

Redesigning the National Park Service (NPS) Gaseous Pollutant Monitoring Network to Meet Servicewide Needs

BACKGROUND

The Air Quality Division's (AQD) Gaseous Pollutant Monitoring Network has grown dramatically since 1986 in response to expressed needs of individual parks and Congress. The network has grown to 42 stations in 35 NPS units and represents one of the largest networks of non-urban air pollution monitoring stations in this country. Although this is a laudable achievement, the resources necessary to maintain this growth has not kept pace. Therefore, it is necessary to implement some changes in the network's design and operations that are in line with available resources while at the same time affording the Service a systematic approach to meet its data needs. This paper discusses several important aspects related to the re-design of this network.

INTRODUCTION

The National Park Service (NPS) seeks "to perpetuate the best possible air quality in parks because of its critical importance to visitor enjoyment, human health, scenic vistas, and the preservation of natural systems ... [and] will assume an aggressive role in promoting and pursuing measures to safeguard [air quality related values] from the adverse impacts of air pollution" [see NPS Management Policies (4:17)]. NPS Natural Resources Management Guideline (NPS-77) includes the following management activities with respect to air resource management:

- inventorying air quality related values associated with each park
- monitoring and documenting the condition of air quality and related values
- evaluating air pollution impacts and identifying causes.

These objectives and activities are based on authorities contained in the NPS Organic Act of 1916, the individual acts establishing the parks, the Clean Air Act, and other Federal statutes. The NPS Organic Act provides the fundamental basis for the protection and preservation of park resources vulnerable to the impacts of air pollution. Moreover, one of the stated purposes for the enactment of the Clean Air Act is to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population" [Section 101(b)(1)]. Recognizing the value of pristine air quality in specially designated areas such as national parks and wilderness areas, the Congress amended the Clean Air Act in 1977 by adding a section to protect the air quality in these areas from any further degradation. One of the purposes of the Prevention of Significant Deterioration (PSD) Section of the Clean Air Act 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.

To accomplish this goal, Congress established a classification system for areas having air quality better than the national ambient standards. The Clean Air Act provides the highest degree of protection in areas designated as class I, allowing only very slight deterioration of air quality over baseline conditions in these areas. These areas include all national parks greater than 6,000 acres and national wilderness areas greater than 5,000 acres in existence at the time the 1977 amendments were enacted (August 7, 1977). Forty-eight NPS units meet this criterion. In terms of maximum allowable increases over existing, or baseline, air quality levels that could occur in areas having air quality better than the national ambient standards.

To meet its general responsibilities with respect to air resource management, the Service has established a framework to protect, preserve, and enhance the air quality in units of the National Park System, particularly class I areas. This framework is heavily dependent on comprehensive monitoring programs to determine the levels of gaseous pollutants, fine particles, and visual air quality occurring or affecting NPS units. The gaseous pollutant monitoring program has historically concentrated on determining the levels of two air pollutants, ozone and sulfur dioxide. These pollutants are particularly toxic to native vegetative species found in NPS units at levels at or below the National Ambient Air Quality Standards established by the Environmental Protection Agency (EPA) for these two pollutants. Other gaseous pollutants (e.g., other photochemical oxidants, nitrogen compounds, and toxic organic compounds) are also of interest to NPS as they relate to physiological, morphological, or histological injury to park biological resources, or to global climate change.

The primary monitoring objectives for the gaseous pollutant monitoring program are to:

- Establish existing, or baseline concentrations in NPS units
- Assess trends in air quality in NPS units
- Judge compliance with national air quality standards
- Assist in the development and revision of national and regional air pollution control policies affecting park resources
- Provide data for atmospheric model development and evaluation
- Identify those air pollutants with the potential to injure or damage park natural resources, monitor these pollutants, and correlate measurable effects on these resources to ambient levels of these pollutants

This paper discusses a systematic approach to meet many of these monitoring objectives and focuses specifically on redesigning the existing network to achieve these objectives within current resource allocations. Before proceeding, however, a brief discussion on the history of gaseous pollutant monitoring activities within the National Park Service is necessary.

Before the NPS Air Quality Division was established in 1977, air quality monitoring activities were not centralized but rather were conducted as a result of individual park initiatives, typically using agreements with State and local air pollution control agencies or universities. Most of the monitoring involved total suspended particulate sampling, with few instances of continuous monitoring of gaseous pollutants. With the formation of the Air Quality Division, air quality monitoring activities were centralized and funded through a Servicewide Air Quality account. The emphasis shifted from total suspended particulate sampling to continuous monitoring for ozone and sulfur dioxide for reasons cited earlier. Most of the monitoring conducted during the period 1979 through 1984 was performed through formal and informal agreements with State and local air pollution control agencies but funded using Air Quality Division (AQD) funds. Relatively few parks funded these activities out of park base funding. Generally speaking, gaseous pollutant monitoring was conducted in NPS units where the AQD was funding some type of air pollution biological effects studies. Lack of sufficient resources, however, allowed for gaseous pollutant monitoring activities to be performed at only a relatively few locations and prevented the NPS from operating a cohesive, well-equipped network which met EPA requirements. In 1984, the Air Quality Division initiated a conscientious effort to upgrade its gaseous pollutant monitoring program by adopting an interim strategy that called for compliance with EPA's monitoring regulations (including quality assurance requirements), standardization and automation of the network, and improved data processing and reporting capabilities. By shifting funds from other AQD programs, the Division was able to address only the first two of these activities, however. Funds were used to procure additional equipment and to increase the level of services provided by monitoring support contractors in the areas of network supervision, field operations, and quality assurance.

In May 1985, the Subcommittee on National Parks and Recreation of the Committee on Interior and Insular Affairs, House of Representatives, conducted hearings on the impacts of air pollution on national parks. The Subcommittee found that there was insufficient air quality monitoring being conducted in Prevention of Significant Deterioration (PSD) class I areas administered by the National Park Service. The Subcommittee identified 17 class I areas in which no air quality monitoring was being conducted. As a result, Congress appropriated increased base funding to NPS in fiscal years 1986 and 1987 specifically designated for air quality monitoring in these areas. With the addition of these stations, the size of the network grew from 14 to 31 sites. The increase in base funding also allowed for further development of the infrastructure necessary to operate and maintain an expanding network. This included the use of NPS personnel for routine site operation, the development of a training program to train NPS personnel as site operators, and the establishment of a data center to process and validate data collected in NPS units. It was also possible to expand parameter coverage to include meteorological monitoring and time integrated sampling for sulfur dioxide at most NPS locations.

Since 1987, the size of the network has gradually increased due to increasing Servicewide needs as articulated by individual parks and Regional Air Quality Coordinators. Presently the NPS gaseous pollutant network consists of 42 stations in 35 parks, 28 of which are class I areas. Figure 1 is a map of the network showing the location of each station and the parameters measured at each location. All but one station (Steamtown National Historic Site which measures only sulfur dioxide on a continuous basis) are equipped with continuous ozone analyzers. Twenty of the sites also measure sulfur dioxide on a time-integrated basis (2 24-hour samples per week).

Figure 1

Thirty-two stations are equipped with meteorological towers. The NPS network represents one of the largest networks of non-urban monitoring stations in this country. As such it contributes significantly to NPS resource management activities at the park level and on a Systemwide basis. In spite of the growth of the network since 1986, the demand for air quality monitoring in NPS units continues to far exceed the Service's available resources. The network also places extreme demands on AQD staff (2 full-time monitoring specialists) responsible for its operation and maintenance.

In order to afford a more systematic approach to the deployment of air monitoring stations and to ensure that air quality data will be available to guide resource management decisions on a Systemwide basis, NPS has developed a monitoring strategy that provides a mechanism to fulfill its highest priority air quality data needs. The major elements of this strategy call for NPS to:

- Establish a classification system and design criteria for a monitoring network.
- Expand parameter coverage to pollutants that would aid in the understanding of environmental processes, cause-effect and source-receptor relationships, documentation of all important air quality parameters in class I areas, and identification of emerging issues, such as global climate change and air toxics.
- Seek out and formalize closer linkages with internal and external programs.
- Promote the development and use of low-cost, low-maintenance monitoring techniques for remote areas, particularly those with complex terrain.
- Conduct intensive special studies as needed to address critical management issues and legal requirements.
- Establish a Quality Assurance program covering all air monitoring activities to ensure the collection of scientifically sound data.
- Ensure sufficient resources are allocated to data analysis, quality assurance, and data dissemination.

