CHAPTER 1

IMPROVE NETWORK – CURRENT AND FUTURE CONFIGURATIONS

1.1 INTRODUCTION

The Regional Haze Rule [64 FR 35714, 1999] requires monitoring representative of each of the 156 visibility protected federal Class I areas (CIAs), as shown in Figure 1.1, beginning in January 2000 in order to track progress toward the national visibility goal. The deciview index calculated from ambient particle chemical speciation data was selected to track haze levels. This entails particle sampling and analysis of the major aerosol components using methods patterned after those utilized since 1987 by the IMPROVE Network [Joseph et al., 1987; Sisler, 1996] and consistent with the aerosol monitoring portion of the 1999 Visibility Monitoring Guidance document issued by EPA [64 FR 35 714, 1999].

The Interagency Monitoring of Protected Visual Environments (IMPROVE) program is a cooperative measurement effort designed:

(1) to establish current visibility and aerosol conditions in mandatory CIAs;

(2) to identify chemical species and emission sources responsible for existing man-made visibility impairment;

(3) to document long-term trends for assessing progress towards the national visibility goal; and

(4) with the enactment of the Regional Haze Rule, to provide regional haze monitoring representing all visibility-protected federal CIAs where practical.

The program is managed by the IMPROVE Steering Committee that consists of representatives from the U.S. Environmental Protection Agency (EPA), the four Federal Land Managers (FLMs—National Park Service, Forest Service, Fish and Wildlife Service, and Bureau of Land Management), the National Oceanic and Atmospheric Administration, four organizations representing state air quality organizations (State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials, Western States Air Resources Council, Northeast States for Coordinated Air Use Management, and Mid-Atlantic

Regional Air Management Association), and an Associate Member, the State of Arizona Department of Environmental Quality.

In 1999, the IMPROVE Network consisted of 30 monitoring sites in CIAs (see Figure 1.1), 20 of which began operation in 1987 with the others starting in the early 1990s. Each monitoring site includes $PM_{2.5}$ sampling on a twice per week schedule with subsequent analysis for the fine particle mass and major aerosol species as well as PM_{10} sampling and mass analysis [Sisler et al., 1993]. Many of the sites also include optical monitoring with a nephelometer or a transmissometer, and color photography to document scenic appearance. In addition, approximately 40 sites, most in remote areas, that use the same instrumentation, and monitoring and analysis protocols (called IMPROVE Protocol sites) were operated individually by federal or state organizations in recent years.

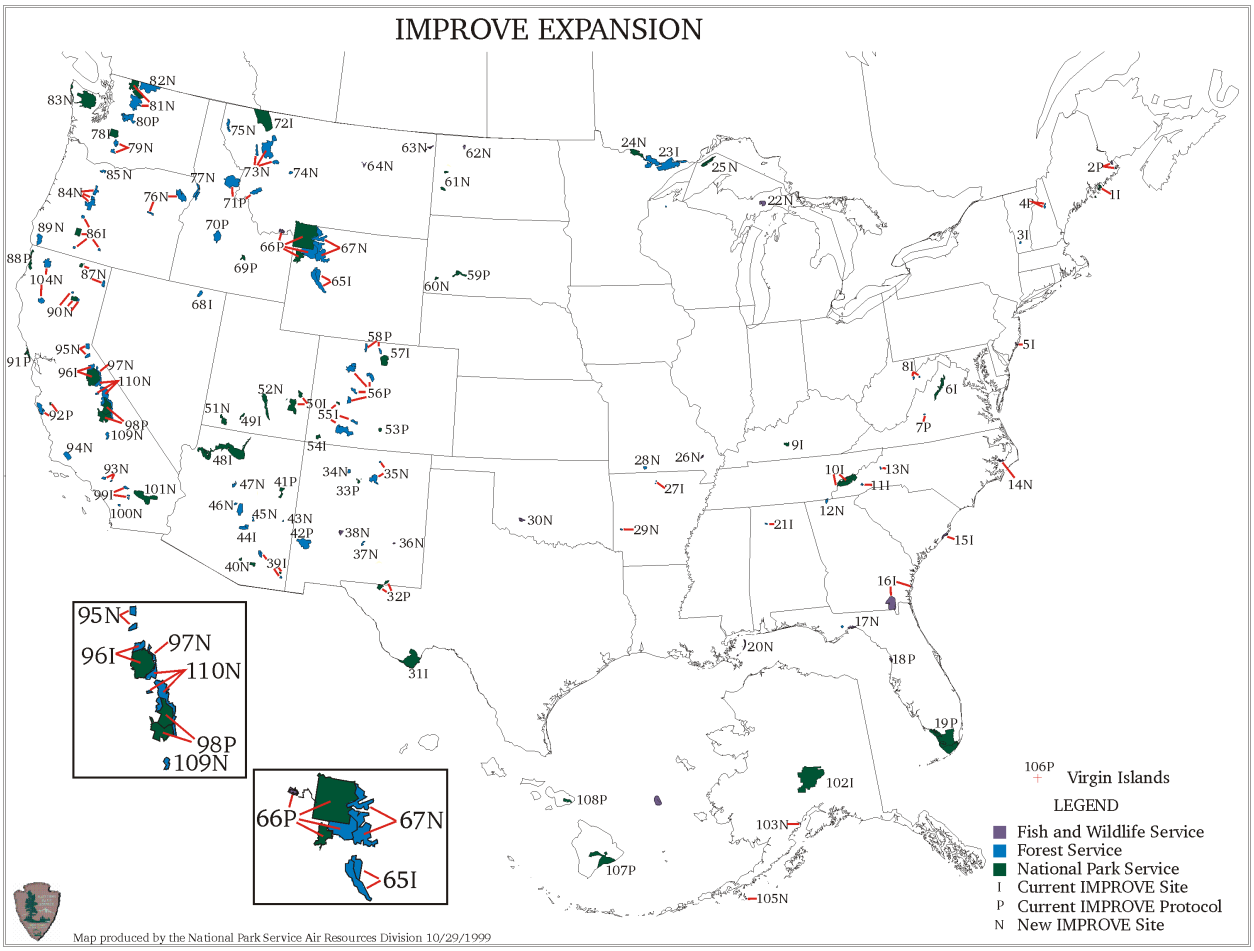

Figure 1.1 *Map showing all of the Federal Class I areas where visibility is deemed an important value and the locations of the original IMPROVE, IMPROVE Protocol and new IMPROVE sites.*

