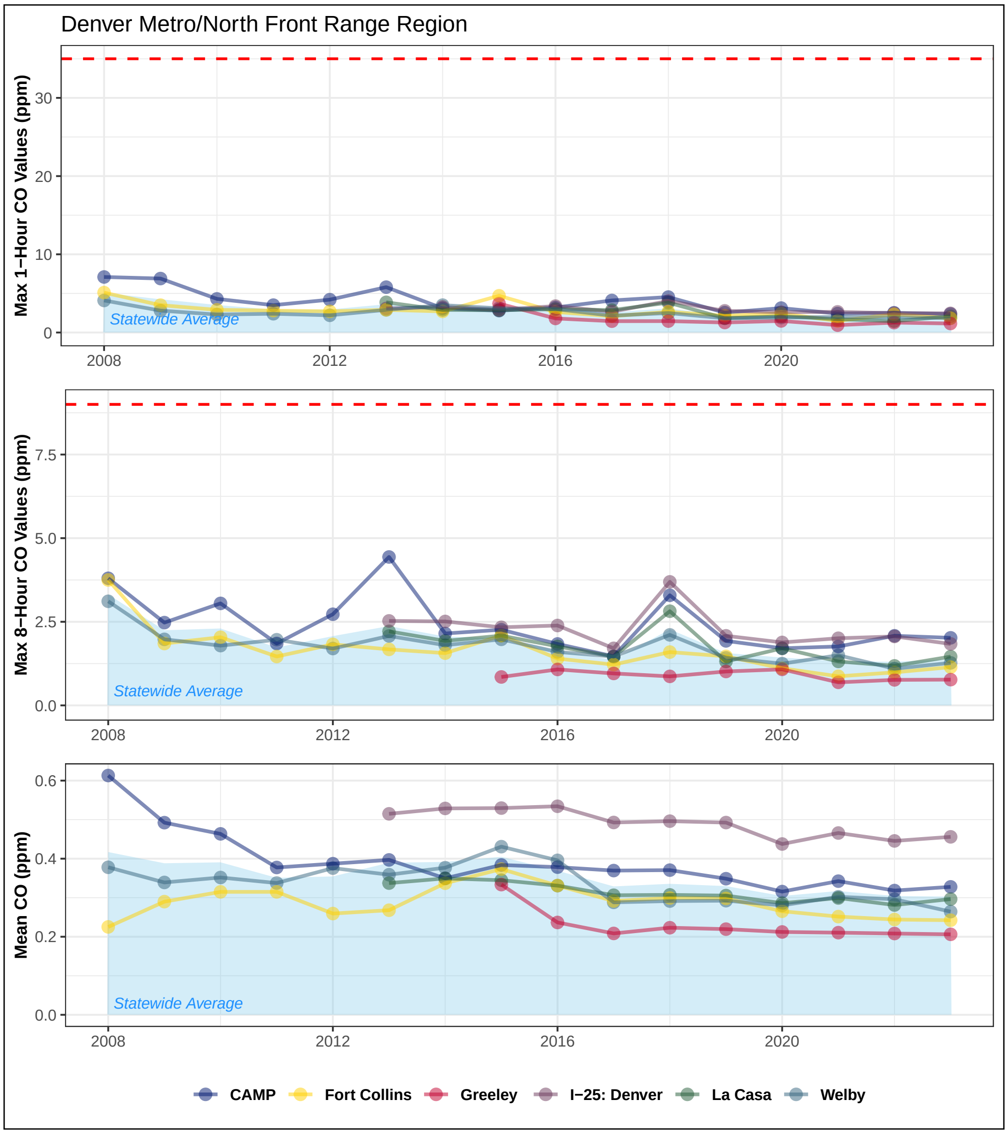

Figure 4.12: Fifteen-year trend in annual maximum one-hour (top) and eight-hour (center) CO values and annual mean eight-hour CO concentrations (bottom) for monitoring sites in the Denver Metro/Northern Front Range region. The one-hour and eight-hour NAAQS (35 ppm and 9 ppm, respectively) are shown as dashed red lines.

4.2.3 Ozone

Table 4.5: Summary of O_3 values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2023. Sites having three-year NAAQS values in excess of 70 ppb are indicated by asterisks.

Site Name	County	Ozone 8-Hour Average (ppb)		
		1st Max.	4th Max.	3-Year Avg. of 4th Max. 8-Hr
Welby	Adams	74	70	74*
Highlands	Arapahoe	77	75	77*
Aurora East	Arapahoe	81	73	73*
Boulder Reservior	Boulder	81	71	75*
CAMP	Denver	74	70	72*
La Casa	Denver	73	70	75*
Chatfield State Park	Douglas	83	76	81*
Black Hawk	Gilpin	79	73	75*
Rocky Flats - N.	Jefferson	83	77	80*
NREL	Jefferson	78	74	80*
Evergreen	Jefferson	79	74	75*
Fort Collins - West	Larimer	88	71	76*
Fort Collins - Mason	Larimer	78	67	71*
Greeley - County Tower	Weld	74	68	71*
PAO	Weld	70	68	74*

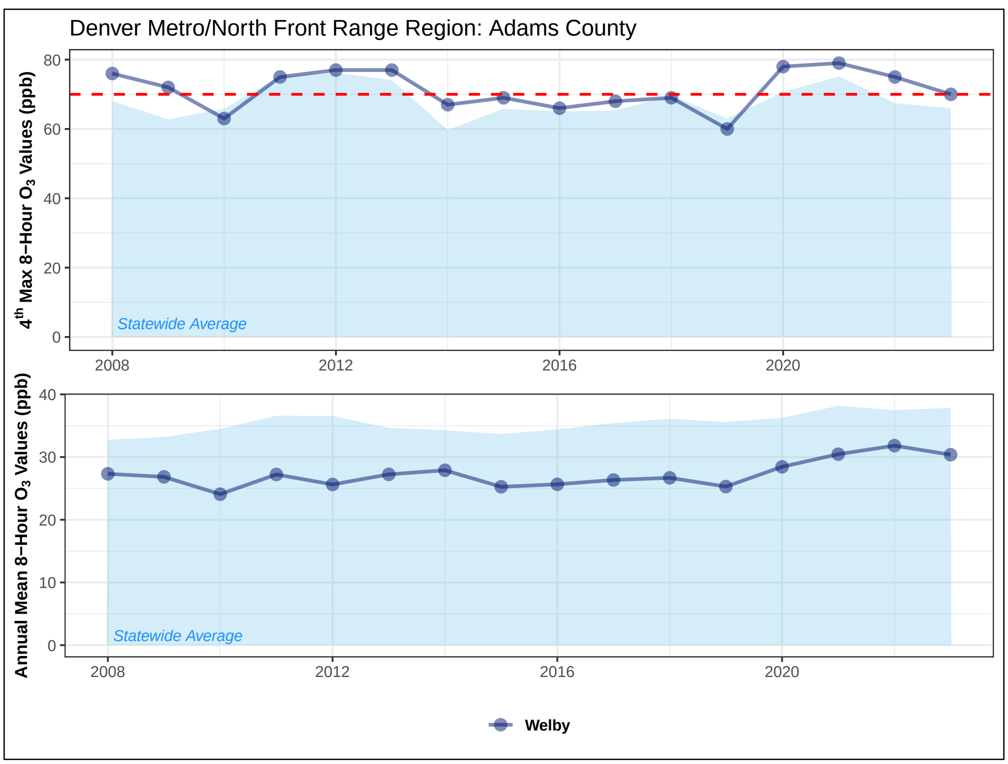

Figure 4.13: Fifteen-year trend in ozone eight-hour NAAQS value (top) and annual mean 8-hour concentration (bottom) for monitoring sites in Adams County. The 8-hour NAAQS (70 ppb) is shown as a dashed red line.

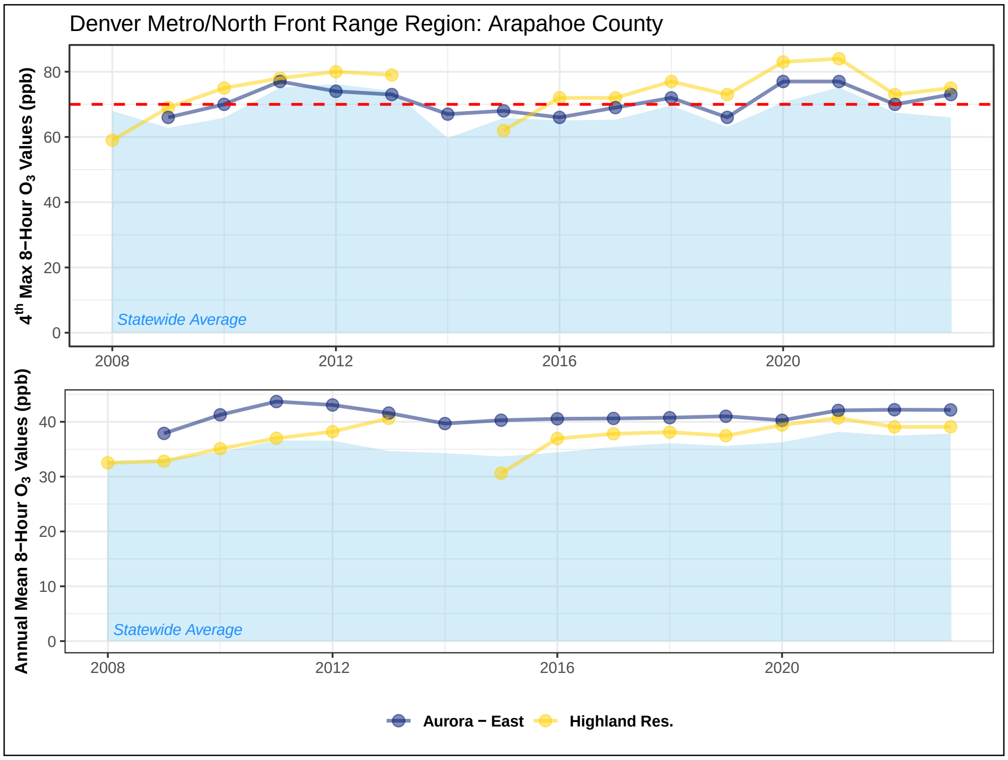

Figure 4.14: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Arapahoe County. The 8-hour NAAQS (70 ppb) is shown as a dashed red line.

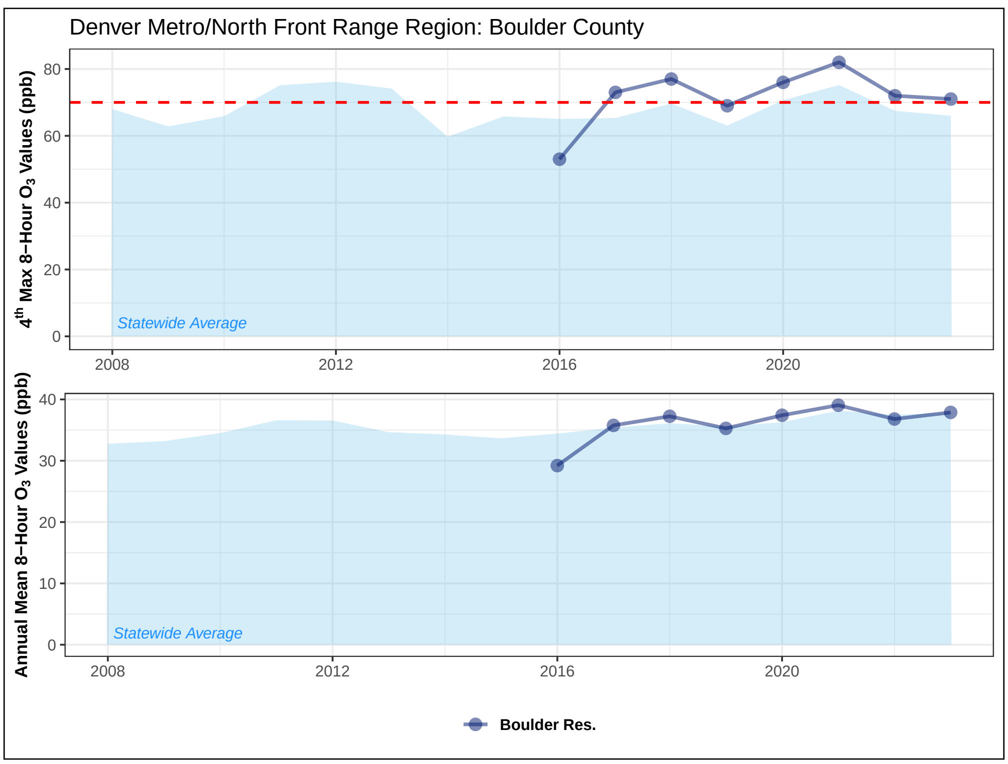

Figure 4.15: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Boulder County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

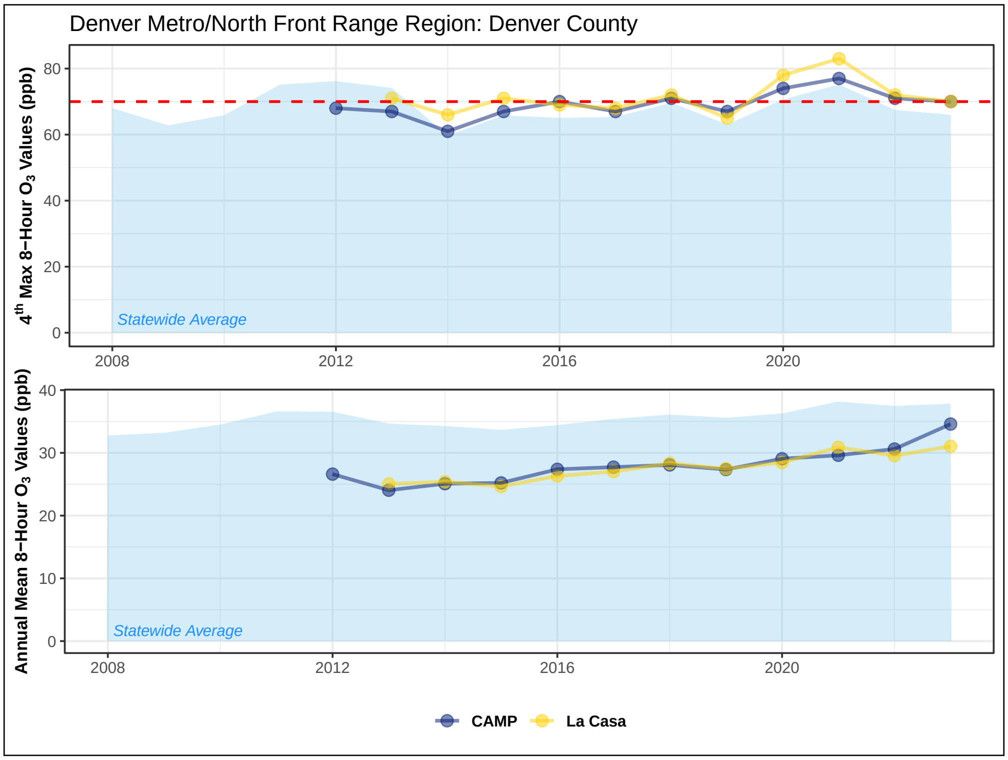

Figure 4.16: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Denver County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

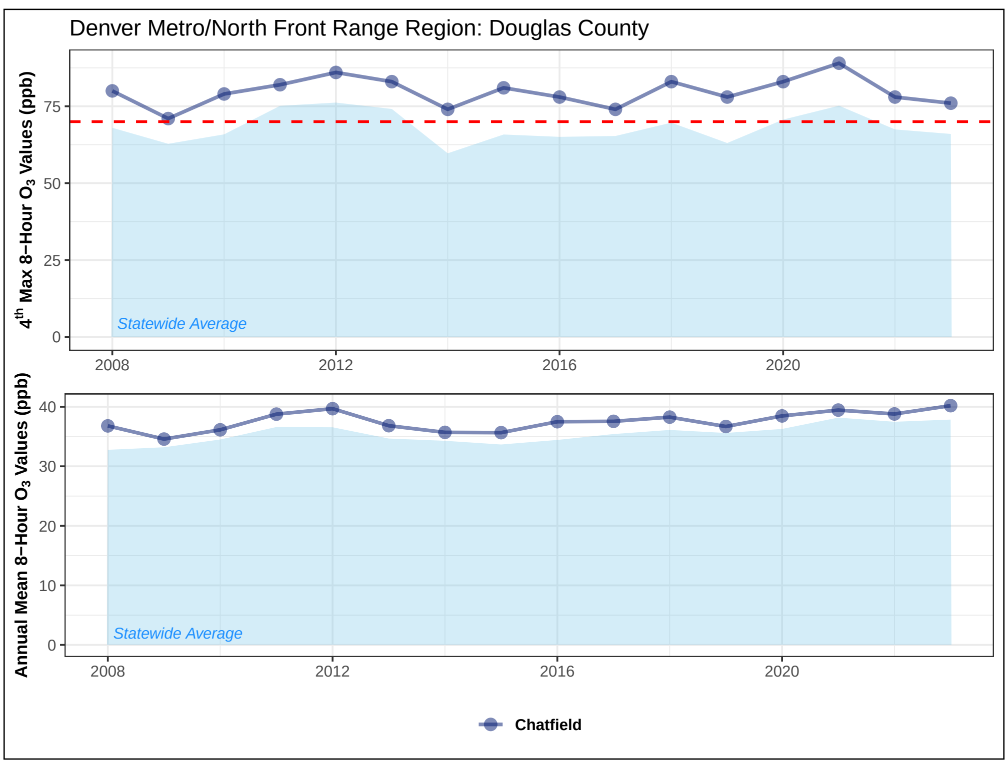

Figure 4.17: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Douglas County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

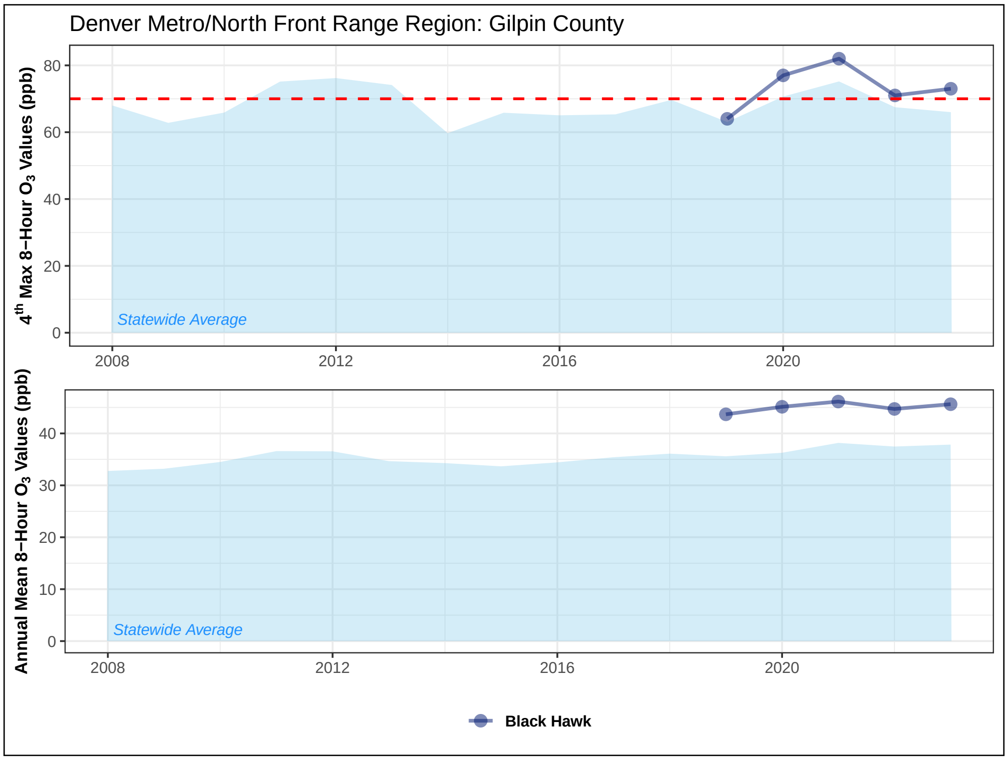

Figure 4.18: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Gilpin County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

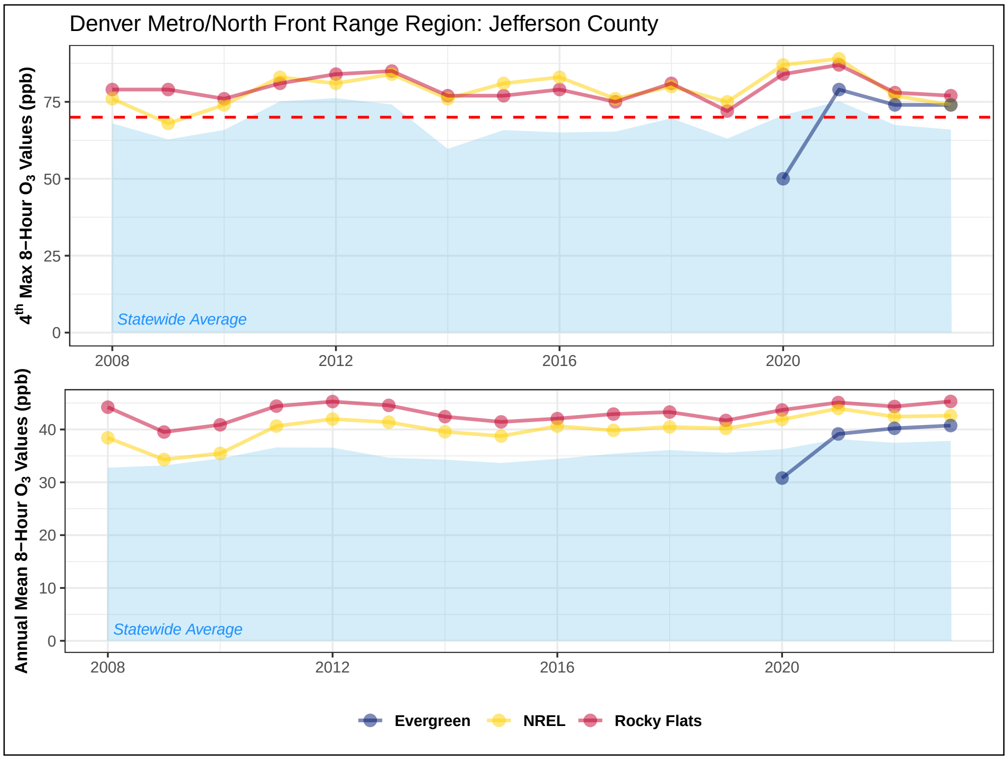

Figure 4.19: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Jefferson County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

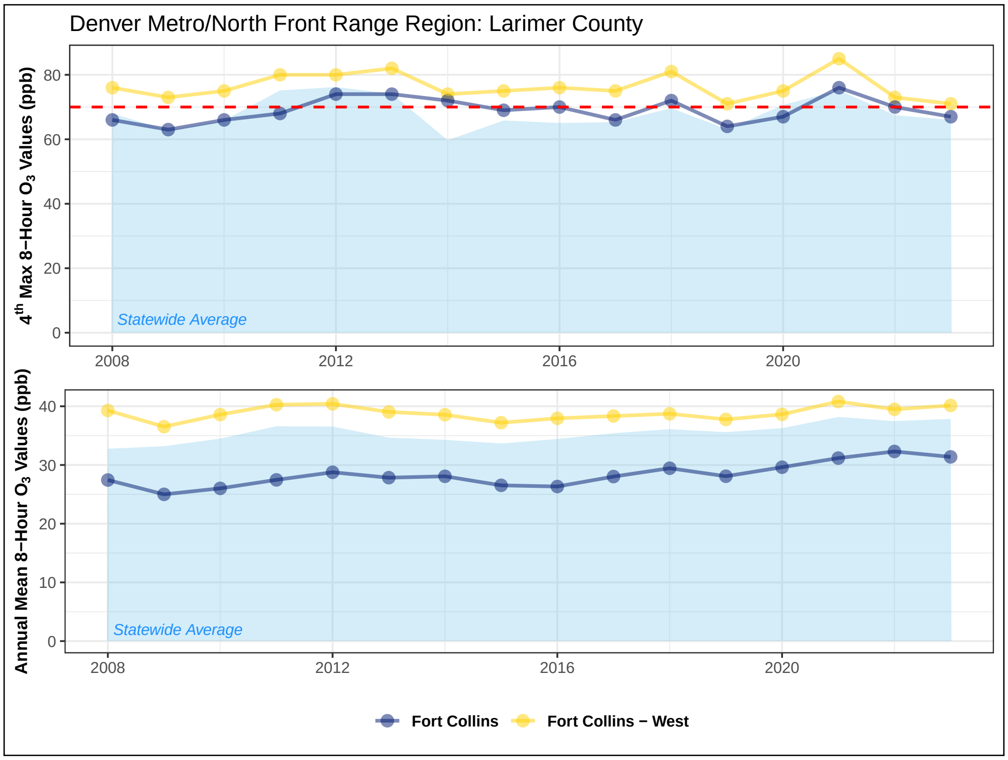

Figure 4.20: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Larimer County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

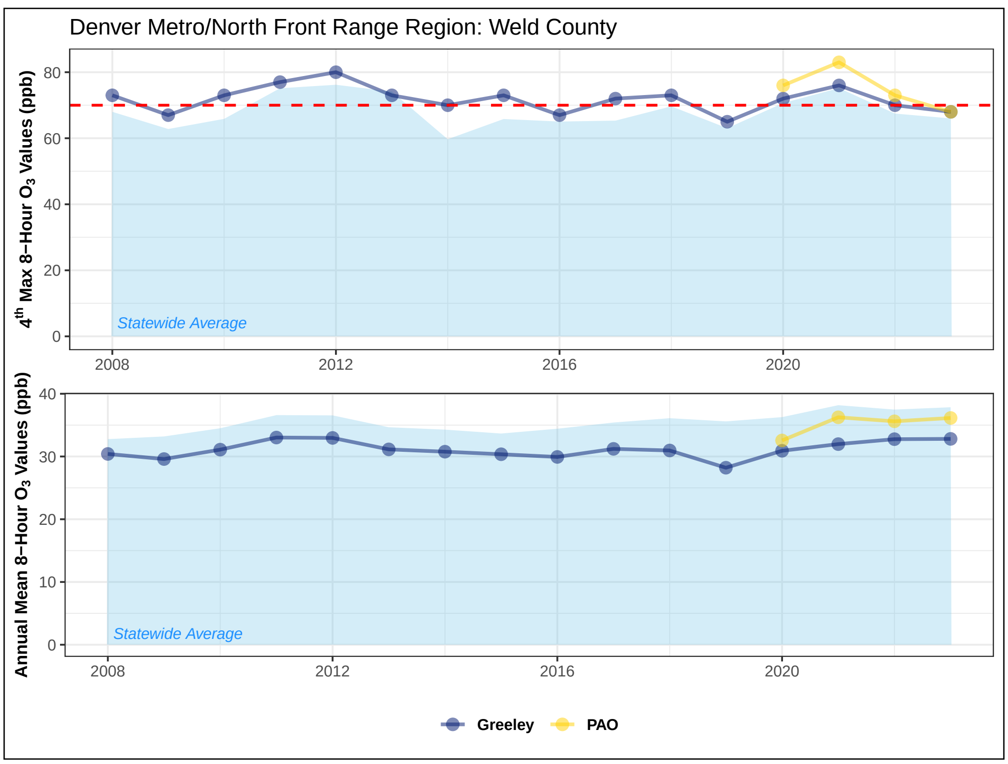

Figure 4.21: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in Weld County. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.2.4 Nitrogen Dioxide

Table 4.6: Summary of NO_2 values recorded at monitoring stations in the Denver Metro / Northern Front Range region during 2023.

