Nebraska DEQ
Air Quality Division

Overview of the Regional Haze Program

Section 1

Introduction

On July 1, 1999 EPA issued final rules amending its 1980 regulations designed to protect visual air quality in 156 of America's national park and wilderness areas. Figure 1-1 delineates the parks and wilderness areas with protected visual environments identified by EPA. These areas are commonly referred to as mandatory Class I areas. Visibility impairment is caused by manmade air pollutants that interfere with the ability to clearly see scenic vistas in these Class I areas. Air contaminants absorb and scatter light, causing a "haze" effect which degrades the visual quality.

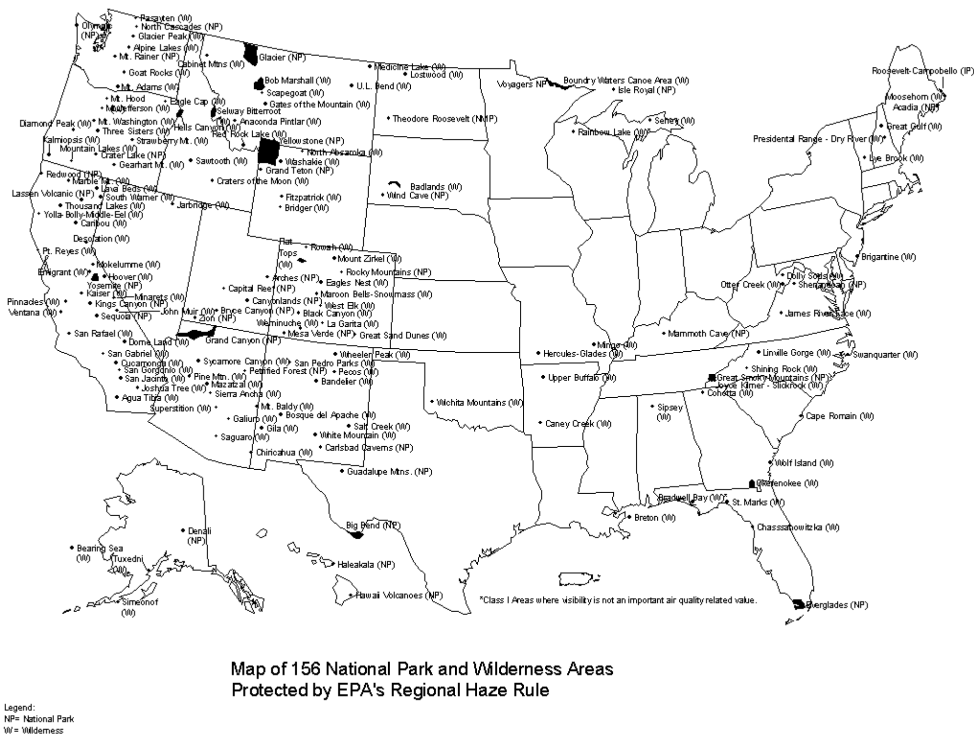

Fig. 1-1. Mandatory Class I areas protected under the regional haze rule. Source: EPA, 1999.

The regional haze rule calls for states to develop long-term goals and plans for reducing emissions that will improve visibility in these parks and wilderness areas. The rule also encourages States and Tribes to work together in developing these plans to improve visibility. Many states that share common airsheds and characteristics have joined together in regional planning organizations (RPOs) to work together in solving these complex air quality problems. In the central United States, Nebraska has joined with 8 other states to examine the science of haze and develop possible solutions in a regional planning organization known as the Central States Regional Air Planning Association (CENRAP). Each of these states share strong agricultural backgrounds, and are working to scientifically evaluate the unique role that this sector has in the formation of fine particles and regional haze.

Section

2 Science of Haze and Visibility

Visibility or visual air quality refers to the relationship of atmospheric contaminants and the ability to see distant scenic objects. Under natural conditions with no manmade atmospheric pollutants, one would be able to see 60 – 80 miles in the eastern United States and 100 – 150 miles in the western United States. Manmade air pollutants, gases and particles, will absorb and scatter visible light, thus reducing the amount of visual information that would reach an observer. This occurs naturally to a very limited degree but manmade air pollutants represent the largest contributor to degradation in visual air quality.

We are most concerned with two types of gases and particles, primary and secondary. Primary refers to a gas or particle emitted from a source directly, while secondary refers to airborne dispersions of gases and particles formed by atmospheric chemical reactions of secondary and primary pollutants (Malm, 2000). Examples of primary particles are smoke from forest fires, carbon from diesel combustion, ash from the burning of coal, and wind-blown dust. Primary gaseous emissions of concern are sulfur dioxides emitted from coal burning, oxides of nitrogen that are the result of any type of combustion such as coal-fired power plants and automobiles, and hydrocarbons usually associated with automobiles but also are emitted by vegetation, especially coniferous vegetation (Malm, 2000).

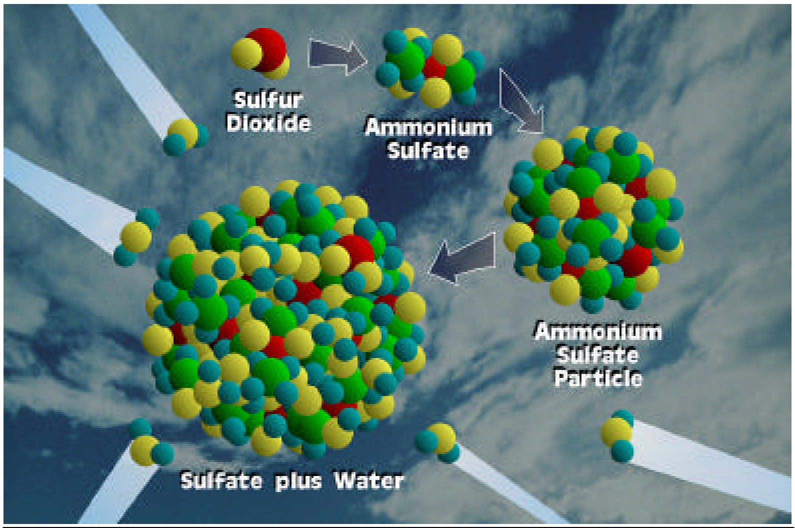

__Fig. 2-1.__ Sulfur dioxide gas converts in the atmosphere to ammonium sulfate particles in the presence of ammonia. These particles are hygroscopic, meaning they grow rapidly in the presence of water to reach a size that is disproportionately responsible for visibility impairment. Source: Malm, 2000.

Some gases, such as sulftur dioxide (SO_2) and nitrogen oxides (NO_x), are transformed into secondary particles through a series of complex chemical reactions in the atmosphere. SO_2 will ultimately be converted to sulfates, usually ammonium sulfate ($(NH_4)_2SO_4$), NO_x convert sto nitrates such as nitric acid or ammonium nitrate (NH_4NO_3), hydrocarbons convert to larger organic or hydrocarbon molecules, and hydrocarbon gases interfere with a naturally occurring cycle between hydrocarbon and NO_2 to yield ozone (O_3). Ammonia plays a significant role in the formation of the secondary particles.

