National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Air Quality in National Parks

2008 Annual Performance & Progress Report

Natural Resource Report NPS/NRPC/ARD/NRR—2009/151

ON THE COVER

Dream Lake, Rocky Mountain National Park, Colorado.
Photo by Debbie Miller.

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Air Resources Division
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Natural Resource Program Center
Denver, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate high-priority, current natural resource management information with managerial application. The series targets a general, diverse audience, and may contain NPS policy considerations or address sensitive issues of management applicability.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data presented in this report were collected and analyzed using methods based on established, peer-reviewed protocols, and were analyzed and interpreted within the guidelines of the protocols.

This report is available from the Air Resources Division of the NPS (www.nature.nps.gov/air) and the Natural Resource Publications Management Web site (http://www.nature.nps.gov/publications/NRPM) on the Internet.

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Executive Summary

The National Park Service works to preserve, protect, enhance, and understand air quality and resources sensitive to air quality in the National Park System. This is crucial to parks because air pollution affects ecological health, scenic views, human health, and visitor enjoyment even at relatively low levels.

The NPS measures progress toward improving park air quality by examining trends for key air quality indicators, including:

- visibility – which affects how well and how far visitors can see;
- atmospheric deposition – which affects ecological health through acidification and fertilization of soil and surface waters; and
- ozone – which affects human health and native vegetation.

The NPS monitors one or more of these indicators in 57 park units, and there are sufficient data to assess conditions and trends in 55 of these parks. In addition, many state and local air quality monitoring stations are located near enough to parks that the data they collect are considered reasonably representative of park air quality. As a result, air quality conditions and trends have been calculated for 181 monitoring locations representing 228 park units.

Air quality trends provide one measure of performance and progress. In general, stable or improving air quality trends may be considered a sign of success. In accordance with the Government Performance and Results Act (GPRA), the NPS has established performance goals based on trends, and reports annually on progress. These goals are stable or improving:

- visibility in 95% of NPS reporting parks,
- atmospheric deposition in 75% of NPS reporting parks, and
- ozone in 85% of NPS reporting parks.

For this Annual Performance Report, ozone, visibility, and deposition data collected between 1998 and 2007 were examined.[1] The NPS exceeds air quality performance goals for 2008, with 99 percent of the reporting parks showing stable or improving trends in visibility, 94 percent showing stable or improving trends in ozone concentrations, and 83 percent showing stable or improving trends in atmospheric deposition.

While improving trends certainly show progress, a stable trend in air quality may not be sufficient to protect an area already experiencing poor air quality. Current air quality conditions are characterized for those park units with available trend information to identify areas where stable trends may be of some concern. Using an index for each type of air quality data collected (visibility, wet deposition concentrations, and ozone concentrations), park air quality is characterized as good, moderate (or cautionary), or of significant concern.

- With respect to visibility, 59 percent of the parks are in good or moderate condition. All of the parks with significant visibility concerns have stable—not improving—trends.
- For nitrogen deposition, only 29 percent of the parks are in good or moderate condition. Of the parks where nitrogen deposition is a significant concern, five parks have degrading trends, 35 have stable trends, and one has an improving trend.
- For sulfur deposition, 48 percent of the parks are in good or moderate condition. Of the parks where sulfur deposition is a significant concern, six have improving trends and 24 have stable trends. No park has a degrading trend with respect to sulfur deposition.
- With respect to ozone, 32 percent of the parks are in good or moderate condition. Among the parks where current ozone conditions are of significant concern, 33 have improving trends, 74 have stable trends, and one has a degrading trend.

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[1] The lag time in data reporting results from quality assurance and data analysis procedures.

Air quality in parks is expected to improve as regulations aimed at reducing tailpipe emissions from motor vehicles and pollution from electric-generating facilities take full effect over the next few years. In addition, states and tribes, with assistance from regional planning organizations, are in the process of implementing programs to improve visibility in national parks and wilderness areas in response to Environmental Protection Agency regulations. Information available through the NPS air quality monitoring program has provided a foundation and impetus for pollution control programs that will benefit parks. The Park Service's ability to offer expert and constructive assistance and advice to regulatory and permitting agencies has stimulated collaborative efforts to find creative and cost-effective air quality management approaches.

The images above show clear, moderate, and hazy visbility conditions (top to bottom) at Denali National Park and Preserve.

Measuring Progress–Air Quality Goals and Trends

The NPS Strategic Plan establishes the following air quality goals to meet by 2012:

- visibility in 95% of NPS reporting parks has remained stable or improved;
- atmospheric deposition in 79% of NPS reporting parks has remained stable or improved; and
- ozone in 89% of NPS reporting parks has remained stable or improved.

The target goals for 2008 were 95 percent for visibility, 85 percent for ozone, and 75 percent for atmospheric deposition. We exceeded these goals with 99 percent of the reporting parks showing stable or improving trends in visibility, 94 percent showing stable or improving trends in ozone concentrations, and 83 percent showing stable or improving trends in atmospheric deposition. Performance exceeded the goals in part because many of the park units included in this year's report are in or near urban areas, where pollution control programs have been in effect for many years. More detail on how trends are calculated appears in Appendix A.

Progress toward these goals is measured annually through target goals. Data from visibility, ozone, and precipitation monitoring are used to assess air quality trends. Six total measures are used in calculating the goal percentages: two are used to measure progress toward the visibility goal, one measure is used for the ozone goal, and three measures are used for the atmospheric deposition goal. Not all parks monitor all six of the indicators. A park is considered to have improving or stable air quality if none of the measures used for that goal show a statistically significant degrading trend (denoted in red on attached figures and table). A summary of the trend results is presented in Table 1 showing the numbers of parks in each category that had stable, improving, and degrading trends. Results of the trend analyses for individual parks are shown in Appendix B . Trends that have at least a 95% probability of being correct (those with p-values <=0.05) are shown in red (degrading trends) and blue (improving trends). Also highlighted in the table are trends that have less than a 95% probability, but greater than an 85% probability of being correct (p-values less than 0.15). They are outlined in blue (improving trends) and red (degrading trends).

All but one of the parks trended for visibility (1998–2007) recorded stable or improving trends on both clear and hazy days.

Visibility Measures

The NPS examines the clearest days and haziest days to measure visibility conditions[2]. The Environmental Protection Agency (EPA) uses these measures to assess progress toward the national goal of remedying any existing and preventing any future human caused visibility impairment in protected Class I areas[3]. This year we are able to report on 147 parks, both Class I and non-Class I, that have representative visibility monitoring and have at least 6 years of visibility data available during the period 1998-2007. All but one of the parks trended for visibility recorded stable or improving trends on both clear and hazy days. This means that 99 percent are meeting the visibility goal. On the clearest days, 35 parks are showing statistically significant improvement; these parks

Trend Category	Total Parks Trended	Stable Trends	Improving Trends	Degrading Trends
Visibility--Clearest Days	147	112	35	0
Visibility--Haziest Days	147	144	2	1
Wet Deposition--Ammonium	58	50	1	7
Wet Deposition--Nitrate	58	45	12	1
Wet Deposition--Sulfate	58	45	13	0
Ozone	161	102	46	13

Table 1. Summary of trend results for national park units with available monitoring data.

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[2] The clearest days are defined as the clearest 20% of those days each year for which visibility measurements are available, and the haziest days are the haziest 20%.

[3] Class I areas include national parks greater than 6,000 acres and wilderness areas greater than 5,000 acres that were in existence or authorized as of August 7, 1977. They receive the highest degree of air quality protection under the Clean Air Act.

include Acadia National Park in the eastern U.S., and several sites in the northwest U.S., California, Colorado Plateau, and the Rocky Mountain region. No parks show degrading trends on the clearest days. These trends are shown in Figure 1. On hazy days, most areas are showing stable—not improving—trends. Only two parks show statistically significant improvement (Mount Rainier and Olympic), while one park shows statistically significant worsening of visibility (Hawaii Volcanoes). Trends on the haziest days are shown in Figure 2.

Atmospheric Deposition Measures

Sulfate, nitrate, and ammonium ions in precipitation (rain and snow) are used as indicators of atmospheric deposition, because they can be directly linked to ecological effects (e.g., acidification of surface waters or nutrient enrichment that disrupts natural systems). This year we determined trends for 58 parks that had representative monitoring. Table 1 gives the results of the trend analyses for wet deposition.

In 45 areas (78 percent), sulfate concentrations were stable, and 13 showed

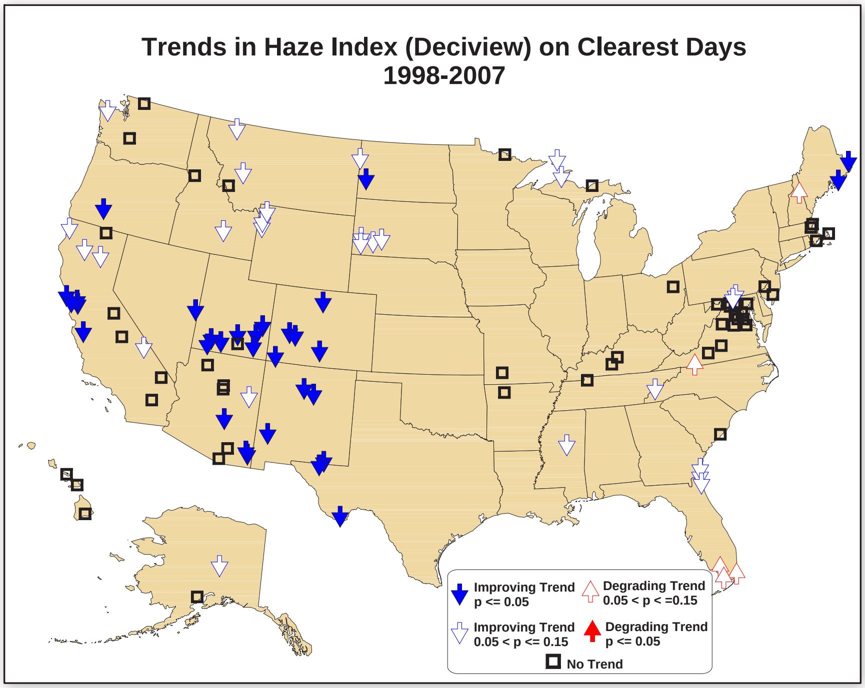

Figure 1. Trends in haze index on the clearest days, 1998-2007.

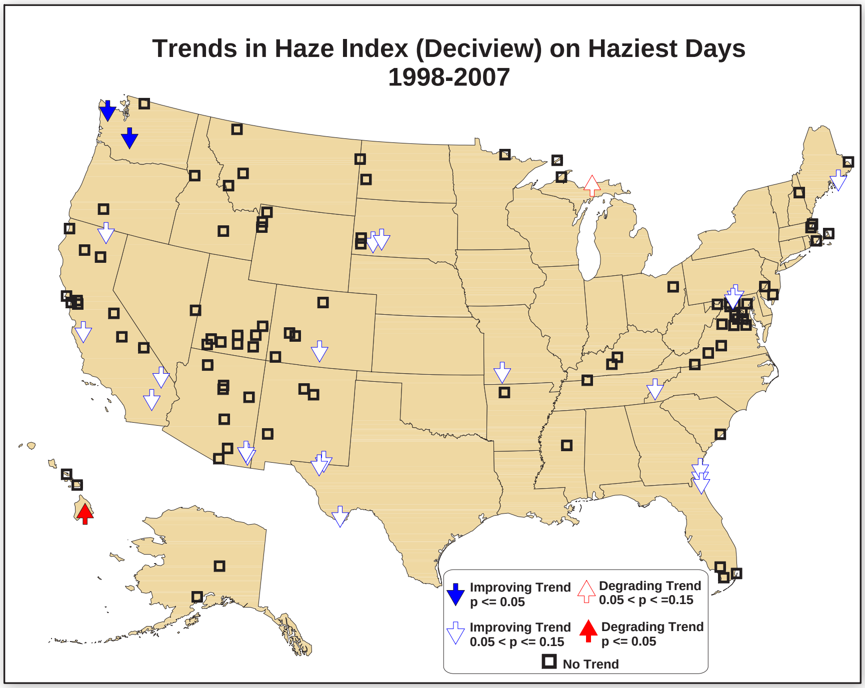

Figure 2. Trends in haze index on the haziest days, 1998-2007.

improvement. No area showed statistically significant deteriorating trends (Figure 3).

Nitrate concentrations are stable or improving in 57 parks and deteriorating in one park (Olympic). Trends in nitrate ion concentrations are shown in Figure 4.

Ammonium, another form of nitrogen, is stable in 50 areas (86 percent), with just one area showing a statistically significant improvement in concentrations. Ammonium concentrations are degrading in 7 areas, primarily in the intermountain west. Trends in ammonium are shown in Figure 5.

In total, eight parks have deteriorating nitrogen loadings: Olympic, Yellowstone, Mesa Verde, Mount Rainier, Chiricahua, Fort Bowie, Canyonlands, and Capulin Volcano. The NPS has shared information and concerns about these trends with EPA, states, tribes, and stakeholders. As explained further below, collaborative efforts are underway to better understand the causes and effects of nitrogen loadings and to explore options for protecting ecosystem health, if necessary.

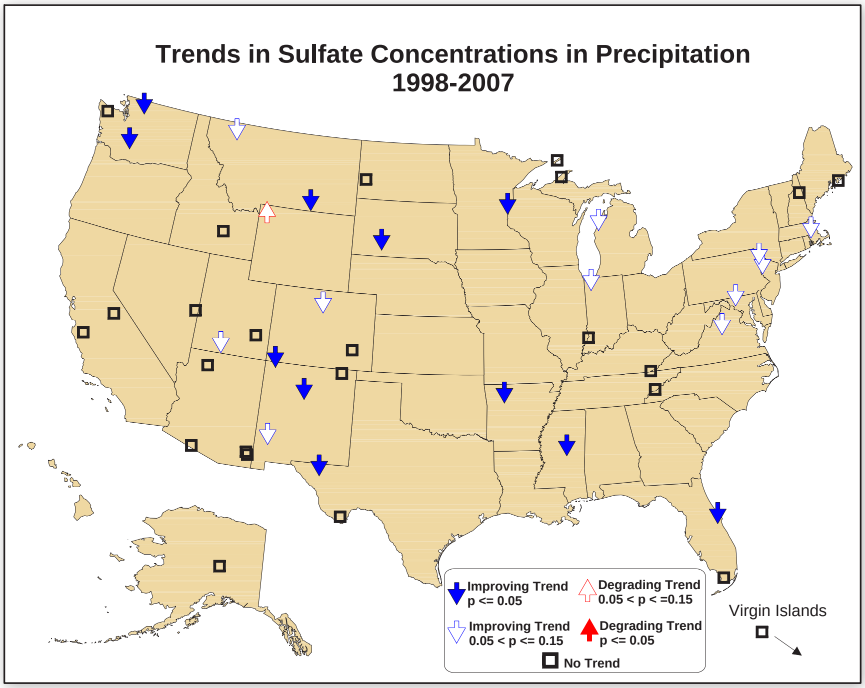

Figure 3. Trends in sulfate concentrations in precipitation, 1998-2007.

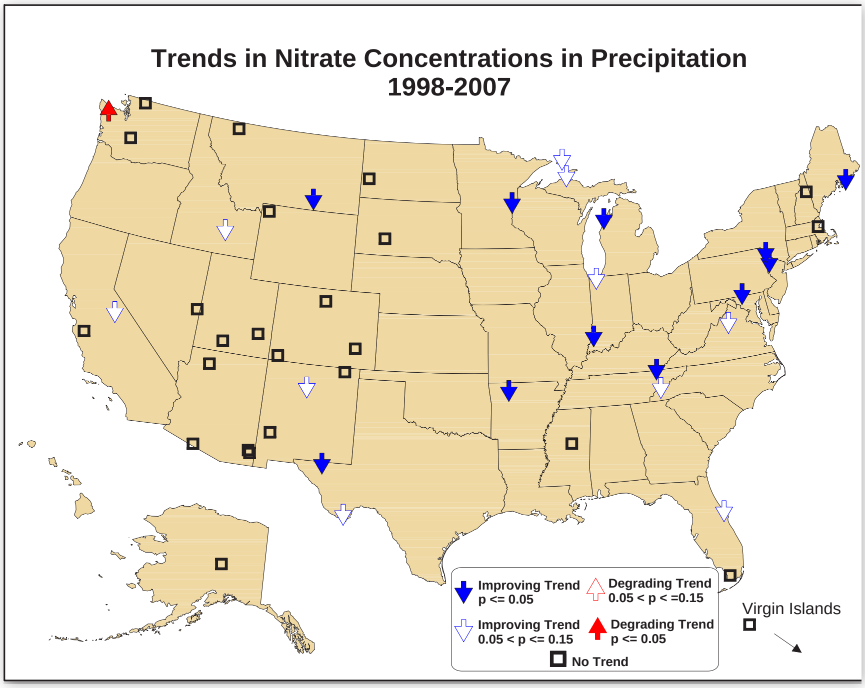

Figure 4. Trends in nitrate concentrations in precipitation, 1998-2007.

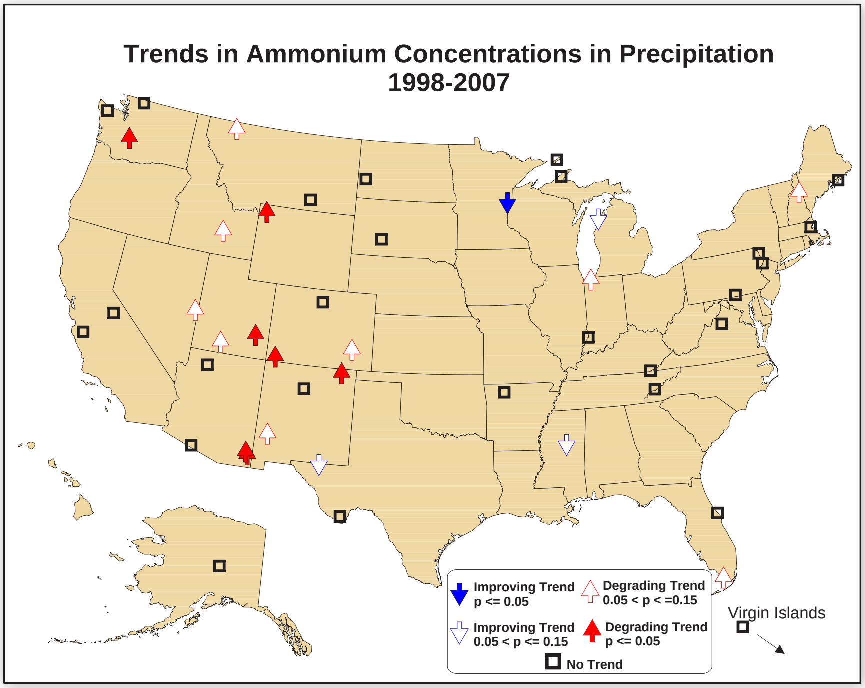

Figure 5. Trends in ammonium concentrations in precipitation, 1998-2007.

