Executive Summary

The national visibility goal was established in section 169A of the 1977 Clean Air Act (CAA) as "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Federal Class I areas which impairment results from manmade air pollution." There are 156 mandatory Federal Class I areas identified for visibility protection under this provision. Section 169B of the 1990 CAA Amendments required EPA to issue a report to Congress estimating the visibility improvement expected in these 156 areas resulting from implementation of the 1990 Amendments. In October 1993, EPA issued its report entitled *Effects of the 1990 Clean Air Act Amendments on Visibility in Class I Areas: An EPA Report to Congress (EPA 452/R-93-014).* Section 169B also requires EPA to provide Congress with regular assessments of the actual progress and improvements in visibility in the mandatory Federal Class I areas. This document is the first report to Congress that reviews past progress. This report presents visibility trends and analyses of annual and seasonal pollutant composition based on 1994-1998 monitoring data from 46 sites (Figure ES-1).

In this report, the term visibility refers to the clarity with which scenic vistas and landscape features are perceived at great distances. Visibility impairment, quantified as light extinction, is caused by the scattering and absorption of light by particles and gases in the atmosphere. Without the effects of human-caused air pollution, a natural visual range is estimated to be about 140 miles in the western U.S. and 90 miles in the eastern U.S.

As part of its visibility protection program, EPA participates in the IMPROVE visibility monitoring program (Interagency Monitoring of Protected Visual Environments) with other representatives from Federal and regional-state organizations. The IMPROVE program was initiated in 1988 at 30 monitoring sites and has been expanded to 110 sites in 2001. These sites were established to be representative of all mandatory Federal Class I areas except the isolated Bering Sea Wilderness.

The five major types of small particles (aerosols) measured by the IMPROVE program are sulfates, nitrates, organic carbon, elemental carbon, and crustal material. These pollutants originate from different emission sources and impair visibility—extinguish light—to varying degrees. The calculated aerosol light extinction coefficients are directly related to the concentrations of the aerosol pollutants, with a correction for relative humidity. Average values are reported in Table ES–1. From 1994 to 1998, the annual average calculated aerosol light extinction coefficients at the Eastern monitors (sites located east of 100° W longitude) and Western monitors were 87 and 23 Mm^{-1}, respectively. All five pollutant species contributed more to the average light extinction in the East than in the West. Table ES–1 also shows the calculated light extinctions, averaged from 1994 to 1998, corresponding to the lowest sampler average, average sampler average, and highest sampler average. Between 1994 and 1998, sulfate particles accounted for 23 to 78 percent of the calculated aerosol light extinction on an annual basis at the sites. Nitrate particles accounted for 3 to 39 percent of the calculated light extinction, organic carbon for 9 to 38 percent, elemental carbon for 2 to 16 percent, and crustal material for 3 to 31 percent.

Sulfate and nitrate aerosols are generally formed in the atmosphere from sulfur dioxide and nitrogen oxide emissions. The major manmade source of sulfur dioxide is coal combustion. Fossil fuel com-

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1 The Clean Air Act defines mandatory Federal Class I areas as certain national parks (over 6,000 acres), wilderness areas (over 5,000 acres), national memorial parks (over 5,000 acres), and international parks that were in existence as of August 7, 1977.

Figure ES–1. Locations of IMPROVE Particulate Matter Samplers Operating Continuously from 1994–1998 (Green Shaded Areas Represent Mandatory Federal Class I Areas)

bustion (e.g., coal, natural gas, and oil, including gasoline and diesel) is the major source of nitrogen oxides. Between 1994 and 1998, the highest calculated visibility impairment from sulfate particles occurred at the IMPROVE monitoring sites in the eastern United States. The highest calculated aerosol light extinction coefficients from nitrate particles occurred at sites in southern California and urban Washington, DC.

