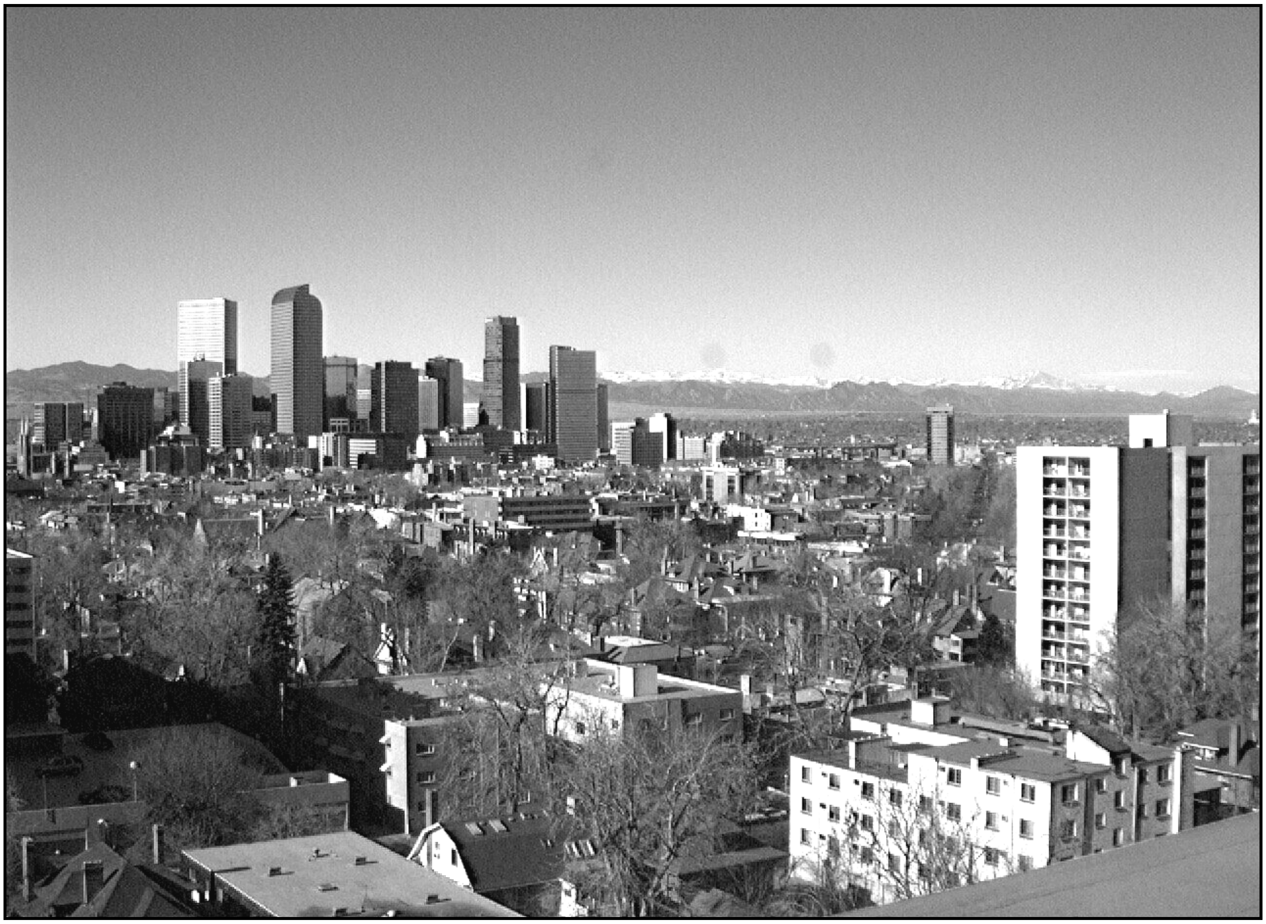
Colorado

2005 Air Quality Data Report



Colorado Department of Public Health and Environment

Air Pollution Control Division

COLORADO AIR QUALITY DATA REPORT

2005

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Air Pollution Control Division
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September 2006

Cover photo

View from the Denver visibility camera on Sunday January 23, 2005 at 11:50 a.m. This is a "Good" visibility day.

The Air Pollution Control Division operates a web-based camera that can be viewed by clicking on the "Live Image" tab on the left side of the screen at the Air Pollution Control Division's web site http://apcd.state.co.us/psi. There is a great deal of other information available from this site in addition to the image at the visibility camera. The Front Range Air Quality Forecast, Air Quality Advisory, Monitoring Reports and Open Burning Forecast are also available.

This report is available electronically at http://apcd.state.co.us/documents/techdocs.html

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1.0 Purpose of the Annual Data Report

The Colorado Department of Public Health and Environment, Air Pollution Control Division (APCD) publishes the Colorado 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 changes in ambient air quality measured by Division monitors. The Report to the Public discusses the policies and programs designed to improve and protect Colorado's air quality.

1.1 Symbols and Abbreviations

The following symbols and abbrevations are used through out this report:

- CO – Carbon monoxide
- SO_2 – Sulfur dioxide
- SOX – Sulfur oxides
- NO_X – Nitrogen oxides
- NO – Nitric oxide
- NO_2 – Nitrogen dioxide
- O_3 – Ozone
- Met – meteorological measurements, wind speed, wind direction, temperature, relative humidity and standard deviation of horizontal wind direction.
- TSP – Total suspended particulates
- PM_{10} – Particulate matter less than 10 microns
- $PM_{2.5}$ – Particulate matter less than 2.5 microns
- Pb – Lead
- ppm – parts per million – this is used with gasseous pollutants.
- $\mu g/m^3$ – micrograms per cubic meter – this is used with particulate pollutants.

1.2 Description of Monitoring Areas in Colorado

The state has been divided into five multicounty areas that are generally based on topography. The areas are: the Eastern Plains; the Northern Front Range; the Southern Front Range; the Mountain Counties and the Western Counties. These divisions are a somewhat arbitrary grouping of monitoring sites with similar characteristics.

The Eastern Plains Counties consist of those east of the I-25 corridor. These counties are generally rolling agricultural plains below 6000 feet.

The Front Range used in this definition is defined by the counties along or associated with the I-25 corridor not by the Continental Divide. A division using the Continental Divide would place Leadville with the same counties as Colorado Springs and Denver. Leadville as the highest city in the U.S. has more in common with Breckenridge and Aspen than Denver or Colorado Springs.

The Mountain Counties are those along both sides of the Continental Divide and the Western Counties are the ones adjacent to the Utah border. Other divisions can and have been made, but these five divisions seemed appropriate for this report. Figure 1 shows the boundries of these areas.

1.2.1 Eastern Plains Counties

The Air Pollution Control Division has only monitored for particulates and meteorology in the Eastern Plains Counties. The Eastern Plains Counties do not have the pollution sources that can generate health impacting concentrations of the other pollutants.

The Division has monitored for particulates in the communities along I-76, I-70 and along US Highway 50. The only monitors still in operation are in Lamar. The other monitors were discontinued after a review of the data showed that levels of particulates were well below the standard and were declining.

1.2.2 Northern Front Range Counties

The Northern Front Range Counties are those along the urbanized I-25 corridor from the Colorado/Wyoming border to just south of the city of Castle Rock. This area has the majority of the population in the state. It also has the majority of the monitors, with the Denver-metro area being the most heavily monitored. The remaining monitors are located in or near Fort Collins, Greeley, Longmont and Boulder.

1.2.3 Southern Front Range Counties

The Southern Front Range Counties are those along the urbanized I-25 corridor from south of the city of Castle Rock to the southern Colorado border. The cities with monitoring in the area include Colorado Springs, Pueblo, Cripple Creek, Cañon City and Alamosa. Colorado Springs is the only city in the area that is monitored for carbon monoxide and ozone; the other cities are only monitored for particulates. In the past the APCD has conducted particulate monitoring in both Walsenburg and Trinidad. The monitoring in those cities was discontinued after a review of the data showed that levels of particulates were below the standard and were declining.

1.2.4 Mountain Counties

The Mountain Counties are those counties along the Continental Divide. The cities are usually located in tight mountain valleys where nighttime temperature inversions trap any pollution near the ground. Their primary monitoring concern is with particulate pollution from wood burning and road sanding. These communities range from Steamboat Springs in the north to Telluride in the southwest and include Silverthorne and Breckenridge in the I-70 corridor; Aspen, Leadville, Crested Butte, Mt. Crested Butte, Vail and Gunnison in the central mountains.

1.2.5 Western Counties

The Western Counties generally contain smaller towns located in fairly broad river valleys. Grand Junction is the only large city in the area and the only location that monitors for carbon monoxide on the western slope. The other Western Slope monitors are located in the cities of Parachute, Delta, Durango and Pagosa Springs. These locations monitor only for particulates.

Table 1 - Statewide Continuous Monitors In Operation For 2005
X - Monitors continued in 2005 A – Monitors added in 2005
D – Monitors discontinued in 2005

County	Site Name	Location	CO	SO_2	NO_X	O_3	Met
Eastern Plains Counties							
Prowers	Lamar - POE	7100 Hwy 50					A
Northern Front Range Counties							
Adams	Commerce City	7101 Birch St.					X
	Welby	78th Ave. & Steele St.	X	X	X	X	X
Arapahoe	Highland Res.	8100 S. University Blvd.				X	X
Boulder	Boulder	2150 28th St.	D				
		1405½ S. Foothills Hwy.				X	
	Longmont	440 Main St.	X				
Denver	Auraria Lot R	12th St. & Auraria Parkway					X
	Denver CAMP	2105 Broadway	X	X	X	A	X
	Denver Carriage	23rd Ave. & Julian St.	X			X	X
	Denver NJH	14th Ave. & Albion St.	X				
	DESCI Building	1901 13th Ave. (Visibility)					
	Firehouse #6	1300 Blake St.	X				
Douglas	Chatfield Res.	11500 N. Roxborough Pk. Rd.				X	X
Jefferson	Arvada	9101 W. 57th Ave.	X			X	X
	NREL	2054 Quaker St.				X	
	Rocky Flats	16600 W. Hwy. 128				X	X
		11501 Indiana St.					D
		9901 Indiana St.					X
		18000 W. Hwy. 72					D
		11190 N. Hwy. 93					D
	Welch	12400 W. Hwy. 285				X	X
Larimer	Fort Collins	708 S. Mason St.	X			X	X
		300 Remington St. (Visibility)					
		4407 S. College Ave.	X				
Weld	Greeley	905 10th Ave.	X				
		3101 35th Ave.				X	
Southern Front Range Counties							
El Paso	Colorado Springs	I-25 & Uintah St.	X				
		USAF Rd. 640				X	
		690 W. Hwy. 24	X				
	Manitou Springs	101 Banks Pl.				X	
Teller	Cripple Creek	Warren Ave. & 2nd St.					X
Mountain Counties							
Routt	Steamboat Springs	137 10th St.					D
Western Counties							
Mesa	Grand Junction	645 ¼ Pitkin Ave.	X				X

Table 2 - Statewide Particulate Monitors In Operation For 2005
X - Monitors continued in 2005 A – Monitors added in 2005
D – Monitors discontinued in 2005 H – Hourly particulate monitor S – Chemical Speciation

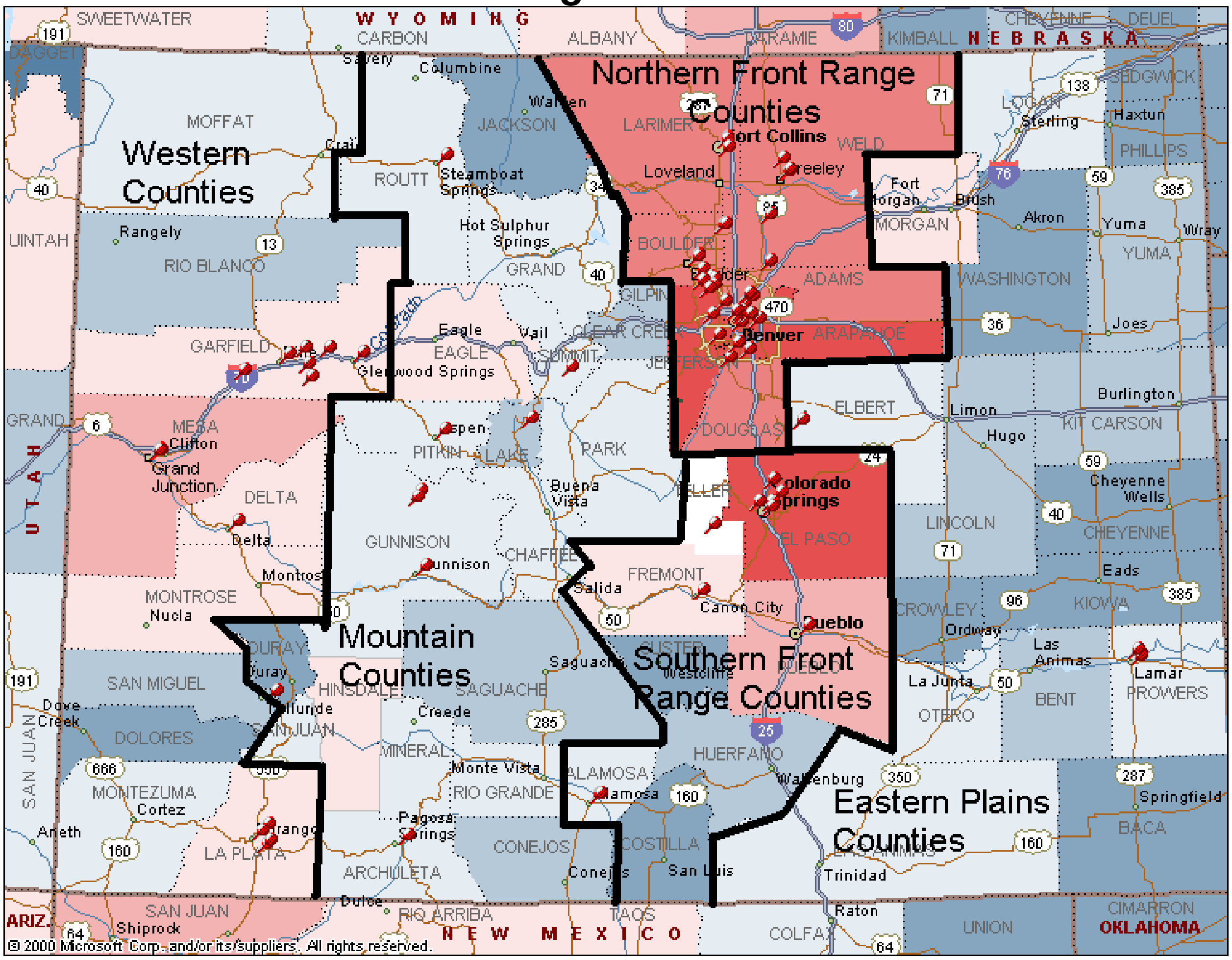
County	Site Name	Location	TSP	Pb	PM_{10}	$PM_{2.5}$
Eastern Plains Counties						
Elbert	Elbert	Wright-Ingraham Inst.				X
Prowers	Lamar	100 2nd St.			X	
		104 Parmenter St.			X	
Northern Front Range Counties						
Adams	Brighton	22 S. 4th Ave.			X	
	Commerce City	7101 Birch St.	X	X	X	X/H/S
	Globeville	5400 Washington St.	X	X		
	Welby	78th Ave. & Steele St.			X/H	
Arapahoe	Arapahoe Comm. College	6190 S. Santa Fe Dr.				X
Boulder	Longmont	350 Kimbark St.			X	X/H
	Boulder	2440 Pearl St.			X	X
		2102 Athens St.				H
Denver	Denver CAMP	2105 Broadway	X	X	X/H	X/H
	Denver Gates	1050 S. Broadway	D	D	D	
	Denver NJH	14th Ave. & Albion St.				H
	Denver Visitor Center	225 W. Colfax Ave.			X	
	Lowry	8100 Lowry Blvd.			X	
	Denver Gates - East	305 E Mississippi Ave.	A/D	A/D	A/D	
	Denver Animal Shelter	678 S. Jason St.	A	A	A/H	
	Swansea Elementary Sch.	4650 Columbine St.				X
Douglas	Chatfield Reservoir	11500 Roxborough Rd				A/H
Larimer	Fort Collins	251 Edison St.			X	X
Weld	Greeley	1516 Hospital Rd.			X	X/H
	Platteville	1004 Main St.				X/S
Southern Front Range Counties						
Alamosa	Alamosa	359 Poncha Ave.			X	
		425 4th St.			X	
El Paso	Colorado Springs	3730 Meadowlands			X	X
		101 W. Costilla St.	X	X	X	X/S
Fremont	Cañon City	128 Main St.			X	
Pueblo	Pueblo	211 D St.			X	X
Teller	Cripple Creek	209 Bennett Ave.			X	
Mountain Counties						
Archuleta	Pagosa Springs	309 Lewis St.			X	X
Gunnison	Crested Butte	Colo.135 & Whiterock			X	
	Mt. Crested Butte	9 Emmons Rd.			D	D
	Gunnison	221 N. Wisconsin St.			X	
	Mt. Crested Butte - New	19 Emmons Rd.			A	A
Lake	Leadville	510 Harrison St.	X	X		
Pitkin	Aspen	120 Mill St.			X/H	
Routt	Steamboat Springs	136 6th St.			X	D
San Miguel	Telluride	333 W Colorado Ave.			X	X
Summit	Breckenridge	501 N. Park Ave.			X	

Table 2 - Statewide Particulate Monitors In Operation For 2005 (continued)
X - Monitors continued in 2005   A – Monitors added in 2005
D – Monitors discontinued in 2005   H – Hourly particulate monitor   S – Chemical Speciation

County	Site Name	Location	TSP	Pb	PM_{10}	$PM_{2.5}$
Western Counties						
Delta	Delta	560 Dodge St.			X	X
Garfield	Parachute	100 E. 2nd St.			X	
	Rifle	144 E. 3rd Ave.			A	
	New Castle	402 W. Main St.			A	
	Silt – Bell Ranch	512 Owens Dr.			A	
	Silt – Daley Ranch	884 County Rd. 327			A	
	Silt – Cox Ranch	5933 County Rd 233			A	
	Glenwood Springs	109 8th St.			A	
La Plata	Durango	1060 2nd Ave.			X	
		56 Davidson Creek Rd.			X	
		1235 Camino del Rio			X	
		1455 S. Camino del Rio			D	
		117 Cutler Dr.			X	
Mesa	Grand Junction	650 South Ave.			X	X/H/S
		645 ¼ Pitkin Ave.			H	

Figure 1

Monitoring Areas in Colorado



The pin symbols on the map show the approximate location of the monitors in Colorado.

2.0 Criteria Pollutants

The criteria pollutants are those for which the federal government has established ambient air quality standards in the Federal Clean Air Act and its amendments. There are six criteria pollutants. They are carbon monoxide, ozone, sulfur dioxide, nitrogen dioxide, lead and particulate matter. The standards for criteria pollutants are established to protect the most sensitive members of society. These are usually defined as those with respiratory problems, the very young and the infirm. The concentrations of each standard for the criteria pollutants are discussed in each section and a summary is presented in Table 3.

Table 3 - National Ambient Air Quality Standards[1]

Pollutant	Averaging Time	Concentration
Carbon Monoxide (CO)		
Primary	1-hour*	35 ppm
Primary	8-hour*	9 ppm
Ozone (O_3)		
Primary	8-hour**	0.08 ppm
Secondary	Same as primary	
Nitrogen Dioxide (NO_2)		
Primary	Annual arithmetic mean	0.053 ppm
Secondary	Same as primary	
Sulfur Dioxide (SO_2)		
Primary	Annual arithmetic mean	0.03 ppm
Primary	24-hour*	0.14 ppm
Secondary	3-hour*	0.5 ppm
Particulate (PM_{10})		
Primary	Annual arithmetic mean****	50 $\mu g/m^3$
Primary	24-hour***	150 $\mu g/m^3$
Particulate ($PM_{2.5}$)		
Primary	Annual arithmetic mean****	15 $\mu g/m^3$
Primary	24-hour*****	65 $\mu g/m^3$
Lead (Pb)		
Primary	Calendar quarter	1.5 $\mu g/m^3$

* This concentration is not to be exceeded more than once per year.
** The 8-hour Ozone standard is set at 0.08 ppm as the 3-year average of the annual 4th maximum 8-hour average concentration.
*** The 24-hour standard is attained when the expected number of exceedances for each calendar year, averaged over three years, is less than or equal to one.
**** The annual arithmetic mean standard is a 3-year average.
***** The 24-hour $PM_{2.5}$ standard is based on the three-year average of the 98th percentile.

2.0.1 Exceedance Summary Table

Table 4 is a summary of the number of exceedances of the ambient air quality standards for Colorado for 2004 and 2005. There were no exceedances of any criteria pollutant at any state operated monitor in 2004. This is only the second time since the APCD began monitoring for criteria pollutants in the early 1970's that no exceedances were recorded at any state operated monitor. The levels of the standards are listed in Table 3.

Table 4 - 2004/2005 Exceedance Summaries

Location	2004*	2005
		PM10
Mt. Crested Butte		X
Breckenridge		X

* There were no exceedances of any National Ambient Air Quality Standard in 2004.

2.1 Carbon monoxide

Carbon monoxide is a colorless and odorless gas, formed when carbon in fuel is not burned completely. It is a component of motor vehicle exhaust, which contributes about 60 percent of all carbon monoxide emissions nationwide. Nonroad vehicles account for the remaining carbon monoxide emissions from transportation sources. High concentrations of carbon monoxide generally occur in areas with heavy traffic congestion. In cities, as much as 85 percent of all carbon monoxide emissions may come from automobile exhaust. Other sources of carbon monoxide emissions include industrial processes, non-transportation fuel combustion, and natural sources such as wildfires. Peak carbon monoxide concentrations typically occur during the colder months of the year when carbon monoxide automotive emissions are greater and nighttime inversion conditions (where air pollutants are trapped near the ground beneath a layer of warm air) are more frequent.[2]

2.1.1 Carbon monoxide – Standards

The U.S. Environmental Protection Agency (EPA) has developed two national standards for carbon monoxide. They are 35 ppm averaged over a 1-hour period and 9 ppm averaged over an 8-hour period. These values are not to be exceeded more than once in a given year at any given location. A location will violate the standard with a second exceedance of either standard in a calendar year. The EPA directive requires that comparison with the carbon monoxide standards will be made in integers. Fractions of 0.5 or greater are rounded up, thus, actual concentrations of 9.5 ppm and 35.5 ppm or greater are necessary to exceed the 8-hour and 1-hour standards, respectively.[3]

2.1.2 Carbon monoxide – Health Effects

Carbon monoxide 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. 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 carbon monoxide than with oxygen. In the presence of carbon monoxide the distribution of oxygen is reduced throughout the body. Blood laden with carbon monoxide can weaken heart contractions with the result of lowering the volume of blood distributed to the body. It can significantly reduce a healthy person's ability to do manual tasks, such as working, jogging and walking. A life-threatening situation can exist for patients with heart disease when these people are unable to compensate for the oxygen loss by increasing the heart rate.[2]

The EPA has concluded that the following groups may be particularly sensitive to carbon monoxide 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.[3]

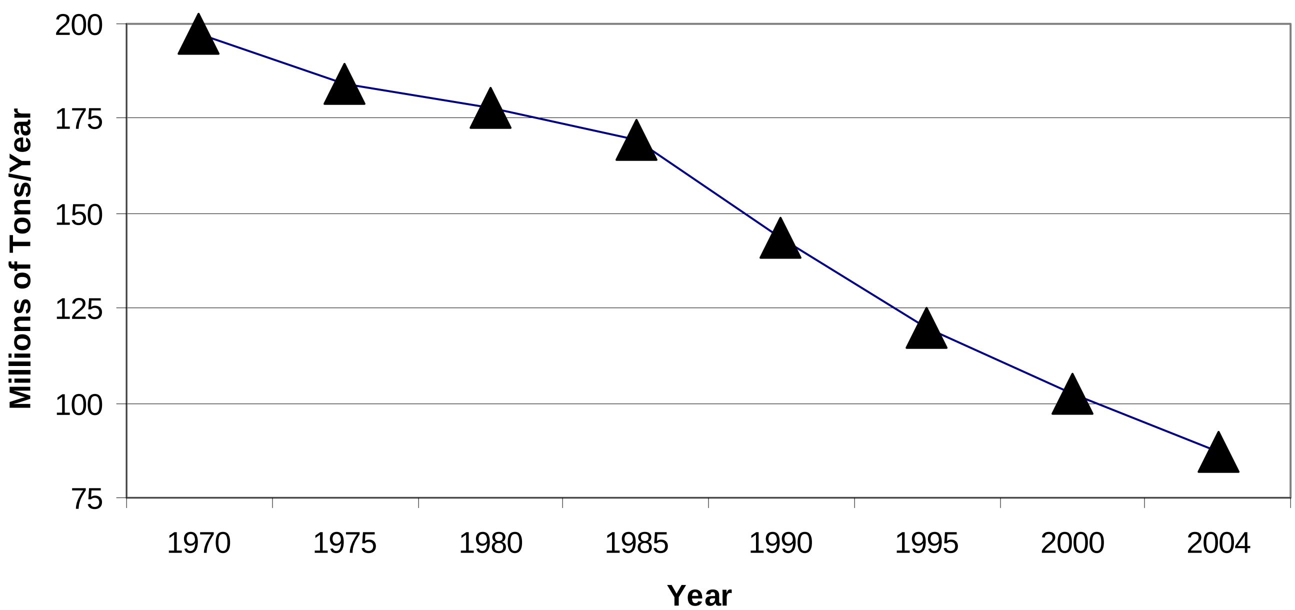
Carbon monoxide is exhausted from the body at varying rates, depending on physiological and external factors. The general guideline is that 20 to 40 percent is lost from the system after 2 to 3 hours following exposure.[3] The severity of health effects depends on both the concentration and the length of exposure because it takes time to remove it from the blood stream.

2.1.3 Carbon monoxide – Sources

In Denver, the APCD estimates that 86 percent of the carbon monoxide emissions are from automotive sources. An estimated 3 percent of Denver's carbon monoxide emissions are from woodburning stoves and fireplaces. The remainder originates from aircraft, locomotives, construction equipment, power plants and space heating.[4] These numbers are similar to the nationwide emissions.[5]

The percentage of carbon monoxide emissions contributed from various sources has not changed appreciably since 1970.[6] What has changed is the amount of carbon monoxide emitted by these sources (Figure 2). In 1970 the total carbon monoxide emissions were approximately 197 million tons in 2004 this had been reduced to 87 million tons.[2]

Figure 2 – Changes in National Carbon Monoxide Emissions from 1970 – 2004[2]



2.2 Ozone

Ozone is a highly reactive form of oxygen. At very high concentrations it is a blue, unstable gas with a characteristic pungent odor often associated with arcing electric motors, lightning storms or other electrical discharges.[7] However, at ambient concentrations, ozone is colorless and odorless. Ozone concentrations at remote locations, such as the Western National Air Pollution Background Network, range from 0.02 to 0.04 ppm year-round.[8]

At ground level, ozone is a pollutant. Although chemically identical, ground level ozone should not be confused with the stratospheric ozone layer. The stratospheric ozone layer is found between 12 and 30 miles above the earth's surface and shields the earth from intense, cancer-causing ultraviolet radiation. Concentrations of ozone in this layer are approximately 10 to 12 ppm or more than 100 times the National Ambient Air Quality Standard for ozone. Occasionally, meteorological conditions result in stratospheric ozone being brought to ground level and this can increase concentrations by 0.05 to 0.10 ppm. This stratospheric intrusion has caused concentrations higher than the 0.12 ppm standard.[8]

2.2.1 Ozone – Standards

In July 1997, the U.S. Environmental Protection Agency established a new ozone standard. The reasons for these changes were:

> *“. . . to provide protections for children and other at-risk populations against a wide range of ozone induced health effects, including decreased lung function (primarily in children active outdoors), increased respiratory symptoms (particularly in highly sensitive individuals), hospital admissions and emergency room visits for respiratory causes (among children and adults with pre-existing respiratory disease such as asthma), inflammation of the lung and possible long-term damage to the lungs.”*[9]

> *“The 1-hour primary standard of 0.12 ppm was replaced by an 8-hour standard at a level of 0.08 ppm with a form based on the 3-year average of the annual 4th-highest daily maximum 8-hour average ozone concentration measured at each monitor within an area.”*[9]

The 8-hour averaging time is more directly associated with health effects of concern at lower ozone concentrations than is the former 1-hour averaging time. Therefore, the 8-hour standard was felt to be more appropriate for a human health-based standard than the 1-hour standard.[9]

2.2.2 Ozone – 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. 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). 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.[10]

The recently completed review of the ozone standard (by the EPA and others) also highlighted concerns with ozone effects on vegetation for which the 1-hour ozone standard did not provide adequate protection. These effects can include reduction in agricultural and commercial forest yields, reduced growth and decreased survivability of tree seedlings, increased tree and plant susceptibility to disease, pests and other environmental stresses and potential long-term effects on forests and ecosystems.[10]

2.2.3 Ozone – Sources

Ozone is not emitted directly from a source, as are other pollutants, but forms as a secondary pollutant. Its precursors are certain reactive hydrocarbons and nitrogen oxides, which react chemically in sunlight to form ozone. The main sources for these reactive hydrocarbons are automobile exhaust, gasoline, oil storage and transfer facilities, industrial paint solvents, degreasing agents, cleaning fluids and ink solvents. High temperature combustion combines nitrogen and oxygen in the air to form oxides of nitrogen. Vegetation can also emit reactive hydrocarbons such as terpenes from pine trees, for example.[10]

Although some ozone is produced all year, the highest concentrations usually occurr in the summer. The stagnant air and intense sunlight on hot, bright summer days provide the conditions for the precursor chemicals to react and form ozone. The ozone produced under these stagnant summer conditions remains as a coherent air mass and can be transported many miles from its point of origin.

2.3 Sulfur dioxide

Sulfur dioxide is a colorless gas with a pungent odor. It is detectable by smell at concentrations of about 0.5 to 0.8 ppm.[11] It is highly soluble in water. In the atmosphere, sulfur oxides and nitric oxides are converted to "acid rain."

2.3.1 Sulfur dioxide – Standards

There are two primary standards for sulfur dioxide. The first is a long-term, one-year arithmetic average not to exceed 0.03 ppm. The second is a short-term, 24-hour average where concentrations are not to exceed 0.14 ppm more than once per year. The secondary standard is a 3-hour average not to exceed 0.5 ppm more than once per year.[11]

2.3.2 Sulfur dioxide – Health Effects

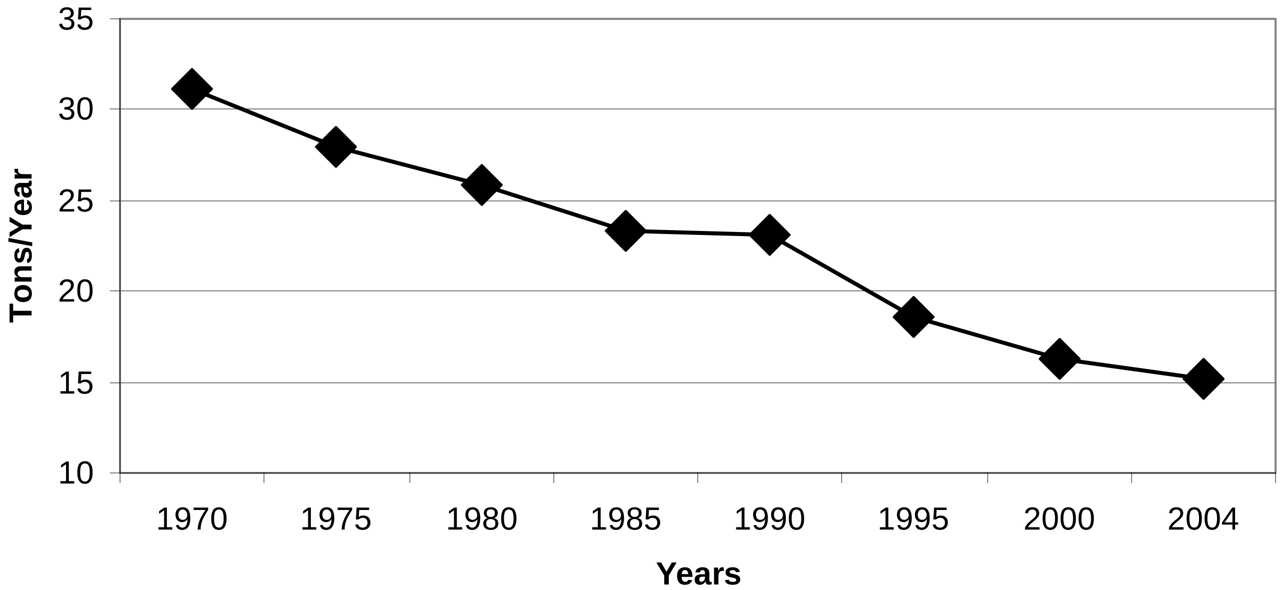
High concentrations of sulfur dioxide can result in temporary breathing impairment for asthmatic children and adults who are active outdoors. Short-term exposures of asthmatic individuals to elevated sulfur dioxide levels during moderate activity may result in breathing difficulties that can be accompanied 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 mater, 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.[12]

Together, sulfur dioxide and oxides of nitrogen are the major precursors to acidic deposition (acid rain), which is associated with the acidification of soils, lakes, and streams and accelerated corrosion of buildings and monuments. Sulfur dioxide also is a major precursor to $PM_{2.5}$, which is a significant health concern, and a main contributor to poor visibility.[12]

2.3.3 Sulfur dioxide – Sources

Sulfur dioxide belongs to the family of gases called sulfur oxides, or SO_X gases. These gases are formed when fuel containing sulfur (mainly coal and oil) is burned at power plants and during metal smelting and other industrial processes. Most sulfur dioxide monitoring stations are located in urban areas. The highest monitored concentrations of sulfur dioxide are recorded near large industrial facilities. Fuel combustion, largely from electricity generation, accounts for most of the total sulfur dioxide emissions.[13]

Figure 3 - Changes in National Sulfur Dioxide Emissions from 1970 – 2004[13]



2.4 Nitrogen dioxide

In its pure state, nitrogen dioxide is a reddish-brown gas with a characteristic pungent odor. It is corrosive and a strong oxidizing agent. As a pollutant in ambient air, however, it is virtually colorless and odorless. Nitrogen dioxide can be an irritant to the eyes and throat. Oxides of nitrogen (nitric oxide and nitrogen dioxide) are formed when the nitrogen and oxygen in the air are combined in high temperature combustion.

