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Air Quality Management Plan
Outline

FIRST DRAFT
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Please send comments by
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Air Quality Management Plan

Introduction

Shenandoah National Park (NP) was authorized in 1926, and established in 1935. Straddling the Blue Ridge Mountains, it is 195,382 acres in size, with 105 miles of the Skyline Drive running its length. Air quality is critical to the protection and preservation of Shenandoah NP because of its effects on natural systems and cultural resources. Air quality also affects visitor enjoyment, human health, and scenic vistas.

The legislation establishing the National Park Service (NPS) mandates the NPS to "...conserve the scenery..." and to manage parks "...in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (USC, Title 16, sec. 1). The Clean Air Act states further that in managing air quality, superintendents should "take actions consistent with their affirmative responsibilities to protect air quality related values in class I areas" (defined below). "The act also establishes a national goal of preventing any future and remedying any existing man-made visibility impairment in class I areas."(NPS Management Policies, Chapter 4:17-18).

Shenandoah NP has been a class I area since its designation by the Clean Air Act on August 7, 1977. Because of this status, the park is to receive the highest level of air quality protection the Clean Air Act can provide. Class I designation allows only small amounts of additional air pollution above baseline levels as long as National Ambient Air Quality Standards (NAAQS) are not violated and air quality related values are not adversely affected.

Air quality related values (AQRVs) are defined as "all those values possessed by an area except those that are not affected by changes in air quality and include all those assets of an area whose vitality, significance, or integrity is dependent in some way upon the air environment. These values include visibility and those scenic, cultural, biological, and recreational resources of an area that are affected by air quality." (43 FR 15016, 1978). AQRVs can include vegetation, visibility, odor, soils and water quality, flora, fauna, ecological systems, historic and prehistoric structures and objects, geological resources, and most other elements of a park environment that are sensitive to air pollution (NPS Management Policies 1988, Christiano and Scruggs 1985).

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Air quality monitoring began in Shenandoah NP in 1978. Data is collected at 3 sites in the park. Concentrations of sulfur dioxide (SO_2) and ozone (O_3) are monitored, as well as particulate amounts and deposition, visibility impairment and meteorological data.

Results of this monitoring show that air pollution in Shenandoah NP is causing adverse impacts to the park's AQRVs. High levels of acid deposition are causing acidification of sensitive park streams and soils, visibility is greatly impaired most of the time, and ozone levels damage vegetation and threaten human health.

Sources of this pollution include stationary industrial sources and mobile sources, both locally and regionally. Solutions to Shenandoah's air pollution problems will require comprehensive, cooperative measures by all contributors to the problem, whether large or small.

Background/History

The overall goal of the Clean Air Act (CAA) is to maintain safe and acceptable ambient air quality through the attainment and maintenance of the NAAQS. The primary NAAQS are designed to protect public health with a margin of safety. The secondary NAAQS are to protect the national "welfare," which include the resources and values associated with parks.

The CAA has two important sections for Shenandoah NP. Section 169A of the act sets a national goal of remedying existing and preventing any future manmade visibility impairment in class I areas like Shenandoah (NPS-77). The "Prevention of Significant Deterioration" or "PSD" section requires new stationary sources or major modifications to submit a permit application to the air pollution emission regulator (the state department of air pollution control, or EPA). The regulator is then required to notify the Federal Land Manager (FLM; for the NPS, the FLM is the Assistant Secretary of Fish and Wildlife and Parks) when the source may impact a class I area. The FLM then evaluates potential AQRV impacts. Section 165 (d) states that a permit shall not be issued "in any case where the federal land manager demonstrates to the satisfaction of the state that the emission from such a facility will have an adverse impact on the air quality related values (including visibility) of such lands."

As required by the provisions of the CAA, park staff with the NPS Air Quality Division (AQD) has reviewed permit applications from major new air pollution sources and assessed potential impacts of these pollutants on the park. Whenever it was determined that a new source might cause or contribute to an adverse impact on AQRVs, the staff has recommended to the permitting authority (in Virginia, the Virginia Department of Air Pollution Control, or VDAPC) that the construction permit be modified to eliminate adverse impacts. Specific recommendations have included reduction in emissions, offsetting emissions to offset impacts to resources in the park, and assessing cumulative pollution impacts from surrounding sources.

In a letter dated May 24, 1990, the superintendent asked the Virginia Secretary of Natural Resources for a moratorium "on all permits not yet approved by the VDAPC for the construction of electrical generating facilities capable of emitting greater than 500 tons per year of either SO2 or NOx, until the cumulative effects of the proposed emissions can be assessed." He also asked that energy needs and planning be done to make the most efficient use of the energy Virginia was currently producing.

Although this letter produced much discussion, no moratorium was set, and in September 1990, the NPS issued a notice for public comment in the Federal Register. The notice stated, in part, "the FLM would recommend that the VDAPC not permit additional major air pollution sources with the potential to affect Shenandoah National Park's resources...unless the State can ensure that such sources would not contribute adverse impacts" (55 FR 38403). This notice was a preliminary declaration of adverse impact to Shenandoah NP. Substantial comment was received, most in favor of NPS efforts to protect the park's air.

Since the Federal Register notice, the NPS FLM has been negotiating each PSD permit on a case-by-case basis. In each case, the FLM has asked for the use of Best Available Control Technology (BACT) and offsetting new emissions by reducing existing emissions to mitigate potential impacts to the park's resources.

Although no permit has been denied on the basis of the Shenandoah adverse impact declaration, the permitted amounts of pollutants allowed has been substantially reduced from the initial proposals. In some cases, emission offsets were obtained.

(generate table of original proposed emissions and final permitted)

Management Objectives

As stated earlier, Shenandoah NP's general mission is to protect park resources and to assure visitor enjoyment of the park and its resources. This is based on the 1916 Organic Act which created the NPS, Shenandoah NP's enabling legislation, the National Environmental Policy Act of 1969, and the Clean Air Act.