Table ES–1. Annual Average Light Extinction (1994–1998)

	Calculated Aerosol Light Extinction Coefficient (Mm^{-1})					
	Eastern Sites			Western Sites		
Pollutant	Lowest Sampler Average	Average	Highest Sampler Average	Lowest Sampler Average	Average	Highest Sampler Average
Sulfate	18.1	61.4	101.3	3.0	8.8	24.7
Nitrate	3.0	6.8	13.7	0.5	3.0	16.9
Organic Carbon	6.0	10.0	15.7	2.3	5.2	14.5
Elemental Carbon	1.8	4.8	12.4	0.9	2.0	5.3
Crustal Material	2.1	4.2	8.2	1.9	3.7	8.1
Observed Aerosol Extinction Coefficients from all Monitors	35	87	130	10	23	50

Organic carbon aerosols can often trace their origins to emissions from vegetative growth, vegetation burning, or solvent usage processes. The organic carbon light extinction coefficients were fairly uniform across the United States, but the values were lowest in Denali National Park in Alaska and near the Four Corners area in the Southwest. Elemental carbon particles are often introduced into the atmosphere by incomplete combustion processes. The highest calculated aerosol light extinction coefficients attributed to elemental carbon were calculated at Glacier National Park in Montana and at southern California, mid-Atlantic, and southeastern sites.

Crustal material is introduced to the atmosphere by disturbances to the soil, such as wind erosion, agricultural tilling, heavy construction, and travel on unpaved roads. Fine soil particle concentrations (particles with aerodynamic diameters less than 2.5 microns) were lowest at Denali National Park and five coastal monitor sites. Fine soil particle concentrations were highest at Sequoia National Park (California) and the two Texas sites. Both the fine soil concentrations and the larger coarse mass concentrations, particles with aerodynamic diameters between 2.5 and 10 microns, are used to calculate the light extinction coefficients from crustal material. Light extinction from total crustal material is calculated to be lowest at Lassen Volcanic National Park (California) and Denali National Park (Alaska) and highest at Sequoia National Park (California) and the Brigantine Wilderness-E.B. Forsythe National Wildlife Refuge (New Jersey).

State summaries are provided when data from more than one IMPROVE particulate sampler is reported (Arizona, California, Colorado, Oregon, Texas, Utah, Washington, and Wyoming). The data at the seven California sites suggested regional similarities when the sites were classified as coastal, southern, or eastern sites. In other states, similar light extinction coefficients were observed for the different monitor sites unless the relative humidities varied between sites. Higher relative humidity levels at one site in a state resulted in the calculation of considerably higher sulfate and nitrate light extinction coefficients and, consequently, higher calculated total aerosol light extinction coefficients.

Under the 1990 CAAA, the EPA promulgated the Regional Haze Rule to protect visibility in 156 national parks and wilderness areas (Regional Haze Regulations, Final Rule, 1999). The final rule calls for states to establish goals aimed at improving visibility in the mandatory Federal Class I areas (Appendix A) and to develop long-term plans for reducing pollutant emissions that contribute to visibility degradation. The rule gives the states the flexibility to develop cost-effective strategies for pollution reductions and encourages states to coordinate with each other through regional planning efforts.

Instead of using the light extinction coefficient scale that is directly related to the particulate matter concentrations, the Regional Haze Rule is based on the deciview index, a scale related to visual perception. The deciview index has a value near zero for a pristine atmosphere, and each deciview unit corresponds to a small but perceptible scenic change that is observed under either clean or polluted conditions. Like the decibel scale for sound, similar changes in deciviews are perceived as equal. Figure ES–2 shows the relationship between the light extinction, deciview, and visual range scales.

The Regional Haze Rule calls for visibility improvements on the most-impaired days (the 20th percentile of the days at the site with the highest deciview index) and no additional visibility impairment on the least-impaired days (the 20th percentile of the days at a site with the lowest calculated impairment). Table ES–2 is constructed to show which sites measured statistically significant trends toward improved visibility, decreased visibility, and no change for least-impaired, mid-range, and most-impaired days. The statistically significant trends in visibility were measured over the entire operational period of the monitor.