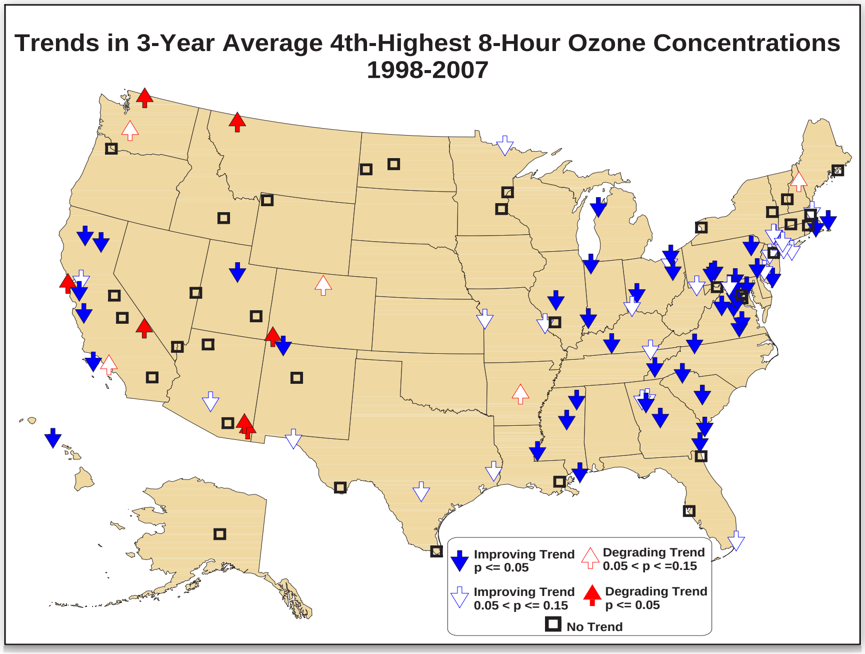

Figure 6. Trends in the 3-year average of the annual 4th-highest 8-hour ozone concentration, 1998-2007.

Ozone Measures

The NPS calculates ozone trends using EPA's metric for the primary National Ambient Air Quality Standard[4]. This standard is designed to protect the public health. Of the 161 park units that have representative ozone monitoring, 148 units have stable or improving trends (92 percent). These trends are shown in Figure 6. In the East, where ozone concentrations in parks like Great Smoky Mountains, Mammoth Cave, and Shenandoah sometimes reach levels high enough to harm human health, the ozone trends are largely improving over the past ten years. Some western parks also have improving trends, while a number of others are stable. On the other hand, several parks in the West have degrading ozone levels, including Death Valley, Mesa Verde, Glacier, North Cascades, Chiricahua, Fort Bowie, and parks in the San Francisco metropolitan area. As with concerns about increasing nitrogen loadings in western parks, the NPS has shared information about ozone trends with regulatory agencies, and several initiatives are underway to understand causes and effects and explore management options.

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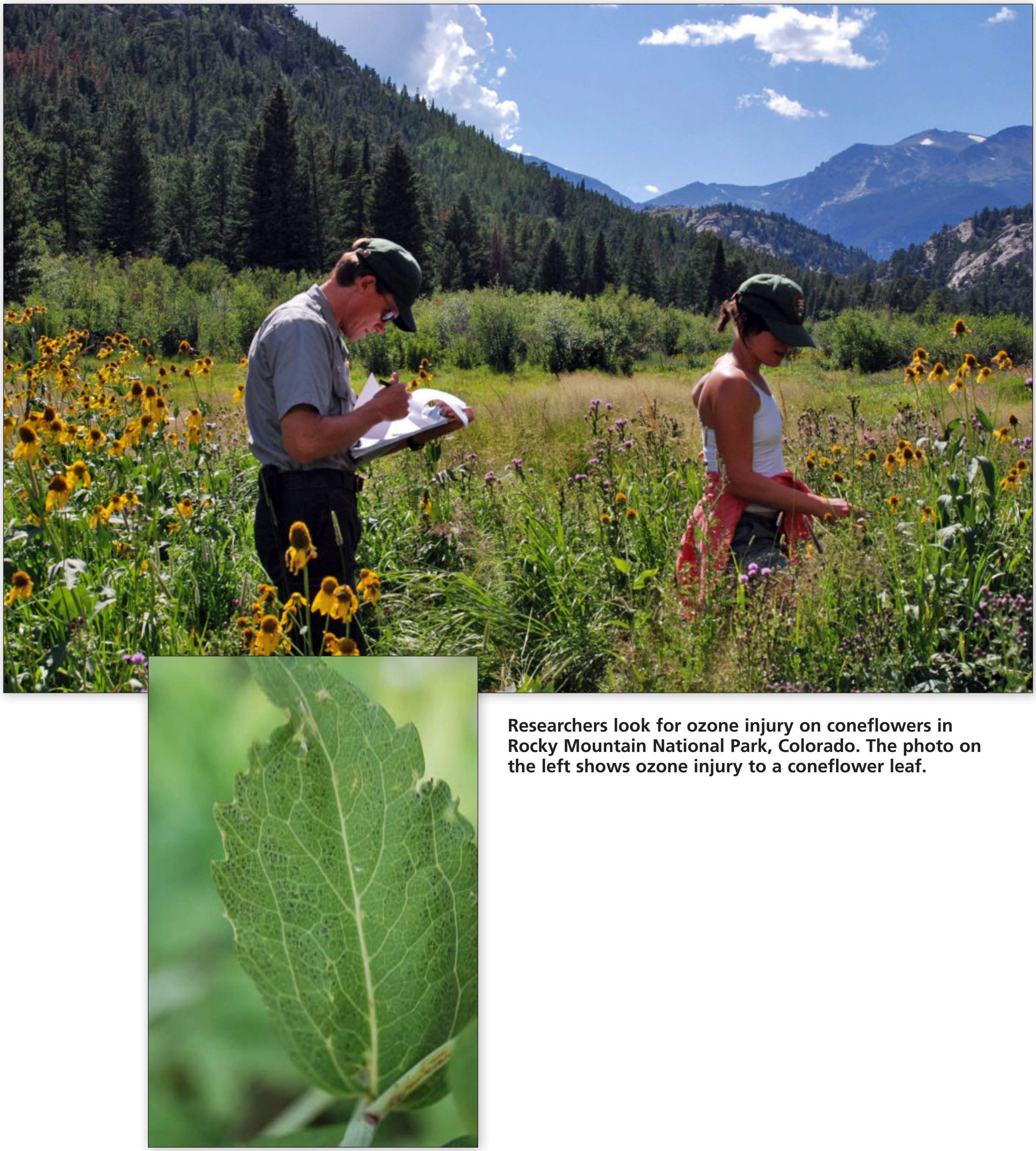
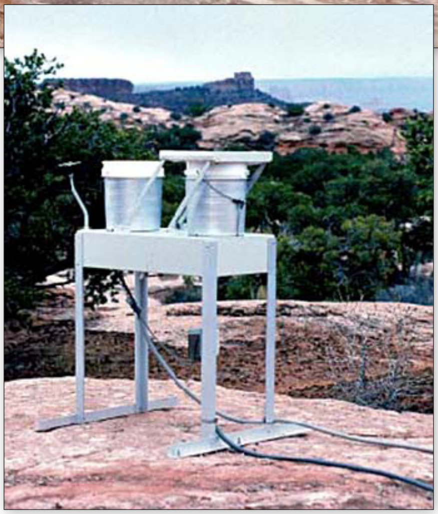
[4] The EPA determines compliance with the ozone standard using the 3-year average of the annual fourth highest daily maximum 8-hour ozone concentration.



Researchers look for ozone injury on coneflowers in Rocky Mountain National Park, Colorado. The photo on the left shows ozone injury to a coneflower leaf.



The photo at right shows deposition monitoring equipment in use at Canyonlands National Park, Utah. This site operates under the National Atmospheric Deposition Program.

The photo above illustrates the sandstone spires that give the Needles district of the park its name.

Measuring Success– Assessment of Air Quality Conditions and Trends

In addition to determining the trends in air quality, the NPS is interested in assessing the current condition of the air resources within NPS units. A stable trend in air quality may not be sufficient to protect an area that is already experiencing poor air quality.

To assess condition, we first used all available monitoring data from NPS, EPA, state, tribal, and local monitors over the period 2003-2007 to estimate air quality parameters for the reported park units. We then used these estimated values to determine an index for each type of air quality data collected (visibility, wet deposition concentrations, and ozone concentrations) that assigns the park to one of three condition categories where air quality is:

Condition Red–a Significant Concern,
Condition Yellow–in Moderate Condition, or
Condition Blue–in Good Condition.

The procedures for estimating the air quality parameters and assigning the condition categories are described in Appendix C.

Air Quality Condition Results

Appendix C gives the results of the air quality condition determinations for parks where we were also able to derive trend estimates. For each park, a blue circle indicates a park assigned to the Good category for the indicated air quality parameter, a yellow circle indicates the park is assigned to the Moderate (or Caution) category, and a red circle indicates the park is assigned to the Significant Concern category. The category symbols in the Appendix C table are also overlaid with arrows indicating the direction of the trend (if any). The arrows represent the trends computed from data collected at individual monitors (presented in Appendix B), not from the methods used to derive the condition estimates. A blue down arrow indicates an improving trend, a yellow double-headed horizontal arrow indicates no trend, and a red up arrow indicates a worsening trend. In the case of the nitrogen deposition and visibility trends, two trend indicators were combined to create one trend arrow, and the less favorable trend was chosen to represent the site. For nitrogen deposition, if the trend in the concentration of either nitrate or ammonium is degrading while the other is stable or improving, an arrow indicating a degrading trend is overlaid on the condition symbol. If the trend in one form of nitrogen is stable while the other is improving, an arrow indicating a stable trend is shown. Similarly, trends in visibility on clear days and hazy days were combined and overlaid on the visibility condition symbol. If a trend in one is degrading while a trend in the other is stable or improving, an arrow indicating a degrading trend is shown for that park, and if there is one stable trend and one improving trend, a stable trend is shown. All up and down arrows represent trends that have at least a 95% probability of being correct (those with p-values <=0.05).

The air quality condition results are shown graphically on maps in Figures 7-10. Figure 7 shows the visibility conditions at park units. Only Denali in Alaska falls into the Good category. Most of the 85 parks in the Moderate category are located in the western US, with a few in the upper Midwest near the Canadian border. The 59 parks in the Significant Concern category are found mostly in the eastern US, with two located in California.

Air quality conditions for nitrogen wet deposition are shown in Figure 8. Only four sites—Denali, Virgin Islands, Canyonlands, and Pinnacles—fall into the Good category. There are 13 parks that fall into the Moderate category; these are located in the southwestern US, Washington State, Montana, North Dakota, and Maine. The other 41 parks, comprising the majority of the monitored parks and located throughout the US, fall into the Significant Concern category. Sulfur wet deposition conditions are shown in Figure 9. The 28 parks in the

Good and Moderate categories are located largely in the western US, along with a few in the upper Midwest. There are 30 parks in the Significant Concern category; they are found in the eastern US, Midwest, Colorado, and Washington State.

Results for the ozone concentration assessment are shown in Figure 10. The 108 parks in the Significant Concern category are concentrated largely on the east and west coasts, with a few located near the Great Lakes region and eastern Texas. There are 39 that fall in the Moderate category; these parks are located throughout the US. Only 13 parks fall in the Good category, located in Alaska, North Dakota, Washington, Oregon, Montana, and the northern coast of California.

Longer Term Trends

The sliding 10-year trend period was originally chosen for trend reporting because different monitors began at different times, making it difficult to select a single common starting point, and because we felt it was important to demonstrate continued progress toward achieving air quality improvements. It is also valuable, however, to examine trends over longer time periods in order to assess overall progress made during the course of each monitoring program, as well as to identify parks that may be of special

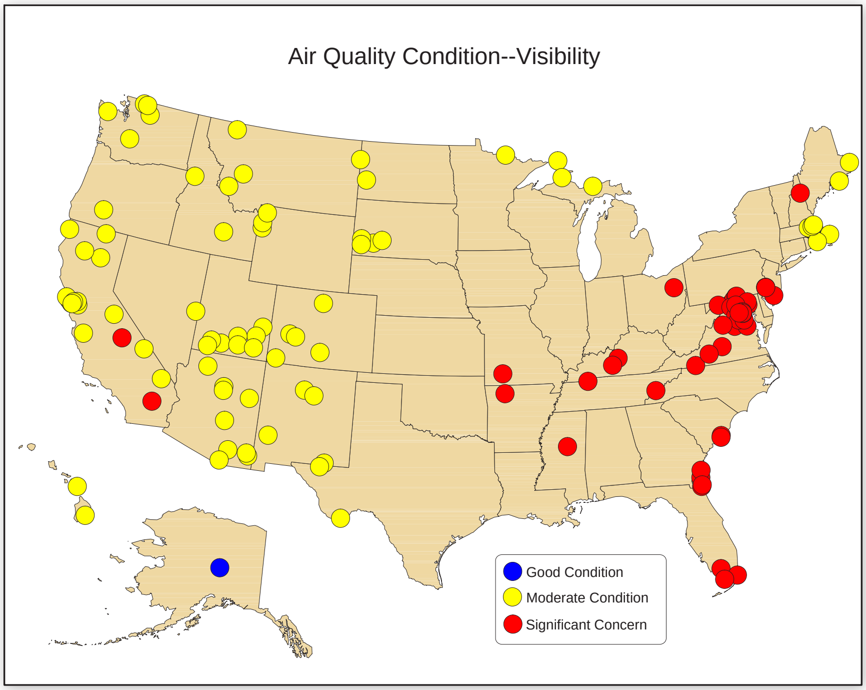


Figure 7. Air quality condition assessments for visibility. Condition assessments were derived from interpolations of average visibility conditions, 2003-2007.

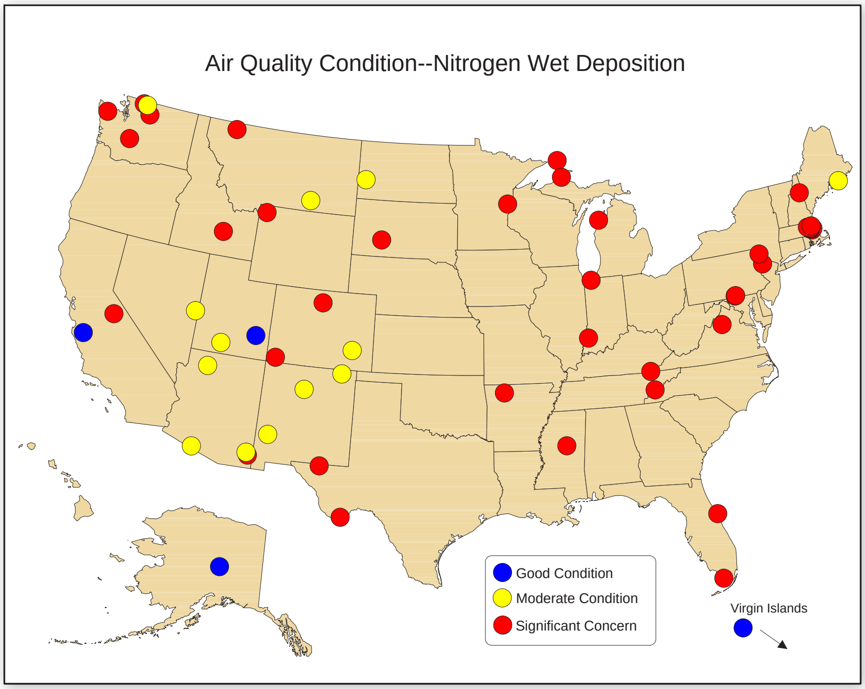


Figure 8. Air quality condition assessments for nitrogen deposition. Assessments were derived from interpolations of nitrogen deposition in precipitation, 2003-2007.

concern. For this evaluation we selected in-park monitors with at least 10 years of data that had a start data of 1997 or earlier (since 1998 is the beginning of the current 10-year trend period, trends beginning in 1998 and later have already been presented). We computed a trend for each of the six indicators used for reporting trend results. The results of these trends are presented below.

We chose to evaluate long-term progress in ozone concentrations using the annual 4th-highest 8-hour daily maximum ozone concentration, rather than the 3-year average of this number that is used by EPA for the ozone standard, as the annual value is available for a longer span of years. Each monitoring location was analyzed over the entire record of available data. We required that each year have at least 75% of possible valid daily 8-hour maximum ozone concentrations during the local ozone season in order for it to be used in the trend analysis. We generated long-term trends for 27 park monitors. The trend results and number of available years of data are presented in Table 2. Statistically significant degrading trends were observed at Craters of the Moon, Denali, Mesa Verde, and Rocky Mountain. Improving trends were found at Cape Cod and Pinnacles. No statistically significant trends were found for the other 21 parks listed in the table.

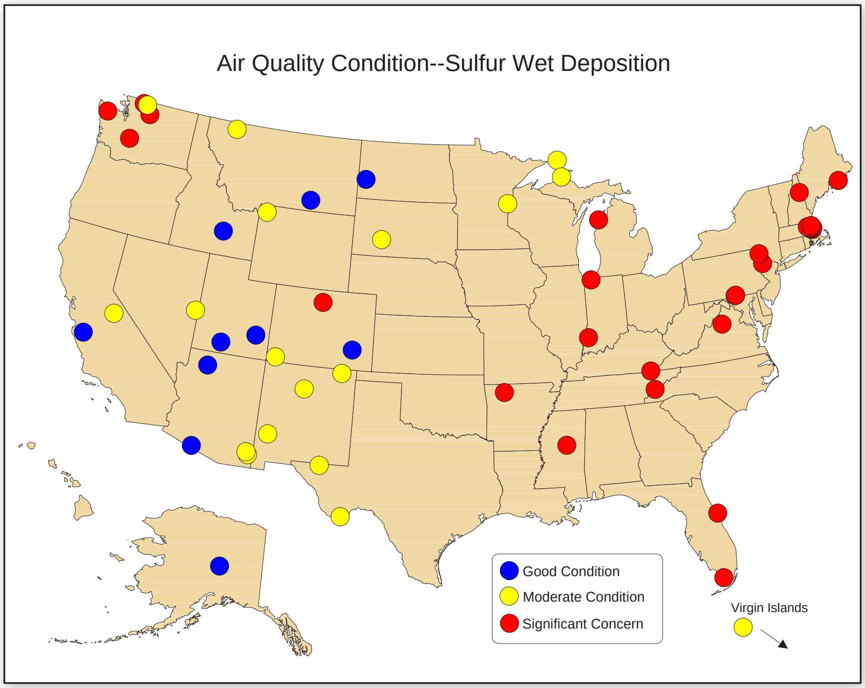


Figure 9. Air quality condition assessments for sulfur deposition. Assessments were derived from interpolations of sulfur deposition in precipitation, 2003-2007.