2.4.1 Nitrogen dioxide – Standards

The annual standard for nitrogen dioxide is 0.053 ppm expressed as an annual arithmetic mean (average).[14] "Los Angeles is the only U.S. city that has recorded exceedances of the nitrogen dioxide annual standard in the past twelve (now sixteen) years."[15]

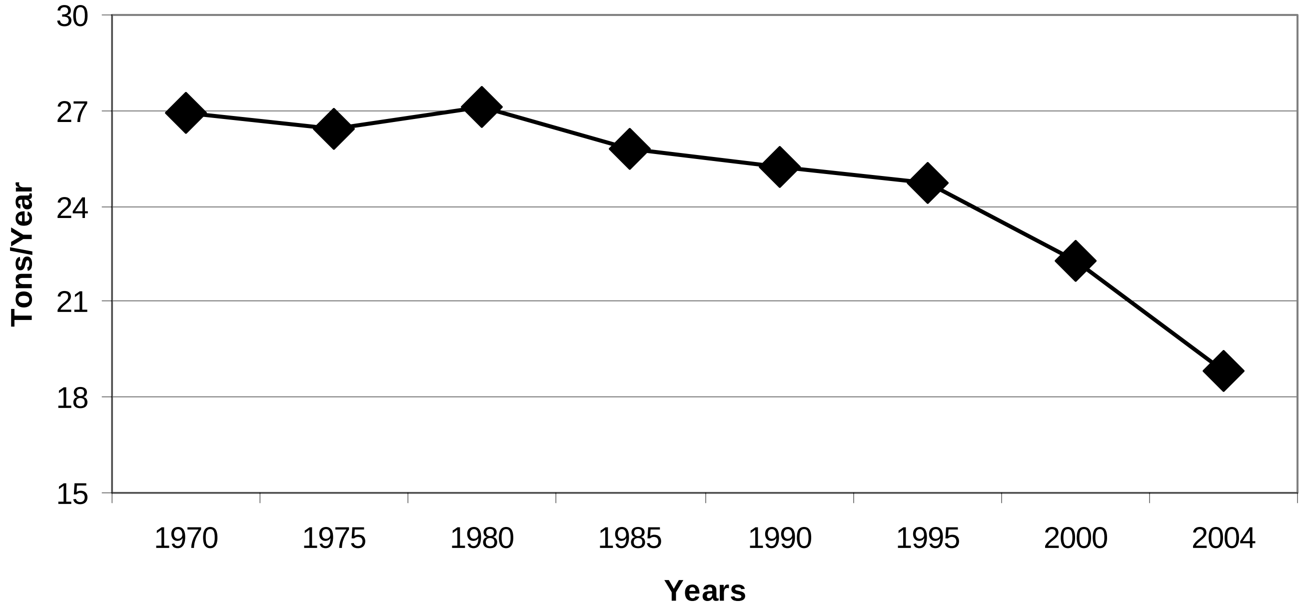
2.4.2 Nitrogen dioxide – Health Effects

Elevated concentrations of nitrogen dioxide cause respiratory distress, degradation of vegetation, clothing and visibility, and increased acid deposition. Nitrate aerosols, which result from nitric oxide and nitrogen dioxide combining with water vapor in the air, have been consistently linked to Denver's visibility problems.

2.4.3 Nitrogen dioxide – Sources

About 44 percent of the emissions of nitrogen dioxide in the Denver area come from large combustion sources such as power plants. Almost 33 percent comes from motor vehicles, 15 percent from space heating, 3 percent from aircraft and 5 percent from miscellaneous off-road vehicles. Minor sources include fireplaces and woodstoves and high temperature combustion processes used in industrial work.[16]

Figure 4 - Changes in National Oxides of Nitrogen Emissions from 1970 – 2004[17]



2.5 Particulate Matter – PM_{10}

Particle pollution is a mixture of microscopic solids and liquid droplets suspended in air. This pollution, also known as particulate matter, is made up of a number of components, including acids (such as nitrates and sulfates), organic chemicals, metals, soil or dust particles, and allergens (such as fragments of pollen or mold spores).

The size of particles is directly linked to their potential for causing health problems. Small particles, less than 10 micrometers in diameter, pose the greatest problems. The smallest particles can get deep into your lungs, and some may even get into your bloodstream. Exposure to such particles can affect both your lungs and your heart. Larger particles are of less concern, although they can irritate your eyes, nose, and throat.

Small particles of concern include "fine particles" (such as those found in smoke and haze), which are 2.5 micrometers in diameter or less; and "coarse particles" (such as those found in wind-blown dust), which have diameters between 2.5 and 10 micrometers.[18]

2.5.1 Particulate Matter – PM_{10} – Standards

In July 1987, EPA promulgated National Ambient Air Quality Standards for particulates with an aerodynamic diameter of 10 microns or less (PM_{10}). This is a size that can be inhaled into the bronchial and alveolar regions of the lungs. The standard has two forms, a 24-hour standard of 150 $\mu g/m^3$ and an annual arithmetic mean standard of 50 $\mu g/m^3$.[19]

1. The 24-hour standard is attained when the expected number of exceedances for each calendar year, averaged over three years, is less than or equal to one. The estimated number of exceedances is computed quarterly using available data and adjusting for missing sample days.
2. The annual arithmetic mean standard is attained when the annual mean, averaged over three years is less than or equal to the level of the standard. Each annual mean is computed from the average of each quarter in the year, with adjustments made for missing sample days.

3. In both cases, a data recovery of 75 percent is needed for each calendar quarter to be considered a valid quarter of data.

The 24-hour standard was modified in by EPA in July 1997, but was subsequently nullified back to this form in May 1999 due to a challenge in the courts.

2.5.2 Particulate Matter – PM_{10} – Health Effects

According to American Lung Association's paper The Perils of Particulates:

"The health risk from an inhaled dose of particulate matter depends on the size and concentration of the particulate. Size determines how deeply the inhaled particulate will penetrate into the respiratory tract where they can persist and cause respiratory damage. Particles less than 10 microns in diameter are easily inhaled deep into the lungs. In this range, larger particles tend to deposit in the tracheobronchial region and smaller ones in the alveolar region. Particulates deposited in the alveolar region can remain in the lungs for long periods because the alveoli have a slow mucociliary clearance system."[20]

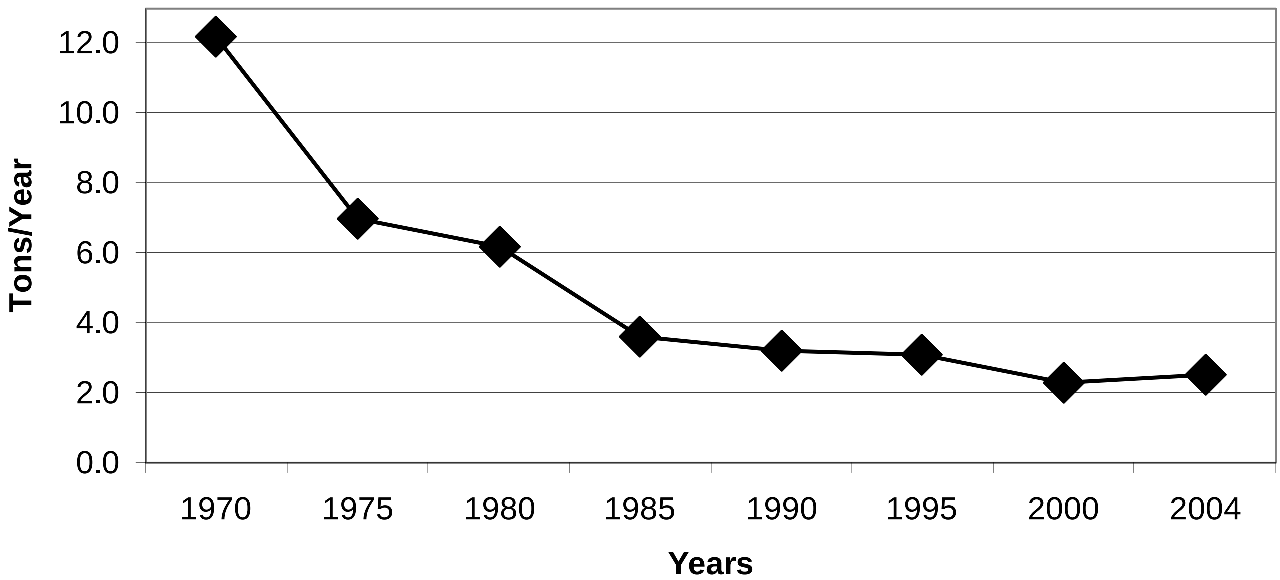
"Fine particulate pollution does not affect the health of exposed persons with equal severity. Certain subgroups of people potentially exposed to air pollutants can be identified as potentially 'at risk' from adverse health effects of air borne pollutants. There is very strong evidence that asthmatics are much more sensitive (i.e., respond with symptoms at relatively low concentrations) to the effects of particulates than the general healthy population. Conversely, little scientific evidence exists that show elderly persons (greater than 65 years old) are particularly sensitive to the effects of particulate matter air pollution"[16]

The welfare effects of particulate exposure may be the most widespread of all the pollutants. Because of the potential for extremely long-range transport of fine particles and chemical reactions that occur, no place on earth has been spared from the particulate pollution generated by urban and rural sources. 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.

2.5.3 Particulate Matter – PM_{10} – Sources

Most anthropogenic (manmade) particulates are in the 0.1 to 10 micron diameter range. Particles larger than 10 microns are usually due to "fugitive dust". Fugitive dust is wind-blown sand and dirt from roadways, fields and construction sites that contain large amounts of silica (sand-like) materials. Anthropogenic particulates are created during the burning of fuels associated with industrial processes or heating. These particulates include fly ash (from power plants), carbon black (from automobiles and diesel engines) and soot (from fireplaces and woodstoves). The PM_{10} particulates from these sources contain a large percentage of elemental and organic carbon. These types of particles play a role in both visual haze and health issues.[21] Figure 5 shows the changes in national particulate emissions from 1970 through 2004.

Figure 5 - Changes in National PM_{10} Emissions from 1970 – 2004[21]



2.6 Particulate Matter – $PM_{2.5}$

According to the Environmental Protection Agency's Latest Findings on National Air Quality: 2000 Status and Trends, Particulate Matter, "$PM_{2.5}$ is composed of a mixture of particles directly emitted into the air and particles formed in the air by the chemical transformation of gaseous pollutants. The principle types of secondary pollutants are ammonium sulfate and ammonium nitrate formed in the air from gaseous emissions of SO_2 and NO_X, reacting with ammonia. The main source of SO_2 is combustion of fossil fuels in boilers and the main source of NO_X are the combustion of fossil fuels in boilers and mobile sources. Some secondary particles are also formed from semi-volatile organic compounds which are emitted from a wide range of combustion sources."

2.6.1 Particulate Matter – $PM_{2.5}$ – Standards

In 1997, the EPA added new fine particle standards, $PM_{2.5}$, to the existing PM_{10} standards. The numbers, 2.5 and 10 refer to the particle size measured in microns. EPA added an annual $PM_{2.5}$ standard set at a concentration of 15 micrograms per cubic meter ($\mu g/m^3$) and a 24-hour $PM_{2.5}$ standard set at 65 $\mu g/m^3$. However, a lawsuit by the American Trucking Association questioned the EPA's authority to create the new standard. A US District court ruling blocked implementation of the $PM_{2.5}$ standard, but the US Supreme court reversed the lower court and unanimously upheld the legality of the EPA and its creation of the $PM_{2.5}$ standard. The Supreme Court decision was issued on February 27, 2001. The annual component of the standard was set to provide protection against typical day-to-day exposures as well as longer-term exposures, while the daily component protects against more extreme short-term events.

Areas will be considered in compliance with the annual $PM_{2.5}$ standard when the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations, from single or multiple community-oriented monitors, is less than or equal to 15 $\mu g/m^3$. The 24-hour $PM_{2.5}$ standard is based on the 98th percentile of 24-hour $PM_{2.5}$ concentrations in a year (averaged over 3 years). The change to a percentile based standard from a second maximum based standard was designed to eliminate the effect of anomalously high concentrations. In addition this change is an attempt to focus more on the true health effects of the pollutant.

2.6.2 Particulate Matter – $PM_{2.5}$ – Health Effects

The health effects of $PM_{2.5}$ are not just a function of their size, 1/20th the size of a human hair, which allows them to be breathed deeply into the alveoli the lungs, but of their composition. These particles can remain in the lungs for a long time and cause a great deal of damage to the lung tissue. They can reduce lung function as well as cause or aggravate respiratory problems. They can increase the long-term risk of lung cancer or lung diseases such as emphysema or pulmonary fibrosis.[22]

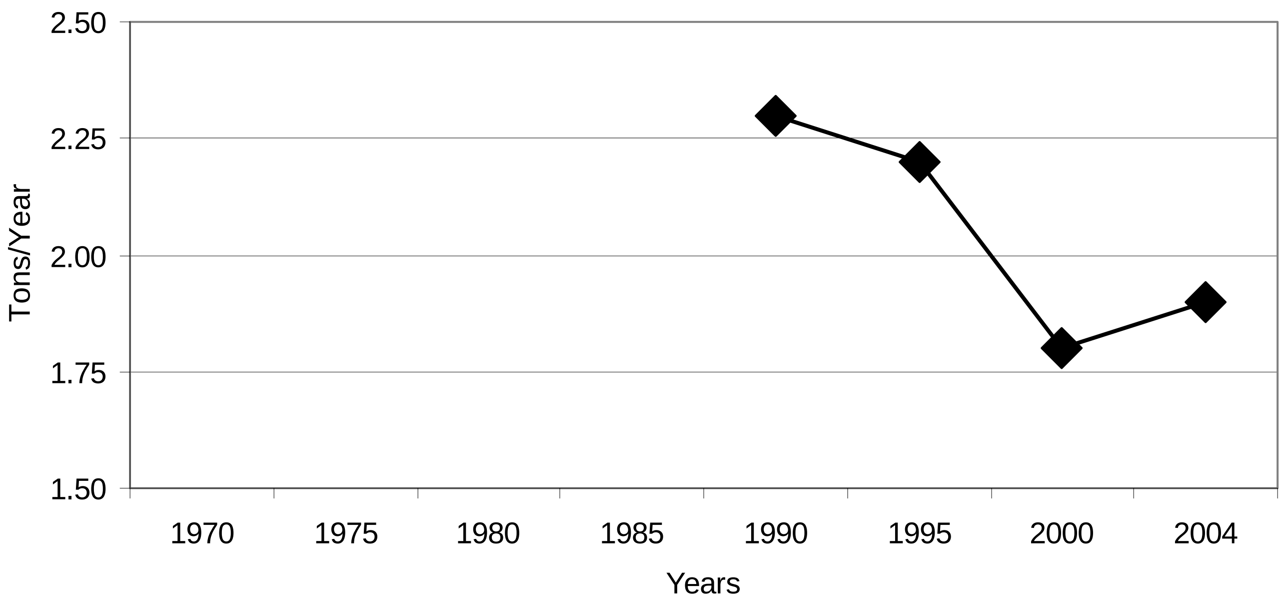
2.6.3 Particulate Matter – $PM_{2.5}$ – Sources

Figure 6 shows the nationwide changes in emissions of $PM_{2.5}$ particulates from 1995 through 2004.

The primary source of fine particles emitted directly into the air come from crustal materials, ground up rock, carbonaceous material. The carbonaceous material is generated by the incomplete combustion of fossil fuels and other organic compounds.[21]

Particles less than 2.5 microns in diameter, or $PM_{2.5}$, are the major contributors to visibility problems because of their ability to scatter or absorb light. In Denver, the effects of this particulate pollution can be seen as the "Brown Cloud" or more appropriately, the "Denver Haze" because it is frequently neither brown nor an actual cloud.

Figure 6 - Changes in National $PM_{2.5}$ Emissions from 1970 – 2004[22]



2.7 Lead

Since the late 1980s the most significant sources for atmospheric lead are battery plants and nonferrous smelters. With the near elimination of lead as an additive in gasoline the contribution from that source has been reduced significantly.

2.7.1 Lead – Standards

The current federal standard for lead is a calendar quarter (3-month) average concentration not to exceed 1.5 micrograms of lead per cubic meter of air ($\mu g/m^3$). This standard was established to maintain blood lead concentrations below 30 micrograms per deciliter (µg/dL) due to exposure to atmospheric lead concentrations.[23] In the future, the focus on lead monitoring will shift to ensure that stationary sources do not create violations of the standard in localized areas. Colorado has at least one such source in the

Denver area that is the subject of monitoring. The Historical Lead Comparison graphs show data back to 1990. The concentrations recorded at most of the monitoring sites are approaching the limits of detection for ambient lead. The last violation of the lead standard in Colorado was the first quarter of 1980.

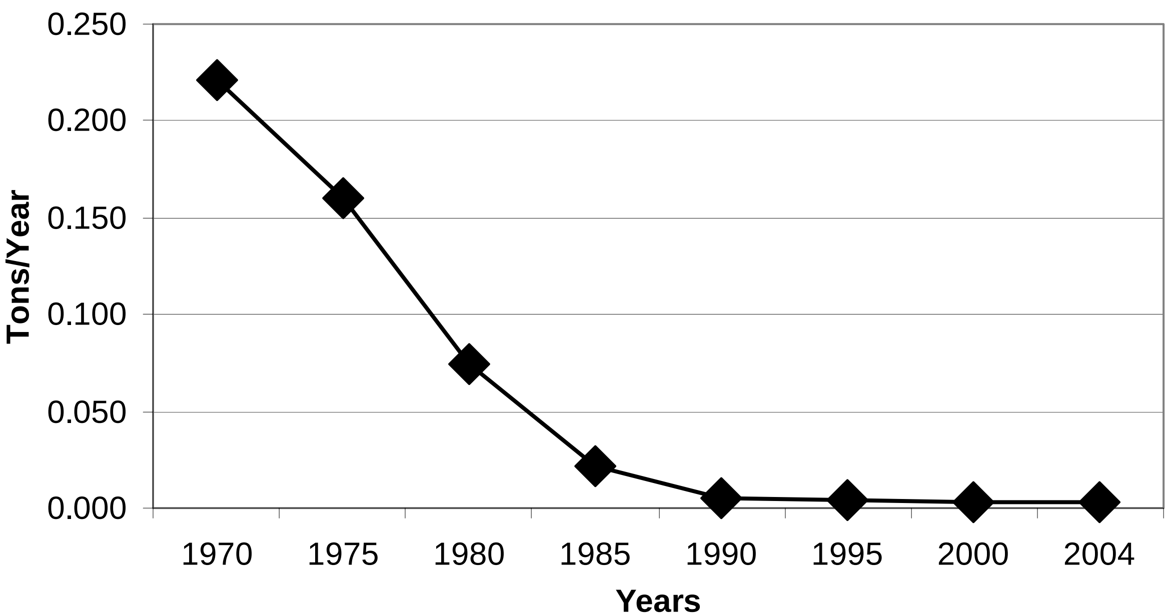
2.7.2 Lead – Health Effects

Exposure to lead occurs mainly through inhalation of air and ingestion of lead in food, water, soil, or dust. It accumulates in the blood, bones, and soft tissues and can adversely affect the kidneys, liver, nervous system, and other organs. Excessive exposure to lead may cause neurological impairments such as seizures, mental retardation, and behavioral disorders. Even at low doses, lead exposure is associated with damage to the nervous systems of fetuses and young children, resulting in learning deficits and lowered IQ. Recent studies also show that lead may be a factor in high blood pressure and subsequent heart disease. Lead can also be deposited on the leaves of plants, presenting a hazard to grazing animals and humans through ingestion.[24]

2.7.3 Lead – Sources

"Because of the phase-out of leaded gasoline, lead emissions and concentrations decreased sharply during the 1980s and early 1990s. Emissions of lead decreased 96 percent over the 24-year period 1980–2004. These large reductions in long-term lead emissions from transportation sources have changed the nature of the ambient lead problem in the United States. Because industrial processes are now responsible for all violations of the lead NAAQS, the lead monitoring strategy currently focuses on emissions from these point sources."[24] Figure 7 shows the decline in lead emissions in the past 34 years.

Figure 7 - Changes in National Lead Emissions from 1970 – 2004[24]



3.0 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, total suspended particulates, nitric oxide and air toxics. Meteorological measurements of wind speed, wind direction, temperature and humidity are also included in this group.

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 human beings experience it.

3.1.1 Visibility – Standards

The Colorado Air Quality Control Commission established a visibility standard in 1990 for the Front Range cities from Fort Collins to Colorado Springs. The standard, an atmospheric extinction of 0.076 per 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 percent of the light in a kilometer of air is blocked. The standard applies from 8 a.m. to 4 p.m. each day, during those hours when the relative humidity is less than 70 percent. 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 woodburning 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[25] 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 manmade air pollution”. The implementation of Section 169a has led to federal requirements to protect visual air quality in large national parks and wilderness areas.[26] Colorado has 12 of these Class I areas. Federal and state law prohibits visibility impairment in national parks and wildernesses due to large stationary sources of air pollution.

3.1.2 Visibility – Health Effects

Visual air quality is an element of public welfare. Specifically, it is an important aesthetic, natural and economic resource of the state of Colorado. The worth of visibility is difficult to measure; yet good visibility is something that people undeniably value. Impaired visibility can affect the enjoyment of a recreational visit to a scenic mountain area. Similarly, people prefer to have clear views from their homes and offices. These concerns are often 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.

There is increasing information that shows a correlation between ambient concentrations of particulate matter and respiratory illnesses. Some researchers believe this link may be strongest with concentrations of fine particles, which also contribute to visibility impairment. In July 1997, the EPA developed a National Ambient Air Quality Standard for particulate matter less than 2.5 microns in diameter ($PM_{2.5}$). See the section 2.6 for more information on $PM_{2.5}$. Any control strategies to lower ambient concentrations of fine particulate matter for health reasons will also improve visibility.

3.1.3 Visibility – Sources

The cause of visibility impairment in Colorado is most often fine particles in the 0.1 to 2.5 micrometer size range (one micrometer is a millionth of a meter). Light passing from a vista to an observer is either scattered away from the sight path or absorbed by the atmospheric fine particulate. 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 woodburning, 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. Woodburning haze is a concern in several mountain communities each winter. Denver's has its"Brown Cloud." Even the national parks, monuments, and wilderness areas shows pollution-related visibility impairment on occasion due to regional haze, the interstate or even regional-scale transport of visibility-degrading pollution.

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 good and improve visibility where it is degraded.

3.1.4 Visibility – Monitoring

There are several ways to measure visibility. Currently, the Division 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 and a transmitter located on the roof of a downtown building. 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 high relative humidity are termed "excluded" (as shown in Figures 21 and 23) and are not counted as violations of the visibility standard. In September 1993, a transmissometer and nephelometer were purchased by the city of Fort Collins to monitor visibility.

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 Class I areas, either individually or jointly through the Inter-agency Monitoring of PROtected Visual Environments (IMPROVE) monitoring program. The goals of the monitoring programs are to establish background visibility levels, identify trends of deterioration or improvement, to 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 monitoring sites in Rocky Mountain National Park, Mesa Verde National Park, Weminuche Wilderness, Mount Zirkel Wilderness, Great Sand Dunes National Monument and Maroon Bells/Snowmass Wilderness. These data are not contained in this report, but are available at this web site address: http://vista.cira.colostate.edu/improve/

3.1.5 Visibility – Denver Camera

The Division operates a 'web' based camera that can be viewed by clicking on the "Live Image" tab on the left side of the screen at the Air Pollution Control Division's web site http://apcd.state.co.us/psi/main.html. There is a great deal of other information available from this site in addition to the image from the visibility camera. The Front Range Air Quality Forecast, Air Quality Advisory, Monitoring Reports and Open Burning Forecast are also available.

The images in Figure 8 show the visibility on one of the the "Best" and "Worst" days in 2005. The "Best " visibility day was March 11, 2005. The "Worst" visibility day was January 16, 2005.

Figure 8 - Best and Worst Visibility Days for 2005

These two pictures are images made by the web camera at the visibility monitor located at 1901 13th Ave. in Denver. These images are centered on the Federal Building at 20th Avenue and Stout Street. The difference in these two pictures is the brightness and detail that can be seen in the image on the left as compared to the image on the right. Look specifically at the edges of the downtown buildings and the area on the horizon at the right edge of the picture.

3.2 Nitric Oxide

Nitric oxide 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, nitric oxide is the precursor, or involved in the reaction, of nitrogen dioxide, nitric acid, nitrates and ozone, all of which have demonstrated adverse health effects.[27] There are no federal or state standards for nitric oxide.

3.3 Total Suspended Particulates

Total suspended particulates (TSP) were first monitored in Colorado in 1960 at 414 14th St. in Denver. This location monitored particulates until 1988. The Adams City and Gates total suspended particulate monitors began operation in 1964 and the Denver CAMP monitor at 2105 Broadway began operating in 1965. Either the Federal EPA or the City of Denver operated these monitors until the mid-1970s when daily operation was taken over by the Colorado Department of Public Health and Environment.

Particulate monitoring expanded to more than 70 locations around the state by the early 1980s. The primary standards for total suspended particulates were 260 $\mu g/m^3$ as a 24-hour sample and 75 $\mu g/m^3$ as an annual geometric mean. On July 1, 1987, with the promulgation of the PM_{10} standards, the old particulate standards were eliminated. The reason that TSP samplers are still in operation is to measure particulate sulfates, lead and other metals such as cadmium, arsenic and zinc. While there are still monitors that exceed the old standards, as can be seen by comparing the current data to the historical maximums, the concentrations have declined dramatically.

3.4 Meteorology

The Air Pollution Control Division takes a limited set of meteorological measurements at eighteen locations around the state. These measurements include wind speed, wind direction, temperature, standard deviation of horizontal wind direction and some monitoring of relative humidity. 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. In addition, the Division does not collect precipitation measurements. The wind speed, wind direction and temperature measurements are collected primarily for air quality forecasting and air quality modeling. The instruments are on ten-meter towers and the data are stored as hourly averages.

The wind roses displayed in this report are placed on a background map that shows the approximate location of the meteorological site. The wind roses 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 broken down in the 16 cardinal directions (i.e. N, NNE, NE, ENE, E, ESE, SE, SSE, S, etc). The wind speed is broken down in six categories. The graphs in this report use 1-3 mph, 4-5 mph, 7-11 mph, 12-14 mph, 15-38 mph and greater than 38 mph. 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 percentage of time the wind is blowing from that direction. A review of the wind rose in Figure 25, for example, shows that in Arvada the majority of the winds come from the west and west-northwest and that these winds are generally in the 1-3 mph and 4-6 mph ranges.

3.5 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 toxic air pollutants 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 (e.g., cars, trucks, construction equipment) and stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., some building materials and cleaning solvents). Some air toxics are also released from natural sources such as volcanic eruptions and forest fires.[28]

People exposed to toxic air pollutants at sufficient concentrations may experience various health effects including cancer and damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory and other health problems. In addition to exposure from breathing air toxics, risks also are 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.

The APCD currently monitors for air toxics in Grand Junction as part of EPA's National Air Toxics Trend Stations. The data from this study will be presented in a separate report.

3.6 $PM_{2.5}$ Chemical Speciation

Particles with an aerodynamic diameter less than 2.5 microns ($PM_{2.5}$), are made up of several elements and chemical compounds, which can cause problems from serious health effects and premature deaths to visibility degradation and regional haze. There are two broad categories of $PM_{2.5}$: primary and secondary particles. Primary $PM_{2.5}$ particles are those emitted directly to the air from crushed geologic materials to carbonaceous particles from incomplete combustion (see section 2.6.3 for more information on $PM_{2.5}$ sources). Secondary $PM_{2.5}$ is formed from gases that combine in the atmosphere through chemical processes and form liquid aerosol droplets. Depending on the problem, if the $PM_{2.5}$ pollution needs to be controlled it is important to know the composition of $PM_{2.5}$ particles so that the appropriate sources can be targeted for control.

Numerous health effects studies have correlated negative health effects to the total mass concentration of $PM_{2.5}$ in ambient air.[18] However, it has not yet been 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 the compliance (mass) monitoring part of the network was established first. Mass concentrations from the compliance network are used to determine attainment of the NAAQS. EPA soon supplemented the $PM_{2.5}$ network with chemical speciation monitoring to provide information on the chemical composition of $PM_{2.5}$. The main purposes are 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 at the states only speciation trend network (STN) site. STN sites were established to determine how the $PM_{2.5}$ concentrations change over the long term. Four other chemical speciation sites were established in 2001 in the following areas: Colorado Springs, Durango, Grand Junction and Platteville. The Durango site was closed in December 2003. Each air filter is analyzed for gravimetric mass, 48 elemental concentrations (sodium through lead), organic (four types) and elemental carbon and five ions (ammonium, sodium, potassium, sulfate and nitrate.) Selected filters are also analyzed for semivolatile organics and microscopic analyses.

4.0 Statewide Summaries For Criteria Pollutants

4.1 Carbon monoxide

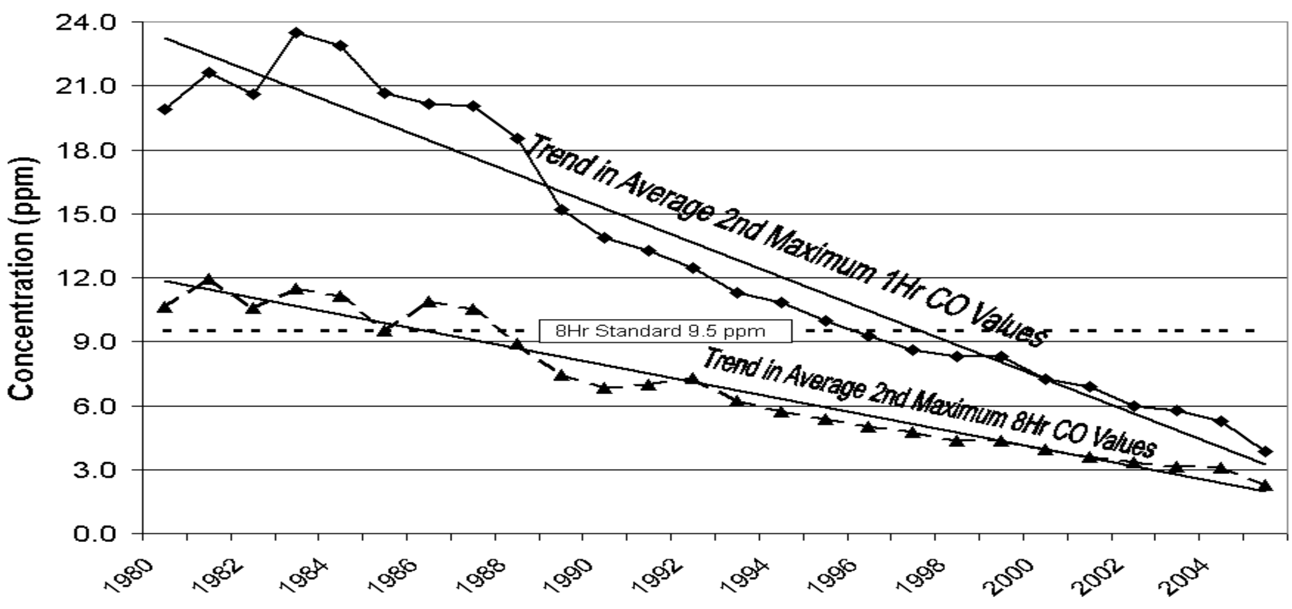
Carbon monoxide concentrations have dropped dramatically from the early 1970s. This change can be seen in both the concentrations measured and the number of monitors in the state that exceeded the level of the 8-hour standard of 9.5 ppm. In 1975, 9 of the 11 state-operated monitors exceeded the 8-hour standard. In 1980, 13 of the 17 state-operated monitors exceeded the 8-hour standard. Since 1996 none of the state-operated monitors have recorded a violation of the 8-hour standard. In 2005 the highest statewide 2nd maximum 8-hour concentration was a 2.8 ppm recorded at the Greeley, 905 10th Ave. monitor.

