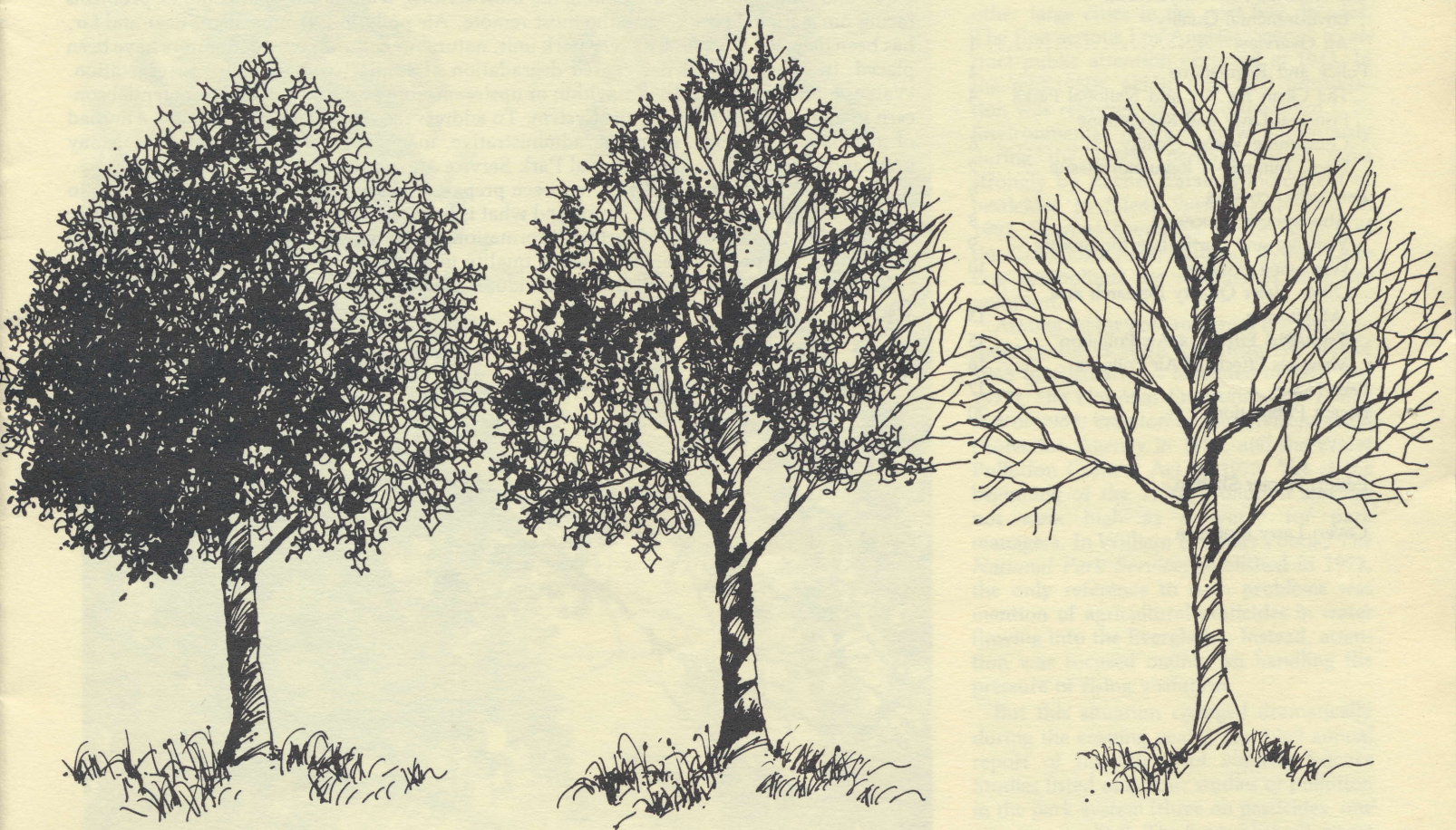


# POLLUTION IN PARKS



Natural Resources Programs  
National Park Service

# POLLUTION IN PARKS

JUNE, 1986

*A report on National Park  
Service activities to maintain  
environmental quality in the  
National Park System*

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## About This Report

Air and water pollution are among the most serious, widespread, and complex problems facing our national parks, even the most remote. Air pollution, from sources near and far, has been detected in virtually every park unit, natural or cultural, where monitors have been placed. In many areas it has caused degradation of scenic views or injury to vegetation. Water pollution due to activities within or upstream from parks is an actual or potential concern in more than 160 units of the System. To address these problems we are using a myriad of available tools: legal, scientific, administrative, managerial, and communicative. Many units and individuals in the National Park Service are involved.

This report, *Pollution in Parks*, has been prepared by the Office of Natural Resources to provide an overview of the problems and what is being done about them, an update on current activities, and sources of further information. We hope such a review will be useful to everyone concerned with environmental quality in our national parks.

My sincere thanks go to all those individuals who contributed to this report.

Richard Briceland  
Associate Director, Natural Resources

# THE NATIONAL PARK SERVICE AND ENVIRONMENTAL QUALITY—AN OVERVIEW



An ozone-injured Jeffrey pine in Sequoia/Kings Canyon NPs contrasts with a healthy, ozone-tolerant specimen in the background.

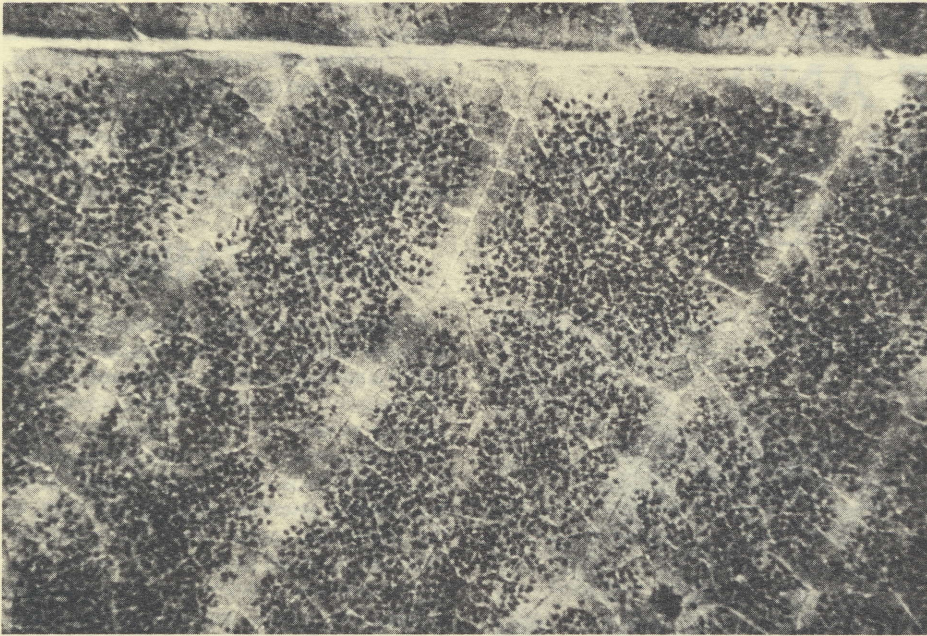
The following preamble to this report briefly describes the ways the National Park Service addresses pollution problems. Subsequent sections discuss current regulations, research activities, situations at specific parks, and other information of interest to those involved with environmental quality in the National Park System.

## A Bit of History

Pollution, as might be expected, became a major concern in the natural national parks later than in more developed parts of the country. Chicago passed a smoke ordinance as early as 1881, to be followed by other large cities in the next few decades. The first serious Los Angeles "smog" to attract public attention occurred in 1943. In the mid-1950s, acidic (low pH) precipitation was reported in the northeastern U.S. Environmental concern grew enormously during the 1960s, perhaps stirred most strongly by Rachel Carson's indictment of pesticides in *Silent Spring*, published in 1962. Burning chemicals on the surface of the Cuyahoga River, and a "dying" Lake Erie symbolized the seriousness of water pollution.

Among major governmental responses to these problems were the Clean Air Act of 1963 (particularly as amended in 1970 and 1977), the National Environmental Policy Act of 1969, creation of the Environmental Protection Agency in 1970, and the Water Pollution Control Act of 1972. Yet at the beginning of the 1970s, pollution still did not rank high as a worry for park managers. In William Everhart's book, *The National Park Service*, published in 1972, the only reference to such problems was mention of agricultural pesticides in water flowing into the Everglades. Instead, attention was focused mainly on handling the pressure of rising visitation.

But this situation changed dramatically during the ensuing years. The 1969 annual report of the Office of Natural Science Studies listed only four studies of pollution in the park system (three on pesticides, one on water quality). The (unpublished) report for 1977, by contrast, listed 48 (28 on water quality, 14 on air quality, 3 on pesticides, and 3 on radiation). This Systemwide annual report was discontinued the following year, but some regions produce such a listing. In 1984, in just three of the ten regions—Mid-Atlantic, Midwest, and Pacific Northwest—a total of 93 projects dealing with environmental quality were listed (64 on air quality, 26 on water quality, 1 on pesticides, 1 on "ecotoxicity," and 1 on toxic waste). Among the ten threatened resources reported most frequently in *State of the Parks, 1980*, air quality ranked second (140 parks) and fresh water quality ranked fifth (130 parks). Air pollution injury to vegetation, acidification of lakes and streams from acid precipitation, and visibility impairment have become widespread concerns in the national parks.



Black spots on this close-up of a common milkweed leaf indicate ozone injury. Milkweed plots have been established in many national parks to monitor ozone effects.

Waste from outside sources poses a threat to surface and ground water quality in many park units. Deterioration of cultural resources from exposure to air pollution is a long-standing, but only recently publicized, problem in many urban parks and even some rural areas.

## Organizational Responsibilities

The National Park Service deals with pollution at the national, regional, and park levels. The principal national offices involved are the Air Quality Division, the Water Resources Division, the Preservation Assistance Division (Cultural Resources), and the Engineering and Safety Services Division (Maintenance). At the regional level, air quality and water resources coordinators provide liaison between the national offices and field units. Regional Chief Scientists administer some of the monitoring of air and water quality conducted in specific parks. A few parks, such as Great Smoky Mountains, Sequoia-Kings Canyon, and Olympic, have staff scientists engaged in research on environmental quality, but most such research is conducted through contracts, by Air Quality and Water Resources personnel, or by institutions not funded by NPS. Park staff members carry out most of the ongoing meteorological and pollutant monitoring.

Mitigating pollution problems that arise within parks is primarily the responsibility of park managers and maintenance staffs, with assistance from the regional or national office if necessary. Addressing problems that originate outside parks often re-

quires cooperation among all levels of the Park Service and relevant Federal, State, and local agencies.

## Air Quality Division

An Air and Water Quality Division was created in the Washington office in 1978 and later was split into two divisions. The Air Quality Division has a professional staff of eighteen people, most of whom are in Denver, with small units in Fort Collins, Colorado, and Washington, D.C. It administers four major technical programs:

1) The Division has been monitoring air quality and visibility in units of the National Park System since 1978. The present monitoring program involves sulfur dioxide monitors at 11 parks, ozone monitors at 19 parks, total suspended particulate monitors at 16 parks, nitrogen dioxide monitors at two parks, a hydrogen sulfide monitor at one park, fine particulate monitors for visibility at 30 parks, teleradiometers for visibility at 29 parks, and cameras for visibility at 36 parks. In FY 1986, air quality monitoring, including visibility, fine particulate matter, gaseous pollutants, and meteorological monitoring, will be initiated in nine additional parks.

2) In 1982, the Air Quality Division launched a major Biological Effects Program to study the effects of air pollution on vegetation. The program includes air pollution effects surveys, sensitivity screenings, trace element surveys, and ecological surveys, with activities in FY 86 in over 60 parks. Pollutant fumigation studies have also been performed to determine levels at which various species are sensitive to air pollutants. Injury to vegetation, especially from ozone and sulfur dioxide, has been documented in almost 40 parks. Lichens,

which are especially sensitive to air pollution, have completely disappeared from parts of some parks. Fumigation studies on quaking aspen genotypes from polluted and non-polluted regions indicate that sensitive genotypes in the more polluted regions are disappearing.

3) Since 1979, the Division has been reviewing permit applications for proposed new facilities that might affect class I parks, which, under the Clean Air Act definition, includes most national parks over 6,000 acres in size and most wilderness areas over 5000 acres, except for the new areas in Alaska. The state in which the proposed project would be located makes the final decision on the permit application, which may be denied if the NPS demonstrates that an adverse impact on park resources would occur. The Division has reviewed permit applications for more than 100 proposed projects. Under a Memorandum of Understanding (MOU) with the Fish and Wildlife Service (FWS), the Division also reviews permit applications affecting FWS areas. To date, 34 applications have been reviewed under this MOU.