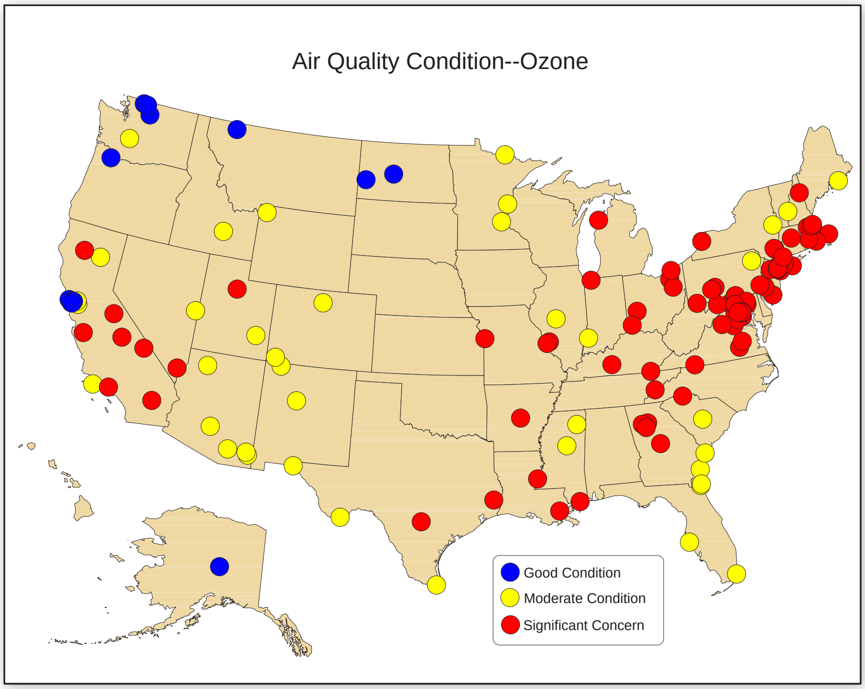


Figure 10. Air quality condition assessments for ozone concentration. Assessments were derived from interpolated values of the annual 4th-highest 8-hour ozone concentrations, 2003-2007.

Trends in Annual 4th-Highest 8-Hour Daily Maximum Ozone Concentration

Park	Slope (ppb/year)	P-value	Number of Valid Years	First Year of Data	Last Year of Data
Acadia	-0.38	0.32	12	1996	2007
Big Bend	0.00	0.46	15	1992	2007
Canyonlands	0.33	0.14	15	1993	2007
Cape Cod	-1.00	**< 0.01**	18	1989	2007
Chamizal	0.13	0.41	16	1992	2007
Chiricahua	0.14	0.15	17	1990	2007
Cowpens	-0.33	0.18	19	1989	2007
Craters Of The Moon	0.76	**< 0.01**	12	1993	2007
Death Valley	0.33	0.06	13	1994	2007
Denali	0.27	**0.02**	18	1990	2007
Glacier	0.24	0.13	19	1989	2007
Grand Canyon	0.00	0.42	15	1993	2007
Great Basin	0.25	0.14	14	1994	2007
Great Smoky Mountains	0.00	0.53	18	1989	2007
Joshua Tree	-0.60	0.17	14	1994	2007
Lassen Volcanic	0.06	0.37	19	1989	2007
Mesa Verde	0.61	**0.02**	13	1994	2007
Mount Rainier	-0.18	0.34	13	1994	2007
North Cascades	0.67	0.11	11	1996	2007
Pinnacles	-0.43	**0.01**	19	1989	2007
Rocky Mountain	0.50	**0.02**	18	1989	2007
Saguaro	0.00	0.42	19	1989	2007
Sequoia/Kings Canyon	-0.07	0.34	19	1989	2007
Shenandoah	-0.14	0.34	19	1989	2007
Voyageurs	-0.50	0.08	11	1997	2007
Yellowstone	-0.11	0.32	11	1997	2007
Yosemite	-0.40	0.10	14	1994	2007

🟥 Degrading air quality trend, statistically significant (p <= 0.05)

□ Degrading air quality trend, not statistically significant (0.05 < p <= 0.15)

🟦 Improving air quality trend, statistically significant (p <= 0.05)

□ Improving air quality trend, not statistically significant (0.05 < p <= 0.15)

Table 2. Long-term ozone trends from park monitors that have been collecting data since 1997 or earlier.

An examination of the time series plots is helpful in identifying parks that may be of concern despite flat or improving trends. Several parks have annual 4th-highest 8-hour ozone concentrations that are consistently at or above the standard of 75 ppb. These parks include Acadia, Great Smoky Mountains, Death Valley, Joshua Tree, Sequoia/Kings Canyon, and Yosemite (see Figure 11). Several other parks with flat trends nonetheless have annual values that are very close to the standard and sometimes over it, including Chamizal, Cowpens, Grand Canyon, Lassen Volcanic, Saguaro, and Shenandoah (Figures 12-17). Canyonlands, Chiricahua, and Great Basin have remained largely under the level of the standard but are also close to it, and there is no indication that ozone is trending downward at these locations (Figures 18-20).

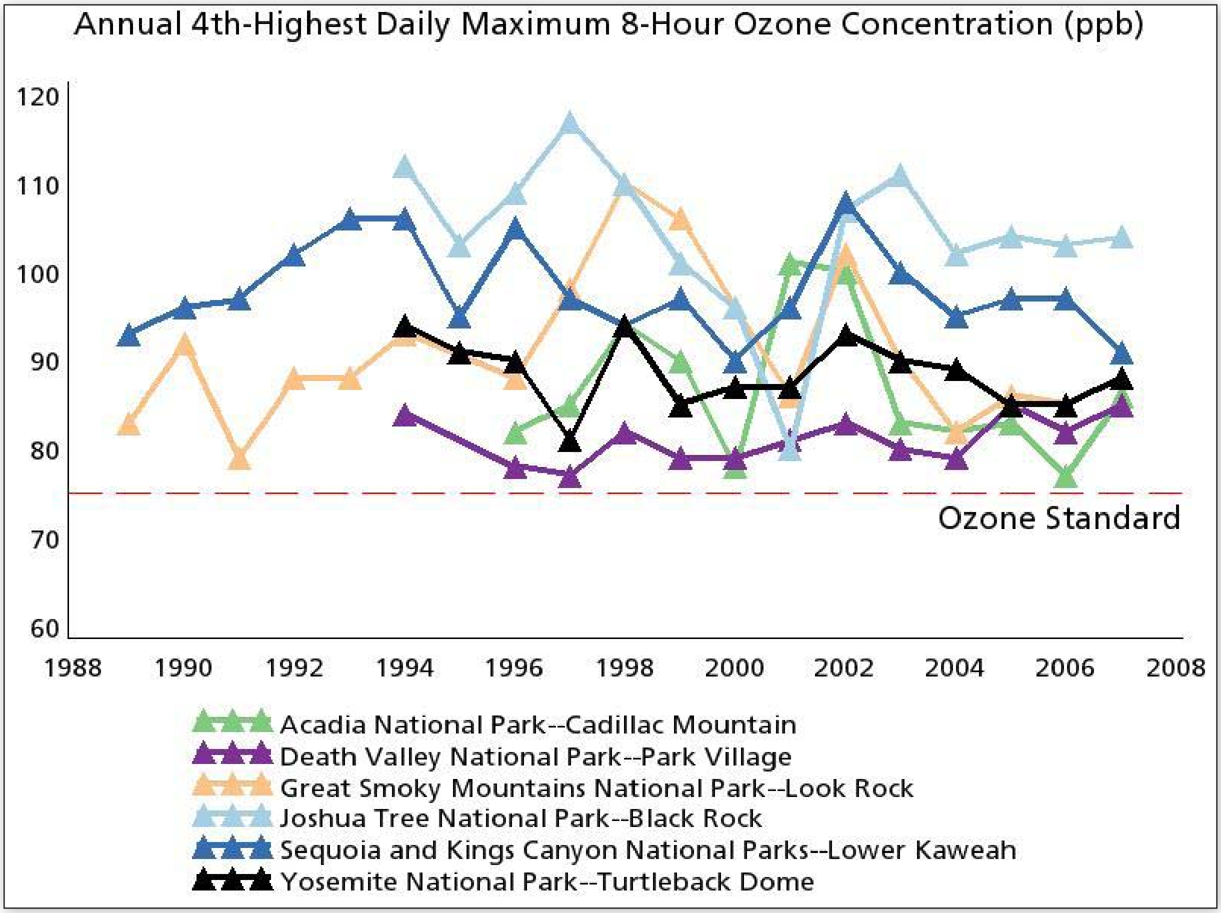


Figure 11. Long-term ozone trends at parks where the annual 4th-highest daily maximum 8-hour ozone concentration has been consistently at or above the ozone standard.

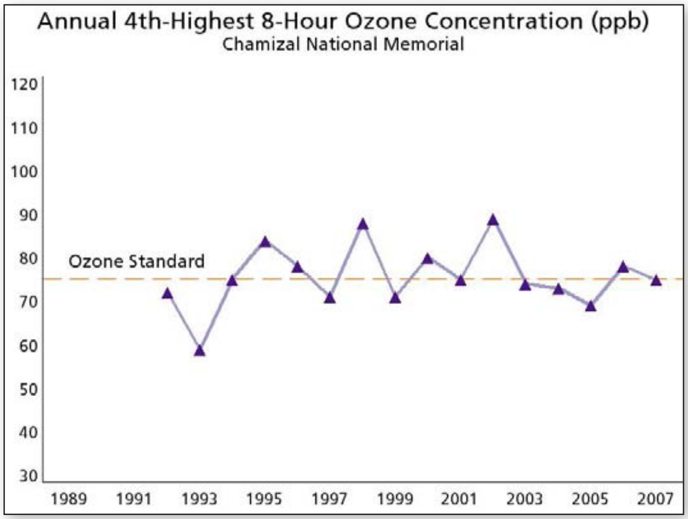


Figure 12.

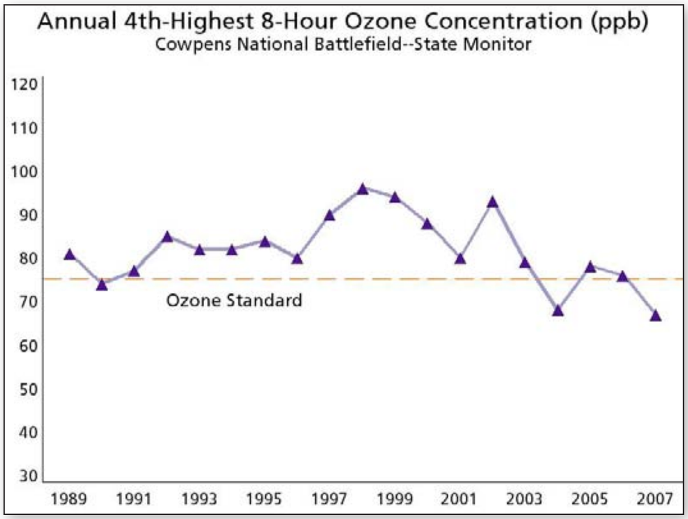


Figure 13.

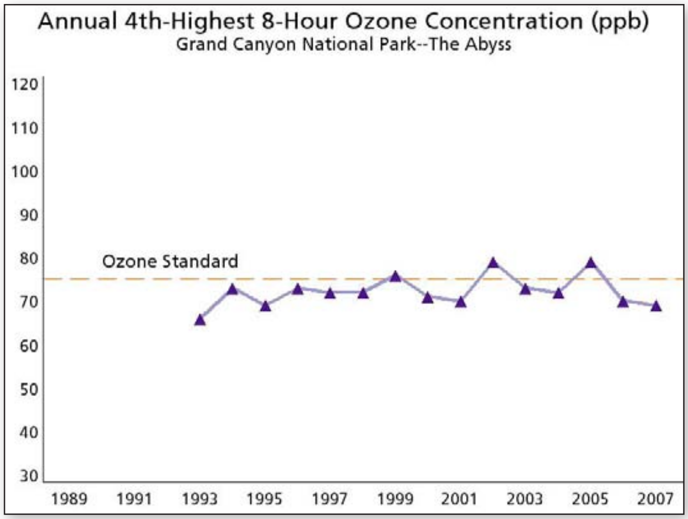


Figure 14.

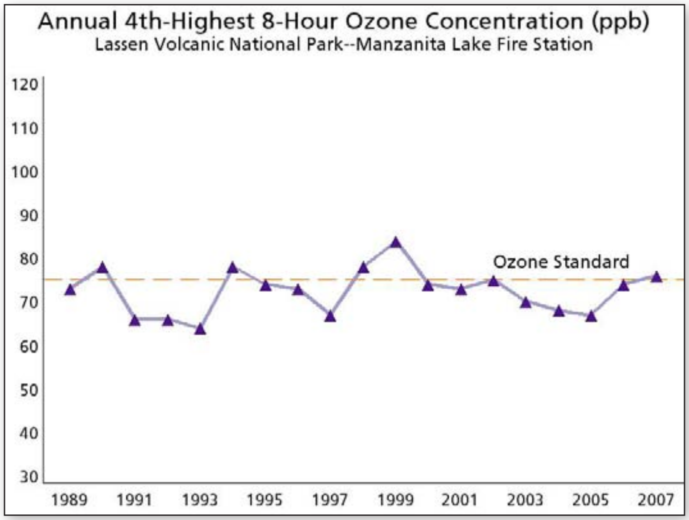


Figure 15.

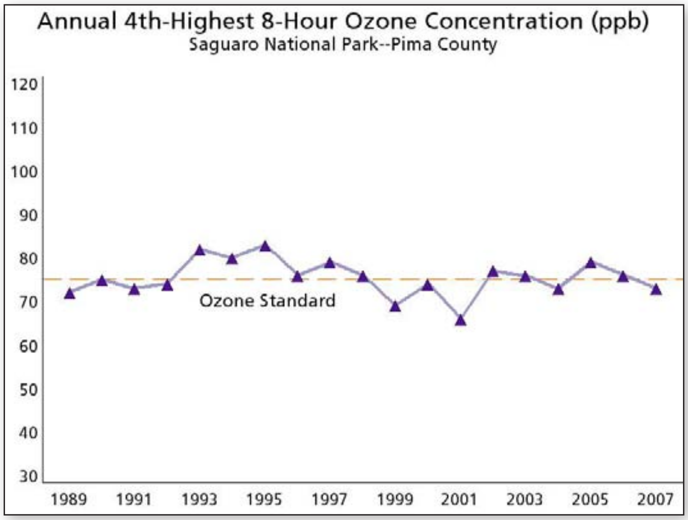


Figure 16.

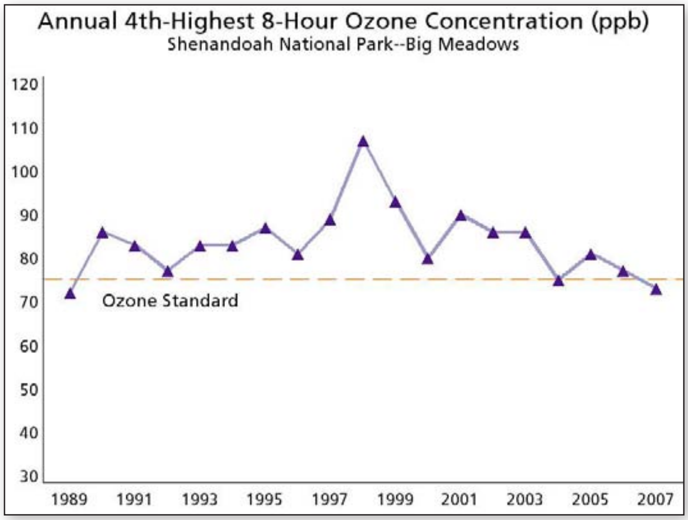


Figure 17.

Figures 12-17 show ozone trends at parks where the annual 4th-highest daily maximum 8-hour ozone concentration has been consistently near or above the ozone standard.

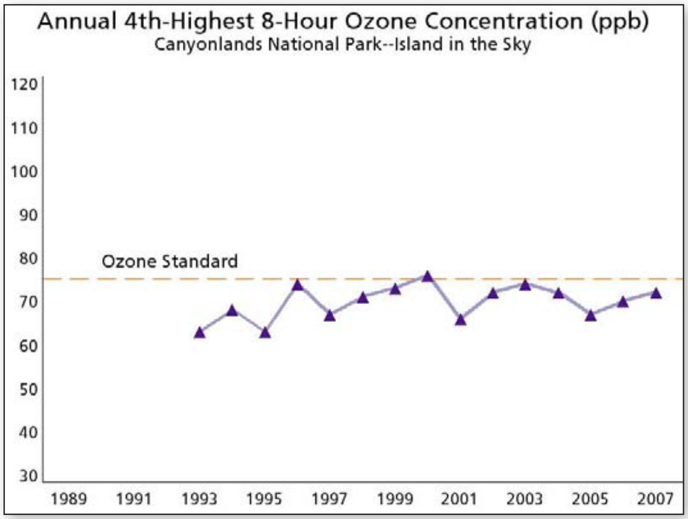


Figure 18.

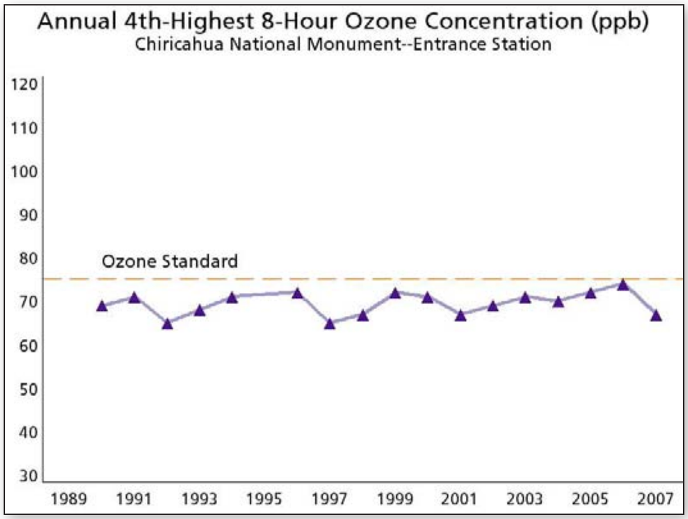


Figure 19.

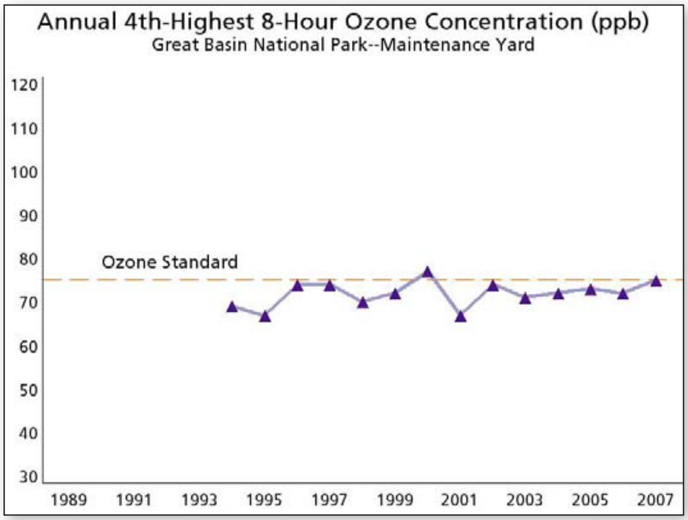


Figure 20.

Figures 18-20 show ozone trends at parks where the annual 4th-highest daily maximum 8-hour ozone concentration has mostly been below, but close to, the ozone standard.