Site Name	County	NO_2 (ppb)		
		Annual Mean	98^{th} Percentile	3-Year Avg. of 98^{th} Percentile
Welby	Adams	15.9	56.2	56
CAMP	Denver	14.6	65.7	62
La Casa	Denver	14.8	55.2	56
I-25 Denver	Denver	20.9	61.5	60
I-25 Globeville	Denver	24.2	64.5	66
Rocky Flats - N.	Jefferson	2.8	31.5	27
PAO	Weld	7.0	47.4	46

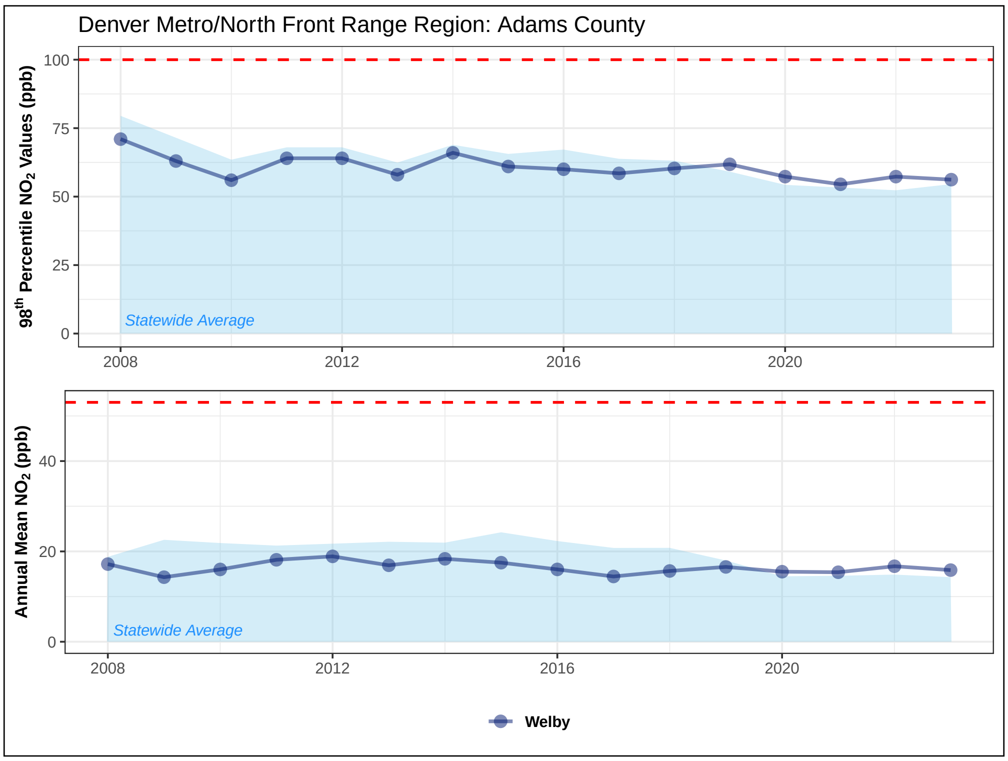

Figure 4.22: Fifteen-year trend in one-hour (top) and annual mean (bottom) nitrogen dioxide NAAQS values for monitoring sites in Adams County. The one-hour and annual mean standards (100 ppb and 53 ppb, respectively) are shown as dashed red lines.

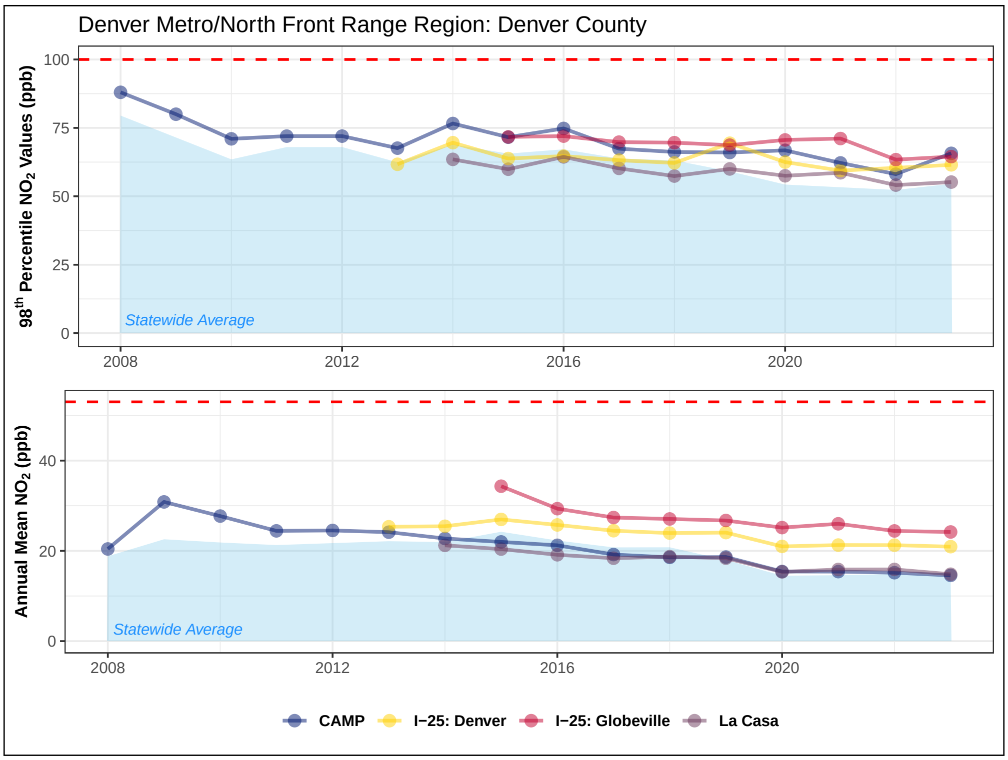

Figure 4.23: Fifteen-year trend in one-hour (top) and annual mean (bottom) nitrogen dioxide NAAQS values for monitoring sites in Denver County. The one-hour and annual mean standards (100 ppb and 53 ppb, respectively) are shown as dashed red lines.

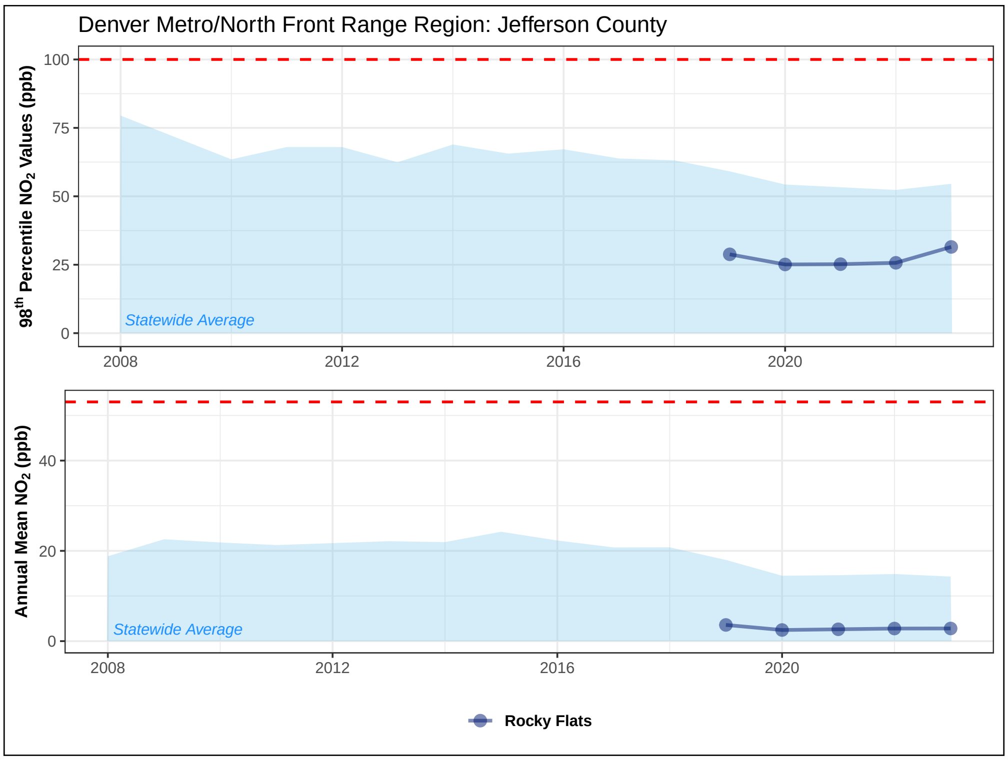

Figure 4.24: Fifteen-year trend in one-hour (top) and annual mean (bottom) nitrogen dioxide NAAQS values for monitoring sites in Jefferson County. The one-hour and annual mean standards (100 ppb and 53 ppb, respectively) are shown as dashed red lines.

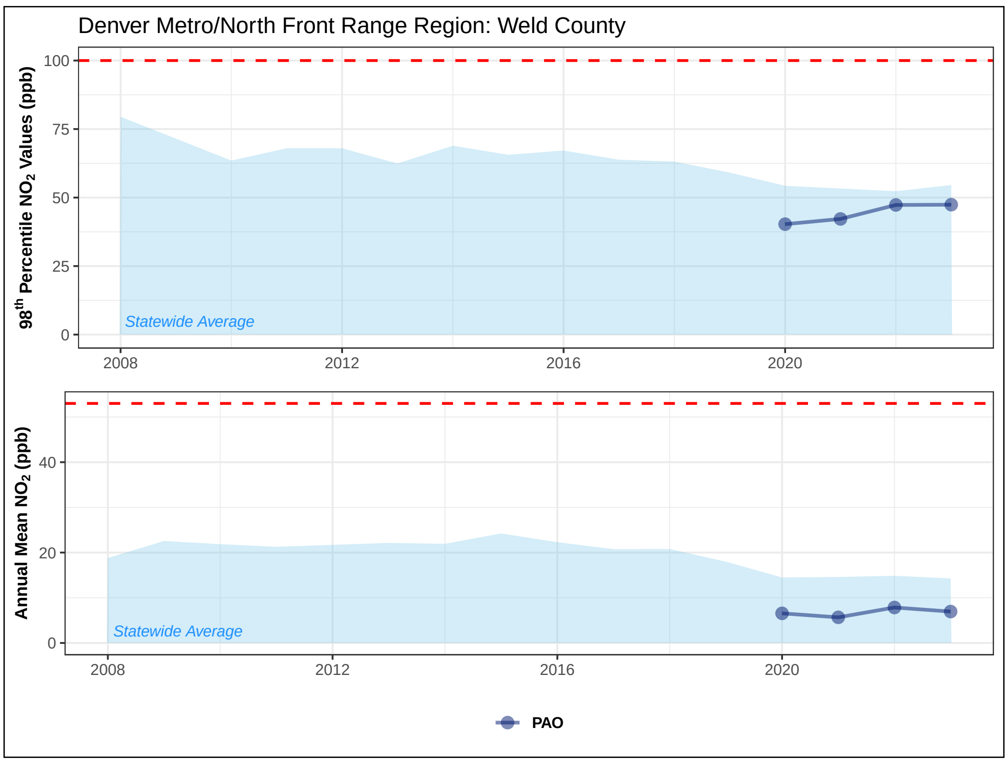

Figure 4.25: Fifteen-year trend in one-hour (top) and annual mean (bottom) nitrogen dioxide NAAQS values for monitoring sites in Weld County. The one-hour and annual mean standards (100 ppb and 53 ppb, respectively) are shown as dashed red lines.

4.2.5 Sulfur Dioxide

Table 4.7: Summary of SO_2 values recorded at monitoring stations in the Denver Metro/Northern Front Range region during 2023.

Site Name	County	SO_2 (ppb)		
		Annual Mean	99^{th} Percentile	3-Year Avg. of 99^{th} Percentile
Welby	Adams	0.89	6	6
CAMP	Denver	0.52	5	5
La Casa	Denver	0.76	5	5

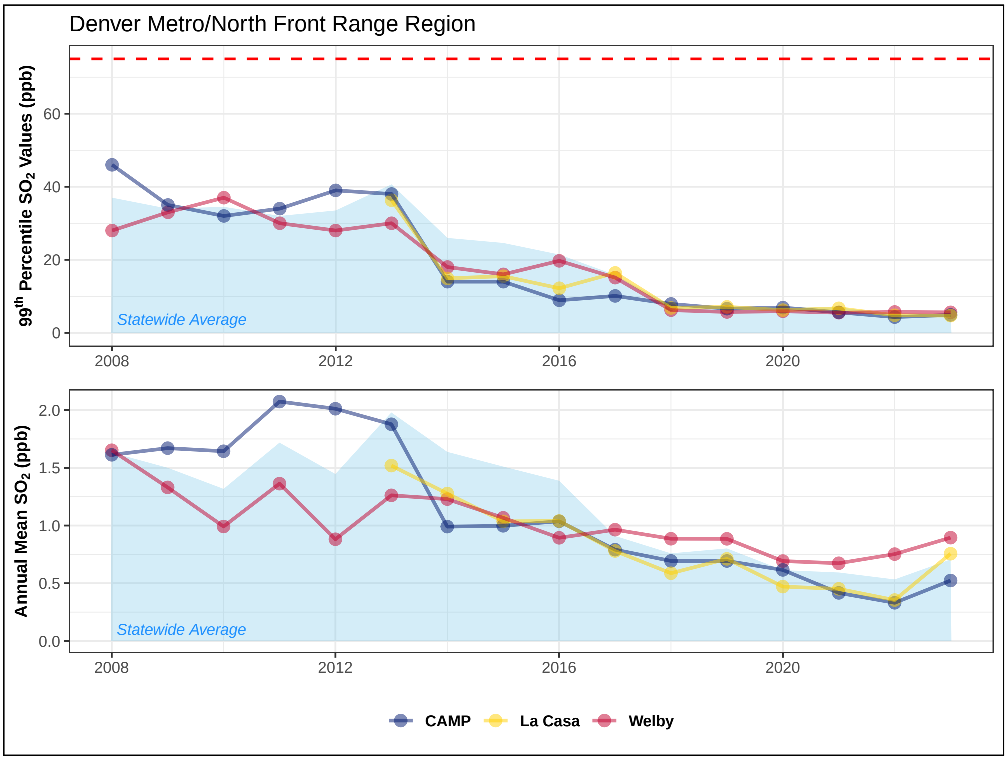

Figure 4.26: Fifteen-year trend in sulfur dioxide one-hour NAAQS values (top) and annual mean one-hour concentrations (bottom) for monitoring sites in the Denver Metro/Northern Front Range region. The one-hour NAAQS (75 ppb) is shown as a dashed red line.

4.2.6 Visibility

Visibility data for Denver is summarized below. Days where the visibility standard was exceeded are classified as "poor" or "extremely poor," while other days are classified as "moderate" or "good." Considering only days with valid data, the standard was exceeded for 25% of the year in Denver.

Table 4.8: Summary of Denver visibility data showing the number of days with extremely poor, poor, moderate, and good visibility, as well as the number of days with missing data and the number of days that were excluded due to high (> 70%) relative humidity.

Month	Extremely Poor	Poor	Moderate	Good	Missing	>70% RH
January	3	7	14	4	1	5
February	5	7	3	4	1	10
March	0	9	7	2	3	5
April	0	12	11	3	0	4
May	0	6	12	8	0	5
June	0	2	7	21	0	0
July	0	7	13	10	1	0
August	0	9	12	10	0	0
September	1	5	13	12	0	0
October	1	5	3	16	0	6
November	1	6	7	9	0	7
December	0	7	5	10	2	6
Sum	11	82	107	109	8	48

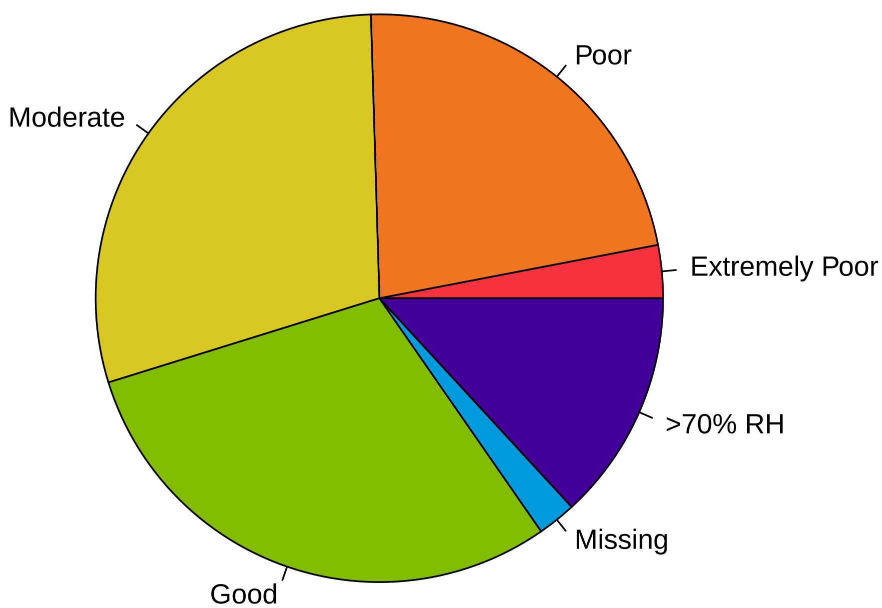

Figure 4.27: Denver visibility data.

4.2.7 Meteorology

See section 3.4 for more details on the wind rose plots below.

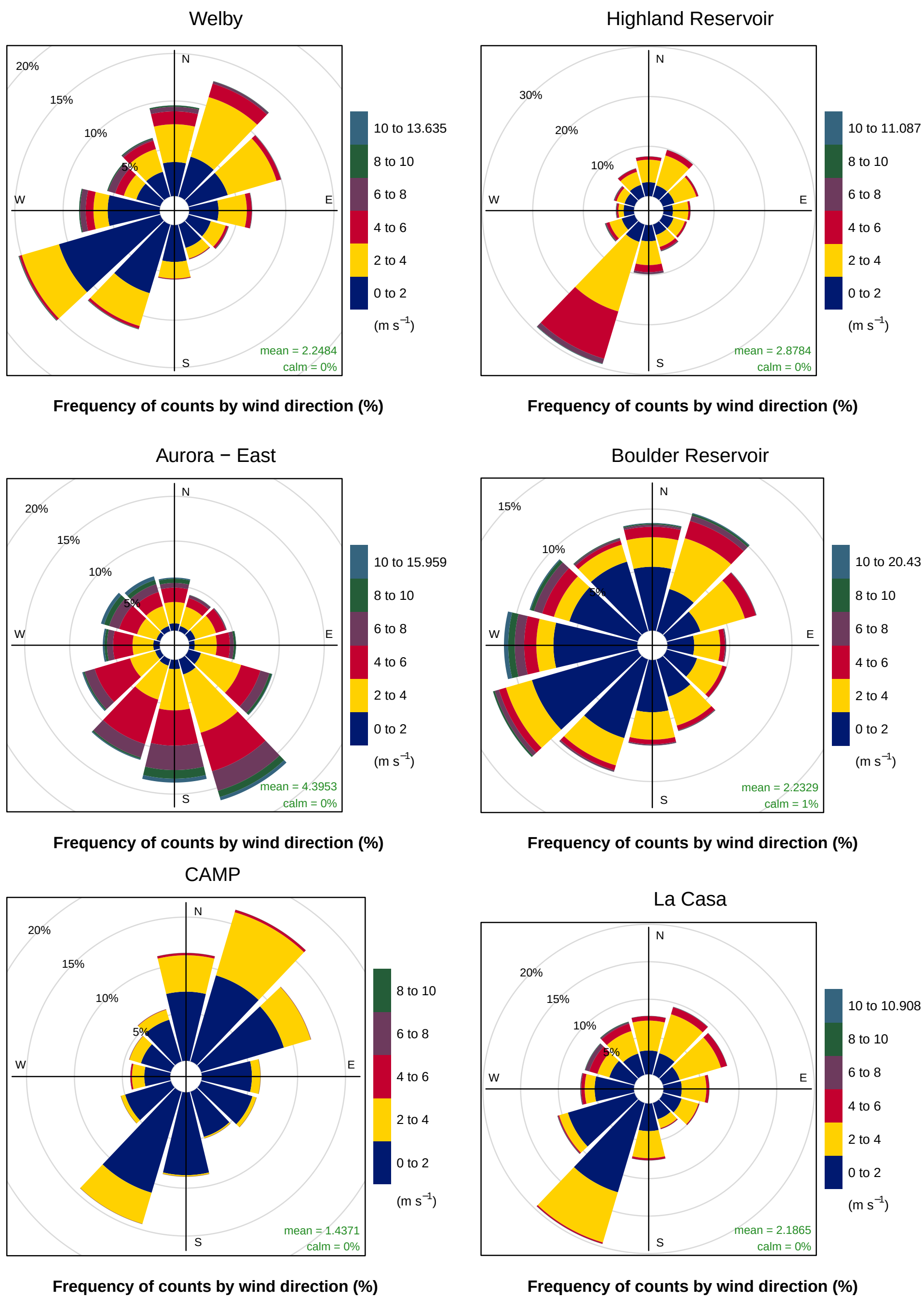

Figure 4.28: Wind roses for sites in the Denver Metro/North Front Range Region during 2023.

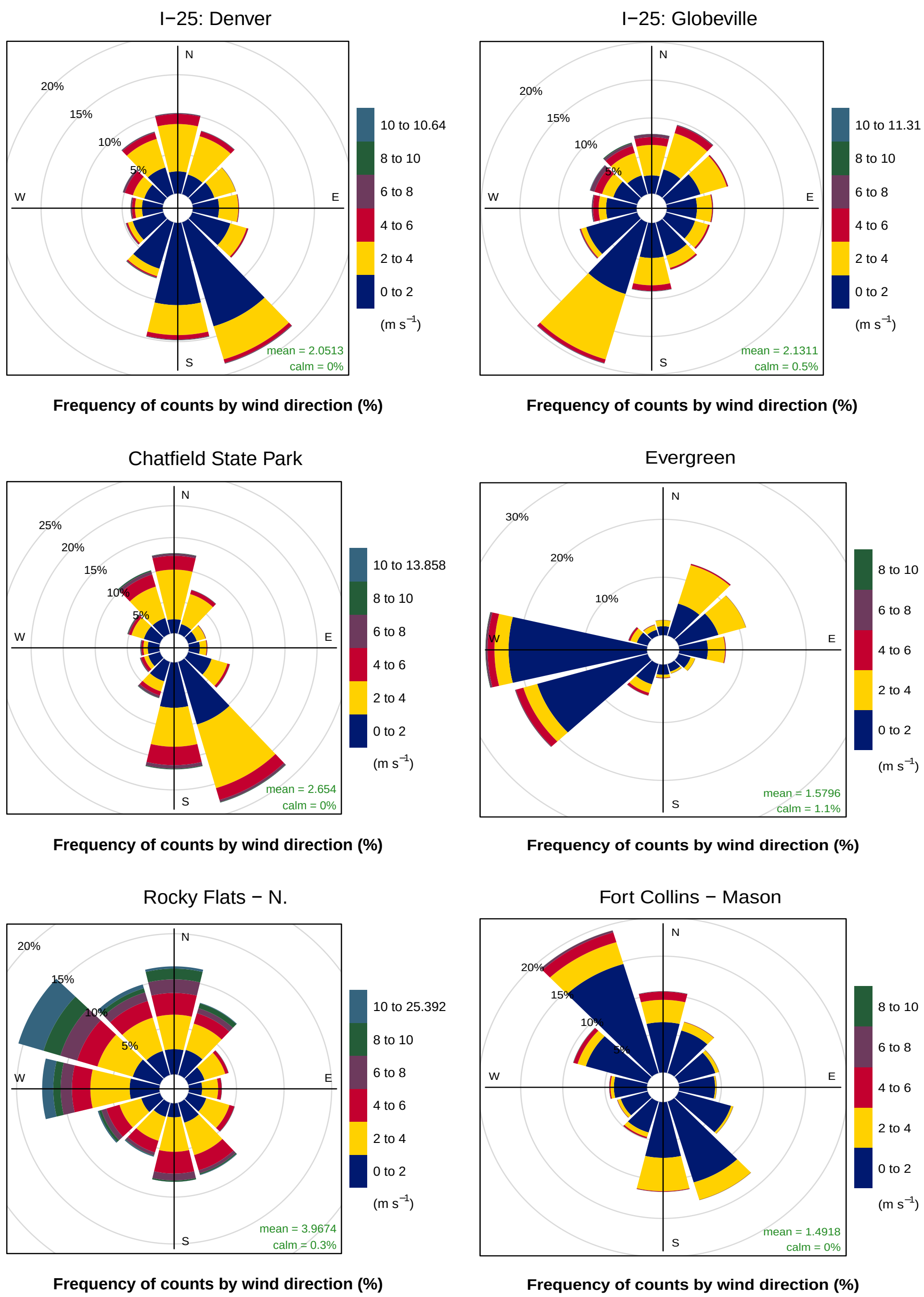

Figure 4.29: Wind roses for sites in the Denver Metro/North Front Range Region during 2023 (continued).

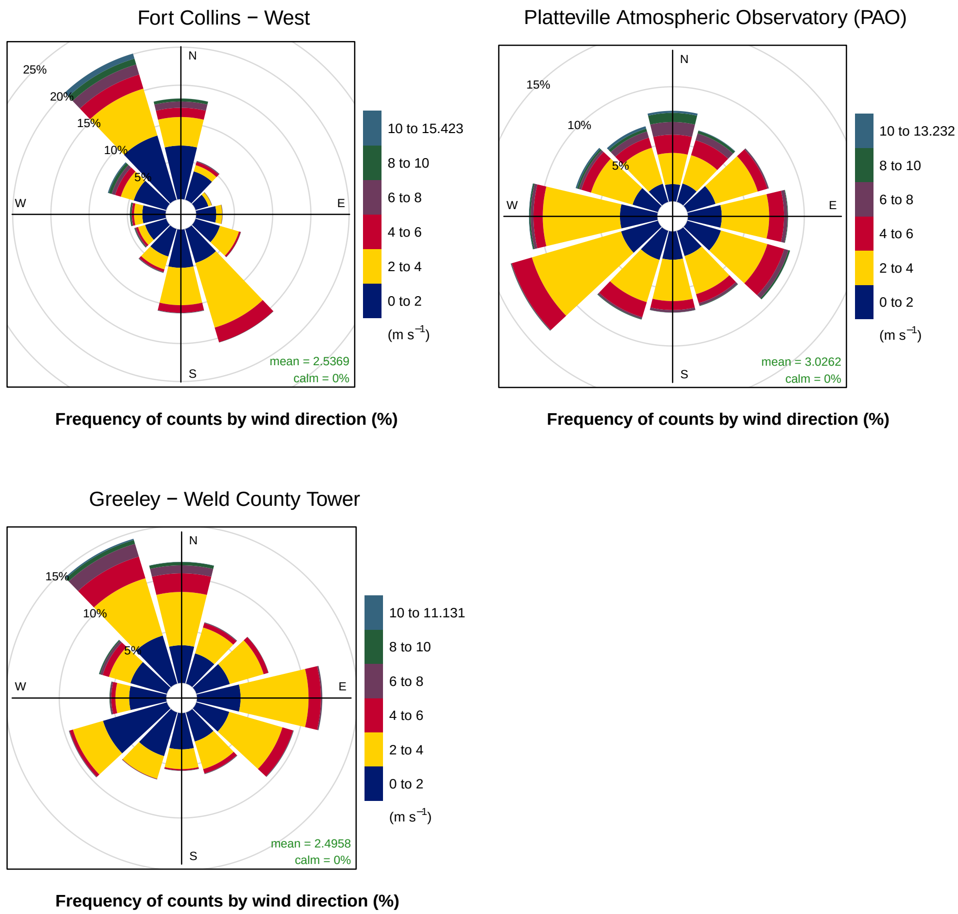

Figure 4.30: Wind roses for sites in the Denver Metro/North Front Range Region during 2023 (continued).