Beginning in 1998 EPA provided supplemental support to IMPROVE to expand the network in order to provide representative particle speciation monitoring that would be needed for the then anticipated Regional Haze Rule for all of the visibility-protected CIAs where it was practical. In making the decision to support the expansion of the IMPROVE Network, EPA also considered the value of the $PM_{2.5}$ mass and speciation data in remote areas for use by states in their implementation of the $PM_{2.5}$ regulation [62 FR 38652, 1997]. Provisions were made in those regulations so that states could elect to use IMPROVE monitoring data to meet their requirements for regional background and transport monitoring sites.

EPA requested IMPROVE change some aspects of its monitoring protocol to increase the comparability of the monitoring to that required of states at their $PM_{2.5}$ compliance and speciation monitoring sites. The IMPROVE Steering Committee agreed to change the twice-weekly sampling schedule to the national every third day sampling, to add routinely operated collocated instruments at 10% of the sites in order to generate quality assurance data, and to provide all of the monitoring data to the Aerometric Information Retrieval System (AIRS) database. To accommodate these changes a new version of the IMPROVE sampler was developed that provides for more flexible sample schedule control and continuous monitoring of sample flow and temperature, while maintaining the same sample collection characteristics of the original version of the sampler.

This chapter briefly describes the current IMPROVE monitoring network with emphasis on the aerosol monitoring program that produced most of the data reported on in subsequent chapters, and it also describes the network expansion including site selection and changes in the monitoring equipment and protocols. None of the data summarized in this report were collected under changed protocols or at new sites. However, data generated by the expanded network will be available for public use several years prior to the preparation of the next IMPROVE report, so the description of the changes to the protocols and monitoring sites can serve to characterize these newly collected data.

1.2 CURRENT NETWORK

1.2.1 Particulate Samplers

The IMPROVE sampler was designed for the IMPROVE Network and has been operated extensively in the network and during field studies since the winter of 1987 [Malm et al., 1994 and Malm et al., 1989]. The IMPROVE sampler consists of four independent modules (see Figure 1.2). Each module incorporates a separate inlet, filter pack, and pump assembly, however, all modules are controlled by a singular timing mechanism. It is convenient to consider a particular module, its associated filter, and the parameters measured from the filter as a channel of measurement (i.e., module A). Modules A, B, and C are equipped with a 2.5 µm cyclone. The module A Teflon filter is analyzed for fine mass ($PM_{2.5}$) gravimetrically, nearly all elements with atomic mass number ≥11 (which is Na) and ≤82 (which is Pb) by proton induced x-ray emission (PIXE) and by x-ray florescence (XRF), elemental hydrogen by proton elastic scattering analysis (PESA), and for light absorption.

For module B, the sampled air is drawn through a carbonate denuder tube in the inlet to remove gaseous nitrates. The material collected from the filter is extracted ultrasonically in an aqueous solution that is subsequently analyzed by ion chromatography for the anions sulfate, nitrate, nitrite and chloride. At the Great Smoky Mountains and Shenandoah National Parks and

Dolly Sods Wilderness Area, the ammonium ion concentration is also measured using extracts from these filters in a separate colorimetric analysis.

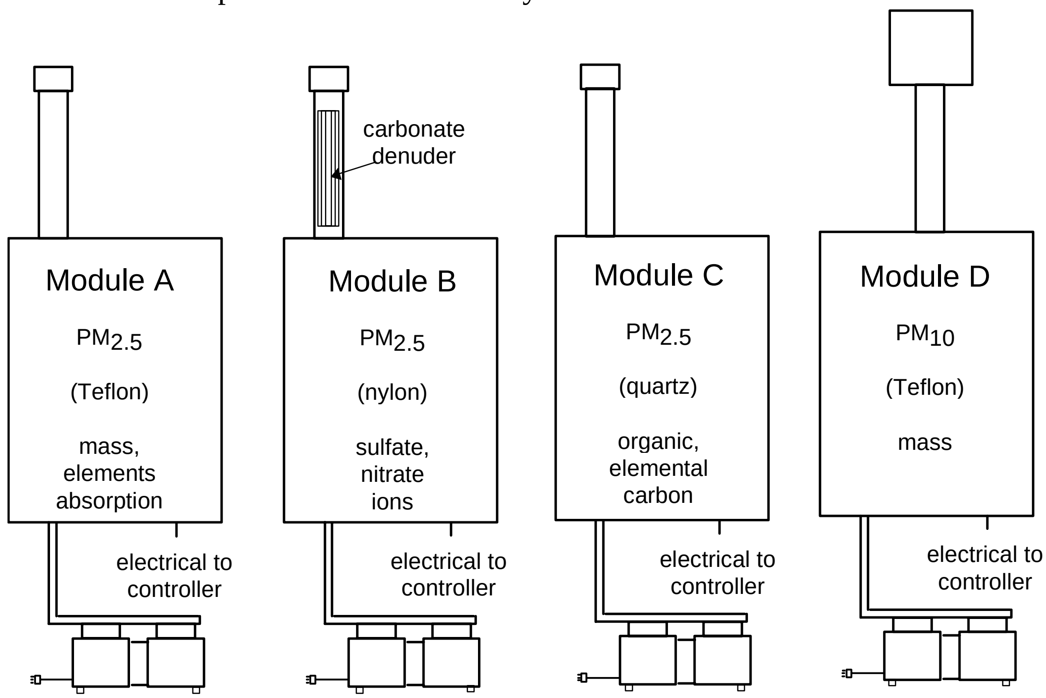

Figure 1.2 *Schematic view of the IMPROVE sampler showing the four modules with separate inlets and pumps. The substrates with analyses performed for each module are also shown.*

Module C utilizes tandem quartz fiber filters for the collection of fine particles; the front filter is analyzed for particulate carbon, while the second filter is used for an estimation of the organic carbon artifact associated with organic gases trapped on the filter substrate. Thermal optical reflectance (TOR) is the analytic technique used for determination of organic and elemental carbon [Chow et al., 1993].

