AIR QUALITY AND AIR QUALITY RELATED VALUES MONITORING CONSIDERATIONS FOR THE NORTHERN GREAT PLAINS NETWORK

May 2005

Introduction

The Northern Great Plains Vital Signs Network (NGPN) includes 13 national park units in North Dakota, South Dakota, Nebraska, and eastern Wyoming: Agate Fossil Beds National Monument (NM), Badlands National Park (NP), Devil's Tower NM, Fort Laramie National Historic Site (NHS), Fort Union Trading Post NHS, Jewel Cave NM, Knife River Indian Villages NHS, Missouri National Recreation River (NRR), Mount Rushmore National Memorial, Niobrara National Scenic River, Scotts Bluff NM, Theodore Roosevelt NP, and Wind Cave NP. Badlands NP, Theodore Roosevelt NP, and Wind Cave NP are Class I air quality areas, receiving the highest protection under the Clean Air Act. The other park units are Class II air quality areas and also receive protection under the Act. Air quality and related information for the network is at http://www2.nature.nps.gov/air/Permits/ARIS/networks/index.htm.

Although the park units in the network are some distance from cities and pollution sources, they experience occasional poor air quality from pollutants such as ozone, nitrogen oxides, sulfur dioxide, volatile organic compounds, particulate matter, and toxics. These air pollutants affect, or have the potential to affect, air quality and natural resources in NGPN, including vegetation, wildlife, soils, water quality, and visibility. For example, nitrogen and sulfur compounds from the atmosphere have the potential to affect water quality and biota, soil nutrient cycling and plant species composition. Pollutant particles in the air reduce visibility in the region and affect how far and how well we can see. Atmospheric deposition of toxic organic compounds and metals, including mercury, may have a wide range of effects on fish and wildlife. The following sections describe air pollutant emissions, air quality monitoring, and air pollutant concerns for resources in the network.

Air Pollutant Emissions

Air quality in the network is affected primarily by air pollution sources in North Dakota, South Dakota, Nebraska, Montana, and Wyoming, although more distant sources can also affect the area's air quality. Air pollutant emissions come from a variety of sources, including mobile sources (e.g., cars, trucks, off-road vehicles), stationary sources (e.g., power plants and industry), and area sources (e.g., oil and gas development, agriculture, fires, and road dust).

Some of the most common and abundant pollutant emissions include nitrogen oxides, ammonia, and sulfur dioxide. Figure 1 shows distribution maps for emissions of nitrogen oxides, ammonia, and sulfur dioxide in North Dakota, South Dakota, Nebraska, Montana, and Wyoming. Similar maps are not available for Mexico, but information on air pollution sources in Mexico has been compiled for the Big Bend Regional Aerosol & Visibility Observational Study (BRAVO) Emissions Inventory and is available at http://www.epa.gov/ttn/chief/net/mexico.html. Major sources of nitrogen oxides include cars and other mobile sources, compressors, power plants and industry. Agricultural activities are the main sources of ammonia. The major sources of sulfur dioxide are coal-burning power plants, industry, and diesel engines. Additional information on pollutant sources in the U.S. can be found at http://www.epa.gov/air/data/index.html.

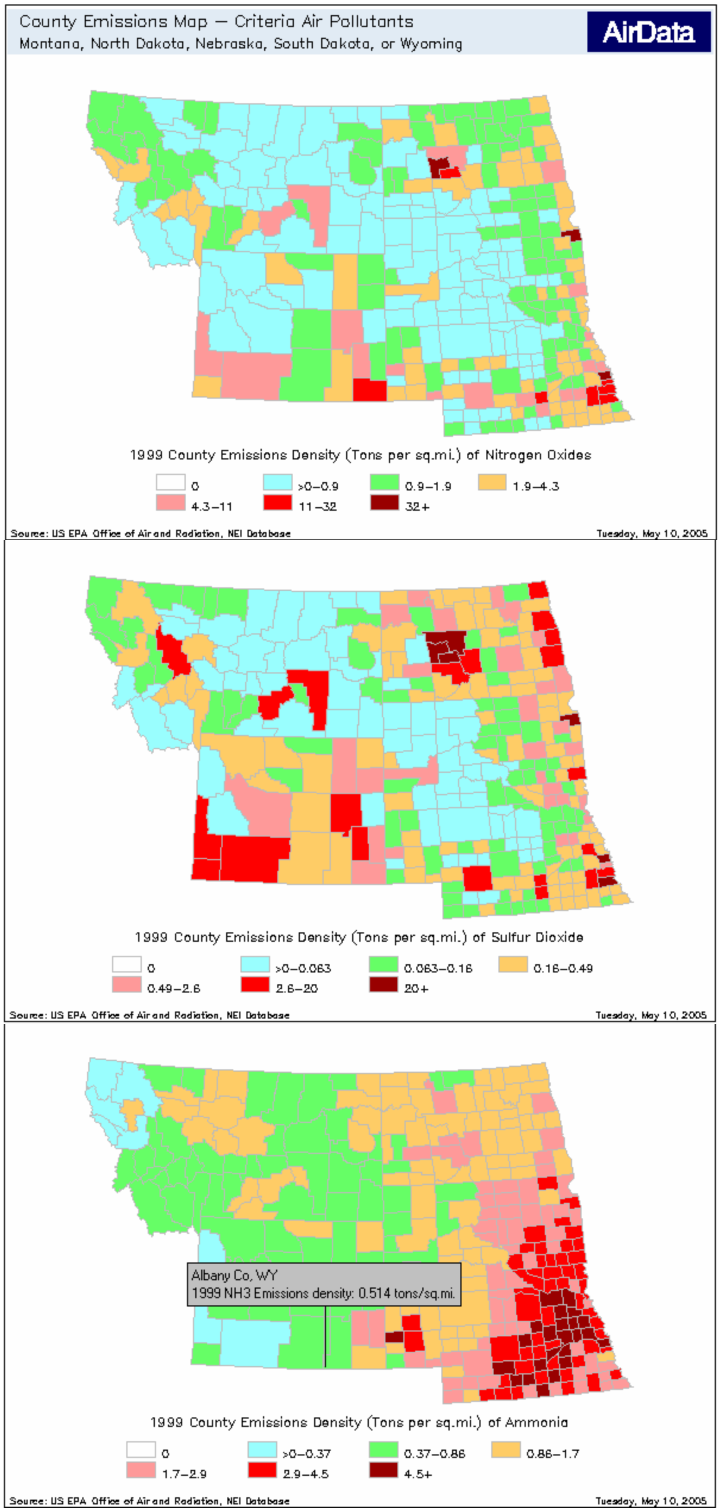


Figure 1. Density of air pollutant emissions of nitrogen oxides, ammonia, and sulfur dioxide (by county) in North Dakota, South Dakota, Nebraska, Montana, and Wyoming. Emissions are given in thousands of tons per year for nitrogen oxides and sulfur dioxide and tons per year for ammonia (from EPA AirData at http://www.epa.gov/air/data/index.html).

Air Quality Monitoring and Effects

Figure 2 shows current air quality monitoring sites in or near NGPN park units. Table 1 lists air quality monitoring site locations. Big Bend NP and Guadalupe Mountains NP have on-site air quality monitoring. Types of monitoring include ozone monitoring by States (Ozone) and by NPS (GPMN – Gaseous Pollutant Monitoring Network for ozone); wet deposition (rain, snow) monitoring of atmospheric pollutants by the National Atmospheric Deposition Program/National Trends Network (NADP/NTN); wet deposition monitoring of mercury by the Mercury Deposition Network (MDN); dry deposition (dryfall) monitoring of atmospheric pollutants by the Clean Air Status and Trends Network (CASTNet); and visibility monitoring by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program.