The remainder of this paper deals primarily with the first strategy element: the establishment of a monitoring network based on a two-tiered site classification system; the criteria employed in the selection of sites that will be part of the network; and a schedule to implement monitoring activities at new NPS locations. Other strategy elements are discussed briefly.

DESIGN CONSIDERATIONS FOR THE NETWORK

The NPS gaseous pollutant monitoring network will be comprised of two types of stations: trends and baseline. Trend stations will be strategically located throughout the U.S. and maintained indefinitely in selected NPS areas to serve as the primary source of air quality information to guide NPS air resource management decisions. To the extent possible, the NPS trends network will be comprised of air monitoring stations that are currently operating (as depicted in Figure 1). The trend stations will be supplemented by a fewer number of baseline stations whose primary purpose will be to document existing air quality levels for a short period of time, typically 3 to 5 years, after which time the stations will be re-deployed to other NPS areas. The intent of the strategy is to establish existing conditions in nearly all 48 NPS class I areas by the year 2000 and to re-activate each of the baseline sites on 5 to 10 year intervals to determine whether air quality levels have changed from those measured when the area was monitored previously.

The primary objective of the trends network is to provide NPS managers with the data necessary to fulfill air resource management mandates on a Systemwide basis. Data from the trends network will serve to characterize the spatial and temporal distribution and trends of key air quality indicators on a Systemwide basis. The data will also be used to influence environmental policy and regulation at the national, regional, and local level. Once established the trends network will be operated and maintained indefinitely, and the data obtained from the network would serve to represent the status of the air resource throughout the entire National Park System. Other objectives of the network would be to assess the attainment status of NPS areas with respect to the national ambient air quality standards, to document existing conditions at each of the parks comprising the network, and to make estimates of the dry deposition of pollutants on NPS lands and resources. From a design standpoint, the data from the trends network should be able to characterize the range of values for these air quality indicators, the extent to which these indicators are influenced by manmade activities (internal or external to the parks), and whether any observed

changes are attributable to natural variation or to man-made activities. In order to characterize the range of air quality levels throughout the System, locations that are influenced from the emissions of urban areas, industrial source areas, or a combination of both, as well as areas with minimal influence from these sources, will be monitored. To the extent possible, trend stations will be representative of regional-scale air pollution levels within relatively large biogeographic areas.

Several factors need to be considered in the design of a trends network. These same factors can also aid in determining the priority in which ambient monitoring would be conducted at baseline sites. The following factors were considered: (1) Clean Air Act designation; (2) potential changes in air quality; (3) existing air quality conditions; (4) ecological region representativeness; (5) park/regional priority; (6) park special designations; and, (7) participation in other NPS monitoring and research programs. These factors were evaluated for their relative importance with respect to air quality monitoring (in the context of network design) and were used to develop a numerical ranking procedure to facilitate the selection of trend sites. This procedure was applied to the largest NPS areas and the numerical score obtained for each of these areas was used to select trend stations. A detailed description of the ranking procedure, how each of the factors was weighted, and how each NPS area was scored on each of the factors is presented in the Appendix. Table A-1 in the Appendix provides a listing of the total scores for each of the NPS areas considered in the analysis broken down by bio-geographic region.

Some of the major considerations used for re-designing the existing NPS network are discussed in more detail in the following sections.

Ecoregion Representativeness. An important consideration for network design, from a resource management standpoint, is the concept of ecoregion representativeness. If the NPS trends network is to be indicative of the air quality levels that may adversely affect the resources entrusted to the NPS, trend sites should be strategically located in areas that are representative of those resources. On a Systemwide basis, the primary natural resource considered to be at high risk from air pollution, from a gaseous pollutant and acidic deposition viewpoint, is vegetation. Some species of vegetation native to national parks have been found to be sensitive to ambient levels of ozone below the National Ambient Air Quality Standard. As a result, the Air Quality Division's biological effects program has traditionally focused on evaluating the incidence and severity of air pollution injury to vegetative species found in NPS lands. It is reasonable, therefore, to use the distribution of vegetation types for design purposes and for the allocation of trends sites within the network.

One categorization that considers vegetation type is that compiled in Robert G. Bailey's *Description of the Ecoregions of the United States*¹. Bailey's description of ecoregions considers not only the dominant vegetation within these regions but also other dominant physical and biological characteristics, i.e., land-surface form, climate, soils, and fauna. According to Bailey public land managing agencies "have recognized the need for a comprehensive system for classifying ecosystems as an aid in achieving quality land management." Bailey's classification facilitates planning at the national level, the organization and retrieval of data gathered in a resource inventory, and the interpretation of inventory data. Therefore, a reasonable basis for achieving a balanced network is to use Bailey's classifications and to allocate sites to each ecoregion proportionally on the basis of NPS land acreage in each ecoregion. Allocating sites in this manner would ensure that lands possessing most dominant vegetation types occurring in NPS areas would be represented in the network.

Network Size. Ideally, resource management needs and monitoring objectives dictate the size of a monitoring network. In general, objectives requiring a high level of temporal and spatial resolution will require more frequent measurements at a greater number of locations. Network size is dependent on the diversity of air pollution emissions, the meteorology, the topography, the number of sensitive receptors, and the degree of spatial resolution required of an area. The greater the diversity in these factors, the greater the number of monitoring sites that will be required to adequately characterize air quality levels. Because of the diversity in these factors with the National Park System and because the System includes units throughout all but one of the 50 states, a large NPS network would be required. Ideally, the NPS network should be able to adequately characterize air quality levels in all ecoregions and

at most, if not all, of its class I areas. Since Bailey's classification consists of 30 Provinces and there are 48 class I areas, the minimum size of the network would be at least 48 stations, assuming that class I areas are sufficient to characterize levels in all of these ecoregions. However, it is unlikely that this number of stations could adequately characterize air quality levels for the entire National Park System, given the diversity of topography, meteorology, etc., within the System.

Realistically, however, network size is usually determined by the budgetary constraints of the organization. Since 1987, the funds allocated to the Air Quality Division have remained constant and has not kept pace with increasing costs of operating and maintaining its widespread monitoring networks. The erosion of an organization's base funds due to inflation lead inevitably to the reduction in the amount of services that an organization can provide. Even at the low annual rates of inflation which have occurred since 1987, the buying power of available funds has decreased on the order of 20%. No program, no matter how efficiently it is operated, can withstand this type of budgetary erosion. Compromises must be made, therefore, to balance data needs with the costs required to obtain information.

In the case of the NPS gaseous pollutant monitoring program, this translates into an overall reduction in the number of sites that the Air Quality Division can operate and maintain while still meeting the Service's data capture goals and quality assurance requirements. Based on our current funding levels, the Division can effectively manage a network of 32 stations over the next 5 years, after which time an additional reduction in the network will have to occur at present funding levels. A network size of 32 stations would require all stations to be designated as trends stations. However, this would not allow NPS to document existing levels at all NPS class I areas, and the Division's goal to document existing levels in all of its 48 class I areas by the year 2000 would not be met. As a compromise, the size of the trends network must be decreased substantially to 24 stations to accommodate this goal. This would leave a total of 8 baseline stations to meet the goal and provide some flexibility to the network. The use of 8 baseline stations would allow for the characterization of air quality levels in all of the 48 NPS class I areas using the re-deployment scheme discussed earlier. However, the designation of only 24 trend stations will not provide the desired coverage in all ecoregions and additional resources will have to be secured in order to establish a network that meets the needs of the Service. A significant deficiency in the network would be its inability to accommodate gaseous pollutant monitoring at any of its class II areas other than the few that are included as part of the trends network.