Module D, fitted with a PM_{10} inlet, utilizes a Teflon filter, which is gravimetrically analyzed for mass (PM_{10}). Exposed cassettes from modules A, B, C, and D are stored in sealed plastic bags and shipped for storage and analysis.

1.2.2 Network Configuration

There are currently a number of monitoring sites in the United States that use IMPROVE instrumentation and follow IMPROVE protocol, however, not all sites are operated as part of the IMPROVE monitoring network. There are 49 sites that are used for the spatial distributions of aerosol mass and extinction analyses presented in Chapters 2 and 3. There are 51 sites in the contiguous United States that are used for the species contribution to extreme fine mass, which is discussed in Chapter 4. There are 29 sites with an 11-year record that extends from March 1988 to February 1999 and these data will be used in the 11-year trend analysis in Chapter 5. Table 1.1 summarizes this information as well as the monitoring site start date, whether it was part of the IMPROVE monitoring network, indicated by an I, or operated by another agency but according to IMPROVE protocol, indicated by a P. In the table, the sites that were used for various analyses are indicated as S, E, or T, which stand for spatial distributions of mass and optical properties, species contribution to extreme concentrations, and trend analysis, respectively. The table also shows the aerosol modules operated at the site and whether that site was operated with an integrated nephelometer (N) or a transmissometer (Tr). Finally, at a number of these sites cameras were operated to document the visual impact of regional and layered hazes as a function of aerosol concentrations. Slides of a subset of the camera monitoring sites have been selected to represent the various haze conditions that occurred and have been transferred to CD-ROM. Storage of pictorial information in a digital format allows for maintenance of a permanent non-degrading visual image database. Those sites that have had the pictorial information transferred to CD-ROM and those sites under pictorial development are also summarized in Table 1.1.

Table 1.1 *Tabular summary of the sites used for spatial, trend, and extreme value analyses presented in this report. Also shown in the table is the protocol under which the site was operated, its start date, the type of equipment at the site and an indicator showing those sites that have selected color slides digitized and transferred to CD-ROM or in the slide development phase.*

Site	**Protocol**	**Start Date**	**Analysis**	**Equipment**	**Slide Database**
Alaska (AKA)					
Denali NP&P	I	3/88	SET	ABCD	
Appalachian Mountains (APP)					
Great Smoky Mountains NP	I	3/88	SET	ABCDN	X
Shenandoah NP	I	3/88	SET	ABCDTr	X
Dolly Sods WA	I	3/91	SE	ABCDN	X
James River Face WA	P	9/94	SE	ABCD	
Shining Rock WA	I	7/94	SE	ABCDN	
Boundary Waters (BWA)					
Boundary Waters Canoe Area	I	3/91	SE	ABCDN	◇
Cascade Mountains (CAS)					
Columbia River NSA	P	6/93	E	ABCDN	
Mount Rainier NP	I	3/88	SET	ABCDN	X
Snoqualmie Pass WA	P	7/93	SE	ABCDN	
Three Sisters WA	P	7/93	SE	ABCDN	
Central Rocky Mountains (CRK)					
Bridger WA	I	3/88	SET	ABCDTr	X
Great Sand Dunes NM	P	5/88	SET	ABCD	◇
Mount Zirkel WA	I	11/93	E	ABCDN	
Rocky Mountain NP	I	9/90	SET	ABCDTr	X
Weminuche WA	I	3/88	SET	ABCD	
Yellowstone NP	P	3/88	SET	ABCD	X
Colorado Plateau (CPL)					
Bandelier NM	P	3/88	SET	ABCDTr	X
Bryce Canyon NP	I	3/88	SET	ABCD	X
Canyonlands NP	I	3/88	SET	ABCDTr	X
Grand Canyon NP	I	3/88	SE	ABCDSoTr	X
Mesa Verde NP	I	3/88	SET	ABCD	X
Petrified Forest NP	P	3/88	SET	ABCDTr	

Table 1.1 *Continued.*

Site	Protocol	Start Date	Analysis	Equipment	Slide Spectrum
Great Basin (GBA)					
Jarbidge WA	I	3/88	SET	ABCDN	X
Great Basin NP	I	5/92	SE	ABCD	
Mid Atlantic (MAT)					
Edwin B. Forsythe (Brigantine) NWR	I	9/91	SE	ABCD	
Mid South (MDS)					
Upper Buffalo WA	I	6/91	SE	ABCDN	
Sipsey WA	I	3/92	SE	ABCD	
Mammoth Cave NP	I	3/91	SE	ABCDN	
Northeast (NEA)					
Acadia NP	I	3/88	SET	ABCDN	X
Lye Brook WA	I	3/91	SE	ABCD	X
Moosehorn NWR (Roosevelt Campobello US-CC)	P	12/94	SE	ABCD	
Northern Great Plains (NGP)					
Badlands NP	P	3/88	SET	ABCDTr	X
Northern Rocky Mountains (NRK)					
Glacier NP	I	3/88	SET	ABCDTr	X
Pacific Coast (PAC)					
Pinnacles NM	P	3/88	SET	ABCD	X
Point Reyes NS	P	3/88	SET	ABCD	X
Redwood NP	P	3/88	SET	ABCD	X
Sierra Nevada (SRA)					
Sequoia NP	P	7/93	SE	ABCD	
Yosemite NP	I	3/88	SET	ABCDTr	X
Sierra-Humboldt (SRH)					
Crater Lake NP	I	3/88	SET	ABCD	X
Lassen Volcanic NP	P	3/88	SET	ABCD	X
Sonoran Desert (SON)					
Chiricahua NM	I	3/88	SET	ABCDTr	X
Gila WA	I	3/94	E	ABCDN	
Tonto NM	I	3/88	SET	ABCD	
Southeast (SOE)					
Chassahowitzka NWR	P	4/93	SE	ABCD	
Okefenokee NWR	I	3/91	SE	ABCDN	
Cape Romain NWR	I	9/94	SE	ABCD	
Southern California (SCA)					
San Gorgonio WA	I	3/88	SET	ABCDTr	X
Wasatch (WAS)					
Lone Peak WA	P	11/93	SE	ABCDN	
Washington D.C. (WDC)					
Washington D.C.	P	3/88	E	ABCD	
West Texas (WTX)					
Big Bend NP	I	3/88	SET	ABCDTr	X
Guadalupe Mountains NM	P	3/88	SET	ABCDTr	X