The Clean Air Act gives the FLM "affirmative responsibility" to protect the air quality in its class I areas, and establishes a national goal of preventing any future and remedying any existing man-made visibility impairment in Class I areas. The CAA

addresses new source emissions pretty well. It does not adequately address individual and cumulative air quality impacts of non-PSD sources, such as minor sources, those located in non-attainment areas, existing sources, sources with fugitive emissions such as surface mining, and those sources in foreign countries. Regional loadings and long-range transport of air pollutants, characteristic of regional haze, ozone and acid deposition are also not addressed adequately (Ross 1990).

Air quality management in the NPS is guided in part by the NPS Management Policies Manual (1988). It quotes the Clean Air Act's purpose of "preserve, protect and enhance air quality," and directs that the NPS "will seek to perpetuate the best possible air quality in parks because of its critical importance to visitor enjoyment, human health, scenic vistas, and preservation of natural systems and cultural resources." Also, the NPS "will assume an aggressive role in promoting and pursuing measures to safeguard these values....[and] In case of doubt...err on the side of protecting air quality and related values for future generations."

The 1990 Federal Register notice for Shenandoah NP cites 2 resource management objectives for the park. The first is that vistas from the Skyline Drive, developed areas, and trails will provide clear views of natural and cultural environments. The second is that native, rare, endangered, and relict species, habitats, and communities will be protected and perpetuated (55 FR 38403). Both of these objectives will require clean air to accomplish.

The Air Resource Management section of NPS-77 (1991) describes what a park air quality management plan should do. A plan should describe past, ongoing, and proposed air quality monitoring and research. It should also describe how information will be used, both internally and externally. Third, it should describe what actions are needed to remedy existing problems and to prevent future ones. The guidelines also say that a park could, if there is enough data, develop park-specific ambient air quality standards or visibility protection standards.

The U. S. Forest Service (USFS) has developed screening documents to assess air pollution effects on its Class I areas when commenting on air pollution permits. These screening documents propose red-yellow-green lines of impacts. Cumulative pollution levels below the "green line" value are permissible and the proposed additional pollution can be approved without further examination of data. Cumulative pollution levels greater than the "red line" value should be denied unless site-specific additional data can prove that the identified AQRV would not be adversely affected by the additional pollution. Predicted pollution levels which fall between the red and green lines should be evaluated on the basis of additional information provided by the permit applicant or the FLM (Fox, et al 1989).

The NPS has never developed any sort of "red-yellow-green" assessment method. Instead, attention has been focused on monitoring air resources to get baseline data. By the time Shenandoah NP's preliminary adverse impact notice was published in 1990, resources were already in adverse conditions. Since existing amounts of pollution were already causing adverse impacts, and more pollution was being proposed in approximately 15 new PSD permits for stationary sources, yellow and green zones seemed moot.

However, as air quality negotiation and cooperation progresses between agencies and between states, the need for a target condition for AQRVs has become obvious. For this reason, the following descriptions of AQRVs for Shenandoah NP will include a statement of current condition and a target "green line" condition. For the "red line" value, a "Class I ambient air quality standard," similar to the nation-wide NAAQS, will be proposed wherever reasonable data exists to support one.

This plan will not address air toxics because EPA and the CAA address them under a different set of regulations, and surrounding monitoring in the state does not indicate a need for Shenandoah NP to monitor yet (Thomson). Since surrounding carbon monoxide (CO) monitoring in the state shows no violation of standards, the plan will not address CO, either.

Resource Concerns

Shenandoah NP has five major concerns about air pollution and its impacts to park resources:

Visibility--Annual average visibility has declined 60 percent between 1948 and 1983, with an 80 percent decrease in summer months and a 40 percent decrease in winter months.

Aquatics---Many park streams are moderately to extremely sensitive to acidification caused by atmospheric pollutants; streamwater acidification is causing adverse effects on aquatic fauna.

Vegetation---Ozone (a secondary pollutant caused by reactions between nitrogen oxides and volatile organic compounds) is causing visible injury to sensitive vegetation.

Human health--Ozone levels in Shenandoah are frequently above 80 parts per billion, a level which the American Lung Association says is high enough to cause adverse effects in many people.

Soils---Because of the underlying bedrock of Shenandoah NP, soils have up to now adsorbed acid deposition. This limited capability is being depleted, perhaps permanently.

Total pollution levels are expected to continue to increase. The vehicle emissions controls enacted in the 1977 CAA are being counteracted by Americans driving more. In the United States as a whole, vehicle miles traveled increased by 26 percent between 1980 and 1987, while the nation's population only increased by 12 percent between 1980 and 1990. In northern Virginia, the number of vehicles registered is 1.63 times greater that the population increase between 1980 and 1990 (Earth 2020). In Albemarle County alone, hydrocarbon emissions have increased 44 percent between 1980 and 1987. EPA projections of statewide emissions show that even with the implementation of the 1990 CAA amendments, Virginia's emissions will increase (Thomson 1993).

Although air pollution can travel long distances, local sources of pollution become important during periods of air stagnation or inversion. During these periods, local emissions cause the greatest impact because they are less able to disperse. This region has one of the highest occurrences of inversion days in the country. The Shenandoah Valley is especially sensitive to periods of air stagnation.

Visibility

In 1979 the Department of Interior determined, and EPA concurred, that visibility is an important value in Shenandoah NP (44 FR 69122). Yet poor visibility is the single most frequent complaint heard from visitors to Shenandoah National Park. The ability to see distance, as well as clarity has diminished by 60 percent since the late 1940s (NAPAP). The NAPAP report estimates that natural annual average visual range (how far one can see) for Shenandoah should be 150 km (+/- 45 km), or 70 to 80 miles. Shenandoah's current annual average visual range is 20 to 35 km, or 12 to 21 miles.

Light extinction is another measure of visibility. It causes impaired ability to perceive form, texture and color when viewing. When regional sulfate emissions from 1940 to 1980 are tracked with light extinction in the southeast, extinction increases as emissions increase (NAPAP). The effect of increased extinction is as if a sheer curtain is pulled in front of a window--clarity and color become muted.