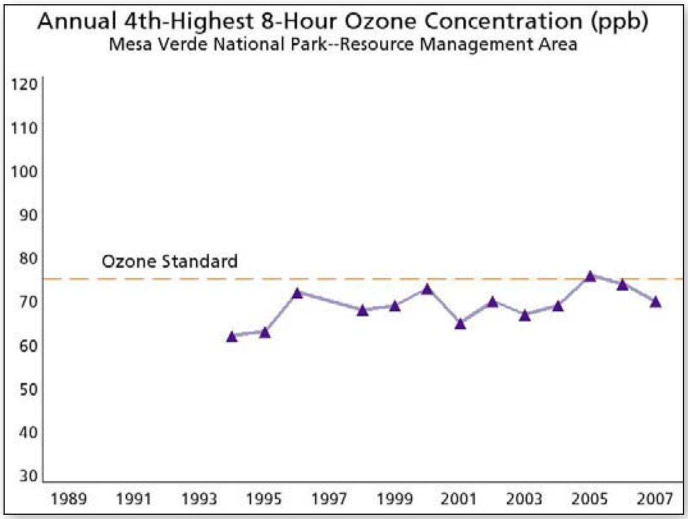


Figure 21. Levels of the annual 4th-highest 8-hour ozone concentration at Mesa Verde increased from 1994 to 2007.

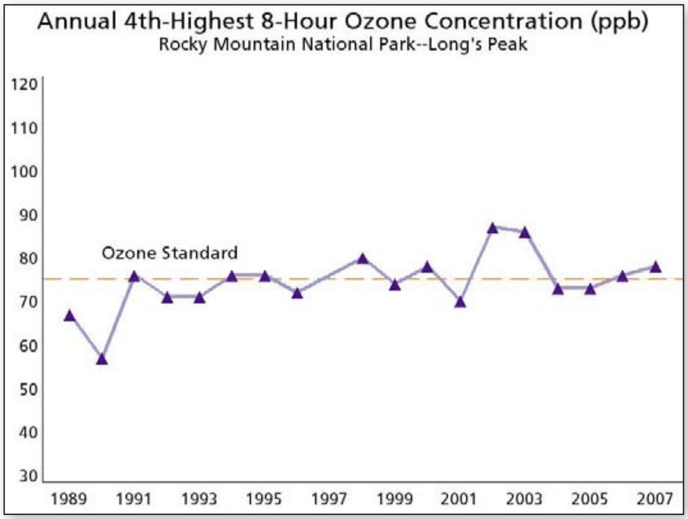


Figure 22. Levels of the annual 4th-highest 8-hour ozone concentration at Rocky Mountain increased from 1989 to 2007.

The ozone concentrations at Great Basin are of particular concern. The park is located in eastern Nevada some distance from population centers and known sources of pollution, and its annual 4th-highest 8-hour ozone concentrations are higher than expected. Great Basin is consistently one of the clearest parks for visibility within the National Park Service, with deciview values comparable to relatively clean sites such as Denali, which occupies a remote location in Alaska. On the haziest days in 2007, Denali had the lowest mean deciview of 47 national parks (8.8 dv), and Great Basin had the second lowest (10.3 dv). Great Basin's ozone concentrations, however, are considerably higher than those in Denali. In 2007, Denali's 4th-highest 8-hour ozone concentration was the second lowest of 41 monitors located in national parks (53 ppb), but Great Basin's 4th-highest 8-hour ozone concentration ranked in the upper half of the monitors at 75 ppb, tying with Chamizal and Pinnacles for the 16th-highest value.

Mesa Verde has a statistically significant increasing trend over the 1994-2007 period and its annual 4th-highest 8-hour ozone concentrations are approaching the standard (Figure 21). Rocky Mountain also has an increasing trend and its annual values have been at or near the standard over the last few years (Figure 22). The trend at Craters of the Moon is increasing, but so far the levels remain below the standard (Figure 23). Denali (Figure 24) also exhibits an increasing trend over the long term but the increase appears to be very slight, and the levels remain well below the standard. Cape Cod and Pinnacles exhibit statistically significant downward trends (Figure 25). Cape Cod's annual levels are still above the standard but are trending strongly downwards. Annual 4th-highest 8-hour ozone concentrations at Pinnacles are still near or slightly above the standard but are also trending down.

Several eastern parks, including Cowpens, Great Smoky Mountains, and Shenandoah, experienced a peak in ozone values around 1998-1999 (Figure 26). As a result, their long-term trends are flat, despite trending downward over the most recent 10-year period. The length of the trend at Mammoth Cave is not as long since the site moved in

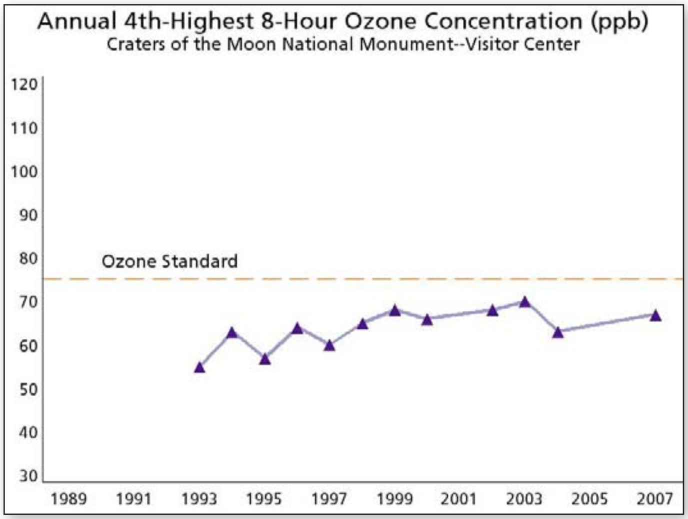


Figure 23. Long-term trend in annual 4th-highest 8-hour ozone concentration at Craters of the Moon. Despite an increase, ozone levels remain below the standard.

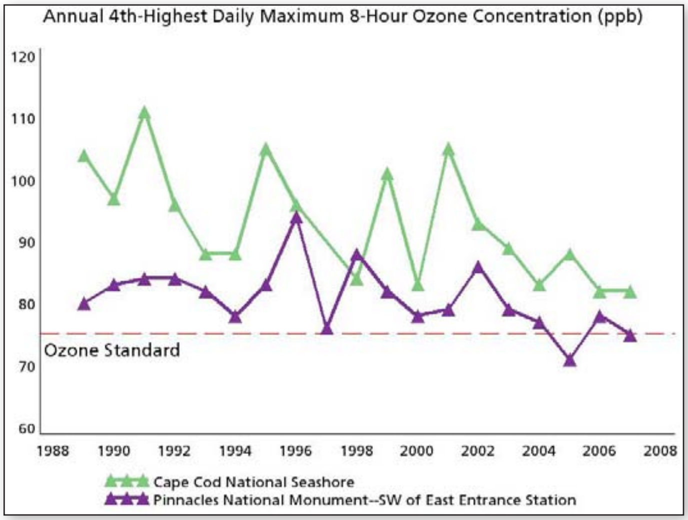


Figure 25. Trends in the annual 4th-highest 8-hour ozone cocnentration show a decrease at Cape Cod and Pinnacles.

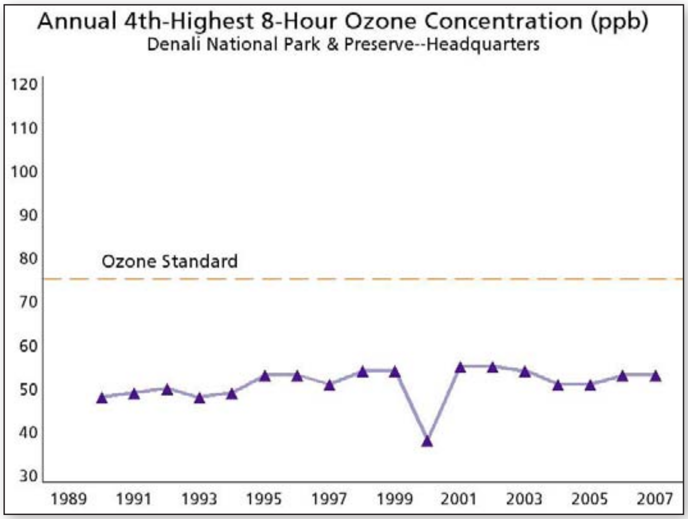


Figure 24. Although the long-term trend in the annual 4th-highest 8-hour ozone concentration showed an increase through 2007, ozone levels at Denali remain well below the standard.

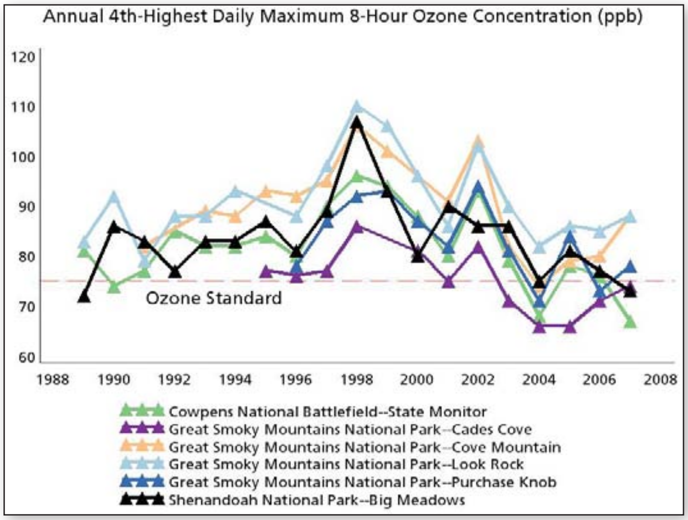
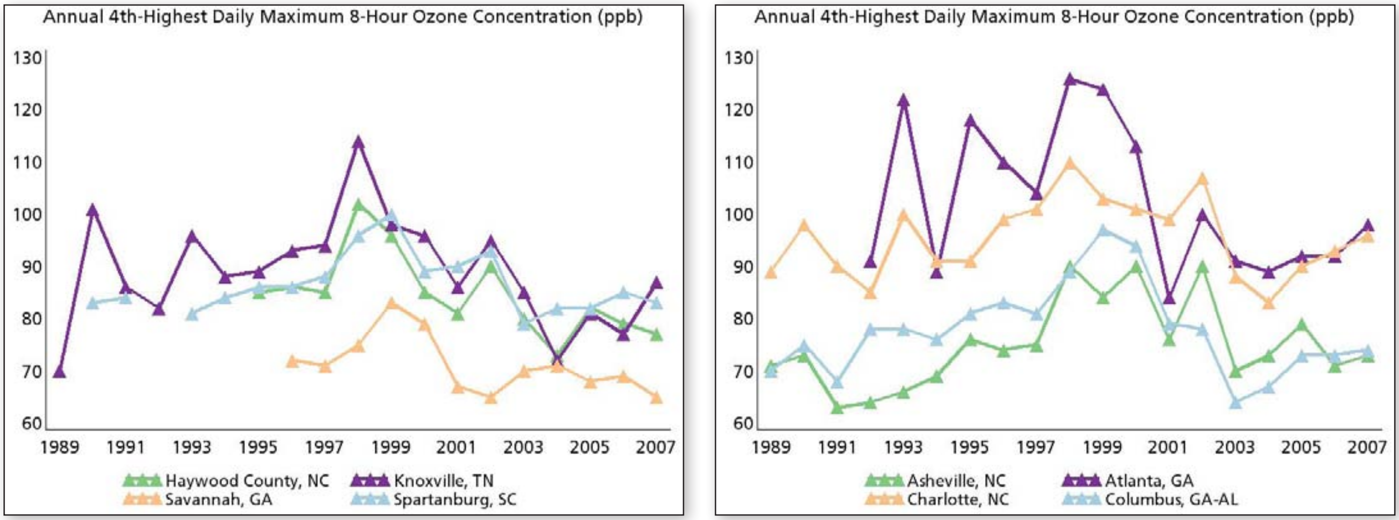


Figure 26. Long-term ozone trends at several eastern monitoring stations show peaks in the annual 4th-highest 8-hour ozone concentration in 1998 and 2002. Long-term trends at these locations are flat.

1997, but a similar decrease in concentrations was observed there beginning in 1998. Despite this recent improving trend the annual ozone levels at Mammoth Cave remain near or above the standard. From other data collected at monitors located in this region it appears as if a peak in ozone values occurred during this time period at some locations outside these parks (Figures 27 and 28). However, this was not the case everywhere, particularly in larger urban areas further to the east (Figure 29).

Long-term visibility trends were also calculated for park visibility monitors with at least 10 years of data beginning in 1997 or earlier. We calculated trends in deciview on the clearest and haziest days for the period of record at 29 locations. The results are shown in Table 3. On the clearest days, most sites indicated a statistically significant improving trend. These locations include: Acadia, Badlands, Bandelier, Big Bend, Bryce Canyon, Canyonlands, Chiricahua, Crater Lake, Denali, Glacier, Great Basin, Great Sand Dunes, Guadalupe Mountains, Lassen Volcanic, Mesa Verde, Mount Rainier, Petrified Forest, Pinnacles, Point Reyes, Redwood, Rocky Mountain, Shenandoah, Tonto, Washington D.C., Yellowstone, and Yosemite. No trend was observed on the best days at Great Smoky Mountains, Mammoth Cave, or Sequoia. On the haziest days, statistically significant improving trends occurred at Acadia, Canyonlands, Denali, Great Smoky Mountains, Mount Rainier, Pinnacles, Point Reyes, Redwood, Shenandoah, and Washington D.C. Statistically significant degrading trends were found at Big Bend and Guadalupe Mountains.



Figures 27-28. Ozone data from some southeastern monitors suggest a peak in the annual 4th-highest daily maximum 8-hour ozone concentration around 1998.

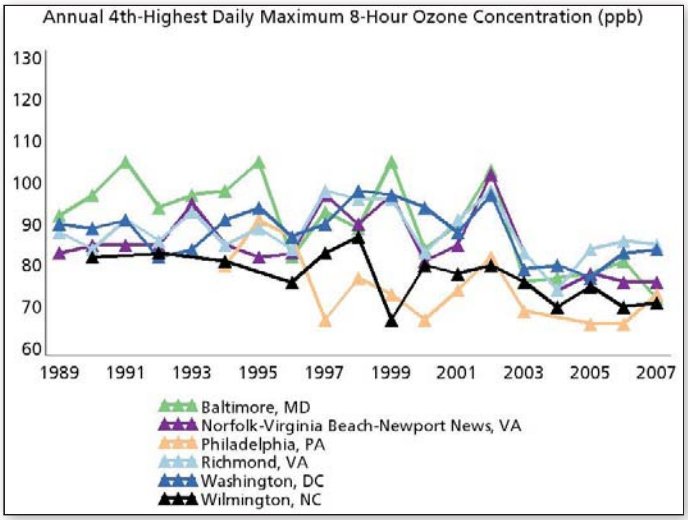


Figure 29. A distinct peak in the annual 4th-highest 8-hour ozone concentration is not evident in ozone data from monitors near several large eastern urban areas.

Trends in Annual Deciview (DV) on Clearest and Haziest Days							
	Clearest Days		Haziest Days				
Park	Slope (DV/year)	P-value	Slope (DV/year)	P-value	Number of Valid Years	First Year of Data	Last Year of Data
Acadia	-0.18	< 0.01	-0.23	< 0.01	18	1990	2007
Badlands	-0.05	0.01	-0.04	0.12	19	1989	2007
Bandelier	-0.10	< 0.01	-0.06	0.15	17	1989	2007
Big Bend	-0.10	0.01	0.07	0.04	16	1990	2007
Bryce Canyon	-0.09	< 0.01	0.05	0.054	17	1990	2007
Canyonlands	-0.15	< 0.01	-0.11	< 0.01	18	1990	2007
Chiricahua	-0.10	< 0.01	-0.03	0.27	18	1990	2007
Crater Lake	-0.18	< 0.01	-0.05	0.34	13	1992	2007
Denali	-0.11	< 0.01	-0.11	0.02	19	1989	2007
Glacier	-0.12	< 0.01	-0.03	0.27	17	1989	2007
Great Basin	-0.14	< 0.01	0.00	0.46	15	1993	2007
Great Sand Dunes	-0.08	0.01	-0.01	0.47	19	1989	2007
Great Smoky Mountains	-0.07	0.07	-0.12	0.01	18	1990	2007
Guadalupe Mountains	-0.08	< 0.01	0.13	0.03	17	1989	2007
Lassen Volcanic	-0.10	< 0.01	0.05	0.18	19	1989	2007
Mammoth Cave	0.00	0.54	-0.07	0.17	14	1992	2007
Mesa Verde	-0.07	0.02	0.03	0.39	17	1989	2007
Mount Rainier	-0.15	< 0.01	-0.38	< 0.01	17	1989	2007
Petrified Forest	-0.05	0.02	0.07	0.11	16	1990	2007
Pinnacles	-0.13	< 0.01	-0.20	< 0.01	17	1989	2007
Point Reyes	-0.07	0.02	-0.12	0.03	16	1989	2007
Redwood	-0.14	< 0.01	-0.18	< 0.01	19	1989	2007
Rocky Mountain	-0.10	< 0.01	0.02	0.42	17	1991	2007
Sequoia/Kings Canyon	-0.06	0.24	-0.18	0.08	10	1994	2007
Shenandoah	-0.17	< 0.01	-0.23	< 0.01	17	1990	2007
Tonto	-0.12	< 0.01	0.00	0.46	14	1991	2007
Washington	-0.21	< 0.01	-0.21	< 0.01	17	1990	2007
Yellowstone	-0.07	0.02	0.00	0.57	10	1997	2007
Yosemite	-0.08	0.01	0.02	0.42	19	1989	2007

🟥	Degrading air quality trend, statistically significant (p <= 0.05)	□	Degrading air quality trend, not statistically significant (0.05 < p <= 0.15)
🟦	Improving air quality trend, statistically significant (p <= 0.05)	□	Improving air quality trend, not statistically significant (0.05 < p <= 0.15)

Table 3. Long-term visibility trends from park monitors that have been collecting data since 1997 or earlier.

Although a majority of the observed trends over the long-term are favorable (either improving or not degrading), visibility at all parks suffers from at least some impairment, particularly on the haziest days. Annual mean deciview values on the haziest days at the 29 NPS locations during the period 2005-2007 ranged from 1.5 dv to 22 dv higher than estimated natural conditions and averaged approximately 8.5 dv higher than estimated natural conditions. Eastern sites such as Acadia, Shenandoah, Great Smoky Mountains, and Mammoth Cave have consistently experienced annual mean deciview values on the haziest days well in excess of estimated natural conditions (Figures 30-33). Some western parks, such as Sequoia, Yosemite, Mount Rainier, and Pinnacles also experience haze levels well above estimated natural conditions, although long-term trends at Mount Rainier and Pinnacles suggest that conditions on the worst days are improving (Figures 34-37).