Figure 2-2 represents a simplified schematic of how particles in the atmosphere interact with light that travels from the distance scene to the observer. Particles along the path from the light from the scene to the observer can absorb or scatter light, reducing the amount of light from the scene. Additionally, particles can also scatter light from other sources into the sight path, further reducing the visual quality of the scene. This light may reflected from clouds or the ground, or be direct sunlight. Since this light is not reflected from a scene, it contains no visual information. The combination of scattering and absorption from many differing sources and directions results in what is referred to as haze, resulting in degradation of visual quality.

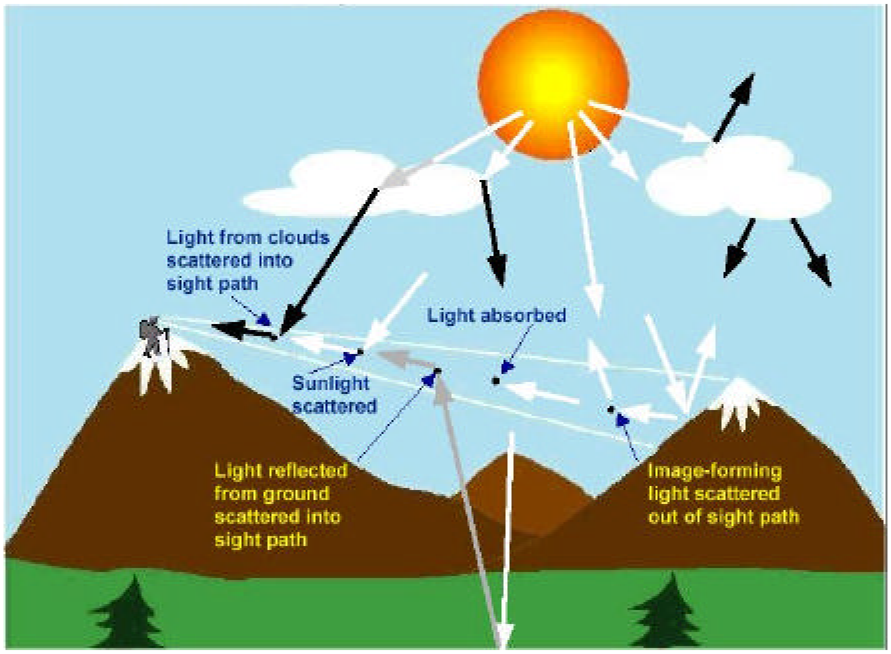

Fig. 2-2. *Schematic of visibility impairment due to light scattering and absorption. Source: NESCAUM, 2001.*

Figure 2-3 and 2-4 are depictions of the affect of light scattering and absorption on the visual quality of a science. Figure 2-3 is from the Mt. Zirkel National Wilderness area, a mandatory Class I area in northwestern Colorado. Figure 2-4 is the effect of haze on the urban skyline in Washington D.C. The left side of each scene represents natural or clean background conditions. The right side of each scene represents the visual effects of haze on the average of the 20% worst days at each location.

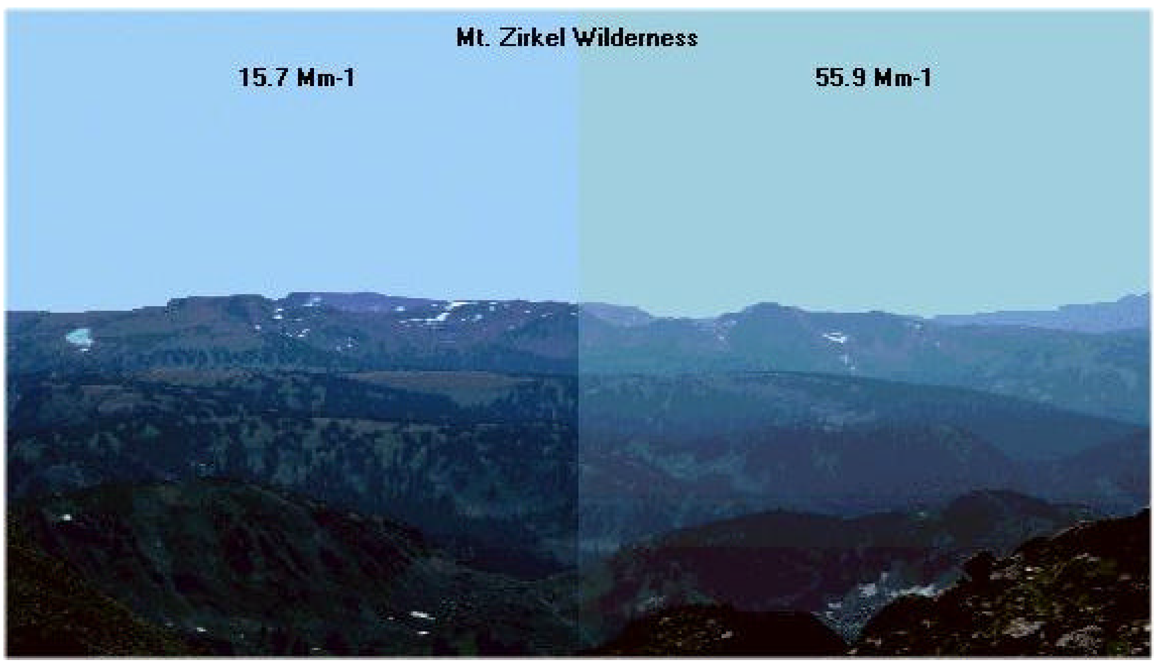

Fig. 2-3. *Visual quality of scene from the Mt. Zirkel Wilderness Area, CO. The left scene is visual quality under natural background conditions. Right scene is visual quality under average of the 20% worst days at this site.*

