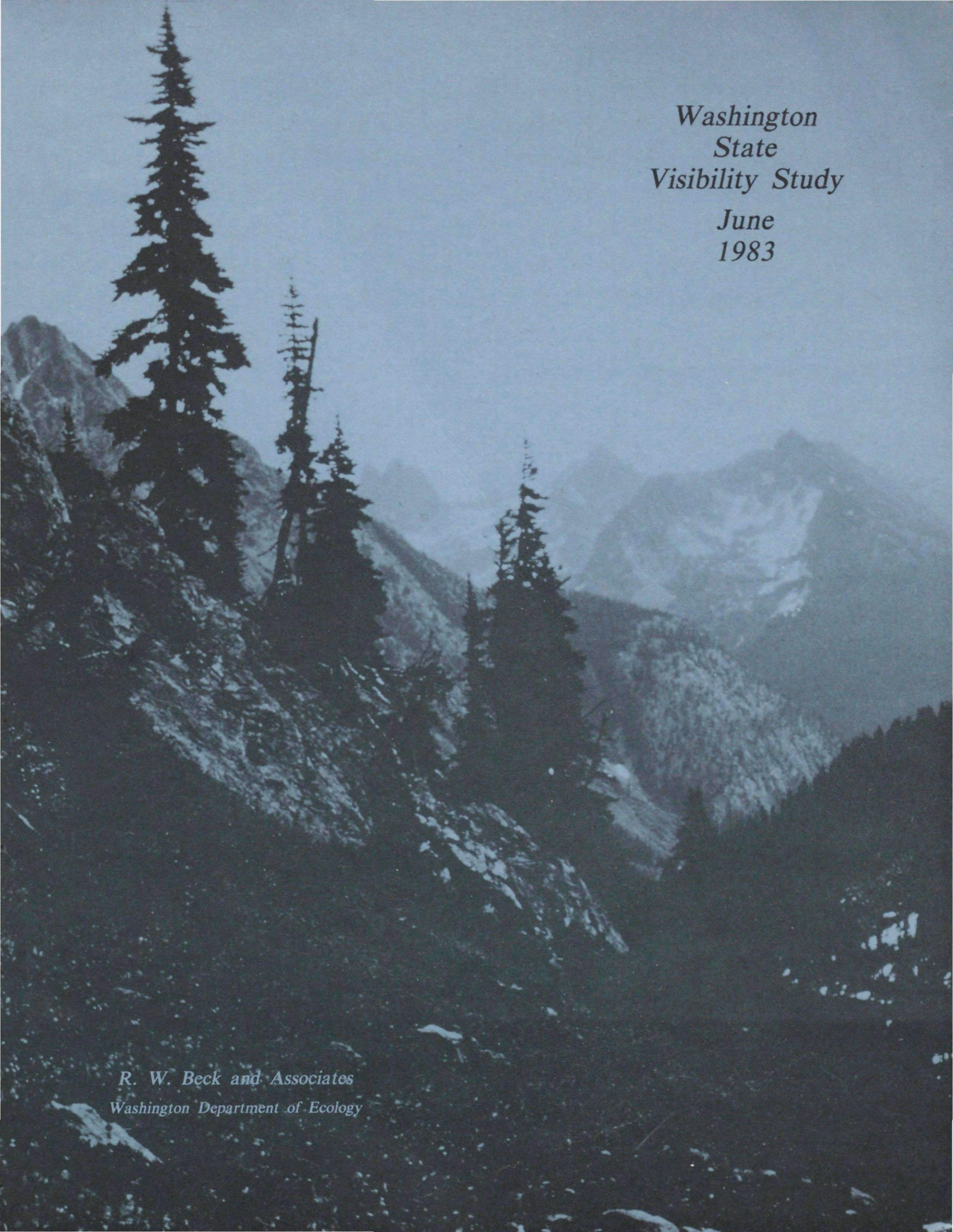

Washington State Visibility Study

June 1983

R. W. Beck and Associates
Washington Department of Ecology

May 1983

WASHINGTON STATE
VISIBILITY STUDY

1982 FINAL REPORT

by

R. W. BECK AND ASSOCIATES

and

THE WASHINGTON DEPARTMENT OF ECOLOGY

Washington Department of Ecology
Contract Number 82-085

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INTRODUCTION

SECTION I

INTRODUCTION

The 1981-1982 Visibility Program for the State of Washington was undertaken in response to the Environmental Protection Agency (EPA) Visibility Regulations of December 2, 1980 (Federal Register, Vol. 45). Visibility regulations are designed to protect the visibility in mandatory Class I areas and their associated integral vistas. Mandatory Class I areas in the State of Washington include three national parks (North Cascades, Olympic, and Mount Rainier) and five wilderness areas (Alpine Lakes, Glacier Peak, Goat Rocks, Mount Adams, and Pasayten). Preliminary integral vistas were designated by the National Park Service (Federal Register, Vol. 46, January 15, 1981) for the North Cascades, Olympic, and Mount Rainier National Parks.

The purpose and goal of the visibility protection regulations are to: (1) require that states develop programs to assure reasonable progress toward meeting the national goal of preventing future, and remedying existing, impairment of visibility in mandatory Class I Federal areas resulting from manmade air pollution; and (2) establish necessary additional procedures in conducting visibility analysis for any new source permits for use by applicants for new source permits, state agencies, and Federal Land Managers (FLM's).

Washington is required by EPA to revise its State Implementation Plan (SIP). In revising the SIP, the State must include: (a) consideration for Best Available Retrofit Technology (BART) for existing stationary sources; (b) FLM/state coordination with respect to BART and New Source Review (NSR); (c) identification of integral vistas; (d) determination of a long-term strategy; and (e) implementation of a NSR procedure.

A study to develop the required visibility program for the State of Washington was conducted during the summer and early fall of 1981 and 1982 by R. W. Beck and Associates and the Washington State Department of Ecology (WDOE). The 1981 study included: (1) initiating the monitoring network and visibility data analysis; (2) determining the sources most likely to cause visibility degradation in Class I areas; (3) exploring control strategy options; and (4) presenting long-range monitoring and control strategy recommendations.

During 1982, the study concentrated on continuing the monitoring network, and refining control strategies to incorporate into the Washington SIP. The monitoring network was improved and expanded in the following areas: visual observation and photographic monitoring techniques; source apportionment studies; and additional sites and instrumentation. Work proceeded among the cooperating agencies toward finalizing long-range control strategies and developing a long-term monitoring program. The resulting