Figure 9, shows the trend of the statewide average for the second maximum 1-hour and 8-hour concentrations for carbon monoxide for the periods from 1980 to 2005.

Two important points to note are:

1. Throughout the 1980s the average 2nd maximum 8-hour concentration for all state-operated carbon monoxide monitors was greater than the 8-hour standard of 9.5 ppm.
2. In the last 5 years the downward trend in concentrations has continued, but at a slower rate. The statewide average 8-hour concentration is now about one quarter of the standard

Figure 9 - Statewide Ambient Trends – Carbon Monoxide



The trend in the 1-hour average carbon monoxide concentrations statewide has fallen even more drastically than the 8-hour concentrations. The maximum 1-hour concentration ever recorded at any of the state-operated monitors was a 79.0 ppm recorded at the Denver CAMP monitor in 1968. Exceedances of both the 1-hour and 8-hour standard were common in the late 1960s and early 1970s. In 2005, the maximum 1-hour concentration was recorded was 8.1 ppm recorded at the Fort Collins monitor. The 1-hour annual maximum concentrations have declined from more than twice the standard in the late 1960s to less than one quarter of the standard in 2005. Table 5 presents the historical maximum values.

Table 5 - Historical Maximum 1-Hr and 8-Hr Carbon Monoxide Concentrations[29]

1-Hour ppm	Location	Date	Number of Annual Exceedances	8-Hour ppm	Location	Date	Number of Annual Exceedances
79.0	CAMP	11-20-68	13	8.1	CAMP	12-21-73	133
70.0	CAMP	11-21-74	15	33.9	CAMP	12-28-65	197
67.0	CAMP	12-21-73	21	33.4	CAMP	12-04-81	42
65.0	CAMP	12-21-73	21	33.2	CAMP	12-23-71	188
64.9	NJH-W	11-16-79	15	33.1	CAMP	11-20-68	98
2005 Maximum Carbon Monoxide Concentration							
8.1	Ft Collins	01-20-06	0	3.7	Colo Spgs Hwy 24	01-18-06	0

4.2 Ozone

A complete analysis of the trend in ozone values over time is more complex than the simple linear regression used for this report since it must deal with variations in meteorological conditions from year to year. However, Figure 10, Statewide Ambient Trends, shows that the second maximum 1-hour ozone concentrations have declined since 1985. The linear regression trend is not as clear for the 8-hour average ozone concentrations, but over the past 20 years it is essentially flat. According to the Denver Early Action Ozone Compact, February 2004 the high values seen in 2003 were the result of "Anomalously high temperatures and anomalously low mixing hights. . . ".

The Division conducted a detailed analysis of the ozone trends as a part of the Denver Early Action Ozone Compact, February 2004. That report concluded that there had been a decline in the daily 8-hour concentrations of 1.2 percent per year for the period from 1993 through 2003. The full report is available on the web at http://apcd.state.co.us/documents/eac/Denver_EAC-WOEv4.pdf.

Table 6 lists the five highest 1-hour ozone concentrations recorded in Colorado. Ozone monitoring began in 1972 at the Denver CAMP station and eight exceedances of the 1-hour standard were recorded that year. However, data before 1975 are not included because quality assurance and maintenance records are no longer available. In addition, a review of the ozone data before 1975 shows several values that are questionable because of time of day, time of year and inconsistencies with other monitors in the area.

Figure 10 - Statewide Ambient Trends – Ozone

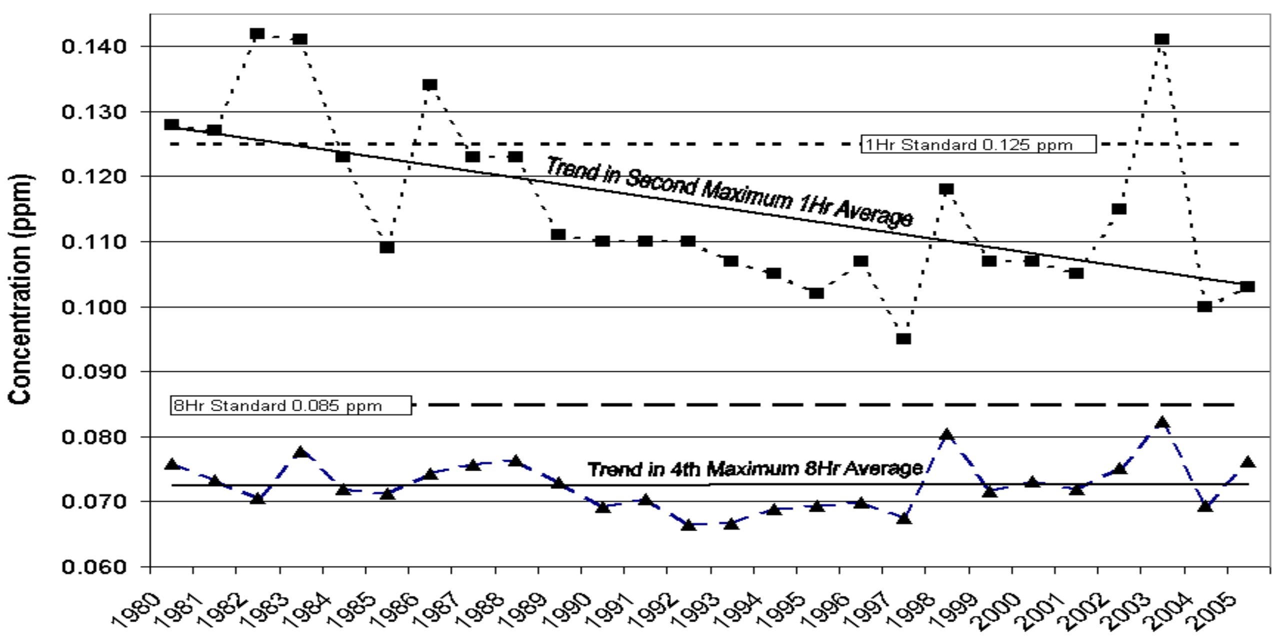


Table 6 - Historical Maximum 1-Hour Ozone Concentrations[30]

1-Hour ppm	Monitor	Date
0.223	Welby	March 3, 1978
0.197	Arvada	July 28, 1975
0.186	Children's Asthmatic Research Institute and Hospital, 21st Ave. & Julian St.	September 17, 1976
0.184	Arvada	June 30, 1976
0.182	Welby	August 5, 1975
2005 Maximum Ozone Concentration		
0.116	Greeley	July 16, 2005

4.3 Sulfur Dioxide

The concentrations of sulfur dioxide in Colorado have never been a major health concern since we do not have the types of industries that burn large amounts of coal. The concern in Colorado with sulfur dioxide has been associated with acid deposition and its effects on the mountain lakes and streams. Historically the maximum annual concentration recorded by APCD monitors was 0.018 ppm in 1979 at the Denver CAMP monitor. The annual standard is 0.030 ppm. Since 1990, the annual average at the Denver CAMP monitor has declined from a high in 1992 of 0.010 ppm to 0.003 ppm in 2004.

Figure 20 shows both the declining trend in sulfur dioxide readings as well as the generally low concentrations of sulfur dioxide recorded at the APCD's monitors. This same trend is evident, although not as pronounced, in the 3-hour and 24-hour averages as well.

Table 7 - Historical Maximum Annual Average Sulfur Dioxide Concentrations[31]

Annual Average ppm	Monitor	Date
0.018	Denver CAMP	1979
0.013	Denver CAMP	1980
0.013	Denver CAMP	1981
0.013	Denver CAMP	1983
0.012	Denver CAMP	1978
2005 Maximum Sulfur Dioxide Concentration		
0.003	Denver CAMP	2005

4.4 Nitrogen Dioxide

Colorado exceeded the nitrogen dioxide standard in 1977 at the Denver CAMP monitor. Concentrations have shown a gradual decline for the past 20 years. However, for the past ten years the annual average has been nearly flat.

Figure 19 shows that levels have declined at the Welby monitor over the past ten years the annual average at the Denver CAMP monitor has shown little to no change at all. The cause of this is most likely due to an increase in the number of vehicles and increased power generation associated with the increases in population in the Denver-metro area.

Table 8 - Historical Maximum Annual Average Nitrogen Dioxide Concentrations[32]

Annual Average ppm	Monitor	Date
0.052	Denver CAMP	1975
0.052	Denver CAMP	1976
0.052	Denver CAMP	1979
0.052	Denver CAMP	1973
0.051	Denver CAMP	1977
2005 Maximum Nitrogen Dioxide Concentration		
0.028	Denver CAMP	2005

4.5 Particulates – PM_{10}

Particulate matter 10 microns and smaller (PM_{10}) data have been collected in Colorado since 1985. The samplers were modified in 1987 to conform to the requirements of the new standard when it was established in July of 1987. Therefore annual trends are only valid back to July 1987.

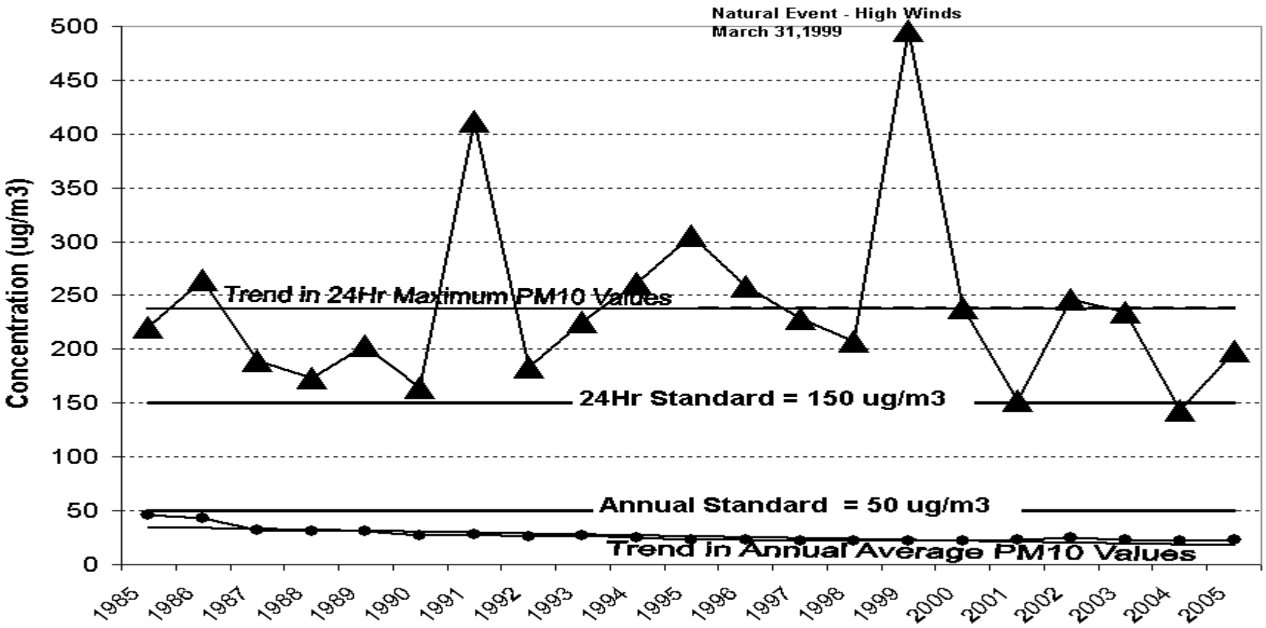
Since 1988, the state has had at least one monitor exceed the level of the 24-hour PM_{10} standard (150 $\mu g/m^3$) every year except 2004. By contrast, no monitor with at least 75 percent data recovery has exceeded the level of the annual standard (50 $\mu g/m^3$). As seen in the following graph the there is a great deal more variation in the 24-hour maximum values than in the annual averages.

The data contained in Figure 11, the Statewide Trends graph, and the data in Table 9, the Historical Maximum values table, include those concentrations that are the result of exceptional events. There have been several of these events documented in Colorado since PM_{10} monitoring began in 1988. In general, in order to qualify for exclusion, a value (or values) has to be associated with a regional natural phenomenon. 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 and Alamosa. These events are not included in NAAQS determinations, not because they are without any health risk but because they are natural and are not controllable or predictable.

Table 9 - Historical Maximum 24-Hour PM_{10} Concentrations[33]

24-Hour Maximum $\mu g/m^3$	Monitor	Date
412	Alamosa	April10, 1991
306	Cripple Creek	December 27, 1995
262	Pagosa Springs	December 29, 1994
236	Aspen	February 22, 1991
235	Cripple Creek	February 11, 1997
2005 Maximum PM_{10} Concentration		
198	Grand Junction	April 19, 2005

Figure 11 - Statewide Ambient Trends –PM_{10}



4.6 Particulates – $PM_{2.5}$

Monitoring for $PM_{2.5}$ in Colorado began with the establishment of sites in Denver, Grand Junction, Steamboat Springs, Colorado Springs, Greeley, Fort Collins, Platteville, Boulder, Longmont and Elbert County in 1999. Additional sites were established nearly every month until full implementation of the base network was achieved in April of 2000. 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 are seven special purpose-monitoring sites. These sites were selected due to historically elevated concentrations of PM_{10} or because citizens or local governments had concerns of possible high $PM_{2.5}$ concentrations in their communities.

Only one site in Colorado has exceeded the level of the 24-hour standard and no sites have exceeded the level of the annual standard. The Denver CAMP site exceeded the 24-hour level of the standard twice in 2001. The exceedances occurred on Thursday, February 15, 2001 (68.4 $\mu g/m^3$) and Saturday, February 17, 2001 (68.0 $\mu g/m^3$).

4.7 Lead

In Colorado the last violation of the federal lead standard occurred in the first quarter of 1980 at the Denver CAMP monitor. Since then, the concentrations recorded at all monitors have shown a steady decline, to the point where now all monitors are regularly at or near the minimum detectable limits of analysis. This decline is the direct result of the use of unleaded gasoline and replacement of older cars with newer ones that do not require leaded gasoline. The reduction in atmospheric lead shows what pollution control strategies can accomplish.

Table 10 - Historical Maximum Quarterly Lead Concentrations[34]

Quarterly Maximum µg/m^3	Monitor	Date
3.47	Denver CAMP, 2105 Broadway	1st Qtr 1979
3.40	Denver, 414 14th St.	4th Qtr 1969
3.03	Denver, 414 14th St.	1st Qtr 1973
3.03	Denver CAMP, 2105 Broadway	4th Qtr 1978
3.02	Denver, 414 14th St.	4th Qtr 1972
2005 Maximum Quarterly Lead Concentration		
0.56	Denver Clinicare	3rd Qtr 2005

5.0 National Comparisons For Criteria Pollutants

5.1 Carbon monoxide

According to the Environmental Protection Agency's emissions trends report: "Between 1993 and 2002, ambient CO concentrations decreased 42 percent. Total CO emissions decreased 21 percent (excluding wildfires and prescribed burning) for the same period. This improvement in air quality occurred despite a 23-percent increase in vehicle miles traveled during the 10-year period."[35]

Table 11 - 2005 National Ranking of Carbon Monoxide Monitors by 8-Hr Concentrations in ppm[36]

Nationwide (426 monitors)					Colorado (14 Monitors)				
National Rank	City/Area	Max	2nd Max	# ≥9.5	Nat'l Rank	City/Area	Max	2nd Max	# ≥9.5
1	Birmingham, AL	9.0	8.0	0	51	Colo Spgs, Hwy 24	3.7	2.7	0
2	Calexico, CA	7.8	6.4	0	87	Ft. Collins	3.2	2.4	0
3	El Paso, TX	6.2	5.4	0	109	Greeley	3.0	2.8	0
4	Lynwood, CA	5.9	4.6	0	113	CAMP	2.9	2.5	0
5	San Juan, PR	5.9	3.3	0	156	Longmont	2.5	2.4	0

5.2 Ozone

Over the past 30 years, EPA, in conjunction with state and local agencies, has instituted various programs to reduce NOx and VOC emissions that contribute to ozone formation. These emission reductions occurred at the same time the nation's economy, energy consumption, and population were growing. For example, between 1970 and 2003, gross domestic product increased approximately 176%; VMT, 155%; energy consumption, 45%; and population, 39%, whereas emissions of NOx and VOCs decreased approximately 25% and 54%, respectively. The ratio of NOx and VOC emissions to population has also dropped since 1970.[34]

This year, both the 1-hour and the 8-hour ozone national rankings have been included. The fourth maximum value is included in the 8-hour table because that is the value that is compared to the standard. The ozone standard is set at 0.08 ppm as the 3-year average of the annual 4th maximum 8-hour average concentration.

Table 12 - 2005 National Ranking of Ozone Monitors by 1-Hr Concentrations in ppm[37]

Nationwide (1,186 Monitors)					Colorado (14 Monitors)				
National Rank	City/Area	Max	2nd Max	Days ≥0.125	National Rank	City/Area	Max	2nd Max	Days ≥0.125
1	Crestline, CA	0.182	0.166	18	236	Greeley	0.116	0.098	0
2	Kansas City, KS	0.177	0.130	2	408	Chatfield Res.	0.108	0.103	0
3	Santa Clarita, CA	0.173	0.171	11	545	Ft. Collins	0.102	0.102	0
4	Seabrook, TX	0.167	0.153	3	601	Boulder	0.100	0.094	0
5	Baytown, TX	0.164	0.156	6	603	Manitou Spgs	0.100	0.089	0

Table 13 - 2005 National Ranking of Ozone Monitors by 8-Hr Concentrations in ppm[38]

Nationwide (1,186 Monitors)					Colorado (13 Monitors)				
National Rank	City/Area	Max	4^{th} Max	Days ≥0.085	National Rank	City/Area	Max	4^{th} Max	Days ≥0.085
1	Crestline, CA	0.145	0.142	69	420	Chatfield Res.	0.091	0.084	2
2	Santa Clarita, CA	0.141	0.141	47	607	Highland Res.	0.086	0.080	1
3	Banning, CA	0.132	0.120	39	608	USAFA	0.086	0.077	1
4	Glendora, CA	0.103	0.117	13	651	NREL	0.085	0.079	1
5	Rubidoux, CA	0.129	0.107	32	658	Greeley	0.084	0.078	0

5.3 Sulfur Dioxide

"Nationally, average SO_2 ambient concentrations have decreased 54 percent from 1983 to 2002 and 39 percent over the more recent 10-year period 1993 to 2002. SO_2 emissions decreased 33 percent from 1983 to 2002 and 31 percent from 1993 to 2002. Reductions in SO_2 concentrations and emissions since 1990 are due, in large part, to controls implemented under EPA's Acid Rain Program beginning in 1995."[39]

Table 14 - 2005 National Ranking of SO_2 Monitors by 24-Hr Concentrations in ppm[40]

Nationwide (531 Monitors)					Colorado (3 Monitors)				
National Rank	City/Area	Max	2^{nd} Max	#>0.14	Nat'l Rank	City/Area	Max	2^{nd} Max	#>0.14
1	Hawaii Nat'l Pk. HI	0.225	0.169	3	347	CAMP	0.011	0.009	0
2	Herculaneum, MO	0.097	0.068	0	396	Welby	0.010	0.008	0
3	Alcoa, TN	0.097	0.089	0					
4	Warren Co, PA	0.094	0.075	0					
5	Steubenville, OH	0.090	0.077	0					

5.4 Nitrogen Dioxide

"Since 1983, monitored levels of NO_2 have decreased 21 percent. These downward trends in national NO_2 levels are reflected in all regions of the country. Nationally, average NO_2 concentrations are well below the NAAQS and are currently at the lowest levels recorded in the past 20 years. All areas of the country that once violated the NAAQS for NO_2 now meet that standard. Over the past 20 years, national emissions of NOx have declined by almost 15 percent. The reduction in emissions for NOx presented here differs from the increase in NOx emissions reported in previous editions of this report. In particular, this report's higher estimate of NOx emissions in the 1980s and early 1990s reflects an improved understanding of emissions from real-world driving. While overall NOx emissions are declining, emissions from some sources such as nonroad engines have actually increased since 1983. These increases are of concern given the significant role NOx emissions play in the formation of ground-level ozone (smog) as well as other environmental problems like acid rain and nitrogen loadings to water bodies described above. In response, EPA has proposed regulations that will significantly control NOx emissions from nonroad diesel engines."[41]

Table 15 - 2005 National Ranking of NO_2 Monitors by 1-Hr Concentrations in ppm[42]

Nationwide (432 Monitors)					Colorado (2 Monitors)				
National Rank	City/Area	1-hr Max	2nd Max	Ann. Avg.	National Rank	City/Area	1-hr Max	2nd Max	Ann. Avg.
1	Albuquerque,NM	0.269	0.088	0.012	14	CAMP	0.114	0.102	0.028
2	Campbell, WY	0.262	0.177	0.007	41	Welby	0.096	0.094	0.021
3	Kingsport, TN	0.183	0.166	0.012					
4	Kenner, LA	0.163	0.062	0.009					
5	Kansas City, MO	0.151	0.128	0.018					

5.5 Particulates

The monitors recording the three highest PM_{10} concentrations are located in Owens Valley, California. These levels are associated with the high winds that blow across the dry bed of Owens Lake. In the past six years monitors in area have recorded levels in excess of 20,000 μg/m³ as a 24-hour average.[43]

Table 16 - 2005 National Ranking of PM_{10} Monitors by 24-Hr Maximum Concentrations in μg/m³ [43]

Nationwide (1,179 Monitors)					Colorado (41 Monitors)				
National Rank	City/Area	1st Max	2nd Max	Annual Mean	National Rank	City/Area	1st Max	2nd Max	Annual Mean
1	Olancha, CA	3,988	3,538	70	32	Grand Junction	198	70	(26)
2	Dirty Sox, CA	3,086	830	50	47	Mt Crested Butte	172	145	40
3	Lee Vining, CA	2,108	1,245	196	50	Breckenridge	170	105	(21)
4	Keeler, CA	1,441	383	31	80	Alamosa – ASC	142	141	20
5	Kennewick, WA	590	268	25	83	Alamosa	141	108	24

"$PM_{2.5}$ concentrations can reach unhealthy levels even in areas that meet the annual standard. In 2003, there were 277 counties with at least one unhealthy day based on $PM_{2.5}$ AQI values. Nearly two-thirds of those counties had annual averages below the level of the standard. Most metropolitan areas had fewer unhealthy $PM_{2.5}$ days in 2003 compared to the average from the previous 3 years, which reflects the improvements observed in 2003."[44]

Table 17 - 2005 National Ranking of $PM_{2.5}$ Monitors by 24-Hr Maximum Concentrations in μg/m³ [44]

Nationwide (1,217 Monitors)					Colorado (22 Monitors)				
National Rank	City/Area	1st Max	2nd Max	Annual Mean	National Rank	City/Area	1st Max	2nd Max	Annual Mean
1	Azusa, CA	133	61	17.0	623	Swansea School	40.0	37.4	10.1
2	San Bernardino, CA	106	45	17.3	718	Denver - CAMP	37.2	36.2	9.3
3	Liberty, PA	100	85	21.4	788	Arapahoe C.C.	36.3	23.2	8.2
4	Rubidoux, CA	99	85	21.0	1040	Boulder	19.5	18.4	7.0
5	Fontana, CA	97	48	18.8	1054	Greeley	24.7	22.7	7.7

5.6 Lead

The statistic used to track ambient lead air quality is the maximum quarterly mean concentration for each year. From 1981 to1990, a total of 228 ambient lead monitors nationwide met the trends completeness criteria; a total of 130 ambient lead monitors met the trends data completeness criteria for the 10-year period 1991 to 2000. Point source-oriented monitoring data were omitted from all ambient trends analyses presented in this section to avoid masking the underlying urban trends.

"Because of the phaseout of leaded gasoline, lead emissions and concentrations decreased sharply during the 1980s and early 1990s. The 2002 average air quality concentration for lead is 94 percent lower than in 1983. Emissions of lead decreased 93 percent over the 21-year period 1982 to 2002. These large reductions in long-term lead emissions from transportation sources have changed the nature of the ambient lead problem in the United States. Because industrial processes are now responsible for all violations of the lead NAAQS, the lead monitoring strategy currently focuses on emissions from these point sources. Today, the only violations of the lead NAAQS occur near large industrial sources such as lead smelters and battery manufacturers. Various enforcement and regulatory actions are being actively pursued by EPA and the states for cleaning up these sources."[45]

Table 18 - 2005 National Ranking of Lead Monitors by 24-Hr Maximum Concentration in $\mu g/m^3$ [46]

Nationwide (226 Monitors)					Colorado (6 Monitors)				
National Rank	City/Area	24-hr Max	Max Qtr	Qtrs >1.5	National Rank	City/Area	24-hr Max	Max Qtr	Qtrs >1.5
1	Herculaneum, MO	35.83	1.88	3	5	Clinicare	5.2	0.56	0
2	Meraux, LA	20.85	0.82	0	39	Denver - Gates	0.66	0.28	0
3	Muncie, IN	5.65	1.34	0	43	Denver - CAMP	0.54	0.18	0
4	Tampa, FL	5.60	1.12	0	44	Commerce City	0.46	0.10	0
5	Clinicare, Co	5.16	0.56	0	52	Colo Spgs	0.31	0.09	0

6.0 Monitoring Results by Area in Colorado

6.1 Eastern Plains Counties

The Eastern Plains Counties are those east of the urbanized I-25 corridor. Historically there have been a number of communities that were monitored for particulates. 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. In the southeast, the US-50/Arkansas River corridor, only Lamar is currently monitored for particulates. The communities of La Junta and Rocky Ford have been monitored in the past, but like the other communities that have been monitored on the Eastern Plains, the monitoring was discontinued when the concentrations were shown to be below the standard.

Table 19 - Eastern Plains Monitors In Operation For 2005

X - Monitors continued in 2005 A – Monitors added in 2005

D – Monitors discontinued in 2005 H – Hourly particulate monitor

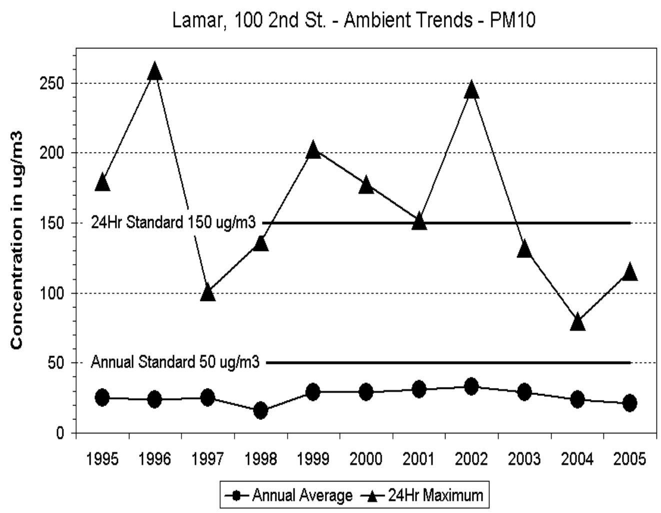
Site Name	Location	PM_{10}	$PM_{2.5}$	Met
Elbert				
Elbert	Wright-Ingraham Inst		X	
Prowers				
Lamar	100 2nd St.	X		
	104 Parmenter St.	X		
Lamar Port of Entry	7200 US Hwy 50			A

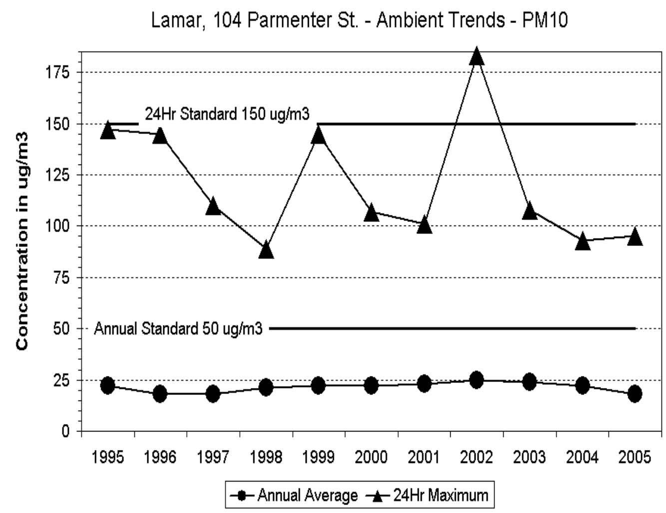
Table 20 - Eastern Plains Particulate Values For 2005

Location	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	Annual Average	24-hour Maximum	Annual Average	24-hour Maximum
Elbert				
Wright-Ingraham Inst			4.7	14.4
Prowers				
100 2nd St.	21.2	116		
104 Parmenter St.	18.3	108		

() indicates <75 percent data recovery in one or more quarters.

Figure 12 - Eastern Plains Particulate Graphs





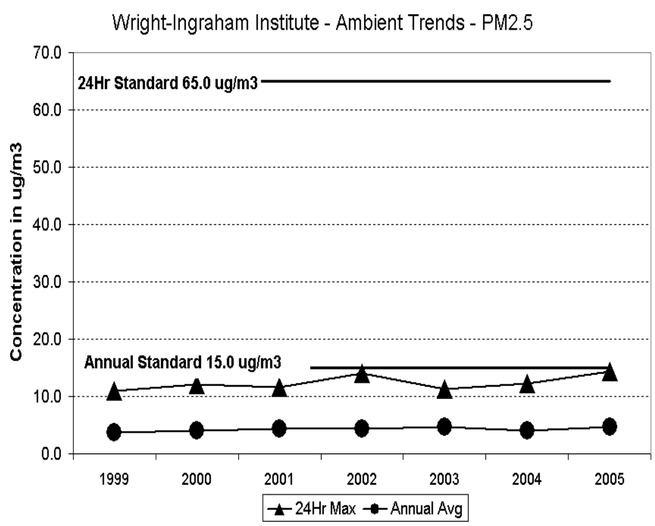
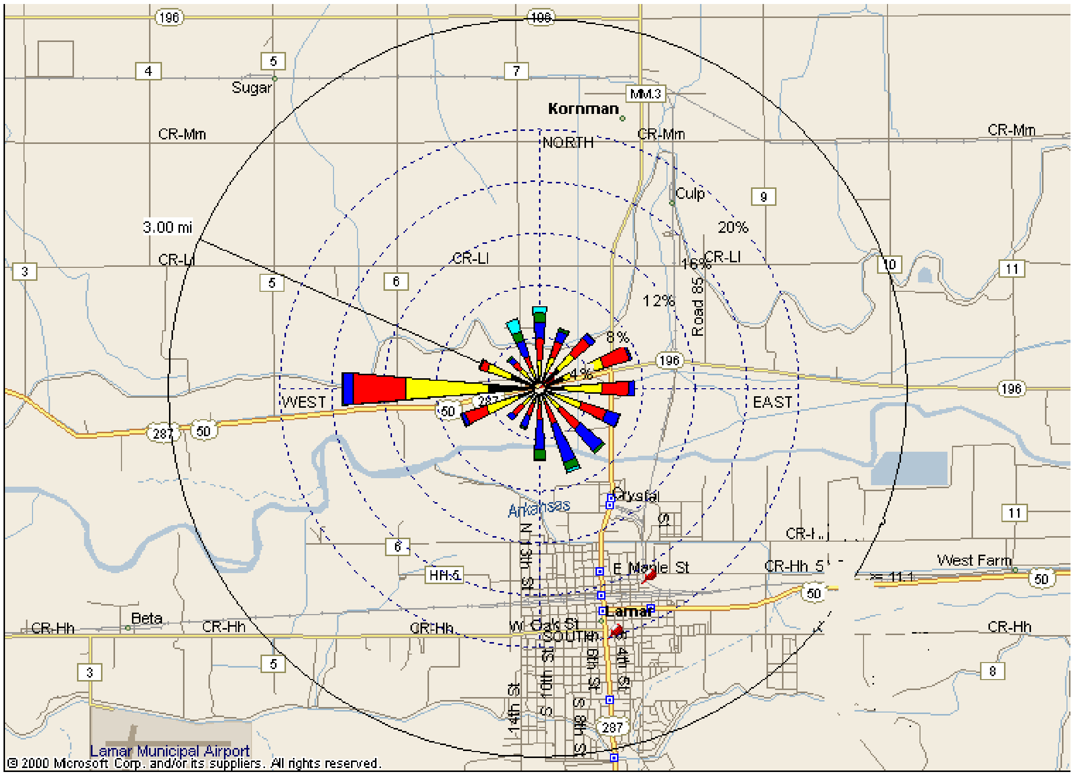


Figure 13 - Eastern Plains Wind Rose Graph
Lamar Port of Entry, 7100 US Hwy 50



6.2 Northern Front Range Counties

The Northern Front Range Counties are those along the urbanized I-25 corridor from the Colorado/Wyoming border to just south of the city of Castle Rock. This area has the majority of the larger cities in the state. The majority of monitors are located in the Denver-metro area and the rest are located in or near Fort Collins, Greeley, Longmont and Boulder.