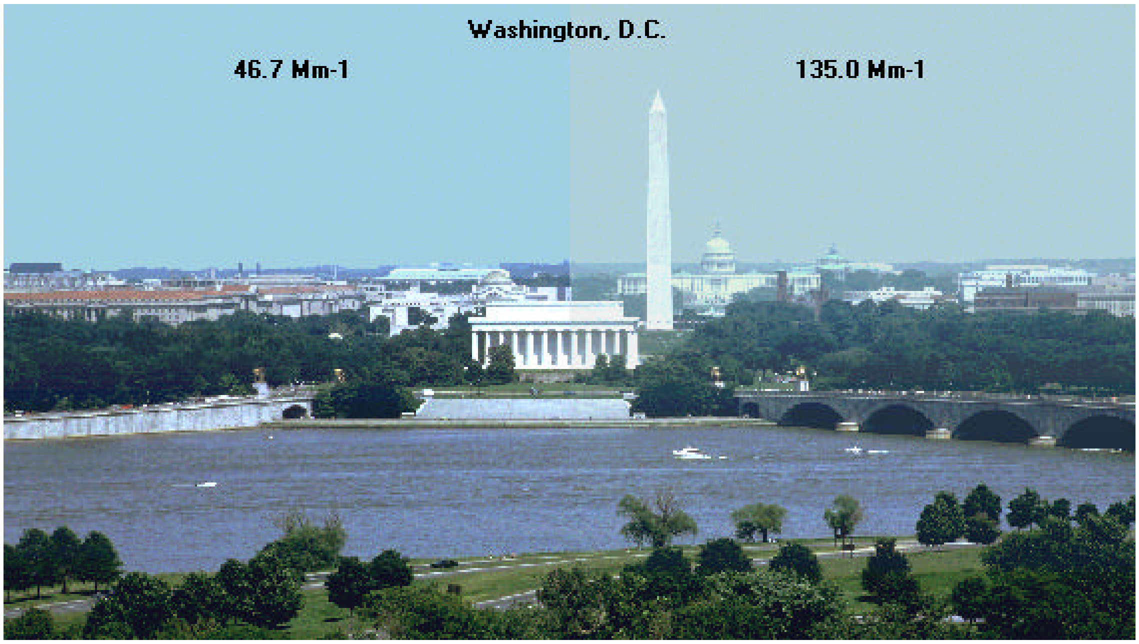

Fig. 2-4. *Visual quality of scene from Washington, D.C. skyline. Left scene is visual quality under natural background conditions. Right scene is visual quality under average of the 20% worst days at this site.*

Section 3 Emissions and Air Quality

As mentioned in Section 2, fine particulate matter (PM) contributing to regional haze is a mixture, with components that are directly emitted into the atmosphere and those that are transformed through complex chemical reactions. Primary particulate matter emissions come from a wide variety of sources ranging from crustal material (dust and soil generated from things such as on and off-road vehicle activity, dirt roads, agricultural tilling, erosion, etc.), soot (inorganic carbon) from fossil fuel combustion (diesel, coal fly ash, etc.), and from a variety of industrial activities.

Secondary particulate matter is has a more diverse set of gases and environmental conditions that are involved in the chemical reactions that take place in the atmosphere. The three most common components of secondary particulate matter are sulfates, nitrates, and organic carbon. Sulfates and nitrates usually result from the atmospheric oxidation of SO_2 and NO_x, where oxygen atoms combine with these gaseous pollutants and ammonia to form a stable particle. SO_2 is most commonly emitted into the atmosphere from the use of coal as fuel in utility and large industrial boilers. NO_x is also released from the combustion of fossil fuels from these boilers. Automobile emissions are also a large source of NO_x, but also contribute significantly to hydrocarbons in the atmosphere that have a role in forming organic carbon particles.

Ammonia is unique in that it combines with both sulfates and nitrates to form secondary particles. Ammonia emissions are the least understood of all of these components. There is significant question about the quantity of ammonia that is actually released into the atmosphere and also the time of year when such releases are most common. It is estimated that 86% of all ammonia is the result of agricultural activities such as animal husbandry and fertilizer application (See Figure 3-1).

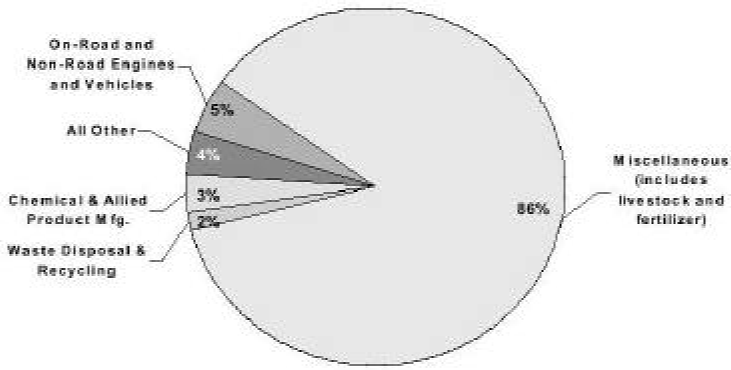

Fig. 3-1. Ammonia Emissions by Principal Source Category. Source: EPA, 2000.

Regions of the United States with large production agriculture sectors such as Nebraska have the highest density of ammonia emissions in the country. Figure 3-2 depicts the ammonia emissions density across the United States. Note that agricultural areas of the north central and upper Midwest have the highest density of ammonia emissions in the U.S.

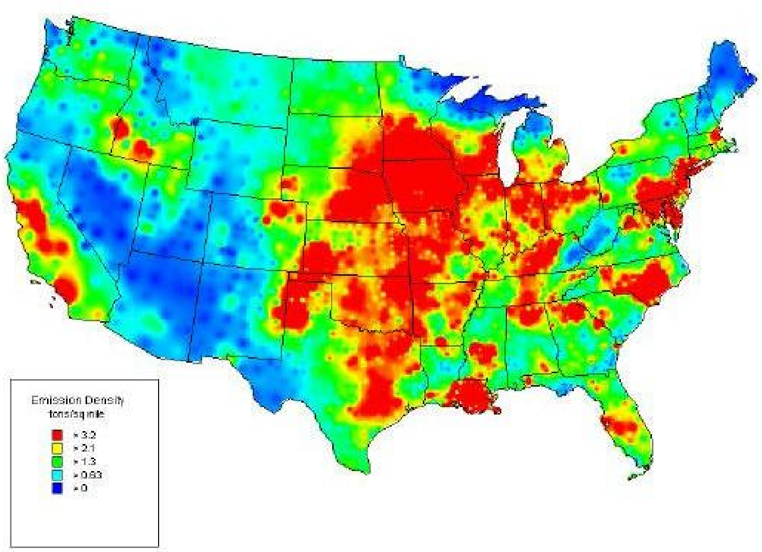

Fig. 3-2. Ammonia Emissions Density Map by County. Source: EPA, 2000.

Meteorological conditions have a significant role in the formation of these secondary particles. While sulfate levels are the most significant component over a large portion of the United States, what component represents the second largest fraction of the overall secondary PM mass is largely a function of the climate of the region. There is a strong transition in PM chemistry as one moves both north-south and east-west across the United States. In areas of the country that are more heavily forested and have colder climates, nitrates and organics represent the second largest component of secondary PM mass. Nitrates form more easily and are more stable in colder temperatures. Figures 3-3 depicts the monthly composition of fine PM mass in the north central United States. Organics are the second largest component, but during the colder months, it is clear that the nitrate composition increases significantly while organic carbon decreases. This is contrasted sharply in the southern United States where primary particulate matter from such things as windblown sand and soil is the second largest component (see Figure 3-4). Nitrates are a very small component of the overall fine PM mass over the south central United States. Warmer conditions in this area are not conducive to the formation of nitrates. This demonstrates the role that climate has in the PM chemistry of a region.