Existing Monitoring Networks.

Another important design criteria to be considered is the availability of air pollution data generated by existing networks and the extent to which these data can meet NPS needs. Although the primary design criteria for state networks is population oriented, several states maintain remote stations -
- sometimes located in national parks -
- to serve as "background" sites for these networks. In addition to these state networks, the U.S. EPA recently established a national network of dry deposition monitoring stations. As of 1989, EPA operates fifty-one stations as part of this network (see Figure 2) with forty-two in the eastern U.S. and nine in the western U. S. Assuming the long-term continuation of EPA's National Dry Deposition Network (NDDN), this network should be able to satisfy most NPS trends data needs



Figure 2. NDDN Monitoring Stations

for the eastern portion of the country, but will be inadequate for the western U.S.

An important recent development that may have significant bearing on existing networks is the enactment of the 1990 amendments to the Clean Air Act. These amendments place significant new requirements on the EPA for air pollution monitoring in non-urban areas. In fact, these requirements call for the EPA to establish national networks of non-urban monitoring stations for the determination of the status and trends of air pollution levels and environmental effects. This Clean Air Status and Trends Network (CASTNET) will likely expand the spatial coverage of the NDDN and other existing networks and will also focus on multiple air pollution monitoring objectives (e.g., wet and dry acidic deposition, aquatic and terrestrial effects, air toxics, and visibility) in an effort to determine (among other things) the effects of the 10-million ton reduction in sulfur oxides emissions required under the 1990 amendments. An integral part of CASTNET will be existing monitoring networks, such as those operated by the NPS, and EPA's NDDN. The extent that the NPS network can complement and supplement existing networks should be a consideration in the NPS network design. Thus, the large number of EPA NDDN monitoring stations in the eastern U.S. obviates the need for NPS trend sites in this region of the country. Also five long-term NDDN monitoring stations operated by EPA (Chiracahua NM, Glacier NP, Grand Canyon NP, and Shenandoah NP) and the State of North Dakota (Theodore Roosevelt NP) will be used to satisfy NPS needs within their respective ecoregions.

Clean Air Act Designation. A park's designation under the Clean Air Act, e.g., class I area, is a major consideration in the NPS network design. Under the 1977 amendments to the Clean Air Act, 48 areas administered by the NPS (national parks, monuments, etc., larger than 6,000 acres and wilderness areas larger than 5,000 acres) were designated as class I areas affording them special protection under the Prevention of Significant Deterioration provisions of the Act. To the extent that these areas can provide adequate coverage of each of the major ecoregion divisions, the NPS trends network should be comprised of class I areas. The total combined acreage of these 48 areas is 21,127,298 acres, or 26% of the total NPS land acreage of 79,997,167². This rather low percentage is due to the fact that Alaska lands (those in Bailey's Polar Domain only) account for 63% of all NPS lands while only 1 national park in Alaska (Denali) is currently designated as a class I area. Nonetheless, with few exceptions these class I areas represent most of Bailey's ecoregions fairly well. Figures 3 and 4 give a breakdown of NPS class I area land acreage by Bailey ecoregion division and the number of class I areas by these divisions, respectively. As can be seen from Figure 3, Denali NP & Preserve, the only class I area in Alaska, accounts for 28.5% of the total NPS class I area acreage yet Denali represents slightly more than 2% of the total number of class I areas (see Figure 4). On the other hand, NPS class I areas in the Steppe division (which includes parks in the Colorado Plateau) not only account for a significant portion of total class I area acreage but also account for nearly one-half of all NPS class I areas. Figure 5 gives the percent of total NPS land acreage that class I areas comprise within each Bailey ecoregion. As can be seen from this figure, the percent of class I area acreage within each of Bailey's ecoregion divisions ranges from 0



Figure 3

(Prairie, Subtropical and Tundra) to nearly 100% (Rainforest). In most cases, class I areas appear to cover each ecoregion adequately. Thus, it appears reasonable to use class I areas primarily as locations for trend sites.

RESULTS AND DISCUSSION

In order to select the NPS trend sites and prioritize monitoring activities at baseline sites a methodology was developed that considered the factors listed earlier. This methodology included the formulation and application of a ranking procedure based on the above factors to the largest 194 NPS areas. The areas ranged in size from 144 acres to 13,188,325 acres representing a combined acreage of 77,334,028 acres, or 97% of total NPS lands. The results of this ranking procedure were incorporated with the results of the proportional allocation based on acreage. NPS areas were designated as trend sites by selecting the highest ranking areas within each ecoregion. Table A-1 of the Appendix provides the listing of total scores for each of the 194 areas considered, listed by descending score within each

Figure 4



Figure 5

ecoregion.

Regional Allocation of Trend Sites. Table 1 provides a breakdown of NPS land acreage by Bailey ecoregion division as well as how sites would be allocated within each of the ecoregions using proportional allocation based on land acreage. As can be seen from column (4) of the table, 15 of the 24 trend sites would be allocated to NPS areas located in Alaska because of vast NPS holdings in that state. Such a design would not meet the Systemwide needs, however. In order to achieve a more reasonable network balance, sites were re-allocated based on the following: (1) each of the Tundra and Subarctic Divisions would be allocated one trend site; and, (2) the remaining 22 sites would be allocated proportionally without considering Alaska land acreages contained in these two divisions. Column (6) of Table 1 gives the number of trend sites to be allocated within each ecoregion based on the above two conditions. This results in a more numerically balanced network although the Prairie and Rainforest divisions would still not be represented.

Table 1. NPS Land Acreage by Bailey's Ecoregions and the Allocation

of Trend Sites within each Ecoregion

| (1) | (2) | (3) | (4) | (5) | (6) |
|-----|-----|---------------------|---------------|---------------------|---------------|
| | | <i>Div. Acreage</i> | <i>No. of</i> | <i>Div. Acreage</i> | <i>No. of</i> |
| | | | | | |

| <i>Bailey's Ecoregion Division</i> | <i>NPS Land Acreage</i> | <i>Percent of Total NPS Acreage</i> | <i>Trend Sites based on Col. (3)</i> | <i>Percent of Total NPS Acreage less Alaska Acreage</i> | <i>Trend Sites based on Col. (5)</i> |
|--------------------------------------|-------------------------|-------------------------------------|--------------------------------------|---|--------------------------------------|
| <u>Polar Domain</u> | | | | | |
| <i>Tundra</i> | 20,242,186 | 26.2 | 6 | -- | 1 |
| <i>Subarctic</i> | 30,476,836 | 39.5 | 9 | -- | 1 |
| <u>Humid Temperate Domain</u> | | | | | |
| <i>Warm Continental</i> | 2,245,722 | 2.9 | 1 | 8.4 | 2 |
| <i>Hot Continental</i> | 1,637,586 | 2.1 | 1 | 6.2 | 1 |
| <i>Subtropical</i> | 461,804 | 0.6 | 0 | 1.7 | 1 |
| <i>Marine</i> | 6,179,295 | 8.0 | 2 | 23.2 | 5 |
| <i>Prairie</i> | 154,458 | 0.2 | 0 | 0.6 | 0 |
| <i>Mediterranean</i> | 2,190,989 | 2.8 | 1 | 8.2 | 2 |
| <u>Dry Domain</u> | | | | | |
| <i>Steppe</i> | 7,686,823 | 9.9 | 2 | 28.9 | 6 |
| <i>Desert</i> | 3,728,525 | 4.8 | 1 | 14.0 | 3 |
| <u>Humid Tropical Domain</u> | | | | | |
| <i>Savanna</i> | 2,061,070 | 2.7 | 1 | 7.7 | 2 |
| <i>Rainforest</i> | 268,734 | 0.3 | 0 | 1.0 | 0 |

To achieve the ecoregion balance of the proposed network several adjustments to the number of sites by ecoregion given in Table 1 were required. To avoid having two Divisions not being represented in the network, sites that would have gone to the Marine and Savanna Divisions were re-allocated to the Rainforest and Prairie Divisions. The desire to have each of the five NPS class I areas located in the eastern U.S. (Acadia, Everglades, Great Smoky Mountains, Mammoth Cave, and Shenandoah NPs) as trend sites resulted in 3 areas within the Eastern Deciduous Forest Province being proposed for inclusion in the network (in contrast to only one site that would have allocated proportionally). The use of NDDN and state operated sites in the Steppe Division to satisfy NPS needs accommodated the needs in other ecoregions. Arguably, a different set of criteria would have resulted in a different allocation, however, the proposed network would do well in providing very minimally the data necessary to meet NPS Servicewide needs.