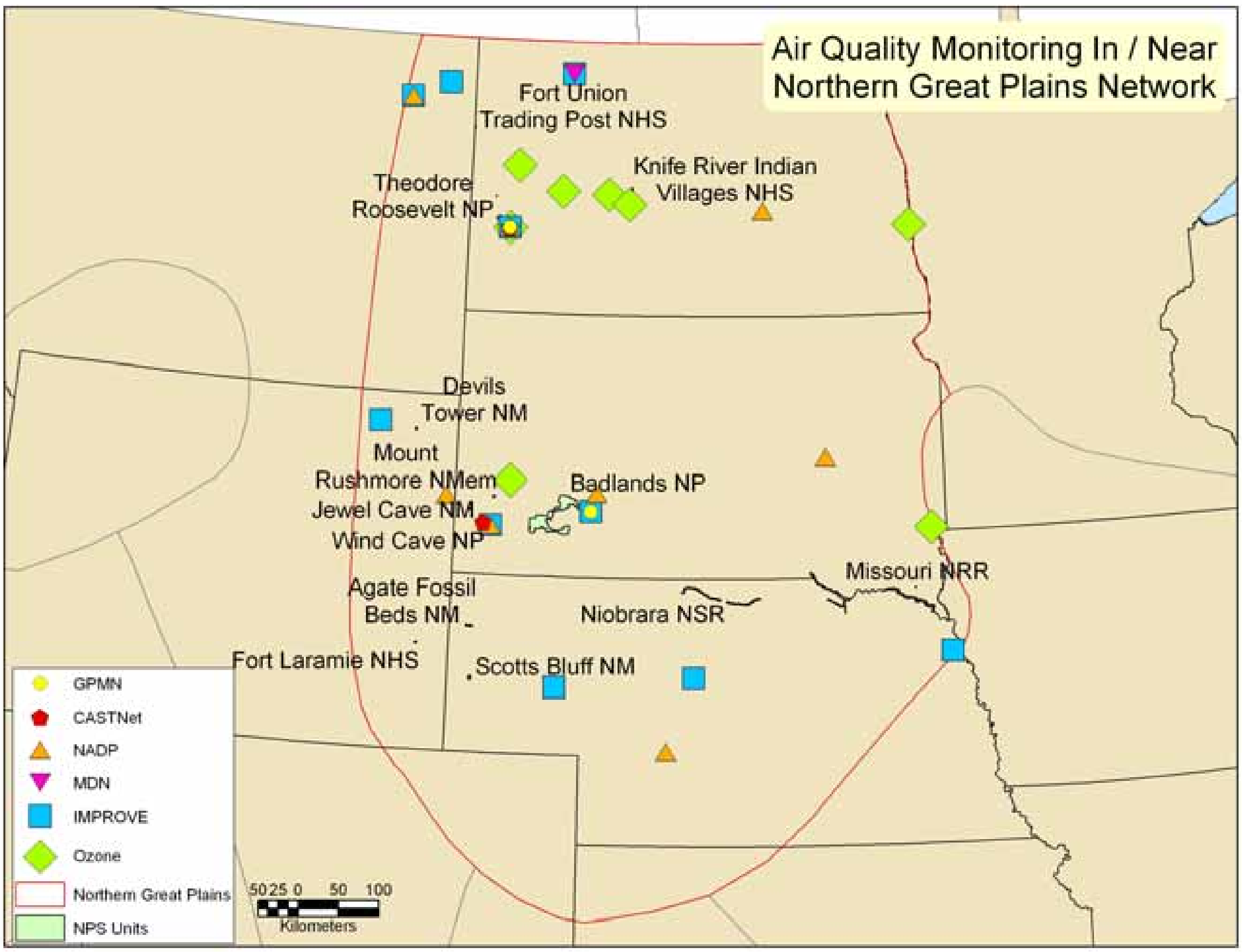


Figure 2. Air quality monitoring in NGPN (GPMN=NPS Gaseous Pollutant Monitoring Network; CASTNet= Clean Air Status and Trends Network; NADP= National Atmospheric Deposition Program; MDN=Mercury Deposition Network; IMPROVE=Interagency Monitoring of Protected Visual Environments; Ozone=ozone monitoring by States.)

Table 1. Current air quality monitoring sites in or near NPS units in NGPN. Air quality data is available from the monitoring network websites listed below. Data from distant monitors are unlikely to be representative of conditions in a park unit; Air Atlas estimates should be used in these cases. Air quality estimates for CHDN park units are available from NPS Air Atlas at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm.

MONITORING NETWORK	SITE I.D.	LOCATION
GPMN Ozone	Badlands Theodore Roosevelt	Jackson County, SD Billings County, ND
CASTNet	THR422 (Theodore Roosevelt) WNC429 (Wind Cave)	Billings County, ND Custer County, SD
NADP	ND00 (Theodore Roosevelt) ND11 (Woodworth) SD08 (Cottonwood) SD04 (Wind Cave) SD99 (Huron Well Field) WY99 (Newcastle) MT96 (Poplar River) NE99 (North Platte Agricultural Exp. Stn)	Billings County, ND Stutsman County, ND Jackson County, SD Custer County, SD Beadle County, SD Weston County, WY Roosevelt County, MT Lincoln County, NE
MDN	ND01 (Lostwood NWR)	Burke County, ND
IMPROVE	THRO1 (Theodore Roosevelt) BADL1 (Badlands) WICA1 (Wind Cave) LOST1 (Lostwood NWR) MELA1 (Medicine Lake NWR) FOPE1 (Fort Peck) NEBR1 (Nebraska NF) CRES1 (Crescent Lake NWR) OMAH1 (Omaha)	Billings County, ND Jackson County, SD Custer County, SD Burke County, ND Sheridan County, MT Chouteau County, MT Nebraska NF, NE Garden County, NE Omaha, NE
Ozone	various	There are several State ozone monitors located in the NGPN region

GPMN = Gaseous Pollutant Monitoring Network at NPS AirWeb at http://www2.nature.nps.gov/air/data/index.htm
CASTNet = Clean Air Status and Trends Network at http://www.epa.gov/castnet/
NADP/NTN = National Atmospheric Deposition Program at http://nadp.sws.uiuc.edu/
MDN = Mercury Deposition Network at http://nadp.sws.uiuc.edu/mdn/
IMPROVE = Interagency Monitoring of Protected Visual Environments at http://vista.cira.colostate.edu/views/
Ozone = EPA AirData at http://www.epa.gov/air/data/index.html

Air Quality Estimates: Air Atlas

NPS Air Resources Division has developed Air Atlas to provide estimates of air quality conditions for park units without on-site monitoring (http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm). Air Atlas serves as the air inventory for parks and is a mini-GIS tool that provides national maps and an associated look-up table with baseline values of air quality parameters for all Inventory and Monitoring (I&M) parks in the U.S. The values are based on 1995-1999 data. An update with 1999-2003 data will be available in summer 2005.

The estimated air quality values provided in Air Atlas are based on monitoring values at the center of the polygon defining the park or multiple units of the park. Data from all available monitors operated by NPS, States, EPA, and other programs are used for the interpolation of the air quality values. Air Atlas contains a comprehensive set of air quality parameters. Table 2 summarizes selected air quality parameters for NGPN.

Table 2. Estimates of selected air quality parameters for units of the NGPN (from Air Atlas at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm). Estimates are not available for all parameters for Missouri NRR and Niobrara NSR; however, estimates of ozone concentrations and exposures were made for the two units for the ozone injury risk assessment and are available at http://www2.nature.nps.gov/air/Pubs/ozonerisk.htm.