NP&P = National Park and Preserve
NP = National Park
WA = Wilderness Area
NM = National Monument
NWR = National Wildlife Refuge
US-CC = U.S.-Canadian Commission
NS = National Seashore

NSA = National Scenic Area
I = Current IMPROVE site
P = Current IMPROVE protocol
◇ = Slide development phase
S = FM/Extinction Spatial Analysis
E = Extreme value analysis
T = Trend analysis

A = Module A aerosol sampler
B = Module B aerosol sampler
C = Module C aerosol sampler
D = Module D aerosol sampler
So = SO_2 afterfilter
N = Nephelometer
Tr = Transmissometer

The locations of all the sites listed in Table 1.1 are shown in Figure 1.3, along with the types of analysis (S, E, T) and presence of optical monitoring (O). The density of sites in the western United States is considerably greater than in the eastern United States. Therefore, data from the Clean Air Status and Trends Network (CASTNet), a program designed to track the sulfur dioxide emission reduction program, are used to "fill in" (described in Appendix A) sulfate and nitrate concentration data in the eastern United States to create a more accurate picture of the spatial variability of extinction.

1.3 FUTURE NETWORK CONFIGURATION

The IMPROVE Steering Committee devised a plan to expand the network to support the regional haze regulation monitoring needs with the following network design objectives: (1) minimize the number of monitoring sites needed to represent regional haze conditions for all of the CIAs where monitoring is possible, (2) continue at current monitoring sites that are representative of regional haze conditions in CIAs to preserve their value for trends analysis, and (3) ensure that every opportunity for input in the site selection process would be afforded to federal land management and state air quality organizations.

1.3.1 Site Selection Process

There are many examples of visibility-protected CIAs that are near to each other, so separate monitoring sites might not be needed. To determine which sites can be grouped together (objective 1) requires consideration of both technical and policy concerns for what constitutes representative monitoring for regional haze. Historical data collected at the current IMPROVE and IMPROVE Protocol sites show striking similarities in the average composition and concentration over distances exceeding 100 km [Sisler et al., 1993]. Site-to-site correlation analysis of aerosol data collected at sites in the same region typically produce highly significant relationships. Thus from a technical perspective, monitoring sites that are relatively near to each other in remote areas can be expected to collect similar data that might be considered redundant. The next section discusses representative monitoring from a policy perspective.

With respect to the second objective, the Steering Committee considers each of the original 30 IMPROVE sites to be representative of the regional haze conditions of the CIA for which it was selected. Reconsideration of the siting of any of these would only be done if requested by a state or land management organization. However, some of the IMPROVE Protocol sites were selected by the operating organization to represent air quality conditions for non-CIAs (typically Class II areas). IMPROVE Protocol sites would be candidates for selection as network expansion sites, but would only be chosen if they were the best of the sites being considered.

The last of these objectives reflects the Steering Committee's recognition of the responsibilities of state air quality and federal land management organizations identified in the Regional Haze Rule. While all of these organizations are represented on the Steering Committee, it was deemed prudent to explicitly solicit input from each individual state air quality agency, since no multi-state organization could be expected to speak for the diverse interests of each state. Moreover, states and the local federal land managers were looked to for