4.3 Eastern High Plains Region

4.3.1 Particulate Matter

The Lamar $PM_{2.5}$ monitor began operation on 10/11/2023 and so does not meet requirements for three consecutive years of operation; therefore, while the 2023 $PM_{2.5}$ values are reported, the data from this site cannot be compared to the NAAQS in terms of a three-year average.

Table 4.9: Summary of PM_{10} values recorded at monitoring stations in the Eastern High Plains region during 2023, with proposed exceptional events included.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Lamar - Mun. Bldg.	Prowers	22.9	160	1.7

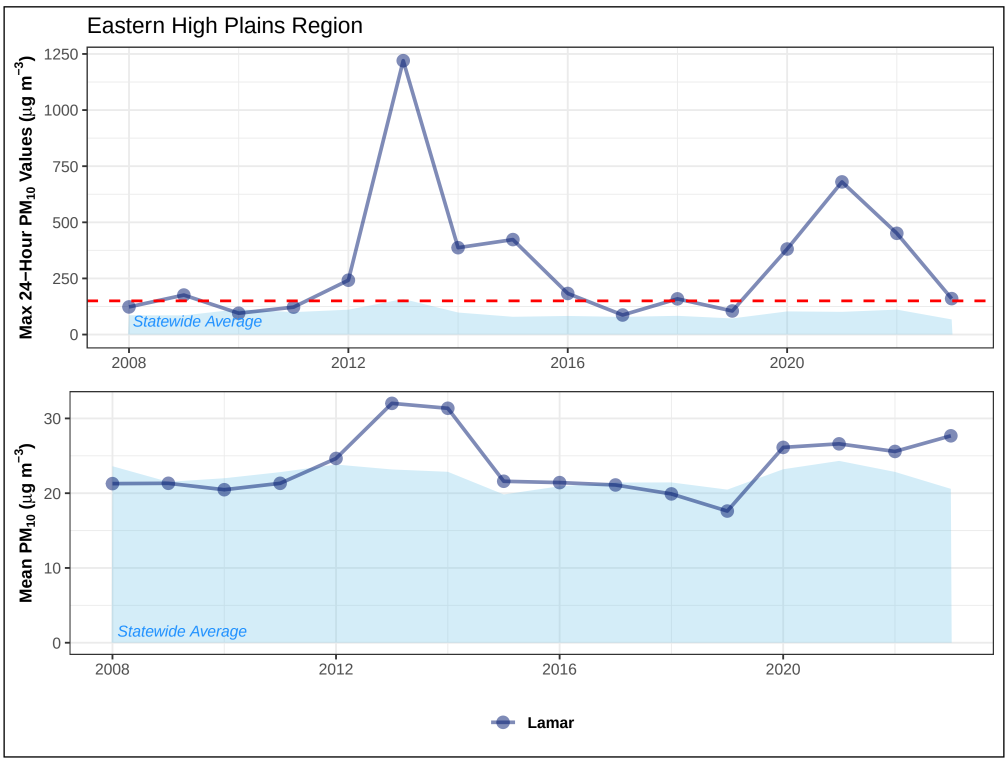

Figure 4.31: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Eastern High Plains region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.10: Summary of $PM_{2.5}$ values recorded at monitoring stations in the Eastern High Plains region during 2023.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98^{th} Percentile	3-Year Avg. of 98^{th} Percentile
Lamar - Mun. Bldg.	Prowers	5.0	9.6	-

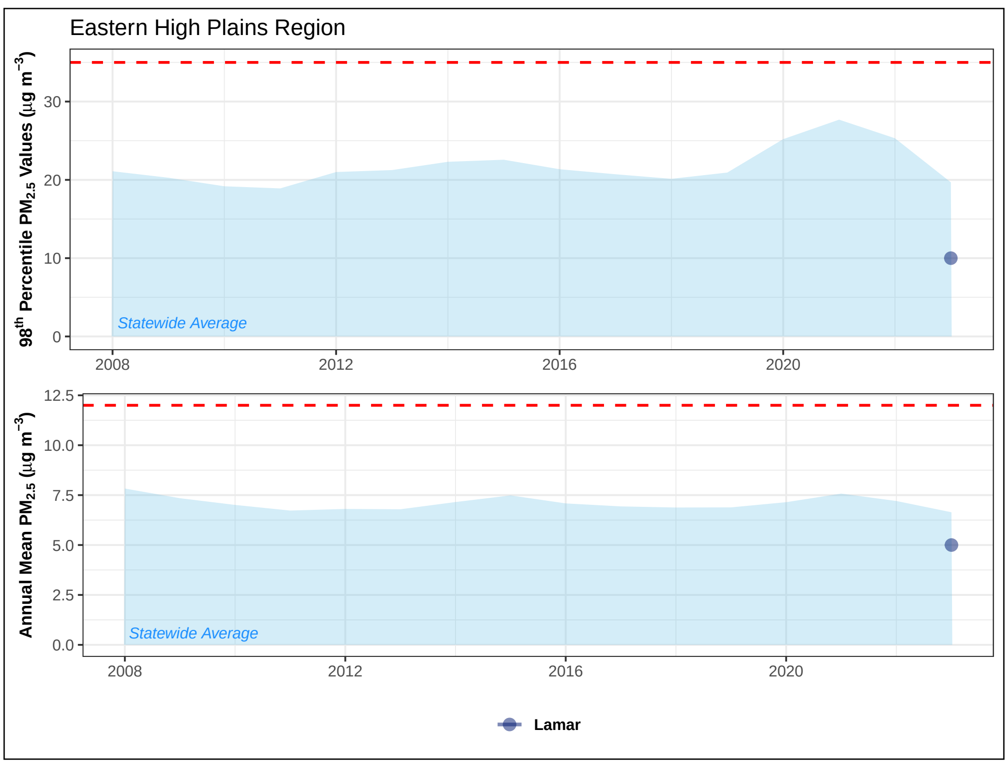

Figure 4.32: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the Eastern High Plains region. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.4 Pikes Peak Region

4.4.1 Particulate Matter

Table 4.11: Summary of PM_{10} values recorded at the Colorado College station during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Colorado College	El Paso	15.3	33	0

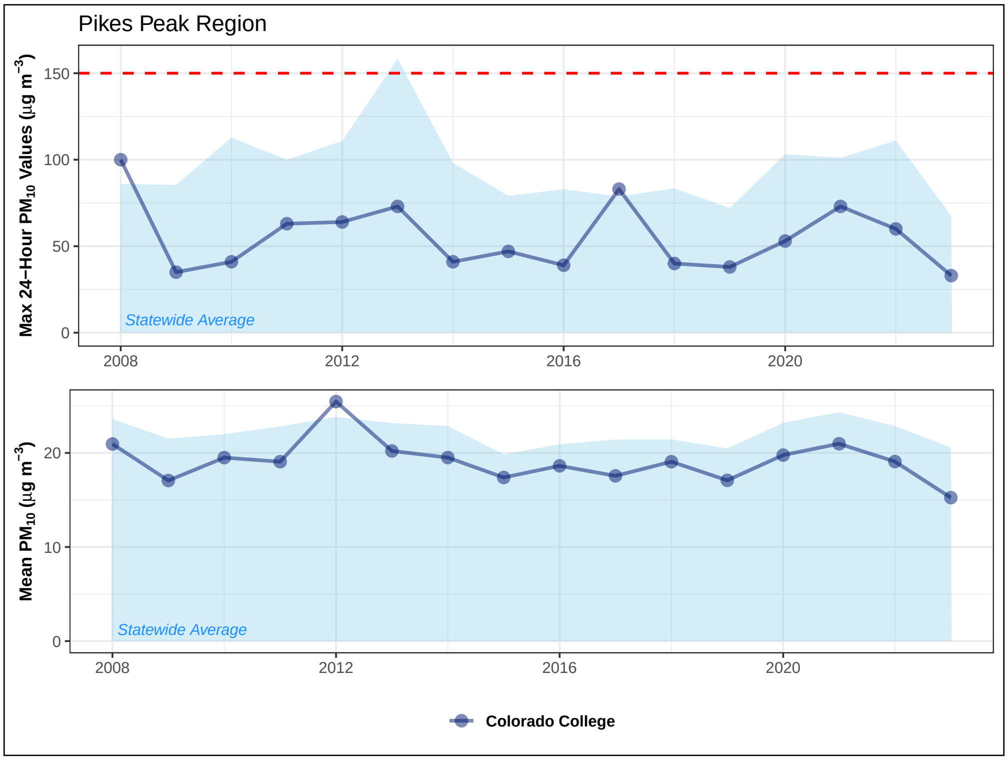

Figure 4.33: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Pikes Peak region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.12: Summary of $PM_{2.5}$ values recorded at the Colorado College station during 2023.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98th Percentile	3-Year Avg. of 98th Percentile
Colorado College	El Paso	5.4	13.3	15

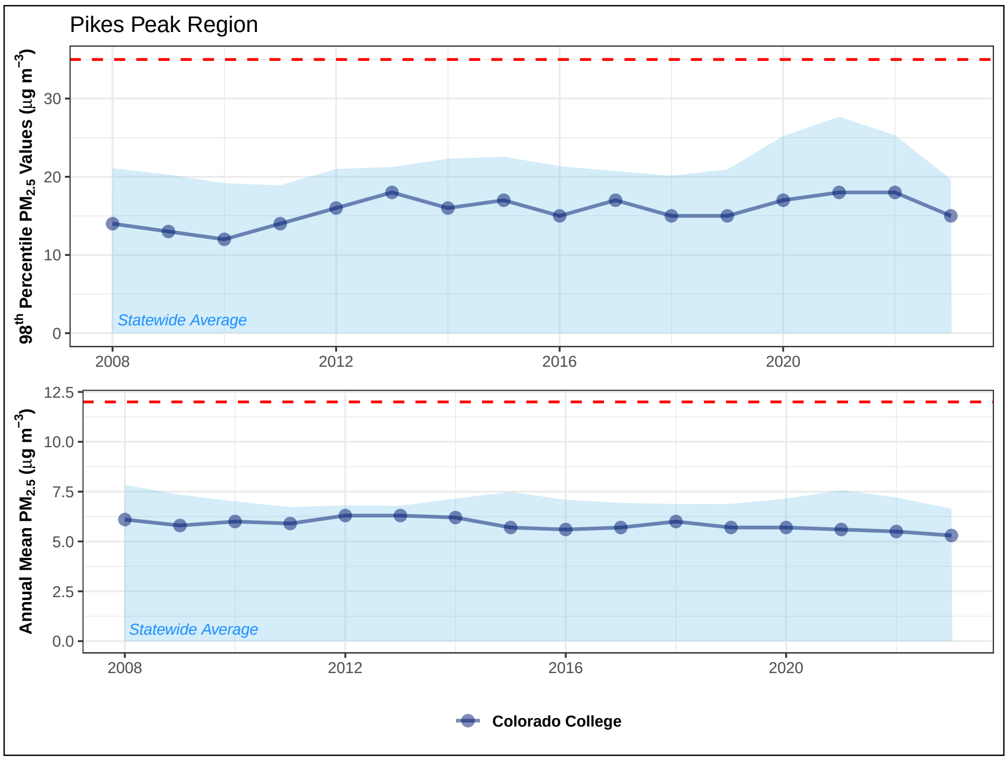

Figure 4.34: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the Pikes Peak region. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.4.2 Carbon Monoxide

Table 4.13: Summary of CO values recorded at the Highway 24 (Colorado Springs) station during 2023.

Site Name	County	CO 1-Hour Average (ppm)		CO 8-Hour Average (ppm)	
		1st Max.	2nd Max.	1st Max.	2nd Max.
Highway 24	El Paso	1.9	1.7	1.2	1.1

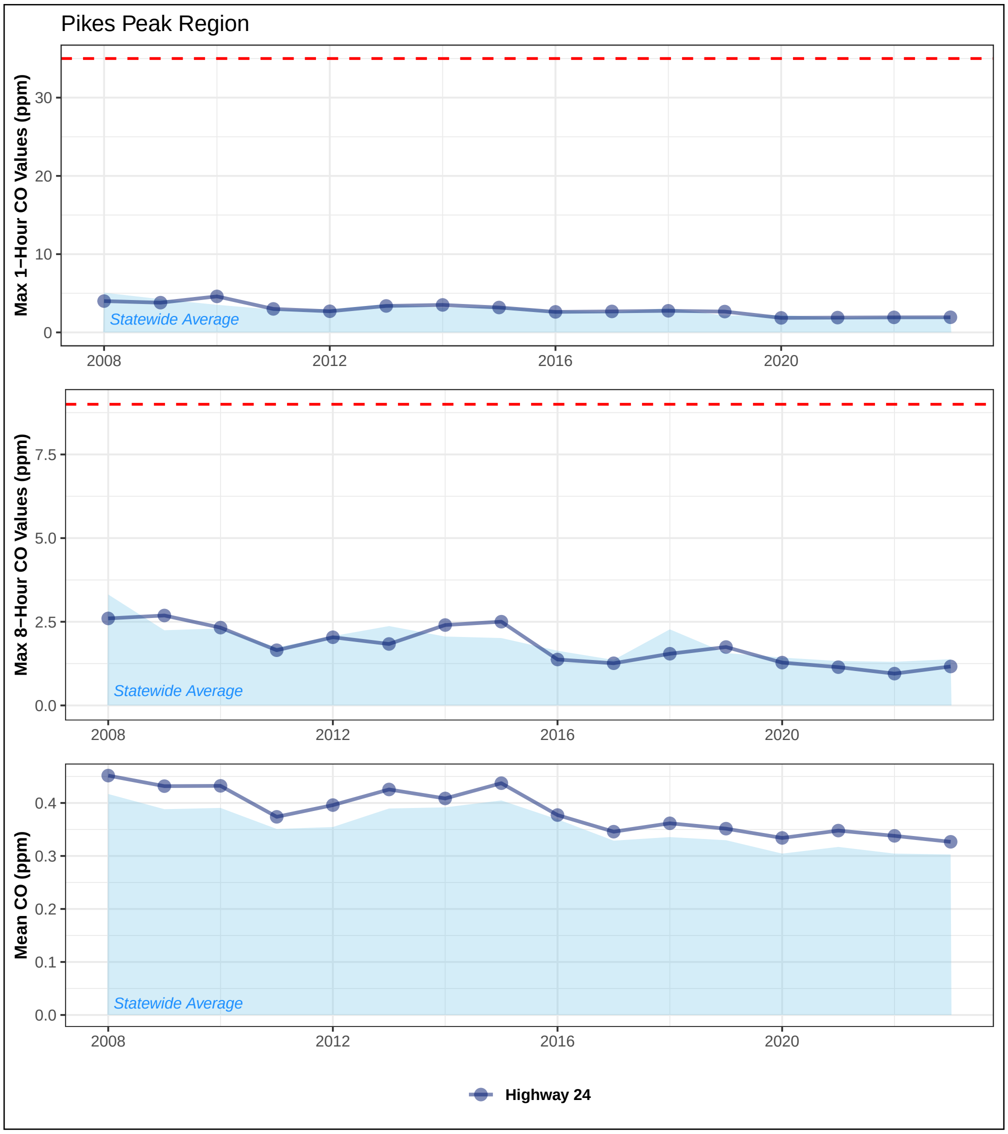

Figure 4.35: Fifteen-year trend in annual maximum one-hour (top) and eight-hour (center) CO values and annual mean eight-hour CO concentrations (bottom) for monitoring sites in the Pikes Peak region. The one-hour and eight-hour NAAQS (35 ppm and 9 ppm, respectively) are shown as dashed red lines.

4.4.3 Ozone

Table 4.14: Summary of O_3 values recorded at monitoring stations in the Pikes Peak region during 2023.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1st Max.	4th Max.	3-Year Avg. of 4th Max.
U.S. Air Force Academy	El Paso	68	64	69
Manitou Springs	El Paso	70	69	71*

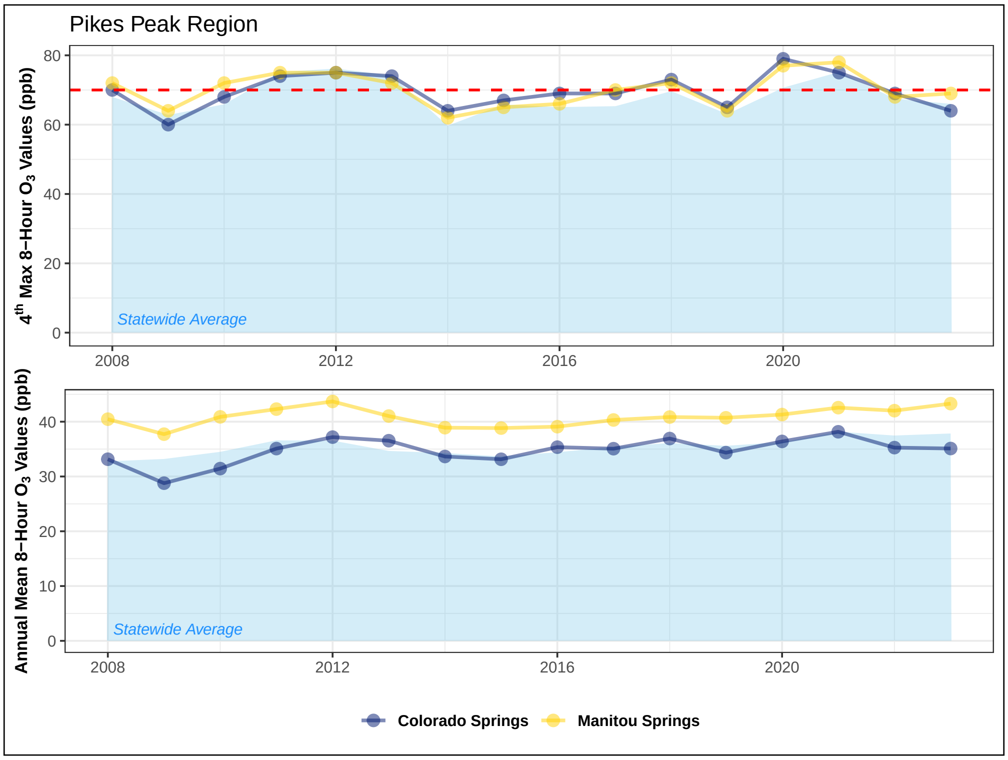

Figure 4.36: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the Pikes Peak region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.4.4 Sulfur Dioxide

Table 4.15: Summary of SO_2 values recorded at the Highway 24 monitoring site in Colorado Springs during 2023.

Site Name	County	SO_2 (ppb)		
		Annual Mean	99^{th} Percentile	3-Year Avg. of 99^{th} Percentile
Highway 24	El Paso	0.65	5	7

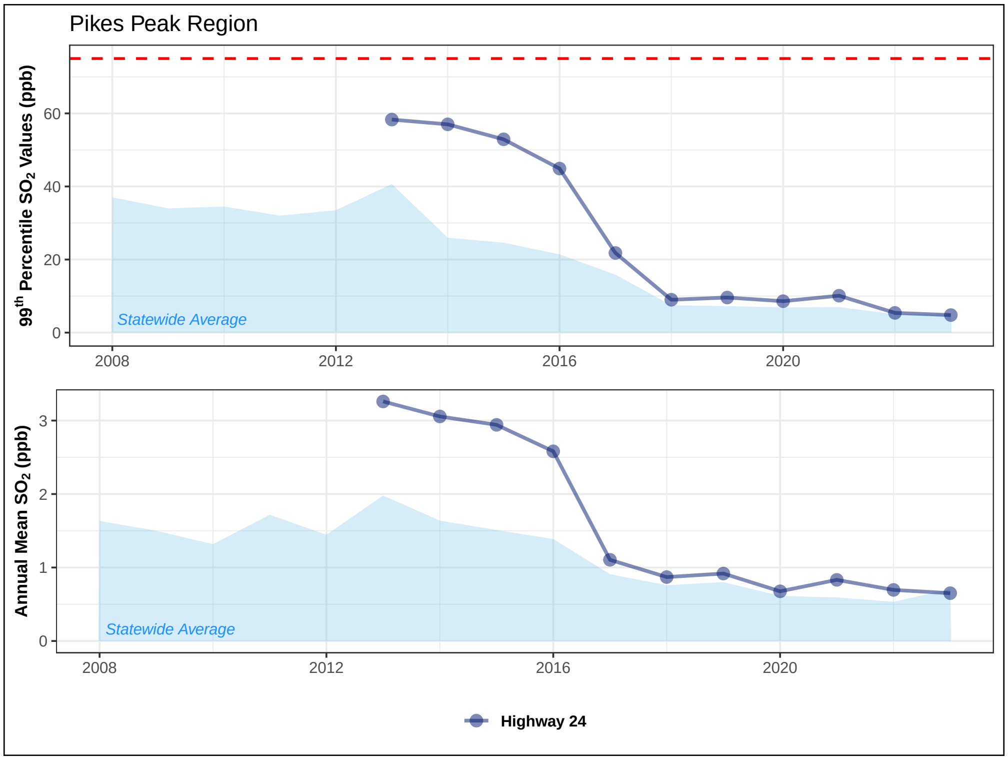

Figure 4.37: Fifteen-year trend in sulfur dioxide one-hour NAAQS values (top) and annual mean one-hour concentrations (bottom) for monitoring sites in the Pikes Peak region. The one-hour NAAQS (75 ppb) is shown as a dashed red line.

4.4.5 Meteorology

See section 3.4 for more details on the wind rose plot below.

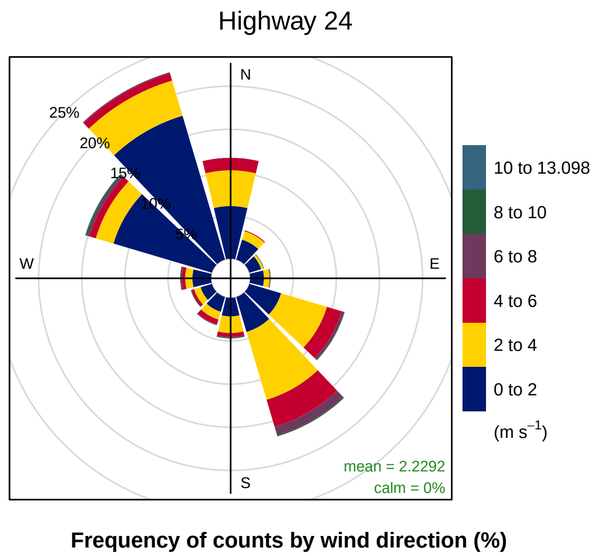

Figure 4.38: Wind rose from the Highway 24 meteorological station.

4.5 San Luis Valley Region

4.5.1 Particulate Matter

The Alamosa $PM_{2.5}$ monitor began operation on 10/26/2023 and so does not meet requirements for three consecutive years of operation; therefore, while the 2023 $PM_{2.5}$ values are reported, the data from this site cannot be compared to the NAAQS in terms of a three-year average.

Table 4.16: Summary of PM_{10} values recorded at the Alamosa monitoring station during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Alamosa	Alamosa	28.8	70	0

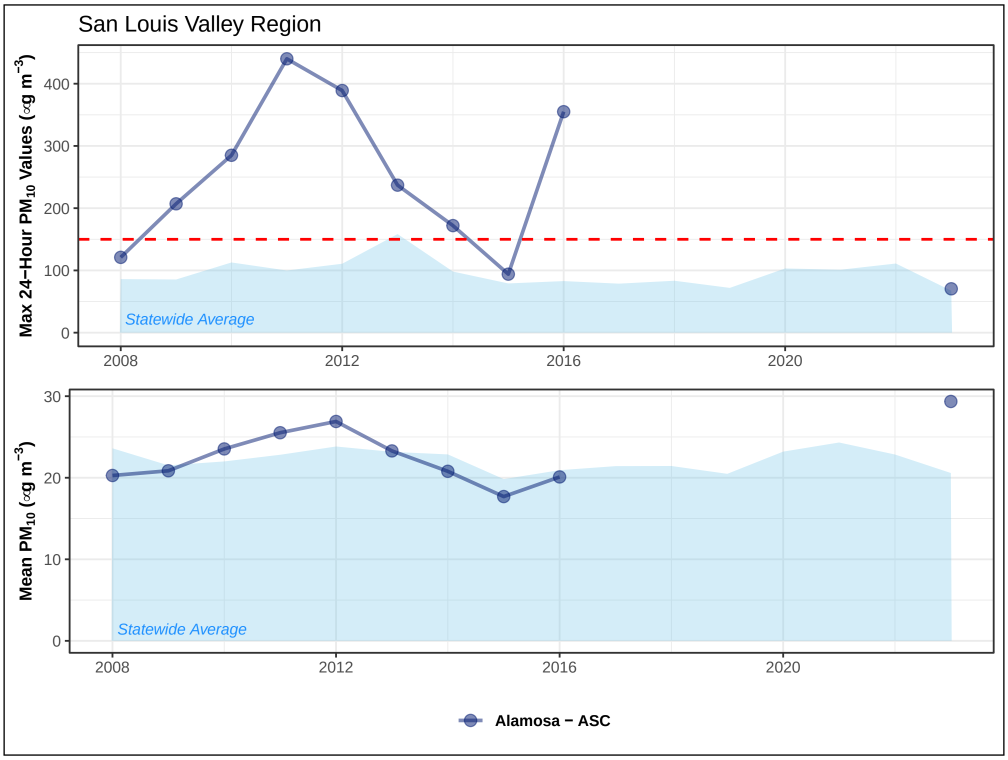

Figure 4.39: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the San Luis Valley region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.17: Summary of $PM_{2.5}$ values recorded at the Alamosa monitoring station during 2023.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98th Percentile	3-Year Avg. of 98th Percentile
Alamosa	Alamosa	8.3	17.8	18

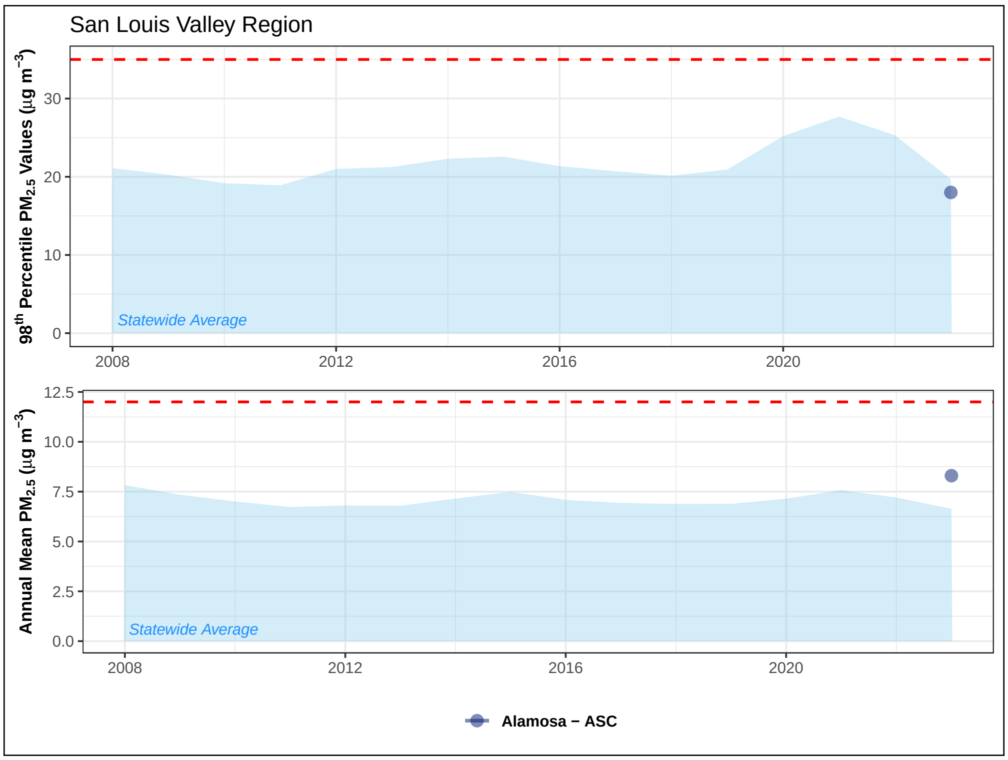

Figure 4.40: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the San Luis Valley region. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.6 South Central Region

4.6.1 Particulate Matter

Table 4.18: Summary of PM_{10} values recorded at the Pueblo monitoring station during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Pueblo	Pueblo	20.4	64	1.1

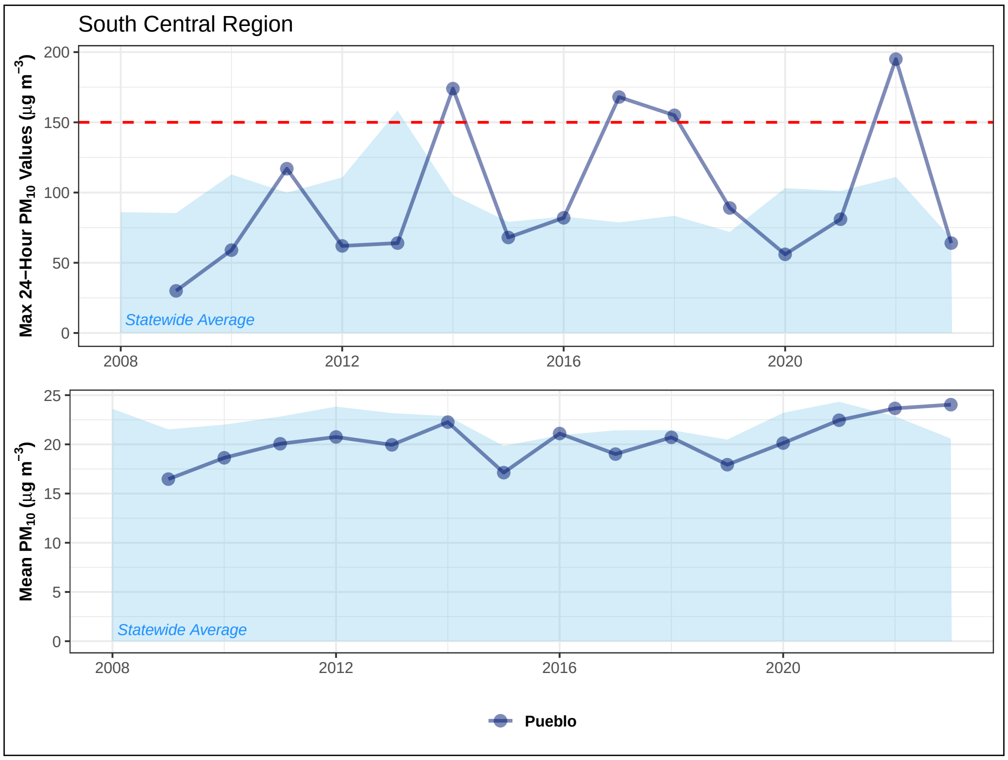

Figure 4.41: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the South Central region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.19: Summary of $PM_{2.5}$ values recorded at the Pueblo monitoring station during 2023.