NORTHERN GREAT PLAINS NETWORK		Ozone ----------					NADP (kg/ha/yr)==		Visibility - IMPROVE -	
Parkname	CLASS	2ndHi1hr	4thHi8hr	#8hr>85	#1hr>100	Sum06_3Mo	Total S	Total N	bextClear	bextHazy
Agate Fossil Beds NM	2	98.5	72.7	1.6	2.1	16.0	1.59	2.77	7	32
Badlands NP	1	90.2	69.1	1.3	1.5	8.9	1.30	2.70	10	46
Devils Tower NM	2	87.6	68.3	0.9	1.0	7.5	1.02	1.89	7	33
Fort Laramie NHS	2	98.2	72.6	1.6	2.1	16.0	1.59	2.68	6	28
Fort Union Trading Post NHS	2	76.6	63.3	0.2	0.2	3.0	0.74	1.46	7	35
Jewel Cave NM	2	92.8	70.3	1.4	1.7	14.0	1.28	2.37	8	38
Knife River Indian Village NHS	2	73.5	61.4	0.1	0.1	2.0	1.05	2.36	8	38
Mount Rushmore N MEM	2	91.8	69.9	1.3	1.6	10.2	1.25	2.42	9	41
Missouri NRR	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Niobrara NSR	2	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Scotts Bluff NM	2	98.7	72.6	1.6	2.1	15.3	1.62	2.83	7	29
Theodore Roosevelt NP	1	75.7	63.1	0.3	0.3	3.0	0.91	1.85	7	36
Wind Cave NP	1	93.7	70.7	1.4	1.8	14.6	1.34	2.53	9	40

Class: refers to an area's designation under the Clean Air Act
Ozone information represents 5-yr average of annual values from 1995-1999
2nd High 1 hr concentration (ppb): indicates peak values for ozone; old standard of 0.12 ppm (120 ppb) was based on 2nd hi,1-hr average
4th high 8 hr concentration (ppb): new ozone standard of 0.08 ppm (80 ppb) is based on 4th hi, 8-hr average
#8 hours>85 ppb: indicates how often the area would be in violation of the new 8-hr standard of 0.08 ppb
hours> 100 ppb: high peaks in ozone concentration, as well as cumulative dose, contribute to vegetation injury
SUM06_3mon (ppm-hrs) - sum of hourly ozone conc.≥0.06 ppm (60 ppb) over 3 months (~ growing season), i.e., cumulative ozone dose
NADP information represents 6-yr average of annual values from 1995-2000
NADP deposition (kg/ha/yr): estimate of pollutants deposited to ecosystem by precipitation (NADP-National Atmospheric Deposition Program)
NADP Total S - sulfur from sulfate deposited by precipitation
NADP Total N - inorganic nitrogen (ammonium plus nitrate) deposited by precipitation
Visibility IMPROVE information represents 5-yr average of annual values from 1995-1999
bextClear - measure of light scattering and absorption, i.e., extinction, by particles in the air on an average clear day
bextHazy - measure of light scattering and absorption, i.e., extinction, by particles in the air on an average hazy day

Wet Deposition Monitoring of Atmospheric Pollutants

Wet deposition is monitored at Theodore Roosevelt NP and Wind Cave NP. In addition, there are several other NADP/NTN samplers in the NGPN area. Figure 2 shows locations of NADP/NTN wet deposition samplers in or near CHDN units. Table 1 lists the site identification codes and locations. Estimates of wet deposition for park units without on-site or nearby monitoring are available from Air Atlas. NADP/NTN collects data on both pollutant deposition (in kilograms per hectare per year – kg per ha per yr) and pollutant concentration (in microequivalents per liter – µeq per L). Deposition measurements are useful because they give an indication of the total annual pollutant loading at the site. However, deposition varies with the amount of annual precipitation. Concentration measurements are independent of precipitation amount; therefore, concentration provides a better indication of whether ambient pollutant levels are increasing or decreasing over time, despite rainfall fluctuations. In general, wet deposition of inorganic nitrogen (from nitrate and ammonium) is low in the western U.S. relative to the Midwest and East (Appendix A, figures A.1 - A.2). Pollutant deposition in the

NGPN is consistent with this pattern. A trend analysis of 1994-2003 data from national parks with long-term data records indicates that sulfate concentrations are decreasing at many sites in the West; however, nitrate and ammonium concentrations are increasing at many sites (Appendix A, figures A.3-A.5).

Dry Deposition Monitoring of Atmospheric Pollutants
There are two dry deposition CASTNet samplers in the NGPN (figure 2, table 1), located in Theodore Roosevelt NP and Wind Cave NP. Estimates of dry deposition for other park units are available from Air Atlas.

Total Atmospheric Deposition
When assessing ecosystem impacts from atmospheric deposition it is desirable to have estimates of total deposition, that is, wet plus dry deposition plus cloud/fog deposition. Cloud and fog deposition are not likely to be significant in the NGPN; total deposition can be estimated from wet plus dry deposition. For example, at Theodore Roosevelt NP, total nitrogen deposition from 1999-2001 was approximately 2.8 kg per ha per yr and total sulfur deposition was approximately 1.5 kg per ha per yr (CASTNet at http://www.epa.gov/castnet/sites/bbe401.html).

For sites with only wet deposition data (monitored or estimated), total deposition can be estimated by assuming that dry deposition rates are approximately equal to wet deposition rates and therefore,

Total deposition = 2 X wet deposition

For example, the Air Atlas estimates of wet inorganic nitrogen deposition (nitrate plus ammonium) for 1995-1999 range from 1.46-2.83 kg per ha per year in the NGPN units, so that:

Total inorganic N deposition = 2.9- 5.7 kg per ha per year

Air Atlas estimates of wet sulfur deposition for 1995-1999 range from approximately 0.74-1.62 kg per ha per year in the NGPN units, so that:

Total S deposition = 1.5-3.2 kg per ha per year

These estimates suggest that deposition of both nitrogen and sulfur are elevated above natural levels of deposition. Estimates of natural deposition for either sulfur or nitrogen in the West show levels approximating 0.2 kg per ha per yr.

Atmospheric Deposition Effects to Ecosystems
Atmospheric deposition of nitrogen and sulfur compounds can affect water quality, soils, and vegetation. Both nitrogen and sulfur emissions can form acidic compounds (e.g., nitric or sulfuric acid); when deposited into ecosystems with low buffering capacity, acidification of waters or soils can occur. Deposition of nitrogen compounds can also have a fertilization effect on waters and soils. In some areas of the country, elevated nitrogen deposition has been shown to alter soil nutrient cycling and vegetation species composition. In grasslands, increased nitrogen has resulted in decreased plant species diversity. Over time, excess nitrogen deposition may cause native plants that have adapted to nitrogen-poor conditions to be out-competed and

replaced by nitrogen-loving nonnative grasses and other exotic species. In addition to changes in species composition, there may be increases in productivity, resulting in increased biomass (i.e., fuel loading) and fire frequency. It is not known whether atmospheric deposition is affecting resources in the NGPN.

Ground-level Ozone Monitoring

Ozone is found throughout the atmosphere. Upper-atmospheric ozone (i.e., stratospheric ozone) acts as a protective shield against ultraviolet radiation; ground-level ozone (i.e., tropospheric ozone) is harmful to human health and vegetation. Ground-level ozone is produced by the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Although ground-level ozone is principally an urban problem, it and its precursor emissions can travel long distances, resulting in elevated ozone levels in national park units. Power plants, automobiles, and factories are the main anthropogenic emitters of nitrogen oxides. Vehicles and industries also emit VOCs. Natural biogenic VOC emissions are significant in some geographic areas.

NPS monitors ozone in Badlands NP and Theodore Roosevelt NP; State and local air quality agencies also operate several ozone monitors near NGPN park units (figure 2). Estimates of ozone peak concentrations and exposure metrics for NGPN park units without on-site monitoring can be obtained from AirAtlas. Data from monitors has been used by the States and EPA to determine compliance with the EPA ozone health standard (based on an 8-hr averaging period). Part or all of 474 counties nationwide are designated as nonattainment for either failing to meet the 8-hour ozone standard or for causing a downwind county to fail (Figure 4). There are currently no nonattainment areas in or near the NGPN units. However, a trends analysis for 1994-2003 indicates that ozone is increasing in many areas of the West (Appendix A, figure A.6).