Table 21 - Northern Front Range Particulate Monitors In Operation For 2005

X - Monitors continued in 2005 A – Monitors added in 2005

D – Monitors discontinued in 2005 H – Hourly particulate monitor S – Chemical Speciation

Site Name	Location	TSP	Pb	PM_{10}	$PM_{2.5}$
Adams					
Brighton	22 S. 4th Ave.			X	
Commerce City	7101 Birch St.	X	X	X	X/H/S
Globeville	5400 Washington St.	X	X		
Welby	78th Ave. & Steele St.			X/H	
Arapahoe					
Arapahoe Community Coll.	6190 S. Santa Fe Dr.				X
Boulder					
Boulder	2440 Pearl St.			X	X
	2102 Athens St.				H
Longmont	350 Kimbark St.			X	X/H
Denver					
Denver CAMP	2105 Broadway	X	X	X/H	X/H
Denver Gates	1050 S. Broadway	D	D	D	
Denver - NJH	14th Ave. & Albion St.				H
Denver Visitor Center	225 W. Colfax Ave.			X	
Lowry	8100 Lowry Blvd.			X	
Swansea Elementary School	4650 Columbine St.				X
Denver Gates - East	305 E. Mississippi Ave.	A/D	A/D		
Denver Animal Shelter	678 S. Jason St.	A	A	A/H	
Douglas					
Chatfield Reservoir	11500 Roxborough Pk. Rd.				A/H
Larimer					
Fort Collins	251 Edison St.			X	X
Weld					
Greeley	1516 Hospital Rd.			X	X/H
Platteville	1004 Main St.				X/S

Table 22 - Northern Front Range Particulate Values For 2005

Site Name	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
	Annual Average	24-hour Maximum	Annual Average	24-hour Maximum
Adams				
Brighton	26.1	52		
Commerce City	38.9	105	9.79	28.0
(Continuous Monitor)			8.32	33.2
Welby	32.3	70		
(Continuous Monitor)	29.0	74		
Arapahoe				
Arapahoe Community Coll.			8.18	36.3
Boulder				
Boulder, 2440 Pearl St.	(19.6)	38	6.97	26.6
Boulder, 2102 Athens St.			(6.06)	31.1
(Continuous Monitor)				
Longmont	(21.1)	42	7.94	20.3
Denver				
Denver CAMP	28.3	57	9.34	37.2
(Continuous Monitor)	24.7	71	10.47	46.2
Denver Gates	(39.3)	57		
Denver – NJH			(8.87)	30.0
(Continuous Monitor)				
Denver Visitor Center	26.9	69		
Lowry	19.4	63		
Swansea Elementary School			10.14	40.0
Denver Gates - East	(41.2)	75		
Denver Animal Center	(28.8)	48		
(Continuous Monitor)	(30.2)	65		
Douglas				
Chatfield Reservoir			(5.57)	17.4
(Continuous Monitor)			(9.28)	31.2
Larimer				
Fort Collins	19.7	50	6.96	21.7
Weld				
Greeley	21.7	52	7.68	24.7
(Continuous Monitor)			5.38	19.2
Platteville			8.18	21.9

() Indicates less than 75% data for one or more quarters.

Figure 14 - Northern Front Range PM_{10} Particulate Graphs

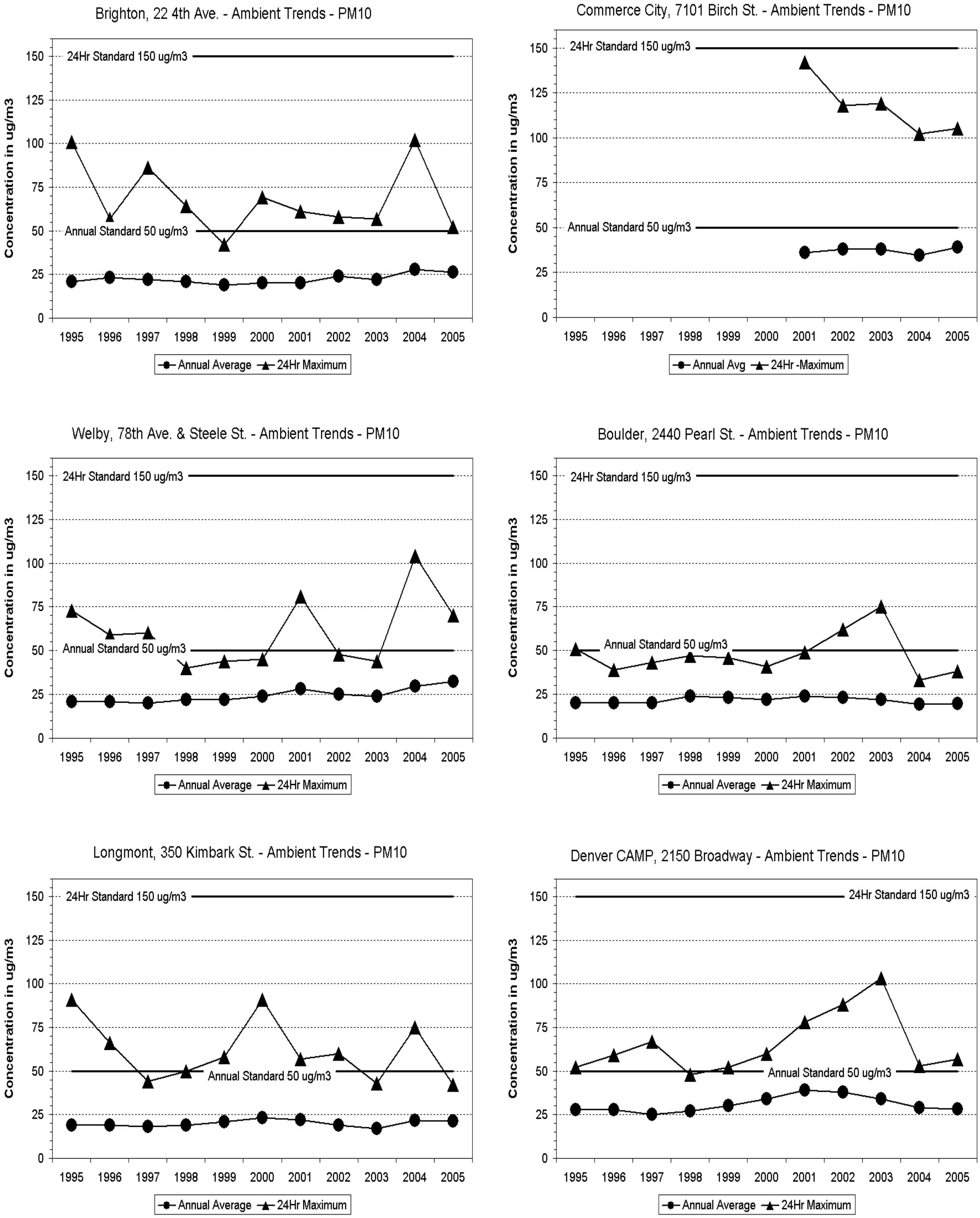
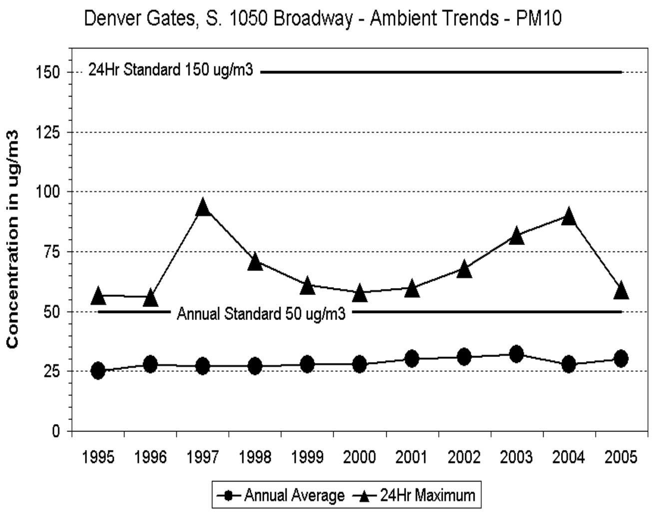
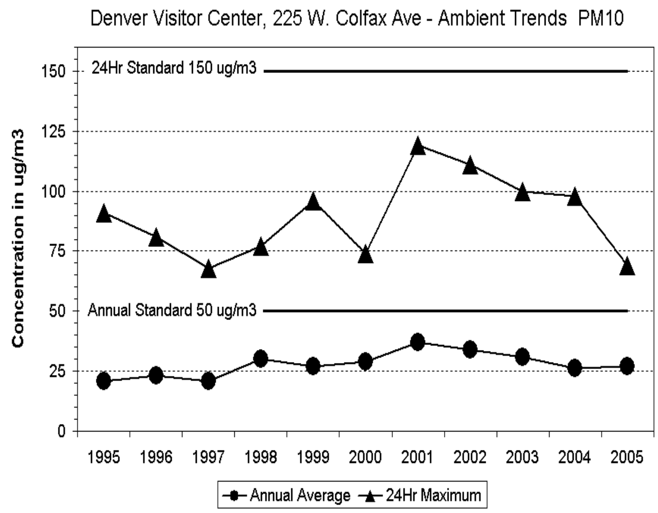
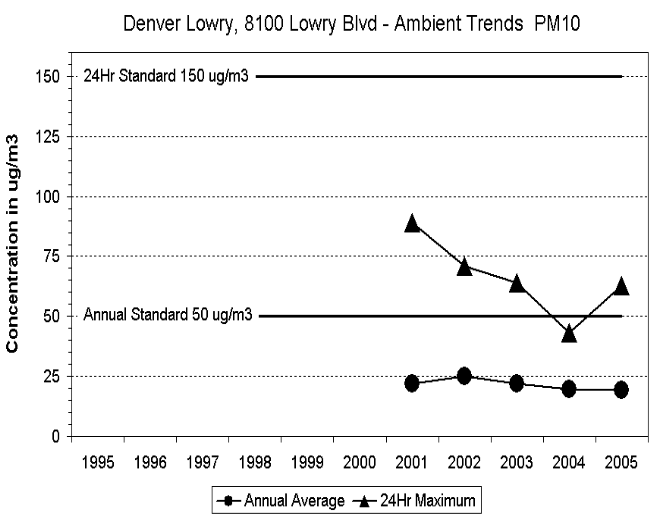
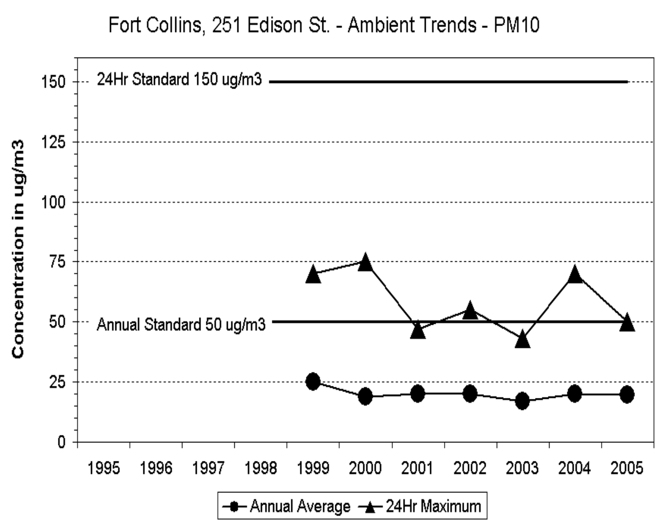


Figure 14 - Northern Front Range PM_{10} Particulate Graphs (continued)









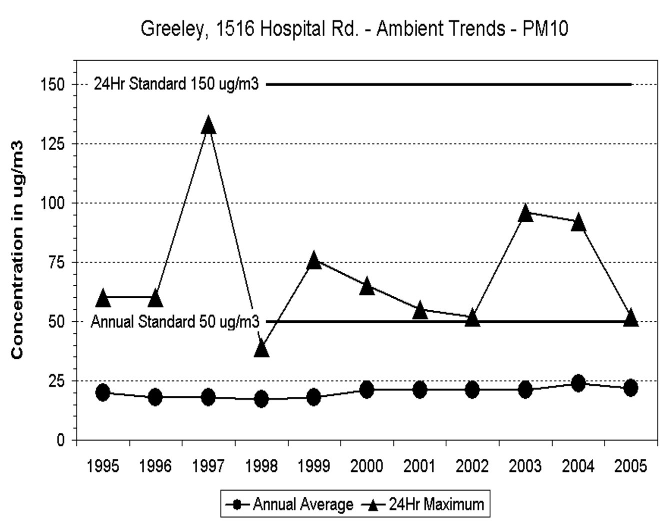


Figure 15 - Northern Front Range $PM_{2.5}$ Particulate Graphs

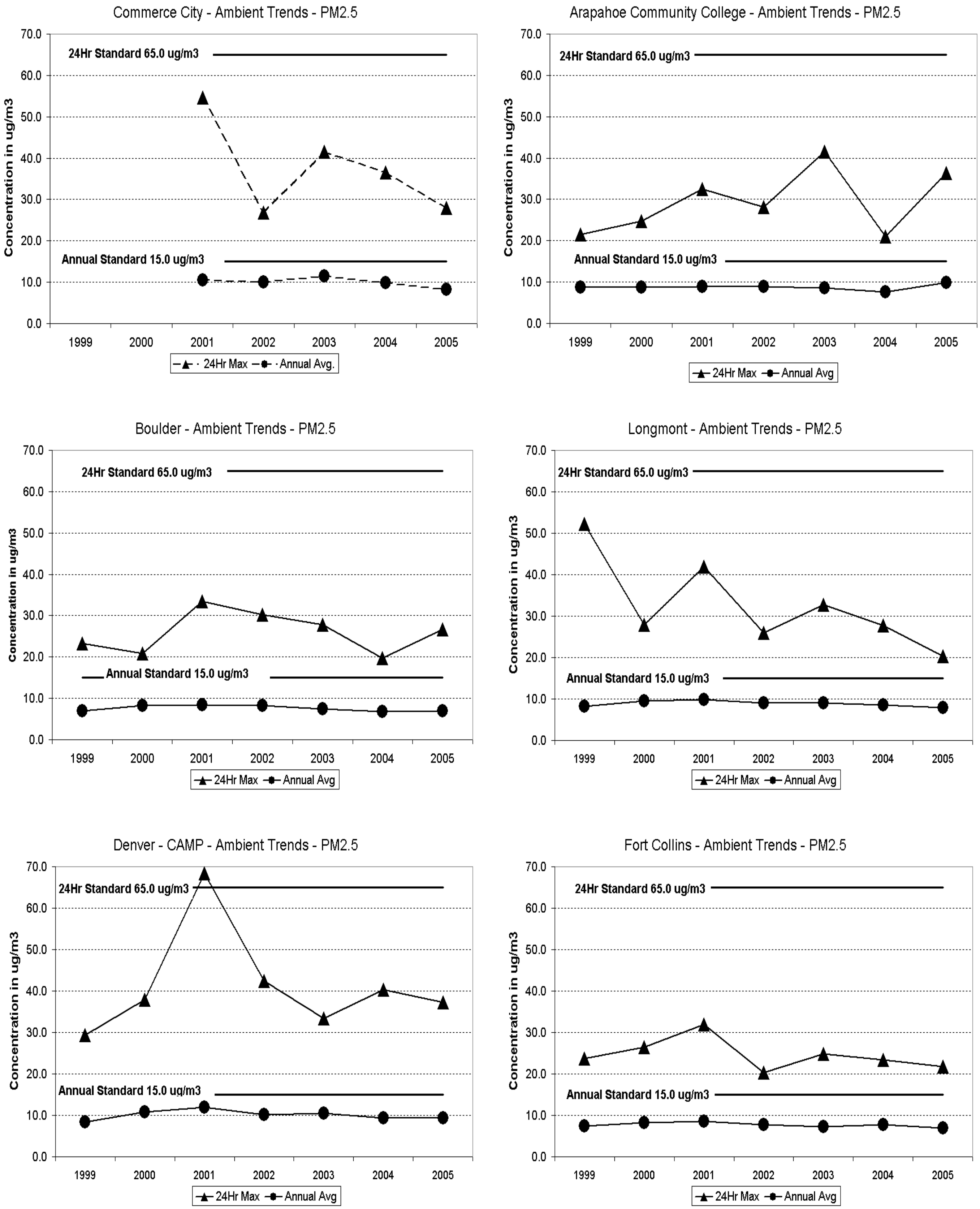


Figure 15 - Northern Front Range $PM_{2.5}$ Particulate Graphs (continued)

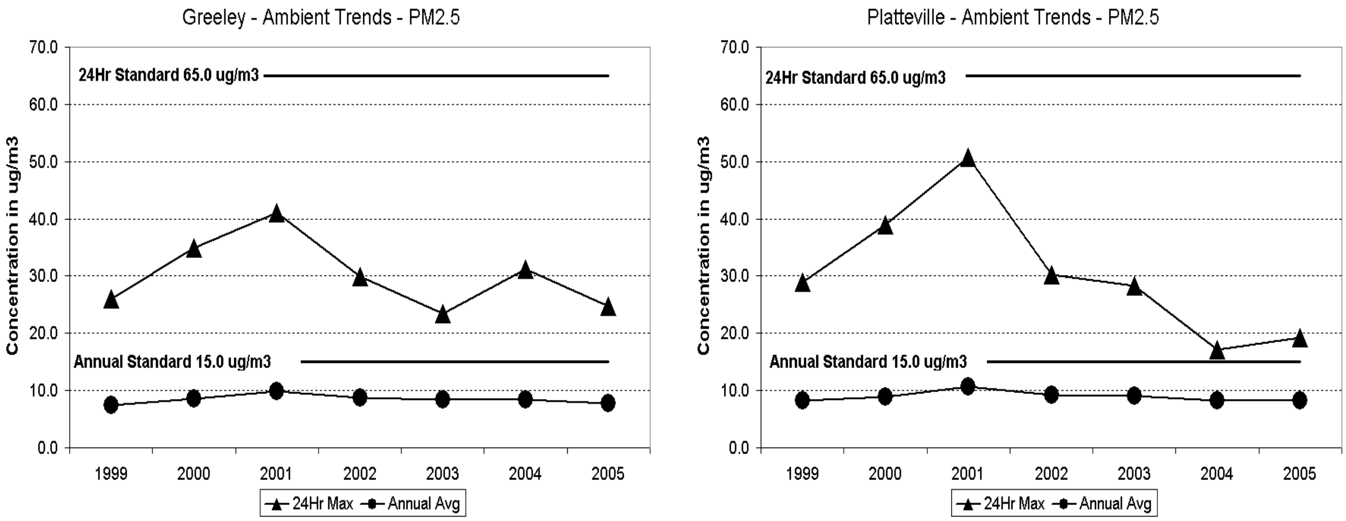


Table 23 - Northern Front Range TSP and Lead Values For 2005

Site Name	Location	TSP (µg/m³)		Lead (µg/m³)	
		Annual Mean	24-hour Maximum	Maximum Quarter	24-hour Maximum
Adams					
Adams	Commerce City	93.5	241	0.10	0.46
	Globeville	91.8	178	0.56	5.16
Denver					
Denver	Denver CAMP	74.9	148	0.18	0.54
	Denver Gates	(88.8)	111	0.08	0.10
	Denver Gates -New	(66.4)	112	0.01	0.01
	Denver Animal	(65.1)	155	0.01	0.03

() indicates less than 75% data for one or more quarters.

Figure 16 - Northern Front Range Lead Graphs

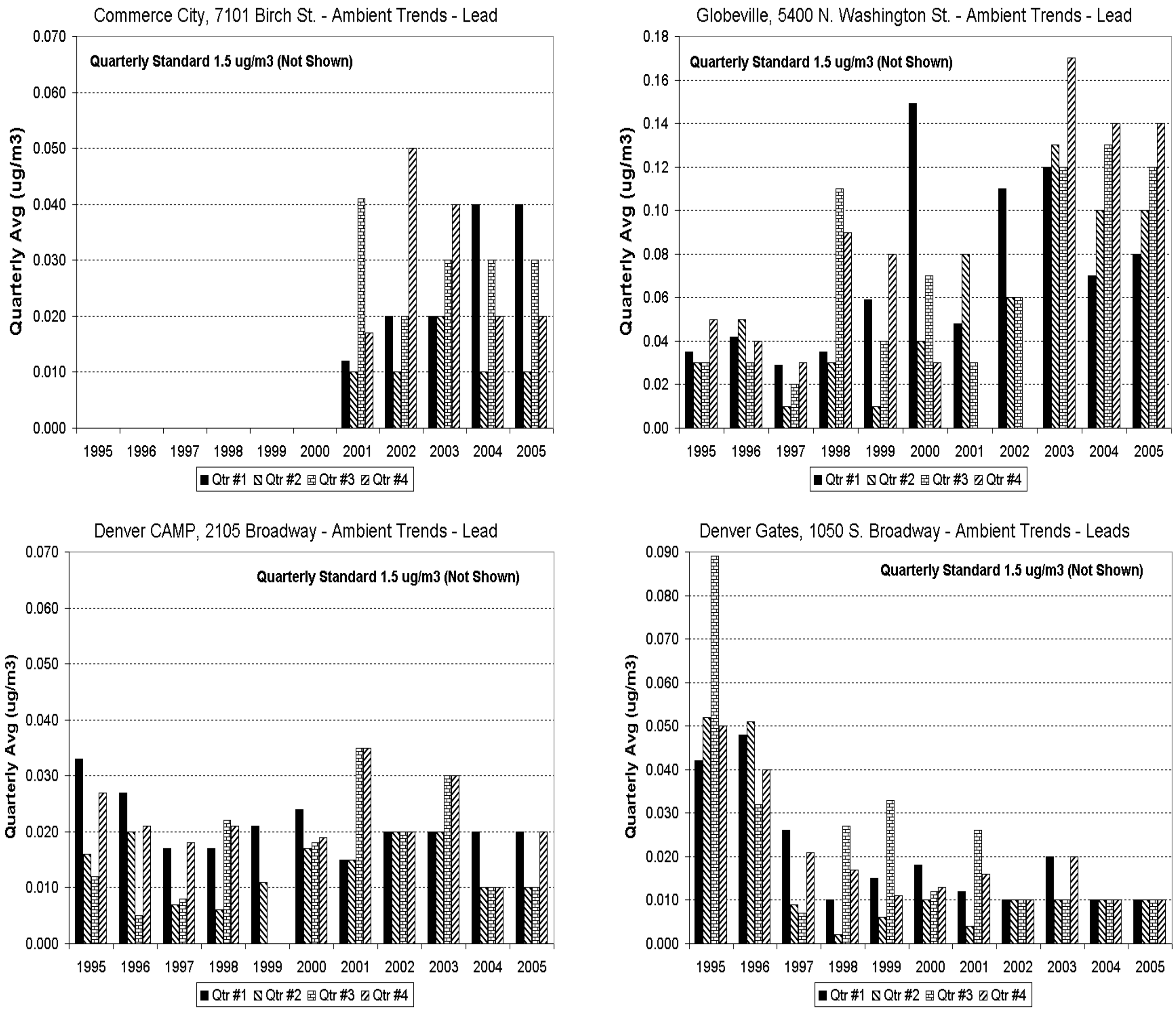


Table 24 - Northern Front Range Continuous Monitors In Operation For 2005

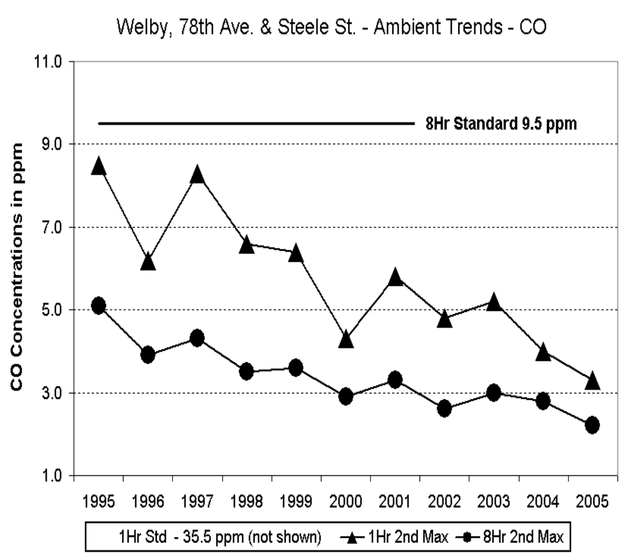
X - Monitors continued in 2005   A – Monitors added in 2005   D – Monitors discontinued in 2005

Site Name	Location	CO	SO_2	NO_X	O_3	Met
Adams						
Commerce City	7101 Birch St.					X
Welby	78th Ave. & Steele St.	X	X	X	X	X
Arapahoe						
Highland Res.	8100 S. University Blvd.				X	X
Boulder						
Boulder	2150 28th St.	D				
	1405½ S. Foothills Hwy.				X	
Longmont	440 Main St.	X				
Denver						
Auraria Lot R	12th St. & Auraria Parkway					X
Denver - CAMP	2105 Broadway	X	X	X	A	X
Denver - Carriage	23rd Ave. & Julian St.	X			X	X
Denver - NJH	14th Ave. & Albion St.	X				
Firehouse #6	1300 Blake St.	X				
Douglas						
Chatfield Reservoir	11500 N. Roxborough Pk. Rd.				X	X
Jefferson						
Arvada	9101 W. 57th Ave.	X			X	X
NREL	2054 Quaker St.				X	
Rocky Flats - N	16600 W. Hwy. 128				X	X
Rocky Flats - NE	11501 Indiana St.					D
Rocky Flats - SE	9901 Indiana St.					X
Rocky Flats - S	18000 W. Hwy. 72					D
Rocky Flats - W	11190 N. Hwy. 93					D
Welch	12400 W. Hwy. 285				X	X
Larimer						
Fort Collins	708 S. Mason St.	X			X	X
	4407 S. College Ave.	X				
Weld						
Greeley	905 10th Ave.	X				
	3101 35th Ave.				X	

Table 25 - Northern Front Range Carbon Monoxide Values for 2005

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		Max	2nd Max	Max	2nd Max
Adams					
Welby	78th Ave. & Steele St.	3.4	3.3	2.5	2.2
Boulder					
Boulder	2150 28th St.	3.6	3.2	2.0	1.9
Longmont	440 Main St.	5.0	4.8	2.5	2.4
Denver					
Denver - CAMP	2105 Broadway	4.6	4.3	2.9	2.5
Denver - Carriage	23rd Ave. & Julian St.	3.9	3.4	2.3	2.1
Denver - NJH	14th Ave. & Albion St.	5.3	3.6	2.5	2.4
Firehouse #6	1300 Blake St.	5.6	4.2	2.4	2.3
Jefferson					
Arvada	9101 W. 57th Ave.	4.1	3.6	2.1	2.0
Larimer					
Fort Collins	708 S. Mason St.	8.1	5.0	3.2	2.4
	4407 S. College Ave.	3.2	3.2	2.2	2.1
Weld					
Greeley	905 10th Ave.	4.8	4.8	3.0	2.8

Figure 17 - Northern Front Range Carbon Monoxide Graphs



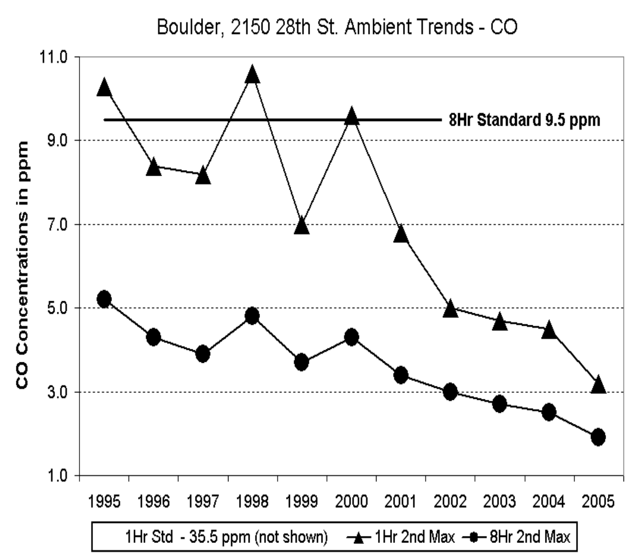
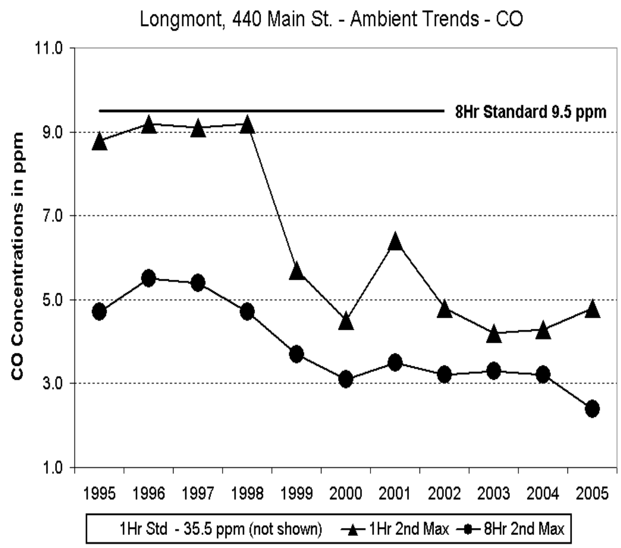
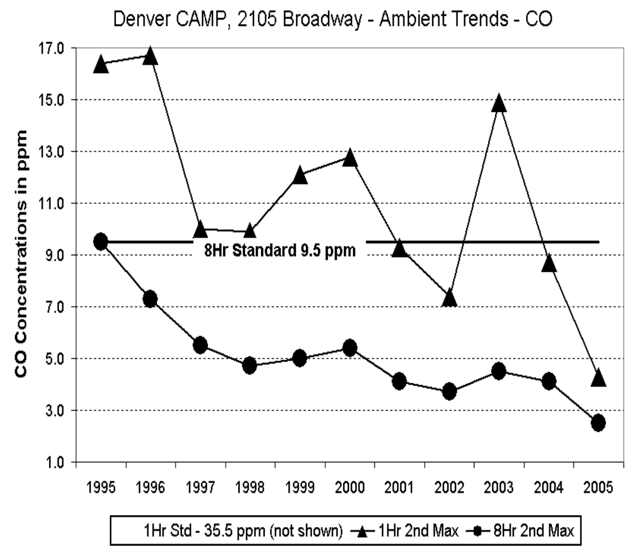
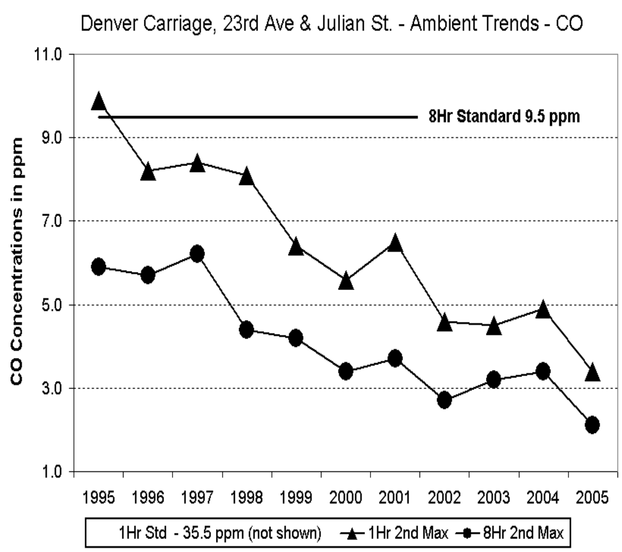
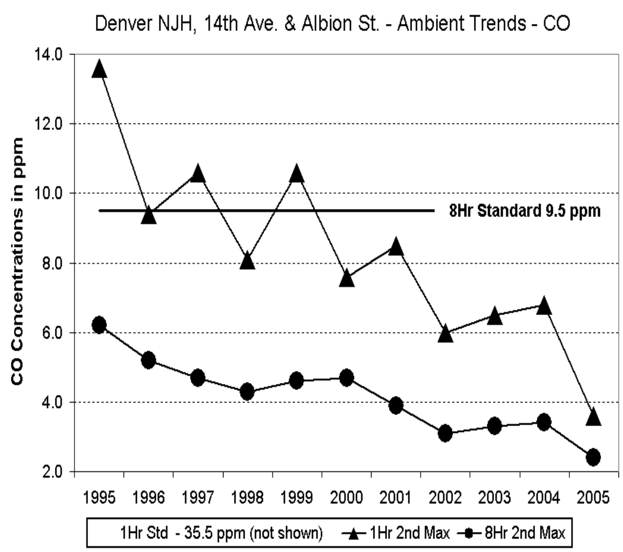