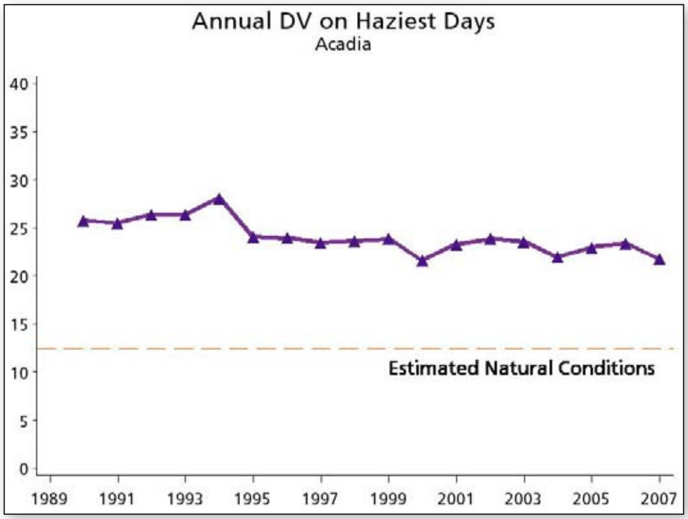


Figure 30.

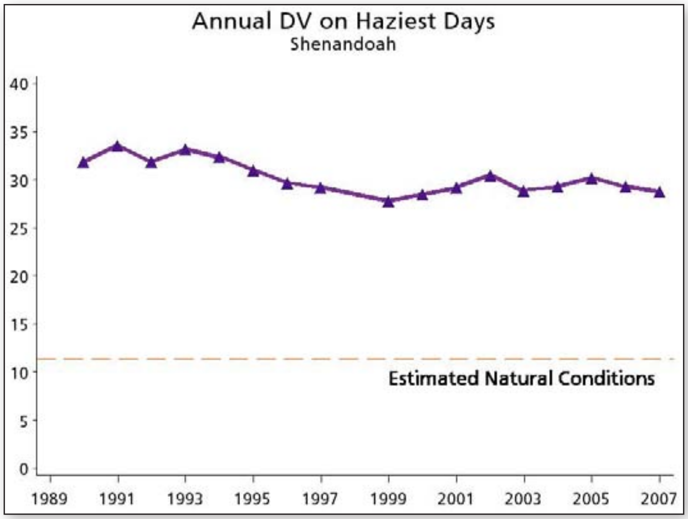


Figure 31.

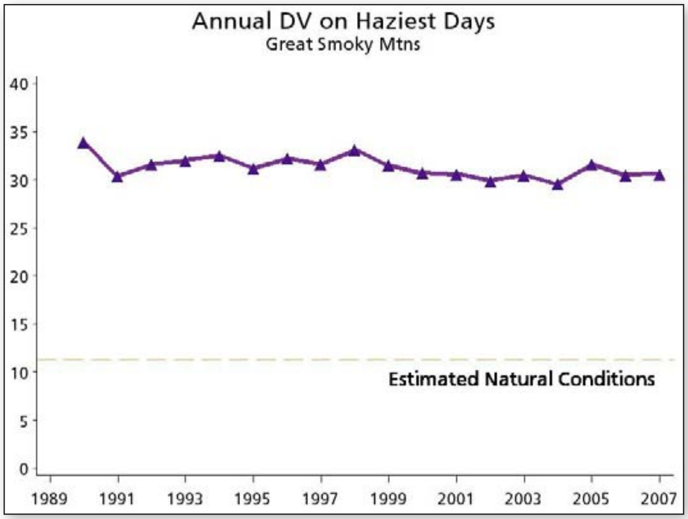


Figure 32.

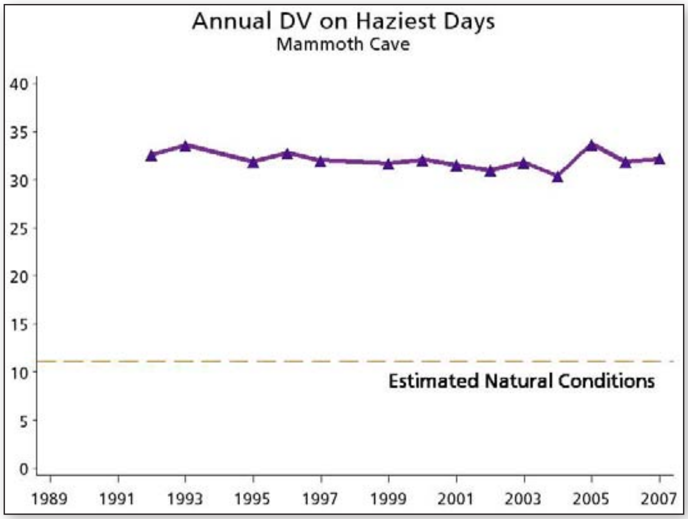


Figure 33.

Figures 30-33: Visibility monitoring data from Acadia, Shenandoah, Great Smoky Mountains, and Mammoth Cave National Parks show annual mean deciview values on the haziest days that are well in excess of estimated natural conditions.

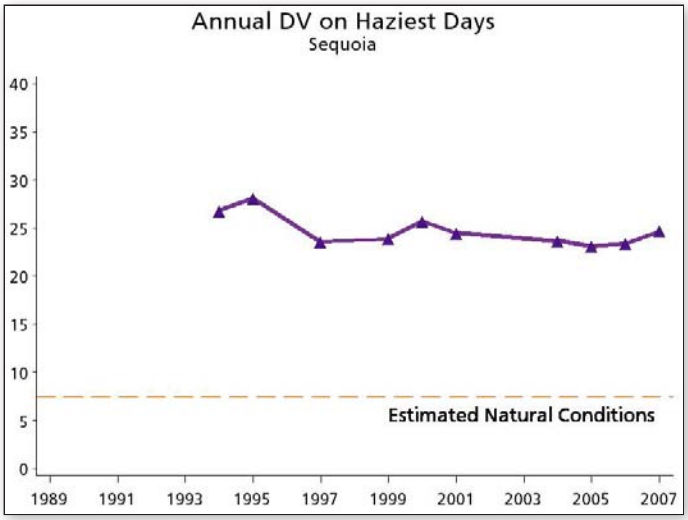


Figure 34.

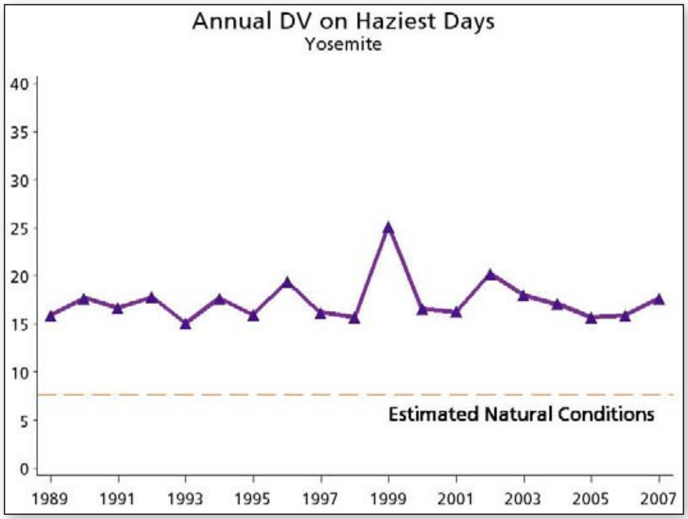


Figure 35.

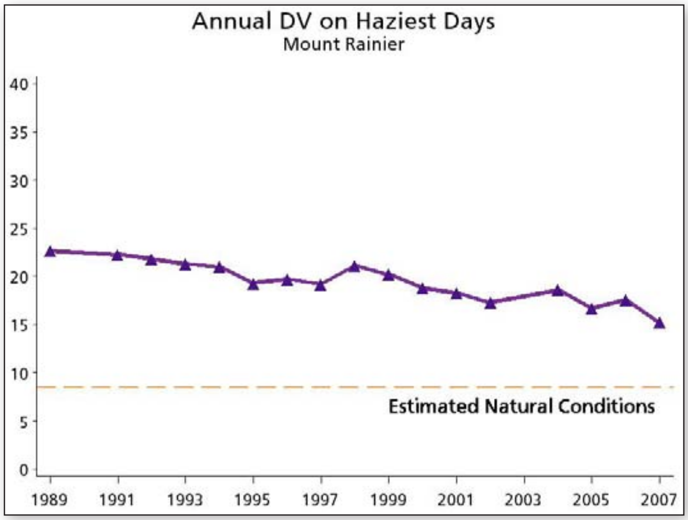


Figure 36.

Figures 34-37: Visibility conditions on the haziest days at some western parks—including Sequoia, Yosemite, and Mount Rainier National Parks and Pinnacles National Monument—show mean deciview values above estimated natural conditions; trends suggest improvement at Mount Rainier and Pinnacles.

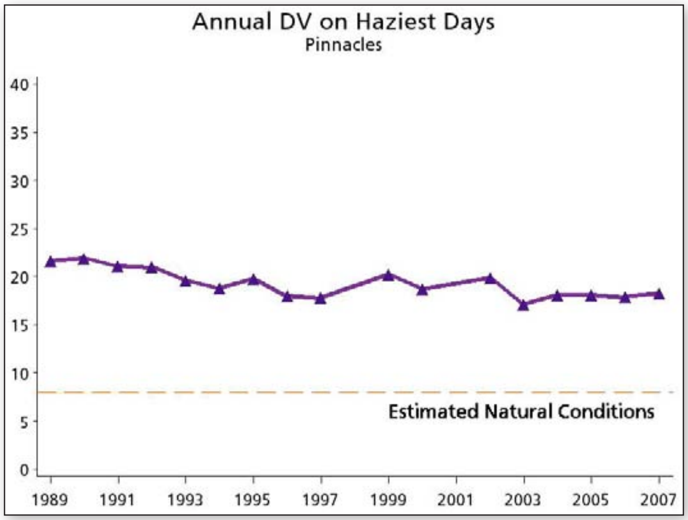


Figure 37.

Visibility conditions on the best days are also impaired, although to a lesser degree. At all NPS sites with data during 2005-2007, mean deciview values on the clearest days ranged from 0.3 to 12 dv above estimated natural conditions, and averaged roughly 3.5 dv above estimated natural conditions. All but three of the 29 monitoring locations evaluated for long-term trends show statistically significant improving trends on the clearest days, while the remaining three show no trends. Monitoring locations with the greatest differences between measured visibility on the clearest days and estimated natural conditions include Washington D.C., Shenandoah, Mammoth Cave, and Great Smoky Mountains (Figures 38-41).

Long-term trends in concentrations of ammonium, nitrate, and sulfate in wet deposition were calculated for in-park monitors with 10 years or more of data beginning in 1997 or earlier. Only data collected from 1994 and later were considered due to changes in measured sulfate and nitrate concentrations that occurred as a result of a change in sample handling procedures[5]. The results are shown in Table 4. There were 27 monitoring locations with sufficient data for long-term trends. Six of the 27 locations exhibited statistically significant degrading trends in ammonium concentrations (Capulin Volcano, Craters of the Moon, Mesa Verde, Rocky Mountain, Yellowstone, and Yosemite). Only one park (Olympic) observed a statistically significant improving trend in ammonium concentrations. Statistically significant improving trends in nitrate concentrations were found at five monitoring locations (Big Bend, Buffalo, Indiana Dunes, Isle Royale, and Shenandoah); no trends in nitrate concentrations were found at the remaining monitors. Sulfate concentrations in precipitation improved at ten NPS monitoring locations (Big Bend, Bryce Canyon, Buffalo, Glacier, Guadalupe Mountains, Indiana Dunes, Little Bighorn, Mesa Verde, North Cascades, and Shenandoah). No long-term trends in sulfate concentrations were found at the remaining 15 NPS monitoring locations.

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[5] See NADP data advisory, http://nadp.sws.uiuc.edu/documentation/advisory.html.

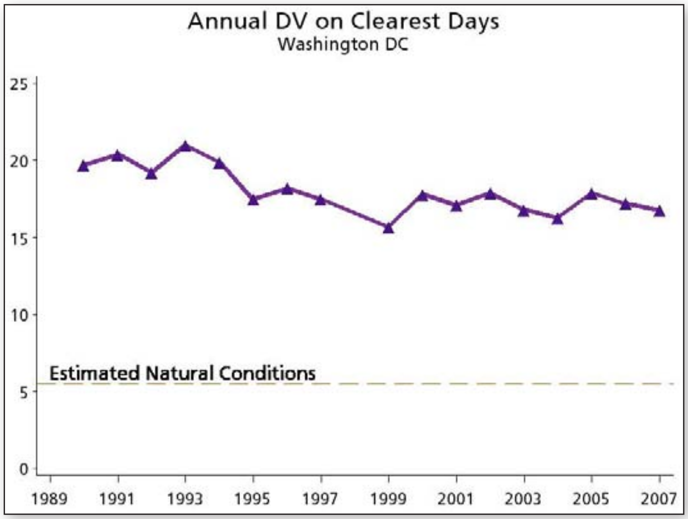

Figure 38.

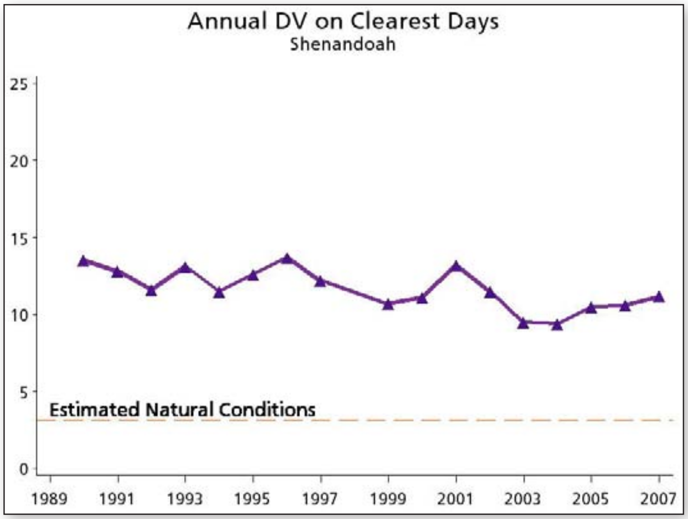

Figure 39.

Figures 38-39: Visibility data from monitors in Washington DC and Shenandoah show that haze levels remain above estimated natural conditions on the clearest days, but long-term trends show improvement.

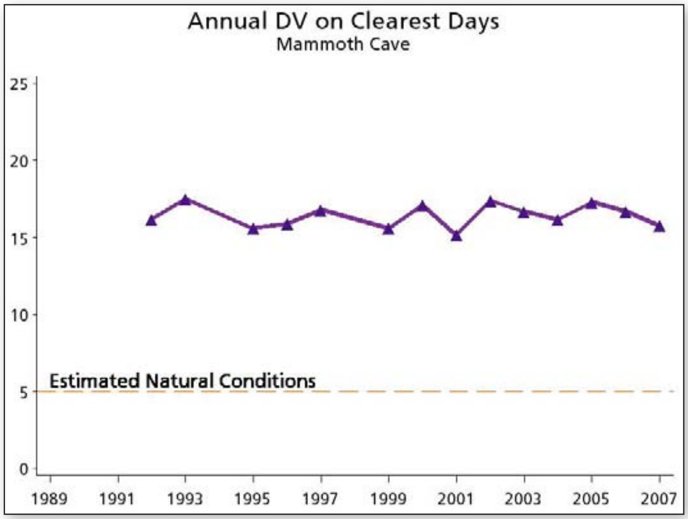

Figure 40. Long-term trends in visibility on the clearest days are flat at Mammoth Cave.

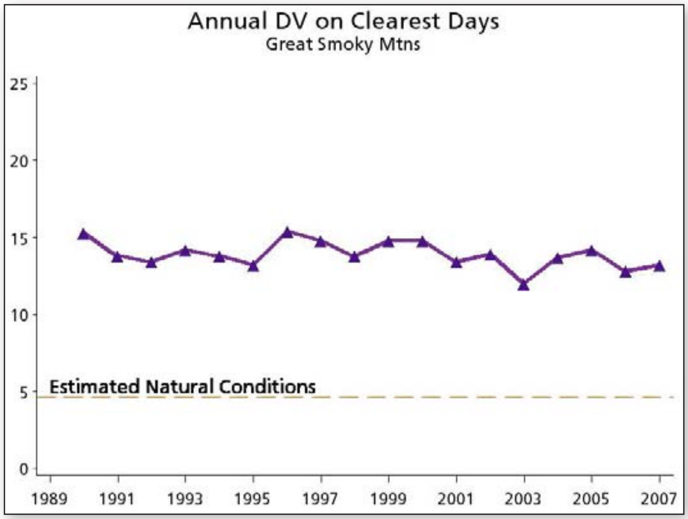

Figure 41. Annual mean deciview trends on the clearest days at Great Smoky Mountains.

Trends in Wet Deposition Concentrations

Park	Ammonium		Nitrate		Sulfate		Number of Valid Years	First Year of Data	Last Year of Data
	Slope µeq/liter/yr	P-value	Slope µeq/liter/yr	P-value	Slope µeq/liter/yr	P-value			
Acadia	0.02	0.43	-0.24	0.06	-0.39	0.06	13	1994	2007
Bandelier	0.31	0.06	0.01	0.52	-0.22	0.13	13	1994	2007
Big Bend	-0.45	0.08	-0.47	< 0.01	-0.67	0.01	13	1994	2007
Bryce Canyon	0.48	0.06	0.03	0.50	-0.45	< 0.01	11	1994	2007
Buffalo	0.06	0.43	-0.22	0.05	-0.45	< 0.01	13	1994	2007
Capulin Volcano	0.35	0.02	-0.11	0.30	-0.08	0.43	10	1994	2007
Craters Of The Moon	0.58	0.01	-0.09	0.17	0.06	0.37	14	1994	2007
Denali	-0.01	0.50	-0.02	0.33	0.07	0.33	14	1994	2007
Everglades	0.10	0.23	-0.01	0.47	-0.04	0.42	12	1994	2007
Gila Cliff Dwellings	0.39	0.06	0.54	0.18	-0.40	0.14	11	1994	2007
Glacier	0.17	0.06	-0.02	0.46	-0.13	0.03	14	1994	2007
Grand Canyon	0.22	0.14	0.10	0.27	-0.07	0.44	11	1994	2007
Great Basin	0.37	0.08	-0.09	0.43	-0.18	0.054	10	1994	2006
Great Smoky Mountains	0.14	0.30	-0.08	0.12	-0.07	0.50	14	1994	2007
Guadalupe Mountains	-0.12	0.38	-0.31	0.10	-1.02	0.01	13	1994	2007
Indiana Dunes	0.02	0.50	-0.64	0.01	-0.99	< 0.01	14	1994	2007
Isle Royale	0.30	0.12	-0.33	0.01	-0.28	0.16	12	1994	2007
Little Bighorn Battlefield	0.14	0.12	-0.26	0.06	-0.25	< 0.01	14	1994	2007
Mesa Verde	0.22	0.03	0.03	0.50	-0.62	< 0.01	14	1994	2007
Mount Rainier	0.01	0.38	0.04	0.18	-0.23	0.08	11	1994	2006
North Cascades	-0.03	0.25	-0.04	0.43	-0.10	0.02	13	1995	2007
Olympic	-0.03	0.04	0.00	0.57	-0.01	0.50	10	1994	2005
Organ Pipe Cactus	0.65	0.12	0.29	0.23	-0.17	0.23	12	1994	2007
Rocky Mountain	0.56	0.01	0.10	0.37	-0.24	0.06	14	1994	2007
Shenandoah	-0.12	0.18	-0.49	0.02	-0.70	0.02	11	1994	2006
Yellowstone	0.53	0.01	0.10	0.18	0.14	0.10	13	1994	2007
Yosemite	0.47	0.03	-0.04	0.47	0.07	0.23	12	1994	2007

🟥	Degrading air quality trend, statistically significant (p <= 0.05)	☐	Degrading air quality trend, not statistically significant (0.05 < p <= 0.15)
🟦	Improving air quality trend, statistically significant (p <= 0.05)	☐	Improving air quality trend, not statistically significant (0.05 < p <= 0.15)

Table 4. Long-term deposition trends from park monitors that have been collecting data since 1997 or earlier.