Natural sulfate concentrations have been estimated to be 0.2 micrograms per cubic meter (ug/m3), while natural fine particulate concentrations are estimated to be 3.3 ug/m3 (55 FR 38403). Between June and September in Shenandoah NP, the SO_2 concentrations range between 8.5 - 10.2 ug/m3, while the fine particulates are between 19.5 - 28.9 ug/m3. Current annual concentrations are almost 30 times the natural concentration of SO_2, and 3 times the fine particulate concentration.

Table___

SO_2 (ug/m3)		fine particulates(ug/m3)	
natural	current summer (annual ave)	natural	current summer (annual)
0.2	8.5-10.2 (5.8)	3.3	19.5-28.9 (10)

Higher humidities in the summer and more frequent air stagnations combine with region-wide pollution to impair visibility. Shenandoah NP's 1990 Federal Register notice referenced a letter from Department of Interior (DOI) to EPA dated November 14, 1985, which stated that scenic views at Shenandoah NP were impaired by anthropogenic pollution more than 90 percent of the time. Between May and October in 1991 and 1992, visitors could see no more than 10 miles 35 percent of the time. Visitors could see 11 to 30 miles about 50 percent of the time, but good visibility--over 30 miles--only occurred about 15 percent of the time.

Section 169A of the CAA requires "reasonable progress" to be made toward elimination of visibility impairment problems. NAPAP projections show that the biggest reductions in annual sulfur deposition will occur in locations in which emissions reductions occur, but the 1990 CAA amendments allow existing sources to trade emissions for offsets instead of reducing on-site. This emissions trading will improve the air in some regions, but not in all regions of the country. In fact, EPA has predicted that SO_2 emissions in Virginia are expected to increase by 24 percent by the year 2005, even with implementation of the 1990 amendments. Other EPA projections of CAA amendment implementation estimate that by 2010, Shenandoah NP's worst visibility days could improve in visual range by as much as 38 percent but that the best days could correspondingly get better by only 6 percent (Thomson).

Depending on the observer, a 5 to 15 percent change in standard visual range will be noticeable (55 FR 38403, Tech. Supp. Doc.). The NAPAP report states that a small reduction in sulfur emissions will yield a small improvement in visibility, but further sulfur emission reduction will yield more dramatic improvements.

> REVIEWERS: My idea here is to establish a rate of "reasonable progress." I have no data for what's "reasonable." How many "just noticeable changes" over time? What concentrations of SO_2 are required to achieve these changes? Also, if we establish an improvement schedule for acidic deposition, visibility will benefit as well; can I get away with having only one schedule for both AQRVs?

Aquatics

Shenandoah NP has over 40 brook trout streams, in about 130 miles of water (Trout magazine, 1991). Historically, it is estimated that only between 0 and 3 percent of Virginia's mountain streams were originally acidic (Trout). In 1987 the Virginia Trout Stream Sensitivity Study (VTSSS) done by the University of Virginia, found that 10 percent of 344 sampled streams in Virginia mountains were acidic.

Acid neutralizing capability, or ANC, is a measure of how well a stream can neutralize any acidity it receives. It is expressed as microequivalents per liter or ueq/L. It is important to understand the relationship between pH and ANC. PH measures present acidity; ANC measures how well the water is buffered. A stream can have very low ANC and have a pH that is close to neutral. If a stream's pH is neutral and it has a high ANC, then it can receive quite a bit of acid deposition and remain at a neutral pH. However, if a stream is neutral in pH and has little or no ANC, then any amount of acidity added to it will make the water become acid quickly.

Streams with ANCs from 100 to 200 ueq/L are classed as moderately sensitive. Sensitive streams have ANCs between 50 and 100 ueq/L, while those with 0 to 50 ueq/L are extremely sensitive. It is possible for a stream to have less than 0 for an ANC value; those streams are acidic. Most of the streams in Shenandoah NP have ANCs of 15 ueq/L or less; all are in the moderately sensitive class of 200 ueq/L or less (Webb, 1991).

Shenandoah NP receives the highest sulfate deposition of any of the national parks in the country (NAPAP, Webb). Total sulfate deposition (wet plus dry) in Virginia mountains is estimated to be about 37 kilograms per hectare per year (kg/ha/yr), 10 times pre-industrial levels (Thomson). Precipitation in Virginia's mountains ranges between 4.2 to 4.3 pH units--Shenandoah NP monitoring has registered rainfall pH as low as 3.8. Ninety percent of the sulfate and 80 percent of the hydrogen ion concentration in this rain is due to anthropogenic (man-made) sources (55 FR 38403, Tech. Supp. Doc.).

Streams get their ANC from the bedrock soils through which they flow. The soils underlying Shenandoah NP have two important characteristics. First, they tend to adsorb sulfates initially. That means they retain incoming acid deposition. The next characteristic is that this first characteristic is limited. Once these soils are "full" they can't hold acidity any more, and they begin to leach acidity. Once a soil has lost its sulfate adsorption capacity, no one knows how long (if ever) the soil will take to recover.

The more sensitive soil types in the park have already reached their limit of buffering capacity. It is in these areas that the sulfates are getting into the streams and causing acidification of the water.

As acidity increases in streams (pH drops), the reproductive ability is impaired in sensitive fish species, amphibians, and macroinvertebrates. As acidification continues, aquatic ecosystems will show a decline in species diversity and density, and a shift in species distribution. Acid-sensitive species will give way to acid-tolerant species.

Although the Saint Marys River is not in Shenandoah NP, its bedrock is similar to that of streams in the park. Monitoring from 1976 to 1988 showed a decrease in number of fish species from 12 to 8. Rainbow trout, more sensitive to acidification than the brook, sharply declined in numbers. Acid-sensitive mayfly genera disappeared, while acid-tolerant Chironomids and Luectra genera increased. If continued acidification does not kill the native brook trout population in the Saint Marys, it is feared that the decline in its food base (aquatic insects) will (Webb et al, Trout magazine).