"Draft Revision to the Washington State Implementation Plan, Washington State's Visibility Protection Program" was issued by WDOE, Division of Air Programs, on February 22, 1983.

An overall description of the program is presented in the Executive Summary, Section II. The 1982 monitoring network is described in Section III. Analysis and discussion of the 1982 monitoring results are presented in Section IV. One of the main purposes and most important products of the visibility project is the proposed SIP revision discussed in Section V, Control Strategies. Conclusions and recommendations are presented in Section VI.

SECTION II

EXECUTIVE SUMMARY

SECTION II

EXECUTIVE SUMMARY

The goals of the 1981-1982 visibility study conducted by the WDOE and R. W. Beck and Associates were to:

1. set up a visibility monitoring network;
2. begin tracking visual air quality levels;
3. identify sources when possible;
4. define a control strategy to remedy existing and prevent future visibility degradation in the Washington mandatory Class I areas and their integral vistas;
5. set up lines of communication between key people in concerned agencies; and
6. prepare the SIP revision for visibility protection.

The initial work on these projects was carried out during the summer and fall of 1981 (R. W. Beck and Associates and WDOE, 1982). This report describes the work accomplished during 1982 and presents the proposed SIP revision in the context of the study.

The visibility network was expanded during 1982 to include two additional nephelometer stations (Mount Baker and Hurricane Ridge); additional information from the observation network (impairment description sheet); an expanded photography network; and additional analyses of the filters from the Dog Mountain fine particulate mass sampler. All of these data can be used for long-range tracking of air quality levels and, in some cases, for source identification.

Data recovery in 1982 improved over 1981. The use of impairment description sheets provided additional information on the type, border color, extent, and possible source of the impairment. The photographic network provided a record of visibility conditions, a basis for estimating air quality levels and, in some cases, a method of source identification. The nephelometer network was expanded to four stations. Nephelometer data are used to record the number, intensity, duration, and timing of plume impacts. The fine particulate mass filters were used to determine concentrations, to identify the chemical constituents of the fine particulates collected and, when possible, to identify sources through statistical analyses of the chemical data.