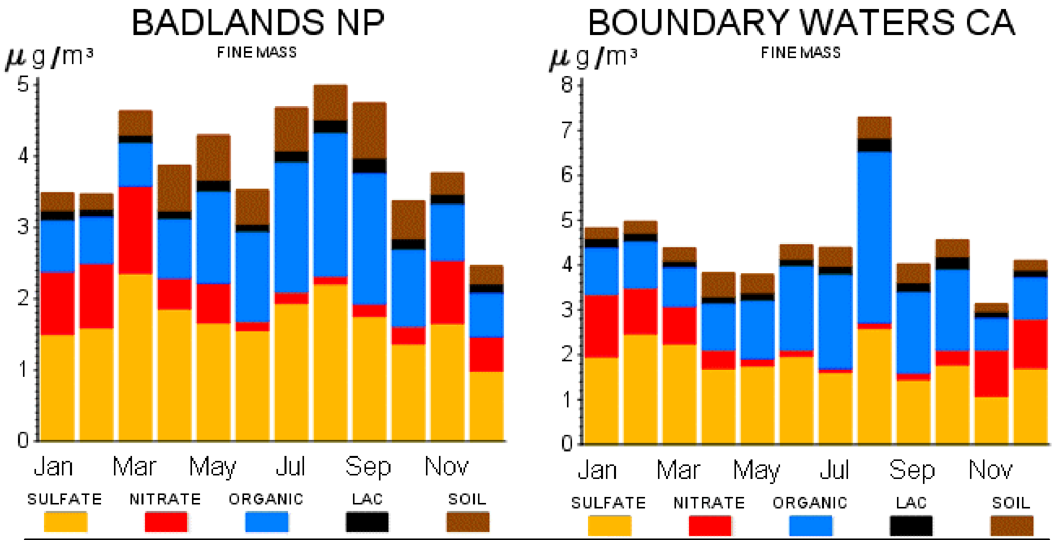

Fig. 3-3. *Monthly fine PM mass composition for Badlands NP, SD and Boundary Waters Canoe Area, MN. Source: CIRA, 2001.*

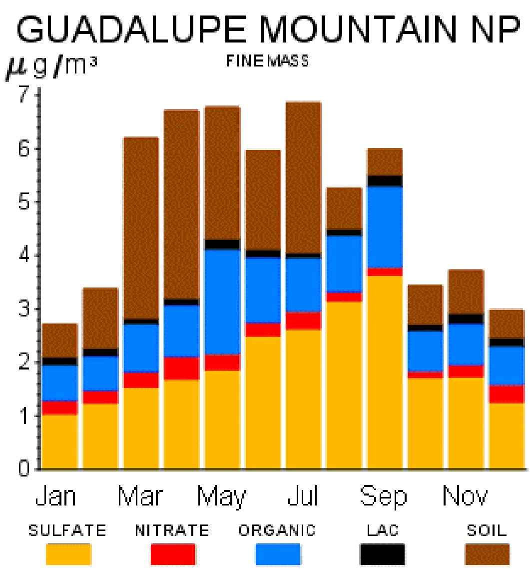

Fig. 3-4. *Monthly fine PM mass composition for Guadalupe Mountain NP, TX. Source: CIRA, 2001.*

Fine particulate matter is ubiquitous in nature, and thus is the result from the emissions from many sources over a broad geographic region. Since fine particles remain suspended in the atmosphere for long periods of time, they can be carried over long distances. Therefore "haze" is often times a combination of air contaminants from both near and distant manmade sources. Therefore, while a state or a region may not have Class I areas within its borders, it is possible for emissions originating in a particular area to be transported hundreds or thousands of kilometers downwind and contribute to the formation of fine PM mass in a more distant Class I area. Figure 3-5 is a depiction of how pollutants originating from one area are transported long distances and can impact visual air quality in more distant Class I areas.

Figure 3-5 is a simulation of utility emissions along the Missouri River corridor during a high PM and ozone episode that occurred over the central United States in early September 1999. A strong high-pressure system was building into the eastern Missouri-western Tennessee region   Surface and upper level winds transported emissions on the backside of the high pressure system from the Nebraska, Iowa, and Kansas areas north and northeast. This simulation shows the potential for transport of fine particulate matter and precursor emissions towards and into Class I areas in South and North Dakota, Minnesota, and Wisconsin.