There are a couple of added complications to the "acid rain" problem. The first is the role nitrogen deposition plays in acidification. Current wet nitrate deposition is estimated to range from 15 to 29 kg/ha/yr (NAPAP). This nitrate can act as a fertilizer (see soils section), but it can also convert to nitric acids which acidify in addition to sulfuric acids. The USFS has estimated that nitrogen deposition has 20 to 25 percent of the acidification effect as the same rate of sulfur deposition (Adams et al 1991, Fox et al 1989).

The second factor is an apparent decrease in neutralizing base cations. The NAPAP report has documented a decrease in sulfate concentrations in precipitation in recent years, but rainfall pH and hydrogen ion concentration have remained unchanged. This is attributed to a decrease in base cations that could neutralize the acids in the rain. The reason for this decrease is unknown.

The 1990 CAA amendments are designed to reduce sulfate deposition over time, by reducing sulfate emissions from stationary sources of pollution. However, projections using computer models of acid-sensitive soils and streams indicate that even if we decrease sulfate deposition by 40 percent by the year 2000, soils will continue to leach acidic compounds into streams for as long as 50 years (**Webb, pers. comm**). Even with a 50 percent reduction in acid deposition, only a small portion of the streams would actually see an improvement. Most would continue to acidify. Like the soils, this situation may be irreversible.

The USFS has set a "red line" value of a pH change of 0.5 and a 0.1 to 0.2 pH change as an acceptable "green line" value for sensitive systems with an existing pH of 6.0 or very low ANC (Fox et al). For ANC values, 25 ueq/L is considered "green," 10 ueq/L is considered "red." Episodes of 0 ueq/L are also considered "red" (Adams et al). Depending on the life stage of aquatic organisms, episodic acidification can be more damaging than chronic (see discussion on research below).

The 1990 CAA amendments has required a reduction in SO_2 emissions of 10 million tons by the year 2000, and a NO_x reduction of over 2 million tons. As stated earlier, however, this reduction may not be enough to keep the park's streams from acidifying. At an international conference on critical loads for air pollution (Agren et al 1992), scientists agreed that total sulfur deposition should be no more than 5 kg/ha/yr. They set a goal to reduce sulfur emissions by 30 percent in 10 years.

Because a direct measure of acidic deposition is easier and more reliable than calculating its effects on stream pH, perhaps an appropriate goal for protecting aquatic systems in Shenandoah NP should be to have no more than 5 kg/ha/yr of sulfur deposition coming into the park.

Terrestrial ecosystems

Combinations of ozone, nitrogen oxides and sulfates can have individual as well as synergistic effects on vegetation (McLaughlin 1985). Forest communities exposed to multiple pollutants, like aquatic ecosystems, tend to become less varied with respect to number of species. In one case, high ozone levels in the San Bernadino Mountains eventually caused a change in species composition from pine trees to oak. McLaughlin (1985) suggests that monitoring species richness and diversity may be a more sensitive indication of pollution damage than monitoring growth of individual tree species.

Ozone is widely considered to be the most widespread and phytotoxic air pollutant. In a survey by de Steiguer et al (1990), 41 scientists ranked ozone as the most damaging single pollutant in 7 major ecosystems in the United States. Ozone absorption through leaves causes black spots--flecking, and loss of chlorophyll, and accelerated aging and death of leaves. At the same time, ozone can induce an increased susceptibility to insects and disease, water stress, winter injury, and a loss of genotypes that are ozone-sensitive (Fox et al, Adams et al). Estimated crop yield reductions for 8 sensitive agricultural species range from 2 to 56 percent, costing the nation between $1.1 billion to $2.9 billion PER YEAR (Thomson).

Both Great Smoky Mountains NP and Shenandoah NP are documenting damage to plants due to ozone (e.g. black cherry, milkweed, etc.). Many of the species that occur in the Smokies are the same ones that occur in Shenandoah NP. Ozone fumigation research in the Smokies is showing that early leaf-drop on some plants, previously thought to be normal senescence, is actually caused by ozone damage.

Typical growing season average levels of ozone for Shenandoah NP are between 50 and 55 ppb (NAPAP). The general consensus of normal background concentrations for ozone are between 15 and 30 ppb. One source suggested that these levels are no longer attainable, and suggested 40 ppb as a goal for background ozone levels (LeFohn and Runeckles 1987).

Peak levels of ozone, or episodic events, are also considered important because vegetative damage occurs during short episodes. Almost all the sources researched defined "peaks" as readings of 80 ppb or higher (NAPAP, LeFohn and Runeckles 1987, Duchelle et al 1983, Thomson 1993). Scientists at the international conference on critical loads for air pollutants came up with a formula for establishing critical levels of ozone concentrations:

[x] ppb-hours above [y] ppb baseline

A higher [y] value will reflect peaks of ozone concentration, while a lower [y] value will account for background levels. The proposed numbers to fill in the [x] and [y] are 300 ppb-hours above 40 ppb baseline (Agren et al 1992). This limit is currently being exceeded all over Europe, but a few scientists think it is still too high a limit to adequately protect vegetation.

Ozone levels in Shenandoah NP were very high in 1988 and comparatively low in 1992. Data from Big Meadows during these years show that the number of hours over 40 ppb during the growing season (24-hour basis--not just during daylight hours) ranges between 3,340 hours in 1988 and 3,427 hours in 1992. Big Meadows is a high elevation site. Dickey Ridge is a mid-elevation site; the 1988 and 1992 hours above 40 ppb were 3,015 and 2,532, respectively. Sawmill Run, a low-elevation site, had 2,476 hours in 1988 and 1,509 hours above 40 ppb in 1992. These levels all exceed the proposed European formula. Shenandoah should adopt this formula until more data proves a better one exists.