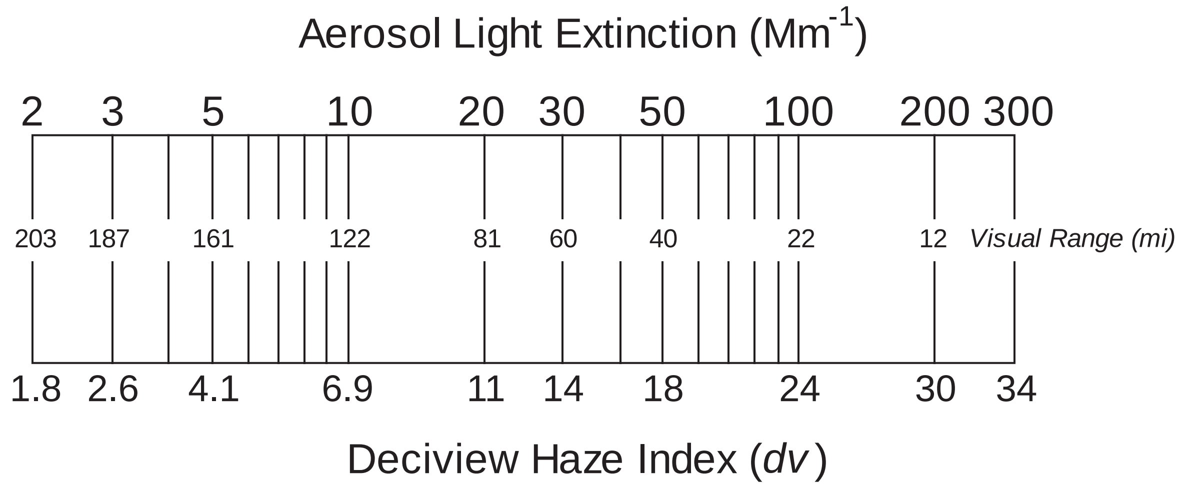

Figure ES–2. Relationship Between the Light Extinction, Deciview, and Visual Range Scales

Of all the IMPROVE particulate samplers, Jarbidge Wilderness Area in Nevada showed the best average visibility on the least-impaired days between 1994 and 1998, with an average of 3.9 deciviews (visual range [VR] 165 miles). Denali National Park in Alaska showed the best visibility on the mid-range and most-impaired days from 1994 through 1998. At the Denali site, the visibility indices on the mid-range and most-impaired days were 6.3 deciviews (VR 130 miles) and 10.4 deciviews (VR 85 miles).

Between 1994 and 1998, the worst visibility on the least-impaired days occurred at the Sipsey Wilderness Area in Alabama that showed an average value of 19.2 deciviews (VR 36 miles). Mammoth Cave National Park in Kentucky displayed the worst visibility on the mid-range and most-impaired days, with visibility indices of 25.2 deciviews (VR 20 miles) on the mid-range days and 32.1 deciviews (VR 10 miles) on the most-impaired days.

Besides the Regional Haze Rule, EPA has put in place other rules and policies that have had, and will continue to have, a positive impact on visibility in mandatory Federal Class I areas and throughout the country. Title IV of the CAAA (the Acid Rain Program) called for reductions in sulfur dioxide and nitrogen oxide emissions in the 1990s, with additional reductions in the year 2000. Implementation of the Particulate Matter and Ozone National Ambient Air Quality Standards (NAAQS), through their associated emission reductions of nitrogen oxides and particulate matter, is expected to improve visibility in urban and rural areas across the country. Other efforts aimed at reducing sulfur dioxide and nitrogen oxide emissions include the recent NO_x State Implementation Plan Call (NO_x SIP Call) to reduce point-source NO_x emissions and the Tier II emission reduction rules aimed at reducing mobile source emissions.

Table ES–2. Visibility Trends at IMPROVE Monitoring Locations[1]