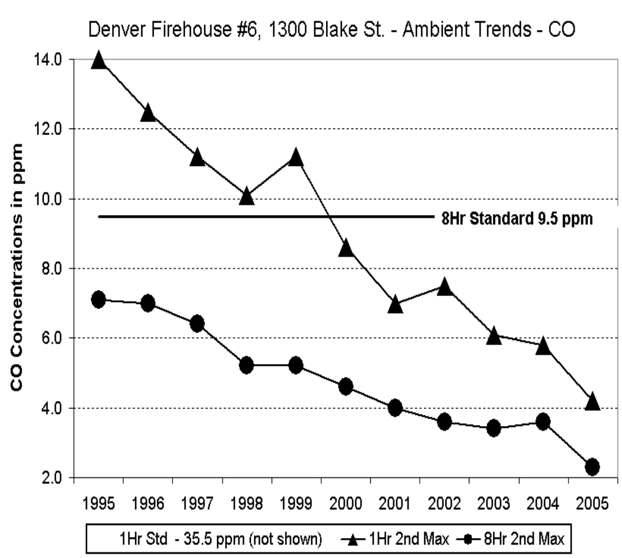
Figure 17 - Northern Front Range Carbon Monoxide Graphs (continued)











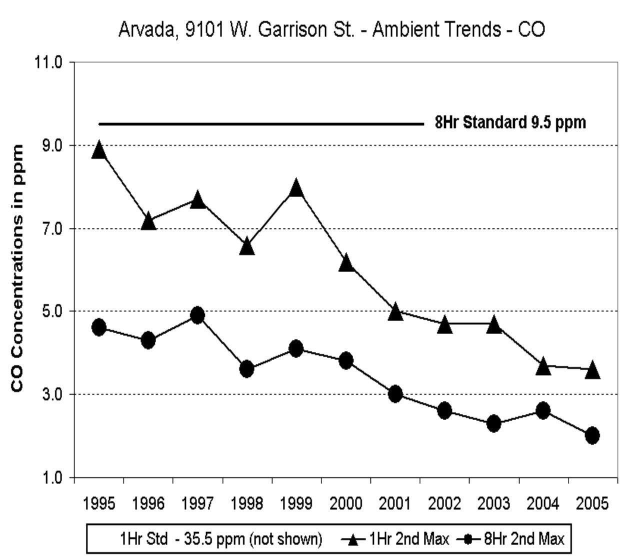


Figure 17 - Northern Front Range Carbon Monoxide Graphs (continued)

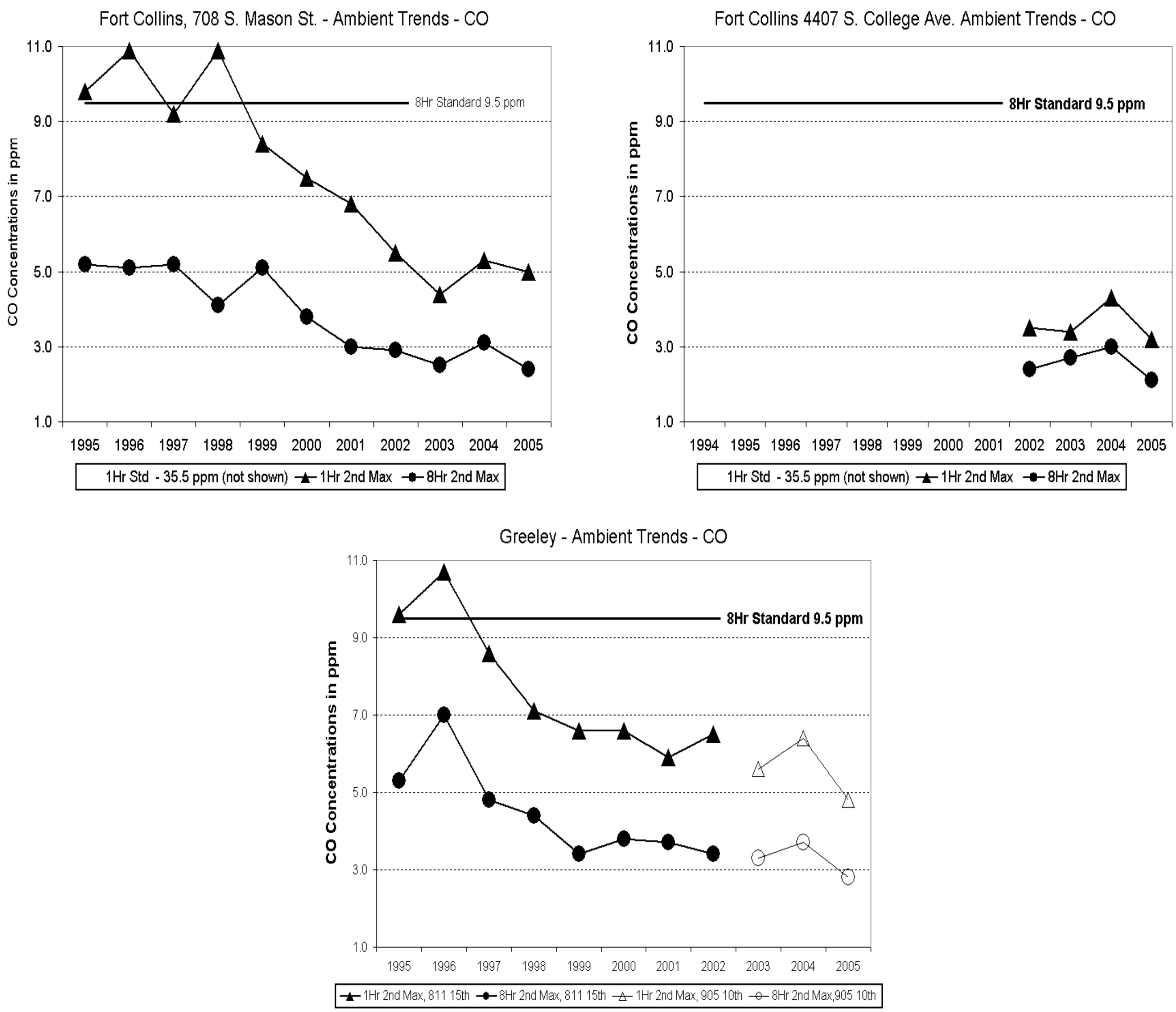


Table 26 - Northern Front Range Ozone Values For 2005

Site Name	Location	Ozone 1-hour Avg. (ppm)		Ozone 8-hour Avg. (ppm)	
		Maximum	2nd Maximum	Maximum	4th Maximum
Adams					
Welby	78th Ave. & Steele St.	0.090	0.086	0.076	0.073
Arapahoe					
Highland Res.	8100 S. University Blvd.	0.099	0.095	0.086	0.080
Boulder					
Boulder	1405½ S. Foothills Hwy	0.100	0.094	0.084	0.076
Denver					
Denver - CAMP	2105 Broadway	0.072	0.067	0.060	0.051
Carriage	23rd Ave. & Julian St.	0.095	0.095	0.080	0.074
Douglas					
Chatfield Res.	11500 Roxborough Park Rd.	0.108	0.103	0.091	0.084
Jefferson					
Arvada	9101 W. 57th Ave.	0.099	0.098	0.084	0.078
NREL	2054 Quaker St.	0.099	0.095	0.085	0.079
Rocky Flats	16600 W. Hwy 128	0.099	0.094	0.083	0.077
Welch	12400 W. Hwy 285	0.081	0.078	0.071	0.064
Larimer					
Fort Collins	708 S. Mason St.	0.102	0.102	0.080	0.076
Weld					
Greeley	3101 35th Ave.	0.116	0.098	0.084	0.078

Figure 18 - Northern Front Range Ozone Graphs

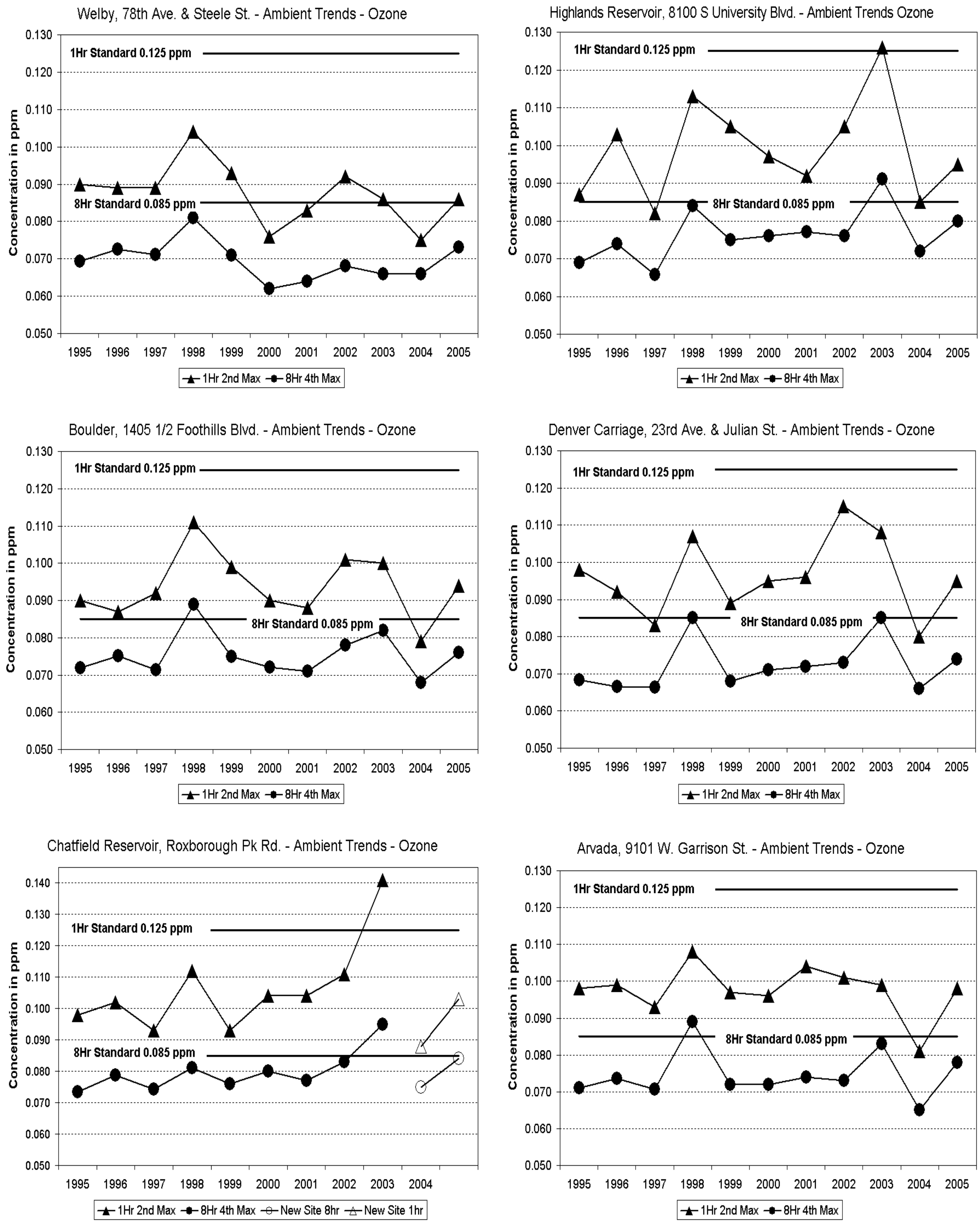
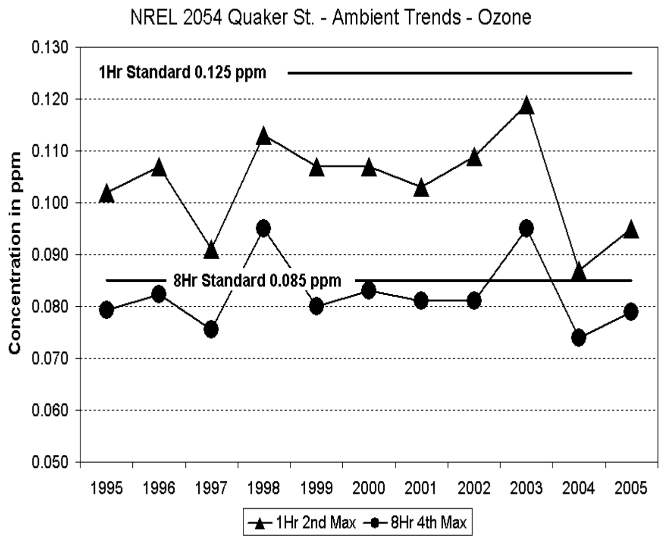
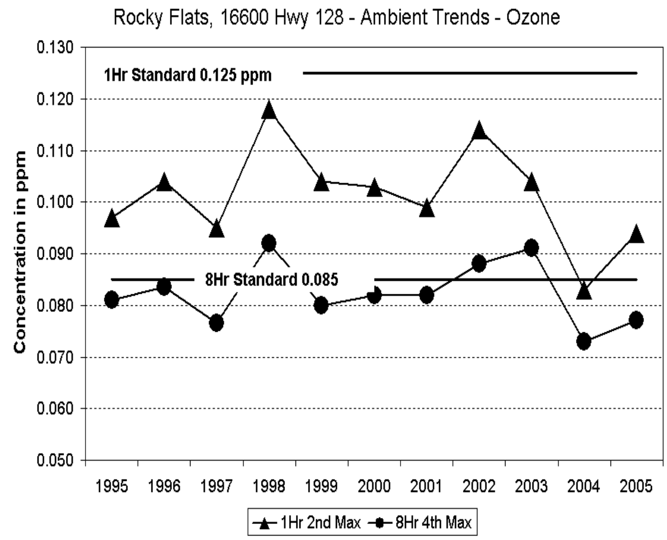
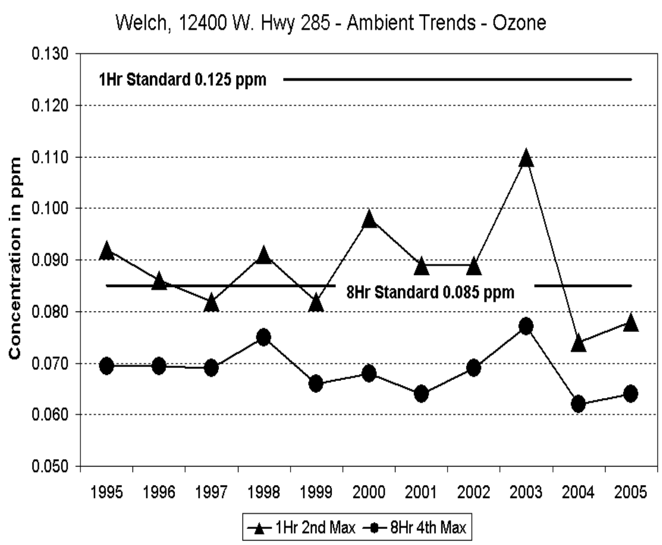
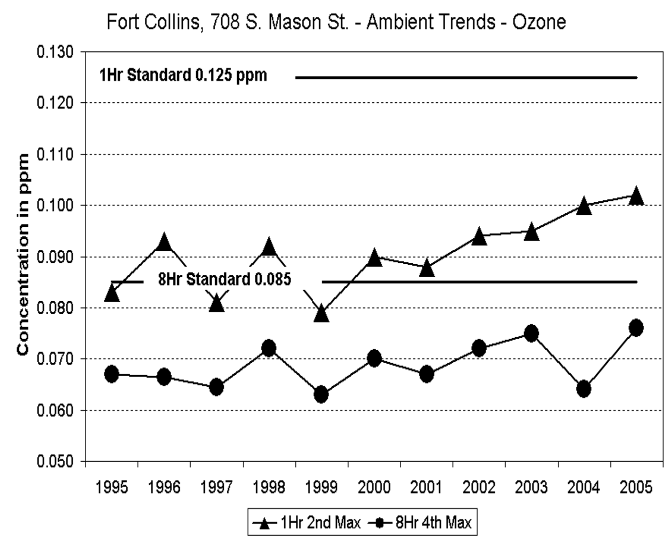


Figure 18 - Northern Front Range Ozone Graphs (continued)









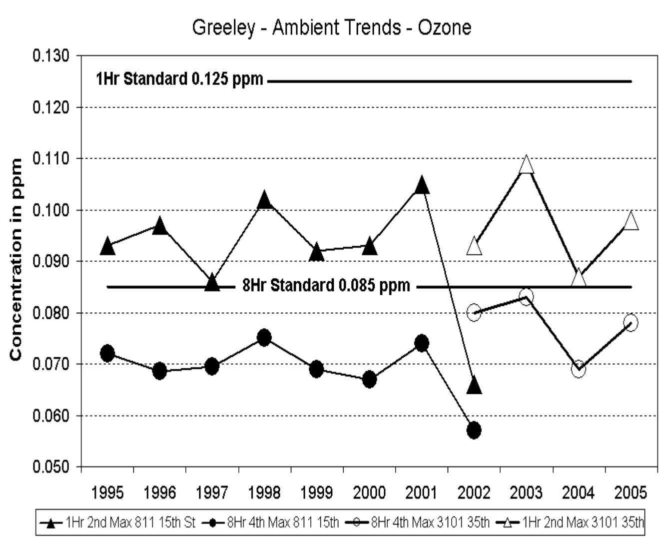


Table 27 - Northern Front Range Oxides of Nitrogen and Sulfur Dioxide Values For 2005

Site Name	Location	Nitrogen Dioxide	Nitric Oxide	Sulfur Dioxide		
		Annual Avg. (ppm)	Annual Avg. (ppm)	3-hour 2nd Max (ppm)	24-hour 2nd Max (ppm)	Annual Avg. (ppm)
Adams						
Welby	78th Ave. & Steele St.	0.0205	0.0312	0.023	0.008	0.0021
Denver						
Denver CAMP	2105 Broadway	0.0276	0.0412	0.026	0.009	0.0025

() Indicates less than 75% data for the year.

Figure 19 - Northern Front Range Nitrogen Dioxide Graphs

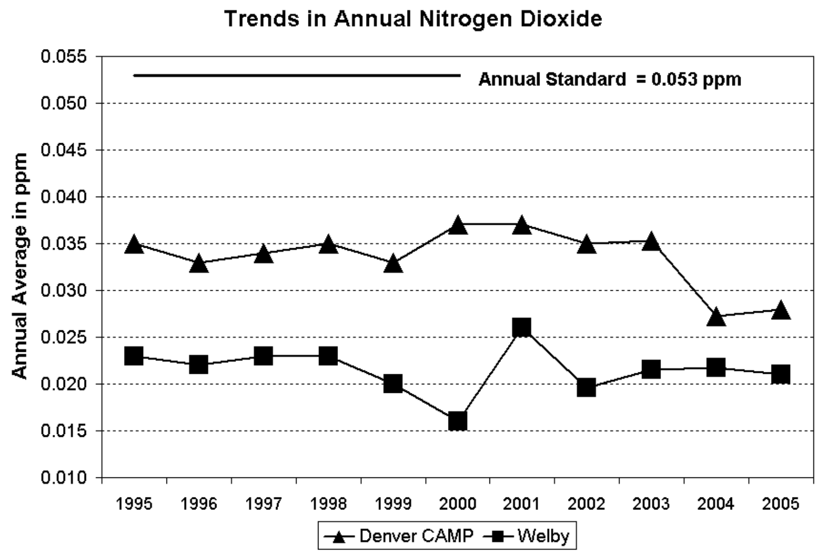


Figure 20 - Northern Front Range Sulfur Dioxide Graphs

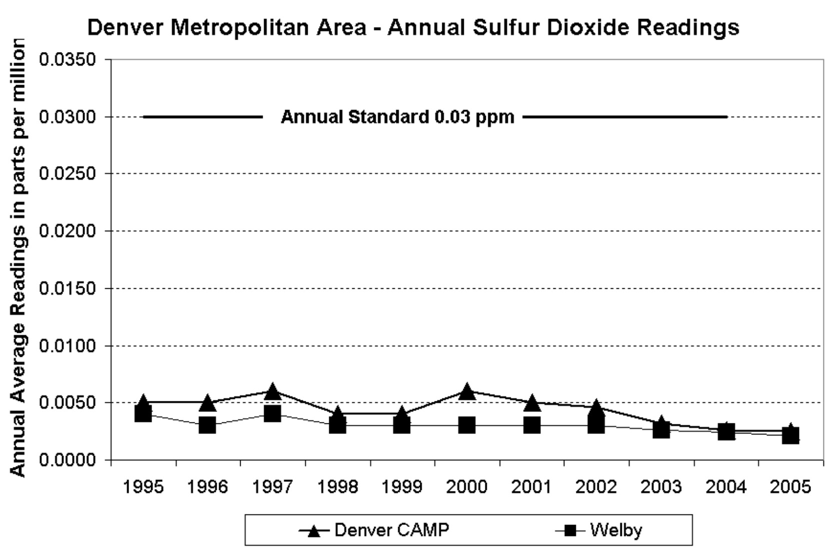


Table 28 - Denver Visibility Standard Exceedance Days
(Transmissometer Data)
January 2005 – December 2005

Month	Days	EX POOR	POOR	FAIR	GOOD	Missing	(>70% RH)
January	31	6	6	6	5		8
February	28	2	12	5	5		4
March	31	1	3	11	14		2
April	30	2	9	5	7	1	6
May	31	2	8	14	4		3
June	30		8	14	5		3
July	31		11	12	7		1
August	31	1	7	11	10		2
September	30	2	12	8	8		
October	31	1	12	10	3		5
November	30	1	10	15	3		1
December	31	3	8	12	2	3	3
Totals	365	21	106	123	73	4	38

Table 28 and Figure 21 show that 4 days or 1 percent of the data for 2005 were listed as missing. In 2003 177 days were listed as missing. This dramatic change has been due to improvements in the bulb calibrations and fewer instrument problems. In short 2005 was as abnormally free of instrument problems as 2003 was plagued with them.

Figure 21 - Denver Visibility Data (January 2005 to December 2005)

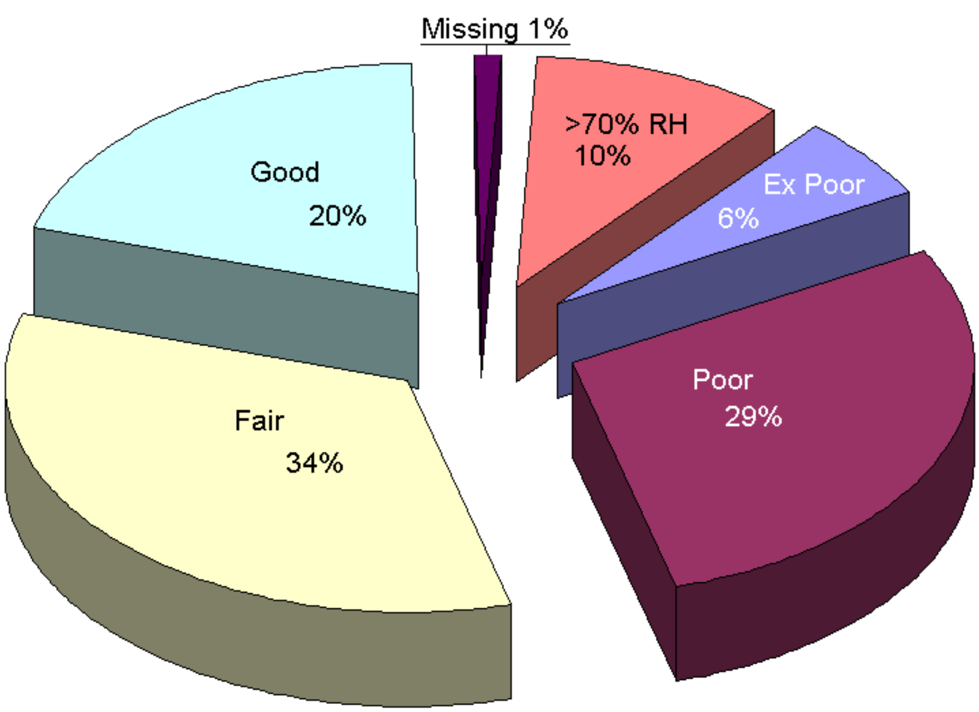


Figure 22 - Denver Visibility Comparison (1995 to 2005)

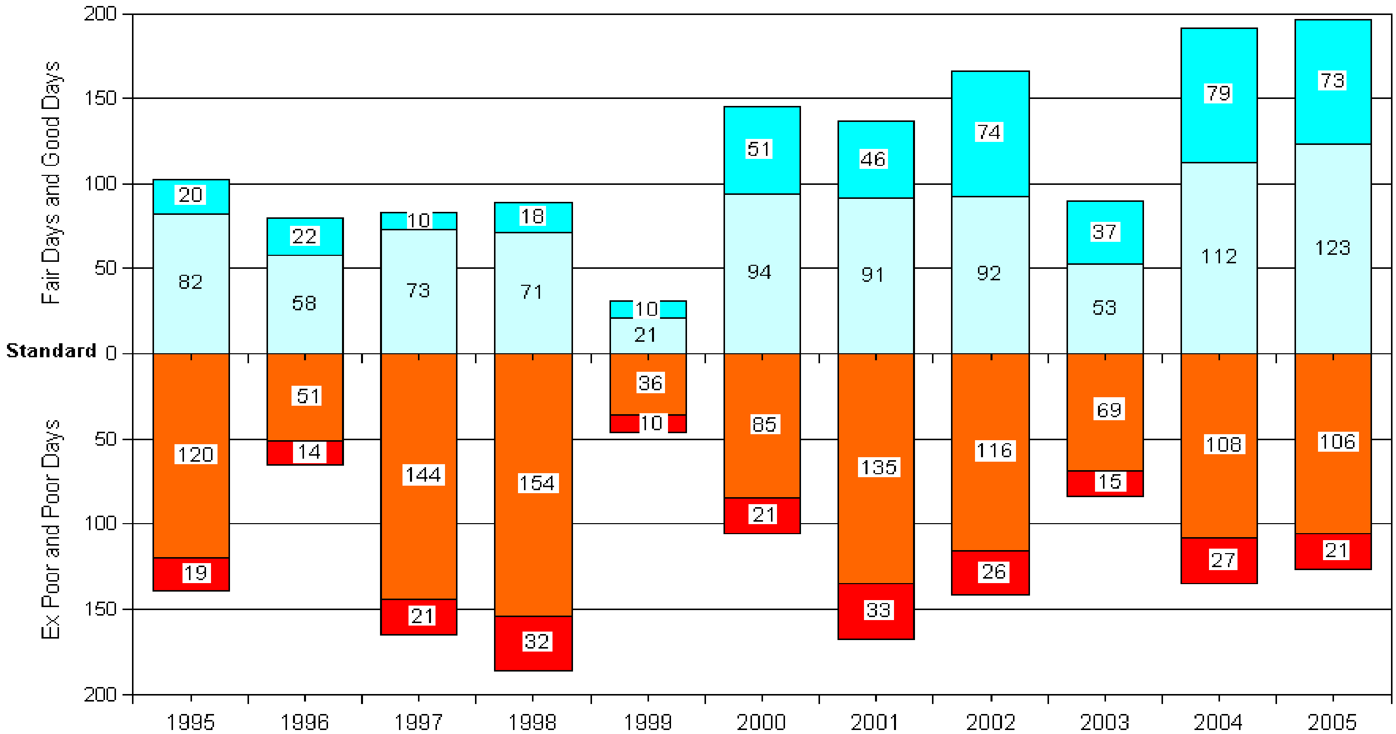


Figure 22 shows the general increase in "Good" and "Fair" days over the past ten years. "Good"and "Fair" days are those where the visibility is better than the standard. "Poor" and "Extra Poor" days are those that are equal to or below the standard. Visibility monitoring began in late 1990. The dip in monitored days in 1996, 1999 and 2003 were caused by problems with the analyzer. With the exception of these years data recovery has been high. Data loss prior to 2000 was primarily due to the one to two months lost each summer for recalibration and testing by the manufacturer. Since 2000 the APCD has been provided with a replacement machine during the summer calibration period.

Table 29 - Fort Collins Visibility Standard Exceedance Days
(Transmissometer Data)
January 2005 – December 2005

Month	**Days**	**EX POOR**	**POOR**	**FAIR**	**GOOD**	**Missing**	**(>70% RH)**
January	31		1			22	8
February	28		3	3	10	8	4
March	31		1	13	11	3	3
April	30		6	11	2	11	
May	31		9	12	1	9	
June	30		3	1		26	
July	31					31	
August	31		9	10		12	
September	30	1	15	11		3	
October	31		13	13	1	4	
November	30		6	12	11		1
December	31		2	8	13	5	3
Totals	365	1	68	94	49	134	19

The missing visibility data from the Fort Collins monitor in January was due to power loss during building construction. The transmissometer was removed from the site for its annual servicing and calibration from June 7 through August 10. The other cause for missing data was normal maintenance of the instrument.

Figure 23 - Fort Collins Visibility Data (January 2005 to December 2005)

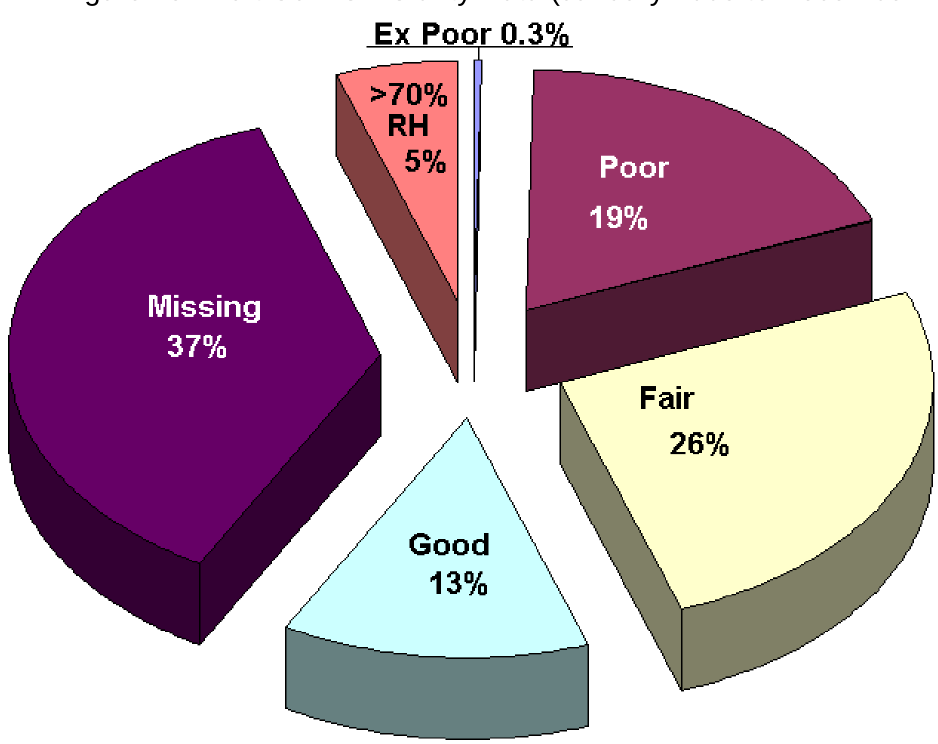


Figure 24 shows that for the past ten years Fort Collins has averaged 164 days per year where the visibility was either "Fair" or "Good" and only 85 days where the visibility was either "Poor" or "Ex Poor". The missing days are lost due to either high relative humidity (greater than 70 percent) or machine maintenance.