Table_____ Hours of ozone above 40 ppb between April 1 - Oct 31

YEAR	Big Meadows	Dickey Ridge	Sawmill Run
1988	3340 hours	3015 hours	2476 hours
1992	3427 hours	2532 hours	1509 hours

At first, added nitrogen deposition to terrestrial ecosystems acts like a fertilizer. But Shenandoah, like most Class I areas, is a nitrogen-limited system, at least at high elevations. In nitrogen-limited areas, added nitrogen can cause a shift in species composition and may encourage pathogens. One study in Connecticut found that nitrogen fertilization of hemlock seemed to enhance the buildup of populations of the hemlock woolly adelgid. In fact, adelgid infestation was twice as bad on fertilized trees (nitrogen enhanced) versus unfertilized (McClure 1991).

Normal background levels of sulfur concentrations have been estimated at 1000 parts per million (ppm). Current sulfur concentrations at Shenandoah NP are 2600 ppm (55 FR 38403, Tech. Supp. Doc.). These levels are high enough to cause morphological change in some species of lichens.

Both nitrates and sulfates can convert to acids and acidify forest soils, leading to changes in plant growth or changes in species that can grow there. NAPAP conducted a Mountain Cloud Chemistry study to study cloud water (fog) deposited on trees. Concentrations of hydrogen, sulfate, nitrate, and ammonium ions were 5 to 20 times higher in high elevation cloud water than in nearby low-elevation precipitation. These high levels of acidity can leach nutrients directly from foliage (Smith 1991).

As the sulfur deposits on the ground, aluminum and other metals become biologically available to plants and soil microbes. McLaughlin (1985) reports a hypothesis that the aluminum toxicity kills off the fine roots of a tree and predisposes it to a variety of secondary symptoms because of reduced uptake of nutrients. McLaughlin also reports that widespread liming of forests was tried to protect forests in Germany in the 1950s. Only a small part of the forest damage was alleviated by liming; acidification of soils was reduced for a while. However, above-ground damage continued and the potential damage of ecosystem from heavy doses of lime is great. Even if Shenandoah NP could manipulate the resource by liming, it is not a viable solution to acid deposition.

Attenders at the critical loads conference came up with a way to measure acidity in forest ecosystems using a calcium ion to aluminum ion ratio in soils (Agren et al 1992). The ratio of Ca/Al should not be greater than 1 to protect the forest ecosystem from effects of acidification. Also, this ratio would address both sulfur and nitrogen deposition, since both acidify the forest soils (by different mechanisms).

Human health

The NPS Management Policies Manual (1988) gives the saving of human life top priority in park operations. The NPS is to "seek to provide a safe and healthful environment for visitors and employees," and is to identify threats and reduce or remove known hazards, or provide other controls (such as fencing or signing).

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One known threat to human health in Shenandoah NP is air pollution. Some asthmatics are sensitive to acute NOx exposure, but the only place in the country with an acknowledged NOx problem is in Los Angeles. The risk to humans from SO_2 is low, but the interaction of SO_2 with other pollutants can cause an effect. Acidic aerosols from sulfur or nitrogen emissions have potential health effects, but they are unknown at this time. The primary pollutants of concern here are ozone, and to a lesser degree, campfire smoke.

Ozone occurs naturally high in the atmosphere (stratosphere) where it blocks cancer-causing sun rays from entering our lower atmosphere. No one breathes ozone up there, so it's not considered a pollutant, but a needed shield against harmful radiation. The ozone of concern in Shenandoah NP is formed down here where people breathe (troposphere). Wherever it occurs, ozone is a form of oxygen (O_3) that is poisonous. In the lower atmosphere, it can damage both plant and animal tissue.

In humans, ozone irritates the lung membrane and reduces the lungs' ability to flush out infectious toxins. It can cause coughing, sinusitis, chest pains and a general feeling of weakness. It can also aggravate asthma and other breathing disorders, making attacks more frequent and severe. It is not known whether acute or chronic ozone exposure causes permanent damage to humans; it does in animal studies (NAPAP).

Some normally healthy people are particularly sensitive to ozone and can feel its effects at levels as low as 80 ppb (NAPAP, American Lung Association). The federal human health standard for ozone is 120 ppb. Medical professionals recommend that people with respiratory ailments, the elderly, and the very young should reduce their physical activity and stay indoors during periods of high ozone.

Standard operating procedures have been drafted for park employees during periods of high ozone. Also, the park currently posts an air quality advisory sign at all entrances during the ozone season (mid-May to mid-October). Ozone levels and visibility classes are designated on these signs and are updated daily. For ozone, the designations are "low"--50 ppb or lower; "moderate"--50 to 79 ppb; "high"--80 to 124 ppb; and "unhealthy"--125 ppb or higher. Because the American Lung Association is gathering information that points to 80 ppb as critical to human health, and because vegetation is also damaged at peaks of ozone as low as 80 ppb, Shenandoah NP should have a single ozone health and resource protection standard of 80 ppb (one hour).

Visitors to park campgrounds have complained about nighttime inversions causing campfire smoke to stay close to the ground and make breathing and sleeping difficult. Park policy does not allow any campfires in the backcountry, but does allow them in the established campgrounds. Shenandoah NP fire management officer Len Dems (pers. comm. 1993) suggested a requirement that campfires be doused with water and not allowed to smolder all night. Campgrounds usually have quiet hours between 10:00 pm and 6:00 am; he suggested that fires be completely out during the same period.

Soils

Soils, streams, and vegetation are interrelated AQRVs, because when a pollutant affects one of these, there is an associated effect on the others as well. This section will address soil-specific effects as much as possible, but some related effects are also discussed in the aquatics and terrestrial sections.

Too much nitrogen in a system leads to a decreased diversity in the forest herb layer, and eventually to nitrification of the soil. When this happens, microbes in the soil form nitrate and nitrite and begin to leach out the nitrate and associated cations. All this leads to either surface or groundwater degradation or high nitrate leaching into aquatic systems (Fox et al 1989). Recent gypsy moth defoliation in sections of the park have caused an interaction between air-deposited nitrogen and the leaching of gypsy moth frass on the ground. Nitrate levels in the streams continue to be elevated after episodic peaks of frass leaching due to rainfall. Not only does this contribute to aquatic acidification, but it is a sign that soils in Shenandoah are becoming nitrogen-saturated (Webb, pers. comm).