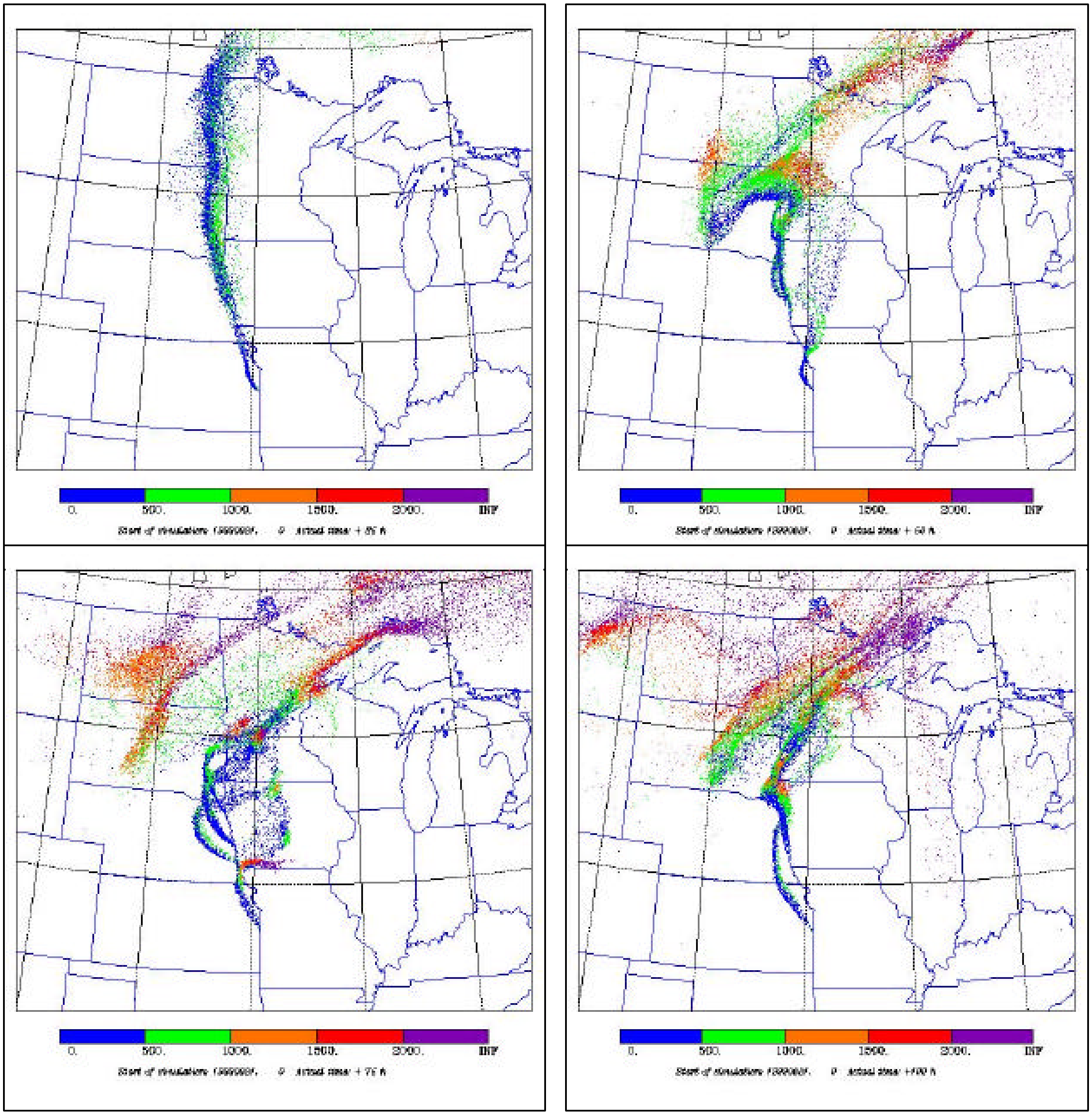

Fig. 3-5 *. Lagrangian particle model simulation of utility emissions along the Missouri River corridor during high ozone/particulate matter event from September 1- 4, 1999. Source: Anderson, 2001a.*

Other types of meteorological conditions may also contribute to the transport of fine particulate and their precursors in the central United States. During the winter and early spring months, low-pressure systems will often develop on the leeside of the Rocky Mountains in Colorado. Surface and aloft wind patterns during these periods are often conducive to the transport of pollutants from the western areas of Nebraska into the Class I areas of South Dakota and Colorado. The cloud moisture that is associated with low-pressure system development can accelerate conversion of sulfur dioxide to sulfates. Figures 3-6 and 3-7 depict the production and transport of sulfates from a large electrical generating station in Western Nebraska during the formation of a low-pressure system over northeastern Colorado. Given the sparse meteorological monitoring network in the Nebraska-Colorado-Wyoming region, an advanced prognostic meteorological model was needed to develop wind, temperature, and related inputs for models used in these analyses. Specifically, the publicly-available Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Model, version 5 (MM5), was used to develop meteorological inputs for all modeling episodes.

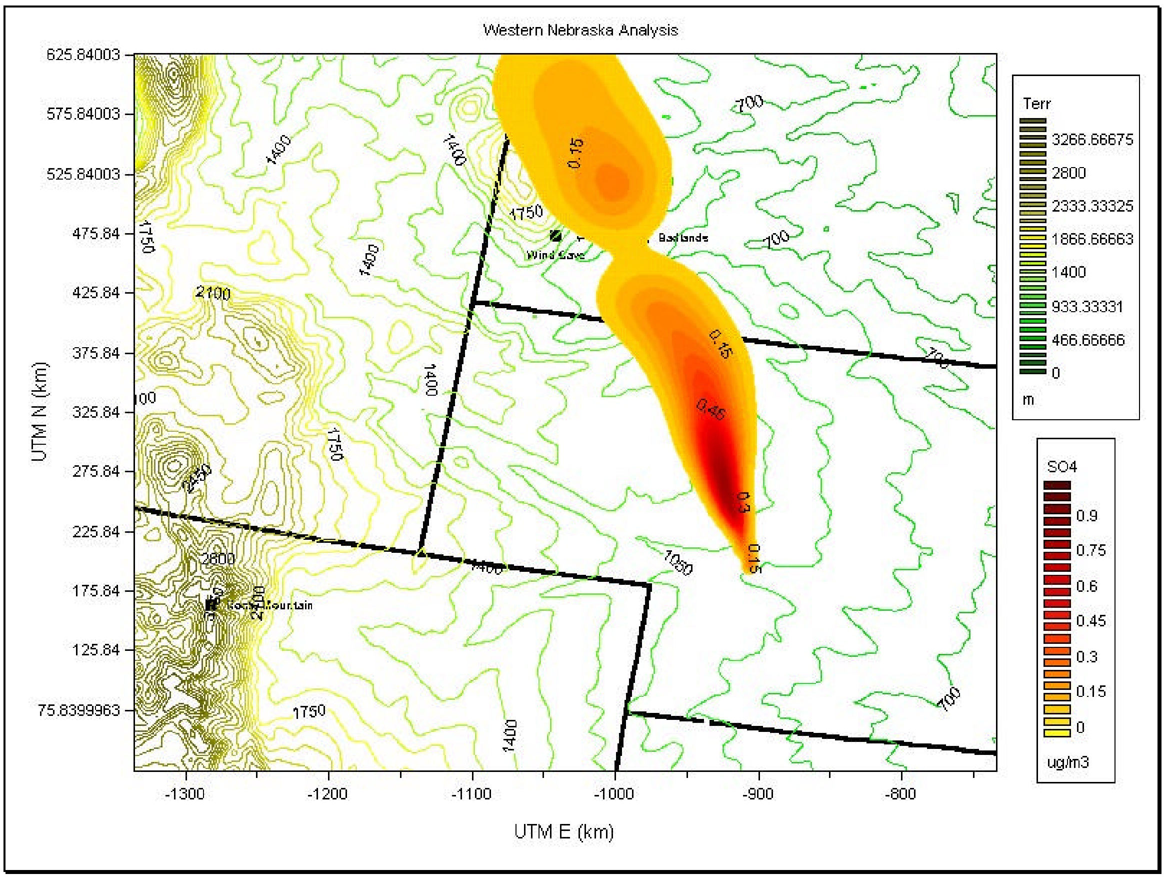

Fig. 3-6. *Lagrangian puff model (CALPUFF) simulation of the formation and transport of sulfates from a large electrical generating station located in Western Nebraska into Class I areas in South Dakota during a lee-side cyclogenesis event. Source: Anderson, 2001b.*

The lagrangian puff model CALPUFF, coupled with MM5 wind and temperature fields, was used to simulate the formation and transport of sulfates during the cyclogenesis event. The modeling analysis indicates that such meteorological conditions during winter and early spring months often facilitate the potential for transport of fine particulates and precursors into Class I areas in neighboring states. This underscores the importance of understanding how climate affects both chemistry and transport patterns in the formation of fine particles.