Ozone Exposure

In July 2007 the EPA proposed a new secondary ozone standard. Secondary standards set limits to protect public welfare, including protection against decreased visibility and damage to vegetation and buildings. The proposed standard is based upon a cumulative sum of hourly ozone concentrations, where the hourly values are weighted according to their magnitude[6]. This sum provides an index of the total amount of ozone that plants are exposed to during the daytime. The three-month period with the highest cumulative exposure index is used as the reporting statistic, which is referred to as the W126 statistic (more details on how this value is calculated are provided in Appendix D). The units of the W126 statistic are ppm-hours. In making this secondary standard proposal, EPA recommended that the level of the standard be set somewhere in the range of 7-21 ppm-hours, so that the annual maximum 3-month cumulative W126 should be less than that value. EPA proposed the new standard on the basis of research showing that a cumulative index, rather than a maximum value, is the best way to relate ozone concentrations to the potential for harmful impacts to vegetation. Although EPA did not adopt this proposed standard in its final ruling, we feel that it is still an important indicator of the potential for damage to ozone-sensitive plant species.

Table 5 shows parks with on-site monitoring that had W126 index values at or above 7 ppm-hours during 2007. There were 28 parks that equalled or exceeded this exposure value, which is the lower range of the proposed EPA standard. Six parks (Sequoia-Kings Canyon, Joshua Tree, Death Valley, Yosemite, Great Smoky Mountains, and Mammoth Cave) exceeded the upper range of 21 ppm-hours. Parks with 3-month maximum ozone exposures between 7 and 21 ppm-hours include Acadia, Badlands, Big Bend, Cape Cod, Canyonlands, Chamizal, Chiricahua, Congaree, Cowpens, Craters of the Moon, Everglades, Great Basin, Grand Canyon, Lassen Volcanic, Mesa Verde, Petrified Forest, Pinnacles, Rocky Mountain, Saguaro, Shenandoah, Wind Cave, Yellowstone, and Zion.

Monitoring Locations With Maximum 3-Month W126 Greater Than or Equal to 7 ppm-hrs (2007)

Park	Maximum 3-Month W126 (ppm-hrs)
Acadia--Cadillac Mountain	7
Badlands	8
Big Bend	10
Canyonlands	17
Cape Cod	13
Chamizal	13
Chiricahua	14
Congaree	9
Cowpens	7
Craters of the Moon	10
Death Valley	32
Grand Canyon	18
Great Basin	15
Great Smoky Mountains--Cades Cove	12
Great Smoky Mountains--Clingmans Dome	23
Great Smoky Mountains--Cove Mountain	20
Great Smoky Mountains--Look Rock	23
Great Smoky Mountains--Purchase Knob	13
Joshua Tree	52
Lassen Volcanic	15
Mammoth Cave	22
Mesa Verde	17
Petrified Forest	16
Pinnacles	14
Rocky Mountain	20
Saguaro	17
Sequoia and Kings Canyon--Ash Mountain	63
Sequoia and Kings Canyon--Lower Kaweah	53
Shenandoah	13
Wind Cave	12
Yellowstone	10
Yosemite	28
Zion	18

Table 5. Parks with on-site monitoring that had W126 index values equal to or greater than 7ppm-hours in 2007. The W126 index provides a useful metric for assessing the potential for harm to vegetation due to cumulative ozone exposure.

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[6] See Federal Register Vol. 72 No. 132, 40 CFR Part 50, National Ambient Air Quality Standards for Ozone; A Proposed Rule, July 11, 2007.

Members of the Western Airborne Contaminants Assessment Project study team take water, fish, and snow samples in Denali National Park and Preserve, and sediment samples in Glacier National Park. This study looked at eight western parks to determine the levels of airborne contaminants in the air, snow, water, sediments, lichens, conifer needles, and fish. Air, lichen, and conifer needle samples were also collected from an additional 12 parks and forests.

Producing Results–Information and Collaboration

Making progress toward meeting park air quality goals is challenging because while we are given a consultation role under the Clean Air Act, the NPS has no direct authority to control sources of pollution located outside park boundaries. In order to achieve park air quality goals, the NPS works collaboratively with federal and state air regulatory agencies, as well as neighboring land management agencies, to enhance and protect air quality in the parks to greatest extent possible. These goals are also achieved by understanding and sharing information about air quality conditions and trends in parks with regulatory agencies and the public, which supports or helps shape federal and state air pollution control programs. Information sharing has supported the NPS in fulfilling its responsibility under the Clean Air Act and led to further collaborative efforts with states, tribes, EPA, the private sector, and the public aimed at protecting air quality in parks. Such efforts include:

Visibility and Regional Haze:
NPS is continuing to consult with states on their Regional Haze State Implementation Plans that are designed to improve visibility due to long-range transport of haze-producing pollutants. States must inform the public of federal land manager concerns and respond to those concerns when they submit the plans for approval to the EPA. The visibility protection plans were due to EPA from all 50 states in December, 2007 and must include strategies for making reasonable progress toward natural visibility conditions. However, due to court actions and program concerns, many state plans have been delayed. The NPS has focused its comments on state actions to retrofit certain larger industrial facilities with pollution control devices and the long-term programs that states will implement to achieve progress towards natural visibility conditions at the mandatory Federal Class I parks. We expect major reductions in visibility-impairing pollutants as a result of these efforts.

NPS is working closely with the U.S. Fish and Wildlife Service and the U.S. Forest Service in reviewing regional haze plans since they also manage Class I units.

Ecosystem Protection Initiatives:
The NPS has been encouraging the use of critical loads for atmospheric deposition as indicators of ecological health and benchmarks for evaluating the effect of air pollution control programs. A critical load is an exposure value below which harmful environmental effects are not known to occur. In cooperation with EPA, other federal land managing agencies, states and others, various research, monitoring, and modeling approaches to developing critical loads are being examined around the country.

Studies on the ecological effects of air pollution in national parks are currently ongoing through agreements with researchers at various universities and other federal agencies. Current research projects are underway to assess the effects of nitrogen, ozone or mercury deposition on plants, soils or waters in three southeast Alaska parks, three National Capitol Region parks, five southeastern U.S. parks, and in Joshua Tree, Sequoia, Yosemite, Grand Teton, Crater Lake, Acadia, and Rocky Mountain National Parks.

Assessing Air Pollution Risk to NPS Resources:
The NPS Inventory and Monitoring Program has enabled broad regional and national-scale assessments of air pollution effects and resource sensitivities to air quality changes in parks. Private sector contractors have been used to assess air pollution risks for 270 national parks. Natural resource risk assessments have been completed for ozone, and are underway for mercury, acid deposition, and nitrogen.

NPS partnered with EPA, the U.S. Geological Survey, the U.S. Forest Service, Oregon State University, and University of Washington in the Western Airborne Contaminants Assessment Project (WACAP). A final report for this six year project was completed in 2008. The project was developed to determine the risk to ecosystems and food webs in 20 western national parks from airborne toxic contaminants. NPS is concerned about airborne contaminants because they can pose serious health threats to wildlife and humans, as some of these compounds tend

Information sharing has supported the NPS in fulfilling its responsibility under the Clean Air Act and led to further collaborative efforts with states, tribes, EPA, the private sector, and the public aimed at protecting air quality in parks.

to accumulate in the food chain. Results from the project have been published in ten different journal articles. Key findings include: (1) over 70 agricultural and industrial contaminants from both international and local/regional sources are being deposited in western national parks; (2) parks with the highest levels of pesticides in snow and vegetation are those closest to croplands and include Glacier, Rocky Mountain, and Sequoia/Kings Canyon National Parks; (3) fish in some parks contained contaminant levels exceeding human health risk thresholds; and (4) lake sediment records show that many contaminants deposited in parks are increasing over time.

Fish are currently being sampled and analyzed for contaminant concentrations and effects on fish health and condition in 10 western national parks, as a follow-up to the WACAP study.

Natural Resource Condition Assessments

The NPS is conducting assessments to determine the current conditions for important natural resources in all parks that are part of the NPS Inventory and Monitoring Program. Each assessment relies on existing data and knowledge, is focused on a park-specific subset of important resource indicators, and summarizes overall conditions by individual park areas. The Air Resources Division is providing guidance, data, and information to assess air quality conditions for ozone, deposition, and visibility as part of the park assessments.

Four Corners Air Quality Task Force

The Four Corners region—the intersection of the states of Colorado, New Mexico, Utah, and Arizona—is home to existing and planned oil and gas production and coal-fired power plants. These activities result in substantial air pollutant emissions. The NPS units near this area include Mesa Verde National Park, Arches National Park, Canyonlands National Park, Capitol Reef National Park, Bryce Canyon National Park, Grand Canyon National Park, Chaco Culture National Historic Park, and Bandelier National Monument.

The states of Colorado and New Mexico initiated a collaborative effort involving Arizona and Utah, interested tribes in the area, the U.S. Environmental Protection Agency as well as federal land management agencies (NPS, the Bureau of Land Management, and the U.S. Forest Service) to explore air quality issues associated with present and future air pollutant emissions in the Four Corners region. These parties entered into a Memorandum of Understanding that defines an Interagency Policy Oversight Group, which, in turn, facilitated the Four Corners Air Quality Task Force.

The Task Force was open to all interested parties to discuss and formulate options to address regional air quality issues. The Four Corners Air Quality Task Force Final Report was issued in November, 2007 and includes hundreds of options to reduce air pollution. The air quality regulators in the area continue to use the report to develop air quality management strategies for the Four Corners region.

Climate Change

The Climate Friendly Parks Program was funded through July 2009 via an interagency agreement between the National Park Service and the EPA. NPS assumes full funding for the program in August 2009. The program encourages and enables national parks to develop strategies to reduce their greenhouse gas emissions. The program also entails a commitment on the part of participating parks to educate the public about what actions the park is taking to mitigate emissions. Over 89 parks are participating in the program and more are gearing up to ‘do their part.’ NPS interpreters have been working in partnership with National Aeronautics and Space Administration and other scientists to develop climate change training materials and interpretive products such as brochures and exhibits. NPS, in cooperation with EPA, Bureau of Land Management, Fish and Wildlife Service, U.S. Forest Service, the National Aeronautics and Space Administration, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey, developed a product entitled Climate Change: Wildlife & Wildlands, a Toolkit for Formal and Informal Educators. The new kit is designed for classroom teachers and for informal educators in parks, refuges, forest lands, nature centers, zoos, aquariums, science centers, etc., and is designed for the middle school level. The kit will aid educators in teaching how climate change is affecting our nation's wildlife and public lands, and how everyone can become "climate stewards." The toolkit is available online at http://www.globalchange.gov/resources/educators/toolkit.

The information, expertise and management concerns that the NPS brings to many external decision making arenas have made a difference in the past and will continue to in the future.

Group photo from a Western Regional Air Partnership meeting, Glacier National Park, Montana. The NPS participates in this regional haze planning group along with other federal land managers, federal agencies, states, and tribes.

Conclusion

An examination of available trend data in and near National Park Service units suggests that progress is being made in some areas of park air quality.

Sulfate concentrations in deposition are trending lower in many areas, and no statistically significant increasing trends were found. Nitrate concentrations in deposition also appear to be trending downward, particularly at eastern monitoring stations over the last 10 years. Visibility on the best days is also improving in many areas, and conditions are remaining stable or improving on the worst days in most areas. Ozone concentrations are trending downward at many areas, particularly in the East over the last 10 years.

Despite these improvements there are significant challenges remaining. Ammonium concentrations in wet deposition are trending higher in many areas, particularly in the West. Ozone concentrations are also trending higher in some areas in the West over the last 10 years. In addition, ambient ozone concentrations remain near or above the standard at many locations. Some parks in more remote areas such as Great Basin and Mesa Verde are experiencing surprisingly high ozone concentrations. Ozone exposures are also high at many parks, creating the potential for harmful impacts to ozone sensitive species. Visibility is impaired to some degree at all units where it is being measured, and remains considerably higher than the target natural conditions in many places, particularly on the haziest days. Furthermore, conditions estimates at park units across the country show quite a few parks where conditions for ozone, visibility, and deposition are of significant concern, and relatively few that are considered to be in good condition. The National Park Service will continue its work to understand the causes of air quality impairment at its units, and maintain its collaborative efforts with states and other agencies in order to improve park air quality.

Appendix A: GPRA Goal Assessment Methodology

FY 2008 Annual Performance Report: Government Performance and Results Act (GPRA)Air Quality Goals Ia3A, Ia3B, and Ia3C

The National Park Service (NPS) recently completed the FY 2008 performance assessment for the Servicewide air quality program as required by GPRA. The NPS evaluates performance based on a few air quality goals established by the NPS.

Long Term NPS Air Quality Goal

The NPS Strategic Plan establishes the following air quality goals for reporting parks to meet by September 30, 2012:

- Ia3A--visibility in 95% of NPS reporting parks has remained stable or improved;
- Ia3B--ozone in 89% of NPS reporting parks has remained stable or improved;
- Ia3C--atmospheric deposition in 79% of NPS reporting parks has remained stable or improved.

Intermediate goals have been established for each of the years from FY 2008 through FY 2011. The FY 2008 target percentages are 95 percent for goal Ia3A, 85 percent for goal Ia3B, and 75 percent for goal Ia3C. All three goals were met or exceeded for FY 2008.

NPS Goal Ia3 Performance Indicators

Determining progress toward meeting NPS Goal Ia3 requires an assessment whether park air quality is stable or improving. Assessing performance for this goal is based on a 10-year trend of three performance indicators: visibility, atmospheric deposition, and ozone. Six measures are used to assess performance under the three indicators.

Visibility: Two measures are used to assess this indicator. Particle measurements made at or near 147 NPS units were used to calculate the annual reconstructed atmospheric extinction in deciviews for both clear and hazy days. (Extinction depends on the mass and chemical composition of the particles and is a quantitative measure of how the passage of light through the atmosphere is affected by air pollutants.) The visibility goal Ia3A was met at 99 percent of reporting parks in FY 2008.

Ozone: This goal is evaluated by determining the 10-year trend in the 3-year average of the annual 4th-highest 8-hour ozone concentration, which is the statistic used for the National Ambient Air Quality Standard for ozone. Ozone measurements made in or near 161 parks were used to evaluate this measure. The ozone goal Ia3B was met at 94 percent of reporting parks in FY 2008.

Atmospheric Deposition: Three measures were used to assess this goal. Annual precipitation-weighted means of sulfate, nitrate, and ammonium ion concentrations at or near 58 NPS areas were trended to gauge air quality for this indicator. Changes in ammonium ion concentration in precipitation were included in the wet deposition indicator beginning in 2004 because ammonium contributes to total nitrogen deposition and data indicate that ammonium concentrations are increasing at a faster rate than nitrate ion concentrations alone. The atmospheric deposition goal Ia3C was met at 83 percent of reporting parks in FY 2008.

Significance Levels Refined: The method used to determine statistical significance of trends was modified to use a value more commonly used in the literature. In past trend reporting, we had used a significance level of 0.15, meaning there was a 15 percent chance that we could wrongly conclude that there was a trend when in fact the change was due to chance. We decided to change the significance level to 0.05, which is commonly used by many researchers. This reduces the chance that we would incorrectly conclude that there is a trend from 15 percent to 5 percent.

Calculating Progress: To calculate the service-wide percentages to compare with the air quality goals, we first performed a trend analysis for each of the above six air quality measures (2 visibility, 1 ozone, and 3 atmospheric deposition) over a ten-year period. The FY2008 analysis used 1998-2007 data and required each monitoring site to have a minimum of six years of data in this 10-year period. Calendar year 2008 data were not used in this FY2008 analysis because all of that year's data were not available. There is typically at least a three to six month lag between the time the data are collected in the field and when they are validated and available for analysis. Our trend time period is a sliding 10-year window and will change to 1999-2008 for next year's analysis. A sliding 10-year trend window was chosen rather than a variable length trend from a single fixed baseline year because individual parks began monitoring in different years and thus there is no individual fixed baseline year that can be applied to all parks. Trends were computed using a non-parametric technique that does not require any assumptions about the distribution of the data. This method was described by Theil (1950). In this method all possible ordered pairs of points are compared and the differences are computed. Each positive difference is recorded as a +1, each negative difference is recorded as a -1, and the sum of the +1 and +1 values is computed. This sum is then used to determine the probability that the observed differences could have occurred by chance as a result of random fluctuations in the time series. The EPA has also used this method to determine trends in air quality data (see http://www.epa.gov/visibility/report/APPd.pdf).

A few parks operate more than one ozone, visibility, or deposition monitor. We considered data from all monitoring sites at a park and if, for example, any one of the ozone monitors at a park showed a statistically significant degrading trend, the park was considered as not meeting the goal for that measure. In past years' analyses, the same park monitoring site was used for the trend analysis, even if other park site monitoring data were available. Initially when the GPRA air quality goal reporting started, we chose to use the park monitoring site with the longest period of data collection. Monitoring at parks with multiple sites has occurred long enough for there to be more than one park monitor that can be used for trend analysis. In addition, some park units that do not have monitors within their borders have more than one nearby monitor with sufficient data for trend analysis. Here also if one of the nearby monitors indicated a degrading trend we chose that monitor to represent the park unit in this report. In all cases if a monitor exists within a park for a particular measure and that monitor has sufficient data for trending we chose the in-park monitor over any nearby monitors.

In this report, we include information from deposition or ozone monitors within 10 miles of the boundary of that park. For a particulate (visibility) monitor, we required that it lie within 100 km (approximately 60 miles) of a park unit and within 130 meters in elevation of the park's minimum or maximum elevation in order to be considered representative of that park. This is consistent with the Interagency Monitoring for Visual Environments (IMPROVE) program, which considers IMPROVE monitors within 100 km of a Class I area to be representative of that area for monitoring progress under the Regional Haze Rule program. In some cases where parks do not have monitors within their borders and are located very close together, particularly in urban areas, these parks have been grouped together and represented by a single nearby monitor. These areas include the San Francisco, Washington D.C., Boston, New York City, Philadelphia, and Baltimore metropolitan areas. They also include the following non-urban parks: Charles Pinckney National Historic Site and Fort Sumter National Monument; Eisenhower National Historic Site and Gettysburg National Military Park; the parks included in the North Cascades Complex (North Cascades National Park, Lake Chelan National Recreation Area, and Ross Lake National Recreation Area); Fort Washington and Piscataway Parks; and Fort Caroline National Memorial and Timucuan Ecological and Historic Preserve.