4) Also since 1979, the Air Quality Division has been applying and developing various mathematical models for tracing and predicting the movement and concentration levels of air pollution. Because sulfates are especially important contributors to visibility impairment, and are an important component of acid deposition, the Division has developed both diagnostic and prognostic long-range transport models to estimate sulfur dioxide and sulfate concentrations. To date the models have been successfully applied to much of the eastern United States, including Shenandoah, Acadia, Great Smoky Mountains, and Mammoth Cave national parks. Because of the observed effects of ozone on natural vegetation, similar model development is underway to identify source regions that contribute to ozone levels in park units.

The Division also integrates air resources management into Service operations and planning, develops interpretive materials for park use, and participates with Federal, State, and local agencies in developing regulatory programs.

## Water Resources Division

The Water Resources Division, with 21 professionals, many of whom deal with water quality, has three units in Fort Collins, Colorado, one in Denver, and one staff member in Washington, D.C. Of the five principal issues the Division deals with, two involve water quality: identification and mitigation of external and internal influences on park water quality and quantity; and location of potable water supplies.

About half of the Division's projects are concerned entirely or partly with water quality. Much of the work is assessing water quality or setting up long-term

monitoring programs. Water quality is a constant concern in the park system, especially as it is affected by external influences. Inadequate waste water treatment by municipalities and industrial plants, acid mine drainage, and toxic waste are some of the major causes of water pollution in parks. A large study of irrigation drainage, sparked by selenium damage in a national wildlife refuge in California, has been launched by the Department of the Interior. Such toxic drainage may be affecting units of the National Park System as well.

## Acid Deposition Research

NPS research on acidic deposition is administered by the Office of Natural Resources and the Preservation Assistance Division in Washington, D.C. It is conducted as part of the National Acid Precipitation Assessment Program (NAPAP), a 10-year, federally sponsored program to study causes and effects of acid deposition and to recommend actions to be taken. The NPS is one of 12 Federal agencies and four National Laboratories in the program. National Park Service personnel at the national, regional, and park levels are involved. Park Service work has focused on deposition monitoring and integrated watershed studies. The Service, in cooperation with the U.S. Geological Survey, Bureau of Land Management, National Oceanic and Atmospheric Administration, and state agencies, is conducting long-term monitoring of the chemistry of wet atmospheric deposition at 32 park sites, part of the 150 sites currently in the National Atmospheric Deposition Program/National Trends Network. Integrated watershed research is underway in five parks—Isle Royale, Rocky Mountain, Sequoia-Kings Canyon, Olympic, and Shenandoah—to learn how atmospheric deposition affects ecosystems.

Effects of acidic deposition on cultural resources of the National Park System are being investigated, also under NAPAP, by the Preservation Assistance Division in Washington. Deterioration of historic materials, particularly marble, limestone, and statuary bronze, is being studied through laboratory research, *in situ* monitoring of cultural resources in parks, and controlled field exposures at several sites selected to represent the range of potentially impacted environments.

Ray Herrmann of the Water Resources Division summarized the situation as follows: "In reference to parks, we can say: 1) Parks are receiving acidic deposition with loadings highest in the east and southeast; 2) there is a potential for irreversible damage to sensitive cultural and natural resources in parks across the country; 3) these effects could be potentially catastrophic for high elevation lake and stream systems, particularly those with salmonid (trout) populations, high elevation boreal forests, and sensitive cultural



A biomonitoring garden, Voyageurs NP. The garden is part of the Minnesota Environmental Board Plot System, which includes biomonitoring gardens throughout the state. Each garden consists of several species of native and crop plants. Biomonitoring studies are used to detect the first signs of air pollution effects on biological resources. Individuals in the photo are harvesting plants for dry weight and trace elements analyses. The NPS has established biomonitoring plots in several NPS units.

resources; and 4) the NPS through its strong tie to the interagency research program will get the needed answers over time." (*Park Science*, Winter 1986).

## Engineering and Safety Services Division

Control of environmental pollution originating within parks is generally the responsibility of park maintenance staffs, which manage sewage treatment facilities, solid waste disposal, use of herbicides and pesticides, and other potential sources of pollution. The NPS record in meeting requirements of Federal, State, and local laws on environmental quality is excellent, but it can be argued that standards within parks, which are intended to be maintained in near-pristine condition, should be set even higher than those of the surrounding jurisdictions.

The Branch of Maintenance in the Washington office, a unit of the Engineering and Safety Services Division, has responsibility for Systemwide policy, budgets, guidelines, and planning for maintenance. It is currently conducting an inventory of waste chemicals in parks and investigation of methods for their disposal. It is also responsible for dealing with external hazardous waste situations that affect parks and come under the Resource Conservation and Recovery Act (RCRA—waste from present operations) or the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA/Superfund—inactive hazardous waste sites). Some currently identified problems include drums of toxic chemicals that wash

ashore at Padre Island, impacts on Gateway National Recreation Area of toxic wastes from two New York City landfills, and radioactive wastes at a lake near the Appalachian Trail at Paulding, New York.

## The Role of Non-NPS Institutions

At some parks, much of the funding for research on pollution problems is provided by non-NPS sources, which find the parks useful sites for answering their research questions. A March 1985 register of completed or ongoing research projects on environmental quality of Great Smoky Mountains National Park listed 103 projects. Of the 77 for which the funding source was recorded, 41 were funded wholly or in part by non-NPS institutions. In terms of total funding amounts, the non-NPS proportion was even larger. Of the 42 acid deposition/ecosystem studies underway in March 1986 in Sequoia National Park, 37 were sponsored wholly or in part by other institutions.

## The Outlook

NPS resources devoted to improvement of environmental quality in the parks have been increasing over the past few years. Whether these resources are adequate or whether this trend will continue in the face of general budget cutbacks is uncertain. The problems, however, are likely to be with us for a long time.



Head of a bronze statue, "The Hiker," honoring soldiers of the Spanish-American War. One of 50 such statues in the U.S., this one, erected in Allentown, PA, in 1937, has suffered pitting on the face and streaking on the hat due to air pollution.

## POLICY AND REGULATIONS

### The Clean Air Act and National Parks

The Clean Air Act, 42 U.S.C. §§7401, *et. seq.*, augments the fundamental resource protection responsibilities of the National Park Service Organic Act with respect to the air quality and related values of park areas. Together, these authorities form the basis for the National Park Service's general policy of promoting and pursuing measures to safeguard the resources and values of units of the National Park System from the adverse impacts of air pollution.

The goal of the Clean Air Act (Act) is safe and acceptable ambient air quality through the attainment and maintenance of national ambient air quality standards. The "primary" standards are to protect the public health "with an adequate margin of safety," and the "secondary" standards are to protect the national "welfare"—defined to include the types of resources and values found in park areas—from all "known or anticipated adverse effects." These primary and secondary standards are air pollutant concentration levels set on the basis of scientific "criteria documents." The Environmental Protection Agency (EPA) has set national ambient air quality standards for six widespread pollutants: sulfur dioxide, particulate matter, carbon monoxide, ozone, nitrogen dioxide, and lead. State

and local governments may set additional, and more stringent, standards.

At any time, a particular area may be "cleaner" or "dirtier" than the standards for these pollutants. The Act supplements its nationwide goal of attaining and maintaining these standards with specific goals for these "clean" and "dirty" areas. For the clean areas of the country, the Act seeks to "prevent the significant deterioration" (PSD) of the air quality, particularly in areas of special natural, recreational, scenic, or historic value. For the "dirty" or "nonattainment" areas of the country, the Act demands that "reasonable further progress" be made toward the attainment and maintenance of the primary and secondary standards.

In pursuit of these standards as well as the PSD and nonattainment goals, the Act imposes various performance and emission restrictions on individual sources. The Act uses the State Implementation Plan process as the means to implement and enforce its goals and source restrictions.

The PSD title of the Act deserves particular discussion as a prime authority for protecting the resources of parks. In certain respects, Part C is a resource protection

statute. One of its purposes is "to preserve, protect, and enhance the air quality in national parks, national wilderness areas, national monuments, national seashores, and other areas of special national or regional natural, recreational, scenic, or historic value." PSD addresses resource protection through the establishment of ceilings on additional amounts of air pollution over baseline levels in clean air areas, the protection of the air quality related values of certain special areas, and additional protection for the visibility value of certain special areas.

More specifically, Part C reflects Congress' judgment that, among the clean air regions of the country, certain areas—the "class I" areas—deserve the highest level of air quality protection under the Act. Congress designated 158 areas as class I areas, including national parks over 6,000 acres and national wilderness areas over 5,000 acres, in existence on August 7, 1977.

In these class I areas, once "baseline" is triggered by submission of the first permit application from a major new source, Part C allows only the smallest "increment" of certain pollutants—to date, only sulfur dioxide and particulate matter—to be add-

ed to the air. In addition to these increment ceilings, PSD also establishes a site-specific resource test, known as the "adverse impact" test, to determine whether emissions from major new sources will cause an "adverse impact" on the "air quality related values" of the class I area. In the case of a major new source (or expansion), the adverse impact test works as follows:

- If the Federal Land Manager determines, and convinces the permitting authority, that the new source will adversely impact the class I area's resources—even though the new source's emissions will not contribute to an increment violation—a "PSD permit" shall not be issued.
- If the Federal Land Manager certifies that the new source will not adversely impact the class I area's resources—even though the new source's emissions will contribute to an increment violation—the permitting authority may issue a "PSD permit."

The adverse impact test imposes an "affirmative responsibility" on the Federal Land Manager "to protect the air quality related issues (including visibility)" of class I areas, and, as the Senate committee wrote, "[i]n the case of doubt, . . . [to] err on the side of protecting the air quality related values for future generations." "Air quality related values" include all values of an area dependent upon and affected by air quality, such as scenic, cultural, biological, and recreational resources, as well as visibility itself. The current working definition of "adverse impact" is any impact that:

- Diminishes the area's national significance, and/or
- Impairs the structure and functioning of ecosystems, and/or
- Impairs the quality of the visitor experience.

In addition to increment ceilings and the adverse impact test, Congress enacted one more resource protection measure for class I areas, namely, "visibility protection" for the 156 (of 158) statutory class I areas where visibility is an "important value." In Part C of the Act, "Congress . . . declares as a national goal 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." In this provision, Congress expressed the national desire to preserve, for its own sake, the ability to see long distances, entire panoramas, and specific features in the statutory class I areas. EPA is still developing the regulatory program to assure "reasonable progress" toward the national visibility goal. EPA has already issued regulations concerning new source review and visibility monitoring requirements, and is now working on regulations concerning "best available retrofit technology" for major existing sources that impair visibility in statutory class I areas as well as "long-term (10-15 year) strategies" for moving toward the national visibility goal. To date, EPA's rulemaking proposals have addressed only "plume blight" and

other visibility impairment "reasonably attributable" to a specific source or sources. EPA has not yet proposed regulations to address visibility impairment from "regional haze."

As the above discussion demonstrates, the Act creates several opportunities and tools for protecting the resources and values of class I areas. New pollution after baseline in class I areas is generally limited to the small class I increment, the Federal Land Manager must determine whether major new sources will adversely impact the areas, and measures must be developed to protect the visibility of class I areas from manmade pollution impairment. The States must develop their PSD plans with Federal Land Manager consultation and a public hearing. Major new sources must undergo an equally public permit review, involving air quality monitoring; analysis of resource impacts; application of "best available control technology;" and effective emission ceilings based on the class I increment, national ambient standards, adverse impacts threshold, or possibly visibility impairment threshold, whichever is the lowest. Existing sources may be regulated to protect visibility or to remedy a violation of an increment, national ambient standard, or arguably class I resource protection.

Part C's concern for resource protection, however, is not limited to class I areas. Congress designated all other clean air regions of the country "class II." Congress further prohibited redesignation not only of statutory class I areas to any other classification, but also of certain class II areas to the "dirtier" class III classification. These so-called class II "floor" areas include the following areas when greater than ten thousand acres: national monuments, national primitive areas, national preserves, national recreation areas, national wild and scenic rivers, national wildlife refuges, national lakeshores and seashores; as well as national parks and wilderness areas established since August 7, 1977. Class II increment ceilings on additional pollution over baseline concentrations allow for moderate development in class II areas. Class II increments constitute an absolute ceiling on additional pollution in these areas, because Congress did not qualify the class II increment with an adverse impact test.

Although the Act does not create as many resource protection tools for class II areas as for class I areas, it nevertheless creates opportunities. The Federal Land Manager can participate in State Implementation Plan proceedings, new source reviews, and other federal, State, and local activities that potentially affect the air quality of their areas. As appropriate, the land manager can undertake or encourage efforts to redesignate the area to class I. Also, for units of the National Park System, the land manager can turn to the Organic Act for protection of park purposes and values from adverse air pollution impacts.