Results from the visual observation data analysis show a high incidence of days with smoke reported with respect to number of days free from weather (fog, rain) impairment. Impairment sources preliminarily identified by the monitoring network included slash burning and Mount St. Helens. Slash burning was associated with concurrent high carbon filter loadings, nephelometer plume impacts, and predicted plume impact using trajectory analysis. Photographs of slash burning interfering with integral vista views as well as smoke intrusions into Class I areas were taken in both Olympic and Mount Rainier National Parks. Filter analysis of 1981 samples from the Dog Mountain site indicates Mount St. Helens SO_2 emissions contribute to high sulfate loadings.

The control strategies proposed in the SIP revision respond to EPA requirements as well as address the impairment sources indicated by the monitoring network. The control strategies propose regulations and procedures to deal with existing stationary sources, new sources and source modifications, and slash burning. The control strategies for prescribed burning include restricting prescribed burning during visibility important weekend days and reducing total emissions. The forest managers have established an objective of reducing total emissions from prescribed burning by 35% in western Washington by 1990. The proposed SIP revision also contains a long-term visibility monitoring strategy, evaluations of secondary long-term control strategies, and procedures for coordination and review.

Study conclusions and recommendations:

1. Class I areas in the State of Washington need visibility protection to remedy existing effects and to prevent further degradation.

2. The control strategy approach proposed by the State is directed toward controlling identifiable sources contributing to existing or future impairment in Class I areas.

3. The foundation formed by control strategies for existing sources, new or modified sources, and slash burning needs to be developed and expanded to include procedures assuring timely and cost-effective implementation.

4. The monitoring network needs to be continued, refined and expanded to provide consistent and reliable data to estimate visibility levels, identify sources and provide a long-term record of changes to evaluate the effectiveness of the control strategies.

SECTION III

VISIBILITY MONITORING PROGRAM

SECTION III

MONITORING PROGRAM

The EPA, recognizing the need to begin protection as soon as possible, established a two-phased approach to visibility protection. Under Phase I, the State must identify the origin of visibility impairment caused by a single source or small group of sources. Identification can be accomplished with simple monitoring techniques such as visual observations (either ground-based or from aircraft) or with other appropriate monitoring techniques at the State's discretion. The pollutants of concern in Phase I are suspended particulates and NO_x. The second phase will address SO_2 impacts and the more complex problems of regional haze and urban plumes. Guidance and regulations on second phase concerns will be forthcoming from EPA.

The Washington State visibility network was designed to address Federal air quality concerns within the framework of the two-phased approach. The purposes of the network are to measure the extent, duration, and magnitude of visibility degradation; track the changes in these values during the course of the study; and identify, whenever possible, the source or sources responsible for visibility degradation.

The State's monitoring strategy employs current instrumentation and methods but anticipates improvements in equipment and methodology through continuing research devoted to visibility monitoring. During periodic review of the monitoring network, the application of additional monitoring techniques and analyses will be considered. Guidance for the monitoring program and research developments in instrumentation and analysis are anticipated from the EPA and the NPS.

MONITORING NETWORK

The visibility monitoring network was set up in the State of Washington during the summer of 1981. Although eight mandatory Class I Federal areas exist within the State, the monitoring program was restricted to the three national parks due to limited funding and the availability of on-site personnel and power. The visibility monitoring program, as described in Washington State Visibility Study (R. W. Beck and Associates and WDOE, 1982), incorporates techniques ranging from the most basic method, human observations, to state-of-the-art instrumentation, as recommended by EPA guidelines (USEPA, 1979, and 1980). Monitoring techniques and locations are listed in Table III-1 and shown in Figure III-1. Figure III-2 shows the viewshed representation of the Camp Muir integral vista viewpoint, Paradise, and Dog Mountain monitoring sites and two of the integral vista targets (Mount Adams and Mount St. Helens).