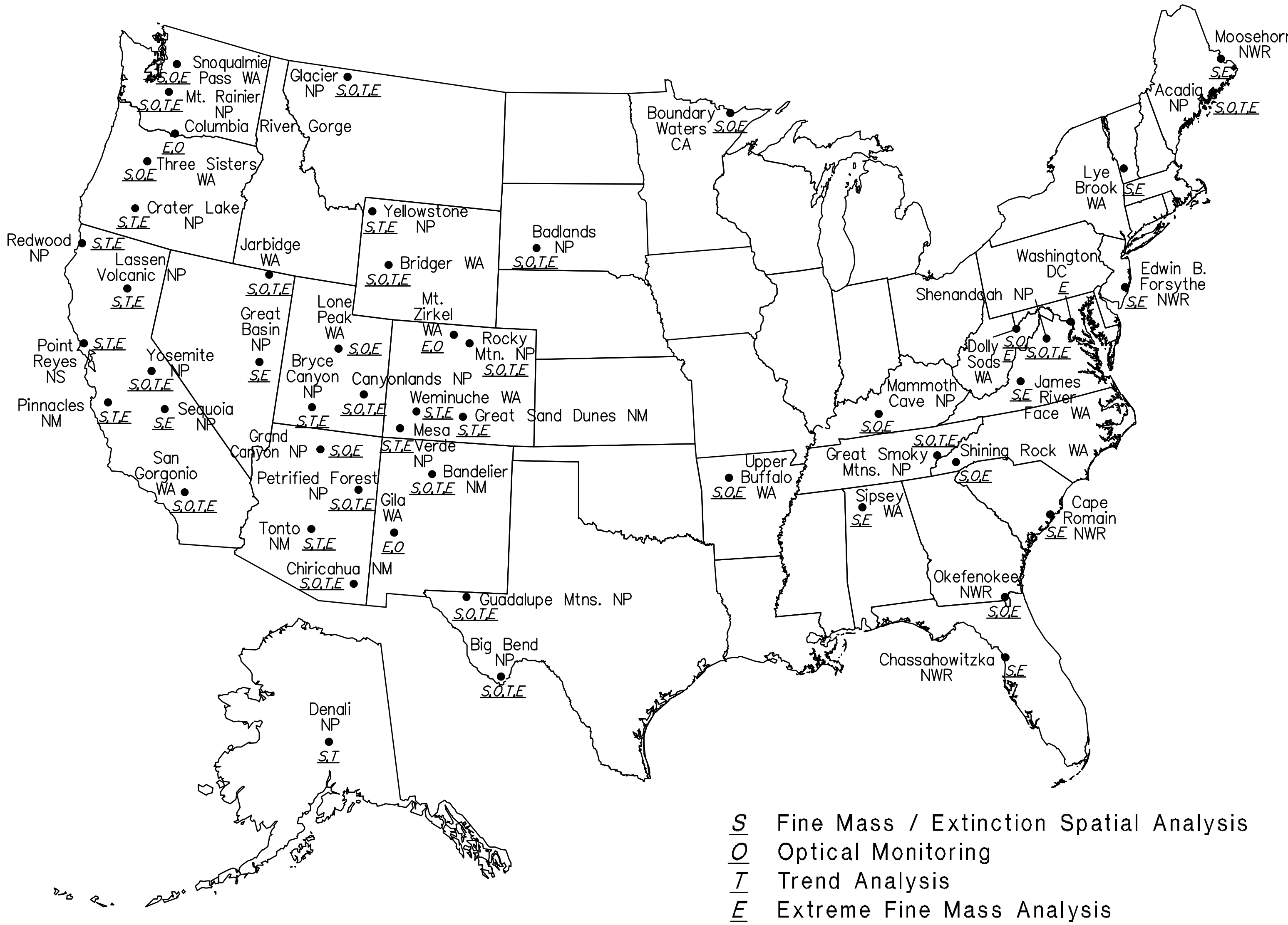

Figure 1.3 *A map of the IMPROVE sites used for the spatial, trend, and extreme value analyses.*

their knowledge and experience concerning air quality, meteorology and pollution emission conditions in their region. Communications and coordination with states was accomplished by a series of letters from the Steering Committee to the states distributed by STAPPA/ALAPCO and posted on the EPA AMTIC web page that described the network expansion plans, progress in site selection, and solicited input to the process. Over the 18-month planning process many states responded to this request for input with letters, email, or phone conversations, and in some cases with state- or site-specific meetings and field trips involving Steering Committee representatives.

1.3.1.1 Representative Monitoring for Regional Haze

Federal visibility protection is limited to specific well-defined locations, the 156 mandatory federal CIAs where visibility was deemed an important value (Figure 1.1). Visibility monitoring must be representative of these locations if the data are to be useful for tracking progress towards the visibility goal of eliminating man-made contributions to visibility impairment. Most of the CIAs are designated national wilderness areas for which the Wilderness Act restricts the siting of man-made items, including environmental monitoring equipment [Public Law 88-577, 1964; 16 USC section 1131, 1997]. Even for CIAs where monitoring is allowed (i.e., national parks), practical requirements such as power, security and access occasionally make it difficult to find a suitable monitoring site within the CIA boundary. Traditionally, the IMPROVE program has dealt with these restrictions by finding representative locations to site monitors that are as near to the CIAs as is practically possible so it could be reasonably claimed that the visibility monitored is the same as what would be experienced in the CIA.

The problems of finding representative monitoring locations are decreased considerably for sites where the primary objective is to monitor the regional haze aspect of visibility. EPA defines regional haze as "…visibility impairment that is produced by a multitude of sources and activities which emit fine particles and their precursors and which are located across a broad geographic area" [64 FR 35714, 1999]. EPA also recognizes a form of visibility impairment that is reasonably attributable to a nearby source or group of sources, which is addressed by the first phase of visibility protection regulations issued in 1980 [45 FR 80084, 1980]. The spatial scale of the impacts and the number and distribution of sources are important factors that distinguish regional haze from reasonably attributable impairment.

Since regional haze impacts are by definition those that are distributed over a broad geographic region, a representative monitoring site does not necessarily need to be located very near to the CIA being represented. It is more important that the monitoring site experience impacts from the same collection of regionally important emission sources that influence the CIA haze and be isolated as much as possible from sources of solely local impacts, even if the localized impacts affect the CIA. A distinction needs to be drawn between isolated individual sources (e.g., diesel generator at the visitor center or a nearby highway) that should be distant from regional haze monitoring sites and individually small but ubiquitous sources that are widely distributed throughout the region (e.g., suspended crustal material in a desert or organic material in a conifer forest) that need not be avoided. Being in or very near a CIA is not as important in selecting a representative regional haze monitoring site as having similar exposure to the regionally important sources of haze and isolation from emission sources with purely localized impacts. The practical significance of the concept that representative monitoring for regional haze can be accomplished at a distance from the protected area is that it should be possible to find sites that represent more than one CIA where they are located within the same regional haze region.

A two-stage process was developed for selecting new monitoring sites. The first stage was to subdivide the 156 CIAs into three categories: those that required a separate monitoring site, those where two or more visibility-protected areas could be represented by a single monitoring site for regional haze, and those for which monitoring was impractical. The second stage involved selection of the actual locations for monitoring for the new sites. These two stages are described in the following separate sections.