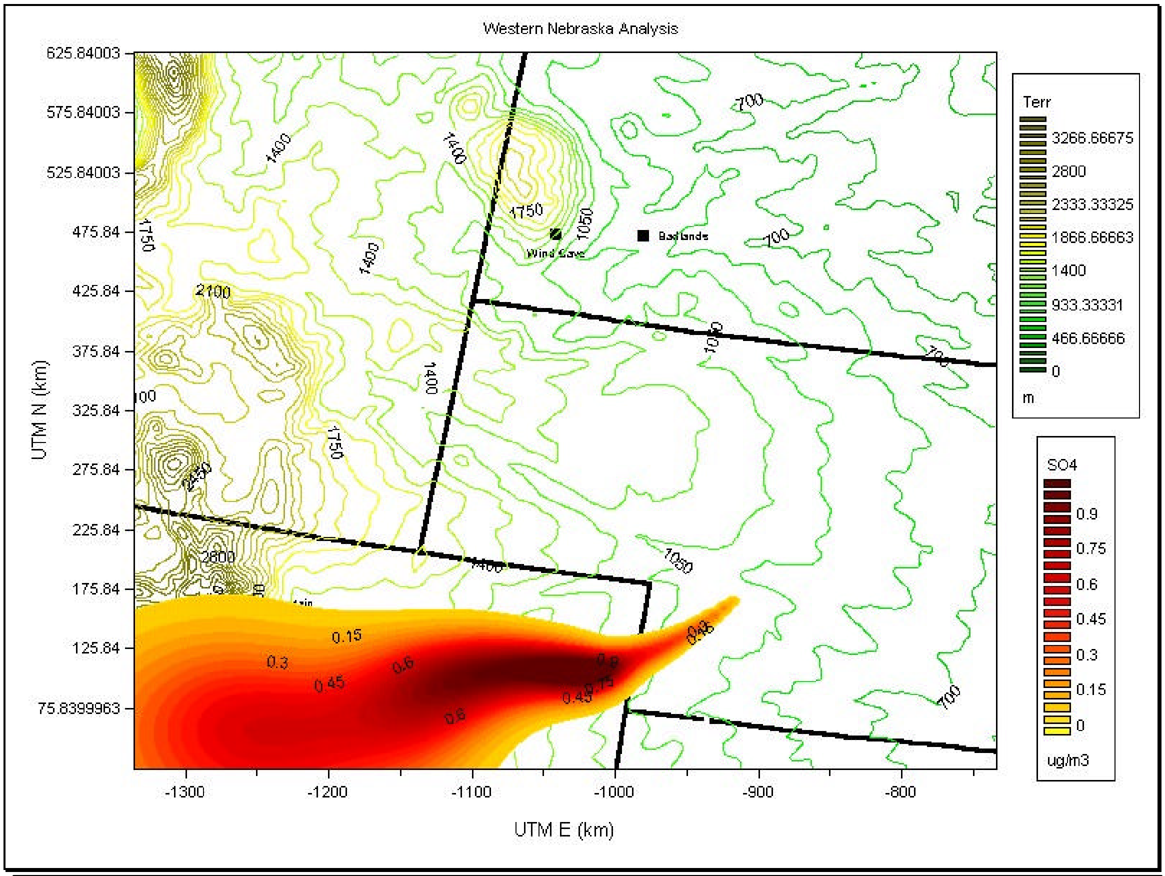

Fig. 3-7. *Lagrangian puff model (CALPUFF) simulation of the formation and transport of sulfates from a large electrical generating station located in Western Nebraska into Class I areas in Colorado later during the same lee-side cyclogenesis event. Source: Anderson, 2001b.*

While states such as Nebraska, Iowa, and Kansas do not have mandatory Class I areas within their respective borders, these simulations clearly demonstrate the potential of transport into neighboring states and contribution to the formation of fine particles that degrade visual air quality. The importance of regional haze to this area is underscored by the role that ammonia emissions have in the atmospheric chemical reactions that form sulfates, nitrates. Ammonia is a significant compound in the formation of these secondary particles, and these states have the highest emissions density of any region in the United States. It is estimated that these 3 states rank in the top 5 in the United States, with Iowa usually leading the nation in mass ammonia emissions. Nebraska usually ranks third and Kansas fourth behind North Carolina. Therefore, it is important that the agricultural sector be aware of the unique role that they have in regional air quality issues in the central United States.

The potential for transport is one of the fundamental reasons while all states have been included in the requirements of the 1999 federal regional haze rule. In its 1999 rulemaking, EPA stated that atmospheric modeling it had conducted “estimated that sulfate and nitrate deposition receptors are influenced by sources located up to 600-800 kilometers away.”

Section

4

Federal Regional Haze Program

Congress established a national goal of reducing and ultimately eliminating the influence of manmade air pollution in the degradation of visibility in our national parks and wilderness areas. The objectives, as expressed in the 1977 Clean Air Act amendments, were:

> "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."

This is widely interpreted to mean that Congress intended the restoration of visual air quality to pristine, unimpaired for scenic vistas in our national parks and wilderness areas.

In 1980, EPA issues the first series of visibility regulations to implement the national visibility goals. These regulations focused primarily upon local sources of air pollution that caused visibility and plume blight in Class I areas. EPA deferred action on the broader "regional haze" issue because the state of the science in 1980 for haze was insufficient to develop a national program. As a result, only localized individual or groups of sources where it could be demonstrated that emissions from these sources could be "reasonably attributed" to causing visibility impairment in a Class I area were subject to pollution control requirements. Thus EPA only required steps for reducing visibility impairment from states that hosted Class I areas by the submission of state implementation plans (SIPs) documenting reasonable progress towards the national goal.

Congress took additional s teps in the 1990 Clean Air Act Amendments by authorizing additional funds for the research into 1) the expansion of visibility related monitoring in Class I areas; 2) assessment of current sources of visibility impairing pollution and clean air corridors; 3) adaptation of regional air quality models for the assessment of visibility; and 4) studies of atmospheric chemistry and physics of visibility. The National Academy of Sciences (NAS) formed the Committee on Haze in National Parks and Wilderness Areas to address these research issues. The 1993 NAS report concluded that sufficient scientific knowledge and adequate air pollution control technologies now existed to take regulatory action on regional haze. In 1997, EPA published proposed amendments to the 1980 haze rules. The final regional haze rule, dated July 1, 1999 calls upon for States to "establish goals and develop emissions reductions reduction strategies for improving visibility in all 156 mandatory Class I national parks and wilderness areas."