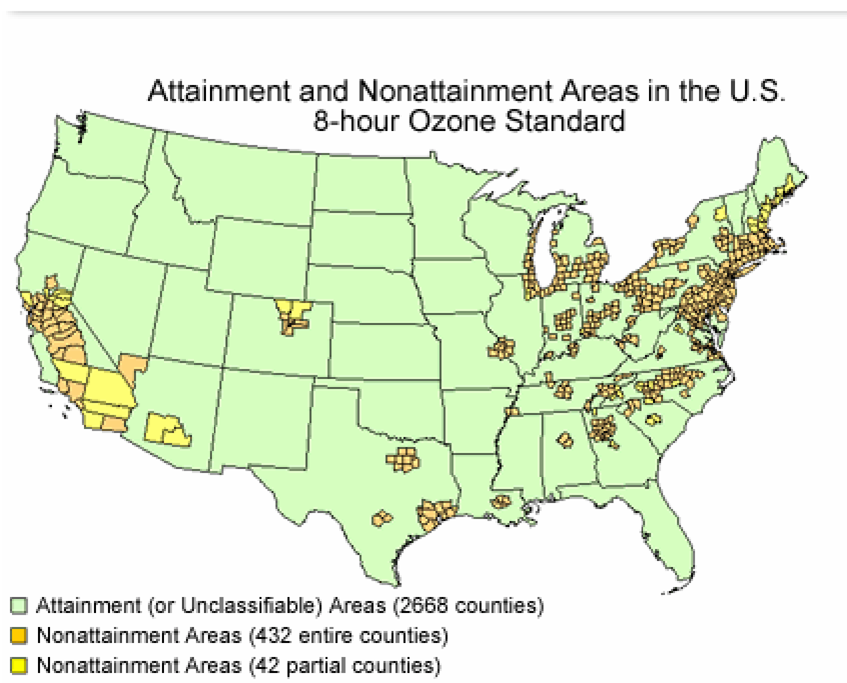


Figure 5. Attainment and nonattainment areas in the U.S. for the 8-hr ozone standard (from http://www.epa.gov/oar/oaqps/glo/designations/index.htm).

In addition to continuous ozone monitoring, NPS has used passive ozone samplers at Badlands NP and Wind Cave NP. Information on the passive ozone samplers is at http://www2.nature.nps.gov/air/studies/passives.cfm.

Ozone affects human health, causing acute respiratory problems, aggravation of asthma, temporary decreases in lung capacity in some adults, inflammation of lung tissue, and impairment of the body's immune system. Chamber studies have shown ozone effects to birds and other wildlife. However, these effects to birds and wildlife have not been demonstrated in the wild. Effects to vegetation have been widely documented and ozone is one of the most widespread pollutants affecting vegetation in the U.S. Ozone enters plants through leaf stomata and oxidizes plant tissue, causing changes in biochemical and physiological processes. Both visible foliar injury (e.g., stipple and chlorosis) and growth effects (e.g., premature leaf loss, reduced photosynthesis, and reduced leaf, root, and total dry weights) can occur in sensitive plant species. Long-term exposures can result in shifts in species composition, with ozone tolerant species replacing intolerant species.

Research shows that some plants are more sensitive to ozone than humans; effects to plants occur well below the EPA standard. Ozone causes considerable damage to vegetation throughout the world, including agricultural crops and native plants in natural ecosystems. Ozone effects on natural vegetation have been documented throughout the U.S., particularly in many areas of the East and in California. A relatively small number of national parks have been surveyed for ozone injury; injury has been documented in Great Smoky Mountains, Shenandoah, Lassen Volcanic, Sequoia/Kings Canyon, and Yosemite National Parks.

Scientists use various metrics to describe ozone exposure to plants, in addition to the 1-hour or 8-hour average concentrations reported by EPA. These metrics, the Sum06 and the W126, are believed to be biologically relevant, as they take into account both peak ozone concentrations and cumulative exposure to ozone. Hourly concentrations from a continuous or portable continuous ozone analyzer are needed to calculate either metric.

Sum06 -- The running 90-day maximum sum of the 0800-2000 hourly ozone concentrations of ozone equal to or greater than 0.06 ppm. The Sum06 is expressed in cumulative ppm-hr. Several thresholds have been developed for Sum06:

Natural Ecosystems	8 - 12 ppm-hr	(foliar injury)
Tree Seedlings	10 - 16 ppm-hr	(1-2% reduction in growth)
Crops	15 - 20 ppm-hr	(10% reduction in 25-35% of crops)

W126 -- A cumulative index of exposure that uses a sigmoidal weighting function to give added significance to higher concentrations of ozone while retaining and giving less weight to mid and lower concentrations. The number of hours over 100 ppb (N100) is also considered in assessing the possible impact of the exposure. The W126 index is in cumulative ppm-hr. Several thresholds have been developed for W126:

	W126	N100
Highly Sensitive Species	5.9 ppm-hr	6
Moderately Sensitive Species	23.8 ppm-hr	51
Low Sensitivity	66.6 ppm-hr	135

In a natural ecosystem, many other factors can ameliorate or magnify the extent of ozone injury at various times and places such as soil moisture, presence of other air pollutants, insects or diseases, and other environmental stresses.

Ozone sensitive and bioindicator plant species have been identified for all of the CHDN units and lists are available from NPSpecies (https://science1.nature.nps.gov/npspecies/). Species were identified by cross-referencing NPSpecies with sensitive species identified in "Ozone Sensitive Plant Species on National Park Service and U.S. Fish and Wildlife Service Lands" (2003) at http://www2.nature.nps.gov/air/Pubs/BaltFinalReport1.pdf.

Sensitive species are those that typically exhibit foliar injury at or near ambient ozone concentrations in fumigation chambers and/or are species for which ozone foliar injury symptoms in the field have been documented by more than one observer. Bioindicator species for ozone injury meet all or most of the following criteria: 1) species exhibit foliar symptoms in the field at ambient ozone concentrations that can be easily recognized as ozone injury by subject matter experts, 2) species ozone sensitivity has been confirmed at realistic ozone concentrations in exposure chambers, 3) species are widely distributed regionally, and 4) species are easily identified in the field. Because of these attributes, bioindicator species are recommended for field surveys to assess ozone injury.

NPS completed a risk assessment for parks in 2004, based on the concept that foliar ozone injury on plants is the result of the interaction of the plant, ambient ozone, and the environment. That is, the risk for foliar injury is high if three factors are present: species of plants that are genetically predisposed to ozone, concentrations of ambient ozone that exceed a threshold required for injury, and environmental conditions, primarily soil moisture, that foster gas exchange and the uptake of ozone by the plant.

The assessment used ozone data from 1995-1999 to evaluate risk. Vegetation in all NGPN park units were judged to be at low risk. The assessments should be re-evaluated if ozone increases in the area.

Visibility Monitoring

Visibility is monitored at Badlands NP, Theodore Roosevelt NP, and Wind Cave NP. These parks have fine particle samplers that measure the types and amounts of particles that obscure visibility. Badlands NP also has a transmissometer that measures light extinction resulting from fine particles of pollution. Data are available from the Visibility Information Exchange Web System (VIEWS) at http://vista.cira.colostate.edu/views/. Theodore Roosevelt NP also has a webcam that records visibility conditions (http://www2.nature.nps.gov/air/WebCams/index.htm). Estimates of visibility conditions for the remaining NGPN units can be obtained from AirAtlas.

Visibility impairment is regional in nature and monitoring indicates that visibility is degraded to some extent throughout the NGPN area. Trend analysis indicates that visibility is improving slightly on the clearest days and worsening on the haziest days in many areas of the West (Appendix A, figures A.7-A.8). States are required to develop plans to make progress towards the national goal of "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I federal areas which impairment results from manmade air pollution." (Clean Air Act 1977) Regional planning organizations are currently discussing these plans. The regional planning group for the western U.S., including North Dakota and South Dakota, is the Western Regional Air Partnership (WRAP), with information at www.wrapair.org. The regional planning group for the central U.S., including Nebraska, is the Central States Regional Air Partnership (CENRAP), with information at http://cenrap.org/.

Toxic Air Pollutant Monitoring (Mercury Deposition Monitoring)
Monitoring of mercury in wet atmospheric deposition is done by the Mercury Deposition Network (MDN), which collects rainfall for mercury analysis at over 60 sites nationwide (http://nadp.sws.uiuc.edu/mdn/).

MDN has one sampler near NGPN units, operated by the U.S. Fish and Wildlife Service at Lostwood National Wildlife Refuge in North Dakota. Sources of atmospheric mercury include power plants, incinerators, mining activities, and natural sources. Coal-burning power plants are major sources of mercury to the atmosphere and, eventually, terrestrial and aquatic ecosystems. Bioaccumulation of mercury in fish and wildlife can result in neurological and reproductive effects to wildlife and humans. Fish consumption advisories have been issued for certain lakes and streams in North Dakota, South Dakota, and Nebraska (see http://epa.gov/waterscience/fish/states.htm).