1.3.1.2 Identification of CIA Clusters

Two location-related parameters, the horizontal distance and elevation range, were employed in the preliminary grouping of CIAs into clusters that might be represented by single monitoring sites. For this preliminary grouping it was arbitrarily decided that a monitoring site should be within 100 km and be at an elevation between the maximum and minimum elevation of the CIAs that it represents. The elevation criterion was soon determined to be unnecessarily restrictive for a number of locations and was relaxed by allowing the site to be within 10% or 100 feet of the elevation extremes of the CIA to be represented. As indicated above, the 30 IMPROVE sites operational in 1999 were expected to be part of the expanded IMPROVE Network to preserve and extend the long-term trend records.

The preliminary grouping criteria were implemented by drawing 100 km circles around the current IMPROVE sites and the centroids for each CIAs using Geographic Information System (GIS) software. From this a table was constructed that grouped into clusters all CIAs with overlapping circles or where the current IMPROVE site circle overlaps one or more CIAs. This generated 92 clusters; 57 of which contain a single CIA; 30 contained 2 or 3 CIAs, and the remaining 5 contained from 4 to 7 CIAs. The table also contained the maximum and minimum elevations of the CIAs, the current IMPROVE sites and the IMPROVE Protocol sites. Application of the elevation criterion subdivided 11 of the clusters for a total of 103 clusters in this preliminary assessment of the required size for regional haze monitoring of the 156 CIAs.

A letter from the IMPROVE Steering Committee explaining each of the criteria including the map and table showing the CIA clusters was sent to all of the state air quality offices and to the federal land managers asking for their comments (at www.epa.gov/ttn/amtic/visinfo.html). The letter specifically asked for comments on the desirability of grouping neighboring CIAs into clusters that would be represented by a single monitoring site, on the specific criteria used to determine the preliminary clusters, and on changes that should be made to improve the cluster groupings of CIAs that take into account their knowledge of factors that influence haze in the various regions (e.g., terrain, pollution source distributions and meteorology). The letter also asked for comments on the identification of one CIA, the Bering Sea Wilderness, as impractical for routine monitoring due to its location in the Bering Sea over 400 km from the nearest source of commercial power and potential field support staff.

Seventeen states responded to the letter with comments. Several states suggested reorganization and additions to the preliminary clusters, with a net effect of raising the number to 110. For a few CIAs the preliminary location and elevation criteria were violated in a minor way by the newly configured clusters, but in every case the new configuration was viewed as an improvement with respect to representative regional haze monitoring. In addition, the state of Alaska asked that the IMPROVE Steering Committee reconsider the siting of the existing site at Denali National Park and Preserve, which they thought was perhaps influenced by park staff and visitors. Figure 1.1 shows the locations of each of the resulting clusters and Table 1.2 lists each cluster and the names of the CIAs they contain. All of the state recommended changes were accepted by the Steering Committee as a blueprint for the site selection stage of the network expansion process.

Table 1.2 *Final list of Class I areas organized by clusters with numbers corresponding to the map in Figure 1.1. Each cluster will have one IMPROVE site to monitor regional haze.*

#	Represented Class I Areas	State	FLM
1	Acadia	ME	NPS
2	Moosehorn, Roosevelt Campobello	ME	FWS, US-CC
3	Lye Brook	VT	FS
4	Great Gulf, Presidential Range-Dry River	NH	FS
5	Edwin B. Forsythe (Brigantine)	NJ	FWS
6	Shenandoah	VA	NPS
7	James River Face	VA	FS
8	Dolly Sods, Otter Creek	WV	FS
9	Mammoth Cave	KY	NPS
10	Great Smoky Mountains, Joyce Kilmer-Slickrock	TN, NC	NPS, FS
11	Shining Rock	NC	FS
12	Cohutta	GA	FS
13	Linville Gorge	NC	FS
14	Swanquarter	NC	FWS
15	Cape Romain	SC	FWS
16	Okefenokee, Wolf Island	GA	FWS
17	St. Marks	FL	FWS
18	Chassahowitzka	FL	FWS
19	Everglades	FL	NPS
20	Breton	LA	FWS
21	Sipsey	AL	FS
22	Seney	MI	FWS
23	Boundary Waters	MN	FS
24	Voyageurs	MN	NPS
25	Isle Royale	MI	NPS
26	Mingo	MO	FWS
27	Upper Buffalo	AR	FS
28	Hercules-Glades	MO	FS
29	Caney Creek	AR	FS
30	Wichita Mountain	OK	FWS
31	Big Bend	TX	NPS

***Table 1.2** Continued.*

#	Represented Class I Areas	State	FLM
32	Guadalupe Mountains, Carlsbad Caverns	TX, NM	NPS
33	Bandelier	NM	NPS
34	San Pedro Parks	NM	FS
35	Wheeler Peak, Pecos	NM	FS
36	Salt Creek	NM	FWS
37	White Mountain	NM	FS
38	Bosque del Apache	NM	FWS
39	Chircahua NM, Chircahua W, Galiuro	AZ	NPS, FS
40	Saguaro	AZ	NPS, FS
41	Petrified Forest	AZ	NPS
42	Gila	NM	FS
43	Mount Baldy	AZ	FS
44	Superstition, Tonto	AZ	FS
45	Sierra Ancha	AZ	FS
46	Mazatzal, Pine Mountain	AZ	FS
47	Sycamore Canyon	AZ	FS
48	Grand Canyon	AZ	NPS
49	Bryce Canyon	UT	NPS
50	Canyonlands, Arches	UT	NPS
51	Zion	UT	NPS
52	Capitol Reef	UT	NPS
53	Great Sand Dunes	CO	NPS
54	Mesa Verde	CO	NPS
55	Weminuche, La Garita, Black Canyon of Gunnison	CO	FS
56	Maroon Bells, West Elk, Eagles Nest, Flat Tops	CO	FS
57	Rocky Mountain	CO	NPS
58	Mount Zirkel, Rawah	CO	FS
59	Badlands	SD	NPS
60	Wind Cave	SD	NPS
61	Theodore Roosevelt	ND	NPS
62	Lostwood	ND	FWS
63	Medicine Lake	MT	FWS
64	UL Bend	MT	FWS
65	Bridger, Fitzpatrick	WY	FS
66	Yellowstone, Grand Teton, Teton, Red Rock Lakes	WY	NPS, FWS
67	North Absoraka, Washakie	WY	FS
68	Jarbidge	NV	FS
69	Craters of the Moon	ID	NPS
70	Sawtooth	ID	FS
71	Anaconda-Pintler, Selway-Bitterroot	MT, ID	FS
72	Glacier	MT	NPS
73	Bob Marshall, Mission Mountains, Scapegoat	MT	FS
74	Gates of the Mountains	MT	FS
75	Cabinet Mountains	MT	FS
76	Eagle Cap, Strawberry Mountain	OR	FS
77	Hells Canyon	ID	FS

Table 1.2 Continued.