At this time, there are no "class III" areas. States or Indian governing bodies have the authority to redesignate to class III any clean air area except a statutory class I or class II "floor" area. Class III designation could allow for substantial air pollution increases over baseline in the area. The redesignation process itself, as well as subsequent new source reviews, provide opportunities for land managers to have their air quality concerns considered.

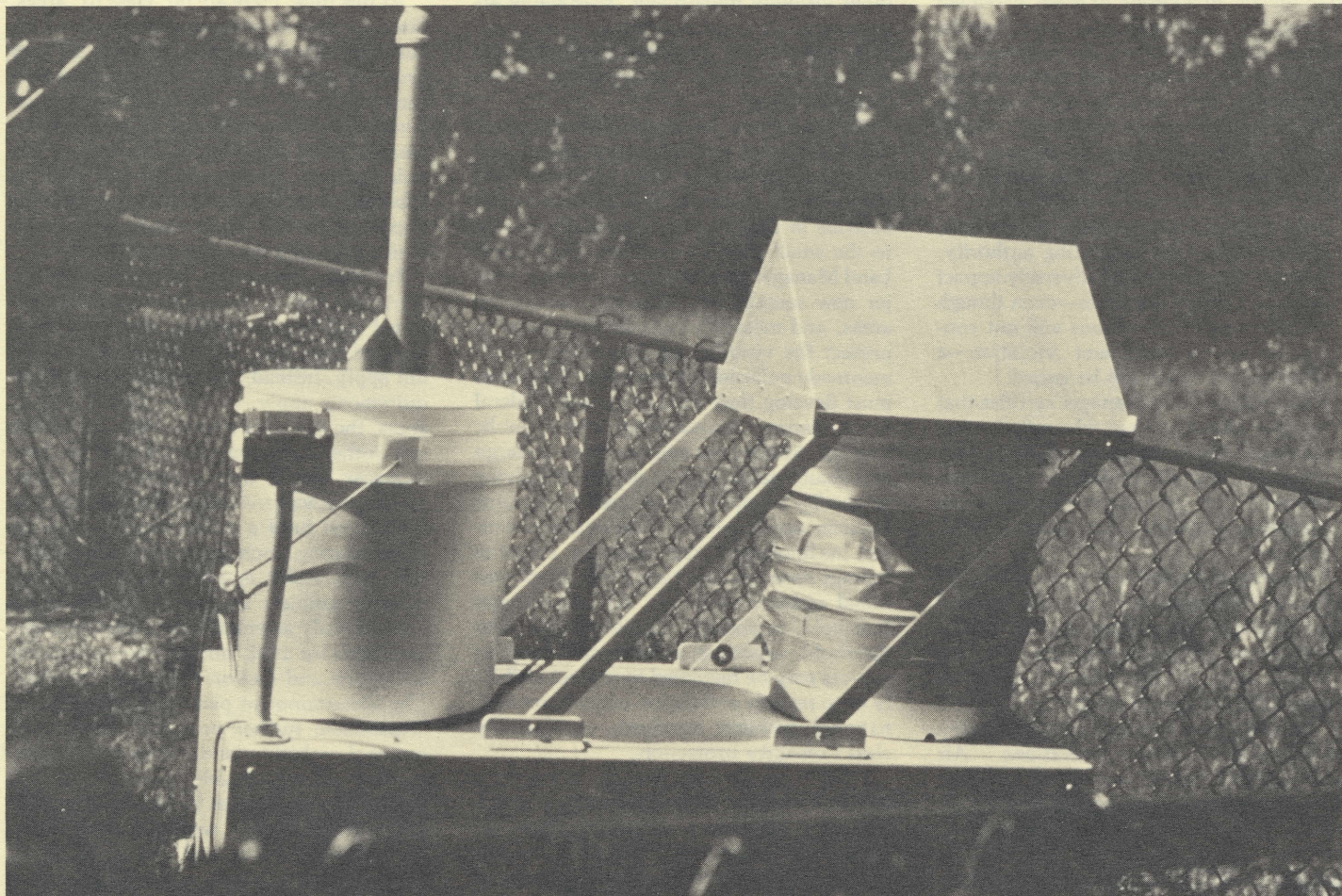
For parks that are in, or affected by, the "dirty regions" of the country where the national ambient air quality standards have not yet been met, the PSD provisions do not apply. Instead, the "nonattainment" requirements apply. As with class II and III areas, the Act does not establish an explicit role (other than consultation) for the land manager, but it does require public proceedings at various times. For example, the State must hold a public hearing prior to promulgating a nonattainment implementation plan, which is a plan for attaining all national ambient air quality standards "as expeditiously as practicable," most primary standards by 1982, and primary standards for ozone and carbon monoxide by 1987. The nonattainment plan must demonstrate "reasonable further progress" toward the national ambient standards in the interim; provide for reasonable available control technology on sources in the area; analyze effects on air quality, welfare, health, society, and economics; and require a public hearing prior to issuing a permit for a new source. To obtain a permit, new sources in urban areas must secure from other facilities "emission offsets" greater than the new source's proposed emissions; in addition, a new source's control technology must comply with the "lowest achievable emission rate" for such a source.

As a final word about the Clean Air Act, the above discussion suggests many provisions that, directly or indirectly, can address many air quality concerns in parks. However, the Act—at least as currently interpreted or implemented—does not address all such resource protection concerns. For example, the Act often does not deal effectively with the following concerns:

- The individual and cumulative air quality impacts of sources not subject to PSD permit requirements, such as "minor" sources, sources located in nonattainment areas, existing sources, and sources located in foreign countries;
- Regional loadings of air pollutants; and
- Long-range transport of air pollutants.

Despite these problems, the Act provides several effective approaches to park resource protection. Essential to making the existing statutory authority work for the protection of the resources, however, is the gathering and development of the relevant scientific and technical information on which the legal system depends.

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An NADP deposition monitor, Glacier NP. The "wet bucket" (with cover) is automatically uncovered when precipitation moistens a sensor.

## Principal Laws and Regulations Concerning Water Quality

### Clean Water Act

(Federal Water Pollution Control Act of 1972 and 1977 Amendments)

The Clean Water Act, one of the first major pieces of comprehensive environmental legislation, established a complete regulatory system for the protection of water quality in the United States. Unlike many earlier responses to environmental problems, the Clean Water Act is equally applicable to activities on both federal and private lands.

The Act has general goals to protect health, to enhance the quality of water and to provide water quality for the protection and propagation of fish, shellfish, and wildlife in and on the water and for agricultural, industrial, and recreational purposes. To meet these goals, the Congress established a system for limiting the discharge of pollutants into the waters of the United States through "effluent limitations;" that is, by limiting the amount or concentration of specified pollutants that may be discharged. The following outlines the major parts of the regulatory system:

**Section 208—Non-Point Source Pollution.** This section of the Act, in its requirements for looking at area-wide waste treatment strategies, requires that states identify non-point sources (sources not in a single, specific location) of pollution (such as silvicultural practices or agricultural erosion) and propose methods for controlling such pollution.

**Sections 301 and 306—Effluent Limitations.** These sections prohibit the discharge of pollutants without a permit and provide for effluent guidelines by industrial category. There are two different performance standards—"best control technology currently available" and "best available control technology economically achievable"—which must be met by point source dischargers.

**Section 303—Water Quality Standards.** These are rules set by the states for the use or uses to be made of a water body or segment and the water quality criteria necessary to protect that use or uses. Standards are enforceable and are developed through a process that takes into account social, legal, economic, and institutional

considerations. They serve to establish water quality goals for specific water bodies and serve as the basis for water quality-based treatment controls.

**Section 402—National Pollution Discharge Elimination System.** This permit system requires that all point source dischargers have permits that specify the effluent limitations and standards that must be met.

**Section 404—Dredge and Fill Permits.** All activities that would result in the filling of wetlands or in dredging of the waters of the United States are subject to permits issued by the Army Corps of Engineers.

**Outstanding National Resource Waters (40 CFR 131.12(a)(3)).** These regulations specifically require that the states' implementation methods and anti-degradation policies must ensure that "where high quality waters constitute an outstanding National resource, such as *waters of National and State parks and wildlife refuges* and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected" (emphasis added). [Units of the National Park

System clearly qualify for consideration for designation under this standard and the National Park Service is pursuing such designations through various state procedures.]

## **Safe Drinking Water Act**

Passed in 1974, the purpose of this act is to safeguard public water systems and to protect groundwater sources of drinking water.

## **Wild and Scenic Rivers Act**

The Wild and Scenic Rivers system was established to preserve free-flowing rivers and their immediate environments for the benefit and enjoyment of present and future generations. The existence of a wild or scenic river does not abrogate any existing rights and privileges but prevents establishing new rights that would affect the river and its environs' suitability for this status.

## **Floodplain and Wetlands Executive Orders**

The two executive orders are designed to ensure that activities undertaken in floodplains or associated with wetlands do not adversely affect public safety or natural resources.

## **Resource Conservation and Recovery Act (RCRA)**

This act provides "cradle to grave" supervision for hazardous wastes. Implementation should prevent resource damage to NPS units that would have resulted without careful supervision of these pollutants.

## **Boundary Waters Treaties**

These agreements require that waters flowing across national boundaries shall not be polluted on either side to the injury of health or property of the other.

## **Adequacy of Protection**

Because the standards provided by the laws and regulations cited are nationwide in applicability and effect, it is difficult to say with any accuracy whether the protection provided is adequate for specific resource protection needs in specific NPS units. It is theoretically possible to require higher standards of performance for activities within NPS units where a clear connection between the existing standards and resource degradation can be demonstrated. The difficulties with this approach are twofold: one, scientific data of the quality necessary to establish an unequivocal nexus between

the activity proposed and resource damage is difficult to come by and two, because of the exceptionally large number of permits issued by the states and EPA, it is difficult to know when permits are being issued. For these reasons, designations of specific national park waters as "outstanding national resource waters" could be important for providing a level of protection commensurate with the resource values contained in National Park System units.

## **Placer Mining— A Regulatory Issue**

One of the major sources of impacts to water quality in units of the National Park System in Alaska, is placer mining for gold. This mining is associated with claims under the 1872 Mining Law that existed prior to establishment of the park units. Contrary to a common perception, Alaska placer mining is a large-scale operation. Because placer mining requires that the gravels of streambeds be physically displaced, the effects to stream biota and water dependent flora and fauna can be both extreme and adverse. Certain operating methods, including the use of sedimentation ponds, limiting the amount of water used in the mining process, and use of portable equipment, can limit the adverse impacts of placer mining.

Presently, the number of placer mines that will be approved for operation this year will be limited because of litigation. The National Park Service is preparing environmental impact statements on the cumulative effects of placer mining in three Alaska units, a necessary first step to settling the lawsuit.

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## **RESEARCH ACTIVITIES**

Many studies in air and water quality are underway. This section presents some of the more important or pressing investigations. Since many of these are part of or relate to the National Acid Precipitation Assessment Program (NAPAP), a description of that program is in order. The program is organized into seven task groups: Emissions and Controls, Atmospheric Chemistry, Atmospheric Transport\*, Atmospheric Deposition and Air Quality\*, Aquatic Effects\*, Terrestrial Effects\*, and Materials Effects\*. The Park Service is importantly involved with five of these (marked with asterisks).

The task groups on Atmospheric Chemistry, Atmospheric Transport, and Atmospheric Deposition and Air Quality seek to provide more credible scientific statements of how a specific source or set of sources contributes to the deposition in a given downwind region. Mathematical models exist to account for gross atmospheric transport, transformation, and deposition. The task groups are working on incorporating more realistic and definitive descriptions of all three processes into more sophisticated models. Empirical studies are underway both to test the models and to learn more about the processes.

The specific goals of the Task Group on Atmospheric Deposition and Air Quality are to 1) determine the spatial and temporal variations in the composition of atmospheric deposition within the U.S. through a nationwide monitoring network; 2) develop and improve methods for reliable measurement of wet and dry deposition; and 3) develop information on the composition of largely pollution-free atmospheric deposition through operation of deposition monitoring and research sites at remote locations throughout the world. The principal source of data in the United States is the National Trends Network (NTN), designed by the Task Group. This network of 150 stations includes many in the National Atmospheric Deposition Program (NADP) network begun by the State Agricultural Experiment Stations in 1978. Thirty-two NADP/NTN stations are located in national parks. No practical method exists for the direct routine measurement of dry deposition, which may be as, or even more, important an environmentally damaging factor than wet deposition. Testing of instruments to measure dry deposition is an important part of the Task Group's current work.