Initial Recommendations

- Obtain air quality data summaries and annual reports from NPS Air Resources Division (http://www2.nature.nps.gov/air/index.htm).

- Consider co-locating an MDN sampler with the existing NADP samplers at Theodore Roosevelt NP and Wind Cave NP.

Relevant Websites
ARIS at http://www2.nature.nps.gov/air/
NPS AirWeb at http://www2.nature.nps.gov/air/
ARD FY 2004 Annual Performance Report: GPRA at
http://www2.nature.nps.gov/air/who/GPRA/GPRA2004review02042005.pdf
Air Atlas at http://www2.nature.nps.gov/air/Maps/AirAtlas/index.htm
NADP at http://nadp.sws.uiuc.edu/
MDN at http://nadp.sws.uiuc.edu/mdn/
CASTNet at http://www.epa.gov/castnet/
EPA Ozone (AirData) at http://www.epa.gov/air/data/index.html
NPS Ozone Data at http://www2.nature.nps.gov/air/data/index.htm
IMPROVE at http://vista.cira.colostate.edu/views/
Pollution sources and air quality data at http://www.epa.gov/air/data/index.html
VIEWS at http://vista.cira.colostate.edu/views/

Appendix A: Conditions and Trends in Ozone, Visibility, and Wet Deposition

Figure A.1. Inorganic wet nitrogen deposition from nitrate and ammonium, 2003. (NADP)

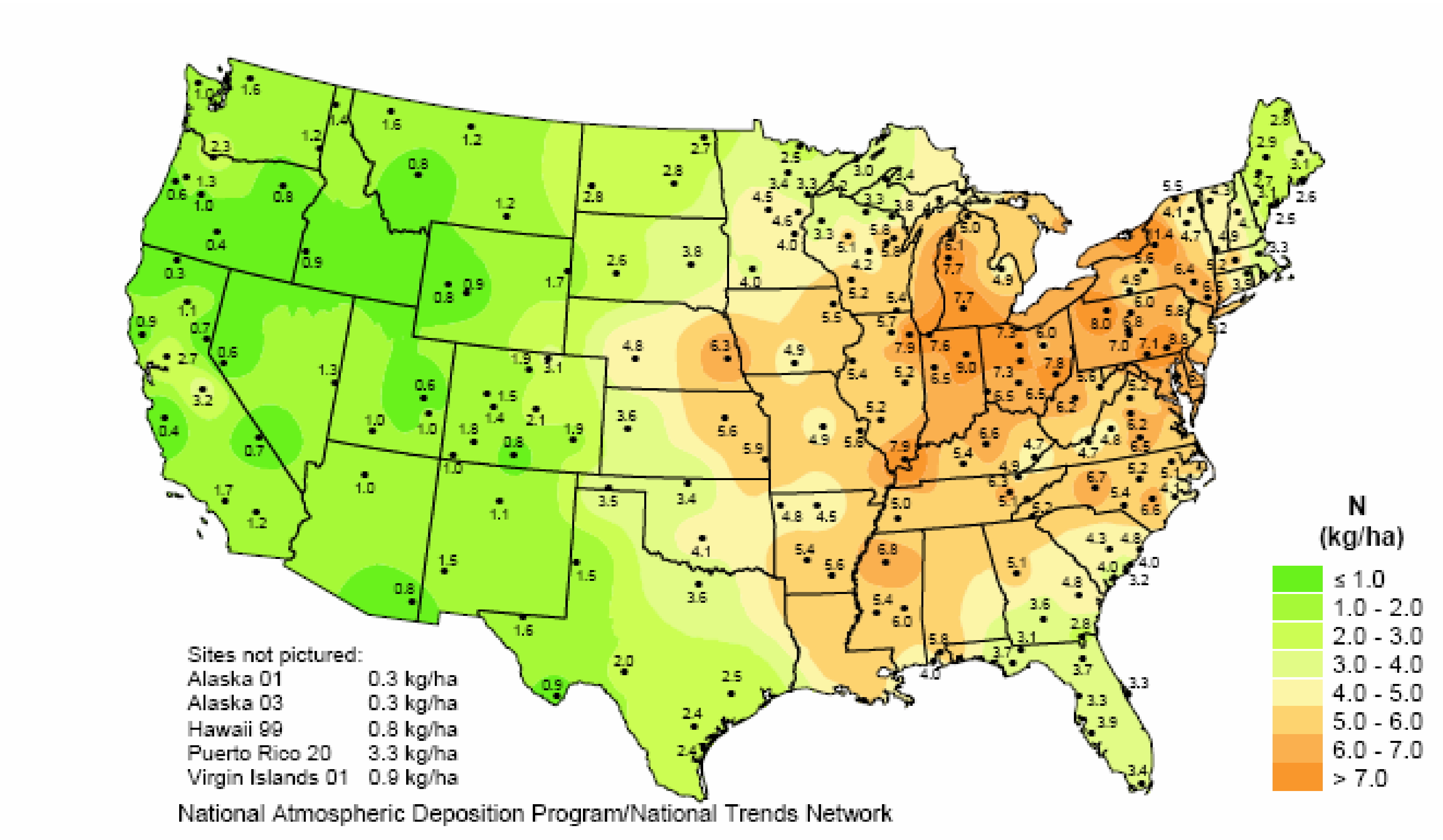


Figure A.2. Sulfate wet deposition, 2003. (NADP)