Site Name	County	$PM_{2.5}$ (µg m^{-3})		
		Annual Average	Annual 98^{th} Percentile	3-Year Avg. of 98^{th} Percentile
Pueblo	Pueblo	5.2	10.4	16

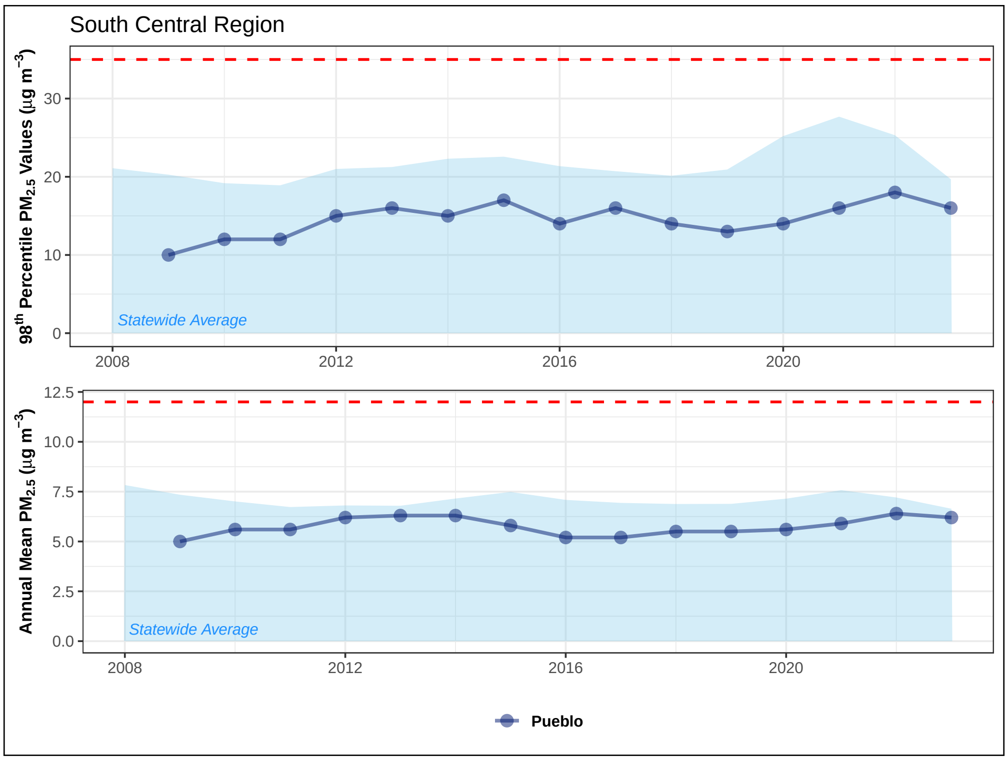

Figure 4.42: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the South Central region. The 24-hour and annual mean NAAQS (35 µg m^{-3} and 12 µg m^{-3}, respectively) are shown as dashed red lines.

4.6.2 Ozone

The Pueblo O_3 monitor began operation on 1/31/2023 and so does not meet requirements for three consecutive years of operation; therefore, while the 2023 O_3 values are reported, the data from this site cannot be compared to the NAAQS in terms of a three-year average.

Table 4.20: Summary of O_3 values recorded at monitoring stations in the South Central region during 2023.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Avg. of 4^{th} Max.
Pueblo	Pueblo	75	67	-

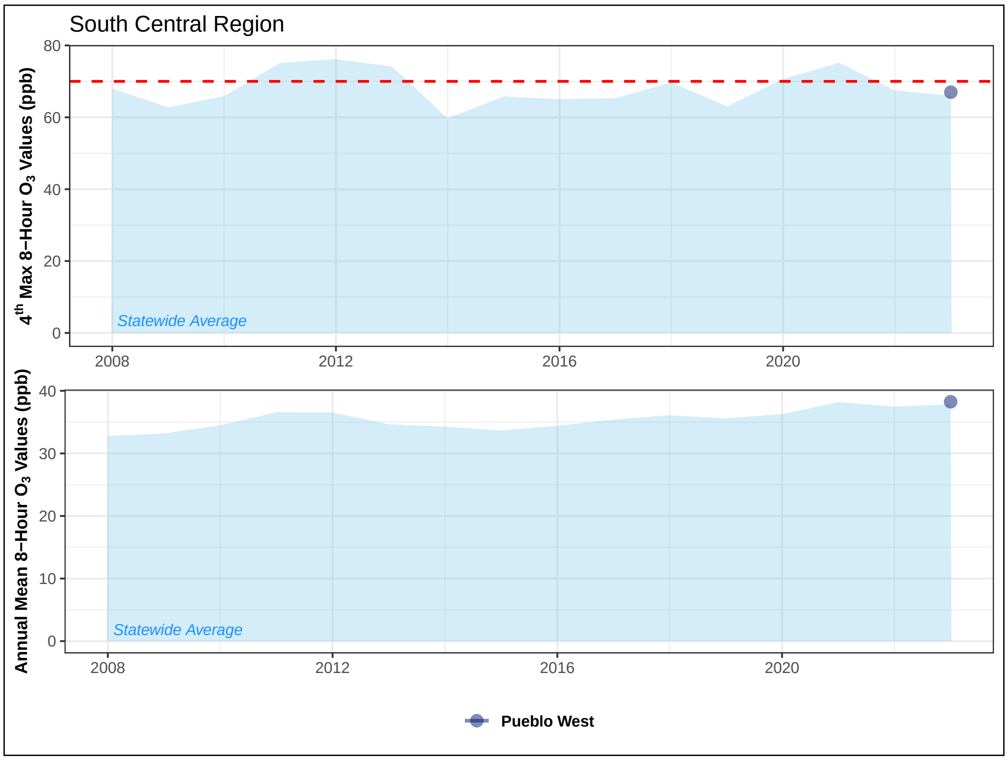

Figure 4.43: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the South Central region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.7 Southwest Region

4.7.1 Particulate Matter

Table 4.21: Summary of PM_{10} values recorded at monitoring sites in the Southwest region during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Pagosa Springs School	Archuleta	24.9	193	1.7

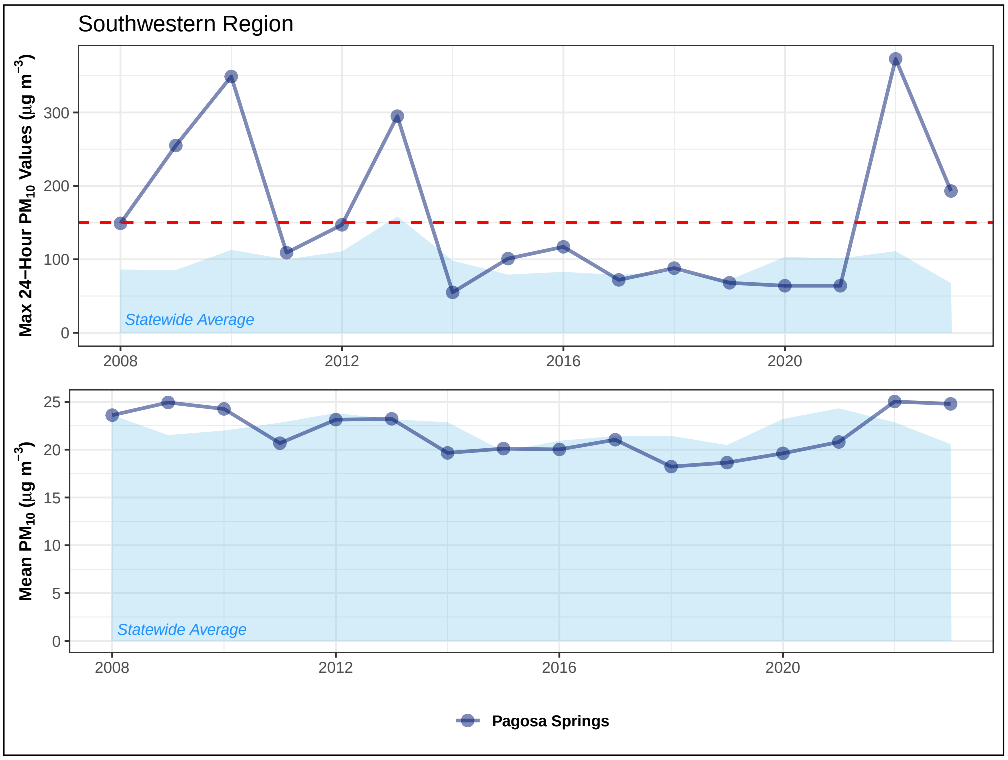

Figure 4.44: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Southwest region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

4.7.2 Ozone

Table 4.22: Summary of O_3 values recorded at the monitoring station in the Southwest region during 2023.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1^{st} Max.	4^{th} Max.	3-Year Avg. of 4^{th} Max.
Cortez - Health Dept.	Montezuma	60	59	62

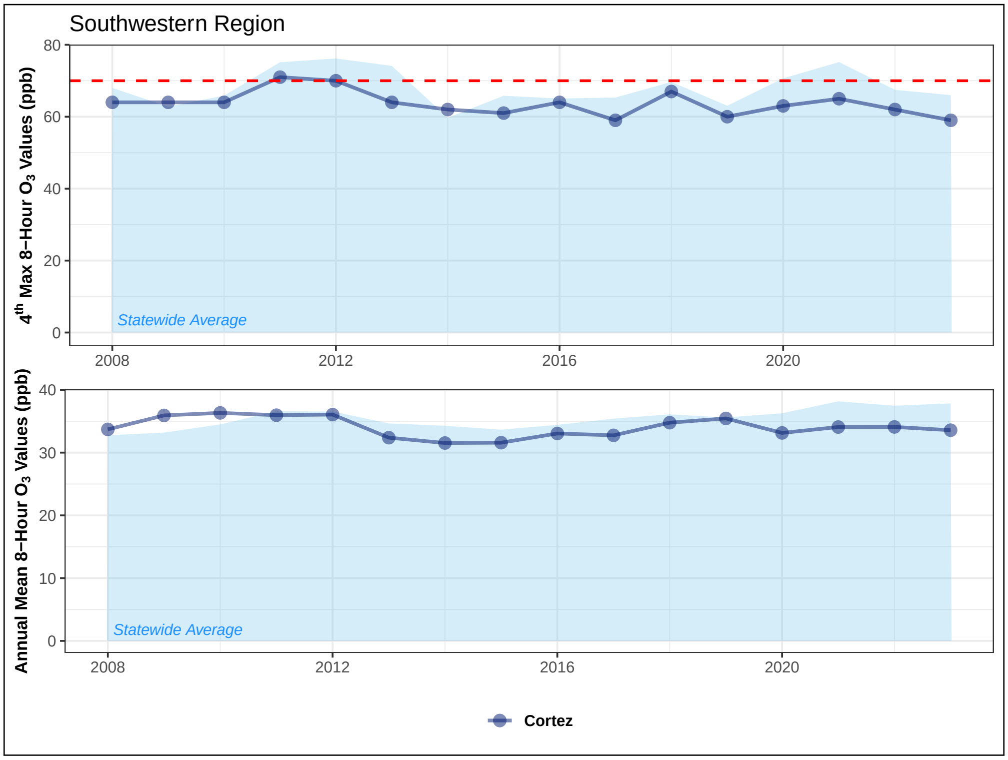

Figure 4.45: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the Southwest region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.8 Western Slope Region

4.8.1 Particulate Matter

Table 4.23: Summary of PM_{10} values recorded at monitoring sites in the Western Slope region during 2023.

Site Name	County	PM_{10} (µg m^{-3})		
		Annual Average	24-Hr Max	3-Year Exceedances
Grand Junction - Powell Bldg.	Mesa	15.6	63	0
Telluride	San Miguel	12.7	62	0

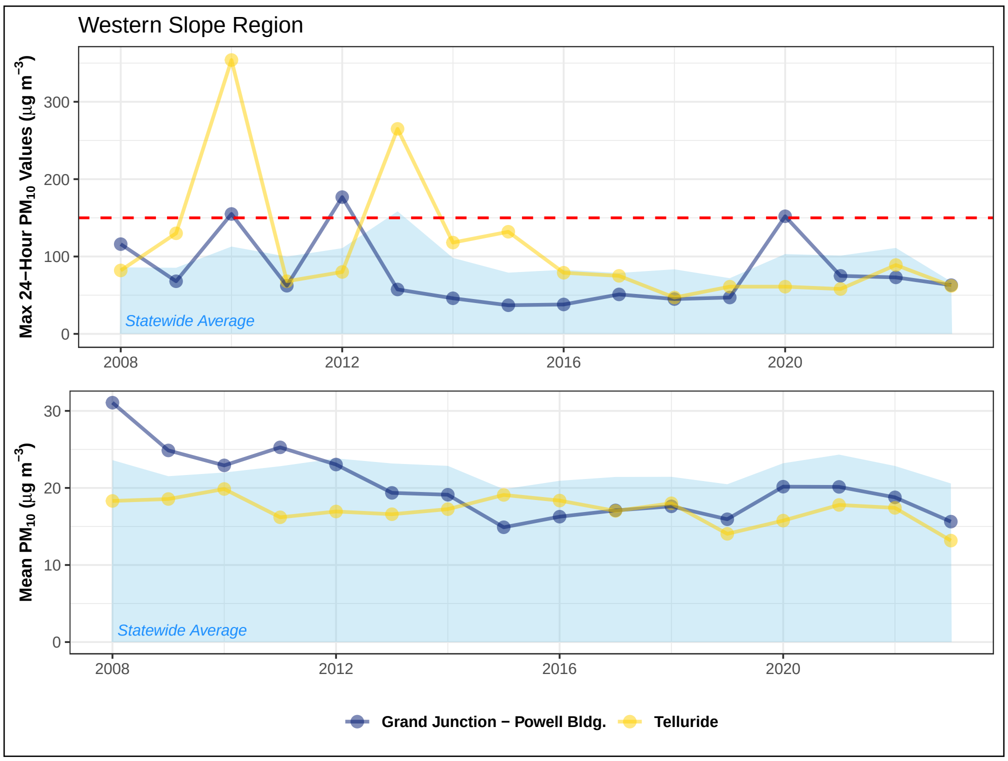

Figure 4.46: Fifteen-year trend in maximum 24-hour PM_{10} values (top) and annual mean concentrations (bottom) for monitoring sites in the Western Slope region. The 24-hour NAAQS (150 µg m^{-3}) is shown as a dashed red line.

Table 4.24: Summary of $PM_{2.5}$ values recorded at the Grand Junction - Powell Bldg. monitoring site during 2023.

Site Name	County	$PM_{2.5}$ ($\mu g\ m^{-3}$)		
		Annual Average	Annual 98^{th} Percentile	3-Year Avg. of 98^{th} Percentile
Grand Junction - Powell Bldg.	Mesa	4.4	10.2	14

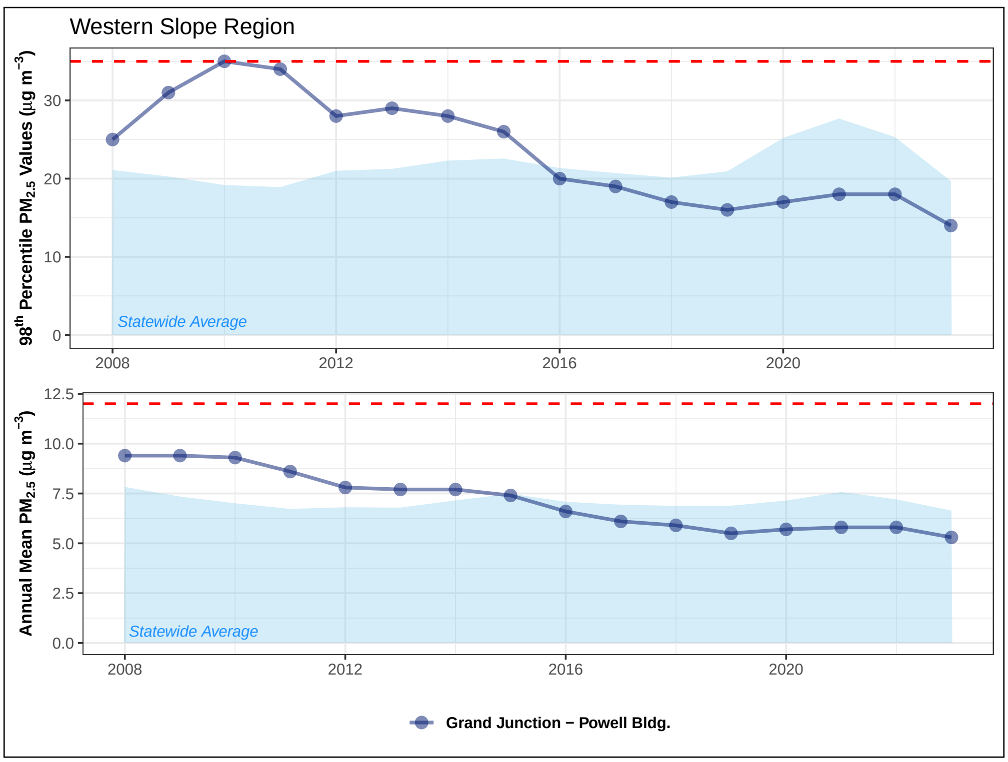

Figure 4.47: Fifteen-year trend in 24-hour $PM_{2.5}$ annual 98^{th} percentile values (top) and annual mean concentrations (bottom) for monitoring sites in the Western Slope region. The 24-hour and annual mean NAAQS (35 $\mu g\ m^{-3}$ and 12 $\mu g\ m^{-3}$, respectively) are shown as dashed red lines.

4.8.2 Ozone

Table 4.25: Summary of O_3 values recorded at monitoring stations in the Western Slope region during 2023.

Site Name	County	Ozone 8-Hour Average (ppm)		
		1st Max.	4th Max.	3-Year Avg. of 4th Max.
Rifle - Health Dept.	Garfield	66	55	59
Palisade Water Treatment	Mesa	63	61	63

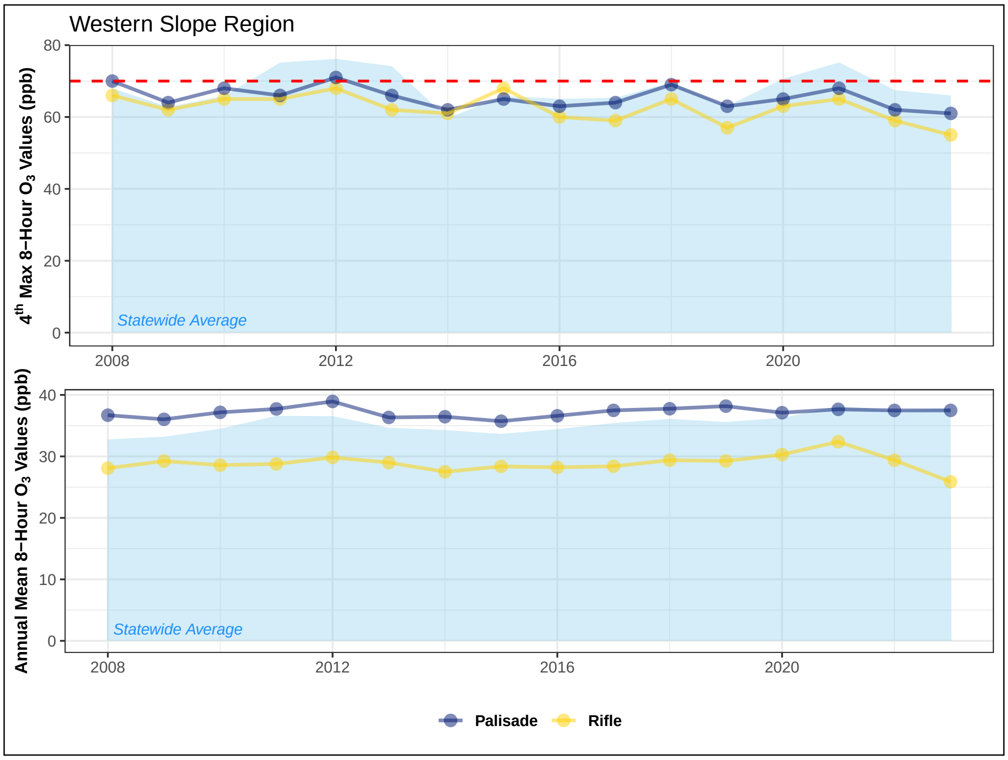

Figure 4.48: Fifteen-year trend in ozone eight-hour NAAQS values (top) and annual mean eight-hour concentrations (bottom) for monitoring sites in the Western Slope region. The eight-hour NAAQS (70 ppb) is shown as a dashed red line.

4.8.3 Meteorology

See section 3.4 for more details on the wind rose plots below.

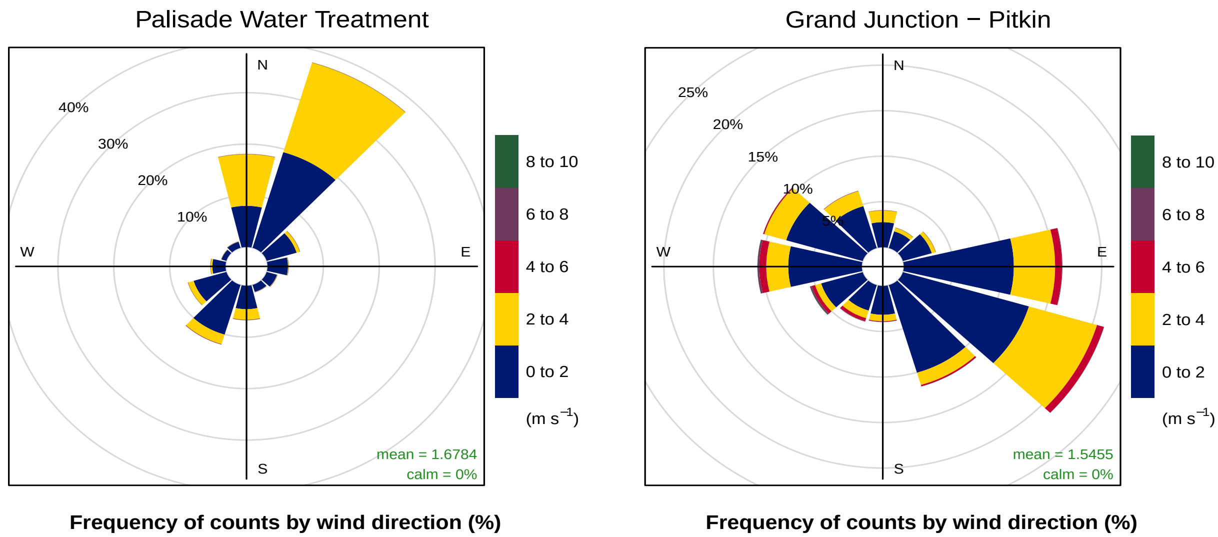

Figure 4.49: Wind roses for sites in the Western Slope Region during 2023.

5

Seasonal Variability in Air Quality

Data has been presented in this report to give an overall picture of the progress of air quality through the years and to compare measured concentrations against the NAAQS. However, APCD collects data as hourly averages (which are themselves the result of even more brief intervals being averaged together) for select criteria pollutants at each site. In this section, monthly averages will be presented for each site.

In some sense, there is little interpretation to be done concerning the air quality information presented in this section. It is not intended to compare Colorado's air quality against the standards, other states, or past air quality. This section is only to suggest a more detailed picture of the air quality in our state throughout the year.

In all of the graphs in this section, the range is illustrated as blue shading, where the lower and upper limits are defined as the minimum and maximum monthly averages, respectively. This is the range for the entire state. The sites are not grouped by monitoring region in this section, rather they are presented in order of their Air Quality Site ID, which is an EPA designated code derived from the state and county where the site is located, along with a unique site number. Each graph has been limited in the number of sites it presents for clarity sake, but for each pollutant set, the minimum and maximum state-wide range is the same. Data in the graphs below may include exceptional events (see subsubsection 2.2.5.4).

5.1 Carbon Monoxide

CO is normally higher in the winter months and lower in the summer, for reasons previously discussed (see subsection 2.2.1).