TABLE III-1

VISIBILITY MONITORING NETWORK AND LOCATIONS

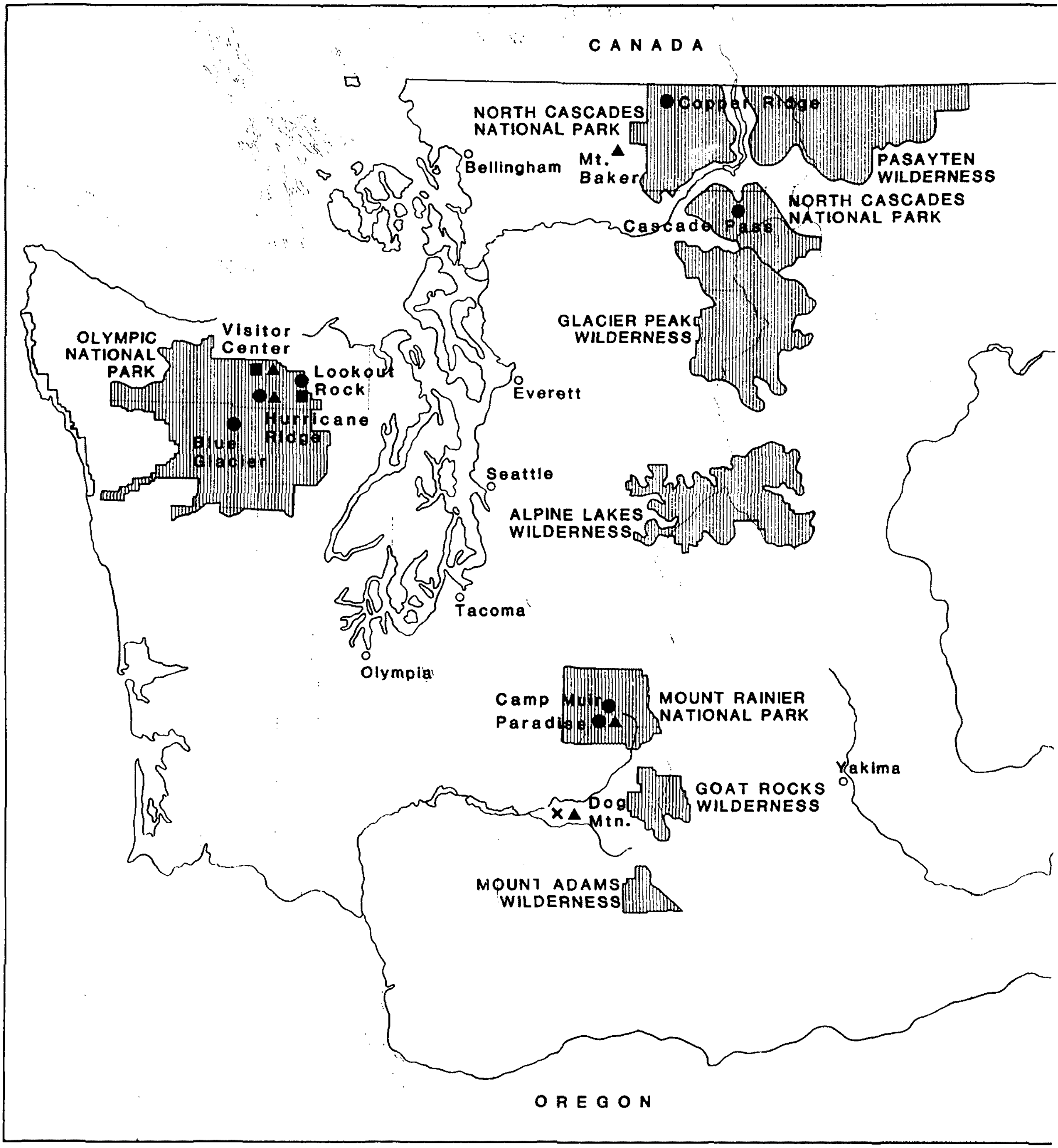
Site and Elevation (ft.)	Data Type
MOUNT RAINIER NATIONAL PARK	
Camp Muir, 10018	Visual observations(a); photography(a)
Paradise, 5400	Visual observations, photography, particle scattering coefficient, meteorological-wind speed/direction(a), relative humidity(a)
Dog Mountain(c), 2860	Fine particle mass; particle scattering coefficient
OLYMPIC NATIONAL PARK	
Blue Glacier, 6800	Visual observations, photography(a)
Hurricane Ridge, 5200	Visual observations(a), photography(a), particle scattering coefficient(a)
Lookout Rock, 2700	Visual observations, photography, teleradiometer(b)
Visitor Center(d), 400	Particle scattering coefficient, ozone, sulfur dioxide, total suspended particulate
NORTH CASCADES NATIONAL PARK	
Sahale Arm, 6000	Visual observations, photography(a)
Copper Ridge, 6100	Visual observations, photography(a)
Heather Meadows(c), 4250	Particle scattering coefficient(a)

(a) - Additions to the monitoring network for the 1982 season.
(b) - Deletion from the monitoring network.
(c) - Located outside park boundaries.
(d) - Operated by the Olympic Air Pollution Control Agency and the Olympic National Park.