A park is considered to have improving or stable air quality for each of the three measures if none of the trends used to assess that measure shows a statistically significant degrading trend. This means that for a park to be assessed as have stable or improving air quality with respect to visibility it must have stable or improving trends on both the clearest and haziest days. In addition, for a park to be considered to have met the air quality goal for atmospheric deposition it must have stable or improving trends for deposition of nitrate, ammonium, and sulfate. The tabulated values (Appendix B) include the slope or change in the measure per year and a level of statistical significance (p-value). Slopes with p values at 0.05 or less are considered statistically significant. The number of NPS areas not showing statistically significant deterioration in each of the performance indicators at the 0.05 level of significance is divided by the total number of NPS units with monitoring in that indicator to calculate a system-wide percentage. The three resulting percentages are then compared to the target percentages for the three GPRA goals.

References

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Appendix B: Table of Trend Results, 1998–2007

Trends in individual park air quality, for 1998-2007, are shown below. Data used to calculate these trends came from air quality monitors that are inside park boundaries, within 10 miles of parks (for ozone and deposition), and within 100 kilometers of parks (for visibility). Red indicates a degrading trend and blue indicates an improving trend. Statistically significant trends, shown with solid backgrounds, have at least a 95% probability that they did not occur by chance (p-values <=0.05). Also shown are trends that have an 85% to 95% probability that they did not occur by chance (p-values from 0.05 to 0.15); these trends are are indicated by colored outlines.

🟥	Degrading air quality trend, statistically significant (p <= 0.05)	□	Degrading air quality trend, not statistically significant (0.05 < p <= 0.15)
🟦	Improving air quality trend, statistically significant (p <= 0.05)	□	Improving air quality trend, not statistically significant (0.05 < p <= 0.15)

Individual Park 1998-2007 Trend Results

	Visibility				***Atmospheric Deposition***						***Ozone***	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
Park	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
Abraham Lincoln Birthplace	0.01	0.54	0.05	0.24								
Acadia	-0.11	**<0.01**	-0.08	0.15	0.09	0.18	-0.50	**0.022**	-0.44	0.18	-0.71	0.19
Allegheny Portage Railroad				-							-2.38	**<0.01**
Antietam	0.01	0.46	-0.14	0.24							-1.60	0.068
Appalachian	0.10	0.14	0.10	0.36	0.43	0.054	-0.02	0.36	0.65	0.19	0.57	0.11
Appomattox Court House	-0.10	0.50	-0.17	0.39								
Arches	-0.20	**<0.01**	-0.08	0.19								
Aztec Ruins											-1.50	**0.028**
Badlands	-0.07	0.11	-0.15	0.15								
Baltimore Metropolitan Area Parks	0.01	0.46	-0.14	0.24							-1.20	**<0.01**
Fort McHenry												
Hampton												
Bandelier	-0.15	**<0.01**	-0.18	0.36	0.10	0.54	-1.01	0.060	-0.71	**0.038**		
Bent's Old Fort					1.09	0.11	-0.11	0.36	0.04	0.50		
Big Bend	-0.29	**0.038**	-0.28	0.060	-0.24	0.38	-0.52	0.09	-0.37	0.18	-0.29	0.24
Big Cypress	0.33	0.12	-0.30	0.50								
Big Hole	-0.07	0.23	2.03	0.23								
Big Thicket											-0.86	0.15
Biscayne	0.33	0.12	-0.30	0.50							-0.67	0.15

Individual Park 1998-2007 Trend Results

Park	Visibility				Atmospheric Deposition						Ozone	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
Black Canyon Of The Gunnison	-0.13	**<0.01**	-0.10	0.24								
Blue Ridge	0.10	0.14	0.13	0.18							-1.29	**<0.01**
Booker T Washington	-0.10	0.50	-0.17	0.39								
Boston Metropolitan Area Parks	-0.20	0.23	-0.25	0.23	0.13	0.38	-0.51	0.18	-1.11	0.060	-0.80	0.28
Adams												
Boston African American												
Boston Harbor Islands												
Boston												
Frederick Law Olmsted												
John F Kennedy												
Longfellow												
Minute Man												
Saugus Iron Works												
Bryce Canyon	-0.13	**<0.01**	0.13	0.19	0.62	0.14	-0.21	0.36	-0.42	0.054		
Buffalo	0.08	0.36	-0.10	0.30	0.25	0.31	-0.29	**0.038**	-0.40	**0.038**		
Canaveral					-0.10	0.31	-0.31	0.060	-0.54	**0.038**		
Canyonlands	-0.20	**<0.01**	-0.08	0.19	0.60	**0.038**	-0.04	0.54	-0.13	0.24	-0.13	0.24
Cape Cod	-0.20	0.23	-0.25	0.23							-1.33	**0.014**
Capitol Reef	-0.13	**<0.01**	0.13	0.19								
Capulin Volcano					0.78	**0.015**	-0.23	0.50	0.08	0.28		
Carlsbad Caverns	-0.13	**<0.01**	-0.20	0.15								
Catoctin Mountain	-0.37	0.14	-0.43	0.14								
Cedar Breaks	-0.13	**<0.01**	0.13	0.19								
Central High School											0.43	0.15
Chamizal											-0.56	0.078
Channel Islands											-1.00	**0.023**
Charles Pinckney/ Fort Sumter	-0.02	0.54	-0.13	0.46								
Charles Pinckney												
Fort Sumter												
Chattahoochee River											-1.14	0.054
Chesapeake & Ohio Canal	0.01	0.46	-0.14	0.24							-0.14	0.45

Individual Park 1998-2007 Trend Results

Park	*Visibility*				*Atmospheric Deposition*						*Ozone*	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
Chiricahua	-0.13	**0.014**	-0.10	0.15	1.72	**<0.01**	0.63	0.19	0.06	0.50	0.33	**<0.01**
Congaree											-1.50	**0.028**
Cowpens											-2.60	**<0.01**
Crater Lake	-0.10	**<0.01**	-0.28	0.20								
Craters Of The Moon	-0.23	0.12	0.05	0.50	0.64	0.054	-0.15	0.15	0.08	0.43	0.25	0.19
Cumberland Gap					0.11	0.38	-0.80	**0.012**	-1.29	0.18	-1.43	0.054
Cumberland Island	-0.12	0.15	-0.07	0.15								
Curecanti	-0.13	**<0.01**	-0.10	0.24								
Cuyahoga Valley											-1.00	0.054
Dayton Aviation Heritage											-2.00	**<0.01**
De Soto											0.00	0.50
Death Valley	-0.06	0.068	0.02	0.50							0.43	**<0.01**
Delaware Water Gap					-0.12	0.36	-0.97	**<0.01**	-0.99	0.11		
Denali	-0.10	0.11	0.00	0.57	-0.04	0.43	-0.08	0.30	0.10	0.24	0.00	0.43
Eleanor Roosevelt											-1.83	0.078
Eugene O'Neill	-0.21	**<0.01**	0.15	0.45							-1.00	**<0.01**
Everglades	0.33	0.12	-0.30	0.50	0.30	0.13	0.11	0.38	-0.11	0.38		
Fire Island											-2.00	0.068
First Ladies	-0.14	0.23	-0.04	0.50							-1.29	**0.036**
Fort Bowie	-0.13	**0.014**	-0.10	0.15	1.72	**<0.01**	0.63	0.19	0.06	0.50	0.33	**<0.01**
Fort Donelson	-0.10	0.36	0.35	0.23								
Fort Frederica	-0.12	0.15	-0.07	0.15							-1.50	**<0.01**
Fort Pulaski											-1.00	**0.023**
Fort Union Trading Post	-0.20	0.054	0.20	0.20								
Fort Vancouver											0.00	0.43
Fredericksburg & Spotsylvania	0.01	0.46	-0.14	0.24							-1.33	**<0.01**
Friendship Hill											-1.67	0.14
George Rogers Clark					0.21	0.31	-0.54	**<0.01**	-0.53	0.24	-1.40	**<0.01**
George Washington Birthplace	0.01	0.46	-0.14	0.24								
Gettysburg/Eisenhower	-0.37	0.14	-0.43	0.14	-0.15	0.38	-1.81	**<0.01**	-1.17	0.090	-1.75	**0.036**
Eisenhower												
Gettysburg												

Individual Park 1998-2007 Trend Results												
	Visibility				*Atmospheric Deposition*						*Ozone*	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
Park	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
Gila Cliff Dwellings	-0.20	**<0.01**	-0.13	0.38	0.36	0.12	-0.03	0.50	-0.70	0.068		
Glacier	-0.12	0.089	-0.15	0.20	0.21	0.15	-0.12	0.30	-0.14	0.078	1.00	**<0.01**
Glen Canyon	-0.02	0.55	0.00	0.55								
Grand Canyon	-0.02	0.55	0.00	0.55	0.27	0.36	-0.08	0.55	-0.11	0.45	0.00	0.24
Grand Teton	-0.07	0.060	0.00	0.50								
Grant-Kohrs Ranch	-0.28	0.068	0.20	0.28								
Great Basin	-0.20	**<0.01**	-0.03	0.43	0.44	0.07	-0.20	0.50	-0.03	0.50	0.00	0.43
Great Egg Harbor River	0.08	0.18	0.07	0.46							-2.00	**<0.01**
Great Sand Dunes	-0.13	**0.014**	-0.15	0.11								
Great Smoky Mountains	-0.13	0.11	-0.14	0.078	0.19	0.30	-0.29	0.054	-0.22	0.36	-1.67	**<0.01**
Guadalupe Mountains	-0.13	**<0.01**	-0.20	0.15	-0.24	0.13	-0.71	**0.038**	-1.69	**<0.01**		
Gulf Islands											-1.13	**0.023**
Haleakala	-0.02	0.50	0.10	0.28								
Harpers Ferry	0.01	0.46	-0.14	0.24								
Harry S Truman											-1.00	0.14
Hawaii Volcanoes	-0.13	0.39	0.87	**0.015**								
Hohokam Pima											-1.00	0.14
Home Of Franklin D Roosevelt											-1.83	0.078
Indiana Dunes					0.22	0.15	-0.70	0.11	-0.97	0.11	-1.50	**<0.01**
Isle Royale	-0.10	0.14	0.06	0.45	0.41	0.27	-0.38	0.14	-0.32	0.20		
James A Garfield											-1.25	**<0.01**
Jean Lafitte											0.00	0.50
Jefferson											0.20	0.24
John D Rockefeller Jr	-0.07	0.060	-0.13	0.24								
John Muir	-0.21	**<0.01**	0.15	0.45							-0.75	0.078
Johnstown Flood											-2.43	**<0.01**
Joshua Tree	-0.10	0.19	-0.33	0.068							-0.75	0.36
Kalaupapa	-0.02	0.50	0.10	0.28								
Kennesaw Mountain											-2.80	0.068
Keweenaw	-0.10	0.14	0.06	0.45	0.41	0.27	-0.38	0.14	-0.32	0.20		
Knife River Indian Villages											-0.25	0.24
Lake Clark	0.00	0.64	-0.40	0.23								
Lake Mead											0.00	0.57

Individual Park 1998-2007 Trend Results

Park	*Visibility*				*Atmospheric Deposition*						*Ozone*	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
	dv/yr	p-value	dv/yr	p-value	μeq/liter /yr	p-value	μeq/liter /yr	p-value	μeq/liter /yr	p-value	ppb/yr	p-value
Lassen Volcanic	-0.13	0.078	-0.18	0.30							-1.00	**0.036**
Lava Beds	-0.10	0.28	-0.45	0.12								
Lincoln Home											-0.71	**0.023**
Little Bighorn Battlefield					-0.14	0.19	-0.46	**<0.01**	-0.29	**0.036**		
Mammoth Cave	0.01	0.54	0.05	0.24							-3.00	**<0.01**
Manassas	0.01	0.46	-0.14	0.24							-1.40	**<0.01**
Martin Luther King Jr											-2.40	**0.023**
Mesa Verde	-0.17	**<0.01**	-0.09	0.30	0.25	**0.036**	-0.40	0.30	-0.73	**0.014**	0.67	**0.023**
Minuteman Missile	-0.07	0.11	-0.15	0.15	0.80	0.19	-0.21	0.36	-0.42	**0.036**		
Mississippi											-0.33	0.24
Mojave	-0.10	0.19	-0.33	0.068								
Monocacy	0.01	0.46	-0.14	0.24							-1.80	**<0.01**
Morristown											-1.50	0.078
Mount Rainier	-0.09	0.18	-0.50	**<0.01**	0.11	**<0.01**	0.08	0.39	-0.35	**0.035**	0.75	0.11
Mount Rushmore	-0.13	0.089	0.06	0.36								
Natchez											-1.00	**<0.01**
Natchez Trace	-0.20	0.14	0.10	0.36	-0.17	0.15	-0.09	0.36	-0.47	**0.036**	-1.00	**<0.01**
Natural Bridges	-0.20	**<0.01**	-0.08	0.19								
New Bedford Whaling	-0.20	0.23	-0.25	0.23							-1.00	**0.036**
New York Metropolitan Area Parks											1.00	0.39
African Burial Ground												
Castle Clinton												
Edison												
Federal Hall												
Gateway												
General Grant												
Governors Island												
Hamilton Grange												
Saint Paul's Church												
Statue Of Liberty												
Theodore Roosevelt Birthplace												
Nez Perce	-0.07	0.23	2.03	0.23								

Individual Park 1998-2007 Trend Results

	Visibility				*Atmospheric Deposition*						*Ozone*	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
Park	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
North Cascades Complex	-0.07	0.39	-0.04	0.50	0.02	0.36	-0.10	0.19	-0.14	**0.036**	0.75	**0.023**
Lake Chelan												
North Cascades												
Ross Lake												
Ocmulgee											-3.23	**<0.01**
Olympic	-0.10	0.14	-0.40	**0.028**	-0.03	0.39	0.06	**0.015**	-0.07	0.50		
Organ Pipe Cactus					0.17	0.45	-0.49	0.36	-0.11	0.45		
Palo Alto Battlefield											0.00	0.43
Pecos	-0.15	**<0.01**	-0.18	0.36								
Petersburg											-1.50	**0.014**
Petrified Forest	-0.10	0.054	0.00	0.57								
Petroglyph											0.00	0.36
Philadelphia Metropolitan Area Parks	0.08	0.18	0.07	0.46							-1.13	0.15
Edgar Allan Poe												
Independence												
Thaddeus Kosciuszko												
Pictured Rocks	0.03	0.36	0.26	0.089								
Pinnacles	-0.20	**0.031**	-0.14	0.14	0.08	0.36	-0.04	0.50	0.04	0.36	-1.00	**<0.01**
Piscataway/ Fort Washington											-0.14	0.45
Fort Washington												
Piscataway												
Point Reyes	-0.21	**<0.01**	0.15	0.45								
Prince William Forest	0.01	0.46	-0.14	0.24							-0.75	**0.014**
Redwood	-0.11	0.078	-0.10	0.30								
Richmond											-1.38	**<0.01**
Rocky Mountain	-0.10	**0.036**	-0.05	0.36	0.45	0.19	0.01	0.50	-0.26	0.11	0.33	0.15
Roger Williams											0.17	0.36
Sagamore Hill											-1.00	0.054
Saguaro	-0.07	0.50	-0.17	0.23							0.33	0.19
Saint Croix					-0.94	**0.031**	-1.04	**0.031**	-0.80	**0.031**	-0.50	0.24
Saint Croix Island	-0.13	**0.023**	-0.10	0.19								
Saint-Gaudens											0.00	0.57

Individual Park 1998-2007 Trend Results

	Visibility				*Atmospheric Deposition*						*Ozone*	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
Park	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
Salem Maritime	-0.20	0.23	-0.25	0.23							-0.78	0.054
San Antonio Missions											-0.45	0.054
San Francisco Bay Area Parks	-0.21	**<0.01**	0.15	0.45							0.25	**0.036**
Fort Point												
Golden Gate												
Muir Woods												
Rosie the Riveter WWII Home Front												
San Francisco Maritime												
Santa Monica Mountains											1.80	0.15
Saratoga											0.00	0.57
Sequoia & Kings Canyon	-0.14	0.19	-0.13	0.28							0.00	0.57
Shenandoah	-0.05	0.38	0.13	0.18	-0.18	0.36	-0.54	0.14	-1.22	0.089	-2.00	**<0.01**
Sleeping Bear Dunes					-0.61	0.14	-1.45	**0.028**	-0.91	0.068	-1.00	**<0.01**
Springfield Armory											0.00	0.50
Steamtown											-1.60	**<0.01**
Sunset Crater Volcano	-0.02	0.55	0.05	0.39								
Theodore Roosevelt	-0.30	**<0.01**	0.10	0.50	0.40	0.39	-0.26	0.39	-0.06	0.50	0.00	0.36
Theodore Roosevelt Inaugural											0.17	0.43
Thomas Stone	0.01	0.46	-0.14	0.24								
Timpanogos Cave											-1.00	**<0.01**
Timucuan/Fort Caroline	-0.12	0.15	-0.07	0.15							-0.25	0.36
Fort Caroline												
Timucuan												
Tonto	-0.15	**0.031**	-0.10	0.27								
Tumacácori	-0.07	0.50	-0.17	0.23								
Tupelo											-2.25	**<0.01**
U S S Arizona											-0.83	**<0.01**
Ulysses S Grant											-1.13	0.089
Upper Delaware					-0.12	0.36	-0.97	**<0.01**	-0.99	0.11		
Valley Forge											-1.50	**<0.01**
Vanderbilt Mansion											-1.83	0.078
Virgin Islands					0.07	0.24	-0.07	0.31	0.08	0.46		

Individual Park 1998-2007 Trend Results

	Visibility				*Atmospheric Deposition*						*Ozone*	
	Clear Days		Hazy Days		Ammonium		Nitrate		Sulfate		Average 3-Yr 4th High 8-Hour	
Park	dv/yr	p-value	dv/yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	µeq/liter /yr	p-value	ppb/yr	p-value
Voyageurs	-0.07	0.20	0.10	0.27							-0.40	0.054
Walnut Canyon	-0.20	0.39	0.05	0.39								
Washington Metropolitan Area Parks	0.01	0.46	-0.14	0.24							-0.14	0.45
Arlington House												
Carter G. Woodson Home												
Clara Barton												
Ford's Theatre												
Frederick Douglass												
Greenbelt												
George Washington												
Lyndon Baines Johnson Mem. Grove												
Mary McLeod Bethune Council House												
National Mall & Memorial Parks												
National Mall												
Pennsylvania Avenue												
Rock Creek												
Theodore Roosevelt Island												
Washington												
President's Park (White House)												
Wolf Trap												
Weir Farm											-0.67	0.11
Whiskeytown	-0.13	0.078	-0.18	0.30							-2.13	**0.023**
William Howard Taft											-1.00	0.07
Wilson's Creek	0.00	0.64	-0.20	0.14								
Wind Cave	-0.13	0.089	0.06	0.36								
Yellowstone	-0.07	0.060	-0.13	0.24	0.72	**0.022**	0.06	0.46	0.14	0.13	-0.25	0.19
Yosemite	-0.09	0.24	-0.08	0.43	0.02	0.45	-0.36	0.054	-0.10	0.27	0.00	0.50
Zion	-0.13	**<0.01**	0.13	0.19								

Appendix C: Determination of Air Quality Condition

To assess condition, we first used all available monitoring data over the period 2003-2007 to generate interpolations for the continental United States. Monitors used included NPS, EPA, state, tribal, and local monitors. These interpolations allowed us to derive estimates of the air quality parameters at NPS units located within the continental United States, including those without on-site monitoring. (Since there were not sufficient monitors to generate interpolations outside the continental US, on-site monitoring data were used to derive the condition category estimates for Denali, Virgin Islands, Hawaii Volcanoes, and Haleakala.) We then used these interpolated values to determine an index for each type of air quality data collected (ozone concentrations, wet deposition concentrations, and visibility) that assigns the park to one of three condition categories:

Condition Red: Air Quality is a Significant Concern
Condition Yellow: Air Quality is in Moderate Condition
Condition Blue: Air Quality is in Good Condition

The interpolated values were then used to assign parks to condition categories using the following procedures.