Figure 24 - Fort Collins Visibility Data (1995 to 2005)

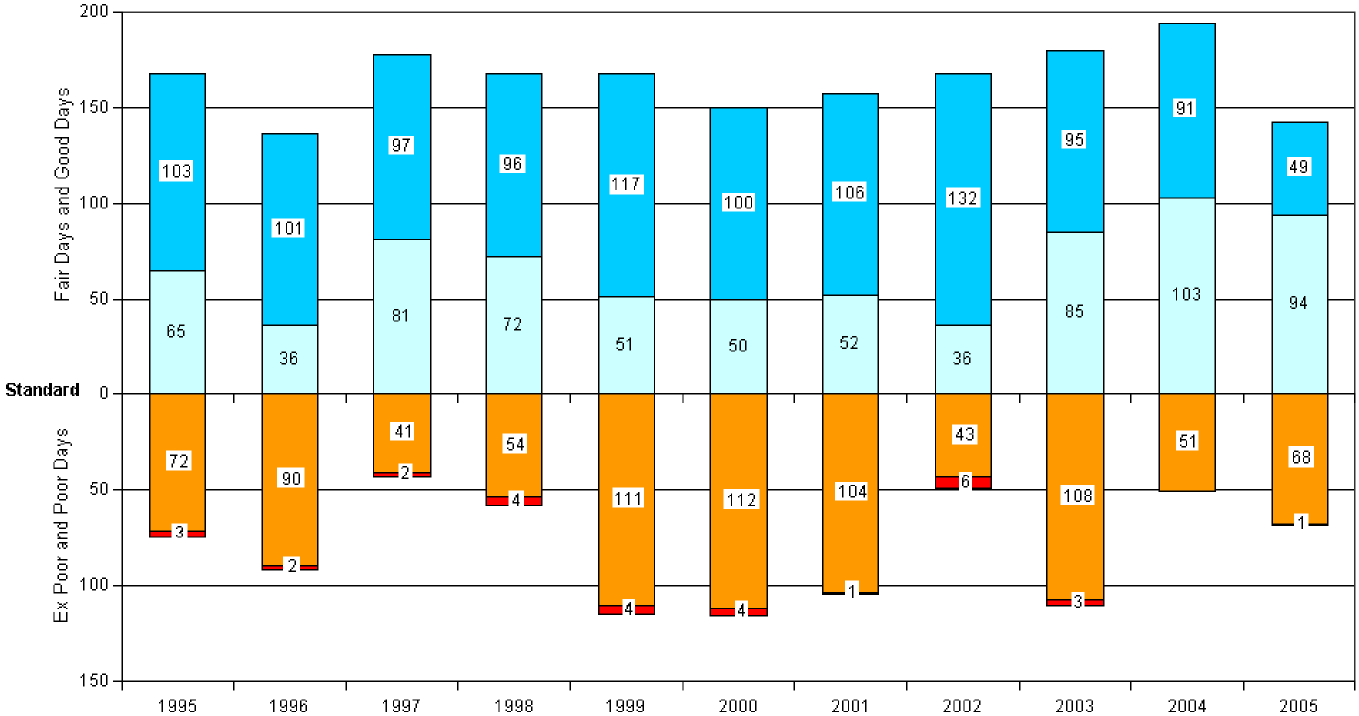
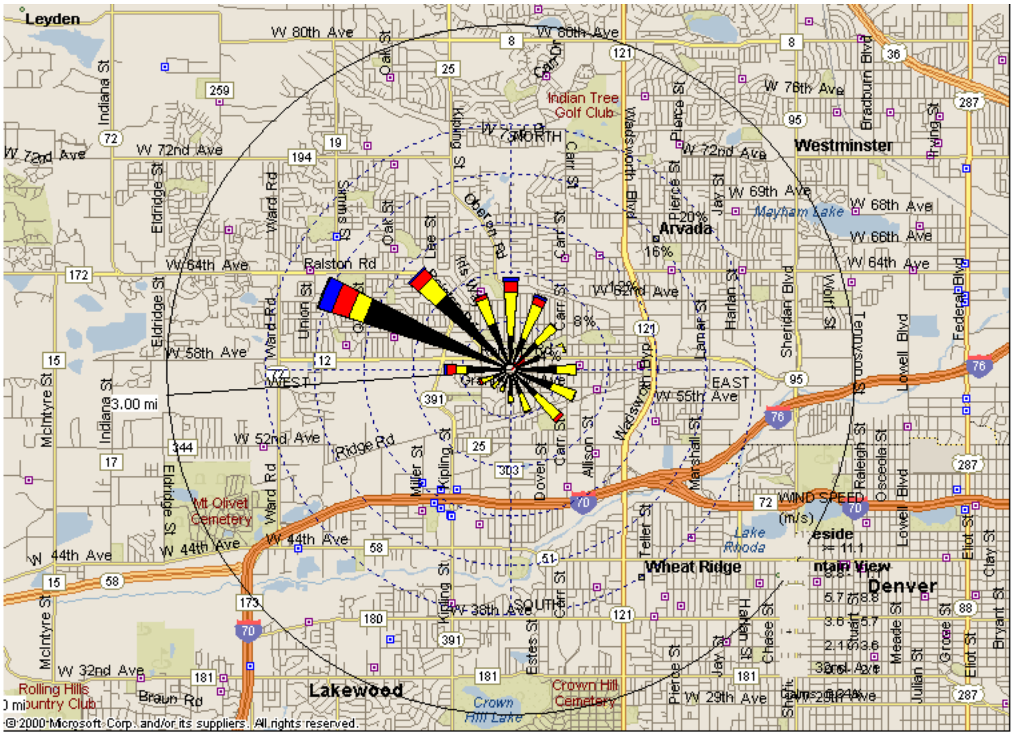


Figure 25 - Northern Front Range Wind Roses
Arvada, 9101 W. 57th Ave.



Auraria, Parking Lot R

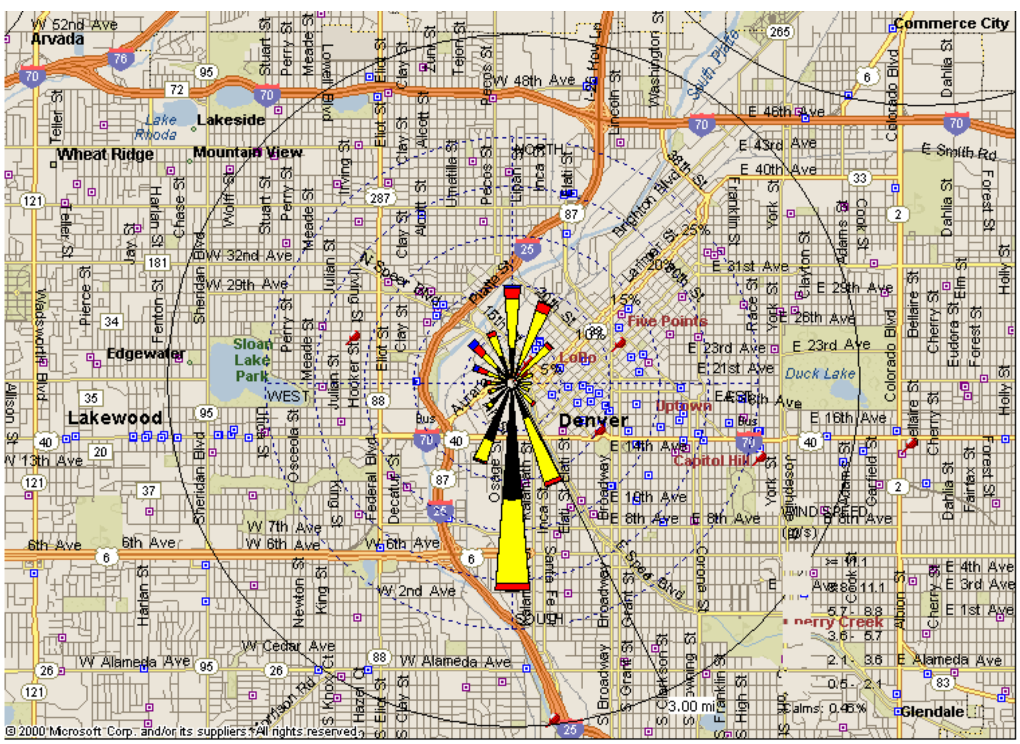
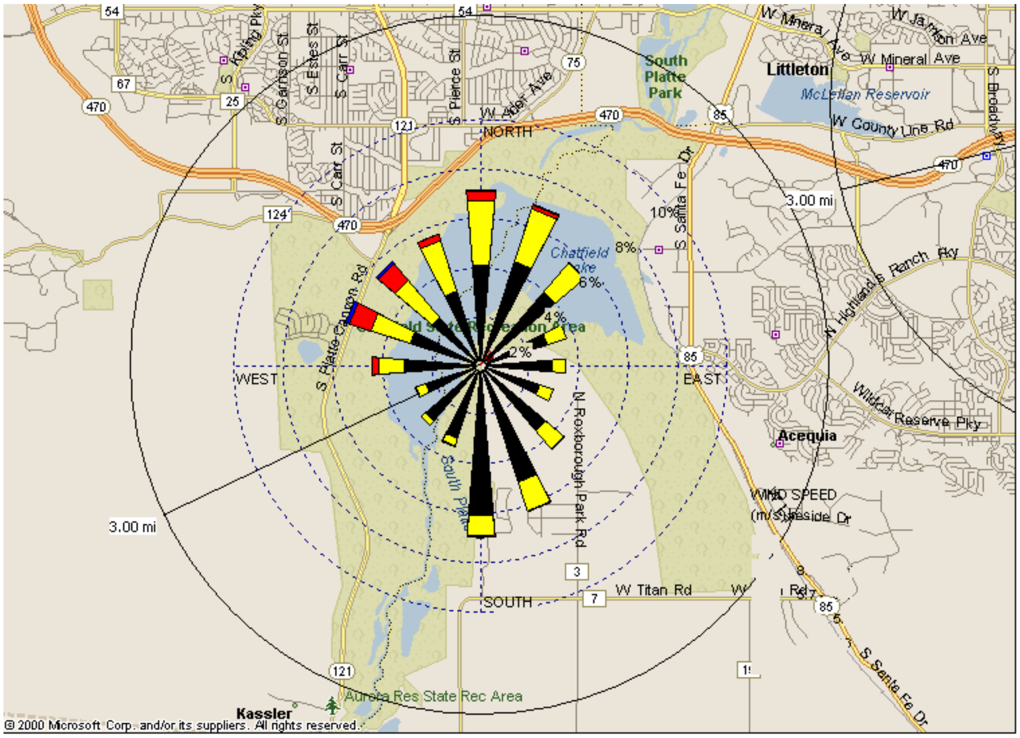


Figure 25 - Northern Front Range Wind Roses (continued)

Chatfield Reservoir, 11500 N. Roxborough Pk. Rd.



Commerce City, 7101 Birch St.

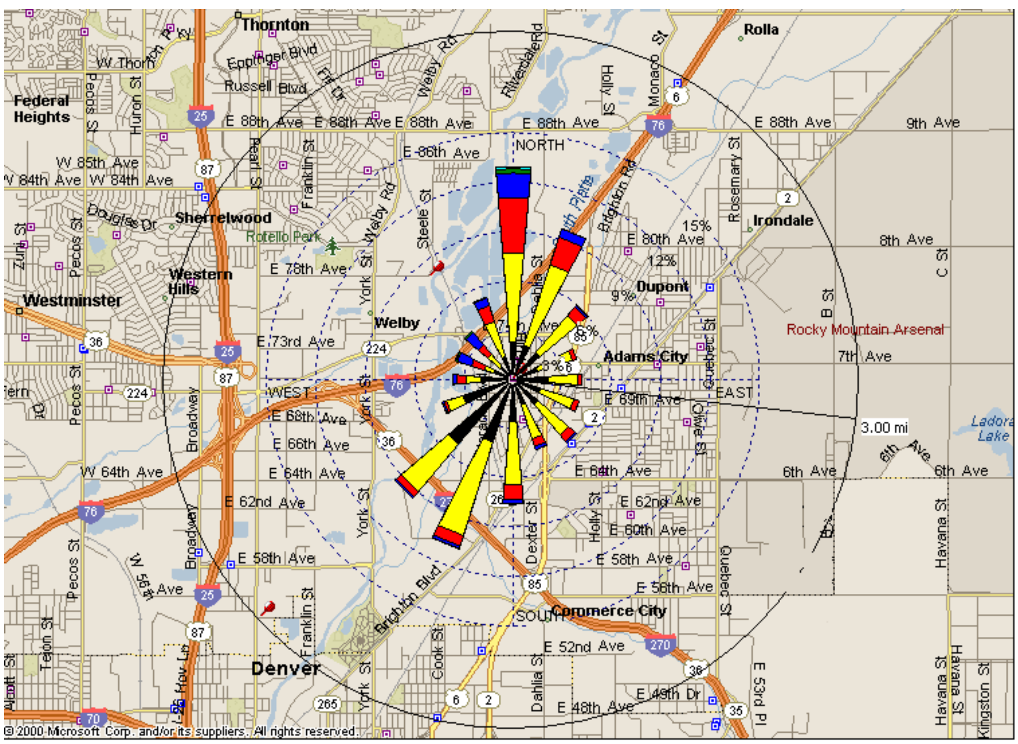
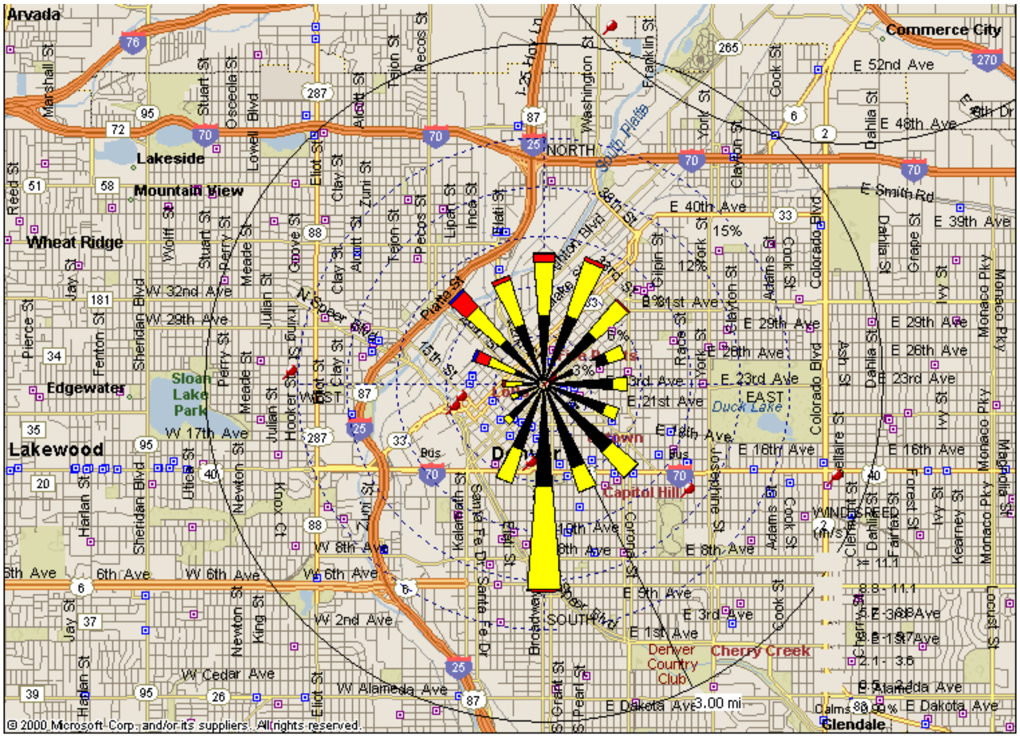


Figure 25 - Northern Front Range Wind Roses (continued)
Denver CAMP, 2105 Broadway



Denver Carriage, 23rd Ave. and Julian St.

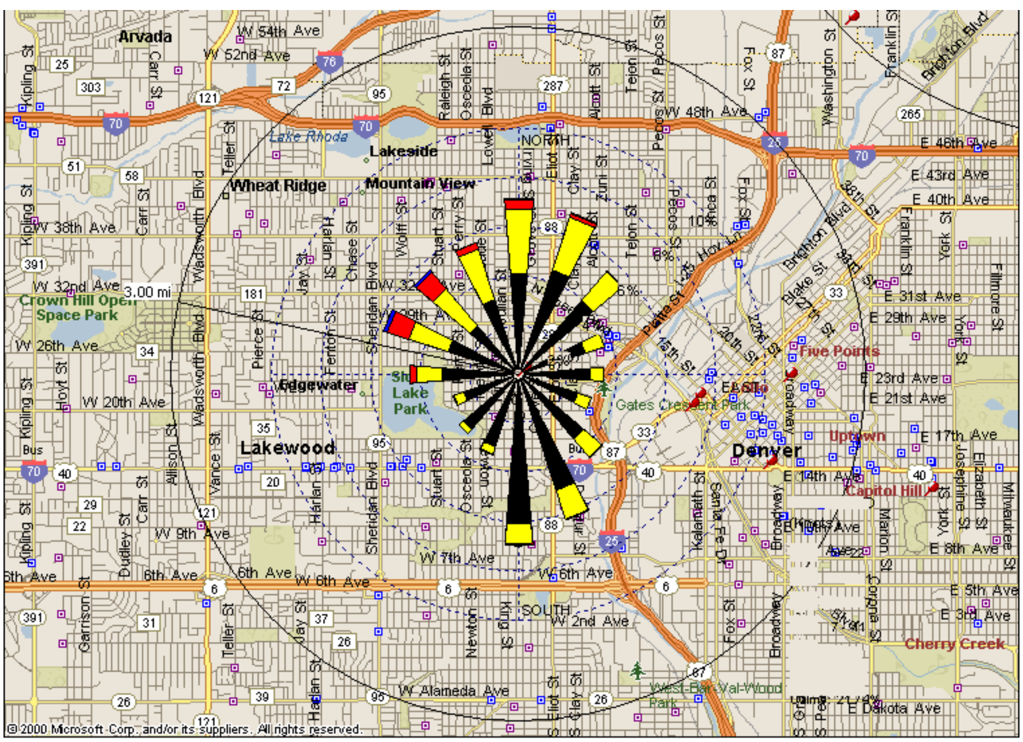
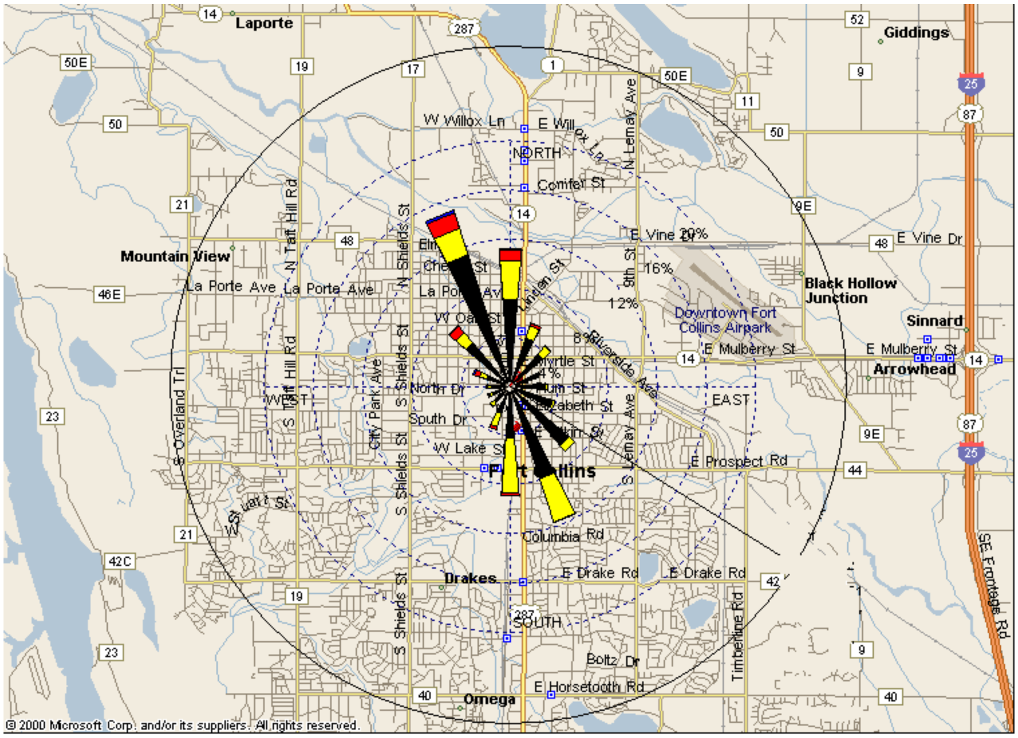


Figure 25 - Northern Front Range Wind Roses (continued)
Fort Collins, 708 S. Mason St.



Highland Reservoir, 8100 S. University Blvd.

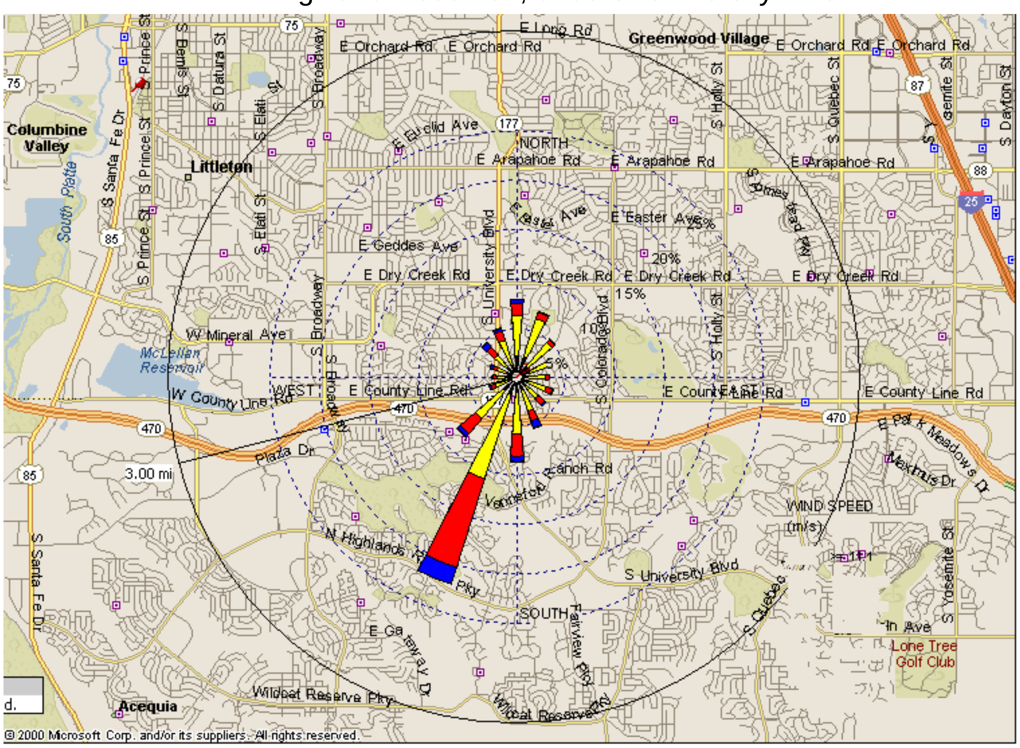
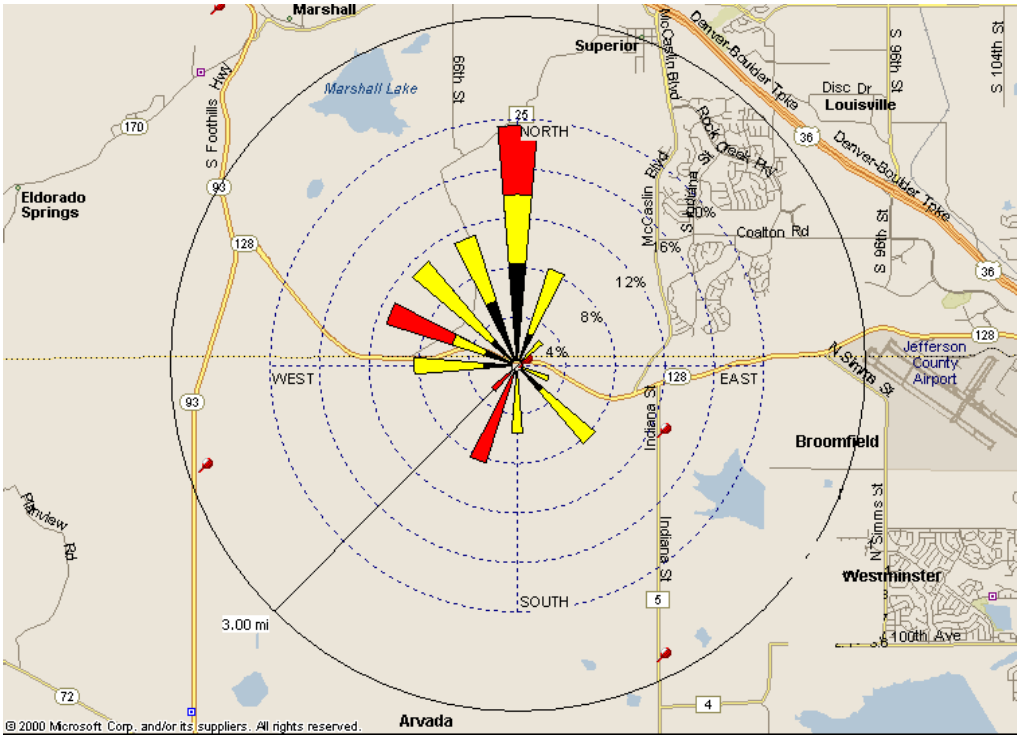


Figure 25 - Northern Front Range Wind Roses (continued)
Rocky Flats-N, 16600 W. Hwy. 128



Rocky Flats-NE, 11501 Indiana St.

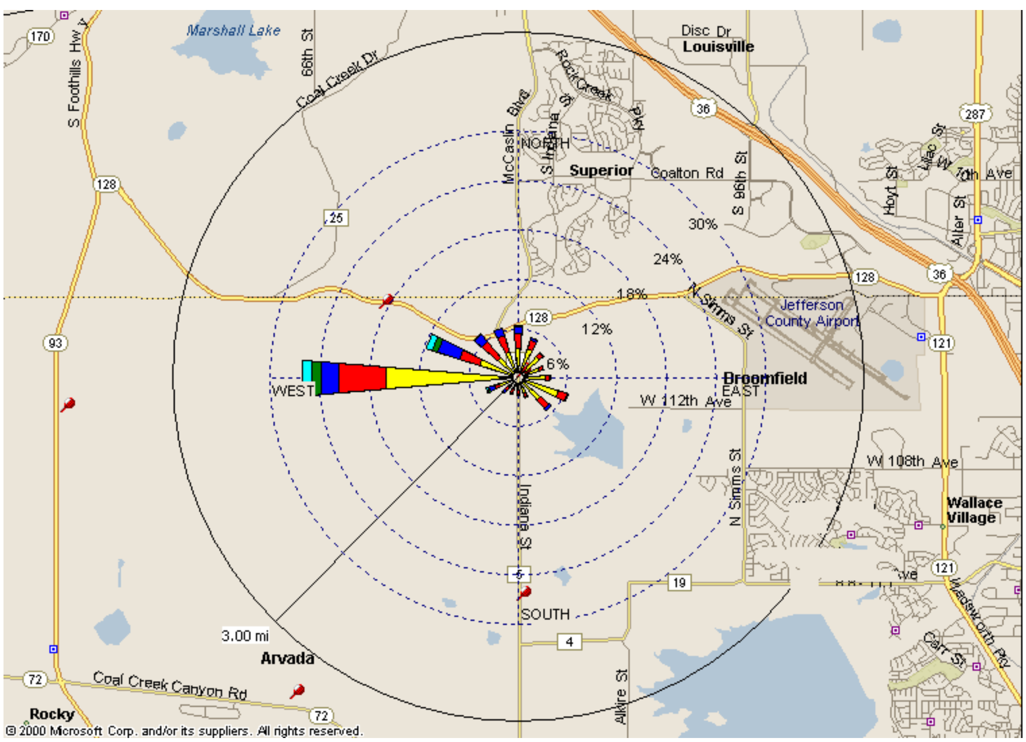
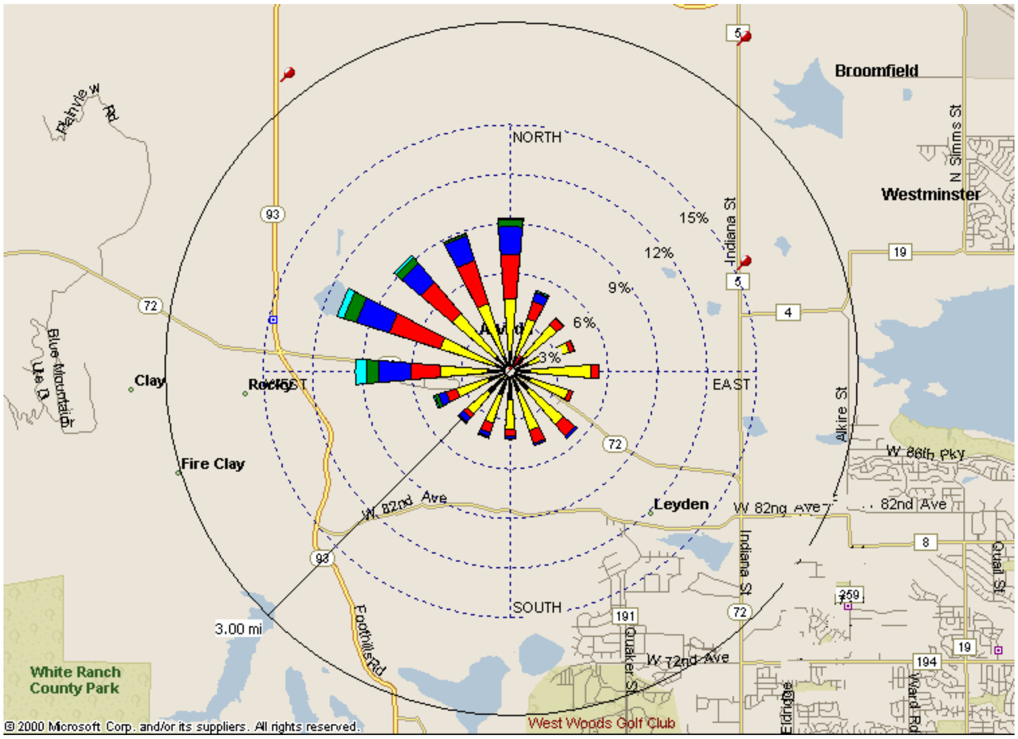


Figure 25 - Northern Front Range Wind Roses (continued)
Rocky Flats-S, 18000 W. Hwy 72



Rocky Flats-SE, 9901 Indiana St.

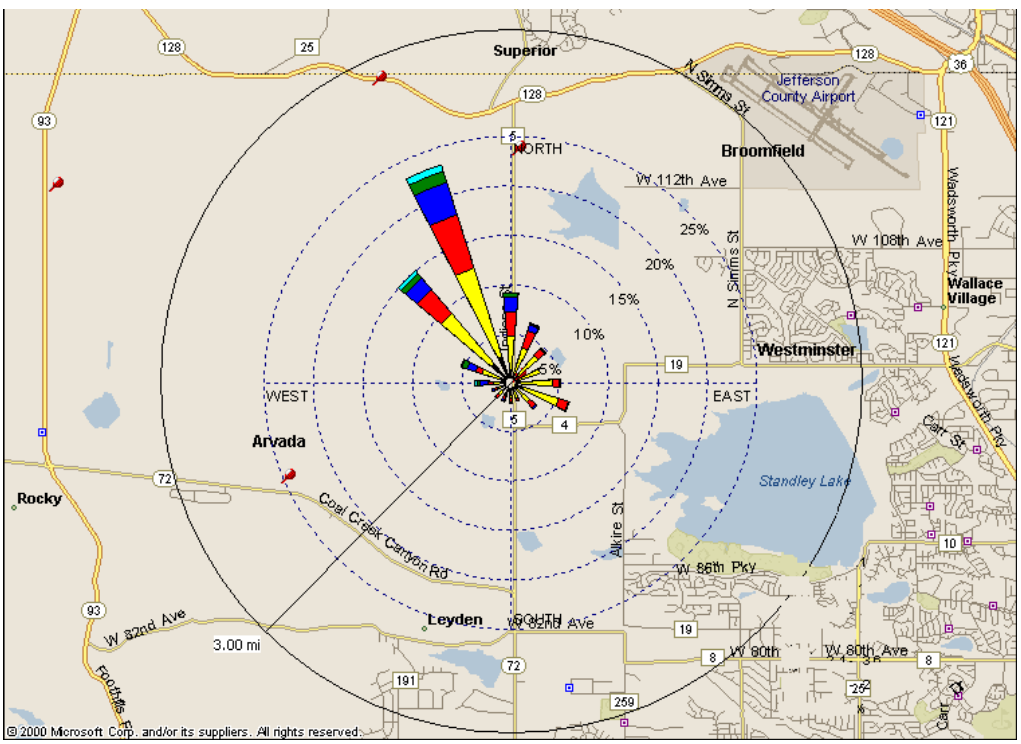
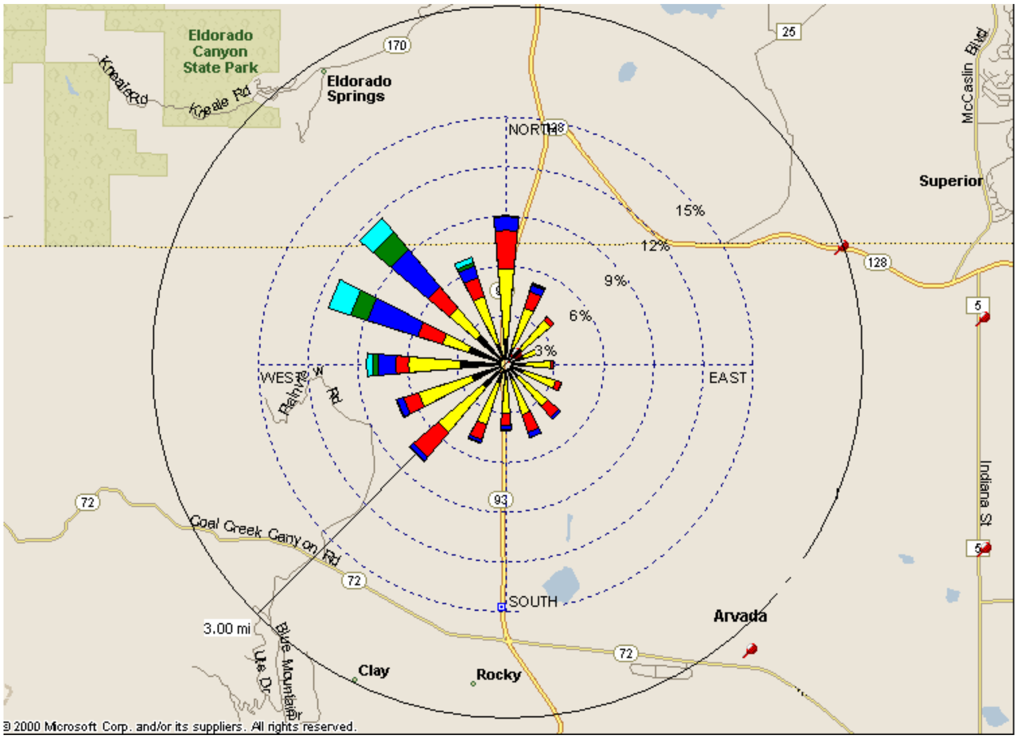


Figure 25 - Northern Front Range Wind Roses (continued)
Rocky Flats – W. 11190 N. Hwy 93



Welby, 78th Ave. & Steele St.