Table 2 lists each proposed trend site within each ecoregion. These sites are displayed on a map of the U.S. in Figure 6. As can be seen from Table 2, only the Subtropical Division (Outer Coastal Plain Forest and Southeastern Mixed Forest Provinces) would not be represented by NPS-operated monitoring sites under the proposed network. This network would allow for at least one trend site in 19 of Bailey's 30 provinces. Of the 24 NPS trend sites being proposed, five areas are currently designated as class II areas (Death Valley, Great Basin, Indiana Dunes, Noatak, and Wrangell/St. Elias).

Allocation and Implementation of Baseline Monitoring. Establishing a network consisting of two types of sites accomplishes several objectives. It allows NPS to document existing air quality levels in all of its class I areas and it provides some degree of flexibility that a rigid design would preclude. The periodic review of the network will dictate any shifts in emphasis at baseline sites to accommodate emerging problems. One of the elements of the monitoring strategy calls for conducting intensive special studies to address these problems, and such studies would take precedence over baseline monitoring. The biggest deficiency of the network is that it will not be able to accommodate monitoring activities in NPS class II areas. This is not a flaw in the design but rather the consequence of budgetary constraints.

To implement the baseline monitoring portion of the network, NPS will periodically re-deploy the 8 stations to different class I areas not part of the trends network. After a 5 to 10 year hiatus at each location, monitoring would be conducted again for a 2 to 3 year period to determine whether air quality levels had changed from the previous monitoring period. Table 3 provides a schedule as to how this might be implemented. The first priority in FY 92 would be to deploy several of the trends stations to areas that are not currently part of the network. In order to achieve this, as well as an overall reduction in the size of the network, monitoring activities at 12 stations will have to be suspended. Monitoring at all class II areas and the lowest ranking class I stations would cease in FY 92. The deployment of trends stations would be completed in FY 93. The deployment of new baseline sites would begin in FY 94, at which time most monitoring at existing non-trends sites would be terminated. Beyond 1995, the schedule given in Table 3 becomes much less certain, however, it does provide an idea as to how the re-deployment scheme would work.

Multiple Sites. Several parks (Sequoia, Shenandoah, and Yosemite) currently operate more than one station due to the biological effects studies being conducted at these parks. It will be the Division's policy to support only one station at each park using Servicewide Air Quality funding. Whenever additional stations are required as part of biological effects studies being conducted at the park, the Division may fund additional sites at a park. In fairness to other parks, however, additional air quality monitoring should be funded from other sources such as park base, NRPP, or I & M. In the case of the three parks in question, suspending monitoring at this time would undermine the results of planned physiological studies by the EPA at these parks, the results from which would benefit the Service as a whole. Therefore, the AQD will continue to support operations at more than one location in each of these parks until such studies are completed in FY 93.

Parameter Coverage. Currently, the only gaseous pollutants monitored in the network are ozone and sulfur dioxide, and several meteorological parameters. There are numerous other pollutants that affect resources within the Park System and that are of interest to the Service. At a minimum, each trends station should incorporate fine particle sampling using the IMPROVE protocols, wet deposition monitoring, and meteorological monitoring, and any other parameters currently monitored by the National Dry Deposition Network. This would facilitate the integration of NPS stations into the EPA's CASTNET program. Given the current funding levels, however, it is uncertain as to when this expansion in parameter coverage could be accomplished.

Table 2. NPS Trend Sites by Ecological Region

| <u>ECOREGION</u> | <u>NPS TREND SITE</u> |
|---|---|
| <u>Polar Domain</u> | |
| <u>Tundra Division</u> | Noatak NPres |
| <u>Subarctic Division</u> | Denali NP&Pres Wrangell/St. Elias NP |
| <u>Humid Temperate Domain</u> | |
| <u>Warm Continental Division</u> | |
| Laurentian Mixed Forest Province | Acadia NP Voyageurs NP |
| Columbia Forest Province | Glacier NP* |
| <u>Hot Continental Division</u> | |
| Eastern Deciduous Forest Province | Great Smoky Mountains NP Mammoth Cave NP Shenandoah NP* |
| <u>Subtropical Division</u> | None (Existing NDDN sites will be used) |
| <u>Marine Division</u> | |
| Willamette-Puget Forest Province | Mount Rainier NP |
| Pacific Forest Province | Olympic NP Redwood NP |

| | |
|---|-------------------------------|
| <i>Prairie Division</i> | |
| <i>Prairie Parkland Province</i> | <i>Indiana Dunes NL</i> |
| <i>Mediterranean Division</i> | |
| <i>California Chaparral Province</i> | <i>Pinnacles NM</i> |
| <i>Sierran Forest Province</i> | <i>Sequoia NP</i> |
| | <i>Yosemite NP</i> |
| <u><i>Dry Domain</i></u> | |
| <i>Steppe Division</i> | |
| <i>Great Plains Shortgrass Pr. Province</i> | <i>Theodore Roosevelt NP*</i> |
| <i>Intermountain Sagebrush Province</i> | <i>Great Basin NP</i> |
| <i>Mex. Highlands Shrub Steppe Province</i> | <i>Chiricahua NM*</i> |
| <i>Rocky Mountain Forest Province</i> | <i>Rocky Mountain NP</i> |
| | <i>Yellowstone NP</i> |
| <i>Colorado Plateau Province</i> | <i>Canyonlands NP</i> |
| | <i>Grand Canyon NP*</i> |
| | <i>Mesa Verde NP</i> |
| <i>Desert Division</i> | |
| <i>Chihuahuan Desert Province</i> | <i>Big Bend NP</i> |
| <i>American Desert Province</i> | <i>Joshua Tree NM</i> |
| | <i>Death Valley NM</i> |
| <u><i>Humid Tropical Domain</i></u> | |
| <i>Savanna Division</i> | |
| <i>Everglades Province</i> | <i>Everglades NP</i> |
| <i>Rainforest Division</i> | |
| <i>Hawaiian Islands Province</i> | <i>Hawaii Volcanoes NP</i> |

* EPA NDDN or State Operated Site

Figure 6

SUMMARY AND CONCLUSIONS

The re-design and various implementation aspects of a gaseous pollutant monitoring network for the National Park Service have been described. A two-tiered system of monitoring stations consisting of trends and baseline stations will be implemented beginning in FY 92. Trends sites, which will operate indefinitely, have been allocated on the basis of ecoregion size, with the number of sites within a given ecoregion being proportional to the NPS land acreage within the ecoregion. The objective of the trends network is to provide NPS managers with information necessary to address most air resource management issues on a Systemwide basis. The data from the network will serve to provide a pulse of what is happening throughout the entire System, to the extent that a relatively few number of sites can accomplish this. A fewer number of baseline sites will also be deployed with the primary objective being to document existing air quality levels in all 48 class I areas administered by the NPS. Baseline sites will be rotated among class I areas on a periodic basis in order to assess any changes in air quality levels from the previous monitoring period.

Air quality data needs within the Park System far exceed the Service's current financial resources available to meet these needs. Moreover, the inflation-caused erosion of the Air Quality Division's budget since the last significant increase in base funding (1987), necessitates a 25% reduction in the number of gaseous pollutant monitoring stations currently operating. This will not only widen the information gap but may also hamper the Service's ability to respond affirmatively to air quality issues on a Systemwide basis. New sources of funding will have to be found if the Service's air quality monitoring needs are to be met.