These new rules set a deadline for the year 2064 for achieving the national visibility goals originally expressed in the 1977 Clean Air Act Amendments. The 1999 rules move away from the localized approach engendered in the 1980 haze rules to a regional approach which recognizes that visual air quality degradation is caused "by the emission of air pollutants from numerous sources located over a wide geographic area." The rule requires that all states with sources that "may reasonably be anticipated to cause or contribute" to visual air quality deterioration in protected visual environments, regardless of whether these states host any of the 156 mandatory Class I areas. The rule allows for states to individually develop implementation plans or to coordinate air quality analysis and pollution reduction strategy development with other states in entities known as regional planning organizations (RPOs). EPA has designated five RPOs to cover all of the United States. Figure 4-1 shows the delineation of each of these RPOs. Figure 4-2 describes the timeline for states participating in the regional planning process. In general, states are required to submit a "committal" implementation plan to EPA one year after designations for the new PM2.5 standard to indicate whether they will submit a plan individually or work within a RPO to coordinate strategy development. It is anticipated that these plans will be required in the 2004-2005 timeframe. The next requirement for states participating in the regional planning process is a comprehensive visibility implementation plan to be submitted 3 years after the designation of the last state in the RPO, but no later than 2008. These plans will set forth the measures to define progress goals towards the final national visibility goal of 2064, define the measures that it will implement to reach these goals, and set a monitoring strategy in place that it will utilize to evaluate and report their contribution to visibility impairment in Class I areas in other states. Once the plan has been established, states will have to submit “reasonable progress” reports every 5 years after the initial SIP. A new visibility SIP will be required in 2018 and every 10 years thereafter until 2064.

One of the primary elements of the 2004-2005 and 2008 plan requirements is an evaluation of the impact of retrofitting sources of air pollution that became operational between 1962 and 1977 with modern air pollution control systems. In the “committal” plan, states must identify air pollution sources that became operational during that period of time that meet certain size categories to determine if they could potentially be subject to more stringent air pollution control requirements. These are referred to as BART (Best Available Retrofit Technology) eligible sources. In the 2008 plans, RPOs must assess the degree of visibility improvement if BART were required of all eligible sources on a regional basis. EPA recently adopted revisions to the haze rule that cover the specific requirements of how to identify sources that are eligible for BART and to determine if such an emission unit would require retrofitting with air pollution control equipment. The largest industrial sector likely to be affected by the BART requirements are electrical utilities.

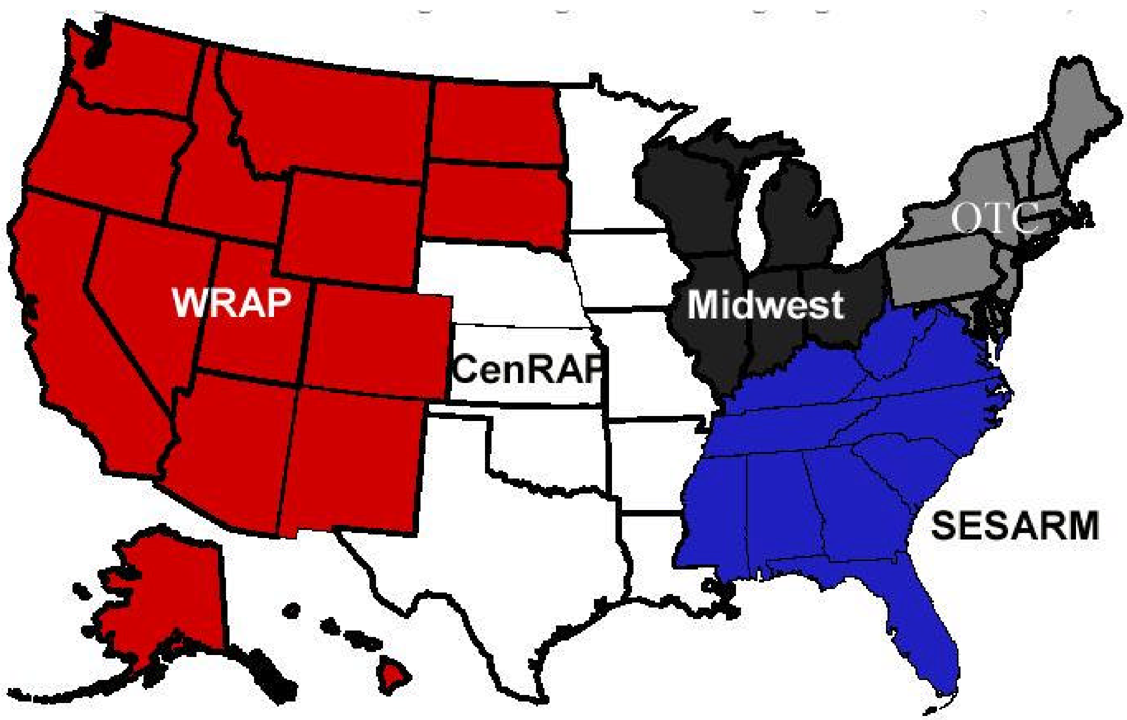

Fig. 4-1. *Regional Planning Organizations designated by EPA. Source: NESCAUM, 2001.*

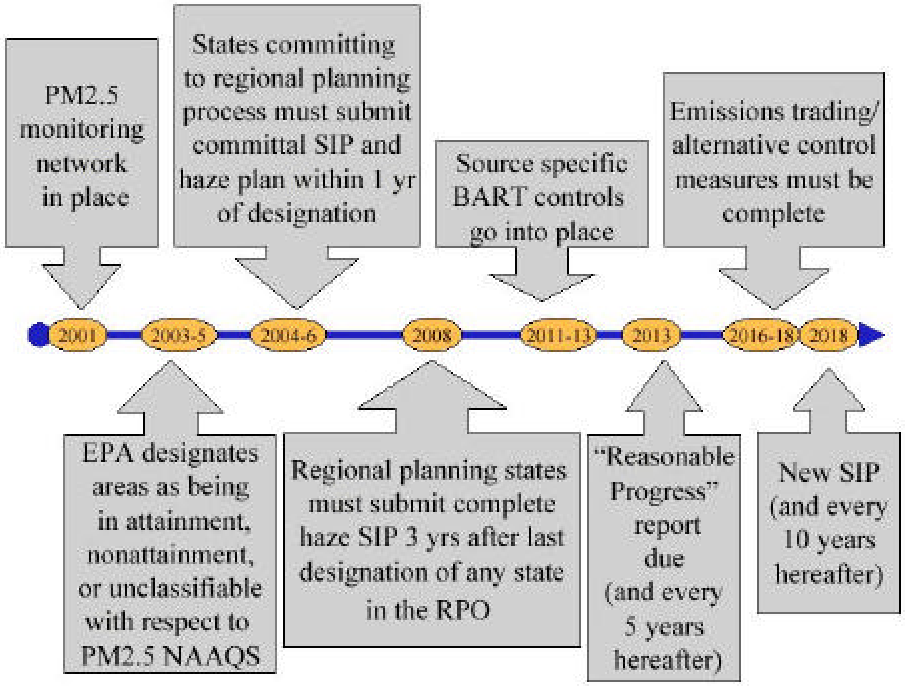

Fig. 4-2. *Timeline for states participating in regional planning organizations. Source: NESCAUM, 2001.*