#	Represented Class I Areas	State	FLM
78	Mount Rainier	WA	NPS
79	Goat Rock, Mount Adams	WA	FS
80	Alpine Lakes, Snoqualmie Pass	WA	FS
81	North Cascades, Glacier Peak	WA	NPS, FS
82	Pasayten	WA	FS
83	Olympic	WA	NPS
84	Three Sisters, Mount Jefferson, Mount Washington	OR	FS
85	Mount Hood	OR	FS
86	Crater Lake, Diamond Peak, Mountain Lakes, Gearhart Mtn	OR	NPS, FS
87	Lava Beds, South Warner	CA	NPS, FS
88	Redwood	CA	NPS
89	Kalmiopsis	OR	FS
90	Lassen Volcanic, Caribou, Thousand Lakes	CA	NPS, FS
91	Point Reyes	CA	NPS
92	Pinnacles, Ventana	CA	NPS, FS
93	San Gabriel, Cucamonga	CA	FS
94	San Rafael	CA	FS
95	Desolation, Mokelumne	CA	FS
96	Yosemite, Emigrant	CA	NPS, FS
97	Hoover	CA	FS
98	Sequoia, Kings Canyon	CA	NPS, FS
99	San Gorgonio, San Jacinto	CA	FS
100	Agua Tibia	CA	FS
101	Joshua Tree	CA	NPS
102	Denali	AK	NPS
103	Tuxedni	AK	FWS
104	Marble Mountain, Yolla Bolly Middle Eel	CA	FS
105	Simeonof	AK	FWS
106	Virgin Islands	VI	NPS
107	Hawaii Volcanoes	HI	NPS
108	Haleakala	HI	NPS
109	Dome Land	CA	FS, BLM
110	Kaiser, Ansel Adams, John Muir	CA	FS

1.3.1.3 Selecting New Sites

To monitor the 110 CIA clusters, 80 new sites needed to be selected and the Denali IMPROVE site needed to be reconsidered. Twenty-five of the 80 clusters where new sites were required had IMPROVE Protocol sites as candidates that would be considered along with other alternative locations. The Air Quality Group of the University of California at Davis (UCD), the particle monitoring and analysis contractor for the IMPROVE Network, was tasked with coordinating the effort to select new monitoring sites. The Steering Committee also sought active participation by the local land managers and the state air quality offices for each new site. The response of these groups varied widely from site to site. In some cases, the land managers and/or state air quality organization were very active in identifying candidate sites, including extensive field siting trips. For some of the new sites, the UCD staff worked with the local land manager over the phone and via email to develop candidate locations.

UCD prepared a document that described the procedures to be used for site selection that was circulated to all states and land management organizations in early 1999 (IMPROVE Particulate Monitoring Network Procedures for Site Selection at www.epa.gov/ttn/amtic/visinfo.html). This document identified three qualities required of a new site: (1) the site must represent all CIAs in the cluster, (2) it should be regionally representative, avoiding local pollution sources or areas with unusual meteorology, and (3) it must avoid nearby obstacles that could affect sample collection. The document contains specific siting criteria, much of it taken from EPA siting guidelines, that indicate minimum allowed distances from sources and obstacles, sampler inlet exposure rules, and the need for reliable 120 volt AC power, security and field staffing requirements.

Specific locations for nearly all sites were identified by the summer of 1999, and the last location was selected (for Breton Wilderness) by the end of October 1999. Various types of permits and/or leases were required to secure many of the sites. The processing time for these varied widely from site to site. As soon as possible site preparations were begun. These usually included construction of a shelter for the monitoring sites with AC power. In some cases, an existing shelter was used. The IMPROVE protocol for particle sampling required that the sampler operate at ambient temperatures. To accomplish this, samplers are housed in a ventilated shelter that provide shielding from direct sunlight. Shelter design varied to meet differing practical and aesthetic concerns for specific sites. Installation of the new version IMPROVE samplers (described below) at all 110 sites began in November and continued through the spring of 2000.

1.3.2 Protocol and Equipment Changes

At EPA's request, the IMPROVE Steering Committee agreed to a few protocol changes with respect to the particle monitoring in the network. These included changing the twice-weekly 24-hour duration sampling schedule to an every-third-day schedule that corresponds to the schedule of the national particulate network operated by state and local governments, addition of a 10% replicate sampling and analysis for $PM_{2.5}$ mass and composition to evaluate precision, and submission of all data to the AIRS database. In addition, the IMPROVE Steering Committee and the EPA Project Officer for the National $PM_{2.5}$ Speciation Monitoring Program have agreed to develop information to aid in determining the degree of comparability of data collected by the two programs.

The change to an every-third-day sampling schedule proved to be the most challenging of the agreed upon changes. The reason for this stems from one of the original IMPROVE design objectives, that field work would be made as simple, fast, and convenient as possible to enhance data recovery and in recognition of the fact that field operators were federal land management staff assigned this work as collateral duties. The original IMPROVE sampling schedule from midnight to midnight on Wednesday and Saturday combined with a sampler capable of two sampling periods of unattended operation controlled by a seven-day timer/controller meant that the operator could service the sampler any time on the same day every week (typically Tuesday).