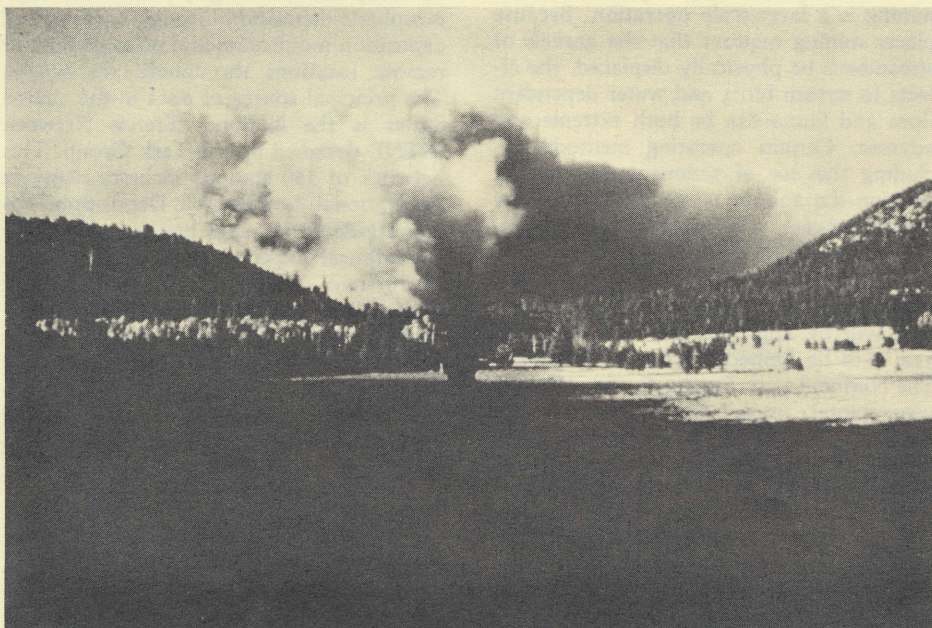
The purpose of the Aquatic Effects Task Group research is to quantify, nationwide, the effects of acid deposition on freshwater resources in the U.S. The two main types of effects emphasized are alterations of water quality and impacts on aquatic organisms. In 1985 the program involved the following: National Surface Water Survey (including sites in several national parks), Direct/Delayed Response Project, Investigation of Biological Processes, Human Health Effects Program, Evaluation of Mitigation Strategies, and Watershed Research. In 1986 the goals will emphasize biologically relevant effects and long- and short-term changes in surface water chemistry.

It has become evident that to understand the potential effects of acid deposition on a lake or stream, chemical processes occurring in the surrounding watershed must be considered. The hydrology, soils, geology, vegetation, and air quality of the watershed all are important determinants of the chemical characteristics of surface waters. Therefore, integrated watershed research involving both the Aquatic Effects and Terrestrial Effects task groups is underway.

Several watersheds in national parks are among those being studied.

Research of the Terrestrial Effects Task Group is directed mainly at the response of vegetation to acid deposition and terrestrial-aquatic linkages. The key questions are: 1) What are the effects of atmospheric deposition on forest structure and function, and how is the response related to soil, biotic, and climatic factors? and 2) How does the terrestrial system alter the deposition chemistry as precipitation flows to ground water, streams, and lakes? The recent decline of certain forest types in the eastern United States adds urgency to these questions. The watershed projects in national parks are among those seeking answers, as is a regional cooperative study in the southern Appalachians, described in the section, Terrestrial Effects of Air Pollution. Also described there are some related findings from the NPS Air Quality Division Biological Effects Program.

The Task Group on Materials Effects seeks to answer five key research questions:



A forest fire in Coconino National Forest, northern Arizona, produces a particulate carbon plume. Smoke from fires—natural or prescribed—causes a visibility problem in some NPS areas as well.

1) What roles do acid deposition and its precursors play in materials degradation relative to other natural and anthropogenic damage agents? 2) What is the rate of damage to specific materials as a function of specific pollutant levels? 3) What is the geographic distribution of susceptible materials? 4) What is the economic value of materials damage? 5) What protection and mitigation strategies are feasible? National Park Service participation in this work is described under Materials Effects of Air Pollution, below.

The NPS representatives on NAPAP task groups are:

Atmospheric Transport: Donald Henderson, Air Quality Division, Denver, Colorado

Atmospheric Deposition and Air Quality: Dr. William Malm, Air Quality Division, Ft. Collins, Colorado

Terrestrial Effects: Dr. Peter White, CPSU, University of Tennessee

Aquatic Effects: Dr. Gary Larson, CPSU, Oregon State University

Materials Effects: Susan Sherwood, Preservation Assistance Division, Washington, D.C.

## Atmospheric Processes

Recent NPS research on atmospheric processes has emphasized development of models of air pollutant transport, and smoke management studies at Grand Canyon.

## Regional Sulfur and Oxidant Modeling

The Air Quality Division has contracted research over the past 6 years to develop and test mathematical models to be used for assessing long distance transport of man-made pollutants. A model (RTM-II) was developed to simulate sulfur dioxide and sulfate concentrations in four national parks (Acadia, Great Smoky Mountains, Mammoth Cave, and Shenandoah). (See *Park Science*, Winter 1985, p. 6-8). A local transport and dispersion model is being applied in Shenandoah National Park. This local model will be coupled with the long-range transport model. By using a combination of the two models, the contribution of

local, as well as far distant, air pollution sources to pollution buildup in the park can be evaluated.

Another version of the long-distance transport model (RTM-III) has been developed for predicting the distribution of photochemical oxidants. Evaluation and testing studies have been made using the Electric Power Research Institute (EPRI) Sulfate Regional Experiment data which were collected at nine stations in the eastern United States.

The model has been applied in a 31-state region of the eastern United States. These results provide ozone concentration estimates for the period July 16-23, 1978. From these results, ozone concentrations have been estimated for this time period in the same four parks to which RTM-II was applied. Ozone concentrations during this brief period are near the one-hour standard of .12 ppm.

An improved version of the model is currently being applied for a smaller area encompassing Shenandoah National Park. For this application a reactive plume model (RPM) is being incorporated into the regional model so the contribution of single sources to the total pollution burden may be assessed. The improved version of the model is being applied to the Central Valley of California to estimate ozone concentrations in Sequoia, Kings Canyon, and Yosemite national parks. The model results from the above applications will be used by the National Park Service to assist with the assessment of observed injury to vegetation, evaluation of acidic deposition, and visibility impairment in the national parks.

The model has received considerable recognition, even outside the United States. It is currently being applied in western Europe, and plans are in progress to apply it in some Canadian provinces. Other Federal agencies have also shown interest in using the model. The Environmental Protection Agency has had the model applied in the central United States to estimate ozone concentrations in agricultural areas. They also have indicated an interest in working with the National Park Service on the above mentioned Central Valley study to estimate ozone concentrations in agricultural areas of the Central Valley.

Donald Henderson  
Air Quality Division  
Denver, Colorado

## Smoke Management

The smoke management studies are being conducted at Grand Canyon NP to advise park managers on the best weather conditions under which to carry out prescribed fires, which in the past have sometimes contributed to reduced visibility in the Canyon, and which could produce smoke drifting into the town of Tusayan on the South Rim. A conceptual model for the mean air motions in the Grand Canyon was developed using existing knowledge of airflow over cavities and abrupt steps, and available wind data. The model was tested with data produced by three wind sensors placed in or near the Canyon and by 39 pilot balloon launches within the Canyon. Some measurements important to understanding the airflow have also been made from aircraft and final recommendations await analysis of these additional data. Preliminary conclusions are that burning should be conducted only during periods when air above and within the Canyon is interacting, not when stable air fills the Canyon. Adverse conditions could be forecast using standard synoptic-scale data plus meteorological information from the Canyon rim and Tonto Plateau. To diminish drift of smoke into the town, most burning should be restricted to periods of southerly airflow and as much as possible to times before sunset.

## Visibility and Particulate Monitoring

The NPS Air Quality Division has been monitoring visibility and particulates that affect visibility at more than 30 park sites. It has also studied the influence of visibility impairment on visitor enjoyment and use of park resources.

Visibility is recorded with both color photography and teleradiometry. The color photography documents the important elements of the scene and how they vary with changing air pollution levels, weather conditions, and sunlight. Teleradiometry uses a special telescope to measure the contrast between the sky in the background and dark landscape features so that changes in contrast caused by pollution or climatic changes can be recorded. Together, the photography and teleradiometry can be used to establish standard visual ranges—the distance from an observer at which a large dark object such as a forested mountain would just disappear against the horizon.

Results to date of visibility monitoring include the following: 1) More than 90 percent of the time, manmade pollution affected scenic views at all NPS monitoring sites. 2) The best average visibility is in northern Nevada, Utah, and southern Idaho. Next best is the Colorado Plateau, where Grand Canyon, Bryce Canyon, and Canyonlands national parks are located. 3)



A ranger removes the air filter from a fine particulate stacked filter at Bandelier NM, one of 30 sites in the NPS visibility monitoring network.

The lowest visibility in the West is in the coastal areas of California and Washington, probably because of natural weather conditions and smoke from prescribed burns. 4) The worst visibility recorded by NPS is in the eastern United States, where relative humidity and air pollution levels are highest. In the summer of 1983, for instance, the median visibility range at Shenandoah National Park was 19 kilometers, as compared with 100 to 200 kilometers for most western parks. 5) Visibility is generally best in the winter and worst in the summer.

Particulates are monitored through the use of stacked filter samplers. Samples are collected over 72-hour periods which are followed by 12 hours off. NPS research and monitoring indicate that particulates are the major contributor to visibility impairment

in parks; especially the very fine particulates (those smaller than 2.5 micrometers in diameter), which scatter light much more effectively than do large particles, which form a large percentage of the pollution mass. Sulfates, the end product of atmospheric chemical transformation of gaseous sulfur dioxide, formed the largest single fraction of the total collected fine particle mass and were the principal impairer of visibility everywhere except in the Northwest, where carbon particles took the lead. On the Colorado Plateau, sulfate particles were responsible for 40 to 65 percent of the visibility impairment and at Shenandoah National Park for over 70 percent. In the Southwest, windblown dust, emissions from construction activities, and traffic on unpaved roads contributed 10 to 30 percent of the visibility reduction, while fine-

particle carbons and nitrates accounted for another 20 percent. (The above information was taken largely from "Pollution Where You'd Least Expect It," by David B. Joseph, *EPA Journal*, March 1986.)

The NPS has studied the influence of visibility on visitor enjoyment of parks through mail-back surveys and on-site interviews. Mail-back surveys to determine which park attributes visitors feel are most essential to a positive experience were conducted at Grand Canyon, Mesa Verde, Mount Rainier, and Great Smoky Mountains national parks during the summers of 1983 and 1984. The results indicated that visitors felt a natural environment, free of pollution and undisturbed by humans was most important to their experience. On-site interviews at Grand Canyon and Mesa Verde were conducted to examine effects visual air quality might have on the recreational experience sought. Seventy-six percent of the visitors interviewed at Grand Canyon said they saw haze and at Mesa Verde, 86 percent. As visitors became more aware of haze, they reported decreased enjoyment of the view and less satisfaction with visual air quality. At the same time, 80 percent or more of the visitors thought the haze was natural, while monitoring showed that 60 to 80 percent of the haze was associated with urban and industrial sources. This suggests the need for expanded interpretation and public education on the state of air quality in parks.

The Park Service is also involved in two cooperative programs to study visibility. The SCENES program is a multi-year research and monitoring investigation of the layered and regional haze problem in the Southwest. SCENES is an acronym for Subregional Cooperative Electric Utility, National Park Service, and Environmental Protection Agency Study. Electric utilities participating in the study are Salt River Project, Southern California Edison, and Electric Power Research Institute. The Department of Defense is also participating. The goal is to establish the relative contributions of various source categories to atmospheric aerosols in the desert southwest, with emphasis on national parks and recreation areas in Arizona and southern Utah and restricted airspace in the western Mohave Desert. Over a dozen monitoring sites have been established. Most are at remote locations designed to monitor regional atmospheric constituents through both optical and aerosol measurements. Field measurements were begun in 1984 and will continue for at least 5 years.

The second cooperative program is IMPROVE (Interagency Monitoring of Protected Visual Environments). Begun in FY1985 (planning only), this program will conduct long-term visibility measurements in national parks, national monuments, and wilderness areas, as required by an EPA regulation written to help carry out objectives of the Clean Air Act. The monitoring program must determine the

background visibility conditions in and around the mandatory class I areas and document the extent of any visibility impairment in those areas that can be attributed to a source or group of sources. All class I areas in the United States will be grouped in visibility regions (tentatively 23). Each region will have one monitoring site representative of all the class I areas in that region. Each site will employ, at a minimum, an automatic teleradiometer, an automatically-actuated 35 mm camera, an SFU particle sampler, and a data collection device to record values from the teleradiometer. The network, under general responsibility of EPA, will consist of 15 NPS sites, 4 U.S. Forest Service sites, and 4 U.S. Fish and Wildlife Service sites. Field measurements are scheduled to begin in FY1986.