Figure III-1

VISIBILITY MONITORING SITES

SUMMER 1981-1982



● Visual Observation / Photography
▲ Nephelometer
× Particulate Sampler
■ Telephotometer

CAMP MUIR:

Visual Observations

Photographs

PARADISE:

Visual Observations

Photographs

Particle Scattering

Meteorological Data

DOG MOUNTAIN:

Particle Scattering

Fine Particulate Mass

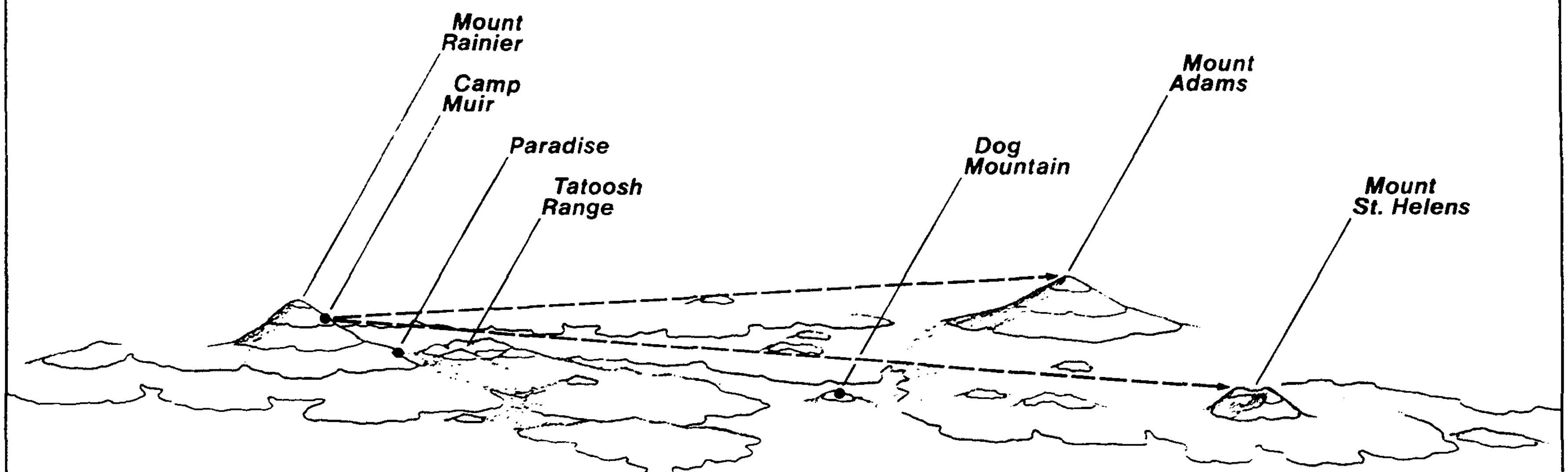


Figure III-2

VIEWSHED MONITORING
MOUNT RAINIER NATIONAL PARK

Improvements and changes to the network were made during the second year of operation. These changes, listed in Table III-1, enhanced the network's capability to measure and record existing visibility. Three sites were added, one in each national park. The monitoring techniques and sites added are: Camp Muir, Mount Rainier National Park - observations and photography; Hurricane Ridge, Olympic National Park - observations, photography and particle scattering; and Mount Baker, adjacent to North Cascades National Park - particle scattering.

The increased number of sites with improved photographic and observation network enabled the documentation and recording of periods of visibility impairment at each of the three parks. These additions were consistent with the primary purpose of the network, i.e. to record the extent, duration, and magnitude of impairment. The monitoring network was implemented to measure impacts of plumes from industrial, prescribed burning, or natural sources. Nephelometers were used to record plume impacts and quantify the duration and extent of the impact. This information, along with photographs of visual impact, establishes a visibility record that can be used to determine impairment levels.

The most significant additions and improvements to the monitoring network in 1982 for identifying sources and defining impairment levels were the impairment description sheet, the photography network, and the chemical composition analysis of the fine particulate mass collected at the Dog Mountain site. The purpose and use of these techniques are presented below.