Table 3. Implementation Schedule for Gaseous Pollutant Monitoring at NPS Locations

| PARK | Year | | | | | | | | | | | | | | | | | | | |
|------------------------------|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 |
| <u>Trend Sites</u> | | | | | | | | | | | | | | | | | | | | |
| Acadia NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Big Bend NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Canyonlands NP | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chiricahua NM (NDDN) | | | | | | | | | | | | | | | | | | | | |
| Death Valley NM | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Denali NP and Preserve | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Everglades NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Glacier Bay NP/Pres/Wrangell | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Glacier NP (NDDN) | | | | | | | | | | | | | | | | | | | | |
| Grand Canyon NP (NDDN) | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Great Basin NP | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Great Smoky Mts. NP (LR) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hawaii Volcanoes NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Indiana Dunes NL | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Joshua Tree NM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mammoth Cave NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mesa Verde NP | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mount Rainier NP | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Noatak | | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Olympic NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pinnacles NM | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Redwood NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Rocky Mountain NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sequoia NP (Lower Kaweah) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Shenandoah NP-BM (NDDN) | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Theo. Roosevelt NP (State) | | | | | | | | | | | | | | | | | | | | |
| Voyageurs NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellowstone NP | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yosemite NP (Wawona Valley) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

0=Monitoring On-going; 1=Monitoring Established; 2=Monitoring Discontinued

| PARK | Year | | | | | | | | | | | | | | | | | | | |
|-----------------------------|------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 |
| <u>Other Class I Areas</u> | | | | | | | | | | | | | | | | | | | | |
| Arches NP | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Badlands NP | 1 | 0 | -1 | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 |
| Bandelier NM | 1 | 0 | 0 | -1 | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 |
| Great Sand Dunes NM | 1 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 |
| Great Smoky Mts.-Cove Mt. | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | | |
| Guadalupe Mountains NP | 1 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 |
| Haleakala NP | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | |
| Isle Royale NP | 1 | -1 | | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 |
| Kings Canyon NP | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | |
| Lassen Volcanic NP | 1 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 |
| Petrified Forest NP | 1 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 |
| Point Reyes NS | 1 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 |
| Saguaro NM | 1 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 |
| Sequoia-Ash Mountain | 1 | 0 | 0 | -1 | | | | | | | | | | | | | | | | |
| Shenandoah-Dickey Ridge | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | | |
| Shenandoah-Sawmill Run | 1 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | | | | | |
| Yosemite-Camp Mather | 1 | 0 | 0 | -1 | | | | | | | 1 | 0 | 0 | -1 | | | | | | |
| Yosemite-Valley | 1 | 0 | 0 | -1 | | | | | | | | | | | | | | | | |
| Black Canyon of the Gunn NM | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | |
| Bryce Canyon NP | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | |
| Capitol Reef NP | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | |
| Carlsbad Caverns NP | | | | | | | | | | | | | | | | | | | | |
| Crater Lake NP | | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | |
| Craters of the Moon NM | | 1 | 0 | 0 | 0 | -1 | | | | | | | | | | | | | | |
| Grand Teton NP | | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | |
| Lava Beds NM | | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | |
| North Cascades NP | | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | |
| Virgin Islands NP | | | | | | | | | | | | | | | | | | | | |
| Wind Cave NP | | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | |
| Zion NP | | | | 1 | 0 | 0 | 0 | -1 | | | | | | 1 | 0 | 0 | -1 | | | |
| <u>Class II Areas</u> | | | | | | | | | | | | | | | | | | | | |

0=Monitoring On-going; 1=Monitoring Established; 2=Monitoring Discontinued

| | | | | | | | | | | | | | | | | | | | | |
|----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Big Thicket NPre | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Colorado NM | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Cuyahoga Valley NRA | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Santa Monica Mountains NRA | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Steamtown NHS | 1 | -1 | | | | | | | | | | | | | | | | | | |
| Total No. of Sites | 42 | 34 | 34 | 31 | 34 | 33 | 33 | 33 | 33 | 35 | 33 | 30 | 28 | 30 | 33 | 33 | 33 | 33 | 33 | 29 |

0=Monitoring On-going; 1=Monitoring Established; 2=Monitoring Discontinued

APPENDIX

A Ranking Procedure for the Determination of Ambient Monitoring Priority in National Park Service Lands

Overview of Ranking Procedure

The proposed ranking procedure considers the following seven factors to rank parks. Each factor has been assigned a numerical weight based on whether the factor is of high, moderate, or low importance with respect to monitoring priority.

| <u>Factor</u> | <u>Importance</u> | <u>Weight</u> |
|---|--------------------------|----------------------|
| 1. Clean Air Act Designation | High | 20 |
| 2. Potential Changes in Air Quality | Moderate | 15 |
| 3. Existing Air Quality Conditions | Moderate | 15 |
| 4. Ecological Region Representativeness | Moderate | 15 |
| 5. Park/Regional Priority | Moderate | 15 |
| 6. Park Special Designation | Low | 10 |
| 7. Participation in Other NPS Monitoring and Research Programs | Low | 10 |

Factors 2 and 3 have sub-factors associated with them and are discussed in more detail under the Discussion section that follows. From the above factor listing, one can see that the maximum possible score is 100. A park's total score is the sum of the scores obtained under each factor. Scoring under each factor is discussed below.

Discussion

This section describes the rationale for each of the factors used and how each park is scored under each factor. A park receives a score equal to 100% of the factor weight if the park ranks high on a factor; 60% of the factor weight if it ranks moderate; and, 40% if the park ranks low on the factor. Given below is the criteria used under each factor to rank parks.

Factor 1: Clean Air Act Designation. Weight: **High** (20 points). The CA affords special protection to the Air Quality Related Values (including visibility) at NPS units designated as Class I. Therefore, Class I parks are given 100% of the weight on this factor. Because class II floor areas cannot be redesignated to the less protective class II category, class II floor areas are scored as moderate. All other NPS areas are scored low on this factor.

Factor 2: Potential Changes in Air Quality. Weight: **Moderate** (15 points). Monitoring priority should be given to those areas where changes in air quality are likely to occur in the future, such as areas where high industrial or urban development has been projected to occur. It is important to monitor in these areas to assess not only Systemwide air quality trends but also air quality changes in individual NPS units resulting from increased emissions. Two sub-factors, or predictors of potential air quality change, are proposed: projected regional emissions changes and the number of past PSD permits (by NPS region) reviewed by the AQD staff.

Based on projections contained in NAPAP's Interim Assessment, Volume II, projected changes for sulfur oxides, nitrogen oxides, and volatile organic compounds emissions between 1980 and 2030 have been broken down as follows:

| | | |
|-----------------------|-------------------------|--------------|
| <u>Sulfur Oxides:</u> | Projected Change | Score |
| | Emissions decrease | Low |

| | | | |
|--------------------------------|-------------------------|--------------|--|
| | 0 to +50 percent | Moderate | |
| | > 50 percent | High | |
| <u>Nitrogen Oxides:</u> | Projected Change | Score | |
| | 0 to +50 percent | Low | |
| | 51 to +100 percent | Moderate | |
| | > +100 percent | High | |
| <u>VOCs:</u> | Projected Change | Score | |
| | 0 to +15 percent | Low | |
| | 15 to +30 percent | Moderate | |
| | > +30 percent | High | |

Scores based on the number of past PSD permits, summed over each NPS region, are as listed below. It is necessary to sum over entire NPS regions otherwise Class II areas would be unnecessarily penalized on this sub-factor.

| Number of Permits Per NPS Region | Score | |
|---|--------------|--|
| <= 10 | Low | |
| 11 to 30 | Moderate | |
| > 30 | High | |

Factor 3: Existing Air Quality Conditions. Weight: **Moderate** (15 points). Ideally, existing conditions are best determined through monitoring, however, the current NPS monitoring networks are small in comparison to the number of NPS units. Therefore, approximations must be made to represent existing conditions at most NPS units. Three sub-factors are proposed to establish existing conditions: (1) current state-wide emissions of sulfur oxides, nitrogen oxides, volatile organic compounds, and toxic compounds; (2) available air quality monitoring data; and (3) proximity to current ozone non-attainment areas. The current emissions and monitoring data sub-factors are weighted high, whereas the proximity sub-factor is weighted as moderate. The total score for this factor is calculated from the weighted score on each of the sub-factors.