## Watershed Projects

Integrated studies of the effects of atmospheric pollutants, especially acidic deposition, on ecosystems of small watersheds are being conducted in five national parks. Those at Sequoia, Olympic, Rocky Mountain, and Isle Royale are funded through NAPAP, with additional funding sources at Sequoia. Studies at Shenandoah are funded primarily by EPA. Each watershed project meets certain core requirements—types of measurements that can be compared among projects—as well as conducts other research that may be unique to the project. Other parks that are interested in setting up such watershed studies should contact one of the watershed project coordinators, listed below.

Sequoia National Park: Dr. David Parsons

Olympic National Park: Dr. John Aho  
Rocky Mountain National Park: Dr. Jill Baron

Isle Royale National Park: Dr. Robert Stottlemeyer

Shenandoah National Park: Dr. James Galloway (Univ. of Virginia)

NAPAP is in the process of developing a questionnaire for gathering information about existing watershed sites that are being monitored. Their goal is to document existing programs and determine what is being monitored, for how long, and what methods are used. This effort will document NAPAP and non-NAPAP sites. This is strictly an informational exercise to be used by those needing to know where monitoring/research is being done that may be relevant to overall NAPAP program goals. The exercise may be helpful for direct future expansion of the program into appropriate existing projects, rather than starting new ones.

## Sequoia National Park

The Sequoia National Park acid deposition project is a long term, interdisciplinary, multi-agency study of the effects of acid precipitation on natural ecosystems. The program collects baseline data on ecosystem processes necessary to detect subtle but potentially devastating changes in natural communities. The project is conducted both under the auspices of the National Acid Precipitation Assessment Program (NAPAP) and as a cooperative program with the California Air Resources Board.

In recent years there has been growing concern over the potential effects of atmospheric pollutants in California. However, without adequate baseline data it will be impossible to assess future changes in atmospheric inputs and their effects on natural ecosystems. The NPS is cooperating in this study with federal and state agencies and private organizations to quantify some pollutant inputs and selected ecosystem properties across a 2200 m elevation gradient in the southern Sierra Nevada of California. The study is designed to produce baseline ecological and input data. Specific studies include analysis of precipitation chemistry, atmospheric chemistry, aquatic chemistry and biology, soil chemistry, nutrient fluxes, vegetation structure and function, and impacts of oxidant air pollutants (ozone). The potential role of fire—a frequent natural occurrence in the area—in buffering the effects of acidic inputs will also be evaluated.

The study has successfully attracted the support and financial involvement of a number of federal, state, and private agencies. These include the California Air Resources Board, the U.S. Geological Survey, the U.S. Forest Service, NASA-Ames Space Flight Center, the University of California, the Electric Power Research Institute, the Southern California Edison Company, and the National Park Service. As a result of such interest, the program has rapidly developed into one of the most comprehensive ecosystem studies ever attempted in the State of California.

The principal goal of the Sequoia program is to develop baseline values for selected biogeochemical processes and aspects of ecosystem structure and function that are believed sensitive to acid precipitation and other anthropogenic pollutants. A first approximation of input/output budgets of water, hydrogen, and nitrogen for each of the study sites (watersheds) will also be obtained. Development of specific objectives for each of the many subprojects included in the program is the responsibility of the individual principal investigators.

Three primary study sites have been selected for intensive investigation. Spanning much of the local elevation gradient, the sites include low elevation chaparral, middle elevation mixed conifer forest, and high elevation subalpine communities. All of the sites are situated within the drainage

of the Middle Fork of the Kaweah River. Each site consists of a headwater drainage basin or watershed that is located distant from development and sources of local contamination. Extensive soil, vegetation, and lake surveys were used to assure that watersheds selected were representative of ecosystems of the southern Sierra Nevada.

At each primary study site, the following baseline measurements are made: meteorology; aspects of atmospheric chemistry, quantity and chemistry of rain and snow (Aerochem-metric weekly event samplers and bulk samplers at all sites, snow buckets, lysimeters and/or cores at the middle and high elevation sites); soil characterization and mapping; soil chemistry; stream discharge (quantity and chemistry); stream periphyton and invertebrate monitoring; litter accumulation and decomposition rates; nutrient fluxes; vegetation composition, phenology, productivity, biomass, and water stress; and plant tissue and soil nutrient analysis. The low elevation Elk Creek site is the focus of additional studies on dry deposition and throughfall chemistry. The middle elevation Log Meadow site is the focus of additional studies on forest productivity and biomass, root production, N mineralization rates, and ozone effects. The high elevation Emerald Lake site is the focus of studies on lake dynamics (physical, chemical, and biological aspects), lake sediment buffering, soil/water interactions, detailed snow hydrology and chemistry, and tree ring analyses of growth rates and trace element levels.

The Park staff has worked together with the California Air Resources Board and other cooperators to identify study priorities and assure integration of individual projects. The National Park Service has given high priority to providing a framework that would be attractive to potential cooperators. This has included development of the Southern Sierra Research Center (laboratory, office, and dormitory facilities) as well as a cadre of trained technicians available to assist in routine data collection activities. The Park staff has taken the responsibility for data collection in the areas of meteorology, precipitation chemistry, stream chemistry and hydrology, forest insects and disease, litter dynamics, and baseline vegetation plots. Other projects have been carried out either under contract or by cooperative agreement with university scientists or other federal and state agencies.

Findings to date document the occurrence of acidic precipitation and the existence of extremely sensitive ecosystems. While winter precipitation generally falls as relatively unpolluted snow, the occasional summer and fall storms that occur in the area contribute potentially significant pulses of hydrogen, sulfate, and nitrate. The granitic bedrock, thin soils, and alkaline lakes that characterize the Park have a low buffering capacity and thus are extremely sensitive to acidic inputs. Addi-

tional studies on the quantity and type of dry deposition occurring in the Park are needed to fully document deposition inputs.

David Parsons  
Research Scientist  
Sequoia-Kings Canyon  
National Parks

## Olympic National Park

Information on ecosystem processes from Olympic National Park, where air pollution presently is minimal, will provide valuable baseline reference levels with which to compare acid deposition effects in other regions of North America, as well as with future effects here. The watershed studies in Olympic, contracted by NPS to the College of Forest Resources, University of Washington, were begun in 1984 and will run until FY1992.

The watershed of the main fork of the Hoh River (299 sq mi, about 60 percent within the park) was chosen as the geographic focus of this research. Because of the large area and the biological diversity represented, the more intensive aspects of the study are being conducted in smaller watersheds representative of major vegetation zones present within the main Hoh drainage. The hypothesis is that the chemistry of the Hoh River is a composite result of biogeochemical processes operating on many smaller units.

If, or when, pollution effects produce a response sufficient to be detected in drainage waters, the effect will probably not be uniform. Some vegetation types potentially are more sensitive to altered input chemistry than others. By focusing research on points near the source, changes in ecosystem function in the fragile subalpine areas, for example, will be detected before changes in chemistry of the Hoh River itself.

Two smaller watersheds are currently being studied: West Twin Creek (elevation 505-2800 ft; Sitka spruce-red cedar-western hemlock old growth rain forest, nearly closed canopy); and Hoh Lake basin (elevation 4100-5000 ft; silver fir forest, undisturbed, more exposure than at West Twin Creek). Both have basic vegetation community maps, permanent sample plots, a sustained history of scientific study, and a meteorological station (measuring relative humidity, air temperature, soil temperature at 8'' and 20'', insolation (pyranometer), windspeed and direction, and rainfall amounts and duration of events). Surface water chemistry is being monitored. In addition, the Twin Creek site, established during the first season of field work in 1984, has a permanent stream gauge, and an array of precipitation collectors to allow comparison of chemistry of direct precipitation, stemflow, and throughfall (drip) to the

chemistry of surface water of Twin Creek.

On the permanent sample plots, soils will be described, and measurements will be made of all trees larger than 5 cm in diameter at breast height, samples of understory vegetation, litterfall rates, biomass and production, and nutrient cycling. A related study in the Hoh River valley by researchers from the Department of Forest Science, Oregon State University is monitoring lichen productivity, moss productivity, canopy litter fall, leaf litter decay, and conifer needle retention times. Together these studies will establish the range of natural variation in Hoh valley ecosystems, so that effects of human influences such as air pollution can be identified.

## Rocky Mountain National Park

Loch Vale Watershed in Rocky Mountain National Park has been the subject of intense scrutiny since 1981. The NPS has been investigating whether there is an acidic deposition problem, and how acidic deposition affects high elevation ecosystems of the southern Rocky Mountains. The first question was addressed by reconstructing lake and atmospheric chemistries from lake sediments and combining that with knowledge of current deposition chemistry. The conclusion was that there has been no discernible trend toward increasing acidity in either lakes or deposition over the past 150 years, and current deposition chemistry, while exhibiting some industrial and automotive influence, is not yet acidic enough to cause ecological damage. The values of acid, sulfate, and nitrate deposition are still well below the levels known to have been responsible for effects elsewhere in the world. The results of this work are published (*Water Resources Bulletin* and *Water, Air, Soil Pollution*) or in press (*Canadian Journal of Fisheries and Aquatic Science*). The latter should be in print by early summer. (See Recent Publications)

In 1982 Loch Vale Watershed (an NADP site) was instrumented with an acid deposition collector, a weather station, a flume to quantify stream flow, and a number of smaller instruments to measure ecosystem processes that might help to mitigate acidic deposition. An intense sampling program was initiated with the help of the U.S. Geological Survey, U.S. Forest Service, Bureau of Reclamation, Solar Energy Research Institute, and Environmental Protection Agency. Measurements are taken on the chemistry of lakes and streams, soils, vegetation, rain, throughfall, snow, and bedrock minerals. Some of the more important results are discussed below.

The high elevation ecosystems of Rocky Mountain National Park are among the most sensitive to acidification of any in the world. The alpine and subalpine lakes are

surrounded by slow-weathering granitic bedrock, thin to nonexistent soils, and little or no vegetation. These ingredients add up to a minimal source of buffering capacity with which to counter increasing acidity. Lakes and streams reflect this with alkalinity values averaging 60 microequivalents/liter over a normal water year. Many lakes within Rocky Mountain NP support healthy populations of trout, and streams show a diverse community of benthic macroinvertebrates. The sensitivity of these lake systems is further increased by the strong seasonality of inputs. Deposition may build up in the snowpack for up to seven months of the year, then melt out in a very short time. Currently, with only a slight increase in atmospheric deposition of acids, spring pH values drop as low as 5.7, a value not much above the threshold for biological effects.

Other factors which restrict the ability to withstand an increase in acidic deposition are complex. Because these high elevation systems (often over 3000m elevation) are so cold and are stressed by a short growing season, lack of sufficient moisture, and desiccating high winds, they do not seem to be limited by lack of the nutrient nitrogen. Consequently, increased NO<sub>3</sub> in deposition (a result largely of automotive emissions and industrial combustion of oil or coal) may cause increased acidity in lakes and streams, just as SO<sub>4</sub> will cause loss of acid neutralizing capacity. Soils in these very cold environments accumulate a lot of organic matter because temperature and moisture regimes prevent rapid decomposition. These soils are already very acidic, with low base recharging capability and low sulfate adsorption capacity. There will be very little replenishment of lake and stream neutralizing capacity from soils. Similarly, bedrock minerals will not provide much buffering, and in-lake processes do not seem to be a source of acid neutralizers.

These results, which have been determined empirically, correlate well with another method of ecosystem analysis employed: systems analysis with computer models. Researchers are currently working with a model developed at the University of Virginia called MAGIC (Model of Acidification of Groundwater in Catchments). The model was first tested on data collected from Shenandoah National Park. This model, which was developed for an environment with a lot of soil and no yearly accumulation of snow, works fairly well in Rocky Mountain NP, in spite of these drawbacks. Portions of it are being modified to better reflect western conditions.

All of this could have important implications for the management of Rocky Mountain National Park. Here is an ecosystem that is very sensitive to acidic deposition but which is not yet affected. Its location in the southern Rockies puts it near growing urbanization, smelting of copper and other metals, and the possible development of oil shale and natural gas facilities. The chances

of atmospheric deposition causing biological effects here in the future are great. With improvement in the computer modeling, it may be possible to make educated guesses about how long it will take for effects to occur given different deposition scenarios. This allows Park managers possibly to prevent the damage before it occurs by offering convincing evidence of how, when, and why. The loss of trout populations, for instance, would be a severe blow to Rocky Mountain National Park. This research may be one way to see that it doesn't occur.