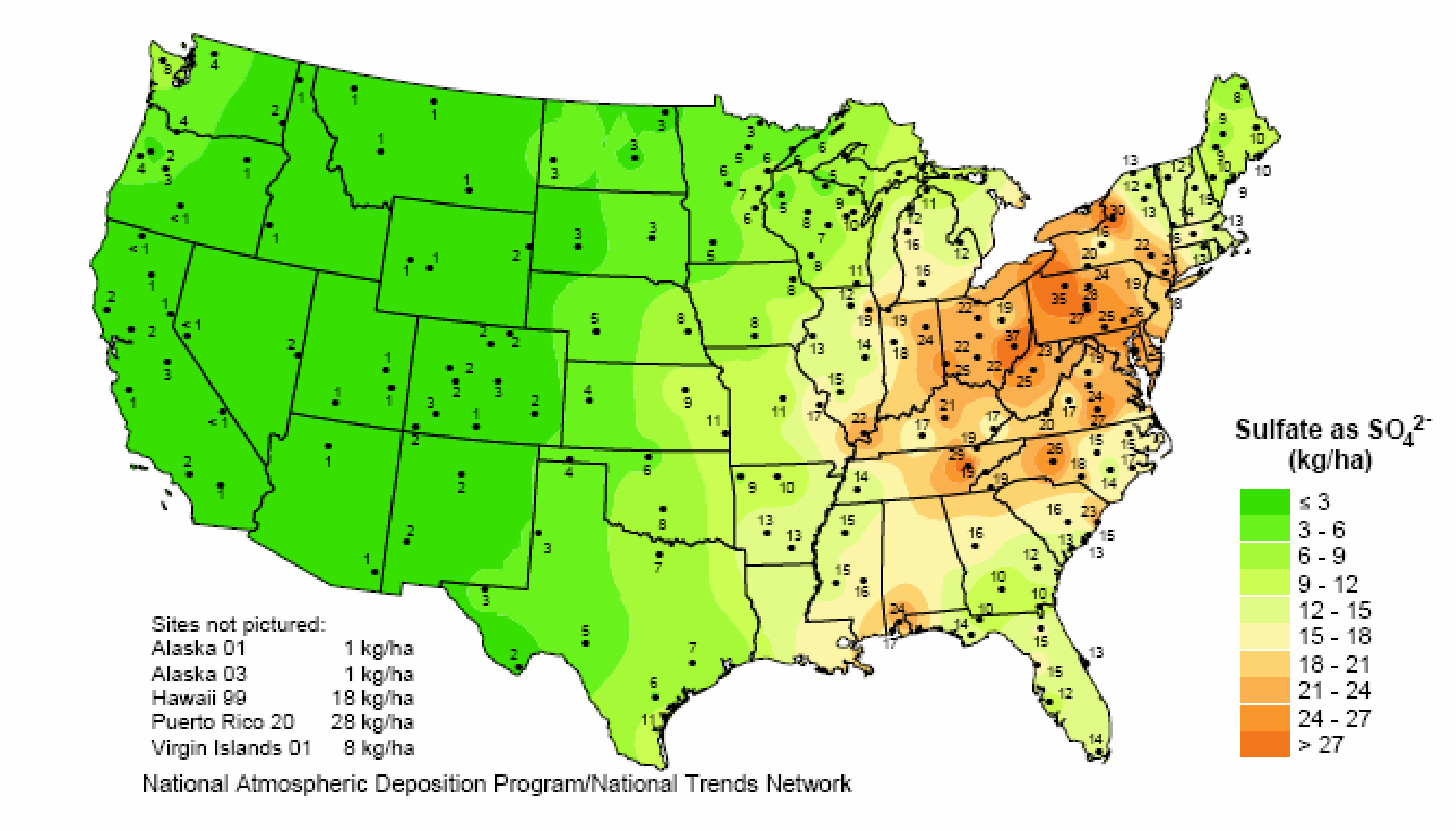
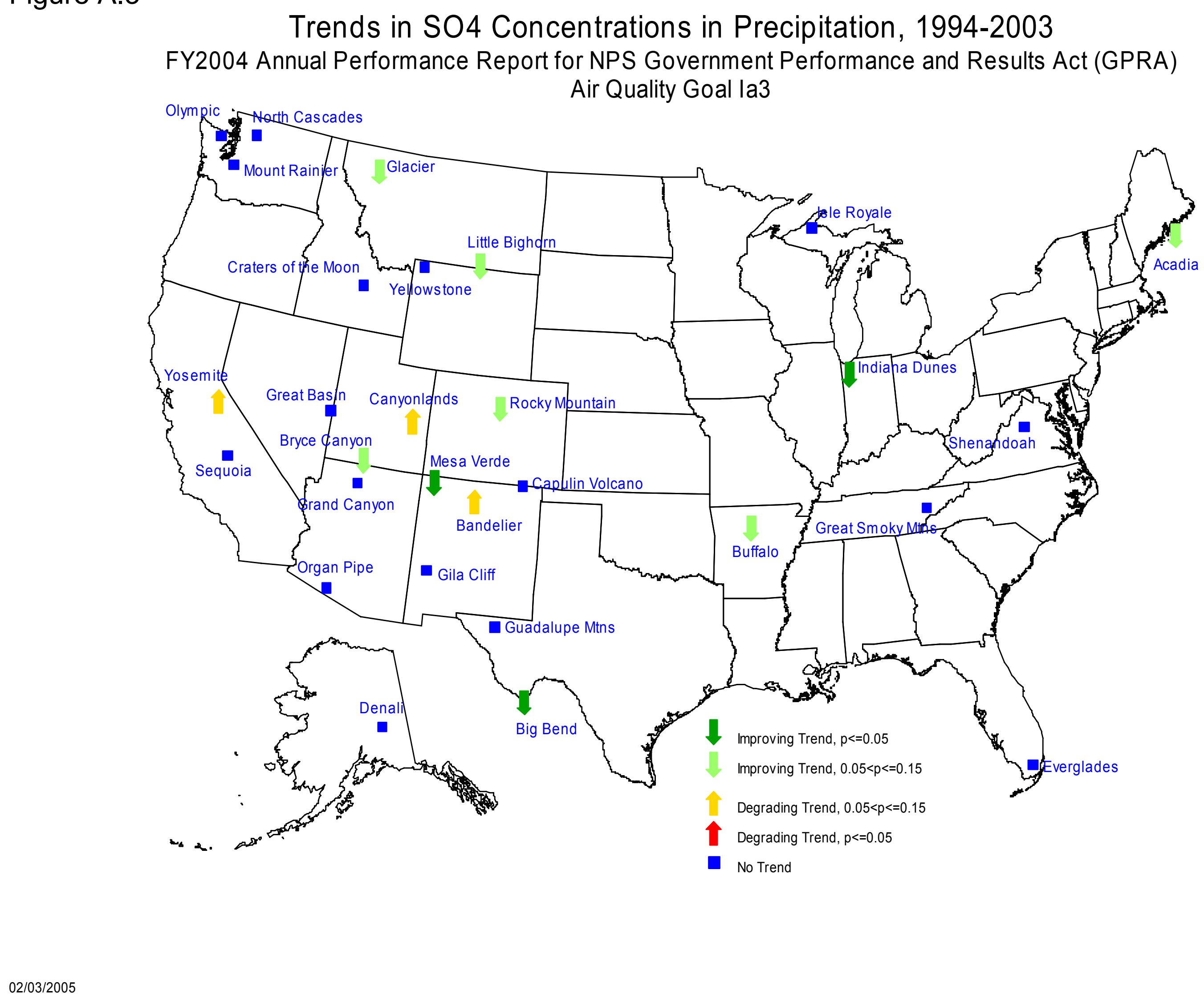
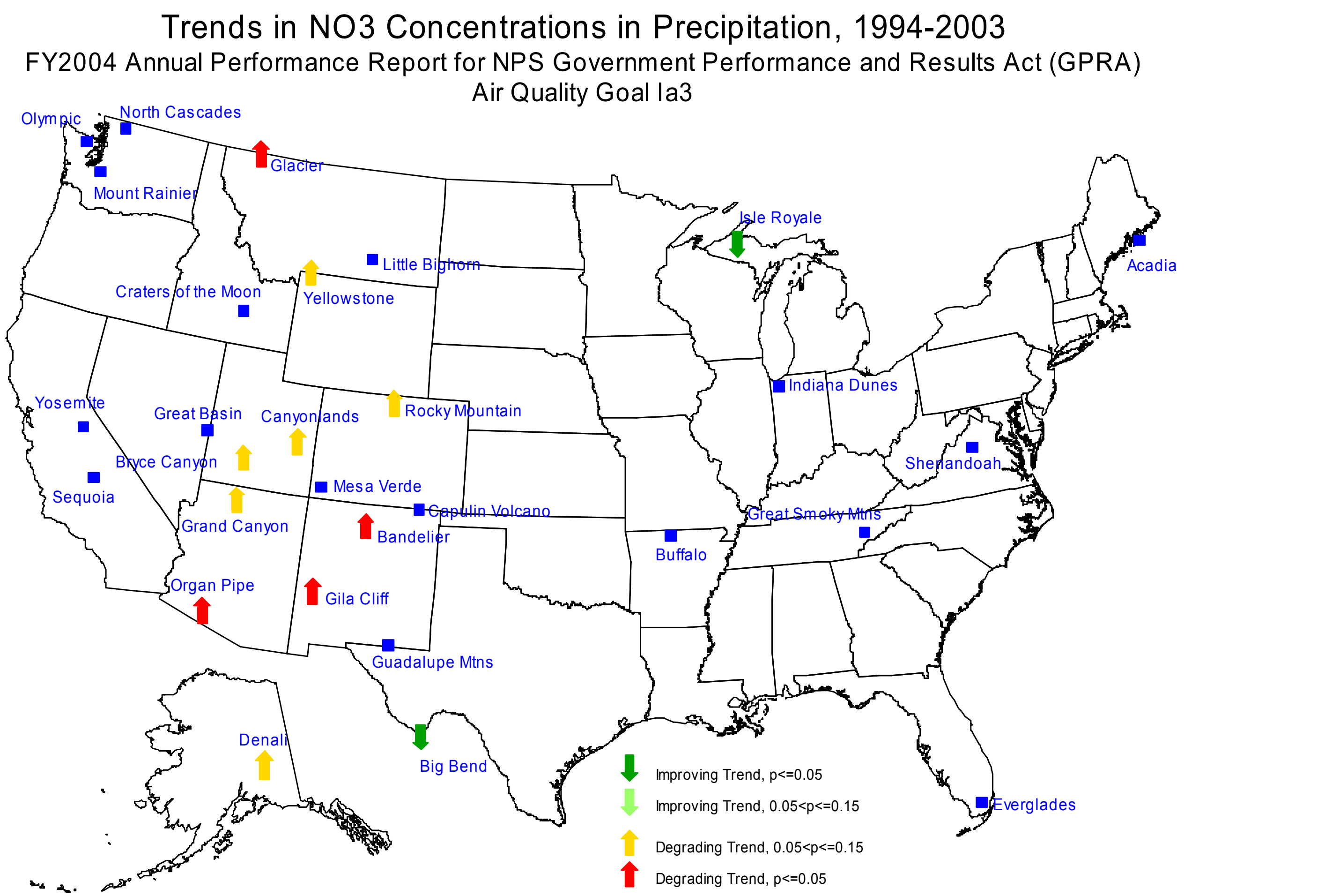