Current Emissions Sub-Factor. Weight: **Moderate**. Proximity to emissions sources greatly influences the concentrations of primary pollutants in an area, and to a lesser extent concentrations of secondary pollutants such as sulfates and ozone. Although long-range transport of pollutants occurs, regional air quality levels are highly and positively correlated with regional emissions of these pollutants. Thus, state-wide emissions can be used as an indicator of existing air quality in an area. However, a moderate weight is assigned to this sub-factor because this indicator cannot reflect the true spatial distribution of air quality levels on a state-wide basis.

The existing level of emissions are scored as follows:

| <u>Sulfur Oxides:</u> | Current Emissions (x 1000 tons) | Score |
|-----------------------|--|--------------|
| | 0 to 1000 | Low |
| | 1000 to 2000 | Moderate |
| | > 2000 | High |

| <u>Nitrogen Oxides:</u> | Current Emissions (x 1000 tons) | Score |
|-------------------------|--|--------------|
| | 0 to 500 | Low |
| | 500 to 1000 | Moderate |
| | > 1000 | High |

| <u>VOCs:</u> | Current Emissions (x 1000 tons) | Score |
|--------------|--|--------------|
| | 0 to 500 | Low |
| | 500 to 1000 | Moderate |
| | > 1000 | High |

| <u>Toxic Compounds:</u> | Current Emissions (x 10⁶ pounds) | Score |
|-------------------------|--|--------------|
| | 0 to 50 | Low |
| | 50 to 100 | Moderate |
| | > 100 | High |

(NOTE: No information on SOx, NOx, or VOC emissions for AK or HI; but assumed to be **low**)

Monitoring Data Sub-Factor. Weight: **High.** Measured air quality levels are the best indicators of existing conditions, but as discussed previously this type of information is available for only a few NPS units. NPS ozone, sulfur dioxide, and visibility data are considered. To supplement NPS air quality data, regional air quality averages (based on EPA regions) are used as indicators of existing air quality. Only ozone and sulfur dioxide regional averages are considered. For ozone, the regional average of the second-highest daily 1-hour concentration is used; for sulfur dioxide, the regional average of the annual average concentration. Both statistics are calculated from all sites operated during the period 1986-1988 that meet the minimum data capture requirements within each EPA region. Each park is scored on each of these components to this sub-factor in terms of the sensitivity of the resource to incremental increases of pollutant concentrations. Thus high levels of pollutants, or high visual ranges, translate to high sensitivity of the resource to being adversely affected by incremental increases in pollutant concentrations. Scores assigned to each component are as follows:

| | Current Levels | Score |
|------------------------------|--------------------------|--------------|
| <u>Ozone (NPS data).</u> | < 75 ppb | Low |
| | 75 to 110 ppb | Moderate |
| | > 110 ppb | High |
| <u>Ozone (EPA data).</u> | < 120 ppb | Low |
| | >= 120 ppb | Moderate |
| <u>Sulfur Dioxide (NPS).</u> | < 25% NAAQS ¹ | Low |

| | | |
|------------------------------|---------------------------|----------|
| | >= 25% NAAQS ¹ | Moderate |
| <u>Sulfur Dioxide (EPA).</u> | < 75 ppb | Low |
| | >= 75 ppb | Moderate |
| <u>Visibility (SVR).</u> | < 100 km | Low |
| | 100 to 150 km | Moderate |
| | > 150 km | High |

¹ NAAQS: National Ambient Air Quality Standard

Proximity Sub-Factor. Weight: **Moderate**. This sub-factor accounts for the influence that large urbanized areas currently not meeting the ozone NAAQS may have on nearby NPS units. Although the direction that an NPS unit is located relative to the non-attainment area is important, only the actual distance from the area to the NPS unit is considered, as indicated below.

| Distance, km | Score |
|--------------|----------|
| > 100 | Low |
| 50 to 100 | Moderate |
| < 50 | High |

Factor 4: Ecological Region Representativeness. Weight: **Moderate** (15 points). To the extent possible, NPS units that account for a significant portion of the total NPS land acreage within an ecological region should be given priority. Arguably, factors other than land acreage are required to determine how representative a particular NPS unit is of its respective ecological region. However, acreage alone is used until such time that other data are readily accessible. Bailey's ecological regions were used, however, only the first two digits (i.e., domain and division) were used in order to minimize the number of regions. This gave a total of 12 different ecological regions, which is a very manageable number, particularly if the trends network is to cover all regions. The score given to each park is the actual percent that the park's acreage is of the total acreage of the ecological region containing that park. As no park constitutes 100% of the total NPS acreage within an ecological region, each park's percent was "normalized" by dividing it by the maximum park percent in all regions. Hawaii Volcanoes NP ranked highest representing 85% of its respective ecological region. Therefore, all percents were divided by this number. Thus, only Hawaii Volcanoes NP can obtain a perfect score on this factor.

Factor 5: Park/Regional Priority. Weight: **Moderate** (15 points). In 1987, each park was asked to rank their air resource as a "primary, secondary, or other" resource as part of the NRAAP ranking procedure identifying critical resource issues within NPS. Parks indicating air as a primary resource are scored high on this factor; those with air as a secondary resource, moderate; and, those parks indicating "other", low.

Factor 6: Park Special Designation. Weight: **Low** (10 points). Parks having special designations, such as Biosphere Reserve or World Heritage Site, are awarded the entire weight on this factor. Other parks receive no points.

Factor 7: Participation in Other NPS Monitoring or Research Programs. Weight: **Low** (10 points). Parks that are currently watershed study sites, that have been identified as core research areas (or contributing areas) for the NPS Global Climate Change Initiative, or as a "targeted park" under the Administration's FY 92 Budget Initiative are scored as follows. Global Climate Change (GCC) recommended Core Research Areas and targeted parks proposing the extension of current air quality monitoring or research are scored high; parks identified as GCC contributing parks are scored moderate; and, watershed study sites are scored low. Other parks receive no points.

| TOTAL SCORE | NPS REGION | STATE | ECOREGION DIVISION | ECOREGION PROVINCE | PARK NAME |
|-------------|------------|-------|--------------------|--------------------|---------------------------------|
| 58.5 | AR | AK | Tundra | | Gates of the Arctic NP and Pres |
| 56.2592 | AR | AK | Tundra | | Noatak National Preserve |
| 49.78715 | AR | AK | Tundra | | Bering Land Bridge Npres |
| 48.56641 | AR | AK | Tundra | | Kobuk Valley NP |
| 47.27879 | AR | AK | Tundra | | Cape Krusenstern NM |
| | | | | | |
| 63.0713 | AR | AK | Subarctic | 1320 | Denali NP and Preserve |
| 53.5 | AR | AK | Subarctic | | Wrangell-St. Elias NP & Pres |
| 50.41357 | AR | AK | Subarctic | | Yukon-Charley Rivers Npres |
| 49.56679 | AR | AK | Subarctic | | Lake Clark NP and Preserve |
| 46.60146 | AR | AK | Subarctic | | Katmai NP and Preserve |
| 43.95759 | AR | AK | Subarctic | | Aniakchak NM & Preserve |
| | | | | | |
| 75.03214 | RMR | MT | Warm Continental | 2112M | Glacier NP |
| 64.80607 | MWR | MI | Warm Continental | 2112 | Isle Royale NP |
| 61.19155 | NAR | ME | Warm Continental | 2114 | Acadia NP |
| 54.25514 | MWR | MN | Warm Continental | 2111 | Voyageurs NP |
| 49.38644 | MWR | WI | Warm Continental | | Apostle Islands NL |
| 47.88347 | MWR | MI | Warm Continental | | Pictured Rocks NL |
| 47.86583 | MWR | MI | Warm Continental | | Sleeping Bear Dunes NL |
| 44.39232 | MWR | WI | Warm Continental | | Saint Croix NSRiverway |
| 41.56104 | PNR | WA | Warm Continental | | Coulee Dam NRA |
| 41.30117 | NAR | NY | Warm Continental | | Saratoga NHP |
| 38.80835 | MWR | WI | Warm Continental | | Lower Saint Croix NSRway |
| 38.77503 | MWR | WI | Warm Continental | | Lower Saint Croix Riverway |
| 38.72212 | MWR | MN | Warm Continental | | Grand Portage NM |
| 74.60357 | SER | TN | Hot Continental | 2214 | Great Smoky Mountains NP |
| 63.21429 | MAR | VA | Hot Continental | 2214 | Shenandoah NP |
| 58.95852 | SER | KY | Hot Continental | 2215 | Mammoth Cave NP |
| 51.96721 | SER | TN | Hot Continental | | Big South Fork NR & RA |
| 50.87963 | MAR | NY | Hot Continental | | Upper Delaware Scenic & Rec. R |
| 49.95844 | MAR | PA | Hot Continental | | Delaware Water Gap NRA |
| 48.34286 | MWR | OH | Hot Continental | | Cuyahoga Valley NRA |
| 47.95812 | SER | NC | Hot Continental | | Blue Ridge Parkway |