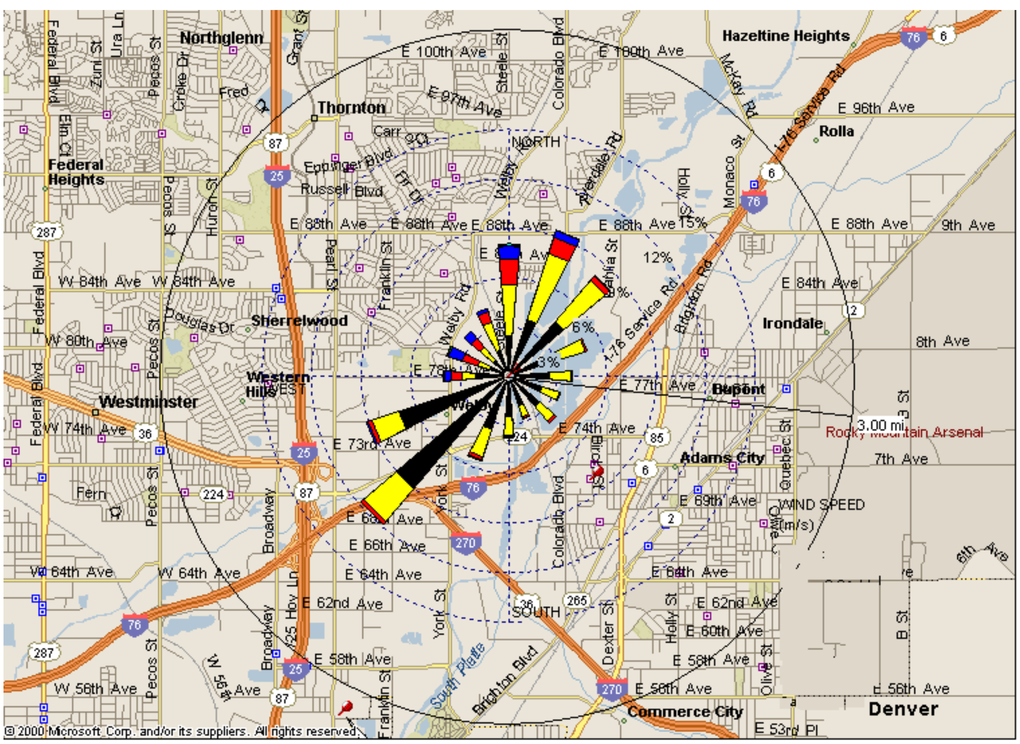
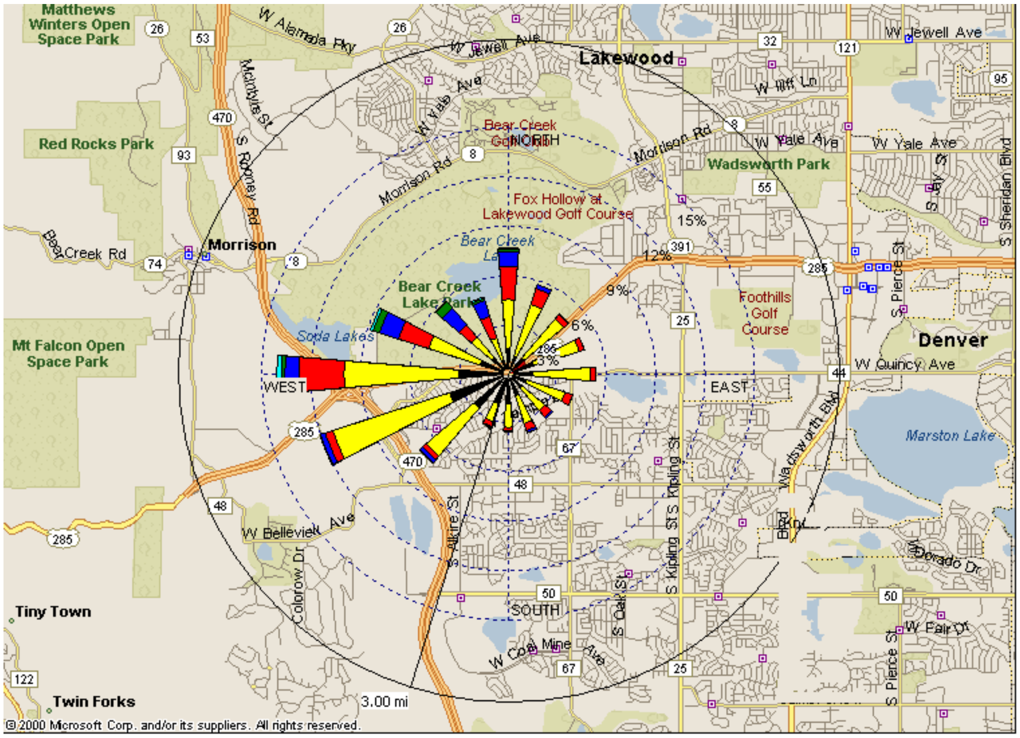


Figure 25 - Northern Front Range Wind Roses (continued)
Welch, 12400 W. Hwy. 285



6.3 Southern Front Range Counties

The Southern Front Range Counties are those along the urbanized I-25 corridor from south of the city of Castle Rock to the southern Colorado border. The cities with monitoring in the area are Colorado Springs, Pueblo, Cripple Creek, Cañon City and Alamosa. These last three cities are not strictly in the Front Range I-25 corridor but fit better with those cities than they do the Mountain Counties. Colorado Springs is the only city in the area that is monitored for carbon monoxide and ozone. The other cities are only monitored for particulates. In the past the APCD has conducted particulate monitoring in both Walsenburg and Trinidad but that monitoring was discontinued in 1979 and 1985 respectively.

Table 30 - Southern Front Range Monitors In Operation For 2005

X - Monitors continued in 2005 A – Monitors added in 2005

D – Monitors discontinued in 2005 H – Hourly particulate monitor S – Chemical Speciation

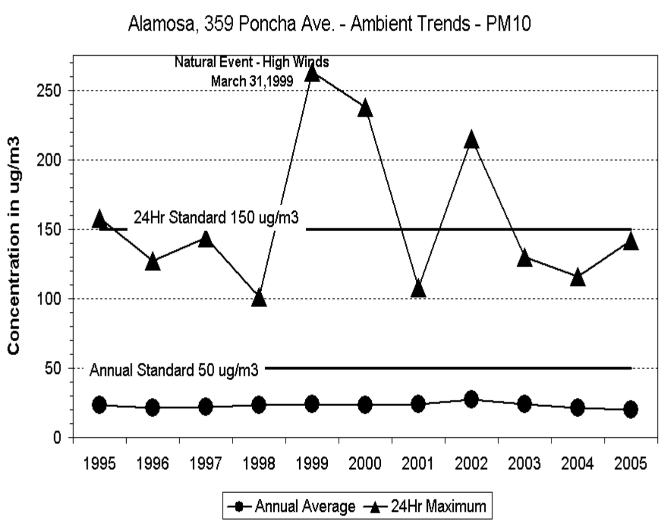
Site Name	Location	CO	O_3	TSP	Pb	PM_{10}	$PM_{2.5}$	Met
Alamosa								
Alamosa	359 Poncha Ave.					X		
	425 4th St.					X		
El Paso								
Colorado Springs	I-25 & Uintah St.	X						
	3730 Meadowlands					X	X	
	101 W. Costilla St.			X	X	X	X/S	
	USAF Rd. 640		X					
	690 W. Hwy. 24	X						
Manitou Springs	101 Banks Pl.		X					
Fremont								
Cañon City	128 Main St.					X		
Pueblo								
Pueblo	211 D St.					X	X	
Teller								
Cripple Creek	209 Bennett Ave.					X		
	Warren Ave. & 2nd St							X

Table 31 - Southern Front Range Maximum Particulate Values For 2005

Site Name	Location	PM_{10} (µg/m^3)		$PM_{2.5}$ (µg/m^3)	
		Annual Average	24-Hr Maximum	Annual Average	24-Hr Maximum
Alamosa					
Alamosa	359 Poncha Ave.	20.3	142		
	425 4th St.	23.9	141		
El Paso					
Colorado Springs	3730 Meadowlands	(23.6)	84	6.64	18.4
	101 W. Costilla St.	22.4	45	7.59	22.7
Fremont					
Cañon City	128 Main St.	18.0	33		
Pueblo					
Pueblo	211 D St.	(21.6)	62	7.15	17.7
Teller					
Cripple Creek	209 Bennett Ave.	18.6	50		

() Indicates less than 75% data for one or more quarters.

Figure 26 - Southern Front Range PM_{10} Particulate Graphs



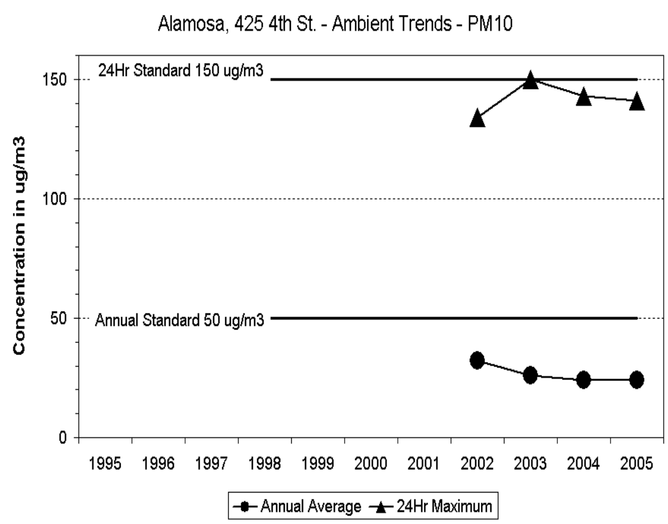
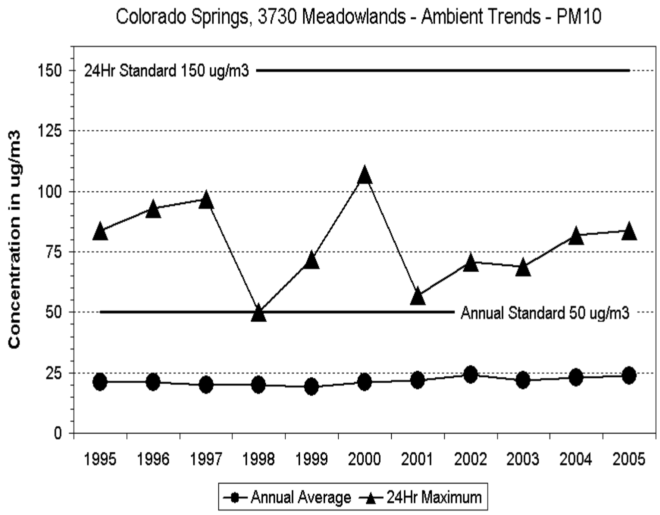
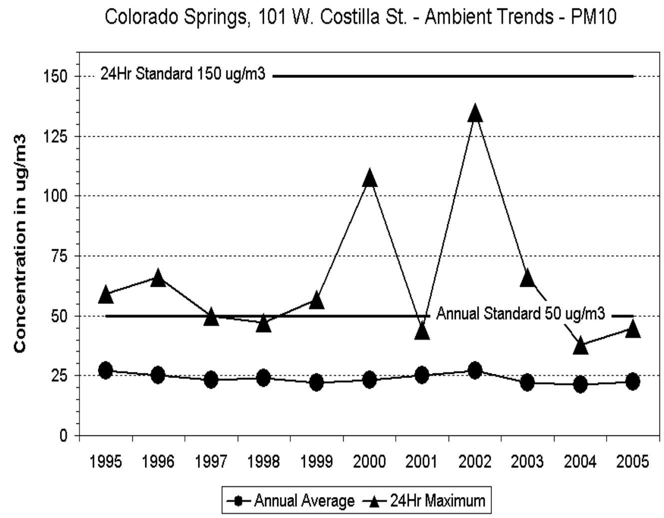
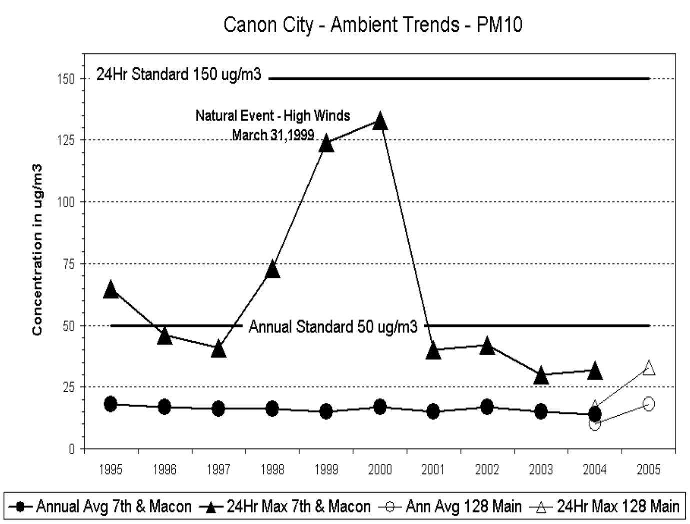
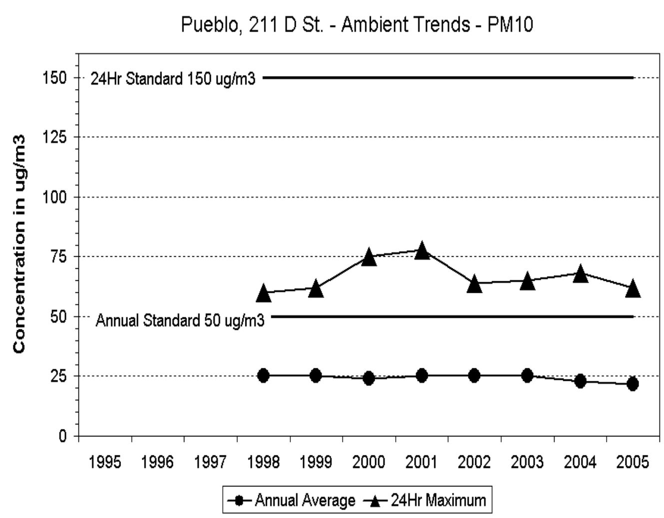


Figure 26 - Southern Front Range PM_{10} Particulate Graphs (continued)









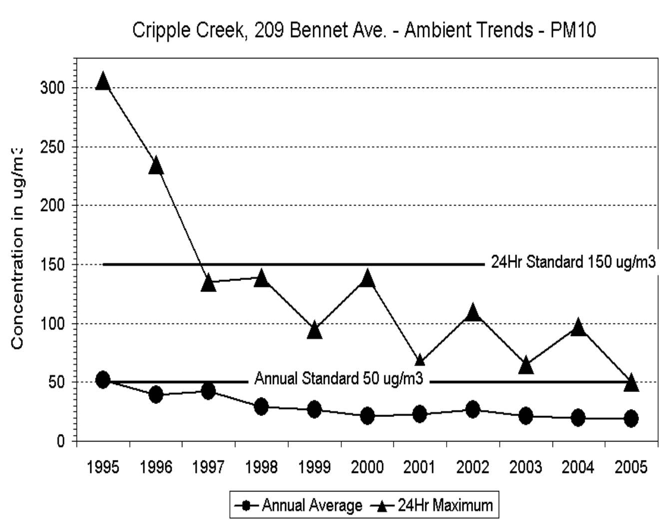


Figure 27 - Southern Front Range $PM_{2.5}$ Particulate Graphs

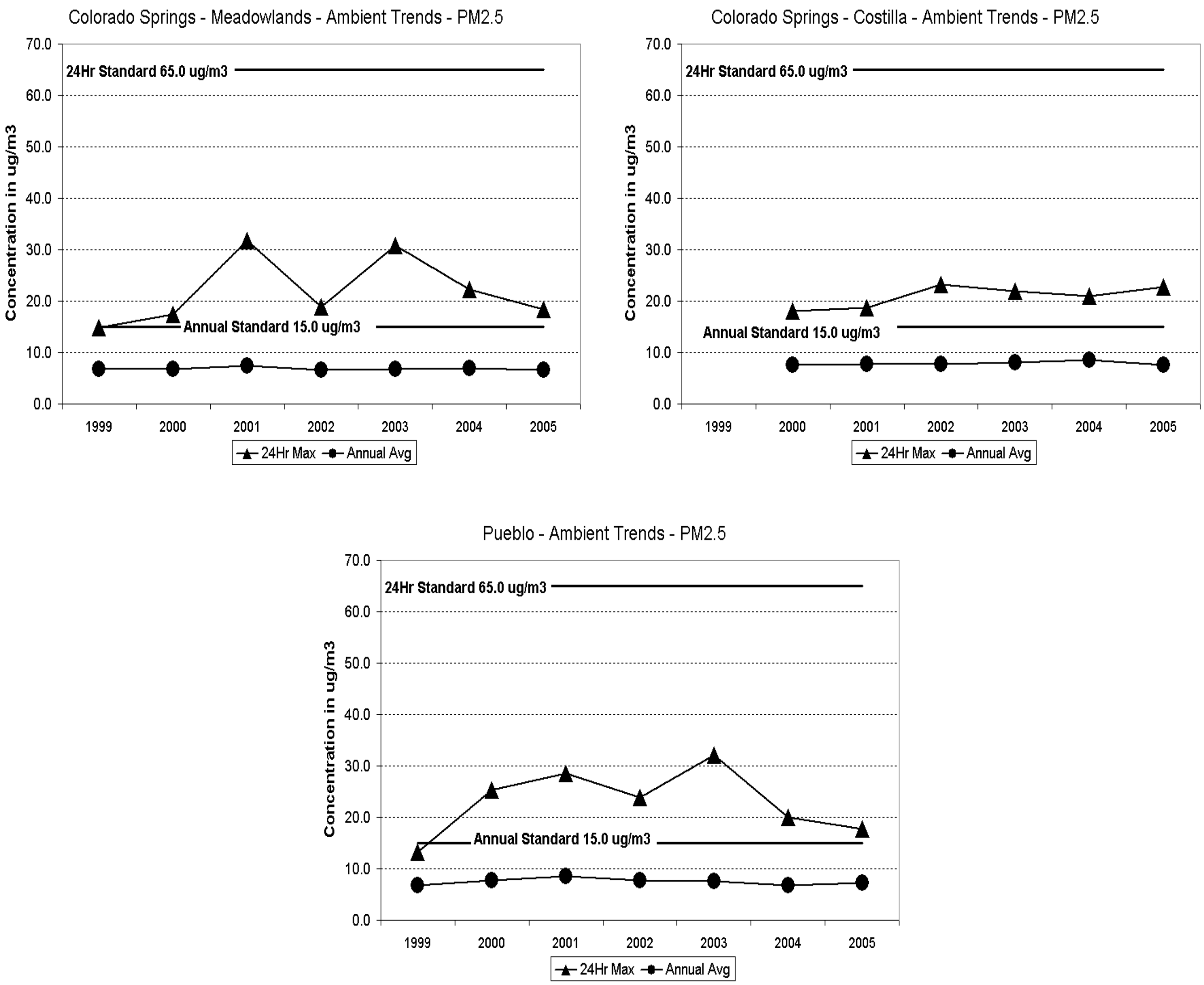


Table 32 - Southern Front Range TSP and Lead Values For 2005

Site Name	Location	TSP (µg/m^3)		Lead (µg/m^3)	
		Annual Mean	24-Hr Maximum	Maximum Quarter	24-Hr Maximum
El Paso					
Colorado Springs	101 W. Costilla St.	54.7	95	0.09	0.31

() Indicates less than 75 percent data for one or more quarters.

Figure 28 - Southern Front Range Lead Graph

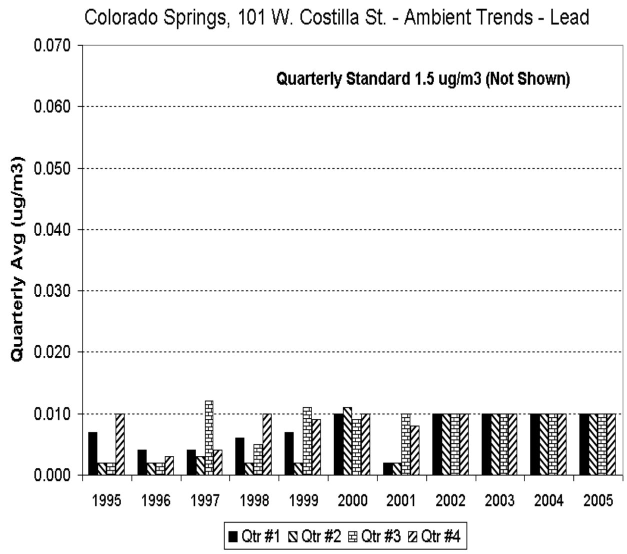
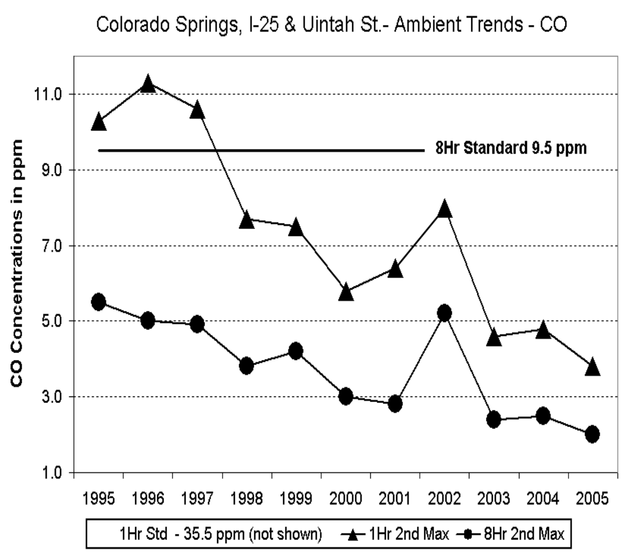


Table 33 - Southern Front Range Carbon Monoxide Values For 2005

Site Name	Location	CO 1-hour Avg. (ppm)		CO 8-hour Avg. (ppm)	
		Maximum	2nd Maximum	Maximum	2nd Maximum
El Paso					
Colorado Springs	I-25 & Uintah St.	4.9	3.8	2.1	2.0
	690 Hwy. 24	5.9	5.2	3.7	2.7

Figure 29 - Southern Front Range Carbon Monoxide Graphs



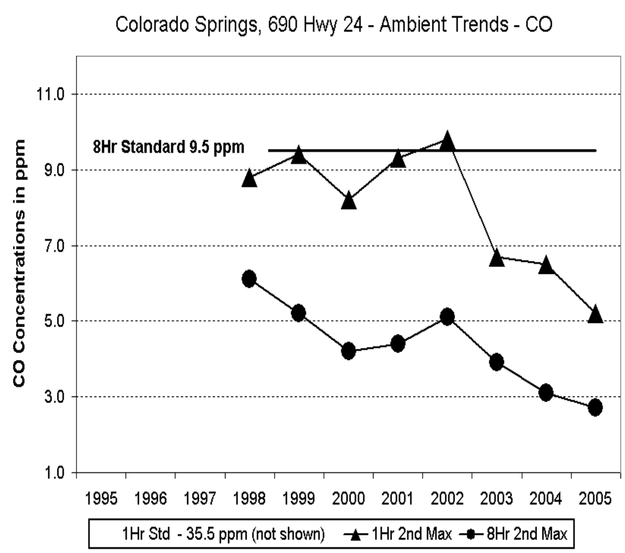


Table 34 - Southern Front Range Ozone Values For 2005

Site Name	Location	Ozone 1-hour Avg. (ppm)		Ozone 8-hour Avg. (ppm)	
		Maximum	2nd Maximum	Maximum	4th Maximum
El Paso					
Colorado Springs	USAFA Rd. 640	0.099	0.098	0.086	0.077
Manitou Springs	101 Banks Pl.	0.100	0.089	0.082	0.075

Figure 30 - Southern Front Range Ozone Graph

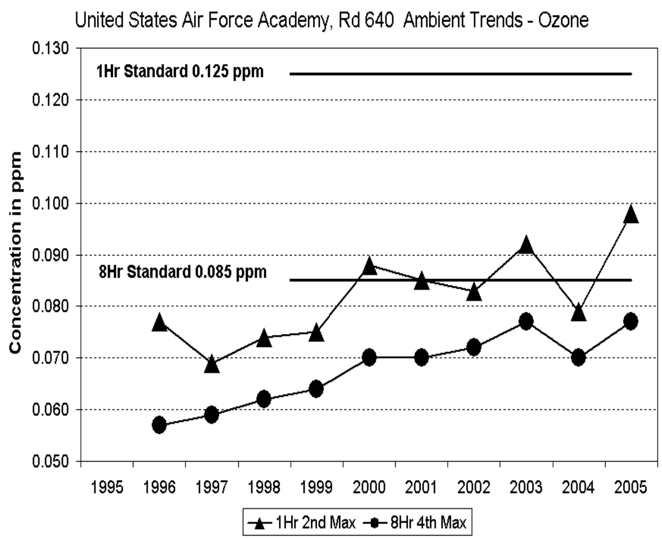
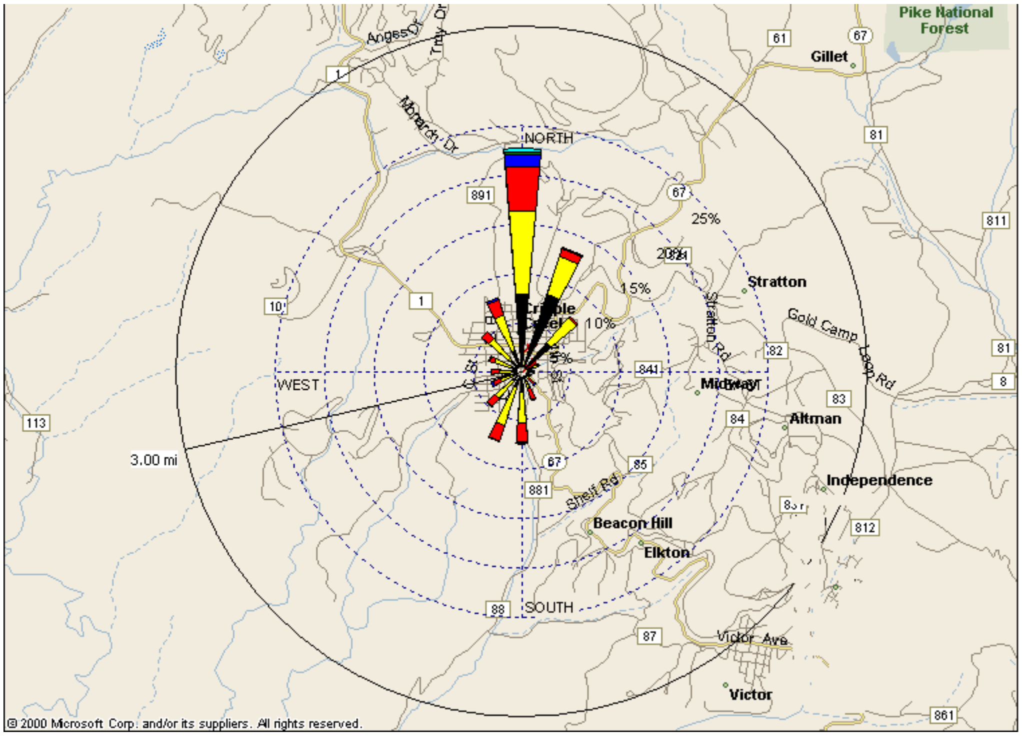


Figure 31 - Southern Front Range Wind Rose
Cripple Creek, Warren Ave. & 2nd St.



6.4 Mountain Counties

The Mountain Counties are generally the towns near the Continental Divide. They are mostly small towns in tight mountain valleys. Their primary monitoring concern is with particulate pollution from wood burning and road sanding. These communities range from Steamboat Springs in the north, to Silverthorne and Breckenridge in the I-70 corridor, Aspen, Leadville, Crested Butte, Mt. Crested Butte and Gunnison in the central mountains to Telluride in the southwest.

Table 35 - Mountain Counties Monitors In Operation For 2005

X - Monitors continued in 2005   A – Monitors added in 2005

D – Monitors discontinued in 2005   H – Hourly particulate monitor

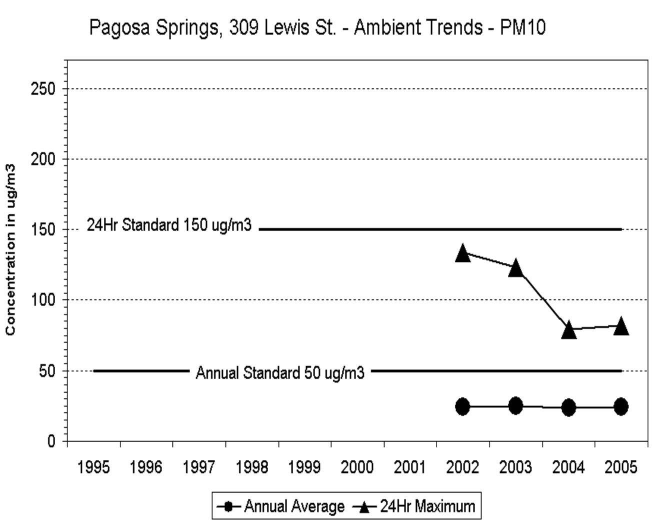
Site Name	Location	TSP	Pb	PM_{10}	$PM_{2.5}$	Met
Archuleta						
Pagosa Springs	309 Lewis St.			X	X	
Gunnison						
Crested Butte	Colo. 135 & Whiterock			X		
Mt. Crested Butte	9 Emmons Loop			D	D	
Gunnison	211 Wisconsin Ave.			X		
Mt. Crested Butte	19 Emmons Loop			A	A	
Lake						
Leadville	510 Harrison St.	X	X			
Pitkin						
Aspen	120 Mill St.			X/H		
Routt						
Steamboat Springs	136 6th St.			X	D	
	137 10th St.					D
San Miguel						
Telluride	333 W. Colordo Ave.			X	X	
Summit						
Breckenridge	501 N. Park Ave.			X		

Table 36 - Mountain Counties Particulate Values For 2005

Site Name	Location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
		Annual Average	24-Hr Maximum	Annual Average	24-Hr Maximum
Archuleta					
Pagosa Springs	309 Lewis St.	(24.0)	82	(5.09)	9.8
Gunnison					
Crested Butte	Colo. 135 & Whiterock	25.5	82		
Mt. Crested Butte	9 Emmons Loop	(39.9)	172	(6.14)	14.1
Gunnison	211 Wisconsin Ave.	16.0	46		
Mt. Crested Butte	19 Emmons Loop	(27.7)	137	(5.59)	14.8
Pitkin					
Aspen	120 Mill St.	(19.0)	51		
	(Continuous Monitor)	18.2	69		
Routt					
Steamboat Springs	136 6th St.	22.0	86	(6.28)	12.6
San Miguel					
Telluride	333 W. Colorado Ave.	(20.8)	70	(4.75)	14.3
Summit					
Breckenridge	501 N. Park Ave.	(21.4)	170		

() Indicates less than 75% data for one or more quarters.