The best explanation of nitrogen deposition and soil acidification was by Harald Sverdrup (Agren et al 1992) at the international critical loads conference. Nitrogen deposition initially acts as a fertilizer, promoting growth. "At the same time the acid deposition pushes nutrients out of the reservoirs in the soils by the process of ion exchange--out of the 'bank account.' This temporarily raises the availability of base cations and so matches the increased availability of nitrogen. The result is increased tree growth--until the 'account' is empty. Then comes bankruptcy and collapse." The end result is acidified soil. Only then do deficiency symptoms such as susceptibility to disease and stress appear in vegetation.

One critical load suggested for nitrogen deposition to soils was 7 to 20 kg N/ha/yr. However, if that critical load is based instead on forest nutrition, it should be lowered to 2 to 5 kg/ha/yr (Agren et al 1992). Actual field data from southern Sweden suggest a median of 6 to 10 kg/ha/yr. This agrees more closely with the USFS "green line" value of 3-10 kg/ha/yr (Fox et al 1989). The USFS "red line" value is 10-15 kg N/ha/yr.

University of Virginia researchers estimate that 60 to 70 percent of sulfur deposited on Shenandoah NP soils is being adsorbed. As adsorption capacity is exhausted, the concentration of sulfates and acidity levels in streams will rise (Trout magazine).

The USFS assumes a soil depth of 30 cm and that it naturally takes 175 years to reduce 1 ueq of base cations per 100 grams of soil (Fox et al 1989). With these assumptions, a "green line" value is 3 kg S/ha/yr, and a "red line" value would be 20 kg S/ha/yr deposition. Research is needed on specific depths and weathering rates of soils in Shenandoah NP in order to develop a specific target value.

Sources of pollution

Ozone is a secondary pollutant, formed from nitrogen oxides (NOx) and volatile organic compounds (VOCs). One NOx molecule can form 1 to 2 ozone molecules or up to 30 to 40 ozone molecules, depending on the area. In areas with low emissions (like Shenandoah NP), the ozone-forming potential of NOx molecules is highest. In urban areas, ozone formation is limited by VOCs; in more rural areas, it is NOx-limited (Agren et al, 1992). EPA's Regional Oxidant Model (ROM) projects that controlling NOx emissions could be very effective in reducing area ozone levels.

Acid rain and dry forms of acid deposition are caused by high levels of atmospheric sulfuric and nitric acids. The primary pollutants are sulfur dioxide (SO2) and NOx. These acids are formed from pollution given off by industrial facilities burning fossil fuels and by auto emissions. McLaughlin (1985) estimated that NOx contributes approximately 25 percent of the acidity in rainfall in the northeastern U.S.

Sulfur dioxide is only given off by burning coal or oil. NAPAP estimates that approximately 2 percent of all sulfur emissions is natural, while Thomson reported that electric utilities in Virginia contributed 42 percent of the statewide SO2 emissions in 1985. Other industries contributed 48 percent of Virginia's SO2 emissions. NAPAP reported that the RADM/EM model showed that over 50 percent of an area's total sulfur deposition comes from within 20 to 200 km (up to 500 km with very tall smokestacks).

The model also predicted that if SO_2 emissions are reduced 50 percent, then the reduction in total deposition at receptors within 200 km is from 35 to 50 percent in the eastern U. S.

Main sources of NOx are auto emissions and industrial burning of oil, gas, and coal. The NAPAP (1991) report estimates that up to 11 percent of all NOx emissions are naturally emitted from soils and lightning. EPA estimates 40 percent of a nationwide annual 20 million tons of anthropogenic NOx comes from transportation (Thomson). Over 33 percent of emitted NOx comes from electric utilities (NAPAP). In Virginia the proportions are similar. Since automobiles emit almost half of the total NOx at ground level, NAPAP states that these emissions do not travel as far as emissions coming from tall smokestacks.

On a park-wide basis, Air Quality Division modelers used the EPA mobile source model to determine what contribution vehicles in the park made to existing pollution levels. For all the vehicles traveling through Shenandoah NP in 1991, the amount of NOx emitted from those vehicles totalled only 70 tons per year. This is a very small amount when compared to the 76,305 tons emitted from utilities in Virginia in 1985 (Thomson 1993).

Anthropogenic VOCs enter the atmosphere as gasses emitted from such things as evaporating gasoline, paint, printing ink, cleaning solvents, dry cleaning solvents, organic chemicals, woodstoves and fireplaces. EPA estimates that 40 percent of an annual 22 million tons of man-made VOCs come from transportation in the United States. Vegetation emits VOCs, as well. In fact, during the growing season, natural VOC emissions may be as high or higher than anthropogenic VOC emissions (NAPAP, Thomson). Because of this and reactivity of NOx mentioned above, ozone mitigation may need to focus on controlling anthropogenic NOx emissions.

McLaughlin (1985) reports that SO_2 emissions increased 110 percent in the southeastern U. S. between 1950 and 1970, and 40 percent in the northeast. As of the mid-1980s, northeast SO_2 emissions were leveling off, but southeastern emissions had almost doubled it emissions since the early 1950s. Thomson (1993) reports that while the new mobile vehicle emission standards will cause a decrease in mobile emissions, utility and industrial NOx emissions are projected to increase more than the mobile decrease.

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Table____: Top 10 SO_2 and NO_x producing states in 1984 (million tons)

SO_2		NO_x	
Ohio	2.58	Texas	3.25
Indiana	1.67	California	1.17
Pennsylvania	1.60	Ohio	1.14
Illinois	1.38	Illinois	0.99
Texas	1.24	Pennsylvania	0.92
Missouri	1.18	Indiana	0.83
West Virginia	1.02	Florida	0.70
Florida	0.99	Michigan	0.69
Georgia	0.93	Louisiana	0.68
Tennessee	0.92	New York	0.62

(EPA 1986)

Seasonal distribution of emissions is important, also. While nationwide annual SO_2 emissions have decreased slightly in recent years, summertime emissions have "continued to rise markedly" (McLaughlin 1985). Summertime rainfall has not gotten less acidic in the northeastern U. S.