| TOTAL SCORE | NPS REGION | STATE | ECOREGION DIVISION | ECOREGION PROVINCE | PARK NAME |
|-------------|------------|-------|--------------------|--------------------|--------------------------------|
| 47.9289 | MAR | WV | Hot Continental | | New River Gorge NR |
| 47.88393 | SWR | AR | Hot Continental | | Buffalo NR |
| 47.58612 | MWR | MO | Hot Continental | | Ozark National Scenic Riverway |
| 47.58093 | NAR | MA | Hot Continental | | Cape Cod NS |
| 47.24286 | NAR | NY | Hot Continental | | Fire Island NS |
| 46.77354 | NAR | NY | Hot Continental | | Gateway NRA |
| 44.70016 | SER | TN | Hot Continental | | Obed Wild and Scenic River |
| 43.72265 | MAR | PA | Hot Continental | | Delaware NSR |
| 43.53482 | SER | GA | Hot Continental | | Chickamauga and Chattanooga NM |
| 43.4155 | SER | NC | Hot Continental | | New River, South Fork |
| 43.38425 | SER | AL | Hot Continental | | Russell Cave NM |
| 43.3392 | SER | KY | Hot Continental | | Cumberland Gap NHP |
| 43.15106 | MAR | PA | Hot Continental | | Valley Forge NHP |
| 43.09992 | MAR | PA | Hot Continental | | Friendship Hill NHS |
| 42.8069 | NCR | WV | Hot Continental | | Harpers Ferry NHP |
| 42.46591 | SER | MS | Hot Continental | | Natchez Trace Parkway |
| 41.15381 | SWR | AR | Hot Continental | | Pea Ridge NMP |
| 41.06623 | MWR | MO | Hot Continental | | Wilson's Creek NB |
| 41.03498 | MWR | MO | Hot Continental | | George Washington Carver NM |
| 40.91485 | NCR | MD | Hot Continental | | Chesapeake and Ohio Canal NHS |
| 39.33929 | MWR | WI | Hot Continental | | Ice Age Natl Scientific Reserv |
| 34.84213 | MWR | IN | Hot Continental | | Lincoln Boyhood NMem |
| 34.38555 | MWR | IA | Hot Continental | | Effigy Mounds NM |
| 33.37679 | NCR | MD | Hot Continental | | Antietam NB |
| 33.33417 | NCR | MD | Hot Continental | | Catoctin Mountain Park |
| 5.24201 | SER | GA | Subtropical | | Cumberland Island NS |
| 54.92919 | SER | NC | Subtropical | | Cape Hatteras NS |
| 54.83165 | SER | NC | Subtropical | | Cape Lookout NS |
| 54.13951 | SWR | TX | Subtropical | | Big Thicket Npres |
| 53.31397 | MAR | MD | Subtropical | | Assateague Island NS |
| 51.01977 | SER | FL | Subtropical | | Gulf Islands NS |
| 50.1856 | SER | FL | Subtropical | | Canaveral NS |
| 49.34396 | SWR | LA | Subtropical | | Jean Lafitte NHP and Preserve |
| 48.9272 | SER | SC | Subtropical | | Congaree Swamp NM |

| TOTAL SCORE | NPS REGION | STATE | ECOREGION DIVISION | ECOREGION PROVINCE | PARK NAME |
|-------------|------------|-------|--------------------|--------------------|---------------------------------|
| 45.32657 | SER | GA | Subtropical | | Kennesaw Mountain NBP |
| 45.09476 | NCR | VA | Subtropical | | Prince William Forest Park |
| 44.61701 | MAR | VA | Subtropical | | Fredericksburg and Spotsylvania |
| 44.19192 | MAR | VA | Subtropical | | Colonial NHP |
| 43.84948 | SER | GA | Subtropical | | Chattahoochee River NRA |
| 43.62495 | NCR | KY | Subtropical | | Manassas NBP |
| 43.58039 | SER | NC | Subtropical | | Kings Mountain NMP |
| 41.37079 | SWR | AR | Subtropical | | Hot Springs NP |
| 41.09161 | SWR | AR | Subtropical | | Arkansas Post Nmem |
| 38.09082 | NCR | DC | Subtropical | | Rock Creek Park |
| 37.41221 | SER | GA | Subtropical | | Ocmulgee NM |
| 35.79866 | SER | TN | Subtropical | | Shiloh NMP |
| 35.50949 | NCR | VA | Subtropical | | George Washington Mem Parkway |
| 35.34119 | MAR | VA | Subtropical | | George Washington Birthplace N |
| 63.85705 | PNR | WA | Marine | 2411M | Olympic NP |
| 62.16288 | WR | CA | Marine | 2414M | Point Reyes NS |
| 61.5 | AR | AK | Marine | | Glacier Bay NP and Preserve |
| 61.48146 | WR | CA | Marine | 2412M | Redwood NP |
| 61.10917 | PNR | WA | Marine | 2415M | North Cascades NP |
| 60.50282 | PNR | WA | Marine | 2415M | Mount Rainier NP |
| 56.13043 | PNR | OR | Marine | 2415M | Crater Lake NP |
| 52.16853 | WR | CA | Marine | | Golden Gate NRA |
| 46.92904 | PNR | WA | Marine | | Ross Lake NRA |
| 45.54028 | AR | AK | Marine | | Kenai Fjords NP |
| 43.94831 | WR | CA | Marine | | Muir Woods NM |
| 38.53953 | AR | AK | Marine | | Klondike Gold Rush NHP |
| 35.57708 | PNR | WA | Marine | | San Juan Island NHS |
| 35.57331 | PNR | OR | Marine | | Oregon Caves NM |
| | | | | | |
| 60.75 | SWR | TX | Prairie | | Padre Island NS |
| 47.4225 | MWR | IN | Prairie | | Indiana Dunes NL |
| 40.37132 | MWR | IA | Prairie | | Herbert Hoover NHS |
| 39.44393 | MWR | NE | Prairie | | Homestead NM of America |
| 38.73556 | MWR | MN | Prairie | | Pipestone NM |