Jill Baron  
Applied Research Unit  
Water Resources Division  
Fort Collins, Colorado

## Isle Royale National Park

This project was initiated in June 1982. Four watershed/lake ecosystems are under study: two on Isle Royale and two on the Upper Peninsula of Michigan. The two on Isle Royale are similar in character except for glacial till composition and water chemistry, and are representative of systems in this national park. These watersheds are dominated by boreal forest. Research shows that the two Isle Royale lakes are not directly sensitive to anthropic acidification. The Upper Peninsula sites are sensitive to present levels of acid inputs. They differ from the Isle Royale sites in geological substrate, and are forested with northern hardwoods.

Routine meteorological data are collected on all sites. Stream discharge into and from the lakes is measured. Periodic baseline measurements are made every 5 years on each site. These include: plant biomass and biomass components, forest litter, soils, and plant community composition. The lakes are sampled seasonally at multiple depths and at multiple stations. Temperature, light, and chemical profiles are determined, and primary productivity and chlorophyll *a* measured. Color, pH, alkalinity, specific conductance, macro ions, total nitrogen, and trace metals are determined on most lake and streamwater samples. Research projects include analysis of lake sediment cores; precipitation modification by forest canopy, litter layer, and soil in both vegetation types; nitrogen budgets as affected by *Alnus* (alder) and beaver activity; forest soil anion mobility; and snowpack nutrient accumulation and ionic movements. Most sample analyses and data processing are conducted at Michigan Technological University.

In 1985, a four-year study of lake primary productivity and chlorophyll was ended. The results are considered valuable in themselves, especially in this region, but recent research has found that this kind of study is not a good indicator of ecosystem change, certainly over periods of less than 10 years. NAPAP-related research is presently focusing on the following topics:

snowpack ionic loading and dynamics in a small first-order watershed (underway for seven years, probably one of the longest intensive snow quality/ionic movement records in the nation—paper submitted); sulfate anion mobility in boreal and northern hardwood forests (papers submitted); qualitative relationships among canopy throughfall, soil solution, and lake water chemistry in a very sensitive aquatic ecosystem; completion of a nutrient cycling study in a boreal forested ecosystem; and a study of a gradient of anthropic atmospheric inputs to national parks of the Great Lakes Basin (paper submitted). There will be an attempt next winter to plug data into an existing watershed model for testing.

## Shenandoah National Park

The Shenandoah Watershed Study (SWAS) was initiated in 1979 as a cooperative research program of Shenandoah National Park and the Department of Environmental Sciences at the University of Virginia. The objective of SWAS, in broad terms, is to understand the processes that govern biogeochemical cycles in forested watersheds. More specifically, the primary research emphasis has been determined by the need to assess watershed response to the deposition of atmospheric acid.

The principal investigators of SWAS are Dr. Jack Cosby, ecosystem modeler; Dr. Jim Galloway, aquatic chemist; Dr. George Hornberger, hydrologist; Dr. Hank Shugart, forest ecologist; and Dr. John Sigmon, forest meteorologist.

From both a scientific and a resource management perspective, the SWAS has been informative. Of principal importance, SWAS research has identified a combination of watershed sensitivity and elevated acid deposition which results in a poor prognosis for large areas of Shenandoah NP.

The concentration of sulfate in precipitation, for example, provides a measure of the anthropogenic component of acid deposition. Compared with remote areas of the world, the current loading of atmospheric sulfate to this part of the Blue Ridge Mountains is conservatively estimated to be about ten times preindustrial levels. This amounts to about 25 lbs. of wet deposited sulfate per acre per year in Shenandoah NP—one of the highest acid deposition levels received by any of the national parks.

This elevated acid influx is made critical by the lack of buffering capacity associated with many of the soils and streams in the area. Approximately one third of the Shenandoah NP watersheds have been identified as susceptible to acidification. Streams draining these watersheds have alkalinity values less than 100 ueq/L (or about 5.0 mg/L), well below commonly cited sensitivity criteria. Our current prediction is that these streams will be subject to significant reductions in pH and alkalinity over

the next few decades—with coincident loss of indigenous eastern brook trout populations.

SWAS has taken a threefold approach to understanding controls on both aquatic and terrestrial response to elevated acid deposition. The first approach treats watersheds as units by measuring their inputs (atmospheric deposition) and outputs (stream discharge) to determine the net effect of the watershed processes. This information is then used to formulate explanatory hypotheses. The second approach uses laboratory and field experiments to test the hypotheses formulated from the results of the input-output studies. The third approach applies the previous results to create models that predict watershed response and impacts.

The information needed to establish input-output budgets, both in terms of net loadings and temporal variation, has been provided by monitoring the quantity and chemistry of precipitation and stream discharge at the White Oak Run and Deep Run watersheds over the past 6 years. These watersheds, located in the Park's southern section, are underlain by relatively inert quartzites, sandstones, and phyllitic shales. A third watershed, the North Fork of Dry Run, which is associated with granitic bedrock in the Park's central section, has recently been adopted into the routine monitoring program.

Field and laboratory studies associated with SWAS have ranged in scale from park-wide surveys of stream chemistry to laboratory studies of soil properties. Major research areas addressed by individual projects over the previous 6 years have included: the control of stream chemistry by watershed characteristics such as bedrock, soil type, and vegetation; the acid neutralization and sulfate retention properties of watershed soils; the mobility of aluminum in soil and streamwater; and the hydrologic controls of the study area.

Currently the SWAS effort is expanding to include establishment of monitored terrestrial sites for integrated soil and vegetation studies. This work, in the North Fork Dry Run area, is coordinated with construction of above-canopy towers to facilitate intensive study of elemental exchange between the atmosphere and the forest system. Three aluminum towers, placed on an elevational gradient within the watershed, have been equipped with sampling systems and micrometeorological instrumentation designed to measure elemental fluxes in solution, gaseous, and solid particulate phases.

An overall integrating factor for SWAS has been the development of MAGIC, a computer model which is a process-oriented, intermediate-complexity model of watershed acidification. This model, which incorporates our present understanding of the most important controls on watershed response, can be applied to explain current watershed stream chemistry, and to predict future changes in streamwater chemistry



A ranger at Canyonlands NP takes visibility measurements with a teleradiometer.

under a range of future acid deposition scenarios.

The bleak prediction that one third of Shenandoah NP streams will suffer acidification over the next few decades is based on the assumption of no change from current acid deposition levels. The MAGIC model indicates that substantial reductions in acid deposition will be required to reverse this trend. Even an immediate 50 percent reduction, for example, may be insufficient to achieve more than a delay in the acidification process. Acid deposition levels would still be elevated compared to preindustrial background levels.

Because of the significance of these predictions, refinement of the MAGIC model has assumed principal importance to the SWAS effort. A second generation of SWAS research within Shenandoah NP focuses on the need to reduce uncertainties in model structure and parameter specification. In addition, the application of the model to watersheds and regions in other areas of the country is being evaluated.

More information concerning SWAS research can be obtained by writing the Shenandoah Watershed Study, Clark Hall, Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903, or by calling (804) 924-0603.

Rick Webb  
Project Manager, SWAS  
University of Virginia

## Other Water Quality Research and Monitoring

Many other water quality studies are looking at the effects of pollution that enters streams, lakes, and groundwater directly from land-based sources, and at methods of control. Acid mine drainage, leachate from landfills, and nutrient loading from agricultural runoff are examples of problems being investigated. A few studies are highlighted below.

### Friendship Hill National Historic Site

This one-square-mile area lies in a bend of the Monongahela River in southwestern Pennsylvania. Polluted water coming from an abandoned coal shaft at the upper boundary of the park forms the headwaters of a small stream that flows for about a mile through the park. This coffee-colored stream is extremely acidic (2.6 pH), has high concentrations of metals, supports virtually no aquatic life, and has killed trees and other vegetation growing along its banks or on overflow areas. Routine chemical and engineering abatement procedures were considered impractical or economically unfeasible. Instead, an artificial bog is being tested to act as a biological filter to improve water quality—a technique that has proved useful elsewhere.

Under supervision of Robert Kleinman of the U.S. Bureau of Mines, the project in its first year included studies of water and soil chemistry, water flow rates, and vegetation tolerance of the water and soil characteristics. Some of the stream's flow was diverted through a vegetated area, and two species

of sphagnum moss were tested in a plexiglass experimental bog tank. *Sphagnum recurvum*, cattail (*Typhus latifolia*), and several sedges and grasses did not appear to have been injured by exposure to the acid mine drainage. Water chemistry data from sample points along the water diversion indicated that acidity, total iron, sulfate, calcium, magnesium, aluminum, and specific conductivity measurements were lowered. If further experimental plots are successful, a full-scale artificial bog will be established.

## Everglades National Park

The quantity, timing, and quality of water flowing into Everglades is a life and death matter for this largely marsh and mangrove park. One concern is the possibility of increased nutrient loadings in water reaching the park from agricultural areas to the north, and from backpumping of water from settled areas to the east in the event of a water shortage. This prompted the NPS Water Resources Division to study the effects of increased nutrients in the Shark River Slough, the largest freshwater flow system in the park. Three experimental channels were set up. One received increased phosphate-phosphorus and nitrate-nitrogen loading from April 1983 through September 1984. Another received only additional phosphate-phosphorus, October 1983 through September 1984; and the third received only nitrate-nitrogen during the latter period. The results indicated that even minor increases in phosphate-phosphorus loading can trigger major changes in periphyton (attached algae) and macrophyte (larger plant) biomass and community structure. Increases in nitrate-nitrogen may trigger more subtle responses in periphyton and macrophyte biomass and community structure. These changes, in turn, may potentially alter higher levels of ecosystem organization. While present nutrient loadings are not a problem in Everglades National Park, this study indicated that higher levels could create one.

## Water Quality Monitoring Strategies in Two NPS Units

More than 160 units of the national park system may be affected by degraded water quality, but in many cases adequate resources are not available to conduct detailed hydrologic or limnological research. In such situations, a strategy for water quality reconnaissance and monitoring using a small number of parameters directly affected by specific activities in the watershed, is most appropriate. The results of these monitoring efforts can then be used to develop management alternatives and to assess the need for more intensive studies. Involvement of park resources management staff, as opposed to the contracting of entire programs to outside entities, both saves

money and helps integrate water quality planning into the operational resource management activities of the park unit.

Programs of two NPS areas illustrate this approach. At **Big Thicket National Preserve**, the principal activities that degrade water quality are oil and gas development, sewage effluent discharge, and local timber operations. Monitoring is restricted to a few parameters associated with these activities. Analysis of certain types of samples is conducted at a park laboratory and of other types at a contract lab. It has been possible to establish a water quality program responsive to Preserve needs for about \$15,000 per year plus staff support. At **Big South Fork National River and Recreational Area**, parameters directly related to acid mine drainage, oil and gas activity, domestic wastes, and watershed disturbance were selected for monitoring. Because of the remote location, a staff hydrologist was hired in 1982 to establish a water quality laboratory and conduct the monitoring program. Analysis of the first two years of data, collected from more than 30 stations, indicates that the park can be categorized into five major water quality types ranging from undisturbed to severely polluted. With the areal extent of each category in hand, park managers now can identify areas needing further research and can formulate management alternatives to help improve water quality.

## Rocky Mountain National Park

Surveys of the distribution of *Giardia*, a protozoan parasite, in high-elevation streams of Rocky Mountain National Park were conducted during the summers of 1984 and 1985. In the Glacier Gorge and Loch Vale basins—two popular watersheds—3 to 11 *Giardia* cysts per 1000 liters were found in 7 of the 35 stream pumpings. In two of three remote backcountry streams sampled, no *Giardia* cysts were found; samples taken from the third stream contained cysts (10-16 per 1000 liters) only in the vicinity of beaver activity. Evidence to date suggests that in Rocky Mountain NP beavers, humans, and possibly muskrats are the principal carriers of *Giardia*, which causes a gastrointestinal illness that can be debilitating and long-lasting if not identified and treated. Park signs and brochures warn visitors of the danger and advise backcountry hikers to boil drinking water. *Giardia*, a cosmopolitan parasite, has also been identified in other western national parks, including Olympic, Sequoia, and Yosemite.

## Olympic National Park

Crescent Lake in Olympic NP is surrounded by substantial residential and concession development. There is concern that these activities are adding to the nutrient loading of the lake and are accelerating the eutrophication process. An investigation is beginning this summer that will assess the

trophic status of the lake and determine the nutrient status.

## Toxic Chemicals

Toxic chemicals from the Cortese Landfill in New York are leaching into the waters of the **Upper Delaware Scenic and Recreational River**. A comprehensive effort is underway to assess the effects of the contaminants on aquatic life and to see if the local fish have accumulated the contaminants and pose a threat to people who eat them. Because the rate of leaching from this landfill is not known, the NPS perceives a need for the development and application of a long-term monitoring tool.

Fort Darcy, at **Richmond National Battlefield Park**, contains an old landfill which is leaching several known toxic organic chemicals into a small creek that flows into the James River below Richmond. There is a planned chemical monitoring effort to establish the magnitude of the problem.