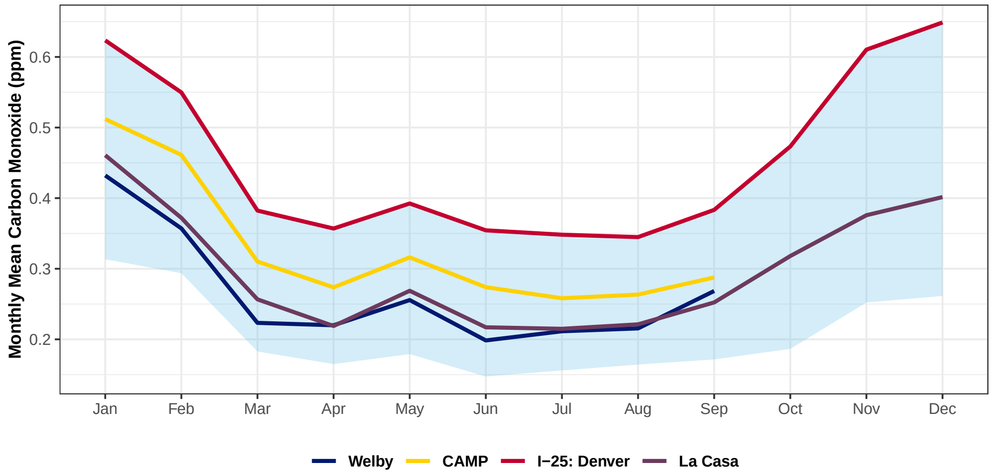

Figure 5.1: Monthly mean carbon monoxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

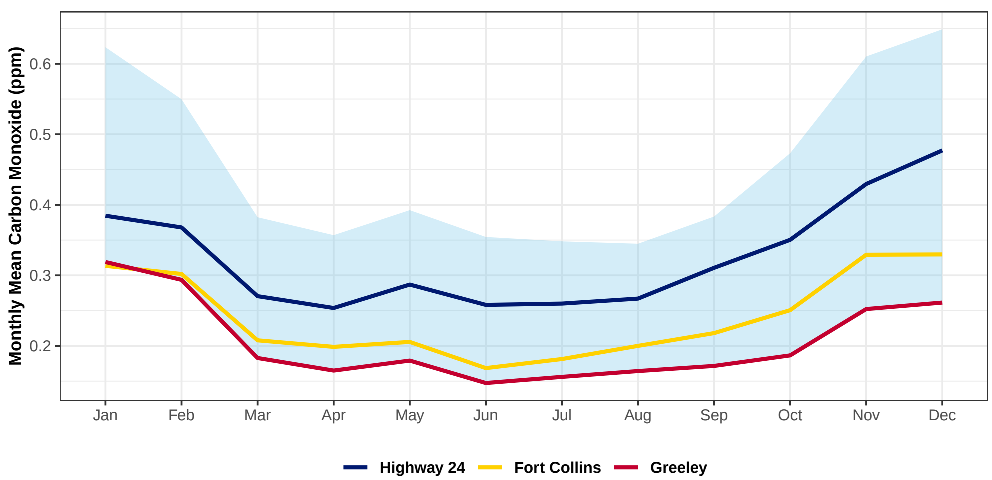

Figure 5.2: Monthly mean carbon monoxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.2 Sulfur Dioxide

Sulfur dioxide was measured at four stations during 2023 by APCD in Colorado: Welby, La Casa, CAMP, and Highway 24 (Colorado Springs). Sulfur dioxide generally follows the same pattern as that for CO, typically being lower in concentration during the warmer months and higher in concentration during the colder months.

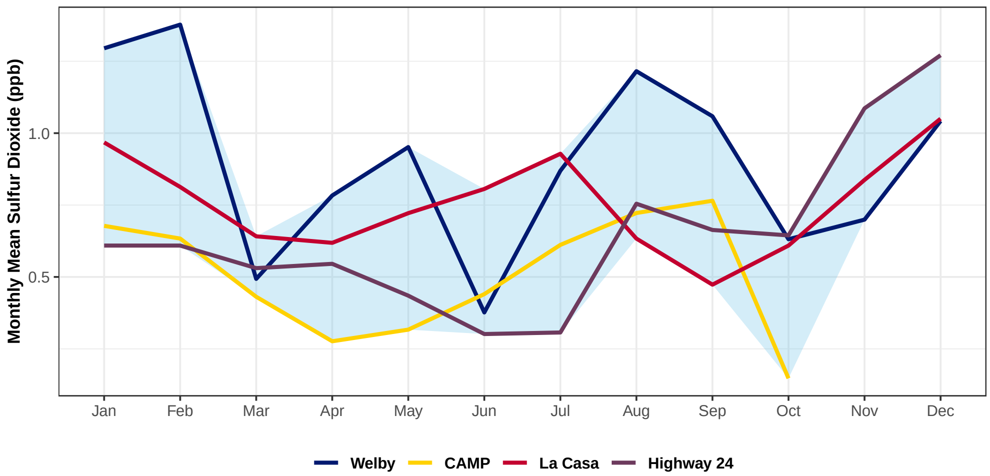

Figure 5.3: Monthly mean sulfur dioxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.3 Ozone

Ozone follows an opposite seasonal pattern relative to CO. The summer months see high ozone and the winter experiences lower levels, in part because of seasonal variations in day length and the angle of the sun relative to the ground. Remember that ozone may be indicative of ground-level smog or the "Denver Brown Cloud." Generally speaking, sites in the Northern Front Range counties experienced higher concentrations of ozone than other areas (especially sites directly west of, and at higher elevation than, metro Denver), though sites outside the Front Range occasionally had the highest averages.

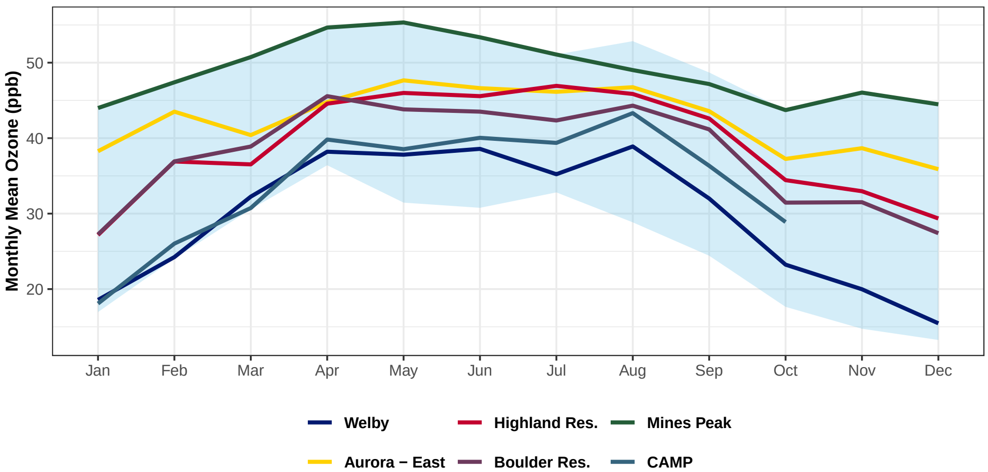

Figure 5.4: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

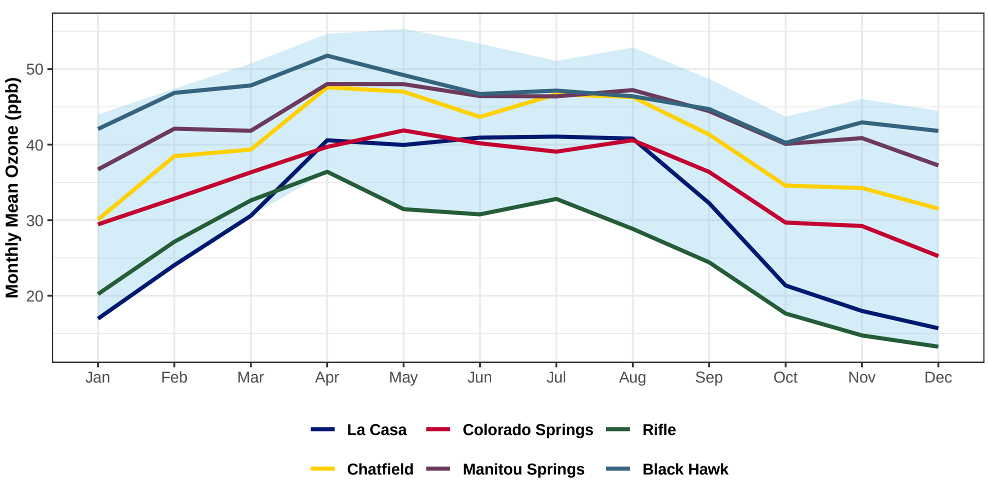

Figure 5.5: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

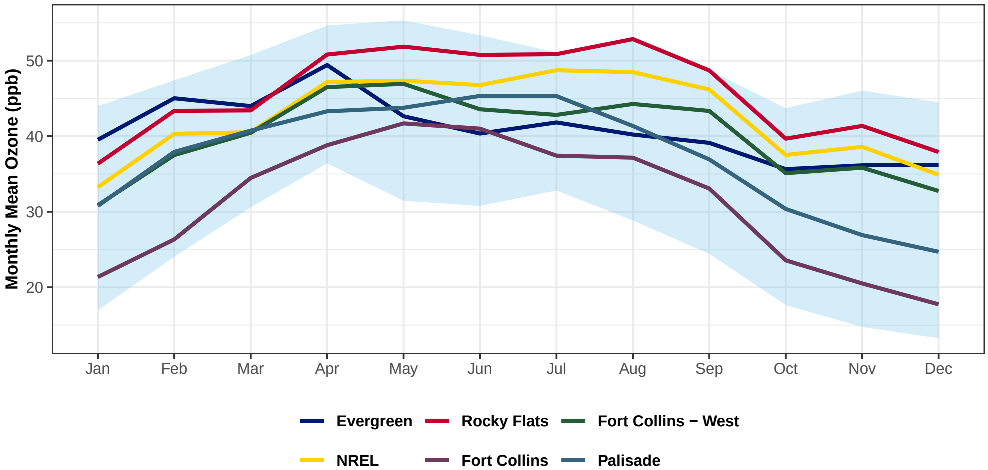

Figure 5.6: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

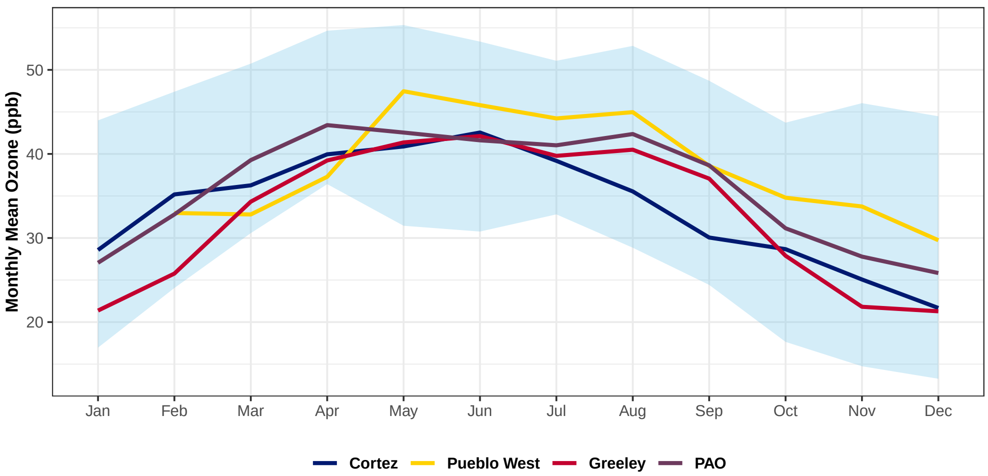

Figure 5.7: Monthly mean ozone concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.4 Nitrogen Dioxide

Nitrogen dioxide was measured at seven stations during 2023 by APCD in Colorado: Welby, CAMP, La Casa, I-25 Globeville, I-25 Denver, Rocky Flats, and PAO. Nitrogen dioxide generally follows the same pattern as that for CO, typically being lower in concentration during the warmer months and higher in concentration during the colder months. NO_2 concentrations at sites in fairly close proximity appear to track well with one another.

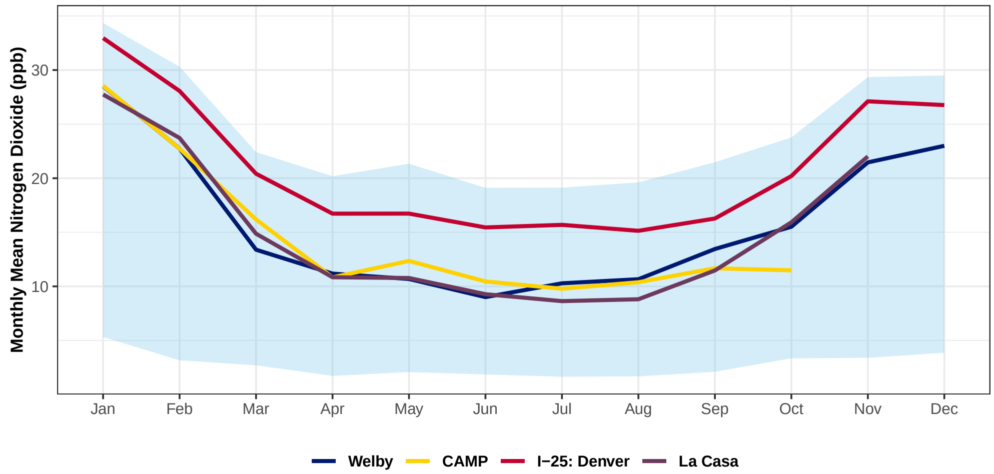

Figure 5.8: Monthly mean nitrogen dioxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

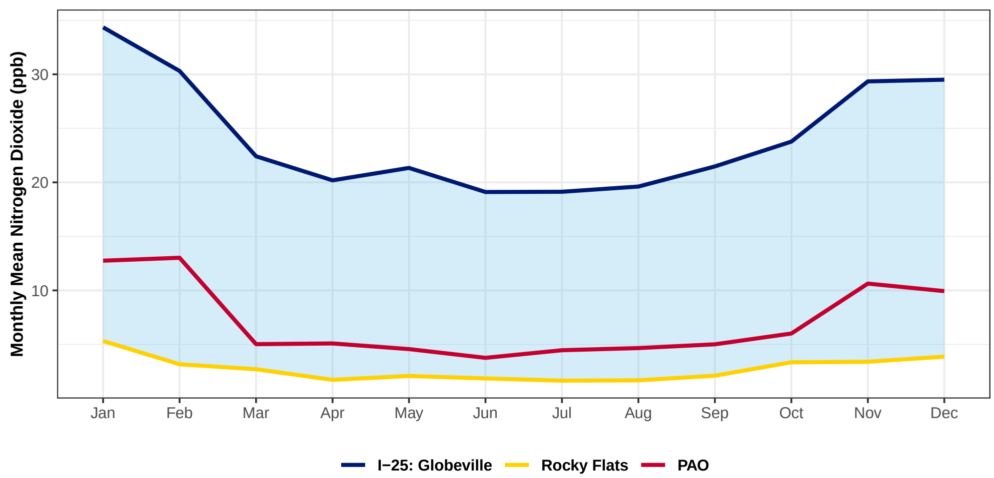

Figure 5.9: Monthly mean nitrogen dioxide concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.5 PM_{10}

PM_{10} concentrations can be elevated for a variety of reasons, including both anthropogenic and natural occurrences. Higher PM_{10} concentrations might be expected during dry months and or droughts, since the soil has a chance to dry out and be entrained by the winds. This is reflected somewhat in the range of PM_{10} concentrations found in the following graphs, but the peaks in concentrations are often due to single-point high-concentration events, typically associated with high winds and blowing dust. The data below contains exceptional events. See subsubsection 2.2.5.4 for an explanation of exceptional events. Many of these exceptional events will be analyzed and documented as natural events and be demonstrated as beyond reasonable control and or not preventable. The documentation package is then sent to the EPA for concurrence. If the EPA concurs with the APCD‘s analysis, then the exceedance or high PM_{10} reading will be removed from regulatory consideration and will not be used in NAAQS calculations.

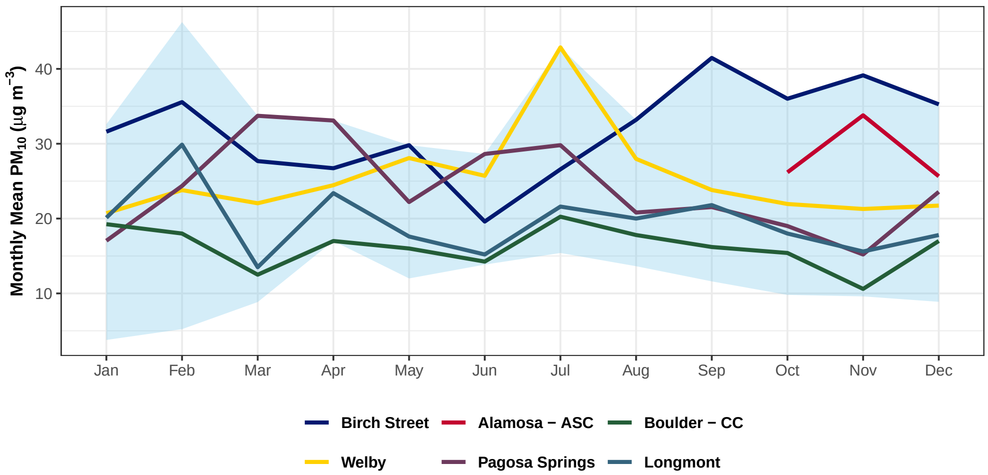

Figure 5.10: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

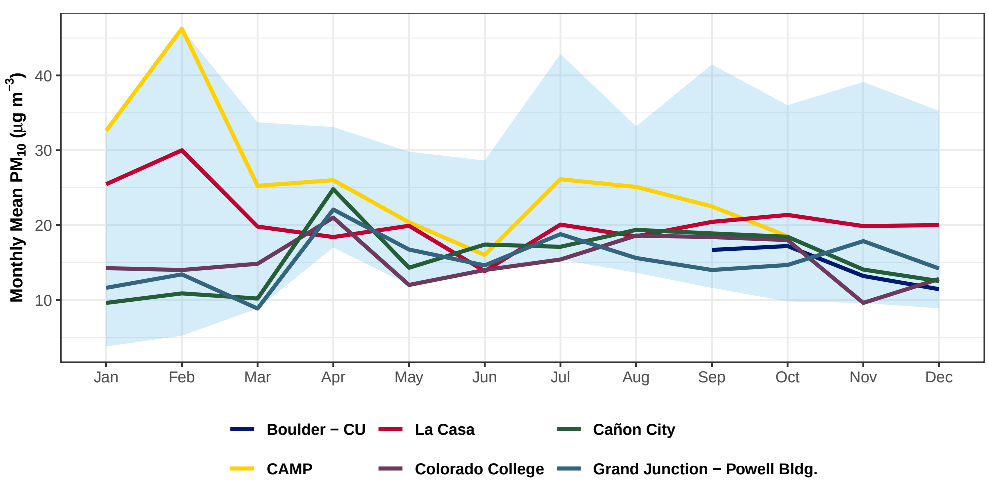

Figure 5.11: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

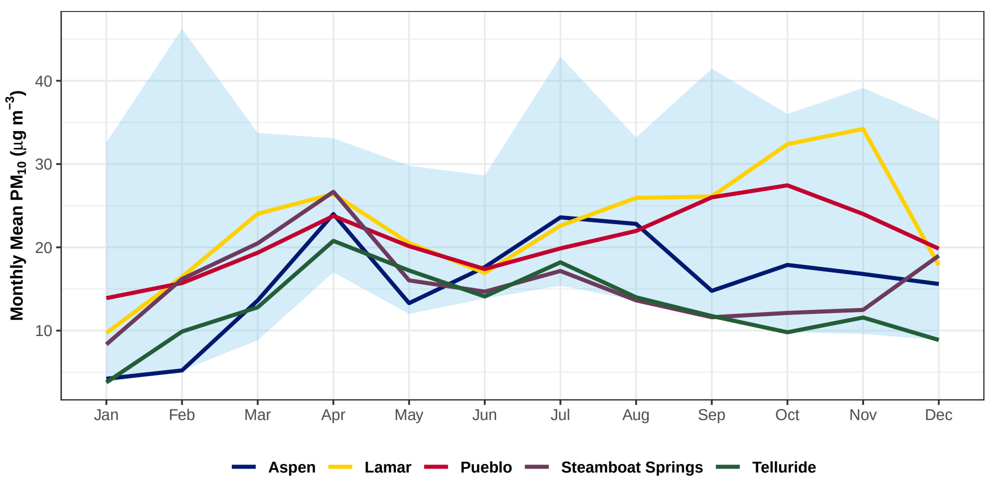

Figure 5.12: Monthly mean PM_{10} concentrations. The blue shaded region shows the statewide range of monthly mean values.

5.6 $PM_{2.5}$

$PM_{2.5}$ concentrations are generally stable throughout much of the year, and relatively similar values are measured at sites throughout the state. The graphs here may include exceptional event data.

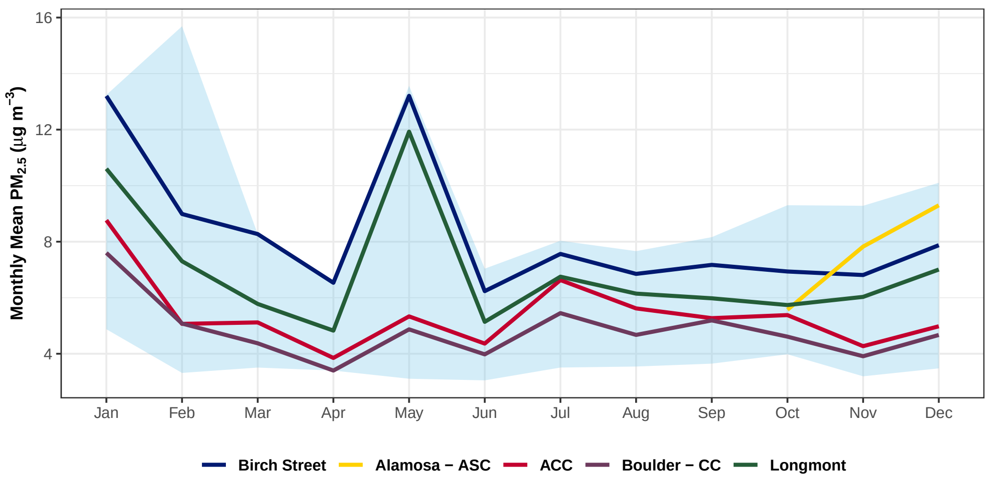

Figure 5.13: Monthly mean $PM_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

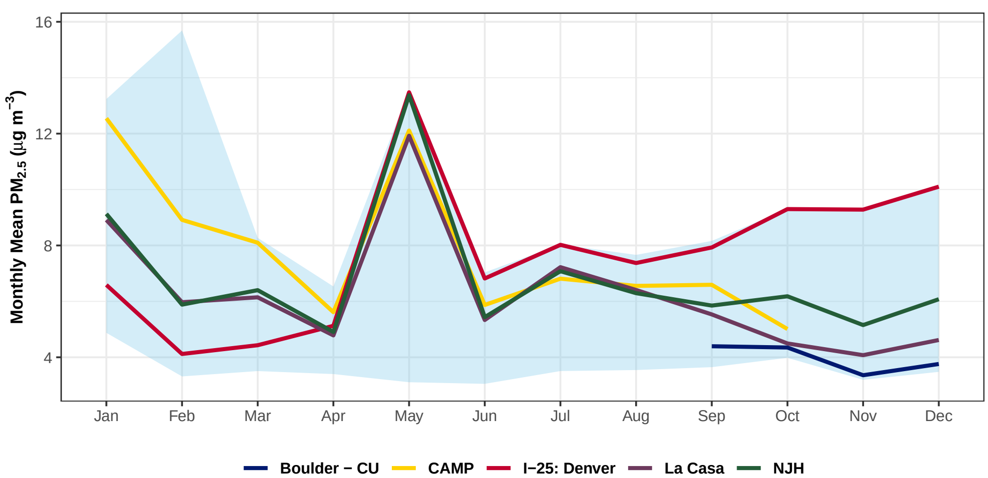

Figure 5.14: Monthly mean $PM_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

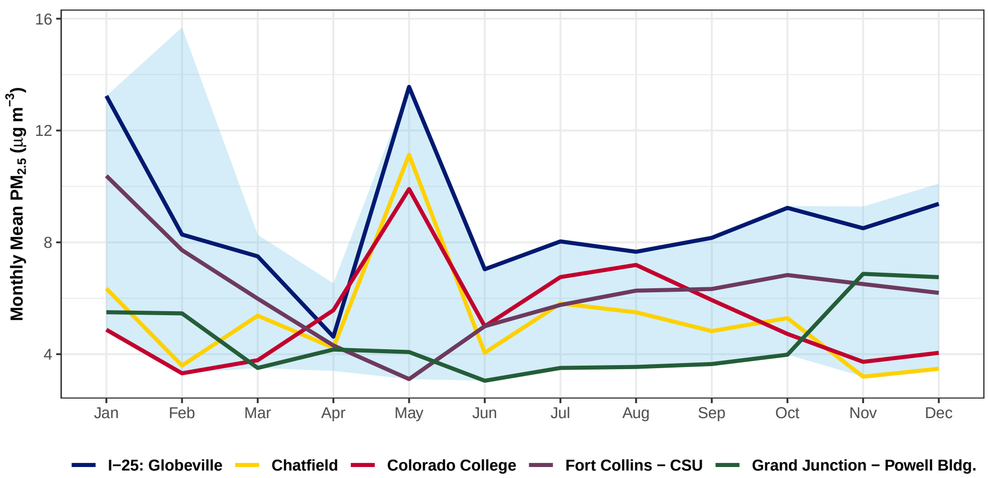

Figure 5.15: Monthly mean $PM_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

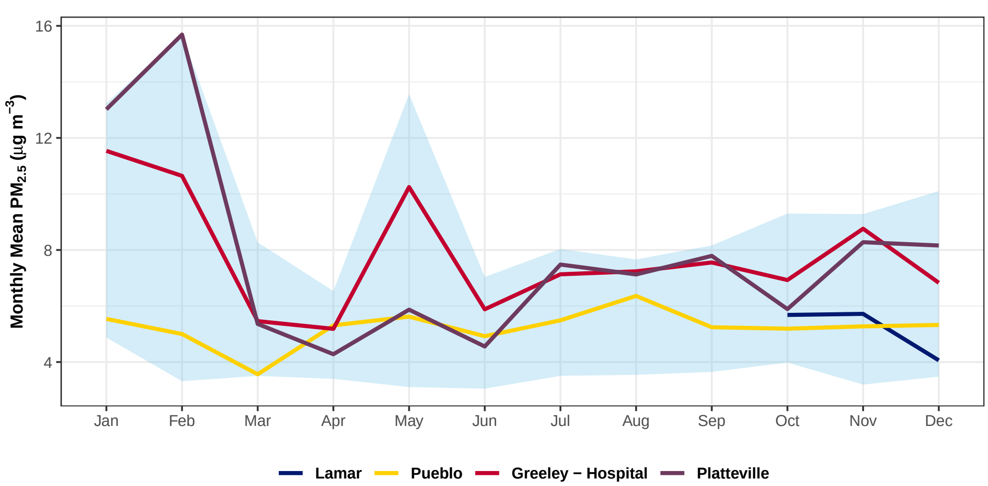

Figure 5.16: Monthly mean $PM_{2.5}$ concentrations. The blue shaded region shows the statewide range of monthly mean values.

6

Data Quality Assurance / Quality Control

This section describes the APCD Technical Services Program's success in meeting its data quality objectives for ambient air pollution monitoring data of criteria pollutants. This section has been prepared in accordance with 40 CFR Part 58 requirements. The statistical methodology used in this assessment is described in detail in the document "*Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58 Appendix A*."