Program activities

Roles and responsibilities

The NPS Air Quality Division (AQD) developed an Air Resource Management Manual in 1984 and updated this in the NPS-77: Natural Resource Management Guidelines (Chapter 2) in 1991. Roles and responsibilities of Department of Interior, AQD, and regional personnel are delineated in these documents. This section will describe park personnel's responsibilities only.

NPS-77 summarizes the park's role and responsibilities as follows:

- Identify AQRVs and threats in the park's Resource Management Plan (including objectives, project statements, and funding requests).
- Submit to the AQD any air quality permits.
- Be aware of and comply with all federal, state, and local air quality regulations that affect park operations and facilities.

- Participate in air quality data acquisition (including operation, maintenance, and monitoring).

- Consult with AQD: issue health warnings or alerts to visitors when pollution levels are expected to exceed levels hazardous to human health. Also notify the regional safety officer.

- Be aware of proposed industry or energy resource development that may affect the park. Participate in scoping processes and get help from AQD when necessary.

- Participate in public hearings and meetings having to do with protecting air quality in parks.

- Cooperate with others in air quality monitoring or research.

- Ensure that interpretive material and media have been reviewed by NPS technical and policy experts.

Air quality management is a Natural Resources and Science (NR&S) Division responsibility in Shenandoah NP. The air quality program manager and monitoring specialist work under the supervisory resource manager, who reports to the chief of the division, who reports directly to the superintendent of the park.

The monitoring specialist maintains all the air quality monitoring equipment and associated data in the park. This includes ozone and sulfur dioxide monitoring, particulate monitoring, precipitation, meteorology and visibility monitoring. Fulfilling special field needs by researchers is also the responsibility of the monitoring specialist. The monitoring specialist interacts with visitors and media personnel who want to see air quality monitoring field operations or evidence of air quality related resource degradation. Technical aspects of the park's education-information efforts, such as designing signs or compiling data, are also this person's responsibility.

The program manager supervises the monitoring specialist and coordinates research efforts in the park. The manager is the contact for other air quality managing agencies (states, EPA) and is the primary media contact when air quality issues arise. The manager identifies AQRVs and issues associated with air resource planning, and coordinates efforts with the regional and Washington (WASO and DEN) NPS offices. The air quality manager represents the superintendent in public hearings and meetings.

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Monitoring

Shenandoah NP monitors air quality for several reasons. Monitoring air pollution levels enables air quality managers to identify the baseline levels, and to detect increases or decreases in pollution levels. Monitoring over a long period of time builds a historical record and can be a tool for linking AQRVs and pollution by type, source and amount. Information gained from monitoring enables managers to make informed decisions regarding air pollution and resource issues.

Visibility monitoring is conducted at Shenandoah NP to determine existing levels and types of visibility impairment, the chemical composition of fine particulates in the air that cause that impairment, and to identify sources of those chemical constituents. Monitoring at Shenandoah NP include a 35 mm camera for view monitoring, a transmissometer for atmospheric extinction, an IMPROVE fine particle sampler to measure and analyze fine particles that cause visibility impairment.

Criteria pollutant monitoring refers to monitoring for pollutants for which the EPA has established NAAQS. Currently, Shenandoah NP is monitoring for ozone, sulfur dioxide (until January 1993), and particulate matter. The gaseous pollutants are measured on a continuous basis to provide hourly concentration values. Ozone and sulfur dioxide are monitored because they have been shown to be phytotoxic to vegetation at levels at or below the NAAQS. Partially because of this, monitoring at Shenandoah NP has concentrated on establishing baseline levels for these pollutants. Criteria monitoring at Shenandoah is in compliance with Federal regulations promulgated by EPA which require strict adherence to quality assurance and quality control requirements.

In order to assist in the analysis of pollutant data measured at Shenandoah NP, meteorological measurements are obtained using a 10-meter tower. Measurements are made for the following parameters: wind speed, wind direction, temperature, relative humidity, solar radiation, and precipitation. The output of these sensors is wired to the dame data logger used for ozone and sulfur dioxide monitoring. Information from the meteorological monitoring can also be used for fire weather work.

The AQD is responsible for protecting 48 class I parks in the country, but has adequate funding to monitor air quality in only about 30. Rather than monitor all of the 48 areas poorly, AQD decided to gather intensive, baseline information on a few parks, then reduce efforts to monitoring trends only. Intensive monitoring could then be moved to another park. Air quality has been monitored at Shenandoah NP since 1983, and enough data has been collected to establish baseline information for the park.

Future plans for monitoring at the park include withdrawing gaseous pollutant monitoring at Dickey Ridge (north), Sawmill Run (south), and Big Meadows (central) during fiscal year 1994. The Big Meadows site will retain the National Dry Deposition Network (now CASTNET) site, which monitors ozone levels as well as dry deposition. Available funding will determine whether the transmissometer and the IMPROVE particulate sampler remain at Big Meadows. The park inventory and monitoring program will continue to monitor meteorology at all 3 sites.

Management Actions

New air pollution sources continue to be proposed around Shenandoah NP. As long as air quality related resources in the park are experiencing adverse impacts from air pollution, added pollution from new sources will exacerbate those impacts. Staff at the park and AQD will continue to examine air pollution permits and their effects on park resources on a case-by-case basis. Best Available Control Technology and emissions reductions to offset new increases will continue to be important components of each permit review. Every effort to come to agreement on permit negotiation will be tried; but if no agreement can be reached to alleviate added impacts, permits will be appealed.