Trend	Least-Impaired Days	Mid-Range Days	Most-Impaired Days
Improved Visibility	Acadia National Park (ME) Badlands National Park (SD) Great Sand Dunes National Monument (CO) Pinnacles National Monument (CA) Washington (DC)[2] Yellowstone National Park (WY)	Acadia National Park (ME) Bandelier National Monument (NM) Dolly Sods Wilderness (WV) Great Sand Dunes National Monument (CO) Pinnacles National Monument (CA) Shenandoah National Park (VA) Washington (DC)[2]	Canyonlands National Park (UT) Mammoth Cave National Park (KY) Pinnacles National Monument (CA) Redwood National Park (CA) San Gorgonio Wilderness (CA)
No Statistically Significant Change in Visibility	Bandelier National Monument (NM) Big Bend National Park (TX) Boundary Waters Canoe Area (MN) Bridger Wilderness (WY) Brigantine Wilderness-E.B. Forsythe Natl. Wildlife Refuge (NJ) Bryce Canyon National Park (UT) Canyonlands National Park (UT) Chassahowitzka National Wildlife Refuge (FL) Crater Lake National Park (OR) Denali National Park (AK) Dolly Sods Wilderness (WV) Glacier National Park (MT) Grand Canyon National Park (AZ) Great Basin National Park (NV)[2] Great Smoky Mountains National Park (TN) Guadalupe Mountains National Park (TX) Indian Garden-Grand Canyon National Park (AZ) Jarbidge Wilderness (NV) Lassen Volcanic National Park (CA) Mammoth Cave National Park (KY) Mesa Verde National Park (CO) Mt. Rainier National Park (WA) Okefenokee National Wildlife Refuge (GA) Petrified Forest National Park (AZ) Point Reyes National Seashore (CA) Redwood National Park (CA) Rocky Mountain National Park (CO) San Gorgonio Wilderness (CA)	Snoqualmie Pass-Alpine Lakes Wilderness (WA) Badlands National Park (SD) Big Bend National Park (TX) Boundary Waters Canoe Area (MN) Bridger Wilderness (WY) Brigantine Wilderness-E.B. Forsythe Natl. Wildlife Refuge (NJ) Bryce Canyon National Park (UT) Canyonlands National Park (UT) Chassahowitzka National Wildlife Refuge (FL) Chiricahua National Monument (AZ) Crater Lake National Park (OR) Denali National Park (AK) Glacier National Park (MT) Grand Canyon National Park (AZ) Great Basin National Park (NV)[2] Great Smoky Mountains National Park (TN) Guadalupe Mountains National Park (TX) Indian Garden-Grand Canyon National Park (AZ) Jarbidge Wilderness (NV) Lassen Volcanic National Park (CA) Lye Brook Wilderness (VT) Mammoth Cave National Park (KY) Mesa Verde National Park (CO) Mt. Rainier National Park (WA) Okefenokee National Wildlife Refuge (GA) Petrified Forest National Park (AZ) Point Reyes National Seashore (CA) Redwood National Park (CA)	Snoqualmie Pass-Alpine Lakes Wilderness (WA) Acadia National Park (ME) Badlands National Park (SD) Bandelier National Monument (NM) Big Bend National Park (TX) Boundary Waters Canoe Area (MN) Bridger Wilderness (WY) Brigantine Wilderness-E.B. Forsythe Natl. Wildlife Refuge (NJ) Bryce Canyon National Park (UT) Chassahowitzka National Wildlife Refuge (FL) Chiricahua National Monument (AZ) Crater Lake National Park (OR) Denali National Park (AK) Dolly Sods Wilderness (WV) Glacier National Park (MT) Grand Canyon National Park (AZ) Great Basin National Park (NV)[2] Great Sand Dunes National Monument (CO) Great Smoky Mountains National Park (TN) Guadalupe Mountains National Park (TX) Indian Garden-Grand Canyon National Park (AZ) Jarbidge Wilderness (NV) Lassen Volcanic National Park (CA) Lye Brook Wilderness (VT) Mesa Verde National Park (CO) Mt. Rainier National Park (WA) Okefenokee National Wildlife Refuge (GA)

Table ES–2. Visibility Trends at IMPROVE Monitoring Locations[1] *(continued)*

Trend	Least-Impaired Days	Mid-Range Days	Most-Impaired Days
No Statistically Significant Change in Visibility (cont.)	Shenandoah National Park (VA) Sipsey Wilderness (AL) Three Sisters Wilderness (OR) Tonto National Monument (AZ) Upper Buffalo Wilderness (AR) Weminuche Wilderness (CO) Yosemite National Park (CA)	Rocky Mountain National Park (CO) San Gorgonio Wilderness (CA) Sipsey Wilderness (AL) Three Sisters Wilderness (OR) Tonto National Monument (AZ) Upper Buffalo Wilderness (AR) Weminuche Wilderness (CO) Yellowstone National Park (WY) Yosemite National Park (CA)	Petrified Forest National Park (AZ) Point Reyes National Seashore (CA) Rocky Mountain National Park (CO) Shenandoah National Park (VA) Sipsey Wilderness (AL) Three Sisters Wilderness (OR) Tonto National Monument (AZ) Upper Buffalo Wilderness (AR) Washington (DC)[2] Weminuche Wilderness (CO) Yellowstone National Park (WY) Yosemite National Park (CA)
Decreased Visibility	Snoqualmie Pass-Alpine Lakes Wilderness (WA) Chiricahua National Monument (AZ) Lye Brook Wilderness (VT)		

[1]The least-impaired days in a year were the 20th percentile with the lowest particulate matter concentrations, mid-range days the 20th percentile nearest the median, and the most-impaired days the 20th percentile with the highest particulate matter concentrations. In this report, an observed trend is considered statistically significant when the probability that a pattern is random is less than 5 percent (Theil method).
[2]Not a mandatory Federal Class I area, but the data from this site are included in the national and regional analyses presented in Chapter 3.