Section

5 Current Status and Future Activity

In response to the issuance of the regional haze rule in 1999, representatives from nine central states met to discuss the requirements of the rule and how it impacted the central U.S. One year later the states of Nebraska, Iowa, Kansas, Minnesota, Missouri, Oklahoma, Arkansas, Louisiana, and Texas officially formed the regional planning organization known as the Central States Regional Air Planning Association. The CENRAP regional planning organization serves to coordinate the scientific assessment and planning efforts for these states and their tribal partners that are necessary to properly implement the regional haze rule. CENRAP will coordinate such activities as the collection and analysis of air monitoring data, inventorying of air emissions from states and tribes, atmospheric modeling simulations to assess current and future air quality conditions, and the evaluation and planning of possible control scenarios to meet the national visibility goal. CENRAP participation is voluntary and states are not bound to the recommendations that the organization makes. Regional planning is a very new concept in air quality management, but provides states and tribes the ability to pool resources and expertise to arrive at common solutions which affect the collection of states.

An important function of CENRAP is to collect and assess air quality data from the central United States. Since 1988, Federal Land Managers (Bureau of Land Management, U.S. Forest Service, National Park Service, and U.S. Fish and Wildlife Service) and the EPA have been monitoring the levels and composition of fine particles in many of these Class I areas. This monitoring program is referred to as the Interagency Monitoring of

Protected Visual Environments (IMPROVE). This data is analyzed to understand how fine particles degrade visual air quality and what the chemical composition of these fine particles is. This helps provide insight into what types of sources may be contributing to visual air quality problems. The current IMPROVE monitoring network is depicted in figure 5-1.

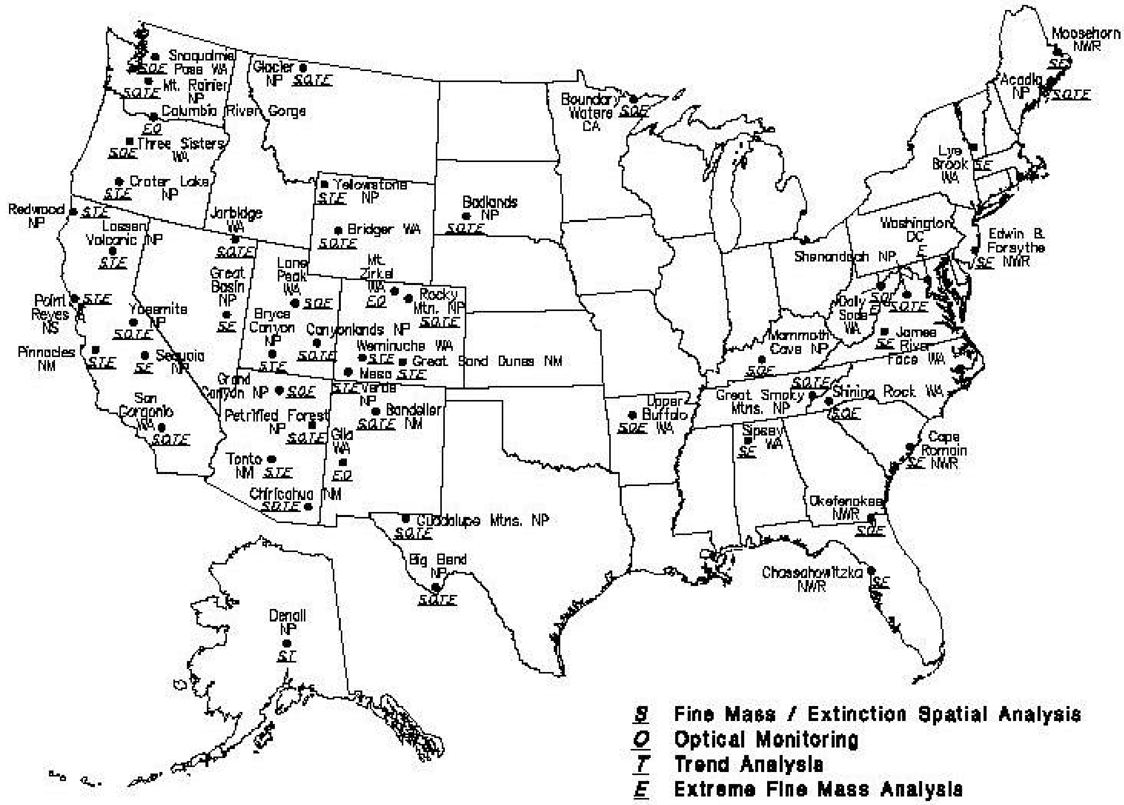

Fig. 5-1. Current IMPROVE monitoring network as of 2000. Source: NPS, 2001.

In the northern half of the CENRAP domain, there is only one IMPROVE monitoring site that exists for data collection and analysis. The remainder of the central United States is largely uncovered by the current IMPROVE network. As mentioned in Section 3, the central United States is considered to be a transition area of differing chemistries that make up the fine particle mixture due to its highly diverse climatology. The paucity of data in this area makes analysis of air quality and gaining a better understanding of the nature of air quality very difficult. To address this gap, CENRAP states are working with EPA and the Federal Land Managers to augment the current IMPROVE network. CENRAP plans to add at least 12 additional IMPROVE protocol sites within its region by 2002. Nebraska will be adding 4 sites throughout the state. 3 of the sites in Nebraska are to be tentatively located at the North Platte National Wildlife Refuge (Scottsbluff), Nebraska National Forest (Halsey), and the Niobrara National Scenic Riverway (Niobrara). The fourth site is to be operated and maintained by the Omaha Indian tribe and will be located near Walthill. Similar plans have been made with the neighboring states of Iowa and Kansas. These monitors are designed to fill in the gaps in the existing IMPROVE network and provide better information about the atmospheric chemistry over the central United States. This data will also aid atmospheric modelers who use computer models to simulate how fine particles are formed and transported in the atmosphere in understanding how well these models simulate actual environmental conditions. A model that performs well can in turn be used to assess how various pollution control strategies work on improving visibility in the Class I areas.

Other CENRAP workgroups are examining various pollution control strategies and alternatives that utilize market trading concepts as innovative methods to achieve pollution reduction goals. While states are not obligated to submit plans with long-term strategies for the reduction of air emissions that contribute to visibility degradation until 2008, the planning and assessment process is lengthy and requires the expertise of both government and industry representatives. Therefore, it is important that private sector representatives play an active role in the scientific and strategy assessment process that is currently underway. Initial control scenarios and market trading alternatives will focus heavily on utility and non-utility sectors that are considered BART eligible. Longer term strategies will likely focus on other sectors such as mobile source and possibly even agriculture. This highlights the importance of assuring that private sectors such as utilities and agriculture are represented and participate in this process.

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