Other quality objectives were assessed via laboratory and site system audits. The results of these audits indicate compliance with APCD's standard operating procedures and EPA acceptance criteria. Copies of APCD laboratory audits may be obtained from the Quality Assurance Unit of the APCD.

Other audits were performed and can be made available for review, including National Air Toxics Trends Station (NATTS) audits, Speciation Trend Network (STN) audits, and audits conducted within Colorado by other organizations. These results are not included in this report because other agencies perform the data assessments for these audits. CDPHE meteorological network audits are not included in this report, as meteorological data is not considered a priority pollutant and so a statistical assessment of this data is not provided.

6.1 Data Quality

In order to provide decision makers with data of adequate quality, the CDPHE uses the Data Quality Objectives (DQO) process to develop performance and acceptance criteria (or data quality objectives) that specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. Quality objectives for measurement data are designed to ensure that the data end user's DQOs are met. Measurement quality objectives include quantitative objectives, such as representativeness, completeness, accuracy, precision, and detection level, as well as qualitative objectives, such as site placement, operator training, and sample handling techniques. There are some data quality indicators underlying the DQOs that relate directly to the measurement system being used to collect ambient air measurements. These data quality indicators include precision, bias, completeness, and sampling frequency. These variables need to be maintained within certain acceptable ranges so that end data users can make decisions with specified levels of confidence.

6.2 Quality Assurance Procedures

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. In addition to performing tests to determine bias and precision, additional quality indicators (such as sensitivity, representativeness, completeness, timeliness, documentation quality, and sample custody control) are also evaluated. Quality assurance procedures fall under two categories:

- Quality Control (QC): procedures built into the daily sampling and analysis methodologies to ensure data quality, and
- Quality Assessment (QA): periodic independent evaluations of data quality.

Some ambient air monitoring is performed by automated equipment located at field sites, while other measurements are made by taking samples from the field to the laboratory for analysis. For this reason, we will divide quality assurance procedures into two parts: field and laboratory quality assurance.

6.2.1 Field Quality Assurance

Quality assurance is a general term for the procedures used to ensure that a particular measurement meets the quality requirements for its intended use. Quality control of continuous analyzers consists of precision checks and/or flow verifications. The overall precision of filter-based sampling methods is measured using collocated samplers. Quality assurance is evaluated by periodic performance and system audits.

Automated analyzers (except O_3) are calibrated by challenging the instrument's response to a known concentration of EPA protocol gas delivered through a dilution system. The analyzer is then adjusted to produce the correct response. O_3 analyzers are calibrated by challenging the analyzer's response with O_3 produced by an independently certified NIST-traceable ozone generator. The site's analyzer is then adjusted to produce the same measured concentration as the traceable analyzer. Manual samplers are calibrated by comparing their volumetric flow rate at one or more levels to the flow measured by a flow transfer standard. Calibrations are performed when an instrument is first installed and at assigned intervals thereafter depending on the analyzer type. Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control checks.

Precision is a measure of the variability of an instrument or the variability of the testing source. The precision of continuous gaseous analyzers are evaluated by comparing a sample of a known concentration against the instrument's response. The precision of filter-based particulate samplers is determined by collocated sampling (i.e., the simultaneous operation of two identical samplers placed side by side). The difference in the results of the two samplers is used to estimate the precision of the entire measurement process (i.e., both field and laboratory precision). Precision of manual particulate samplers is assessed by regular periodic flow checks. Precision of continuous particulate samplers is assessed through the comparison of the ambient data to the FRM data and by regular periodic flow checks. Manual samplers are calibrated by comparing their volumetric flow rate at one or more levels to the flow measured by a flow transfer standard. Calibrations are performed when an instrument is first installed and at assigned intervals thereafter depending on the analyzer type. Calibrations are also performed after instrument repairs or when quality control charts indicate a drift in response to quality control checks.

The bias of automated methods is assessed through field performance evaluations (also called accuracy audits) and through site precision checks. Performance audits are conducted by challenging the instrument with a gas of known NIST-traceable concentration. Bias is evaluated by comparing the measured response to the known value. Typically, performance evaluations are performed biannually using samples of several different concentrations.

System audits indicate how well a sampling site and site operator conforms to the standard operating procedures as well as how well the site is located with respect to its mission (e.g., urban or rural sampling, SLAMS or special purpose sampling site, etc.). Some areas reviewed include: site location (possible obstruction, presence of nearby pollutant sources), site security, site characteristics (urban versus suburban or rural), site maintenance, physical facilities (maintenance, type and operational quality of equipment, buildings, etc.), record-keeping, sample handling, storage, and transport.

6.2.2 Laboratory Quality Control

Laboratory quality control includes calibration of analytical instrumentation, analysis of blank samples to check for contamination, analysis of spikes to evaluate interferences and target analyte matrix recovery, and analysis of duplicate samples to evaluate precision. Quality assurance is accomplished through laboratory performance and system audits.

Laboratory analytical instruments are calibrated by comparing the instrument's response with standards of a known concentration level. The differences between the measured and known concentrations are then used to adjust the instrument to produce the correct response.

A blank sample is one that has intentionally not been exposed to the pollutant of interest. Analysis of blank samples reveals possible contamination in the laboratory, during field handling, or during transportation.

Duplicate analyses of the same sample are performed to monitor the precision of the analytical method.

A regular sample is spiked with a known concentration to determine if the sample matrix is interfering with detection capabilities of the instrumentation. Regular performance audits are conducted by having the laboratory analyze samples whose physical or chemical properties have been certified by an external laboratory or standards organization. The difference between the laboratory's reported value and the certified value is used to evaluate the analytical method's accuracy.

System audits indicate how well the laboratory conforms to its standard operating procedures. System audits involve sending a QA Auditor to the laboratory to review compliance with standard operating conditions. Areas examined include: record keeping, sample custody, equipment maintenance, personnel training and qualifications, and a general review of facilities and equipment.

6.3 Gaseous Criteria Pollutants

6.3.1 Quality Objectives for Measurement Data

Data Quality Objectives for the APCD's ambient air monitoring program for gaseous criteria pollutants are shown in Table 6.1.

Table 6.1: Data quality objectives for gaseous criteria pollutants.

Data Quality Indicator	APCD Goal	EPA Requirement
Precision for O_3	7%	7%
Precision for CO, SO_2, NO_2	10%	10%
Precision Completeness	90%	75%
Bias for O_3	7%	7%
Bias for CO, SO_2, NO_2	10%	10%
Accuracy for O_3	15%	15%
Accuracy Audits Completeness	2 audits per analyzer per year	25% of analyzers quarterly
90% Probability Intervals	Meet EPA requirement	95% of audit values
NPAP TTP Audits for O_3	Meet EPA requirement	10%
NPAP TTP Audits for for CO, SO_2, NO_2	Meet EPA requirement	15%
Overall Data Completeness	90%	75%

6.3.2 Gaseous Data Quality Assessment

6.3.2.1 Summary

Assessment of the data for APCD gaseous criteria pollutants showed that all gaseous analyzers met the minimum EPA criteria and most monitoring sites met APCD goals for precision, bias, accuracy, national performance evaluations, and completeness.

Table 6.2: Summary of precision, accuracy, bias, and completeness for site-level gaseous monitoring data.

Site	Parameter	Precision Count	Precision Complete (%)	CV (%)	Bias (%)	Prob. Limits		Data Complete (%)
						Lower	Upper	
Welby	CO	20	100	4.62	+/-3.99	-8.3	7.1	91
CAMP	CO	20	100	1.3	+/-1.11	-2.6	1.73	94
La Casa	CO	26	100	2.8	+/-2.78	-3.14	6.39	98
I-25: Denver	CO	26	100	2.27	+3.53	-0.9	6.85	99
Highway 24	CO	26	100	2.27	+/-1.9	-3.29	4.44	98
Fort Collins - Mason	CO	26	100	1.06	-1.82	-3.34	0.28	97
Greeley - Weld County Tower	CO	26	100	0.33	-0.68	-1.17	-0.04	99
Welby	SO_2	26	100	3.22	+4.6	-1.77	9.2	97
CAMP	SO_2	21	81	2.81	+/-2.25	-4.39	5.0	77
La Casa	SO_2	26	100	2.33	+2.99	-1.59	6.36	93
Highway 24	SO_2	26	100	2.59	+5.35	0.4	9.24	89
Welby	NO_2	26	100	2.88	+/-2.36	-5.55	4.26	93
CAMP	NO_2	21	81	2.32	+/-1.87	-4.02	3.73	74
La Casa	NO_2	26	100	1.66	+/-1.67	-3.83	1.84	86
I-25: Denver	NO_2	26	100	3.32	+/-2.61	-5.56	5.75	95
I-25: Globeville	NO_2	26	100	2.21	+4.0	-0.27	7.26	94
Rocky Flats - N.	NO_2	24	92	3.46	+3.76	-3.32	8.35	88
Platteville Atmospheric Observatory (PAO)	NO_2	26	100	2.67	+/-2.52	-2.95	6.14	91
Welby	O_3	26	100	3.54	+/-3.42	-7.73	4.33	85
Highland Reservoir	O_3	26	100	2.05	+/-1.72	-4.19	2.78	99
Aurora - East	O_3	26	100	2.58	+/-1.97	-4.88	4.06	92
Boulder Reservoir	O_3	26	100	3.16	+/-2.76	-6.26	4.71	99
CAMP	O_3	21	81	3.6	+/-3.38	-7.7	4.33	70
La Casa	O_3	26	100	2.73	+/-2.21	-5.04	4.25	94
Chatfield State Park	O_3	26	100	2.59	+/-2.23	-3.57	5.27	98
U.S. Air Force Academy (USAFA)	O_3	26	100	2.5	+/-2.06	-4.16	4.35	95
Manitou Springs	O_3	26	100	3.46	+/-2.82	-6.17	5.64	98
Rifle - Health Dept.	O_3	26	100	1.76	+/-1.44	-3.43	2.58	99
Black Hawk	O_3	26	100	2.08	+/-1.75	-3.4	3.68	99
Rocky Flats - N.	O_3	24	92	3.5	+/-3.04	-6.41	5.41	92
NREL	O_3	26	100	2.82	+/-2.35	-4.45	5.17	98
Evergreen	O_3	26	100	2.71	+/-2.42	-5.64	3.61	94
Fort Collins - West	O_3	26	100	2.54	+/-2.15	-4.49	4.16	97
Fort Collins - Mason	O_3	26	100	2.27	+/-1.74	-4.09	3.64	95
Palisade Water Treatment	O_3	24	92	1.6	+/-1.47	-3.43	1.98	96
Cortez - Health Dept.	O_3	26	100	2.63	+/-2.16	-4.44	4.51	99
Pueblo West	O_3	23	100	3.21	+/-2.78	-4.73	6.12	92
Greeley - Weld County Tower	O_3	26	100	2.97	+/-2.52	-5.8	4.31	95
Platteville Atmospheric Observatory (PAO)	O_3	26	100	3.09	+/-3.11	-7.11	3.41	96

6.3.2.2 Coefficient of Variation (CV)

At least once every two weeks, precision is determined by sampling a gas of known concentration for every gaseous analyzer. The table above summarizes the number of precision checks that were performed (precision count) by site (Table 6.2) as well as the percent completeness of those precision checks. Table 6.2 also summarizes the statistical data quality assessment of these precision checks for all gaseous criteria pollutants. The coefficient of variation (CV) for the precision checks is summarized annually by site. The equations used to calculate precision, bias, and upper and lower confidence limits for the 90% probability intervals using the bi-weekly precision checks are described in detail in the document "*Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58 Appendix A*."

6.3.2.3 Bias

For gaseous pollutants the bias is also calculated using the bi-weekly precision checks. Bias is summarized in Table 6.2 by the same groupings as CV. A plus or minus bias is assigned to the annual site and organization grouping levels based on an evaluation of where the 25^{th} and 75^{th} percentiles of percent differences for the precision data fell. If both percentiles fell below zero then the bias was assigned a minus sign, and if both percentiles fell above zero, then the bias was assigned a plus sign. If one bias was positive and one bias was negative (i.e. straddling zero), no sign was associated with the bias.

Organizationally, CO showed a non-signed bias of 2.10% in 2023. SO_2 showed a non-signed bias of 3.69%. O_3 showed a non-signed bias of 2.09% for 2023. There was no sign associated with the calculated bias (2.46%) for the NO_2 precision checks for the organization as a whole in 2023.

6.3.2.4 Performance Evaluation (Accuracy Audits)

Audits were performed at least twice on every gaseous analyzer within the APCD network during the 2023 calendar year. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

All Performance Evaluations (accuracy audits) performed for all gaseous analyzers during 2023 passed the EPA criteria of 15%.

6.3.2.5 Probability Intervals (Upper and Lower Confidence Limits)

Probability intervals (upper and lower confidence limits) are calculated per 40 CFR 58 Appendix A section 4, by using the percent differences retrieved from station precision checks. The EPA has established that 95% of the independent audit points taken for a given year should fall within this calculated probability interval to validate the bias calculated from the precision checks. The percent differences between the audit concentrations and the indicated concentrations taken in 2023 for CO were compared to the probability intervals. Out of the 56 audit concentration points taken for CO in 2023, 77% fell between the probability intervals for the organization. There were 172 audit concentration points taken during 2023 for the APCD's O_3 network. Of those 172 ozone audit points, 24 fell outside the probability intervals. This means that 86% of the audit points for O_3 fell between the probability intervals in 2023. Out of the 119 audit points taken in 2023 for NO_2, 71% fell between the confidence limits. Out of the 31 audit points taken for SO_2 in 2023, 58% fell between the probability intervals. Therefore, all four gaseous criteria pollutants do not meet the requirement that specifies that ninety-five percent of the individual percent differences (all audit concentration levels) for the performance evaluations should be captured within the probability intervals for the primary quality assurance organization (40CFR 58 Appendix A).

APCD believes the reason it did not meet the above requirement in 2023 is due to the fact that the probability intervals are calculated based on precision checks that are closer to the middle of the calibration scale, which give small percent differences and tight probability intervals. A newer requirement in the CFR is pushing APCD to audit in the lower portion of the site instrumentation's calibration scale, due to the fact that this is where 80% of the ambient data is being captured. By auditing in the low end of the calibration scale, APCD is seeing higher percent differences between the audit concentration and the instrument response. APCD believes this is due in part to the low audit concentration differences producing large percent differences and partly because the instruments are calibrated on a higher scale than where the audits are being conducted. The instruments are being calibrated at a higher scale than where 80% of the ambient data falls due to the relatively small number of episodes that do produce high ambient concentrations which have an effect on public health. Recently, APCD has begun to lower the calibration range on most pollutants and lower the precision values at most of its sites. This will hopefully help to rectify this problem but still allow APCD to capture the higher concentration pollution episodes within the instrument's calibration range.

6.3.2.6 Completeness

Data completeness for the year is shown by site in Table 6.2. Precision completeness is shown as the number of precision checks that were performed and submitted to AQS for the year. Precision completeness is evaluated against the number of checks that should have been performed at each site during the year. Completeness for accuracy audits in 2023 met or exceeded APCD DQO goals for every gaseous analyzer, with a minimum of two audits performed on every analyzer.

Table 6.2 summarizes completeness statistics. Precision completeness is shown as the number of precision checks that were performed and submitted to AQS for the year. Precision completeness is evaluated against the number of checks that should have been performed at each site during the year. Data completeness is evaluated as the percentage of expected data uploaded to AQS for the year. Both precision completeness and data completeness in 2023 met or exceeded APCD DQO goals for every gaseous analyzer.

6.4 Particulate Data Quality Assessment

6.4.1 Summary

Assessment of the data quality for APCD particulate criteria pollutants showed that most samplers met minimum EPA criteria and most monitoring sites met APCD goals for accuracy, precision, completeness, and bias. Table 6.3 summarizes statistical evaluations for particulate matter measurements. The basis for these calculations can be found in 40 CFR 58 Appendix A.

6.4.2 Precision

The CV for filter-based particulate monitoring is determined from the collocated precision data collected (i.e., two identical samplers operated in an identical manner). Due to the anticipated poor precision for very low levels of pollutants, only collocated measurements at or above a minimum level (greater than or equal 15 $\mu g\ m^{-3}$ for PM_{10}, 20 $\mu g\ m^{-3}$ for Total Suspended Particulate or TSP, and 3 $\mu g\ m^{-3}$ for $PM_{2.5}$) would be called valid pairs and are used to evaluate precision. The calculations for the statistical presentations in Table 6.3 are found in 40 CFR 58 Appendix A section 4.2.

The CV for continuous based particulate monitoring is determined by monthly flow verifications (precision checks) performed on the continuous particulate monitors. The calculations for the statistical presentations in Table 6.3 are the same calculations that were performed on the precision data for gaseous analyzers.

6.4.3 Bias

Results of the flow rate verifications conducted by APCD personnel are shown in Table 6.3 below. There is no requirement for bias on the high-volume filter-based particulate monitoring, since the precision is based on collocated sampling. For the filter-based particulate monitoring, Table 6.3 summarizes bias based on the verifications that were performed during the year, since APCD performs particulate audits four times more frequently than the EPA requires. These additional verifications are conducted to compensate for the lack of a flow verification precision check program in place for the high-volume samplers. The bias for the continuous particulate monitoring was calculated on the monthly flow verification precision checks with the same calculations that were used to determine the gaseous bias.

6.4.4 Performance Evaluation (Accuracy Audits)

Audits were performed at least quarterly on every particulate sampler within the APCD network during the 2023 calendar year. The primary goal of these audits is to evaluate the analyzer performance and calibration. Other factors are also noted during these audits such as operator performance, station operational criteria, record keeping, site upkeep issues, and general safety problems.

6.4.5 Completeness

Precision completeness for the year is shown by site in Table 6.3. Precision completeness is based on the number of monthly flow verifications that were performed. Precision completeness is evaluated against the number of verification checks that should have been performed at each site during the year. Completeness for accuracy audits met or exceeded all APCD DQO goals for every particulate analyzer, with a minimum of two audits performed on every analyzer per year.

6.4.6 Results

Table 6.3 below summarizes statistical evaluations for all particulate completeness, bias, and precision (percent difference). The values were calculated as described in 40 CFR 58 Appendix A Section 4.2.

Table 6.3: Summary of completeness, bias, and precision (percent difference) for particulate monitoring data.

Site	Parameter	Verification Count	Verification Complete (%)	Bias (%)	Mean % Difference	Std. Dev. % Difference
Birch Street (1)	PM_{10}	23	100	+/-0.95	-0.52	0.79
Birch Street (3)	PM_{10}	16	100	+/-1.01	0.02	0.98
Welby (3)	PM_{10}	44	100	+/-1.1	0.25	1.14
Alamosa - ASC	PM_{10}	6	100	+/-1.21	0.17	0.98
Pagosa Springs School (3)	PM_{10}	16	100	+/-2.93	1.42	2.53
Pagosa Springs School (4)	PM_{10}	4	100	+/-3.29	1.38	1.76
Boulder - CU	PM_{10}	10	100	+/-1.04	0.11	0.93
CAMP (1)	PM_{10}	2	50	+/-8.17	1.07	1.96
CAMP (2)	PM_{10}	2	50	+/-8.61	1.11	2.29
La Casa (1)	PM_{10}	13	100	+/-2.13	-0.19	1.96
La Casa (2)	PM_{10}	11	92	-0.92	-0.59	0.56
Colorado College	PM_{10}	23	100	+1.65	1.19	1.05
Cañon City - City Hall (1)	PM_{10}	4	100	+/-5.39	0.59	4.88
Cañon City - City Hall (3)	PM_{10}	6	100	+0.75	0.39	0.44
Grand Junction - Powell Bldg. (1)	PM_{10}	12	100	+/-0.68	0.26	0.57
Grand Junction - Powell Bldg. (2)	PM_{10}	12	100	-1.21	-0.85	0.67
Aspen	PM_{10}	4	100	+/-2.37	-0.86	1.36
Lamar - Municipal Bldg. (2)	PM_{10}	10	100	+/-5.83	1.65	5.37
Lamar - Municipal Bldg. (3)	PM_{10}	6	100	+/-0.83	0.36	0.57
Pueblo - Fountain School (1)	PM_{10}	8	100	-4.04	-2.19	2.65
Pueblo - Fountain School (3)	PM_{10}	14	100	-1.49	-0.7	1.22
Steamboat Springs (2)	PM_{10}	12	100	-2.08	-1.2	1.45
Steamboat Springs (4)	PM_{10}	6	100	+2.07	0.41	1.63
Telluride (1)	PM_{10}	5	100	-1.94	-0.93	1.06
Telluride (3)	PM_{10}	4	100	+/-3.17	-0.7	2.04
Birch Street (2)	$PM_{2.5}$	16	100	-1.38	-0.74	1.06
Birch Street (3)	$PM_{2.5}$	22	100	+/-1.5	0.4	1.56
Alamosa - ASC	$PM_{2.5}$	3	100	-1.22	-0.53	0.41
Arapaho Community College (ACC)	$PM_{2.5}$	14	100	+/-0.69	-0.24	0.61
Longmont - Municipal Bldg. (1)	$PM_{2.5}$	25	100	+/-0.83	0.42	0.76
Longmont - Municipal Bldg. (3)	$PM_{2.5}$	10	100	-1.77	-1.18	1.0
Boulder Chamber of Commerce (CC)	$PM_{2.5}$	22	100	+/-0.99	0.62	0.79
Boulder - CU	$PM_{2.5}$	5	100	-1.33	-0.23	1.06
CAMP (1)	$PM_{2.5}$	18	100	+/-0.55	-0.19	0.53
CAMP (2)	$PM_{2.5}$	13	100	+/-0.54	0.27	0.43
CAMP (3)	$PM_{2.5}$	20	100	+/-2.17	0.17	2.07
National Jewish Health (NJH)	$PM_{2.5}$	11	100	+/-1.42	-0.0	1.37
La Casa (1)	$PM_{2.5}$	12	100	-1.3	-0.82	0.85
La Casa (3)	$PM_{2.5}$	11	100	+/-1.62	-0.49	1.43
I-25: Denver (1)	$PM_{2.5}$	13	100	+/-0.85	-0.16	0.8
I-25: Denver (3)	$PM_{2.5}$	22	100	+/-2.12	-0.9	1.87
I-25: Globeville	$PM_{2.5}$	23	100	+/-1.97	0.36	1.92
Chatfield State Park (1)	$PM_{2.5}$	14	100	+/-0.99	-0.42	0.87
Chatfield State Park (3)	$PM_{2.5}$	12	100	+/-1.29	0.03	1.26
Colorado College	$PM_{2.5}$	23	100	+/-2.35	0.16	2.34
Fort Collins - CSU	$PM_{2.5}$	34	100	+/-2.13	0.54	2.17
Grand Junction - Powell Bldg.	$PM_{2.5}$	27	100	+/-2.25	-0.16	2.47
Lamar - Municipal Bldg.	$PM_{2.5}$	3	100	+/-1.39	0.14	0.81
Pueblo - Fountain School (1)	$PM_{2.5}$	16	100	+/-0.96	-0.1	0.92
Pueblo - Fountain School (3)	$PM_{2.5}$	7	100	-1.11	-0.71	0.55
Greeley - Hospital	$PM_{2.5}$	25	100	+/-2.1	0.28	2.12
Platteville - Middle School	$PM_{2.5}$	25	100	+/-0.55	-0.29	0.48

Table 6.4: Collocated QC check statistics for particulate monitoring data.

Site	Parameter	Total Valid Pairs	CV
Longmont	PM_{10}	35	5.23
CAMP	PM_{10}	31	3.59
La Casa	PM_{10}	46	8.37
GJ - Powell Bldg.	PM_{10}	48	6.96
Birch Street	$PM_{2.5}$	24	9.27
CAMP	$PM_{2.5}$	42	10.68
I-25 Denver	$PM_{2.5}$	57	28.32
Chatfield State Park	$PM_{2.5}$	63	15.14

APPENDIX A: MONITORING SITE DESCRIPTIONS

This appendix provides detailed information for all monitoring sites considered in this Data Report. Table A-1 summarizes the locations and monitoring parameters of each site currently in operation, by county, alphabetically. The shaded lines in the table list the site AQS identification numbers, address, site start-up date, elevation, and longitude and latitude coordinates. Beneath each site description the table lists each monitoring parameter in operation at that site, the orientation and spatial scale, which national monitoring network it belongs to, the type of monitor in use, and the sampling frequency. The parameter date is the date when valid data were first collected.

The following abbreviations are used in Table A-1 below, with orientation (Orient) referring to the monitoring objective and scale referring to the size of the area that concentrations from the monitor represent.

Orientation
P.O. - Population oriented
S.O. - Source oriented
Back - Background orientation
SPM - Special Purpose Monitor
H.C. - Highest Concentration
POC - Parameter Occurrence Code
SLAMS - State or Local Air Monitoring Stations

Scale (Area Represented)[1]
Micro - Micro-scale (several m – 100 m)
Middle - Middle Scale (100 – 500 m)
Neigh - Neighborhood Scale (0.5 – 4 km)
Urban - Urban Scale (4 – 50 km)
Region - Regional Scale (50 – hundreds of km)

Table A-1. Monitoring Locations and Parameters Monitored

AQS #	***Site Name***	***Address***	***Site Start***	***Elevation (m)***	***Latitude***	***Longitude***
	Parameter	***POC***	***Start***	***Orient/Scale***	***Monitor***	***Type***
Adams						
080010010	Birch Street	7275 Birch St	Mar 2021	1569	39.8281	-104.93647
	$PM_{2.5}$	3	Jul 2023	P.O. Neigh	TAPI - 640X	SLAMS
	PM_{10}	1	Dec 2023	P.O. Neigh		SLAMS
	$PM_{2.5}$	2	Dec 2023	P.O. Neigh		SLAMS
080013001	Welby	3174 E. 78TH AVE.	Jan 1975	1554	39.838119	-104.94984
	Temperature	1	Jan 1975		Met One - 062MP	OTHER
	Wind Speed	1	Jan 1992		RM Young - 05305V	OTHER
	Wind Direction	1	Jan 1992			OTHER
	SO_2	2	Jan 2006	P.O. Neigh	TAPI - 100E	SLAMS

[1] "Appendix D to Part 58 – Network Design Criteria for Ambient Air Quality Monitoring," 40 Federal Register 58 (15 January 2015).