This was both easy to remember and to fit into a busy schedule. Use of a seven-day timer to sample every third day would have required re-programming it each week, which was expected to produce unacceptable mistakes. A sampler with only a two-sampler period of unattended operation was also a problem since the service day would change each week and would include days the operator might normally be unavailable each week. To maintain the same day of the week service schedule, the sampler controller and number of unattended sampler periods needed to be changed.

A new version of the IMPROVE particle sampler was designed and produced at UCD. The objective was to build a sampler that would be comparable from a sample collection perspective but use state-of-the-art microprocessor technology to increase the control and provide feedback on operating status. The new version sampler was designed to be identical to the original IMPROVE sampler including the four modules to sample on various substrates (shown in Figure 1.2), the same materials and dimensions for each module from the sample inlet to the face of the filter and with the same flow controller and flow rates. Preliminary tests at UCD confirm the comparability of the original and new version samplers. Additional testing will be conducted at typical field sites during the first few years of sampling.

A microprocessor-based controller that can be programmed to sample any period of time on any schedule replaced the seven-day timer/controller. The microprocessor includes a memory card reader/writer that is being used to record flow-rate, sample temperature and other performance related information monitored continuously throughout the sample period. The original IMPROVE sampler flows were manually checked at the beginning and end of each sample period and the seasonal mean site temperature and pressure were used for flow calculations, so that for the infrequent cases where the final flow was outside of the allowed range or the temperature was seasonably abnormal, the sample volume could not be adequately determined. The microprocessor also permits programming changes to be distributed to the controller on data cards sent to the field locations by UCD.

The new version sampler has a four-filter manifold for each module in place of the original sampler two-filter manifolds. The manifold with the solenoids is directly above the filter cassettes and is raised or lowered as a unit to unload and load the filters. The four filter cassettes are held in a cartridge (shown in Figure 1.4) that is designed to only allow one orientation in the sampler. Fully prepared date- and site-labeled filter cartridges along with memory cards will be sent from the analysis laboratory to the field and returned in special mailing containers to prevent confusion concerning the order of sampling among the filters. If filter change service is performed on a sample day, the operator moves the cassette containing that day's filter to the open position in the newly loaded cartridge. The few minutes that it takes to perform this sample change is recorded by the microprocessor on the memory card so that the correct air volume is used to calculate concentrations.

The new version of the IMPROVE sampler makes it simple to add a fifth module at 10% of the monitoring sites to accommodate replicate sampling and analysis for mass and composition. This quality assurance module will be operated for each sample period and collect a replicate sample for any of the three $PM_{2.5}$ substrates (Teflon, nylon, or quartz) so that over time precision information can be developed for each type of data.

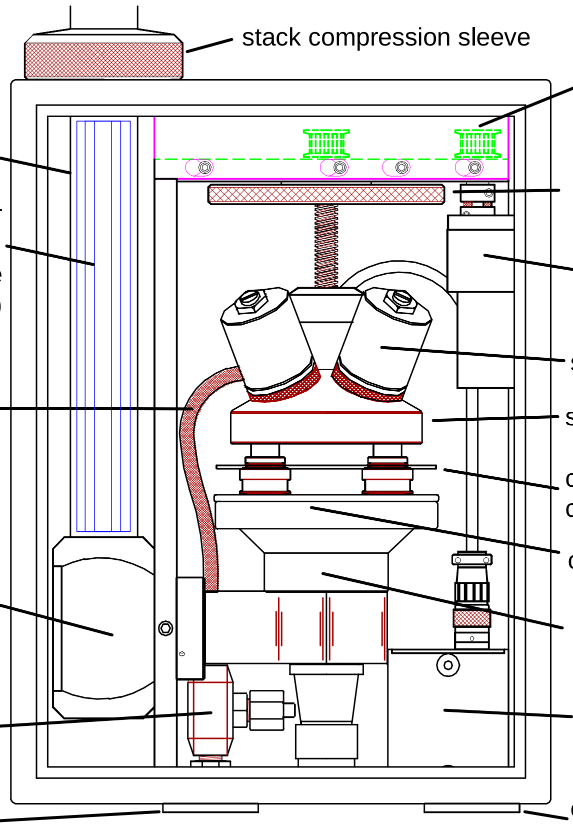

Figure 1.4 *Schematic of a new version of the IMPROVE sampler $PM_{2.5}$ module.*

The tentative approach agreed upon by EPA and IMPROVE to evaluate the comparability of the IMPROVE and the National $PM_{2.5}$ Speciation data sets involves having each network contribute samplers and analysis for up to three monitoring sites in the other's network for at least one year. In other words, IMPROVE samplers with IMPROVE mass and composition analysis would be operated by the speciation program at three of their typically urban sites, and speciation samplers with their analysis methods would by operated by IMPROVE at three of their remote sites. This permits long-term paired-data comparisons at six sites representing a range of concentrations and compositions likely to be experienced in either program.

1.4 CURRENT REPORT OBJECTIVES

This report is the third in a series of periodic reports that describe the data collected by the IMPROVE monitoring network. Following are the objectives of this report:

(1) to describe the spatial variation of aerosol species contributing to visibility impairment over the time frame from March 1996 through February 1999;

(2) to provide a first estimate of the apportionment of visibility impairment to these chemical species;

(3) to document long-term trends (11 years) of aerosol mass, its principal aerosol species, and visibility as expressed in terms of deciview;

(4) to examine how the contribution of various aerosol species changes at the extremes of fine mass distributions;

(5) to examine the inter-comparability of data collected in the IMPROVE Network and the Clean Air Status and Trends Network;

(6) to report on a number of special studies that were designed to examine the robustness of algorithms used to make extinction estimates from aerosol mass concentrations. The hygroscopicity of aerosol species is examined.

1.5 REFERENCES

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