Figure 32 - Mountain Counties PM_{10} Particulate Graphs



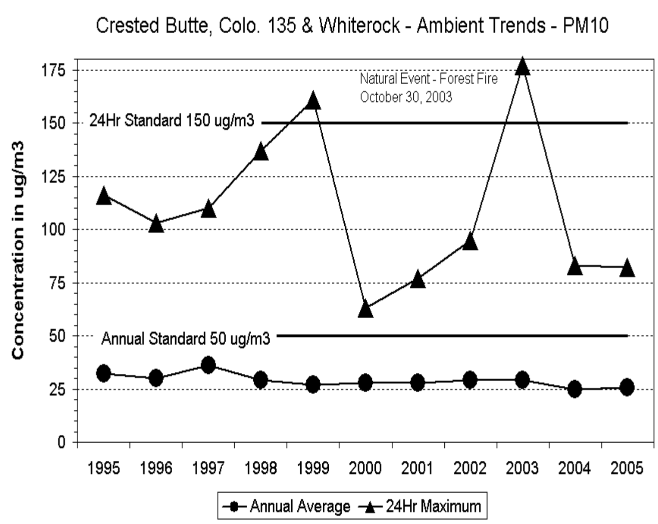
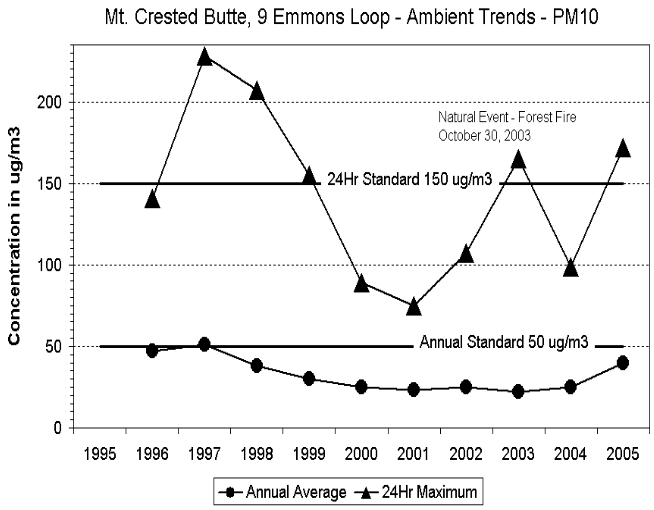
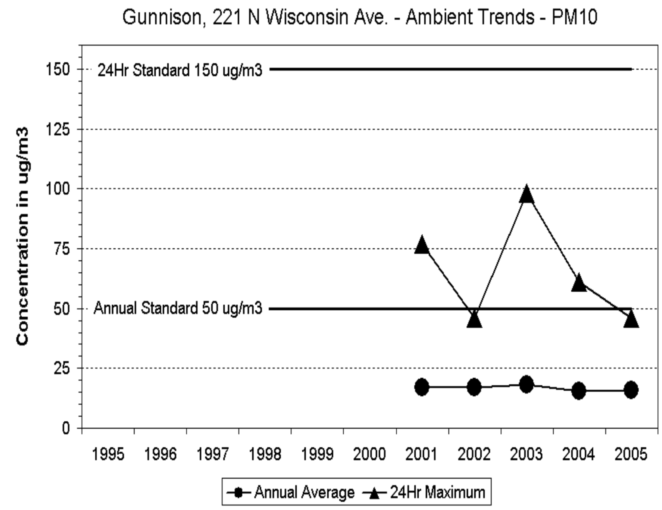
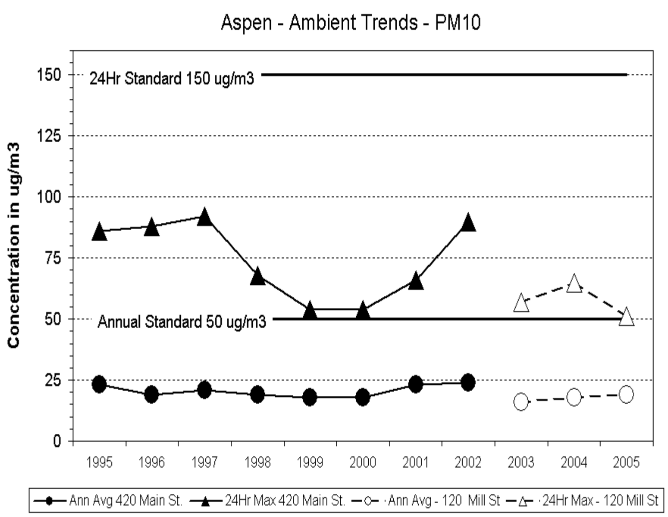
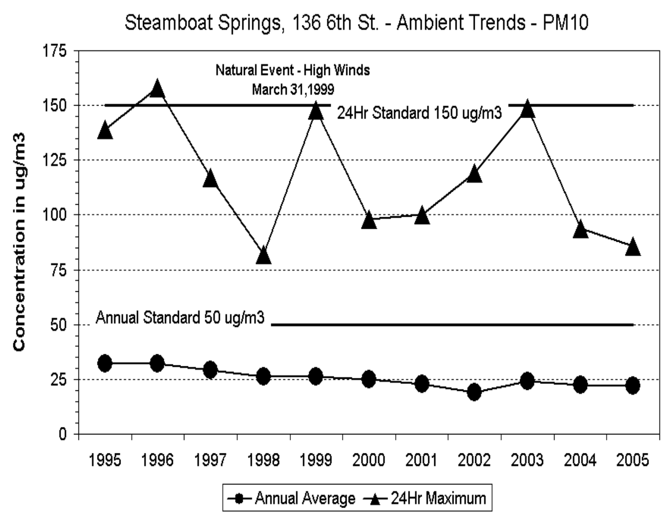


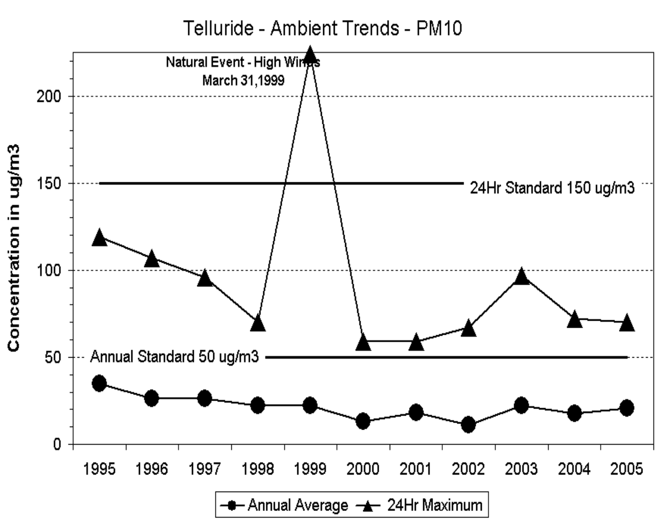
Figure 32 - Mountain Counties PM_{10} Particulate Graphs (continued)











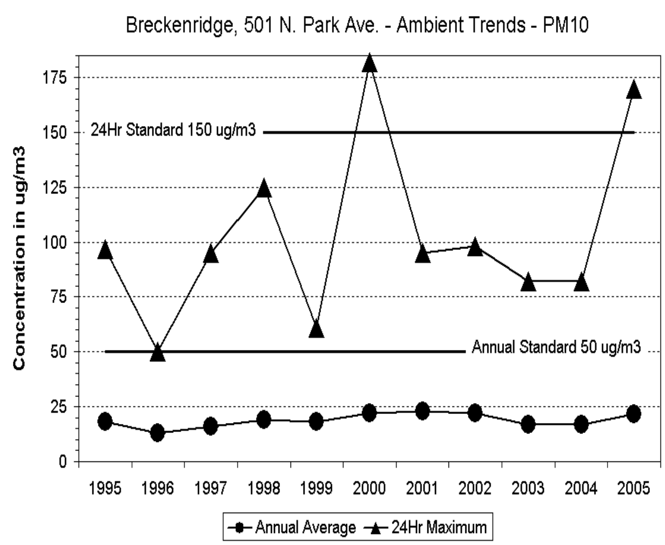
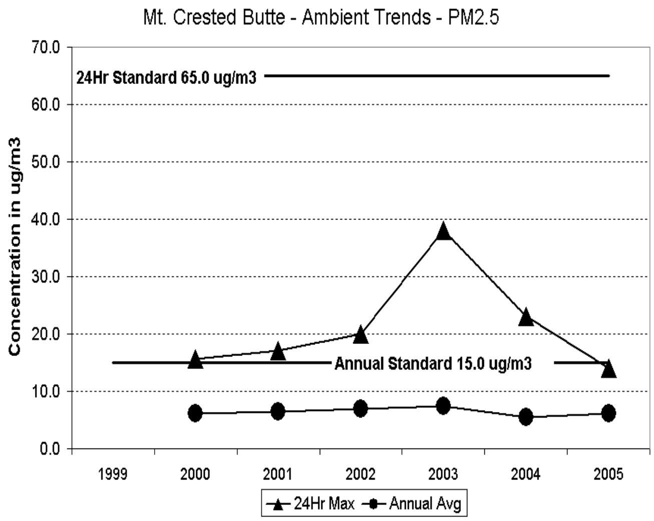
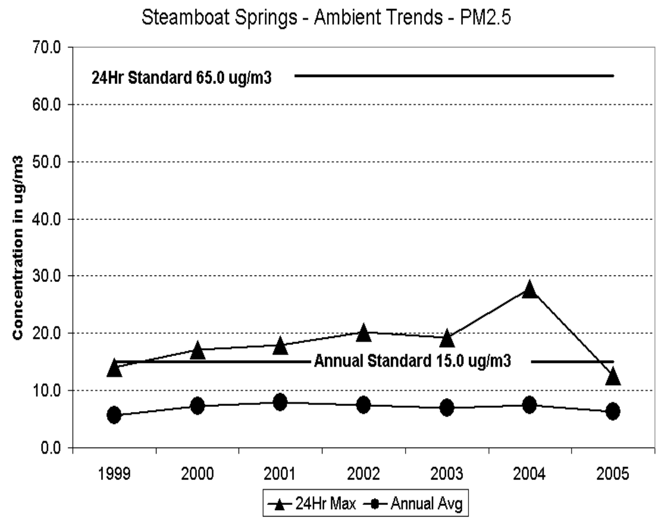


Figure 33 - Mountain Counties $PM_{2.5}$ Particulate Graphs





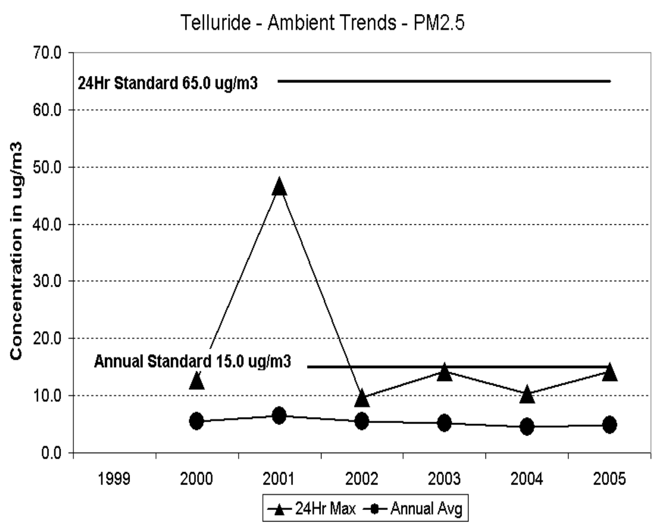


Table 37 - Mountain Counties TSP and Lead Concentrations For 2005

Site Name	Location	TSP (µg/m³)		Lead (µg/m³)	
		24-Hr Maximum	Annual Mean	Maximum Quarter	24-Hr Maximum
Lake					
Leadville	510 Harrison St.	(29.3)	64	0.02	0.055

Figure 34 - Mountain Counties Lead Graphs

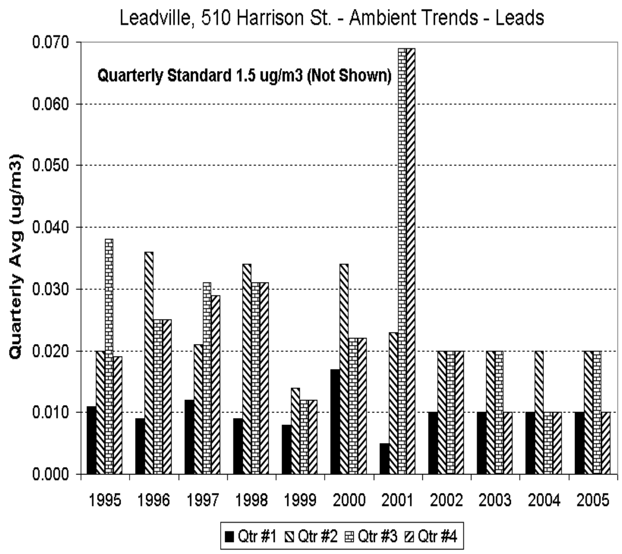
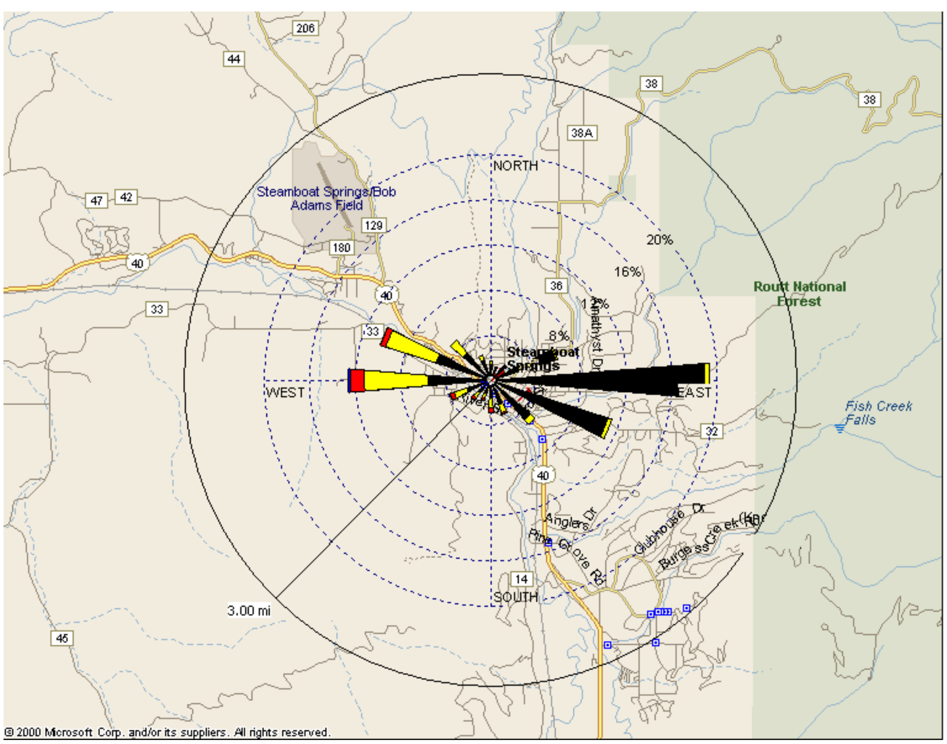


Figure 35 – Mountain Counties Wind Roses
Steamboat Springs, 137 10th St.



6.5 Western Counties

The Western Counties are generally smaller towns in fairly broad river valleys. Grand Junction is the only large city in the area and the only location that monitors for carbon monoxide on the western slope. The other locations monitor only for particulates. They are located in Parachute, Delta, Durango and Pagosa Springs.

Table 38 - Western Counties Monitors In Operation For 2005

X - Monitors continued in 2005 A – Monitors added in 2005

D – Monitors discontinued in 2005 H – Hourly particulate monitor S – Chemical Speciation

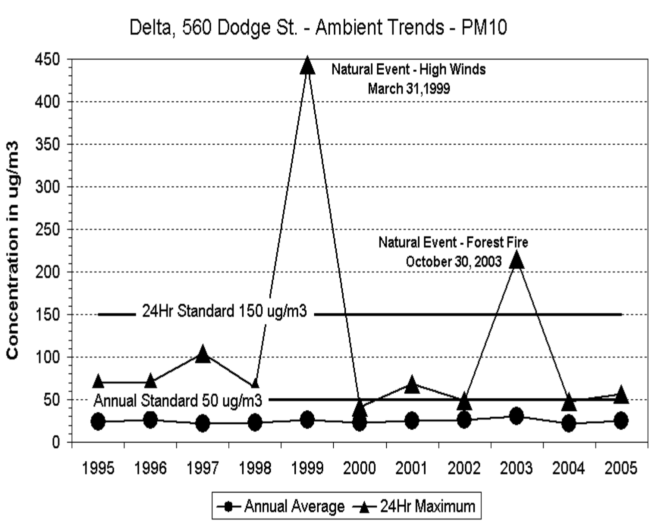
Site Name	Location	CO	PM_{10}	$PM_{2.5}$	Met
Delta					
Delta	560 Dodge St.		X	X	
Garfield					
Parachute	100 E. 2nd Ave.		X		
Rifle	144 E. 3rd Ave.		A		
New Castle	402 W. Main St.		A		
Silt – Bell Ranch	512 Owens Dr.		A		
Silt – Daley Ranch	884 County Rd. 327		A		
Silt – Cox Ranch	5933 County Rd. 233		A		
Glenwood Spgs	109 8th St.		A		
La Plata					
Durango	1060 2nd Ave.		X		
	56 Davidson Creek Rd.		X		
	1235 Camino Del Rio		X		
	1455 S. Camino del Rio		D		
	117 Cutler Dr.		X		
Mesa					
Grand Junction	650 South Ave.		X	X/H/S	
	645¼ Pitkin Ave.	X	H		X

Table 39 - Western Counties Particulate Values For 2005

Site Name	Location	PM_{10} (µg/m³)		$PM_{2.5}$ (µg/m³)	
		Annual Average	24-Hr Maximum	Annual Average	24-Hr Maximum
Delta					
Delta	560 Dodge St.	25.5	56	(6.98)	16.8
Garfield					
Parachute	100 E. 2nd Ave.	23.4	64		
Rifle	144 E. 3rd Ave.	(24.5)	52		
New Castle	402 W. Main St.	(21.6)	92		
Silt – Bell Ranch	512 Owens Dr.	(10.4)	26		
Silt – Daley Ranch	884 County Rd. 327	(9.2)	26		
Silt – Cox Ranch	5933 County Rd. 233	(15.1)	62		
Glenwood Springs	106 8th St.	(14.4)	26		
La Plata					
Durango	1060 2nd Ave.	17.0	66		
	56 Davidson Creek Rd.	(26.0)	96		
	1235 Camino Del Rio	20.7	85		
	1455 S. Camino del Rio	(14.2)	24		
	117 Cutler Dr.	(12.7)	30		
Mesa					
Grand Junction	650 South Ave.	(26.0)	198*	8.36	19.0
(Continuous Monitor)	645¼ Pitkin Ave.	31.9	147*		

() Indicates less than 75% data for one or more quarters.
* This value occurred on April 19 2005 as a result of a dust storm blowing from Arizona and Utah.

Figure 36 - Western Counties PM_{10} Particulate Graphs



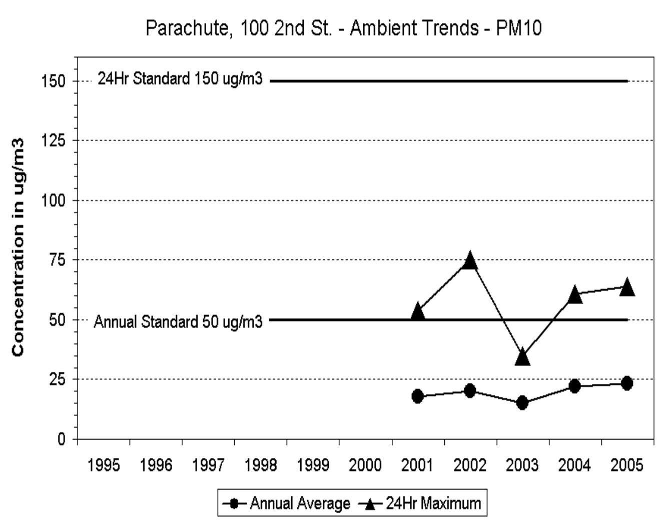
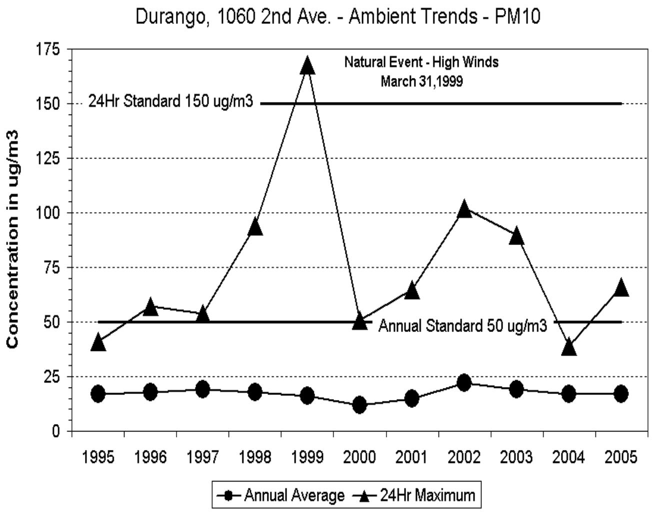
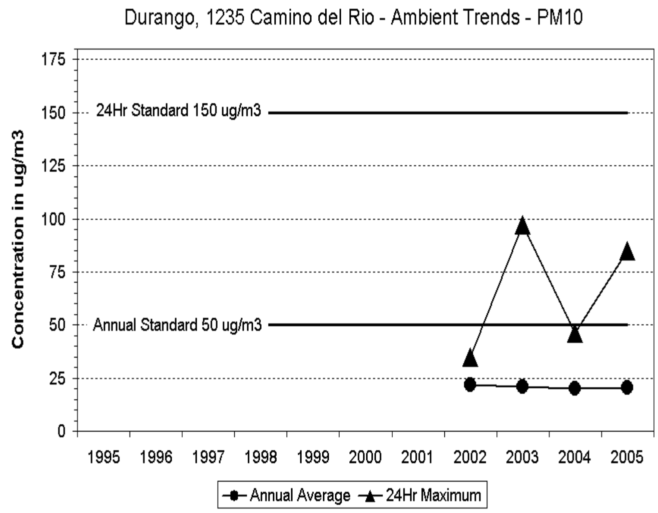
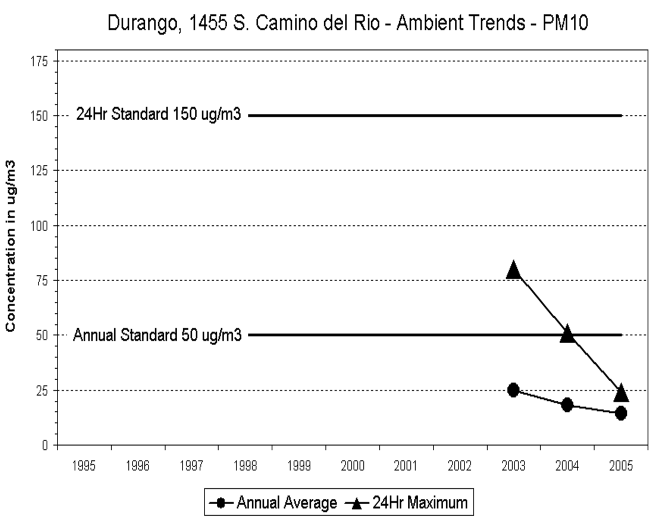
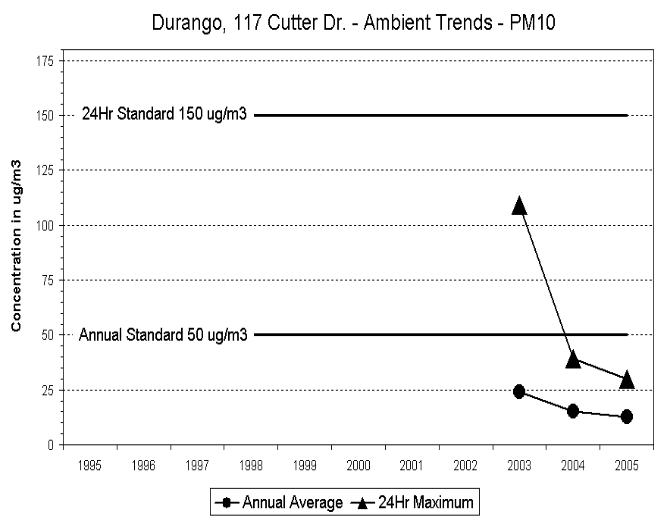


Figure 36 - Western Counties PM_{10} Particulate Graphs (continued)









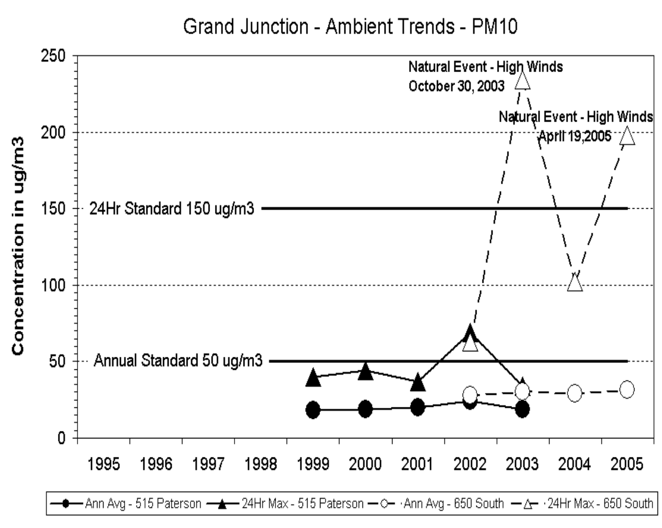


Figure 37 - Western Counties $PM_{2.5}$ Particulate Graph

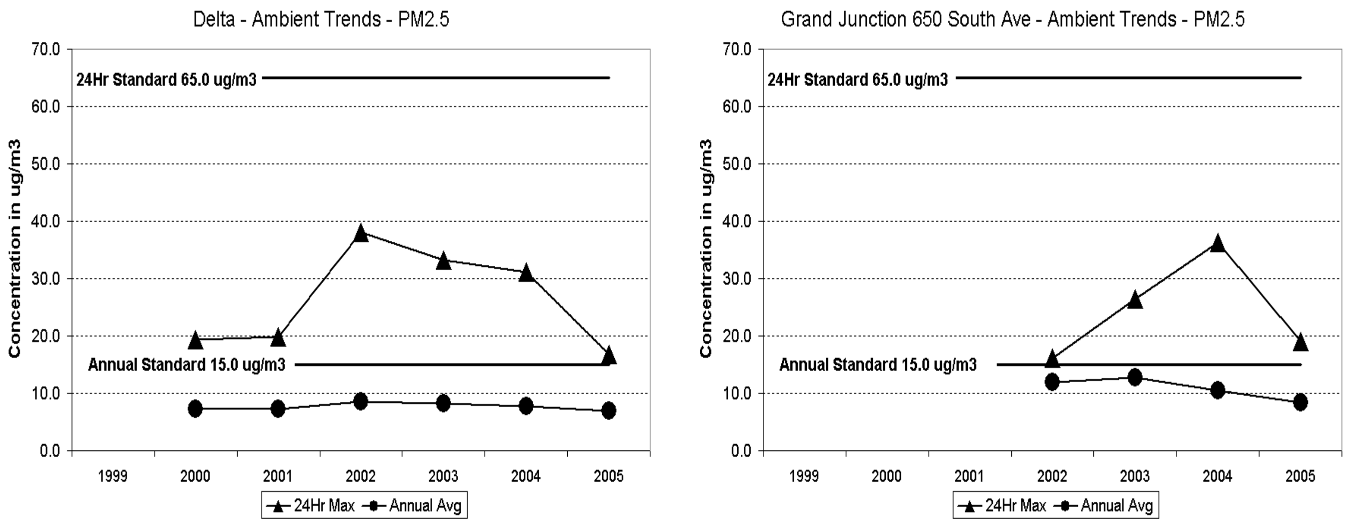


Table 40 - Western Counties Carbon Monoxide Values For 2005

Site Name	Location	CO 1-hour Avg.(ppm)		CO 8-hour Avg.(ppm)	
		Maximum	2nd Maximum	Maximum	2nd Maximum
Mesa					
Grand Junction	645¼ Pitkin Ave.	2.8	2.7	2.0	2.0

Figure 38 - Western Counties Carbon Monoxide

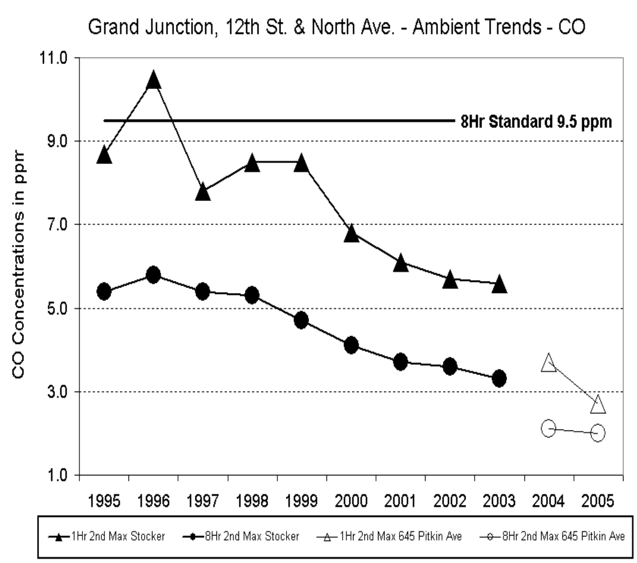
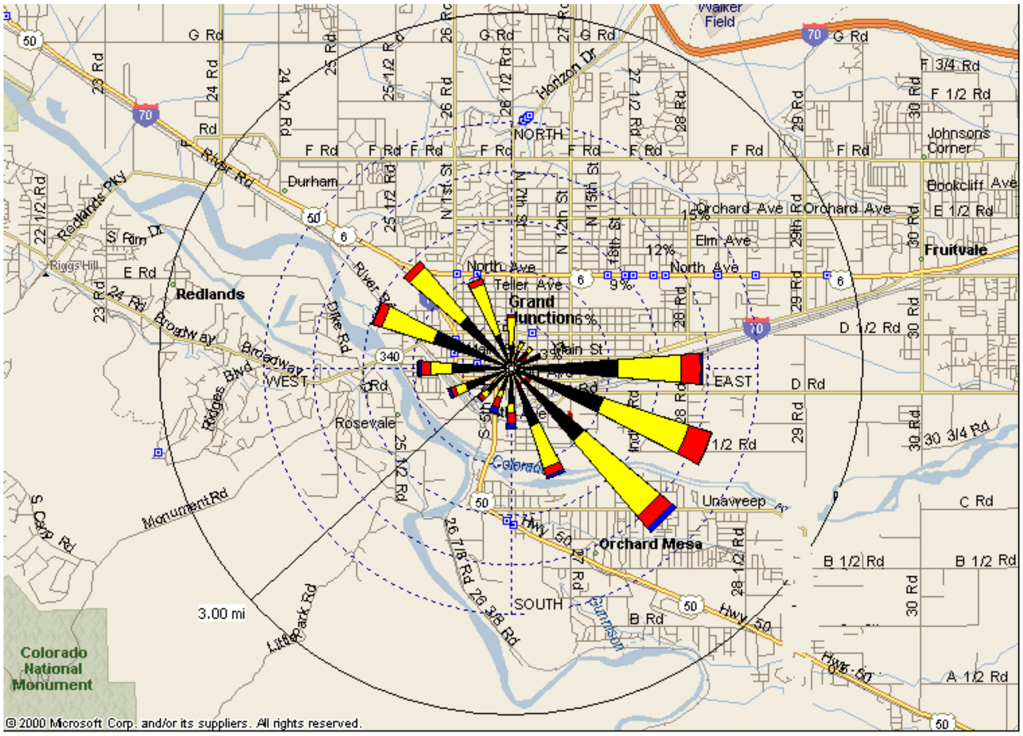


Figure 39 - Western Counties Wind Roses
Grand Junction, 645¼ Pitkin Ave.



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