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type
	O_3	2	Sep 2007	P.O. Neigh	TAPI - T400	SLAMS
	PM_{10}	2	Sep 2011	P.O. Neigh		
	CO	1	Dec 2016	P.O. Neigh		
	NO_2	1	Nov 2019	P.O. Urban	TAPI - T200	SLAMS
	PM_{10}	3	Jan 2023	P.O. Neigh		SLAMS
Arapahoe						
080050002	HIGHLAND RESERVOIR	8100 S. UNIVERSITY BLVD	Jun 1978	1747	39.567887	-104.957193
	O_3	1	Sep 2015	H.C. Neigh	TAPI - T400	SLAMS
	Wind Speed	1	Sep 2015		Met One - 010C	OTHER
	Wind Direction	1	Sep 2015		Met One - 020C	OTHER
	Temperature	1	Sep 2015		Met One - 62	OTHER
080050005	Arapahoe Community College	6190 S. SANTA FE DR.	Mar 1999	1636	39.604399	-105.019526
	$PM_{2.5}$	1	Jun 2003	P.O. Neigh		
080050006	Aurora East	36001 E. Quincy Ave.	Jun 2009	1799	39.638522	-104.569335
	O_3	1	Jun 2009	P.O. Urban	TAPI - T400	SLAMS
	Wind Speed	1	Jun 2009	P.O. Urban	Met One - 010C	OTHER
	Wind Direction	1	Jun 2009	P.O. Urban	Met One - 020C	OTHER
	Temperature	1	Jun 2009	P.O. Urban	Met One - 60	OTHER
Archuleta						
080070001	PAGOSA SPRINGS SCHOOL	309 LEWIS ST.	Jun 2001	2165	37.26842	-107.009659
	PM_{10}	3	Nov 2011	P.O. Neigh		
Boulder						
080130003	LONGMONT - MUNICIPAL BLDG	350 KIMBARK ST.	Jan 1999	1520	40.164576	-105.100856

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	***POC***	***Start***	***Orient/Scale***	***Monitor***	***Type***
	$PM_{2.5}$	1	Jun 2003	P.O. Neigh	R&P - Partisol 2025	
	PM_{10}	2	Feb 2011	P.O. Neigh		
	PM_{10}	3	Sep 2014	P.O. Neigh		
	Temperature	3	Jul 2018	P.O. Neigh		SLAMS
	$PM_{2.5}$	23	Jul 2018	P.O. Neigh		SLAMS
	$PM_{2.5}$	3	Jul 2023	P.O. Neigh		
080130012	BOULDER CHAMBER OF COMMERCE	2440 PEARL ST.	Jan 1999	1619	40.021097	-105.263382
	$PM_{2.5}$	1	Jun 2003	P.O. Neigh		
	PM_{10}	1	Oct 2010	P.O. Neigh		
080130014	Boulder Reservoir	5545 Reservoir Road.	Sep 2016	1586	40.070016	-105.220238
	O_3	1	Sep 2016	P.O. Urban	TAPI - 400E	SLAMS
	Wind Speed	1	Sep 2016	P.O.	RM Young - 05305V	OTHER
	Wind Direction	1	Sep 2016	P.O.		OTHER
	Temperature	1	Sep 2016	P.O.	RM Young - 41372V	OTHER
	Relative Humidity	1	Sep 2016	P.O.		OTHER
080131001	BOULDER - CU-ATHENS	2102 ATHENS ST.	Nov 2004	1622	40.012969	-105.267212
	$PM_{2.5}$	3	Nov 2006	P.O. Neigh		
Clear Creek						
080190006	Mines Peak	Near summit of Berthoud Pass off US Highway 40	Jul 2014	3806	39.794391	-105.76398
	O_3	1	Jul 2014	Back Region	TAPI - T400	SPM
Denver						
080310002	DENVER - CAMP	2105 BROADWAY	Jan 1985	1593	39.751184	-104.987625
	Temperature	1	Jan 1985			OTHER

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	**POC**	**Start**	**Orient/Scale**	**Monitor**	**Type**
	Wind Speed	1	Jan 1992			OTHER
	Wind Direction	1	Jan 1992			OTHER
	SO_2	1	Nov 2005	H.C. Neigh	TAPI - T100	SLAMS
	PM_{10}	1	Oct 2011	H.C. Micro		
	PM_{10}	2	Oct 2011	H.C. Micro		
	O_3	6	Jan 2012	P.O. Neigh	TAPI - T400	SLAMS
	$PM_{2.5}$	3	Apr 2013	H.C. Micro	Grimm - EDM 180	SPM
	NO_2	1	Jan 2014	H.C. Neigh	TAPI - T200U	SLAMS
	CO	2	Apr 2017	H.C. Micro		
	$PM_{2.5}$	1	Feb 2024	P.O. Micro	R&P - Partisol 2025	SLAMS
	$PM_{2.5}$	2	Feb 2024	P.O. Micro	R&P - Partisol 2025	SLAMS
080310013	DENVER - NJH-E	14TH AVE. & ALBION ST.	Mar 2018	1620	39.738578	-104.939925
	Temperature	3	Mar 2018	P.O. Neigh		SLAMS
	$PM_{2.5}$	23	Mar 2018	Neigh		SLAMS
	$PM_{2.5}$	3	Jul 2023	P.O. Neigh	TAPI - 640	SPM
080310026	La Casa	4545 Navajo St.	Jan 2013	1602	39.77949	-105.00518
	CO	1	Jan 2013	P.O. Neigh	Thermo - 48i-TL	SLAMS
	NOy	1	Jan 2013	P.O. Neigh		SLAMS
	NOy - NO	1	Jan 2013	P.O. Neigh	TAPI - T200U-NOY	SLAMS
	O_3	1	Jan 2013	P.O. Neigh	TAPI - T400	SLAMS
	Wind Speed	1	Jan 2013	P.O. Neigh	Met One - 010C	SLAMS
	Wind Direction	1	Jan 2013	P.O. Neigh	Met One - 020C	SLAMS
	Temperature	1	Jan 2013	P.O. Neigh	Met One - 010C	SLAMS

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	**POC**	**Start**	**Orient/Scale**	**Monitor**	**Type**
	Temperature	2	Jan 2013	P.O. Neigh	Met One - 010C	SLAMS
	SO_2	1	Apr 2013	P.O. Neigh	TAPI - T100U	SLAMS
	NO_2	1	Jul 2014	P.O. Neigh	TAPI - T500U	SLAMS
	Relative Humidity	1	Nov 2014	P.O. Neigh	Met One - 083E-1-35	SLAMS
	Solar radiation	1	Apr 2018	P.O. Neigh	KIPP&ZONEN - CMP11	SLAMS
	$PM_{2.5}$	23	Dec 2018	Neigh		SLAMS
	$PM_{2.5}$	3	Jul 2023	P.O. Neigh	TAPI - 640	SPM
	PM_{10}	1	Apr 2024	P.O. Neigh	Met One - E-Seq	SLAMS
	PM_{10}	2	Apr 2024	P.O. Neigh	Met One - E-Seq	SLAMS
	$PM_{2.5}$	1	Apr 2024	P.O. Neigh	Met One - E-Seq	SLAMS
080310027	I-25	971 Yuma Street	Jun 2013	1583	39.73217	-105.0153
	CO	1	Jun 2013	P.O. Micro	Thermo - 48i-TL	SLAMS
	Wind Speed	1	Jun 2013	P.O.	Met One - 010C	OTHER
	Wind Direction	1	Jun 2013	P.O.	Met One - 020C	OTHER
	Temperature	1	Jun 2013	P.O.	RM Young - 41372V	OTHER
	$PM_{2.5}$	3	Jan 2014	P.O. Micro	Grimm - EDM 180	SLAMS
	Relative Humidity	1	May 2020	P.O.	RM Young - 41372V	OTHER
	NO_2	1	May 2021	P.O. Micro	TAPI - T200	SLAMS
	$PM_{2.5}$	1	Sep 2023	P.O. Micro	R&P - Partisol 2025	SLAMS
080310028	Globeville	4903 Acoma St.	Oct 2015	1587	39.7861	-104.9886
	NO_2	1	Oct 2015	P.O. Micro	TAPI - T200	SLAMS
	Temperature	1	Oct 2015	P.O.	RM Young - 41372V	OTHER
	Relative Humidity	1	Oct 2015	P.O.		OTHER

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	***POC***	***Start***	***Orient/Scale***	***Monitor***	***Type***
	$PM_{2.5}$	3	Oct 2015	P.O. Micro	Grimm - EDM 180	SLAMS
	Wind Speed	1	Mar 2020	P.O.	RM Young - 05305V	OTHER
	Wind Direction	1	Mar 2020	P.O.		OTHER
Douglas						
080350004	Chatfield State Park	11500 N. Roxborough Park Rd.	Apr 2004	1676	39.534488	-105.070358
	O_3	1	Apr 2004	H.C. Urban	TAPI - T400	SLAMS
	Wind Speed	1	Apr 2004		Met One - 010C	OTHER
	Wind Direction	1	Apr 2004		Met One - 020C	OTHER
	Temperature	1	Apr 2004		Met One - 62	OTHER
	$PM_{2.5}$	1	Jul 2005	P.O. Neigh	R&P - Partisol 2025	
	$PM_{2.5}$	23	Jun 2017	P.O. Neigh		SLAMS
	$PM_{2.5}$	3	Jul 2023	P.O. Neigh	TAPI - 640	SPM
El Paso						
080410013	U.S. AIR FORCE ACADEMY	ROAD 640, USAF ACADEMY	Jun 1996	1971	38.958341	-104.817215
	O_3	1	Aug 2010	H.C. Urban	TAPI - T400	SLAMS
080410015	COLORADO SPRINGS - HIGHWAY 24	690 W. HIGHWAY 24	Jan 2013	1824	38.830895	-104.839243
	CO	2	Jan 2013	H.C. Micro		
	SO_2	1	Jan 2013	H.C. Micro		
	Wind Speed	1	Aug 2014	P.O.		
	Wind Direction	1	Aug 2014			
	Temperature	1	Aug 2014	P.O.		
	Relative Humidity	1	Nov 2014	P.O.		
080410016	MANITOU SPRINGS	101 BANKS PL.	Apr 2004	1955	38.853097	-104.901289

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	**POC**	**Start**	**Orient/Scale**	**Monitor**	**Type**
	O_3	1	Oct 2007	H.C. Neigh	TAPI - T400	SLAMS
080410017	COLORADO SPRINGS - COLLEGE COLLEGE	130 W. CACHE LA POUDRE	Jun 2016	1832	38.848014	-104.828564
	$PM_{2.5}$	3	Jun 2016	P.O. Neigh	Grimm - EDM 180	SLAMS
	PM_{10}	1	Sep 2024	P.O. Neigh	R&P - Partisol 2025	SLAMS
Fremont						
080430003	CANON CITY - CITY HALL	128 MAIN ST.	Oct 2004	1626	38.43829	-105.24504
	PM_{10}	1	Dec 2011	P.O. Neigh		
Garfield						
080450012	Rifle-Health Dept	195 W. 14th St.	Jun 2008	1640	39.54182	-107.784125
	O_3	1	Jun 2008	P.O. Neigh		SLAMS
Gilpin						
080470003	Black Hawk	831 Miners Mesa Road, Black Hawk Colorado 80422	Jul 2019	2633	39.792519	-105.49127
	O_3	1	Jul 2019	P.O. Urban	TAPI - 400E	SLAMS
Jefferson						
080590006	ROCKY FLATS-N	16600 W COLO #128	Jun 1992	1802	39.912799	-105.188587
	Wind Speed	1	Jun 1992		RM Young - 05305V	OTHER
	Wind Direction	1	Jun 1992			OTHER
	Temperature	1	Jun 1992		RM Young - 41372V	OTHER
	Temperature	2	May 2018		RM Young - 41372V	OTHER
	Relative Humidity	1	Jun 2018	Back Neigh		OTHER
	Barometric pressure	1	Jun 2018	Back Neigh	RM Young - 61302V	OTHER
	NOy	1	Feb 2019	H.C. Urban	TAPI - 501Y	SLAMS
	NO_2	1	Feb 2019	Urban	TAPI - T500U	SLAMS

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	POC	Start	Orient/Scale	Monitor	Type
	NOy - NO	1	Feb 2019	H.C. Urban	TAPI - T200U-NOY	SLAMS
	Solar radiation	1	Jun 2019	Urban	KIPP&ZONEN - CMP11	SLAMS
	O_3	1	Jul 2024	H.C. Urban	TAPI - T400	SLAMS
080590011	NATIONAL RENEWABLE ENERGY LABS - NREL	2054 QUAKER ST.	Jun 1994	1832	39.743724	-105.177989
	O_3	1	Jul 2024	H.C. Urban	TAPI - T400	SLAMS
080590014	Evergreen	5124 South Hatch Drive	Oct 2020	2225	39.620408	-105.33872
	O_3	1	Oct 2020	P.O. Urban	TAPI - T400	SLAMS
	Wind Speed	1	Oct 2020	P.O. Urban	RM Young - 05305V	OTHER
	Wind Direction	1	Oct 2020	P.O. Urban		OTHER
	Temperature	1	Oct 2020	P.O. Urban	RM Young - 41372V	OTHER
	Relative Humidity	1	Oct 2020	P.O. Urban		OTHER
Larimer						
080690009	FORT COLLINS - CSU - Edison	251 EDISON DR.	Jun 2015	1524	40.571288	-105.079693
	$PM_{2.5}$	3	Jun 2015	P.O. Neigh	Grimm - EDM 180	SLAMS
080690011	FORT COLLINS - WEST	3416 LA PORTE AVE.	May 2006	1571	40.592543	-105.141122
	O_3	1	Jul 2024	H.C. Urban	TAPI - 400E	SLAMS
080691004	Fort Collins - CSU - S. Mason	708 S. Mason St.	Jan 1981	1524	40.57747	-105.07892
	Temperature	1	Jan 1981			OTHER
	Wind Speed	1	Jan 1992			OTHER
	Wind Direction	1	Jan 1992			OTHER
	O_3	1	May 2004	P.O. Neigh	TAPI - T400	SLAMS
	CO	1	May 2016	P.O. Neigh	Thermo - 48i-TL	SLAMS
Mesa						

AQS #	Site Name / *Parameter*	Address / *POC*	Site Start / *Start*	Elevation (m) / *Orient/Scale*	Latitude / *Monitor*	Longitude / *Type*
080770017	GRAND JUNCTION - POWELL BLDG	650 SOUTH AVE.	Dec 2003	1398	39.063798	-108.561173
	PM_{10}	2	Nov 2010	P.O. Neigh	R&P - Partisol 2025	
	$PM_{2.5}$	3	Jan 2014	P.O. Neigh	Grimm - EDM 180	SLAMS
	PM_{10}	1	Jul 2024	P.O. Neigh	R&P - Partisol 2025	SLAMS
080770018	GRAND JUNCTION - PITKIN	645 1/4 PITKIN AVE.	Jan 2004	1398	39.064289	-108.56155
	Wind Speed	1	Jan 2004			OTHER
	Wind Direction	1	Jan 2004			OTHER
	Temperature	1	Jan 2004			OTHER
	Relative Humidity	1	Nov 2014			OTHER
	Barometric pressure	1	Sep 2020			OTHER
080770020	Palisade-Water Treatment	865 Rapid Creek Rd.	May 2008	1521	39.130575	-108.313835
	O_3	1	May 2008	P.O. Urban		SLAMS
	Wind Speed	1	May 2008	P.O. Urban		SPM
	Wind Direction	1	May 2008	P.O. Urban		SPM
	Temperature	1	May 2008	P.O. Urban		SPM
Montezuma						
080830006	Cortez - Health Dept	106 W. North Street	Jun 2008	1890	37.350054	-108.592334
	O_3	1	Jun 2008	P.O. Neigh		SLAMS
Pitkin						
080970008	Aspen Yellow Brick Building	215 N. Garmisch	Jan 2015	2408	39.19296	-106.82323
	PM_{10}	1	Jan 2015	P.O. Neigh		
Prowers						
080990002	Lamar Municipal Bldg	104 E. PARMENTER ST.	Mar 1987	1107	38.084688	-102.618641

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	**POC**	**Start**	**Orient/Scale**	**Monitor**	**Type**
	PM_{10}	2	Jan 2012	P.O. Neigh		
Pueblo						
081010015	Pueblo - Fountain School	925 N. GLENDALE AVE.	Jun 2009	1433	38.276099	-104.597613
	$PM_{2.5}$	1	Jun 2009	P.O. Neigh	R&P - Partisol 2025	SLAMS
	PM_{10}	1	Jul 2011	P.O. Neigh		
Routt						
081070003	Steamboat Springs	136 6TH ST.	Mar 1987	2054	40.485201	-106.831625
	PM_{10}	2	Dec 2011	P.O. Neigh		
San Miguel						
081130004	Telluride	333 W. COLORADO AVE.	Mar 1990	2684	37.937872	-107.813061
	PM_{10}	1	Jan 2012	P.O. Neigh		
Weld						
081230006	Greeley - Hospital	1516 HOSPITAL RD.	Jun 2016	1441	40.414877	-104.70693
	$PM_{2.5}$	3	Jun 2016	P.O.	Grimm - EDM 180	SLAMS
081230008	Platteville - Middle School	1004 MAIN ST.	Aug 1999	1469	40.209387	-104.82405
	$PM_{2.5}$	1	Aug 2003	P.O. Region	R&P - Partisol 2025	
081230009	Greeley - Weld County Tower	3101 35TH AVE.	Jun 2002	1484	40.386368	-104.73744
	O_3	1	Jan 2004	P.O. Neigh	TAPI - T400	SLAMS
	Wind Speed	1	Feb 2012	P.O.	Met One - 010C	OTHER
	Wind Direction	1	Feb 2012	P.O.	Met One - 020C	OTHER
	Temperature	1	Feb 2012	P.O.	Met One - 060A	OTHER
	CO	1	Apr 2016	P.O. Neigh	Thermo - 48i-TL	SLAMS
081230013	Platteville Atmospheric Observatory	17065 County Road 28	Jun 2020	1521	40.181625	-104.72613

AQS #	Site Name	Address	Site Start	Elevation (m)	Latitude	Longitude
	Parameter	**POC**	**Start**	**Orient/Scale**	**Monitor**	**Type**
	O_3	1	Jun 2020	S.O. Region		
	Wind Speed	1	Jun 2020	S.O. Region		
	Wind Direction	1	Jun 2020	S.O. Region		
	Temperature	1	Jun 2020	S.O. Region		
	Relative Humidity	1	Jun 2020	S.O. Region		
	NO_2	1	May 2022	S.O. Region		

Adams County Birch Street, 7275 Birch Street (08 001 0010):

The Birch Street site in Adams County, which started operations on March 1, 2021, is situated in a mixed-use area that includes residential, commercial, and industrial zones. Located north of Denver's Central Business District, near the Platte River Valley, it lies downstream from Denver's urban air mass. The site is surrounded by educational institutions, with an elementary school to the south, a middle school to the north, and a high school to the southeast. Additionally, a significant industrial region borders it to the south and east, with gravel pits approximately one kilometer to the west and northwest.

This location serves as a replacement for the former Tri County Health Department site in Commerce City, which was decommissioned due to roofing renovations on its building. Monitoring of PM_{10} and $PM_{2.5}$ at the site commenced in August 2016, ensuring continued environmental oversight in the region.

Welby, 3174 E. 78th Avenue (08 001 3001):

Situated 8 miles north-northeast of Denver's Central Business District (CBD) along the South Platte River, the monitoring site is strategically placed to assess the nocturnal air mass drainage from the Denver metropolitan area and the thermally driven daytime flows upriver. Data indicate that elevated CO levels correlate with winds from the south-southwest, a direction that not only aligns with five of the six major local sources but also with the primary drainage winds of the South Platte River. This monitor is part of the SLAMS network and focuses on population exposure at a neighborhood scale.

CO monitoring at this site commenced in 1973 and ran until the spring of 1980, after which it was paused until October 1986. It resumed under a special study initiative. Since January 1988, there have been no exceedances of either the one-hour or eight-hour CO standards at Welby. In recent years, the primary importance of this monitor has shifted towards serving as an indicator of changes in the Air Quality Index (AQI).

O_3 (ozone) monitoring started in July 1973 at Welby. The monitor has recorded no exceedances of the former one-hour O_3 standard since 1998, indicating improvements in local air quality over time.

Highland Reservoir, 8100 S. University Boulevard (08 005 0002):

The Highlands monitoring site was established in June 1978, initially intended as a background location. However, due to urban expansion and the construction of C-470, it has evolved into a long-term trend site that tracks air quality changes in the region. Although positioned near the southern edge of high urban ozone concentrations, it might not be situated at the area of maximum concentrations. The site functions as a population-oriented neighborhood scale SLAMS monitor.

Meteorological monitoring at the site commenced in July 1978. In September 2010, the site and its meteorological tower were moved approximately 30 meters east to accommodate the construction of an emergency generator system, which is located about 20 meters northwest of the new site location. Due to significant construction activities on the property, the Highlands monitoring site was temporarily shut down from October 2013 to September 2015.

Arapahoe Community College (ACC), 6190 S. Santa Fe Drive (08 005 0005):

The ACC monitoring site is strategically situated in the southern suburbs of metropolitan Denver, specifically on the south side of Arapahoe Community College in a lesser-used parking area. Located at 6190 S. Santa Fe Drive, Littleton, near the boundary with Englewood, this site lies close to the base of the Platte River Valley along Highway 85. A residential zone extends eastward, across the railroad and Light Rail tracks.

The $PM_{2.5}$ monitor is housed within a mobile shelter, offering unobstructed 360-degree exposure, advantageous for accurate atmospheric sampling. Its proximity to the Platte River enhances its ability to capture potential high concentrations of $PM_{2.5}$ pollutants, especially during periods characterized by upslope airflow and temperature inversions in the valley. Despite this, the pollutant concentrations here are generally lower compared to other areas in Denver due to its southern, less populated location.

Wind patterns predominantly from the south-southwest and south, with secondary winds from the north and north-northeast, support the site's compliance with neighborhood scale monitoring as per federal guidelines (40 CFR, Part 58, Appendix D). The location qualifies as a population-oriented neighborhood scale SLAMS (State and Local Air Monitoring Stations) site, effectively meeting all required criteria for such designation.

Aurora – East, 36001 Quincy Ave (08 005 0006):

The Aurora East monitoring site commenced operations in June 2009. Positioned along the eastern border of the former Lowry bombing range, this site is situated on a flat, grassy plain. Its primary purpose is to serve as a regional facility, assisting in monitoring the easternmost spread of high urban ozone (O_3) concentrations. Notably, the site is located outside the swiftly expanding urban area near Aurora Reservoir, providing a strategic vantage for regional air quality assessment. Initially established as a Special Purpose Monitor (SPM) for regional assessment, Aurora East was upgraded to a State and Local Air Monitoring Station (SLAMS) in 2013, enhancing its role in environmental monitoring and data collection.

Pagosa Springs School, 309 Lewis Street (08 007 0001):

The Pagosa Springs monitoring station was originally situated on the roof of the Town Hall from April 24, 2000, until May 2001. Due to the planned demolition of the Town Hall, the PM_{10} monitor was subsequently moved to Pagosa Springs Middle School, where sampling began on June 7, 2001.

Located near the center of town adjacent to Highway 160, the Pagosa Springs School site is nestled in a valley surrounded by hills, typical of a small-town setting spread across a large area. The San Juan River flows through the southern part of town, enhancing the site's characteristic small bowl-like landscape. This area, primarily consisting of a commercial strip along Highway 160 and single-family homes, represents typical residential neighborhood exposure. Historically, Pagosa Springs was designated as a PM_{10} nonattainment area, leading to the implementation of a State Implementation Plan (SIP) due to a few exceedances of PM_{10} concentrations in the late 1990s.

Wind patterns in this region predominantly come from the north, with secondary winds from the north-northwest and south, aligning with the valley's topography. McCabe Creek flows north-south near the former meteorological station at the Town Hall. Notably, the highest wind gusts are recorded from the west and southwest during regional dust storms. The site functions as a population-oriented neighborhood scale SLAMS monitor.

Longmont – Municipal Bldg., 350 Kimbark Street (08 013 0003):

Longmont, a medium-sized community on Colorado's Front Range, is strategically located between the Denver/Boulder

Metro area and Fort Collins. Situated about 30 miles north of Denver and roughly six miles east of the foothills along St. Vrain Creek, Longmont combines suburban and rural characteristics. The town serves partly as a residential area for people working in the Denver-Boulder region. Longmont stands at an elevation of 4,978 feet, with nearby Front Range peaks reaching up to 14,000 feet. The area benefits from low humidity, modest precipitation, and plentiful sunshine.

The town has been monitoring air quality since 1985, starting with PM_{10} monitors and expanding to include $PM_{2.5}$ monitors in 1999. Longmont's prevailing winds, which generally flow from the north to the west, are influenced by the St. Vrain Creek Canyon. The PM_{10} monitoring station is centrally located amidst commercial and residential zones, offering optimal assessment of particulate matter exposure to the population. This location adheres to federal guidelines as outlined in 40 CFR, Part 58, Appendix D, qualifying it as a neighborhood scale SLAMS monitor.

In an effort to comply with EPA regulations, a collocated sampler was added in September 2014 to fulfill the high-volume collocation requirements for PM_{10}.

Boulder Chamber of Commerce, 2440 Pearl Street (08 013 0012):

The city of Boulder is situated at the eastern edge of the Rocky Mountain foothills, with most of the urban area extending across the rolling plains. The Boulder $PM_{2.5}$ monitoring site is located about 7,000 feet east of the Front Range foothills and roughly 50 feet south of a minor tributary of Boulder Creek, the principal waterway traversing the city.

PM_{10} monitoring at this site commenced in December 1994, and $PM_{2.5}$ monitoring started in January 1999. The dominant wind direction recorded at the nearest Air Pollution Control Division meteorological station (Rocky Flats – North) generally flows from the west, with significant contributions from the west-northwest and west-southwest directions.

The site, situated between Pearl Street and Folsom Street, falls under the middle traffic category but has been designated to represent a neighborhood scale in alignment with the federal guidelines stipulated in 40 CFR, Part 58 and Appendix D. This site serves as a population-oriented State and Local Air Monitoring Station (SLAMS) and operates on a 1-in-6-day sampling schedule, effectively capturing neighborhood-scale air quality data.

Boulder Reservoir, 5545 Reservoir Road (08 013 0014):

Boulder, located approximately 30 miles northwest of Denver, manages the Boulder Reservoir, which spans 700 acres and serves as both a multi-use recreational facility and a water storage site. This reservoir, which is owned by the city, is operated by the Northern Colorado Water Conservancy District primarily for water supply purposes. Situated about 5.5 miles northeast of Boulder, the reservoir was established as a replacement for the South Boulder Creek site. The latter was closed on January 1, 2016, due to overgrown large trees that could not be removed and thus failed to meet the necessary siting criteria.

The Boulder Reservoir functions as a key urban-scale SLAMS (State and Local Air Monitoring Stations) site, focusing on high concentration measurements. It has been active since September 2016, monitoring ozone levels and various meteorological parameters to assess air quality and environmental conditions.

Boulder – CU - Athens, 2102 Athens Street (08 013 1001):

The Boulder - CU monitoring site is conveniently situated adjacent to a lightly used parking lot, positioned directly north of the site and south of the University of Colorado's football practice fields. This strategic location offers an excellent representation of the neighborhood's particulate levels. The site has been operational since November 2004, providing valuable data that helps in assessing and managing air quality in the area.

Mines Peak, Near summit of Berthoud Pass off US Highway 40 (08 019 0006):

The Mines Peak site, located in Clear Creek County, sits atop Mines Peak near the summit of Berthoud Pass off US Highway 40 at an impressive elevation of 12,487 feet. This remote, high-elevation site provides a unique vantage point for monitoring air quality in an area far from urban pollution sources.

Ozone monitoring at Mines Peak began on July 1, 2014, as part of an initiative to measure ozone levels in this remote, elevated environment. Due to challenges in controlling the shelter temperature, this site operates as a Special Purpose Monitor (SPM). Consequently, the ozone data collected here is not used for regulatory purposes, such as comparison to the National Ambient Air Quality Standards (NAAQS).

Only ozone levels are monitored at Mines Peak. The site poses accessibility challenges, especially during the winter months, when heavy snow accumulation can make it difficult to reach.

CAMP, 2105 Broadway (08 031 0002):

The City and County of Denver, situated about 30 miles east of the Rocky Mountains foothills, features a landscape of gently rolling hills and is traversed by the Platte River running southwest to northeast near its downtown. Air quality monitoring at the downtown Continuous Air Monitoring Program (CAMP) site began in February 1965, with the aim to assess pollution exposure in the central business district. This site, positioned in a high-traffic street canyon, often records significant pollution episodes primarily due to its topography and urban setting.

Updates to the monitoring equipment include the replacement of the carbon monoxide (CO) monitor in April 2017 with a Thermo 48iTLE trace level monitor to better detect lower concentration levels. Additionally, various other pollutants have been monitored over the years: Nitrogen dioxide (NO_2) monitoring started in January 1973, sulfur dioxide (SO_2) in January 1967, and ozone (O_3) has been tracked intermittently since 1972, with the current monitor operational since February 2012. Particulate matter (PM_{10} and $PM_{2.5}$) monitoring began in 1986 and 1999 respectively, with continuous enhancements to technology, most recently in April 2013 when a GRIMM EDM 180 continuous monitor was installed.