Figure A.3



(Source: FY 2004 Annual Performance Report: Government Performance and Results Act, Air Resources Division)

Figure A.4



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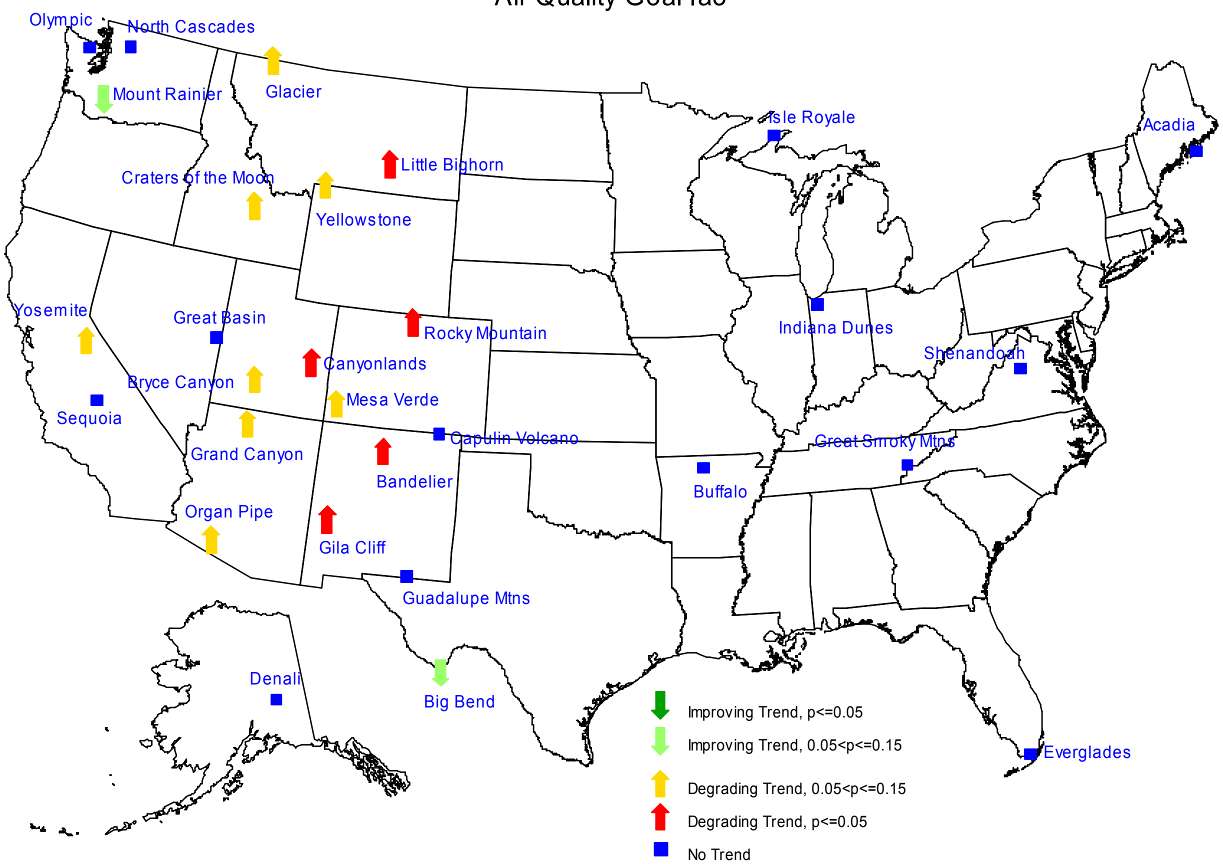
(Source: FY 2004 Annual Performance Report: Government Performance and Results Act, Air Resources Division)

Figure A.5

Trends in NH4 Concentrations in Precipitation, 1994-2003

FY2004 Annual Performance Report for NPS Government Performance and Results Act (GPRA)
Air Quality Goal Ia3