Section 169A of the CAA addresses visibility. NPS-77 explains NPS responsibilities:

> "The FLM is also charged with notifying states (or EPA, if the affected state has not adopted a visibility protection SIP) if there is existing visibility impairment in any class I area and identifying the suspected source(s) of the impairment, if possible. This notification of 'existing impairment,' which can be made at any time, triggers certain additional requirements. First, the state (or EPA) must determine if the impairment is reasonably attributable to a specific source or small group of sources....If it is determined that the source at least contributes to visibility impairment, then the state (or EPA) must assess whether further emission reductions at the source would perceptibly improve visibility. If a perceptible change would result, then the state (or EPA) must determine the best available retrofit technology (BART)." (NPS-77, Ch. 2, pp. 182-183.)

Back trajectory modeling done for Shenandoah NP suggest that pollution comes from sources in the Ohio River Valley and sources in the southeast. Visibility degradation in the park has already been established. The next step as prescribed in the above paragraph is to petition those states (and EPA) to determine BART for sources in those areas.

NPS-77 also delineates what the NPS should do if the above option is not possible:

> "In cases where existing visibility impairment in a class I area cannot be reasonably attributed to a specific source or small group of sources, the NPS will encourage states (or EPA) to develop more comprehensive, long-term strategies to minimize regional visibility impacts (p. 183).

Staff at Shenandoah NP are working on this option on several fronts. A new Memorandum of Understanding covering air pollution permit review in Virginia was signed on March 31, 1993. This agreement specifies what the park and the VDAPC will do in each type of permit review. Communication and responsibilities are made clear and permit review facilitated.

The VDAPC is in the process of revising its State Implementation Plan (SIP). As each regulation change is proposed, Shenandoah NP and AQD staff prepare comments focused on protecting and remedying air quality problems in the park and surrounding areas.

Every opportunity to encourage cleaner air is pursued. Even in the 1990 Federal Register notice, the NPS recommended that the VDAPC develop statewide emissions control strategy to protect AQRVs in the park. Strategies suggested were implementing an offset program with greater than 1:1 offsets, and setting statewide emission caps "to reflect a level of allowable pollution that will provide long-term protection for critical natural resources throughout the Commonwealth of Virginia" (55 FR 38403).

Because of the northern Virginia nonattainment area, Virginia is a part of the northeast Ozone Transport Commission (OTC). The OTC is a group of states in the northeast planning together to reduce air pollution in their region. Another group, the Southern Appalachian Mountain Initiative (SAMI), has recently developed in the southeastern states, and Virginia is also part of that group. The air quality manager from Shenandoah NP is participating in the SAMI group. It is hoped that both these interstate groups can cooperate to reduce pollution on a regionwide basis.

Reducing energy consumption is another way to reduce pollution.

From 1975 to 1987 national per capita energy consumption dropped 5.1 percent. Virginia increased its per capita consumption of energy 10.5 percent (Air/Energy '92). Using more energy efficient technology could eliminate 93 percent of the forecasted growth in energy demand for the 1990-2010 period (Air/Energy '92). Saving energy does not mean "roughing it;" using compact fluorescent lamps instead of the traditional incandescent bulbs can save electricity that can make a cumulative savings. Dr. Arthur Rosenfeld and Dr. Evan Mills of Lawrence Berkeley Laboratory in California estimate that 40 nuclear reactors in eastern Europe could be closed down completely by exchanging 600 million light bulbs for compact fluorescent (Acid News 1992). Nor is saving energy accomplished at a cost of jobs. Richard Morgan (Manager of the Utility Regulatory Program in the Acid Rain Division of EPA) cited a study showing an aggressive conservation program in Virginia could add about 3500 jobs to the state's employment pool (Air/Energy '92).

NPS policy (1988) directs minimization of energy use, as well. The same policy directs the NPS to educate and interpret wise energy use for employees and visitors alike (Management Policies). Implementation of energy conservation measures within the park, such as using alternative-fueled vehicles and the use of compact fluorescent bulbs, will be encouraged as soon as they can be practically accomplished. Interpretive staff will be encouraged to inform visitors of the value of energy conservation to resources in the park, as well as other conservation measures. The air quality program manager and the monitoring specialist will assist with any air quality information efforts to the public and employees alike.

Proposed Research and Monitoring Projects

Class I area managers need to continue to refine their knowledge of effects on AQRVs due to air pollution and their ability to predict these effects with varying levels of pollution. The following is a list of needed research projects for Shenandoah NP (updated February 18, 1993).

Ozone Effects and Monitoring

Take over operation of the two ozone monitoring stations to be phased out under the AQD's "trends network" plan (Dickey Ridge, Sawmill Run).

Continue development of an "expert system" to allow us to train and check field researchers on "scoring" ozone injury to leaves. This project would include the addition of digital images (and associated CD capability) and video compression software. We could also add some indicator species to the system that are representative of Shenandoah NP.

Develop/test/refine different intensities of ozone-injury surveys for indicator plant species.

Perform physiological measurements in situ on sensitive tree species.

Effects of Nitrate and Sulfate Deposition

Perform an analysis of the wet, dry, and cloudwater data sets for the park to estimate total loading of nitrate, sulfate, and ammonium. Determine the best method for estimating dry deposition and perform these measurements at more than one site in the park.

Measure sulfur isotope ratios in wet deposition to determine sources of wet inputs, and use this technique in selected watersheds to trace sulfur species through the watersheds and into surface waters.

Measure the amount and chemistry of specific storm events to link them to the severity of episodic acidification in sensitive streams.

Develop and apply models of episodic acidification for different types of stream waters in the park.

Investigate the effect of nitrogen inputs on soil and water chemistry and on possible changes in plant species community composition; determine the contribution of other sources of N to total watershed loading (e.g. gypsy moth).

Develop precise geologic maps to estimate the total number of sensitive stream reaches in the park.

Calculate "f-factor," describing how surface water chemistry responds to acid deposition. This is dependent on mineral weathering, soil percolation, and soil base saturation. "F-factor" could be used to determine adverse impact of added deposition.

Perform an amphibian survey and dose-response experiments to determine the impact of temporary pond acidification on these species.

Visibility

Develop an expert system to teach visitors about aspects of visibility, and produce a data base on visitor opinions on visibility.

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