Furthermore, meteorological monitoring commenced in January 1965. The site experienced a temporary pause from June 1999 to July 2000 due to construction activities. This historical and ongoing monitoring is crucial for understanding and managing air quality in Denver's urban environment.

National Jewish Health, 14th Avenue & Albion Street (08 031 0013):

This site is situated three miles east of the Central Business District (CBD) in Denver, near the bustling intersection of Colorado Boulevard and Colfax Avenue. It has been operational since 1982, following the relocation from two previous sites located just west of its current position. Initially, the first site was briefly active for a few months, then moved to a corner within the laboratory building at the same intersection.

The data collected from this continuous particulate monitor is utilized specifically for short-term forecasting and public notifications, rather than for comparison with the National Ambient Air Quality Standards (NAAQS). The monitoring equipment installed at this location is designed to serve as a population-oriented, middle-scale special project monitor. This setup helps in assessing the immediate environmental impacts on the surrounding community.

DESCI:

A visibility site was installed in Denver in late 1990 using a long-path transmissometer. Visibility in the downtown area is monitored using a receiver located near Cheesman Park at 1901 E. 13th Avenue, and a transmitter located on the roof of the Federal Building at 1929 Stout Street. Renovations at the Federal Building forced the transmissometer to temporarily move to 1255 19th Street in 2010, and quality control measurements showed no meaningful difference between old and new locations. This instrument directly measures light extinction, which is proportional to the ability of atmospheric particles and gases to attenuate image-forming light as it travels from an object to an observer. The station also monitors relative humidity in order to resolve low visibility because of fog or rain.

La Casa, 4587 Navajo Street (08 031 0026):

The La Casa site, established in January 2013, serves as the NCore site for the Denver Metropolitan area, replacing the former Denver Municipal Animal Shelter (DMAS) site due to a land use change. Located in northwest Denver, La Casa features a comprehensive array of monitoring equipment including trace gas/precursor-level CO and NOy analyzers, and trace-level SO_2, O_3, and meteorological and particulate monitors. All these instruments started operation in January 2013.

Certified by the EPA in 2013, La Casa adheres to NCore compliance standards and focuses on neighborhood-scale monitoring. The site hosts both PM_{10} and $PM_{2.5}$ monitoring, employing a pair of collocated low volume PM_{10} samplers, a Lo-Vol $PM_{2.5}$, and other specialized instruments on the shelter roof. These measurements are particularly valuable for calculating PM_{10}-2.5, or coarse particulate matter.

In early 2015, the site upgraded its $PM_{2.5}$ monitoring capabilities by replacing the TEOM/FDMS with a GRIMM EDM 180 continuous monitor, which simultaneously measures PM_{10} and $PM_{2.5}$ concentrations. Lead monitoring, which began in January 2013, was discontinued on December 31, 2015, due to persistently low concentrations. Consequently, the EPA has eliminated the lead monitoring requirement for all NCore sites. However, ambient lead levels will continue to be assessed at designated $PM_{2.5}$ speciation and IMPROVE sites across the state, as well as at the PM_{10} sampler at Grand Junction Powell (08 077 0017) as part of the National Air Toxics Trends Stations project.

I-25 Denver, 913 Yuma Street (08 031 0027):

The I-25 Denver site, established in June 2013, functions as a mandated EPA near-roadway NO_2 monitoring location. It employs chemiluminescence to measure NO, NO_2, and NO_x levels. Additionally, the site is equipped with advanced tools for environmental monitoring, including a Teledyne API Model 633 Black Carbon Aethalometer for trace-level carbon monoxide, and a filter-based sequential Federal Reference Method (FRM) sampler that collects $PM_{2.5}$ on a 1 and 6-day schedule. Continuous PM_{10} and $PM_{2.5}$ levels are monitored using a GRIMM EDM 180. The site also records various meteorological parameters to support and enhance the accuracy of its air quality measurements. These comprehensive monitoring activities help assess and manage air quality effectively in the area.

I-25 Globeville, 4905 Acoma Street (08 031 0028):

The I-25 Globeville site, established on October 1, 2015, serves as a crucial monitoring station for nitrogen dioxide (NO_2) near roadways as mandated by the Environmental Protection Agency (EPA). This site employs chemiluminescence technology to measure nitrogen oxides (NO, NO_2, and NO_x) levels. Additionally, it is equipped with instruments to continuously monitor particulate matter (PM_{10} and $PM_{2.5}$) using a GRIMM EDM 180 instrument. The facility also includes sensors that track various meteorological parameters to provide comprehensive environmental data. This integration of technologies ensures accurate and reliable monitoring of air pollutants that are critical for assessing air quality and implementing appropriate public health safeguards.

Chatfield State Park, 11500 N. Roxborough Park Road (08 035 0004):

Chatfield State Park became a designated monitoring location following the 1993 Summer Ozone (O_3) Study. Initially, the monitoring equipment was installed at the campground office but was subsequently moved to a more secluded spot on the south side of the park near the park offices. This new location was chosen over the Corps of Engineers Visitor Center across the reservoir due to its distance from the traffic on C-470, which could influence the readings. Situated in the South Platte River drainage area, this site is strategically positioned to monitor the formation of ozone coming from the southwest of the Denver metropolitan area.

Monitoring for $PM_{2.5}$, or fine particulate matter, commenced in 2004 with the installation of a continuous monitor. The following year, an FRM (Federal Reference Method) sequential filter-based monitor was added to enhance data collection. Additionally, meteorological monitoring began in April 2004, providing comprehensive environmental data to assess air quality and atmospheric conditions in the area.

Colorado Springs, USAFA Road 640 (08 041 0013):

The United States Air Force Academy has been selected as the new site for a maximum concentration ozone (O_3) monitoring station, replacing the previous monitor at Chestnut Street (08 041 0012). Predictive modeling in the Colorado Springs area suggests that elevated O_3 levels are typically found along the Monument Creek drainage north of the central business district (CBD) of Colorado Springs, or to a lesser degree, along the Fountain Creek drainage to the west of the

CBD. Consequently, the decision was made to position the new monitoring station near the Monument Creek drainage, approximately 9 miles north of the CBD. This site is strategically located near the southern entrance of the Air Force Academy, distanced from any major roads to avoid vehicular emissions. It serves as a population-oriented urban scale State and Local Air Monitoring Station (SLAMS).

Colorado Springs Hwy-24, 690 W. Highway 24 (08 041 0015):

The Highway 24 monitoring site is strategically positioned to the west of Interstate 25 and to the east of the intersection of U.S. Highway 24 and 8th Street. It lies approximately 0.8 miles west of the Colorado Springs Central Business District. Established in November 1998, this site replaced the Tejon Street CO monitor and is located in the Fountain Creek drainage area. It is situated in one of the busiest traffic zones in Colorado Springs, where vehicle congestion often occurs, particularly due to a traffic light at 8th Street. As such, it is an excellent location for the State and Local Air Monitoring Stations (SLAMS) network to track peak CO levels originating from both vehicular emissions and nearby industrial activities, including a power plant. This site provides detailed, micro-scale environmental monitoring that was previously unattainable in the region.

In response to the population growth identified in the 2010 census, an SO_2 monitor was installed at this site in January 2013. To further enhance monitoring capabilities, the Air Pollution Control Division (APCD) added an RM Young meteorological tower in August 2014, which includes a relative humidity (RH) sensor. This addition aids in comprehensive air quality assessment at the site.

Manitou Springs, 101 Banks Place (08 041 0016):

The Manitou Springs ozone monitoring site, situated 4 miles west of Colorado Springs, was established in response to concerns that urban ozone concentrations were extending along the Fountain Creek drainage, and the existing monitoring network was insufficient. Operations at the Manitou Springs site commenced in April 2004. This monitor is strategically placed in the foothills above Colorado Springs, at the rear of the city maintenance facility. To date, it has not detected ozone levels exceeding current environmental standards. The site functions as a population-oriented, neighborhood-scale State and Local Air Monitoring Station (SLAMS), aimed at providing accurate local air quality data.

Colorado College, 130 W. Cache la Poudre Street (08 041 0017):

The Colorado College monitoring site was established in January 2007 following revisions in particulate regulations that mandated a continuous $PM_{2.5}$ monitor in Colorado Springs. The Air Pollution Control Division (APCD) decided to place this new $PM_{2.5}$ monitor alongside existing filter-based monitors from the RBD site at the Colorado College location. This arrangement included an FRM $PM_{2.5}$ monitor, and in November 2007, a low volume FEM PM_{10} monitor was also added. The continuous monitor commenced operations in April 2008.

By summer 2016, the filter-based $PM_{2.5}$ FRM instrument was removed, and the GRIMM EDM 180 was designated as the primary sampler for comparison against the $PM_{2.5}$ NAAQS standards. Additionally, a low volume filter-based PM_{10} sampler, operating on a 1-in-6 day schedule, is currently in use at the site.

The nearest meteorological site is located at the Highway 24 monitoring site. The wind patterns at the Colorado College site are influenced by its proximity to Fountain Creek, resulting in light drainage winds that typically flow north and south along the creek. The three monitoring stations at this location are part of the SLAMS network, focusing on neighborhood-scale population monitoring for PM_{10} and $PM_{2.5}$ levels.

Cañon City - City Hall, 128 Main Street (08 043 0003):

Located 39 miles west of Pueblo, Cañon City began its particulate monitoring on January 2, 1969, with the installation of a Total Suspended Particulate (TSP) monitor on the roof of the courthouse building at 7th Avenue and Macon Street. In October 2004, this monitoring site was relocated to the top of the City Hall building.

The PM_{10} monitoring site in Cañon City commenced operations in December 1987. On May 6, 1988, the Macon Street monitor recorded a PM_{10} concentration of 172 µg/m^3, marking the only occurrence where either the 24-hour or annual National Ambient Air Quality Standards (NAAQS) were exceeded since the initiation of PM_{10} monitoring in the area. The monitor at this site operates on a neighborhood scale under the State and Local Air Monitoring Stations (SLAMS) network, following a 1-in-6-day sampling schedule.

Rifle – Health Dept., 195 14th Ave (08 045 0012):

The Rifle Health monitoring site is situated at the Garfield County Health Department building, approximately one kilometer north of Rifle's downtown area, adjacent to the Garfield County Fairgrounds. Positioned uphill from the downtown, the site is surrounded by a residential area to the north and a commercial district to the east. Established in June 2008, the site serves as a key location for measuring ozone (O_3) levels in Rifle. As the largest population center in the oil and gas-impacted region of the Grand Valley, Rifle's air quality is of particular concern. This site is classified as a State and Local Air Monitoring Station (SLAMS) and operates at a neighborhood scale, providing crucial environmental health data to the community.

Black Hawk, 195 14th Ave (08 047 0003):

The Black Hawk Site was selected as the replacement for the Aspen Park Site, which failed to meet the EPA's siting requirements due to tree obstructions. This decision followed findings from a recent Front Range ozone study which detected higher ozone concentrations at Black Hawk compared to other sites evaluated in the study. Situated at an elevation of 2,633 meters, the Black Hawk monitoring station has been operational since July 2019. This location is now critical for ongoing environmental monitoring and research into regional ozone levels.

Rocky Flats North, 16600 W. Highway 128 (08 059 0006):

The Rocky Flats - North site is situated on the south side of Colorado Highway 128, approximately 1.25 miles west of Indiana Street, north-northeast of the former plant. This site was established in June 1992, featuring an O_3 monitor and meteorological equipment as part of the Air Pollution Control Division's (APCD) initial monitoring efforts around the Rocky Flats Environmental Technology Site.

During the Summer 1993 Ozone Study, this site recorded some of the highest ozone (O_3) levels among all monitoring locations, leading to its permanent inclusion in the APCD's O_3 monitoring network. The Rocky Flats - North monitor often records levels exceeding the current standards, classifying it as a high-concentration urban scale State and Local Air Monitoring Station (SLAMS).

In line with the EPA's 2015 revised ozone monitoring rule (80 CFR 65292), Colorado is mandated to establish and maintain a Photochemical Assessment Monitoring Station (PAMS) at all NCore sites in metropolitan areas with populations over 1,000,000, from June 1 to August 31 annually. The PAMS site at Rocky Flats - North will monitor various atmospheric conditions and pollutants including volatile organic compounds, ozone, nitrogen oxides, and meteorological parameters on an hourly basis. APCD plans to start operations for volatile organic compounds and carbonyl measurements by mid-summer 2023.

NREL Solar Radiation Research Laboratory, 2054 Quaker Street (08 059 0011):

The National Renewable Energy Laboratory (NREL) is situated on the southern edge of South Table Mountain, close to Golden. It was initially included in the Summer 1993 Ozone Study due to its unique location. Observations during this study revealed elevated ozone concentrations, prompting its designation as a permanent monitoring site in 1994. Since then, NREL has consistently recorded some of the highest eight-hour ozone (O_3) levels in the Denver area, often surpassing the existing environmental standards. This ongoing issue highlights the site's critical role in regional air quality monitoring and environmental research.

Evergreen, 5124 S. Hatch Dr. (08 059 0014):

The Evergreen Site was chosen to replace the now-closed Welch Site, which was deemed redundant due to the presence of other ozone monitoring facilities in the Denver Metro/North Front Range Region. Located in a densely populated area in the western foothills south of the I-70 corridor—an area previously unmonitored but suspected to have elevated ozone levels based on special studies—the Evergreen Site expands the scope of ozone monitoring. Situated at an elevation of 2,225 meters, this site has been operational since September 2020. This strategic placement ensures more comprehensive air quality monitoring across the region.

Fort Collins – CSU – Edison, 251 Edison Street (08 069 0009):

Fort Collins, despite being one of the largest cities along the Front Range, does not meet the population criteria required by federal regulations to necessitate a particulate monitor. In the summer of 2016, the Air Pollution Control Division (APCD) removed the filter-based Federal Reference Method (FRM) $PM_{2.5}$ sampler. Subsequently, the GRIMM EDM 180, a continuous particulate monitor, was designated as the primary method for comparisons with the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS).

Currently, the monitoring site is equipped with filter-based, high-volume PM_{10} neighborhood scale State and Local Air Monitoring Stations (SLAMS) that operate on a one-in-three-day schedule. Additionally, there is a continuous GRIMM EDM 180 monitor in place that measures both PM_{10} and $PM_{2.5}$ particulates. This setup ensures ongoing assessment and compliance with environmental standards, despite the initial absence of a federally required monitor due to population thresholds.

Fort Collins - West, 3416 W. La Porte Avenue (08 069 0011):

The Fort Collins-West ozone monitoring station commenced operations in May 2006. It was strategically located based on predictive modeling and to fulfill permit requirements for a significant source within the Fort Collins region. During its inaugural season, the data indicated that this station consistently recorded higher ozone concentrations compared to the monitor at 708 S. Mason Street. The Fort Collins-West station is designed as an urban-scale SLAMS (State and Local Air Monitoring Stations) site, focusing on capturing areas with the highest concentration levels. Moreover, plans are in place to enhance the station by mid-2023 with the addition of a meteorological tower. This new feature will measure wind speed, wind direction, temperature, and relative humidity, providing a more comprehensive understanding of local air quality conditions.

Fort Collins- Mason, 708 S. Mason Street (08 069 1004):

The facility at 708 S. Mason Street, operational since December 1980, is situated one block west of College Avenue in the Central Business District. It has occasionally exceeded air quality standards, notably the one-hour carbon monoxide (CO) standard of 35 ppm, which was surpassed on December 1, 1983, at both 4:00 PM and 5:00 PM with levels of 43.9 ppm and 43.2 ppm, respectively. Additionally, the eight-hour CO standard of 9 ppm was exceeded annually from 1980 to 1989, with the most recent exceedances occurring on January 31 and December 6, 1991, registering 9.8 ppm and 10.0 ppm.

Despite not meeting the population requirements for mandatory CO monitoring under federal regulations, Fort Collins, one of the largest cities along the Front Range, was designated a nonattainment area for CO in the mid-1970s after exceeding the eight-hour standard in 1974 and 1975. In response, the CO monitor was upgraded in May 2016 to a Thermo 48i-TLE trace level instrument, enhancing the State Maintenance Plan (SMP) for CO. The site also includes a population-oriented neighborhood scale SLAMS monitor.

Ozone (O_3) monitoring started at the site in 1980 and continues to the present. Meteorological monitoring commenced on January 1, 1981. The meteorological tower was relocated in March 2012 during the Mason Street Redevelopment Project, moving from a freestanding structure to one mounted on the south side of the shelter.

Grand Junction - Powell, 650 South Avenue (08 077 0017):

Grand Junction, the largest city on Colorado's Western Slope, is situated in the expansive valley of the Colorado River. The monitoring equipment is installed on county-owned buildings located on the city's south side, near the southern edge of the central business district and close to the industrial areas adjacent to the train tracks. This site is approximately a half-mile north of the river and a quarter-mile east of the railroad yard.

In the summer of 2016, the primary filter-based Federal Reference Method (FRM) was replaced, and the GRIMM EDM 180 continuous particulate monitor was designated as the primary instrument for comparison against the $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS). Currently, the GRIMM monitors continuously measure both $PM_{2.5}$ and PM_{10}. Additionally, two low-volume filter-based collocated PM_{10} monitors operate at the site, following a sampling schedule of one day in three and one day in six, respectively.

Grand Junction - Pitkin, 645¼ Pitkin Avenue (08 077 0018):

In 2004, meteorological monitors equipped with sensors for measuring wind speed, wind direction, and temperature were installed. Subsequently, on January 5, 2015, the meteorological tower was upgraded with RM Young meteorological sensors, which included a relative humidity (RH) sensor.

Additionally, this site is integrated into the National Air Toxics Trends Station Network. This network is a significant project managed by the Environmental Protection Agency (EPA) and aims to monitor and assess the levels of urban air toxics across the United States. This initiative helps in understanding and managing air quality issues related to toxic pollutants in urban environments.

Palisade Water Treatment, Rapid Creek Rd (08 077 0020):

The Palisade site is situated at the Palisade Water Treatment Plant, approximately 4 kilometers east-northeast of downtown Palisade, near the entrance of De Beque Canyon. This location is relatively isolated, far from any large population centers. Established to monitor potential peak ozone (O_3) concentrations, the site aims to capture data on how summertime up-flow conditions can lead to increased ozone levels in this topographically unique area. Ozone and meteorological monitoring began in May 2008. The facility serves as a special-purpose, urban-scale monitor designed to study specific environmental conditions and their effects on air quality.

Cortez, 106 W. North St (08 083 0006):

The Cortez monitoring site is situated at the Montezuma County Health Department building in downtown Cortez, Colorado. As the largest population center in Montezuma County, located in the state's southwest corner, Cortez is strategically important for environmental monitoring.

The site was equipped with an ozone (O_3) monitor in response to local concerns about potential high ozone levels resulting from emissions by nearby oil, gas, and power plants, many of which are located in New Mexico. Ozone monitoring began in May 2008. Additionally, particulate matter ($PM_{2.5}$) monitoring started on June 20, 2008. However, $PM_{2.5}$ monitoring was discontinued in July 2015 after fulfilling all sampling requirements and consistently recording low $PM_{2.5}$ concentrations.

The Cortez site operates as an urban scale State and Local Air Monitoring Station (SLAMS), focusing on tracking air quality and assessing compliance with environmental standards. This ongoing monitoring is crucial for ensuring the health and safety of the area's residents and the environment.

Aspen Yellow Brick School, 215 North Garmisch (08 097 0008):

Aspen is located at the upper end of a steep mountain valley and is not served by an interstate highway. Previously classified as nonattainment for PM_{10}, Aspen is now adhering to an attainment/maintenance plan for air quality. The geographical configuration of the valley tightens at the lower end, making it an effective trap for pollutants.

The area experiences significant seasonal population increases due to winter skiing and summer mountain activities, further exacerbated by a substantial number of commuters traveling daily from communities as far as 41 miles northeast, including Glenwood Springs. These factors collectively contribute to heightened traffic and pollution levels.

To monitor air quality, Aspen utilizes advanced equipment including a high-volume filter-based PM_{10} monitor and a continuous PM_{10}/ $PM_{2.5}$ GRIMM EDM 180 monitor. Additionally, a neighborhood scale SLAMS high volume PM_{10} monitor operates on a 1-in-3 sample schedule, helping track and manage particulate matter in the air. This comprehensive monitoring is crucial for maintaining air quality and ensuring public health in the region.

Lamar Municipal Building, 104 Parmenter Street (08 099 0002):

Established in January 1996, the Lamar Municipal site was chosen for its central location, making it more accessible to the population compared to the previously used Power Plant site. The latter was situated on the northern edge of Lamar and remained operational until its decommissioning in 2012. Both sites have experienced exceedances of the 24-hour air quality standard for particulate matter (PM_{10}), which is set at 150 µg/m³. Additionally, it is common for both locations to record 24-hour average concentrations above 100 µg/m³.

The Power Plant site was ultimately shut down due to its failure to meet essential siting criteria. On the other hand, the Lamar Municipal Building now supports neighborhood-scale State and Local Air Monitoring Stations (SLAMS) with high-volume PM10 monitors that operate on a daily sampling schedule. This setup ensures continuous monitoring and assessment of air quality to better protect the health of the local community.

Pueblo Fountain School, 925 N. Glendale Ave (08 101 0015):

Pueblo, the third largest city in the state excluding Metropolitan Denver, is characterized by rolling plains and moderate slopes with elevations ranging between 4,474 and 4,814 feet. It is located approximately 25 miles west of the Rocky Mountain Front Range, with Pikes Peak visible on clear days.

Meteorologically, Pueblo enjoys mild weather, boasting an average of about 300 sunny days per year. Winds typically flow up the valley from the southeast during the day and down the valley from the west at night. The average wind speed varies, ranging from 7 miles per hour in the fall and early winter to 11 miles per hour in the spring.

Previously, the official site was situated on the roof of the Public Works Building at 211 E. D Street, a relatively flat area two blocks northeast of the Arkansas River. In June 2011, operations were relocated to the Magnet School site due to the construction of a new multi-story building that significantly altered the flow dynamics at the original site. Traffic and distance estimates for the surrounding streets are classified as middle scale, in line with federal standards specified in 40 CFR, Part 58, Appendix D.

Steamboat Springs, 136 6th Street (08 107 0003):

Like many ski towns, Steamboat Springs faces environmental challenges such as wintertime inversions, high traffic, wood smoke, and the use of street sand. These issues are compounded by temperature inversions that trap pollutants in the valley, exacerbating air quality concerns.

The first air quality monitoring site in Steamboat Springs was established in June 1985 at 929 Lincoln Avenue. In October 1986, it was relocated to a more central and accessible location at 136 6th Street. This site provides a better representation of the population's exposure to pollutants. It employs high-volume filter-based sampling to monitor PM_{10}, a particulate matter that can adversely affect respiratory health. Operating under a daily sampling schedule, this site serves as a neighborhood-scale State and Local Air Monitoring Station (SLAMS), focusing on assessing air quality and the associated risks to the community.

Telluride, 333 W. Colorado Avenue (08 113 0004):

Telluride is a high-altitude ski town nestled in a narrow box canyon with the San Miguel River flowing through its southern end. The town spans approximately half a mile from north to south. During winter, the unique topography of this mountain valley often leads to temperature inversions that can persist for several days. These inversions have the potential to trap air pollution close to the ground, exacerbating environmental concerns.

The valley, primarily oriented east to west, is particularly susceptible to trapping air pollutants. This is because the prevailing westerly winds, common at this latitude, are hindered by the valley's closed eastern end. In response to these environmental challenges, the area is monitored by a population-oriented neighborhood scale SLAMS (State and Local Air Monitoring Stations) system. This system operates on a sampling schedule of every third day, helping to track and manage air quality in Telluride effectively.

Greeley Hospital, 1516 Hospital Road (08 123 0006):

The Greeley PM10 and $PM_{2.5}$ monitoring station is situated atop a hospital office building at 1516 Hospital Road. In the summer of 2016, filter-based samplers were replaced with the GRIMM EDM 180, a continuous particulate monitor now serving as the primary device for NAAQS comparisons. This station operates at a neighborhood scale under the State and Local Air Monitoring Stations (SLAMS) program. It is positioned near Greeley Central High School to the east and is surrounded by a mix of residential and commercial areas, making it ideal for monitoring population exposure at the neighborhood scale. The site conforms to federal guidelines for neighborhood scale monitoring as per 40 CFR, Part 58, based on its distance and traffic from major streets.

Local winds predominantly come from the northwest, often at speeds below 5 mph, with secondary winds from the north, north-northwest, and east-southeast. The most recent wind data available is from December 1986 to November 1987. Residential growth is expanding to the west and north, with significant industrial development anticipated to the west. Historically, there were feedlots approximately 11 miles east of Greeley, and another closer to the town's east edge that ceased operations in early 1999 after its purchase by the town in 1997.

Platteville, 1004 Main Street (08 123 0008):

Platteville is situated just west of Highway 85 along the Platte River valley, about five miles east of I-25, with an elevation of 4,825 feet. The region is marked by its relatively flat terrain and is located approximately one mile east of the South Platte River. Historically, the National Oceanic and Atmospheric Administration managed a network of meteorological monitors called the Prototype Regional Observational Forecasting System Mesonet in northern Colorado's Front Range from the early to mid-1990s. Data from this period indicate that Platteville is one of the last areas to experience the dispersal of cold air pools formed by temperature inversions during winter, largely due to solar heating.

The unique geographical features of the Platte River Valley, including its upslope and downslope air flows between Denver and Greeley, make Platteville an excellent location for monitoring $PM_{2.5}$ and performing chemical speciation sampling. This latter activity has been ongoing since 2001.

The monitoring station is located at 1004 Main Street, housed within the South Valley Middle School. The setup includes easy roof access for equipment installation and maintenance. The site features three monitors: two are regional scale monitors aimed at population studies—one part of the SLAMS network and the other for additional speciation. The third is a neighborhood-scale supplemental speciation monitor. The $PM_{2.5}$ filter-based FRM SLAMS monitor operates on a 1 in 3-day sample schedule, and the other two monitors operate on a 1 in 6-day schedule. This configuration aligns with the regional transport scale as per federal guidelines outlined in 40 CFR, Part 58, Appendix D.

Greeley, Weld County Tower, 3101 35th Avenue (08 123 0009):

The Weld County Tower O_3 monitor commenced operations in June 2002, following the sale of the building at 811 15th Street, which was set for repurposing. This site, located in a densely populated area, generally registers higher pollution levels compared to its predecessor. It functions as a neighborhood-scale SLAMS (State and Local Air Monitoring Stations) monitor, focusing on the community's air quality.

The carbon monoxide monitoring that was previously conducted at the Greeley West Annex site ceased in June 2015, when the equipment was relocated to the Weld County Tower site. Carbon monoxide monitoring at this new location started in April of 2015 using a Thermo 48C monitor. An upgrade was made on April 28, 2016, when the Thermo 48C was replaced with a Thermo 48iTLE trace level analyzer, enhancing the precision of the measurements.

Additionally, meteorological monitoring was initiated at the Weld County Tower site in February 2012, providing further environmental data to support air quality assessments.

Plattville Atmospheric Obsevatory (PAO), 17065 County Rd 28 (08 123 0013):

On June 12, 2020, the Air Pollution Control Division (APCD) initiated monitoring of ozone, nitrogen dioxide, and meteorological conditions at the NOAA facility near Platteville, Colorado. This activity aligns with the findings from the 2017 Western Air Quality Study Monitoring Network Assessment, which specifically recommended the establishment of nitrogen dioxide monitoring within the Denver-Julesberg Basin—an area previously underserved and unmonitored. The PAO air monitoring site was strategically set up to gather critical data on nitrogen dioxide levels in this region, enhancing our understanding and management of air quality in the basin.