Marshall Brook in **Acadia National Park** is being affected by toxic leachate from Worcester Landfill in the southern part of Mount Desert Island. The Park Service is cooperating with the EPA in evaluating the extent of chemical contamination and biological effects. Data from both agencies are being used to force the dump's closure and are specifying mitigation measures to render the leachate non-toxic.

Valley Creek in **Valley Forge National Historical Park**, is impacted by a polychlorinated biphenyl (PCB) spill upstream of the park. Fishing has been banned in Valley Creek by the State of Pennsylvania because of high concentrations of PCB's in fish. The NPS is planning work with the State of Pennsylvania and U.S. Geological Survey to fully assess the problem and develop mitigation procedures.

A potential problem exists in **Glen Canyon National Recreation Area**, where high levels of selenium are occurring in the flesh of some game fish. Lake Powell is believed to be a regional depositional sink concentrating naturally occurring heavy metals.

DDT and its metabolites are still being found in significant amounts in areas of southwest Texas in the vicinity of **Big Bend, Carlsbad Caverns, and Guadalupe Mountains national parks**. Several piecemeal investigations have yet to determine the source and whether new, illegal use is occurring.

A new Department of Interior-wide effort is underway to determine the extent of water quality degradation and toxic substances in irrigation return water. Several Park Service areas in the West may be peripherally involved.

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# Terrestrial Effects of Air Pollution

Results from the first four years of the Air Quality Division's Biological Effects Program are summarized in *Park Science* (Summer 1985, p. 8-9). The main points: 1) The worst effects of air pollution on national park vegetation come from elevated levels of ozone. 2) Heavy metals, such as lead, have the next most serious effects. 3) The worst effects are found in parks, such as Indiana Dunes and Santa Monica Mountains, that are designated class II under the Clean Air Act. 4) Fumigation exposure studies indicate that selection is favoring genotypes tolerant of air pollution and sensitive ones are being removed from the existing populations. The Biological Effects Program excludes study of terrestrial and aquatic effects from acidic deposition, which fall under a program of the NPS Office of Natural Resources. Some major additional results of the Biological Effects Program up to March 1986 are summarized below.

## Ozone Injury on Pine Plots, 1985

	% Trees injured	% Injury/tree
Great Smoky Mountains NP	90	5
Acadia NP	89	4
Indiana Dunes NL	100	5
Cuyahoga Valley NRA	97	3
Sequoia NP	87	9
Yosemite NP	58	5
Saguaro NM	52	3
Rocky Mountain NP	0	0
Everglades NP	(03-like symptoms awaiting final diagnosis)	

(Eastern parks = *Pinus strobus* (white pine) and *Pinus elliotii* (slash pine); western parks = *Pinus ponderosa* (ponderosa pine) and *Pinus jeffreyi* (Jeffrey pine))

## Mammoth Cave National Park

The results of an air pollution injury survey in the fall of 1985 have been analyzed and summarized. Ozone injury was found on most of 14 species examined, and was common on six: *Cercis canadensis* (redbud), *Fraxinus americana* (white ash), *Fraxinus pennsylvanica* (red ash), *Platanus occidentalis* (sycamore), *Liriodendron tulipifera* (tuliptree), and *Asclepias syriaca* (common milkweed). Percent of injured individuals ranged from 3 for *Acer negundo* (boxelder) and *Acer saccharinum* (silver

maple) to 100 for common milkweed. Injury per plant was greatest on the common milkweed, followed by wild grape (*Vitis* sp.), the ashes, and redbud. Significant differences between sites demonstrated that trees on ridges and higher elevations were most likely to be injured. Injury was found throughout the park, indicating uniform ozone concentrations (probably greater than 0.06 ppm).

## Isle Royale National Park

Elemental analyses of bryophytes collected as far back as 1900 show concentrations of sulfur as high as 6120 ppm, nearly three times higher than normal values found in pristine areas in northern Canada. These values are consistent with elevated sulfur levels found in lichens in the park. Possible sources include the pulp mills and a power plant in Thunder Bay, Ontario and long-distance transport.

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## The SARRMC Spruce-Fir Ecosystem Assessment Program

High elevation spruce-fir forests are a key natural resource for the National Park Service. Great Smoky Mountains National Park (GRSM) has the highest visitation of any U.S. natural area park; and the high backbone of the Smokies is the most visited part of the Park. The dark evergreen spruce-fir forests, rugged mountain scenery, and cool mountain temperatures

form the aesthetic background of the visitor experience. In the South, spruce-fir forests are scarce and found only as a series of isolated island-like areas on the highest ranges. Those high elevation islands are rich in rare plants and animals, including both northern and endemic species. These forests form the headwaters of two-thirds of the Park's major streams. By far the largest block of southern Appalachian spruce-fir is found within Great Smoky Mountains National Park. Logging of spruce from 1880 to 1930 affected many spruce-fir islands in the south. GRSM protected a large block of virgin forest of this type. This makes the current threats to this ecosystem type all the more alarming. In fact, the remnant old-growth spruce-fir forests of the southern Appalachians will be forever changed within the next several decades.

What are the threats? The first recognized threat to these forests was the exotic insect, balsam woolly adelgid (aphid). The adelgid poses a severe threat to the narrowly distributed southern Appalachian endemic, Fraser fir (*Abies fraseri*). The insect has been in GRSM for about 20 years, has spread throughout the full range of Fraser fir, and is causing heavy mortality. The second threat is atmospheric deposition of pollutants. Of course the two threats may—and probably do—interact in their effects on this ecosystem.

The Terrestrial Effects Program under the National Acid Precipitation Assessment Program (NAPAP) is organizing regional cooperatives to address effects of atmospheric deposition of acidity on forests. Because of the relatively sudden and heavy mortality experienced by red spruce over the last 5 years in the mountains of Vermont and New York, because of several reports of unexplained growth declines



Visibility impairment due to emissions from the Atlas Mineral Processing Plant, Moab, UT, Arches National Park, September 13, 1979, at 9:45 a.m. Such air pollution is not unusual, even in western national parks.

throughout the range of red spruce, and because of widespread decline of conifer forests in western Europe, spruce-fir forest was the first type to be addressed under this program.

In 1984, the Southern Appalachian Research/Resources Management Cooperative (SARRMC), a regional consortium of universities, federal agencies, and state agencies, received funding from the U.S. Forest Service to develop a prototype research program on southern Appalachian spruce-fir forests. This effort was later used as a model for the Spruce-Fir Research Cooperative (administered by the U.S. Forest Service in Broomhall, PA), which includes both the southern and northern spruce-fir effort. Late in 1984, Great Smoky Mountains National Park was chosen as one of three intensive research sites in the South, and Peter White and Chris Eagar of the Park's research staff were named co-leaders (with Shep Zedaker of VPI) of one of the central research projects (the establishment of permanent vegetation plots to serve as the focus of other research efforts).

The SARRMC spruce-fir ecosystem assessment program is a 4-year integrated and interdisciplinary study. There are eight core projects which will develop data on basic ecosystem parameters. These eight projects, with 15 principal investigators from eight institutions, involve studies of atmospheric deposition; aerial survey; soil and plant tissues chemistry; dendro-chronology; modeling; mycorrhizae, pests, and pathogens; disturbance history; and vegetation structure, composition, and vigor. Beyond these eight core projects there are several hypothesis testing projects, including recently started projects on soil nitrogen transformations and on red spruce physiology (using field and laboratory experiments). Additional grants will be awarded in the coming years. Since the full program is only a year old, it is too early to state by what mechanism and to what degree pollutant exposure and deposition is affecting these forests. The studies have produced enough information to cause serious concern, and the SARRMC spruce-fir ecosystem assessment program has been designed to provide the answers needed.

Because of their biological value and presumed sensitivity to acid deposition, spruce-fir forests in the Smokies have attracted other research attention as well—some 21 studies are being done or have been recently completed in these high elevation forests (ranging from studies of lichens, rare plants, and avifauna to stream and soil solution chemistry). A particularly important project with regard to NAPAP goals is being funded by the Electric Power Research Institute and is being carried out by Oak Ridge National Laboratory in cooperation with the GRSM Science Division. This project is looking in depth at the ecosystem processes associated with the movement of deposition from atmosphere,

through tree canopies, and into soils.

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## Materials Effects of Air Pollution

Research is underway in four areas: 1) Deterioration rates of stone and bronze; 2) *in situ* monitoring of cultural resource degradation; 3) distribution of cultural properties; 4) protection and mitigation strategies. The bulk of the research began in 1983-84.

Deterioration rates of stone are being studied through 10-year field exposure tests at four sites, in cooperation with the Bureau of Mines and EPA, who are sponsoring tests of metals and paints, respectively. These sites are at Research Triangle Park, North Carolina; West End Branch Library, Washington, D.C.; Environmental Measurements Laboratory, Chester, New Jersey; and Huntington Wildlife Forest, Newcomb, New York. A fifth NPS site will be established at Steubenville, Ohio in FY1986. At each site slabs and briquettes of Vermont marble and Indiana limestone are being used for measurements of surface and water runoff chemistry, as well as surface recession and other changes. Stone deterioration data will be correlated with environmental data recorded at these sites by EPA. In the first year of testing, recessions near 15 micrometers were measured for skyward surfaces of briquettes. Results of the surface chemistry suggest that the direct effect of gaseous sulfur dioxide at skyward surfaces was much less than the effect of acid rainfall. Research on bronze deterioration is limited. A field study is underway of more than 100 bronze plaques from the same foundry and exposed in sites across the northern U.S. since the early 1960s. The amount of corrosion will be correlated with environmental data from nearby monitoring sites.

The NPS is also establishing a network of monitored cultural resources. Intensive monitoring is underway at Mesa Verde National Park, Independence National Historical Park, and, as of mid-1986, Gettysburg National Military Park. As in the stone field exposure program, deterioration and environmental data are being collected and correlated. At Mesa Verde, two test walls built of native sandstone are being used, one fully exposed, one sheltered in the cliff. Field test kits for park managers have been developed for intermittent monitoring at additional sites.

A geographic inventory of cultural properties with respect to pollution regimes is also being conducted to help assess pollution effects. Estimates of the distribution of cultural resources by their size, material,



Dr. Steve Norton from the University of Maine prepares to section a sediment core taken from the bottom of a study lake, Rocky Mountain National Park. The sediments revealed no discernible trend toward increasing acidity over the past 150 years, but growing development in the southern Rocky Mountain region is likely to cause increased acidic deposition in the future.

and location are being prepared from existing documentation. Exposure histories will be estimated from historic emissions and estimated deposition levels.

Protection and mitigation strategies are being evaluated through laboratory and field testing of the long-term performance of stone and other masonry treatments, and through cost comparisons of methods for cleaning masonry structures and bronze statues. The costs will be compiled from actual project costs in northeastern states.

# PARK NOTES

This section highlights environmental quality problems or informational activities in selected parks.

## Glacier National Park

Cabin Creek Mine is a proposed surface coal mine located 6 miles north of Glacier National Park on a tributary to the North Fork of the Flathead River in British Columbia, Canada. Based on evaluations of the NPS, the State of Montana, and EPA, it is believed that construction, operation, and post-mine reclamation of the Cabin Creek Mine represent a significant threat to the water quality and quantity of the North Fork of the Flathead River, the western boundary of Glacier National Park. Similarly, the mine represents a very real threat to the bull trout fishery in the Flathead River Basin, since 15 percent of the spawning habitat for bull trout in the entire basin is in the immediate vicinity of the mine.

Based on these concerns, a reference on the Cabin Creek Mine was submitted by the United States and Canada to the International Joint Commission (IJC) in February 1985. This reference called for the IJC to investigate the potential transboundary water impacts of the Cabin Creek Mine under the Boundary Waters Treaty of 1909. In order to assess these concerns, the IJC established the Flathead River International Study Board to investigate the potential impacts of the proposed Cabin Creek Mine on water quality and quantity in the Flathead River Basin and also to assess the effects of the mine on fisheries and water uses in the Basin. The NPS is represented on the study board and on a number of the technical committees which have been established to evaluate various transboundary water effects of the mine. In the course of the study, effects on the waters and fisheries of Glacier National Park will be evaluated and effects on Glacier's special designations (e.g., Biosphere Reserve and nominated World Heritage Site) will also be assessed. The present schedule calls for the study board to submit a report to the IJC by the end of December 1986.

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Sky Pond and Taylor Glacier, Rocky Mountain National Park. Sky is the uppermost lake in the Loch Vale Watershed, where NAPAP acid deposition studies are being conducted.