| TOTAL SCORE | NPS REGION | STATE | ECOREGION DIVISION | ECOREGION PROVINCE | PARK NAME |
|-------------|------------|-------|--------------------|--------------------|---------------------------------|
| 37.72796 | SWR | OK | Prairie | | Chickasaw NRA |
| 34.19722 | MWR | KS | Prairie | | Fort Larned NHS |
| | | | | | |
| 70.14643 | WR | CA | Mediterranean | 2610M | Yosemite NP |
| 68.21436 | WR | CA | Mediterranean | 2610M | Kings Canyon NP |
| 67.43428 | WR | CA | Mediterranean | 2610M | Sequoia NP |
| 61.02219 | WR | CA | Mediterranean | | Channel Islands NP |
| 53.91822 | WR | CA | Mediterranean | | Santa Monica Mountains NRA |
| 52.54251 | WR | CA | Mediterranean | 2610M | Lassen Volcanic NP |
| 52.35944 | WR | CA | Mediterranean | 2620M | Pinnacles NM |
| 42.15794 | WR | CA | Mediterranean | | Devils Postpile NM |
| 42.14931 | WR | CA | Mediterranean | | Cabrillo NM |
| 37.70486 | WR | CA | Mediterranean | | Whiskeytown-Shasta-Trinity NRA |
| 73.21429 | RMR | WY | Steppe | 3112M | Yellowstone NP |
| 66.22244 | RMR | CO | Steppe | 3113M | Rocky Mountain NP |
| 61.77395 | WR | AZ | Steppe | 3131P | Grand Canyon NP |
| 59.81287 | RMR | UT | Steppe | 3131P | Zion NP |
| 59.16378 | RMR | CO | Steppe | 3132P | Mesa Verde NP |
| 57.35669 | WR | CA | Steppe | 3130 | Lava Beds NM |
| 56.33917 | WR | AZ | Steppe | 3140 | Chiricahua NM |
| 55.67531 | RMR | UT | Steppe | 3131P | Canyonlands NP |
| 55.24409 | RMR | UT | Steppe | 3131P | Capitol Reef NP |
| 55.09948 | PNR | ID | Steppe | 3130 | Craters of the Moon NM |
| 54.66348 | WR | AZ | Steppe | 3140 | Saguaro NM |
| 54.485 | RMR | UT | Steppe | 3131P | Arches NP |
| 54.31394 | RMR | UT | Steppe | 3131P | Bryce Canyon NP |
| 54.02622 | RMR | SD | Steppe | 3112 | Badlands NP |
| 54.02123 | RMR | CO | Steppe | 3113M | Black Canyon of the Gunnison NM |
| 53.1032 | RMR | CO | Steppe | 3113M | Great Sand Dunes NM |
| 53.07377 | RMR | AZ | Steppe | | Glen Canyon NRA |
| 53.05687 | RMR | SD | Steppe | 3112 | Wind Cave NP |
| 52.08503 | NAR | ND | Steppe | 3112 | Theodore Roosevelt NP |
| 52.02464 | SWR | NM | Steppe | 3113M | Bandelier NM |
| 51.45314 | SWR | TX | Steppe | | Lake Meredith RA |

| TOTAL SCORE | NPS REGION | STATE | ECOREGION DIVISION | ECOREGION PROVINCE | PARK NAME |
|-------------|------------|-------|--------------------|--------------------|-------------------------------|
| 49.8801 | RMR | CO | Steppe | | Dinosaur NM |
| 49.02123 | RMR | CO | Steppe | | Colorado NM |
| 48.61486 | RMR | WY | Steppe | 3112M | Grand Teton NP |
| 47.58568 | PNR | OR | Steppe | | John Day Fossil Beds NM |
| 46.8494 | PNR | WA | Steppe | | Lake Chelan NRA |
| 46.6314 | WR | NV | Steppe | | Great Basin NP |
| 45.89884 | RMR | MT | Steppe | | Bighorn Canyon NRA |
| 45.80633 | SWR | AR | Steppe | | Canyon de Chelly NM |
| 45.36071 | RMR | MT | Steppe | | Big Hole NB |
| 44.36071 | RMR | MT | Steppe | | Custer Battlefield NM |
| 44.18921 | RMR | UT | Steppe | | Natural Bridges NM |
| 44.18208 | RMR | UT | Steppe | | Cedar Breaks NM |
| 43.93214 | RMR | CO | Steppe | | Hovenweep NM |
| 43.70624 | WR | AZ | Steppe | 3120M | Petrified Forest NP |
| 43.3212 | RMR | WY | Steppe | | John D. Rockefeller, Jr., Mem |
| 42.9357 | RMR | SD | Steppe | | Jewel Cave NM |
| 42.9357 | RMR | SD | Steppe | | Mount Rushmore NMem |
| 42.5 | RMR | AZ | Steppe | | Rainbow Bridge NM |
| 42.21785 | RMR | WY | Steppe | | Fort Laramie NHS |
| 42.21785 | RMR | ND | Steppe | | Fort Union Trading Post NHS |
| 42.01039 | SWR | NM | Steppe | | Chaco Culture NHP |
| 41.88928 | WR | AZ | Steppe | | Tonto NM |
| 41.3071 | WR | AZ | Steppe | | Coronado Nmem |
| 41.29641 | WR | AZ | Steppe | | Walnut Canyon NM |
| 41.28928 | WR | AZ | Steppe | | Fort Bowie NHS |
| 40.86071 | SWR | NM | Steppe | | Capulin Volcano NM |
| 40.25713 | SWR | TX | Steppe | | Alibates Flint Quarries NM |
| 40.11745 | RMR | CO | Steppe | | Curecanti NRA |
| 39.95357 | RMR | UT | Steppe | | Timpanogos Cave NM |
| 39.81394 | SWR | AZ | Steppe | | Wupatki NM |
| 39.44283 | MWR | NE | Steppe | | Scotts Bluff NM |
| 37.24992 | RMR | WY | Steppe | | Fossil Butte NM |
| 36.95708 | RMR | CO | Steppe | | Florissant Fossil Beds NM |
| 36.22141 | RMR | WY | Steppe | | Devils Tower NM |

| TOTAL SCORE | NPS REGION | STATE | ECOREGION DIVISION | ECOREGION PROVINCE | PARK NAME |
|-------------|------------|-------|--------------------|--------------------|--------------------------------|
| 35.86427 | SWR | NM | Steppe | | El Morro NM |
| 35.86071 | SWR | NM | Steppe | | Gila Cliff Dwellings NM |
| 35.85714 | SWR | NM | Steppe | | Pecos NM |
| 35.28928 | WR | AZ | Steppe | | Montezuma Castle NM |
| 35.16426 | RMR | UT | Steppe | | Golden Spike NHS |
| 34.44283 | SWR | AZ | Steppe | | Sunset Crater NM |
| 33.44283 | MWR | NE | Steppe | | Agate Fossil Beds NM |
| 32.86071 | SWR | NM | Steppe | | Salinas NM |
| 62.14643 | WR | CA | Desert | | Death Valley NM |
| 60.80636 | SWR | TX | Desert | 3212 | Big Bend NP |
| 59.85518 | WR | CA | Desert | 3222 | Joshua Tree NM |
| 59.6197 | SWR | TX | Desert | 3212 | Guadalupe Mountains NP |
| 54.08257 | SWR | NM | Desert | 3212 | Carlsbad Caverns NP |
| 51.55146 | SWR | NM | Desert | | White Sands NM |
| 51.52773 | SWR | TX | Desert | | Amistad Recreation Area |
| 50.29293 | WR | AZ | Desert | | Organ Pipe Cactus NM |
| 46.42277 | WR | NV | Desert | | Lake Mead NRA |
| 46.29689 | SWR | TX | Desert | | Rio Grande Wild & Scenic River |
| 43.09473 | WR | AZ | Desert | | Hohokam Pima NM |
| 35.88752 | WR | AZ | Desert | | Casa Grande NM |
| | | | | | |
| 54.31115 | SER | FL | Savanna | | Big Cypress NPres |
| 50.78235 | SER | FL | Savanna | | Biscayne NP |
| 43.79161 | SER | VI | Savanna | | Buck Island Reef NM |
| 72.23571 | SER | FL | Savanna | 4110 | Everglades NP |
| 60.89033 | SER | VI | Savanna | 4110 | Virgin Islands NP |
| | | | | | |
| 70.07143 | WR | HI | Rainforest | 4210M | Hawaii Volcanoes NP |
| 55.82143 | WR | HI | Rainforest | 4210M | Haleakala NP |
| 40.04751 | WR | HI | Rainforest | | Kalaupapa NHP |