Visibility Condition

Individual park scores for visibility were based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions[1], where Group 50 is defined as the mean of the visibility observations falling within the range from the 40th through the 60th percentiles. For parks within the continental US, current visibility was estimated from the interpolation of the five-year averages of the Group 50 visibility. For sites outside the continental US, five-year averages were computed from on-site data. Visibility in this calculation is expressed in terms of a haze index[2] in deciviews (dv). As the haze index increases, the visibility worsens. The visibility condition is expressed as:

Visibility Condition = current Group 50 visibility – estimated Group 50 visibility under natural conditions

Visibility Condition	**Difference from Estimated Natural Condition (dv)**
Red 🔴	> 8
Yellow 🟡	2-8
Blue 🔵	< 2

Condition Blue was assigned to parks with a visibility condition estimate of less than two dv above estimated natural conditions. Parks with visibility condition estimates ranging from two to eight dv above natural conditions were considered to be in moderate condition, and parks with visibility condition estimates greater than eight dv above natural conditions were considered to have a significant concern. The dv ranges of these categories, while somewhat subjective, were chosen to reflect as nearly as possible the variation in visibility conditions across the monitoring network.

Atmospheric Deposition Condition

Park scores for current condition of atmospheric deposition were based on wet deposition because dry deposition data was not available for most areas. Wet deposition for sites within the continental US was calculated by multiplying nitrogen (N) or sulfur (S) concentrations in precipitation by a normalized precipitation amount.[3] (For sites outside the continental US, where interpolations could not be calculated and normalized precipitation amounts were not available, five-year averages of on-site deposition were used. Deposition data were obtained from the National Atmospheric Deposition Program.) Several factors were considered in rating deposition condition, including natural background deposition estimates and deposition effects on ecosystems. Estimates of natural background deposition for total deposition are approximately 0.25 kilograms per hectare per year (kg/ha/yr) in the West and 0.50 kg/ha/yr in the East for either N or S. For wet deposition only, this is roughly equivalent to 0.13 kg/ha/yr in the West and 0.25 kg/ha/yr in the East.[4] Certain sensitive ecosystems respond to levels of deposition on the order of 3 kg/ha/yr total deposition, or about 1.5 kg/ha/yr wet deposition.[5]

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[1] The natural visibility conditions used in this treatment are those visibility conditions that have been estimated to exist in a given area in the absence of human-caused visibility impairment. These estimates were determined in accordance with with the EPA's Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Rule, EPA-454/B-03-005

[2] The Haze Index is a measure of visibility derived from calculated light extinction (EPA-454/B-03-005).

[3] Normalized 30-year precipitation values from the PRISM database were used to calculate deposition in order to minimize interannual variation in deposition caused by interannual fluctuations in precipitation (http://www.ocs.orst.edu/prism/).

[4] The proportion of wet to dry deposition varies by location but, in general, wet deposition is approximately one-half of total deposition.

[5] Fenn et al. 2003. BioScience 53: 404-420; Krupa 2002. Environmental Pollution 124: 179-221

Nitrogen/Sulfur Deposition Condition	Wet Deposition (kg/ha/yr)
Red 🔴	> 3
Yellow 🟡	1-3
Blue 🔵	< 1

Evidence indicating that wet deposition amounts less than 1 kg/ha/yr cause ecosystem harm is not currently available. Therefore, parks with wet deposition less than 1 kg/ha/yr were considered to be in good condition for deposition; parks with 1-3 kg/ha/yr were considered to be in moderate condition; and parks with greater than 3 kg/ha/yr were considered to have a significant concern for deposition. Scores for parks with ecosystems potentially sensitive to N or S[6] were adjusted up one category (e.g., a park with N deposition from 1-3 kg/ha/yr that contains N-sensitive ecosystems was assigned the condition "red").

Ozone Condition

The ozone standard was used as a benchmark for rating current ozone air quality. This standard was revised in 2008 in order to be more protective of human health. To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 75 parts per billion (ppb). To derive an estimate of the current ozone condition at parks, the five-year average of the annual 4th-highest 8-hour ozone concentration was determined for each park from the interpolated values described above. If the resulting five-year average was greater than or equal to 76 ppb then Condition Red was assigned to that park. Condition Yellow for ozone was assigned to parks with average five-year 4th-highest 8-hour ozone concentrations from 61 to 75 ppb (concentrations greater than 80 percent of the standard). Condition Blue for ozone was assigned to parks with average five-year ozone concentrations less than 61 ppb (concentrations less than 80 percent of the standard).

In addition to the standard, vegetation sensitivity was considered for park condition. Data show that some plant species[7] are more sensitive to ozone than humans and the ozone standard is not protective of some vegetation. Ozone injury to vegetation has been documented at a number of parks, including Great Smoky Mountains NP, Shenandoah NP, and Sequoia/Kings Canyon NPs. A risk assessment completed in 2004 rated parks at low, moderate, or high risk for ozone injury to vegetation, based on presence of sensitive plant species, ozone exposures[8], and environmental conditions, i.e., soil moisture. For this report, parks that were evaluated at high risk were moved into the next condition category (e.g., a park with an average ozone concentration of 72 ppb, but judged to be at high risk for vegetation injury, would move from the category "yellow" for ozone to "red").

Ozone Condition	Ozone concentration
Red 🔴	≥ 76 ppb
Yellow 🟡	61-75 ppb
Blue 🔵	≤ 60 ppb

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[6] Ecosystems that are considered potentially sensitive to N or S deposition include high-elevation ecosystems in the West, upland areas in the East, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands.

[7] Lists of ozone sensitive species, by park, are available from NPSpecies (https://science1.nature.nps.gov/npspecies/).

[8] The ozone risk assessment for injury to vegetation was based on ozone exposures over the growing seasons from 1995-1999. The ozone exposure metrics are described in the ozone risk assessments at http://www2.nature.nps.gov/air/Pubs/ozonerisk.htm.

Air Quality Condition		Air Quality Trend	
Red–Significant Concern	🔴	Degrading	⇧
Yellow–Moderate Concern	🟡	Stable	⇔
Blue–Good Condition	🔵	Improving	⇩

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Abraham Lincoln Birthplace	🔴⇔			
Acadia	🟡⇔	🟡⇔	🔴⇔	🟡⇔
Adams	🟡⇔	🔴⇔	🔴⇔	🔴⇔
African Burial Ground				🔴⇔
Allegheny Portage Railroad				🔴⇩
Antietam	🔴⇔			🔴⇔
Appomattox Court House	🔴⇔			
Appalachian	🔴⇔	🔴⇔	🔴⇔	🔴⇔
Arches	🟡⇔			
Arlington House	🔴⇔			🔴⇔
Aztec Ruins				🟡⇩
Badlands	🟡⇔			
Bandelier	🟡⇔	🟡⇔	🟡⇩	
Bent's Old Fort		🟡⇔	🔵⇔	
Big Bend	🟡⇔	🔴⇔	🟡⇔	🟡⇔
Big Cypress	🔴⇔			
Big Hole	🟡⇔			
Biscayne	🔴⇔			🟡⇔
Big Thicket				🔴⇔
Black Canyon Of The Gunnison	🟡⇔			
Blue Ridge	🔴⇔			🔴⇩
Boston African American	🟡⇔	🔴⇔	🔴⇔	🔴⇔
Boston Harbor Islands	🟡⇔	🔴⇔	🔴⇔	🔴⇔
Boston	🟡⇔	🔴⇔	🔴⇔	🔴⇔
Booker T Washington	🔴⇔			
Bryce Canyon	🟡⇔	🟡⇔	🔵⇔	
Buffalo	🔴⇔	🔴⇔	🔴⇩	

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Castle Clinton				🔴⇔
Cape Cod	🟡⇔			🔴⇩
Canaveral		🔴⇔	🔴⇩	
Canyonlands	🟡⇔	🔵⇧	🔵⇔	🟡⇔
Capitol Reef	🟡⇔			
Catoctin Mountain	🔴⇔			
Carlsbad Caverns	🟡⇔			
Capulin Volcano		🟡⇧	🟡⇔	
Carter G. Woodson Home	🔴⇔			🔴⇔
Cedar Breaks	🟡⇔			
Chamizal				🟡⇔
Chattahoochee River				🔴⇔
Chiricahua	🟡⇔	🔴⇧	🟡⇔	🟡⇧
Channel Islands				🟡⇩
Chesapeake & Ohio Canal	🔴⇔			🔴⇔
Charles Pinckney	🔴⇔			
Central High School				🔴⇔
Clara Barton	🔴⇔			🔴⇔
Congaree				🟡⇩
Cowpens				🔴⇩
Crater Lake	🟡⇔			
Craters Of The Moon	🟡⇔	🔴⇔	🔵⇔	🟡⇔
Cumberland Gap		🔴⇔	🔴⇔	🔴⇔
Cumberland Island	🔴⇔			
Curecanti	🟡⇔			
Cuyahoga Valley				🔴⇔
Dayton Aviation Heritage				🔴⇩
Denali	🔵⇔	🔵⇔	🔵⇔	🔵⇔
De Soto				🟡⇔
Death Valley	🟡⇔			🔴⇧
Delaware Water Gap		🔴⇔	🔴⇔	
Edgar Allan Poe	🔴⇔			🔴⇔
Edison				🔴⇔

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Eisenhower	🔴↔	🔴↔	🔴↔	🔴↓
Eleanor Roosevelt				🔴↔
Eugene O'Neill	🟡↔			🟡↓
Everglades	🔴↔	🔴↔	🔴↔	
Federal Hall				🔴↔
Fire Island				🔴↔
First Ladies	🔴↔			🔴↓
Fort Bowie	🟡↔	🟡↑	🟡↔	🟡↑
Fort Caroline	🔴↔			🟡↔
Fort Donelson	🔴↔			
Fort Frederica	🔴↔			🟡↓
Fort McHenry	🔴↔			🔴↓
Fort Point	🟡↔			🔵↑
Fort Pulaski				🟡↓
Fort Sumter	🔴↔			
Ford's Theatre	🔴↔			🔴↔
Fort Union Trading Post	🟡↔			
Fort Vancouver				🔵↔
Fort Washington				🔴↔
Frederick Douglass	🔴↔			🔴↔
Friendship Hill				🔴↔
Frederick Law Olmsted	🟡↔	🔴↔	🔴↔	🔴↔
Fredericksburg & Spotsylvania	🔴↔			🔴↓
Gateway				🔴↔
General Grant				🔴↔
George Rogers Clark		🔴↔	🔴↔	🟡↓
Gettysburg	🔴↔	🔴↔	🔴↔	🔴↓
George Washington Birthplace	🔴↔			
Gila Cliff Dwellings	🟡↔	🟡↔	🟡↔	
Glacier	🟡↔	🔴↔	🟡↔	🔵↑
Glen Canyon	🟡↔			
Golden Gate	🟡↔			🔵↑
Governors Island				🔴↔

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Great Basin	🟡⇔	🟡⇔	🟡⇔	🟡⇔
Grand Canyon	🟡⇔	🟡⇔	🔵⇔	🟡⇔
Greenbelt	🔴⇔			🔴⇔
Great Egg Harbor River	🔴⇔			🔴⬇
Grant-Kohrs Ranch	🟡⇔			
Great Sand Dunes	🟡⇔			
Great Smoky Mountains	🔴⇔	🔴⇔	🔴⇔	🔴⬇
Grand Teton	🟡⇔			
Gulf Islands				🔴⬇
Guadalupe Mountains	🟡⇔	🔴⇔	🟡⬇	
George Washington	🔴⇔			🔴⇔
Harpers Ferry	🔴⇔			
Hamilton Grange				🔴⇔
Haleakala	🟡⇔			
Hampton	🔴⇔			🔴⬇
Hawaii Volcanoes	🟡⬆			
Home Of Franklin D Roosevelt				🔴⇔
Harry S Truman				🔴⇔
Independence	🔴⇔			🔴⇔
Indiana Dunes		🔴⇔	🔴⇔	🔴⬇
Isle Royale	🟡⇔	🔴⇔	🟡⇔	
James A Garfield				🔴⬇
Jefferson				🔴⇔
Jean Lafitte				🔴⇔
John D Rockefeller Jr	🟡⇔			
John F Kennedy	🟡⇔	🔴⇔	🔴⇔	🔴⇔
Johnstown Flood				🔴⬇
John Muir	🟡⇔			🟡⇔
Joshua Tree	🔴⇔			🔴⇔
Kennesaw Mountain				🔴⇔
Keweenaw	🟡⇔	🔴⇔	🟡⇔	
Knife River Indian Villages				🔵⇔
Lava Beds	🟡⇔			

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Lake Chelan	🟡↔	🔴↔	🔴↓	🔵↑
Lake Mead				🔴↔
Lassen Volcanic	🟡↔			🟡↓
Little Bighorn Battlefield		🟡↔	🔵↓	
Lincoln Home				🟡↓
Longfellow	🟡↔	🔴↔	🔴↔	🔴↔
Lyndon Baines Johnson Memorial Grove	🔴↔			🔴↔
Mammoth Cave	🔴↔			🔴↓
Martin Luther King Jr				🔴↓
Mary McLeod Bethune Council House	🔴↔			🔴↔
Manassas	🔴↔			🔴↓
Mesa Verde	🟡↔	🔴↑	🟡↓	🟡↑
Minute Man	🟡↔	🔴↔	🔴↔	🔴↔
Minuteman Missile	🟡↔	🔴↔	🟡↓	
Mississippi				🟡↔
Mojave	🟡↔			
Monocacy	🔴↔			🔴↓
Mount Rainier	🟡↔	🔴↑	🔴↓	🟡↔
Morristown				🔴↔
Mount Rushmore	🟡↔			
Muir Woods	🟡↔			🔵↑
Natural Bridges	🟡↔			
National Mall & Memorial Parks	🔴↔			🔴↔
National Mall	🔴↔			🔴↔
Natchez				🔴↓
Natchez Trace	🔴↔	🔴↔	🔴↓	🟡↓
New Bedford Whaling	🟡↔			🔴↓
Nez Perce	🟡↔			
North Cascades	🟡↔	🔴↔	🔴↓	🔵↑
Ocmulgee				🔴↓
Olympic	🟡↔	🔴↑	🔴↔	
Organ Pipe Cactus		🟡↔	🔵↔	
Palo Alto Battlefield				🟡↔

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Pennsylvania Avenue	🔴⇔			🔴⇔
Pecos	🟡⇔			
Petrified Forest	🟡⇔			
Petersburg				🔴↓
Petroglyph				🟡⇔
Hohokam Pima				🟡⇔
Pinnacles	🟡⇔	🔵⇔	🔵⇔	🔴↓
Pictured Rocks	🟡⇔			
Piscataway				🔴⇔
Point Reyes	🟡⇔			
Prince William Forest	🔴⇔			🔴↓
Redwood	🟡⇔			
Richmond				🔴↓
Rock Creek	🔴⇔			🔴⇔
Ross Lake	🟡⇔	🟡⇔	🟡↓	🔵↑
Rocky Mountain	🟡⇔	🔴⇔	🔴⇔	🟡⇔
Rosie the Riveter WWII Home Front	🟡⇔			🔵↑
Roger Williams				🔴⇔
San Antonio Missions				🔴⇔
Saint Croix		🔴↓	🟡↓	🟡⇔
Saint Croix Island	🟡⇔			
San Francisco Maritime	🟡⇔			🔵↑
Saint-Gaudens				🟡⇔
Saguaro	🟡⇔			🟡⇔
Sagamore Hill				🔴⇔
Saugus Iron Works	🟡⇔	🔴⇔	🔴⇔	🔴⇔
Salem Maritime	🟡⇔			🔴⇔
Santa Monica Mountains				🔴⇔
Saint Paul's Church				🔴⇔
Saratoga				🟡⇔
Sequoia & Kings Canyon	🔴⇔			🔴⇔
Shenandoah	🔴⇔	🔴⇔	🔴⇔	🔴↓
Sleeping Bear Dunes		🔴⇔	🔴⇔	🔴↓

Park	Condition and Trend Symbol			
	Visibility	Nitrogen Deposition	Sulfur Deposition	Ozone
Springfield Armory				🔴⇔
Steamtown				🟡⇩
Statue Of Liberty				🔴⇔
Sunset Crater Volcano	🟡⇔			
Theodore Roosevelt Island	🔴⇔			🔴⇔
Thaddeus Kosciuszko	🔴⇔			🔴⇔
Theodore Roosevelt Birthplace				🔴⇔
Theodore Roosevelt Inaugural				🔴⇔
Theodore Roosevelt	🟡⇔	🟡⇔	🔵⇔	🔵⇔
Thomas Stone	🔴⇔			
Timpanogos Cave				🔴⇩
Timucuan	🔴⇔			🟡⇔
Tonto	🟡⇔			
Tumacácori	🟡⇔			
Tupelo				🟡⇩
Ulysses S Grant				🔴⇔
Upper Delaware		🔴⇔	🔴⇔	
Valley Forge				🔴⇩
Vanderbilt Mansion				🔴⇔
Virgin Islands		🔵⇔	🟡⇔	
Voyageurs	🟡⇔			🟡⇔
Walnut Canyon	🟡⇔			
Washington	🔴⇔			🔴⇔
Weir Farm				🔴⇔
President's Park (White House)	🔴⇔			🔴⇔
Whiskeytown	🟡⇔			🔴⇩
Wind Cave	🟡⇔			
Wilson's Creek	🔴⇔			
William Howard Taft				🔴⇔
Wolf Trap	🔴⇔			🔴⇔
Yellowstone	🟡⇔	🔴⇧	🟡⇔	🟡⇔
Yosemite	🟡⇔	🔴⇔	🟡⇔	🔴⇔
Zion	🟡⇔			

Appendix D: Ozone W126

Calculation of the Ozone W126 Statistic

In July 2007 the EPA proposed a new secondary ozone standard. The proposed standard was based upon a cumulative sum of hourly ozone values, where the hourly values are weighted according to their concentrations. The weighted value is usually referred to as the W126 statistic. Each hourly index value is computed by multiplying the hourly concentration (O3) by the weighting function as given by the following equation:

$$W126 = O_3 * \left(\frac{1}{1 + \left(4403 * e^{-126 * O_3}\right)} \right)$$

The hourly index values are then summed over the daylight hours from 8am to 8pm for each 3-month period during the local ozone season. The three-month period with the highest cumulative W126 value is the annual standard-related summary statistic, and it is expressed in ppm-hours. For a month to be valid, it must have hourly ozone values available for at least 75% of possible hours. The W126 index is then adjusted for missing hourly data by multiplying it by the ratio of the number of possible hours to the available hours. Months with fewer than 75% of possible hourly ozone measurements are not considered.

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