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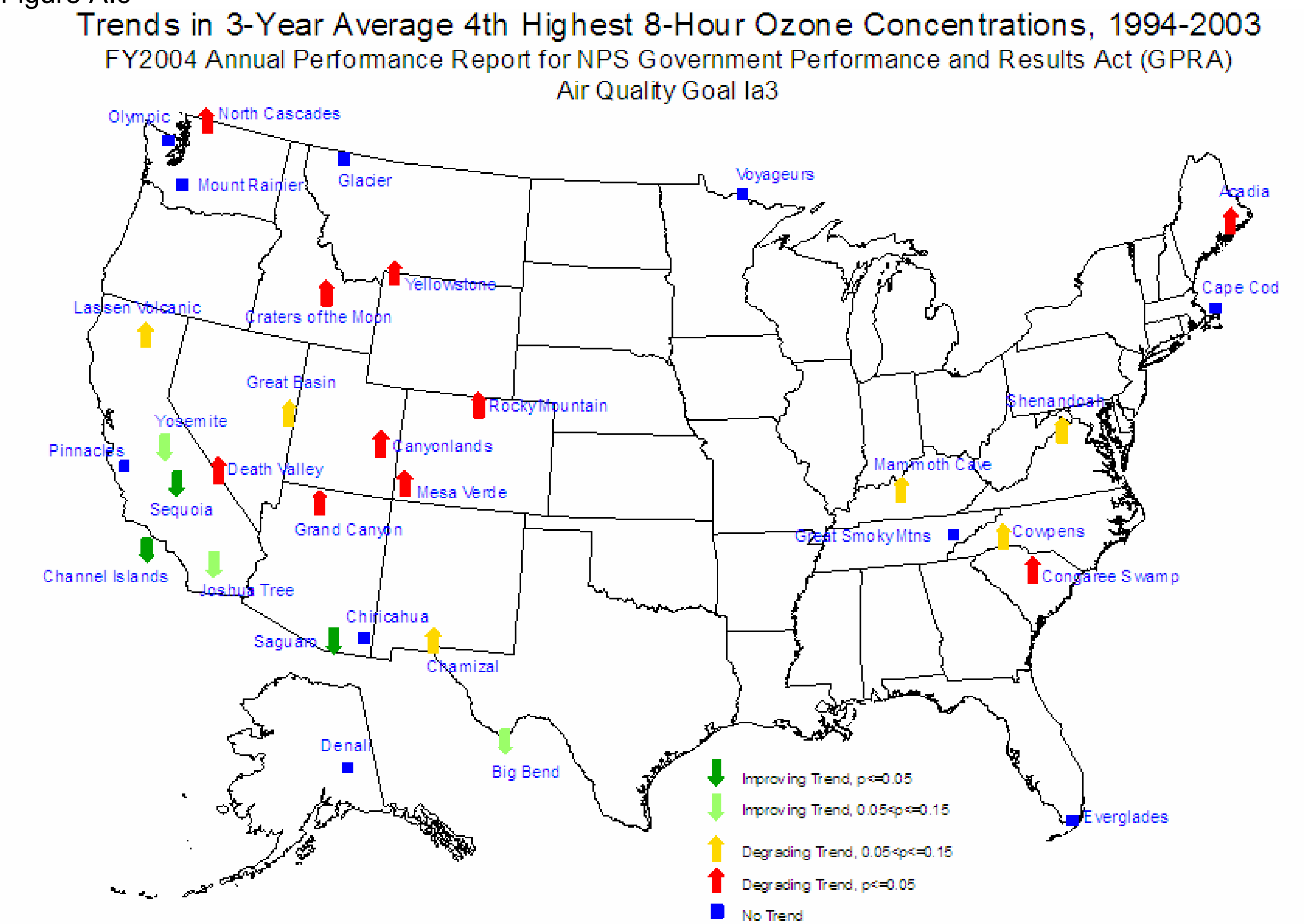
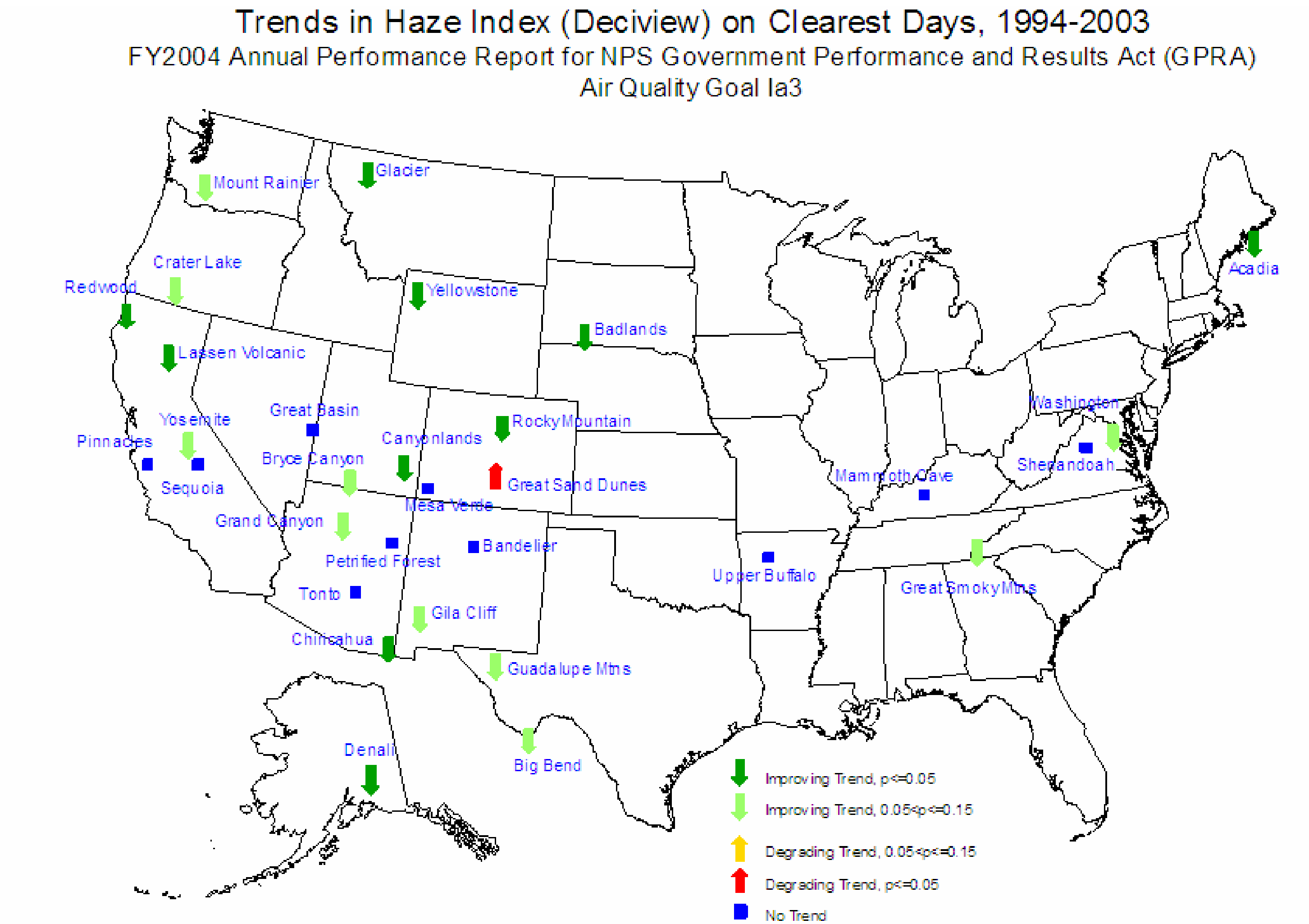
(Source: FY 2004 Annual Performance Report: Government Performance and Results Act, Air Resources Division)

Figure A.6



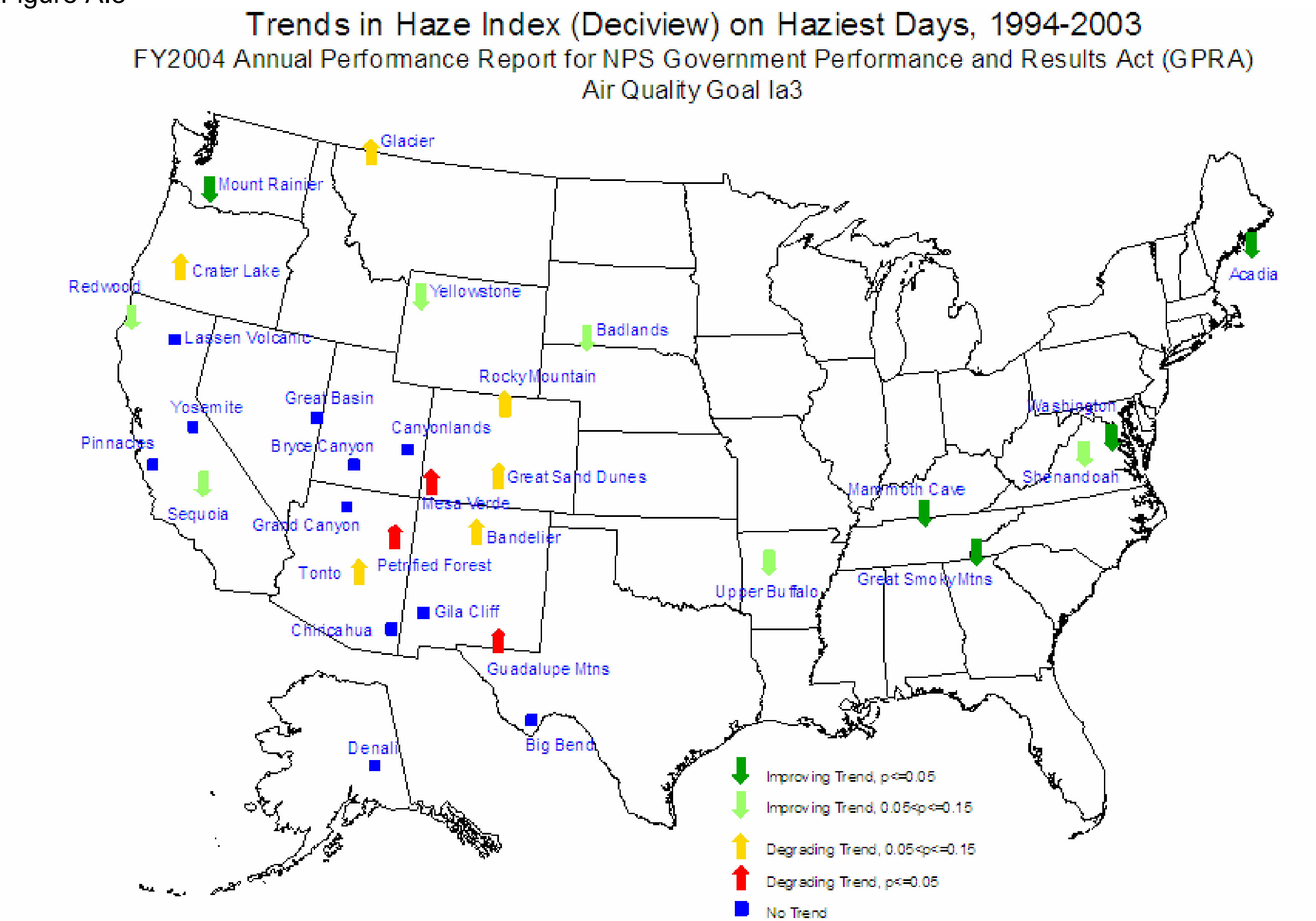
(Source: FY 2004 Annual Performance Report: Government Performance and Results Act, Air Resources Division)

Figure A.7



(Source: FY 2004 Annual Performance Report: Government Performance and Results Act, Air Resources Division)

Figure A.8



(Source: FY 2004 Annual Performance Report: Government Performance and Results Act, Air Resources Division)