## High-level Radioactive Waste Disposal

In accordance with the Nuclear Waste Policy Act, the Department of Energy (DOE) identified nine candidate sites, predominantly in the western United States, for the nation's first high-level radioactive waste repository. Two of the nine sites (Davis Canyon and Lavender Canyon) are immediately adjacent to Canyonlands National Park. Neither of these two sites are among the three selected by DOE for characterization (i.e., further in-depth field studies); however, either site could be selected for characterization later if none of the three originally selected meets the requirements. NPS reviewed the Draft Environmental Assessments for the Davis Canyon and Lavender Canyon sites and

recommended that both be declared unsuitable as repository sites. Among other things, a major concern of NPS was the geologic instability of the area and the potential for contamination of surface and ground water in Canyonlands National Park and ultimately the Colorado River.

DOE has recently completed the regional screening for a second high-level radioactive waste repository in the northeastern, north central, and southeastern United States as called for in the Nuclear Waste Policy Act. Based on this screening, DOE has identified 20 preliminary candidate areas for a nuclear repository site. NPS has reviewed DOE's Draft Area Recommendation Report on these areas and has raised a number of concerns about four of these areas where a high-level nuclear repository might have hydrologic impacts on nearby NPS units (namely, Great Smoky Moun-



A view down White Oak Run (foreground), a Shenandoah NP acid deposition watershed study area in the South District. Research in Shenandoah indicates that one third of the Park's streams will become acidified in the next few decades.

tains National Park, Blue Ridge Parkway, Appalachian National Scenic Trail, and Saint Croix National Scenic Riverway). At this time, DOE plans to conduct area field studies in 12 of the 20 areas; a final decision as to which will be studied is expected in the fall of 1986.

Dan Kimball

Visual effects are also a concern at any proposed repository near a park unit. The repository would operate 24 hours each day with necessary outdoor lighting to perform the work and provide lighting for security at night. The NPS Air Quality Division conducted a study of night sky glow at the two Canyonland sites, using a mathematical model to predict effects (*Park Science*, Fall 1985). Conclusions were drawn that 1) the proposed repository, at either site, would probably cause a perceptible night glow and obscure the view of dim stars and the Milky Way in some portions of the sky from many locations within Canyonlands, and 2) some terrain features visible from Canyonlands would be illuminated directly by repository lighting and would be visible from adjacent parts of the park. The model presumably could be used at other locations if modified for local conditions.

## Gateway National Recreation Area

Discharges from New York City, including chlorinated hydrocarbons, petroleum, heavy metals, leachate from sanitary landfills, and sewage treatment plant effluent, have seriously polluted Jamaica Bay, at the heart of this park unit. Two of the landfills used by the city are part of Gateway. Under a New York State court order against New York City, dumping was supposed to cease as of December 31, 1985, and it has, in fact, virtually stopped. The Park Service plans eventually to develop these landfills into recreation areas, but first they must be rendered safe. This is expected to cost hundreds of millions of dollars, and simply determining who will pay is likely to be a lengthy procedure.

## Appalachian National Scenic Trail

Radioactivity has been detected at buildings and grounds of a research lab beside a lake near the Trail at Pauling, New

York. It is suspected that radioactive material and other hazardous wastes have been dumped in the lake. The dam at "Nuclear Lake," as it has been dubbed, is in poor condition, presenting the possibility that dangerous materials will be released downstream if the sediments are disturbed. Investigation of the matter is now in the hands of the Nuclear Regulatory Commission.

## Padre Island National Seashore

Currents of the Gulf of Mexico bring to Padre Island some 100 to 300 barrels of hazardous waste each year from freighters, oil and gas platforms and other sources. Some of these barrels contain material so toxic that a person could die within minutes if he or she took the lid off and smelled the contents. Not knowing the danger, people sometimes use such barrels for shelter or as a windbreak for campfires. Under a special agreement with EPA, the Park Service is using Superfund money to analyze and dispose of this hazardous material, but in FY1987 NPS will be required to fund this work itself.



An abandoned mine opening in the Big South Fork NRA produces acid drainage that contaminates nearby streams. This is a widespread problem in the central Appalachians.

## Sequoia-Kings Canyon National Parks

Evidence to date indicates that ozone is the air pollutant currently causing the greatest effects on biological resources in these parks, injuring ponderosa and Jeffrey pine and black oak. Injury to pines along the front range (western side) of Sequoia and Kings Canyon National Parks has doubled since 1980. Eighty-seven percent of the pines in study plots in Sequoia in 1985 were injured. The San Joaquin Valley, immediately west of the parks, is a major source of ozone.

## Great Smoky Mountains National Park

An exhibit on air pollution sources and its effects in the Park is in preparation and should be on display at Newfound Gap sometime this summer. Consisting of one large panel flanked by two smaller ones, it will explain the causes of the frequent haze that obscures views; describe research and monitoring in the Park and the effects of air pollution on vegetation, such as ozone damage to white pine and retarded growth of red spruce; and present general information on types of pollutants, their sources, and the prevailing directions from which pollutant-bearing air masses reach the Smokies. The concepts and information for the display were developed by the park scientists and interpretive staff and the NPS Air Quality Division. The Harpers Ferry exhibits unit is working with a contractor who is producing the finished product.

This project is seen as a prototype that can be adapted for use in other parks as well. Great Smokies is one of at least 40 park units that now have some interpretation of air quality issues.

## Delaware Water Gap National Recreation Area

This park has streams that are sensitive to acid deposition, acidified lakes, slow weathering parent material, and vulnerable organisms including trout and salamanders. In February 1985 a workshop was held here to bring together scientists who are investigating acidic deposition effects in or near the Recreation Area. The workshop was eminently successful in fostering communication among regional scientists and with the park staff, and in developing management recommendations for the park. See Recent Publications for citation of the workshop report.

# RECENT PUBLICATIONS

This section lists selected publications on environmental quality that resulted from studies in the National Park System or that relate more generally to pollution issues.

## General and Miscellaneous

Bennett, J. 1985. Regulatory uses of SO<sub>2</sub> effects data. Chapter 2 in Winner, W., H. Mooney, and R. Goldstein, eds. *Sulfur Dioxide and Vegetation*. Stanford University Press, Stanford, CA.

Berrang, P., D. Karnosky, R. Mickler, and J. Bennett. 1986. Natural selection for ozone tolerance in *Populus tremuloides*. Submitted to *Science*.

Council on Environmental Quality. 1986. *Environmental Quality, 1984*. U.S. Government Printing Office, Washington, D.C.

Glass, G., and O. Loucks. 1986. Implications of a gradient in acid and ion deposition across the northern Great Lakes States. *Environmental Science Technology* 20: 35-43. This is a nice summary and statistical analysis of National Atmospheric Deposition Program (NADP) data up to 1982 for the Upper Midwest. It points out approaches others might want to use in the analysis of NADP data for their region. (Stottlemeyer)

Hogsett, W., M. Plocher, V. Wildman, D. Tingey, and J. Bennett. 1985. Growth response of two varieties of slash pine seedlings to chronic ozone exposures. *Canadian Journal of Botany* 63:2369-2376.

Interagency Task Force on Acid Precipitation. National Acid Precipitation Assessment Program, Annual Report, 1985. Expected to be available about June 1986.

Interagency Task Force on Acid Precipitation. National Acid Precipitation Assessment Program, 1985 Assessment Report. Expected to be available about September 1986. This and the report above are available from: Director, NAPAP, 722 Jackson Place, N.W., Washington, D.C. 20506.

Malm, W., R. Eldred, T. Cahill, and J. Molenar. Visibility and particulate measurements in the western United States. Paper presented at 78th annual meeting of the Air Pollution Control Association, Detroit, Michigan, June 1985.

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Oppenheimer, H., C. Epstein, and R. Yuhnke. 1985. Acid deposition, smelter

emissions, and the linearity issue in the western United States. *Science* 229:859-862.

Rosencranz, A. 1986. The acid rain controversy in Europe and North America: a political analysis. *Ambio* 15(1):47-51.

Roth, P., C. Blanchard, J. Harte, and H. Michaels. 1985. The American West's Acid Rain Test. World Resources Institute, Washington, D.C. 50 p. Copies may be purchased from WRI Publications, P.O. Box 620, Holmes, PA 19043-0620.

Schindler, D., K. Mills, D. Malley, D. Findlay, J. Shearer, I. Davies, M. Turner, G. Linsey, and D. Cruikshank. 1985. Long-term ecosystem stress: the effects of years of experimental acidification on a small lake. *Science* 228:1395-1401. While there have been numerous testimonies to the value of ecosystem-level research in terrestrial ecosystems, this is a strong testimony to the value of such research in an experimentally manipulated aquatic system. (Stottlemeyer)

Stottlemeyer, R. 1986. Monitoring and quality assurance procedures for the study of remote watershed ecosystems. Amer. Soc. Test. Materials. In press. Abstract of this is in *Ecol. Bull.* 66(2):277.

U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards. 1986. National Air Quality and Emissions Trends Reports, 1984. U.S.E.P.A. Available from Public Information Center, U.S.E.P.A., 820 Quincy St., N.W., Washington, D.C. 20011. Phone: 800-828-4445.

Waring, R., and W. Schlesinger. 1985. *Forest Ecosystems: Concepts and Management*. Academic Press, New York. 340 p. Excellent summary of factors one should consider when undertaking and designing ecosystem-level research, especially in terrestrial systems. (Stottlemeyer)

## National Park System—General

American Law Division, Congressional Research Service, Library of Congress. (1985?). Comments on "Protection of national park system units from the adverse effects of air pollution." Legal memorandum.

Bennett, J. 1985. Overview of air pollution effects on national parks vegetation in 1985. *Park Science* 4(4):8-9.

Buffone, S., and C. Fulco. 1986. Acid Rain in the National Parks. Available summer 1986 from National Parks and Conservation Association, 1701 Eighteenth St., N.W., Washington, D.C. 20009.

Cooperative Institute for Research in the Atmosphere. 1985. Assessment of Visibility Impairment on Visitor Enjoyment and Utilization of Park Resources. Colorado State University, and National Oceanic and Atmospheric Administration. Prepared for the National Park Service.

Flora, M., and S. Kunkle. Development of water quality monitoring strategies in two units of the National Park Service. Paper presented at the National Wilderness Research Conference, Fort Collins, CO, July 23-26, 1985.

Henderson, D., M. Liu, and D. Stewart. 1985. Long distance transport of man-made air pollutants. *Park Science* 5(2):6-8.

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National Park Service, Air Quality Division. 1984. National Park Service Air Resource Management Manual. 80 p. plus appendices. Available from NPS, Air Quality Division, P.O. Box 25287, Denver, CO 80225.

National Park Service, Water Resources Field Support Laboratory. 1984. Water Quality Criteria: An Overview for Park Natural Resource Specialists. WRFSL Report No 84-4. 46 p. Available from: Director, Water Resources Field Support Laboratory, NPS, 107C Natural Resources, Colorado State University, Fort Collins, CO 80523.

Ross, D., and W. Malm. 1986. Visual air quality and the national park visitor. *Park Science* 6(2):14-15.

Sherwood, S. 1984. The National Park Service research program on the effects of air pollution on cultural properties. Paper presented at annual meeting of Air Pollution Control Association, San Francisco, CA, June 24-29, 1984.

U.S. Dept. of the Interior, Associate Solicitor. (1985?). Protection of National Park System Units from the Adverse Effects of Air Pollution. Legal memorandum.



Mine spoil embankments along the Big South Fork of the Cumberland River, Big South Fork NRRA. The highly acidic, pyritic shale in these spoils prevents natural revegetation and adds to erosion and acid runoff problems.

## National Park System—Specific Areas

### Acadia NP

Kahl, J., J. Anderson, and S. Norton. 1985. Water Resource Baseline Data and Assessment of Impacts from Acidic Precipitation, Acadia National Park, Maine. Prepared for NPS, Water Resources Program, North Atlantic Region. Technical Report No. 16. Includes the technical report and an evaluation for management that summarizes the technical report.

### Canyonlands NP

Henderson, D. In press. A mathematical model for predicting night sky glow and its application to Canyonlands National Park. *Jour. Astronomical Society of the Pacific*.

### Delaware Water Gap NRA

Baron, J., J. Karish, and E. Johnson (eds.). 1985. Acidic Atmospheric Deposition in Delaware Water Gap National Recreation Area. Proceedings of a Workshop, January 18, 1985 and Management Recommendations, 56 p. Contains a summary of the workshop, abstracts presented at the workshop, management recommendations, references, and a list of participants.

### Great Smoky Mountains NP

Baes, C., and S. McLaughlin. 1986. Multielemental Analysis of Tree Rings: A Survey of Coniferous Trees in the Great Smoky Mountains National Park. Oak Ridge National Laboratory Publ. No. 6155. Environmental Sciences Division Publ. No. 2640.

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A technician examines a field exposure test rack with Vermont marble (foreground) and Indiana limestone (background) at Research Triangle Park, NC.