Impairment Description Sheet

The purpose of the impairment description sheets is to collect more definitive data during impairment occurrences. Observers were instructed to fill out the additional information for all occurrences of obscured visibility other than weather events. The questions on the impairment description sheets were phrased to provide objective information on the type, border, color, possible source, and extent of the impairment. A sample impairment description sheet appears in Appendix A.

Photography Network

Standardized photographic monitoring is combined with human observation programs at the seven sites listed in Table III-1. The principal purpose of photographic monitoring is to document the scene as originally perceived and record any instances of impairment. Photography can also be used for photogrammetry, a process that measures the color density of individual sections of the picture to determine quantitative contrast values. While this technique is presently being used only for the photographs from the Lookout Rock site, film calibration procedures have been implemented at all sites for possible future color density measurements. All photographic monitoring follows recommended EPA and NPS methodology (EPA, 1980; NPS, 1981), which define quality assurance procedures, film type, exposure, time, and target selection.

Briefly, these recommended procedures include: using a standard film with all film development for NPS photographic sites performed at the same laboratory (Kodak ASA 25 Kodachrome slide film with processing by the Kodak Los Angeles lab); filming a standard color chart and grey scale for each role; using a standard camera and lens (Olympus OM-2 with 50 mm or 135 mm lenses with UV filter used in the auto mode); taking all photographs at a standard time; and filming a predetermined set of targets from each site.

The advantages of using photography as a monitoring technique are low equipment cost, low operating expense and labor requirements, and a permanent record of visibility at critical viewpoints. The photographs can be used to track changes in visibility, to identify certain sources of impairment, and as a basis for calculating air pollution concentrations.

An additional function of the photographic monitoring program is to establish an historical reference for demonstrating reasonable progress. Future monitoring considerations for this program include time-lapse photography to document plume impacts, and automatic camera monitoring stations to record the visibility conditions at remote or un-manned locations. Photographic monitoring includes photo-observation flights. These flights are used to document conditions of impairment, to attempt source identification, and to record impacts from point sources, prescribed burns, and urban haze, when possible.

Chemical Composition Analysis

The fine particulate sampler (2.5 um, 50% transmission cut) at the Dog Mountain site was in operation from May through October 1982. Daily 24-hour samples were taken from noon to noon either on glass fiber or cellulose acetate filters. All sampled filters were measured for fine particulate mass concentrations. Filters from days of interest (e.g., low visibility due to plumes and/or hazes, or extremely clear days) were selected for chemical analysis to determine the chemical composition of the collected particles.

Data from the fine particulate mass sampler are used to determine the air pollution sources contributing to visibility impairment within the Mount Rainier-Camp Muir viewshed. Selected filters have undergone analysis to determine the chemical composition of the material collected. This information is used with statistical models to establish the relative source classification contribution to the collected particle mass. Source (or source classification) data needed to determine the source apportionment of the filter mass are an accurate physical and chemical characterization of the emissions. Information available for this study of source emissions characterization is presented in Table III-2. Of particular interest to this study are the source signatures determined by the Oregon Department of Environmental Quality (ODEQ) and used in source apportionment studies in Oregon (Cooper & Watson, 1979; DeCesar and Cooper, 1981).

Analytical methods and laboratories used for chemical characterization are presented in Table III-3. The ODEQ Laboratory and facilities at the

TABLE III-2

DATA INVENTORY FOR CHEMICAL COMPOSITION ANALYSIS

A. 1982 Dog Mountain Filters (150 exposed filters + blanks)

date
fine particulate mass (fpm)
fpm concentration
b(sp) particle scattering coefficient
b(ap) particle absorption coefficient - by the IPM

B. 1981 Dog Mountain Filters (50 exposed filters)

date
fpm
fpm concentration
b(sp)
b(ap) (by IPM on most, not all of filters)
chemical analysis of 9 (7 good) samples:
Cl, NO_3, SO_4, NH_4, K, Na, C

C. Compilation of Source Signatures from Literature

sea salt	fly ash
soil dust	refuse-derived fuel
fuel oil fly ash	auto exhaust
Portland cement	tire dust
coal-fired boilers	copper smelters (Arizona)
ASARCO (only 5 metals)	St. Helens (limited info)
urban aerosols:	remote areas:
Denver, Houston,	northern Michigan
Wash. D.C., N.Y.	northern Canada

D. Compilation of Source Signatures in Oregon (by DEQ)

soil	fireplaces
road dust	field burning
marine air	Kraft mill
slash burning	woodstoves
hog fuel boilers	several mfg. processes

E. Slash Burn Smoke Signature

aircraft and ground level samples from the Portland, Willamette Valley, and Eugene areas

F. Oregon DEQ 1982 Filters (14 each at 2 remote sites)

date
fpm
metals
anions
cations
carbon

University of Washington were used for the chemical and optical analyses. The analysis scheme included determining the particle absorption coefficient by the optical integrating plate method (IPM) (Lin et al., 1973) which has been shown to infer elemental carbon mass loadings (Hansen, et al., 1979; Weiss et al., 1979; Sadler, et al., 1981); the total carbon content by flame ionization at both facilities; and elemental and chemical species by x-ray fluorescence and by ion chromatography at ODEQ and by the inductively coupled plasma technique at the University of Washington. Comparisons between laboratories and analytical methods are presently being analyzed at the University of Washington.

The final goal of the analysis is to use the laboratory results to seek possible correlations between visibility degradation and chemical tracers and thus identify, if possible, the associated source or sources responsible for reducing visibility.

TABLE III-3

ANALYTICAL METHODS AND CHEMICAL CHARACTERIZATION
FOR FILTER ANALYSIS BY LABORATORY USED

Laboratory	Analytical Method	Element/Species Ion Capability
Oregon Dept. of Env. Quality	X-Ray Fluorescence(b)	Al, Si, S, Cl, K, Ca, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, Br, Cd, Ba, Pb
	Volatilization-Flame Ionization(a)	Total carbon
	Ion Chromatography(c)	F, Cl, Br, NO_3^-, $SO_4^=$
University of Washington		
Dept. of Geological Sciences	Inductively Coupled Plasma(c)	Hg, Al, P, Sr, Pb, Cd, Ba, Fe, Mn, Mg, Si, V, As, B, Nb, Zn, Cu, Na, Ca, Ti, Zr, Co, Li, Ni, Cr, Sc, Y, La, K
Dept. of Oceanography	Flame Ionization(a)	Total carbon
Dept. of Civil Engineering	Integrated Plate(c)	Absorption (elemental carbon)

(a) - Glass fiber filters only.
(b) - Cellulose acetate filters only.
(c) - Both filters.

SECTION IV

DATA ANALYSIS
1982 MONITORING RESULTS
AND DISCUSSION

SECTION IV

DATA ANALYSIS
1982 MONITORING RESULTS AND DISCUSSION

Federal and Washington State's draft visibility regulations define impairment in terms of humanly perceptible changes in visibility from natural conditions taking into account geographic extent, intensity, duration and frequency, and how these factors correlate with times of visitor use and enjoyment of Class I areas. Therefore, the information required to determine visibility impairment levels includes both Class I visitation data and source emission data.

Information presented in this section includes data collected through the visibility monitoring network, and the support data of visitor usage and emissions from natural and manmade pollution sources.

VISITOR USE - CLASS I AREAS

National Park Visitor Use

Total visitation to the three national parks in the State of Washington declined steadily from 1978 through 1981. However, visitation increased sharply in 1982 to a five-year high. (See Table IV-1.)

Total visitation in July and August decreased from 1978 to 1980 but increased from 1980 to 1982. Although the number of July and August visitors was greater in 1982 than in the previous two years, the percentage of total annual visitation ascribed to July-August visitors dropped to a five-year low in 1982. This decline means, of course, that non-summer visitation to Washington national parks greatly increased during 1982. This conclusion is supported by the June-September percentages which hover around 72% (1978-1981) and drop to 66% in 1982.

Daily visitation in Mount Rainier National Park approximately doubles on weekends (Saturday, Sunday, and Holidays) as compared to weekdays (Monday-Friday). (See Table IV-2).

The important conclusions to be drawn from these data are (1) that although use in July and August decreased in 1982, these months still account for by far the heaviest visitor use of the year, and (2) that Saturday, Sunday, and holiday use is heavier (per day) than weekday use.

TABLE IV-1

ANNUAL VISITATION
MOUNT RAINIER, NORTH CASCADES, AND
OLYMPIC NATIONAL PARKS

	1978	1979	1980	1981	1982
Annual Total	5,039,740	4,373,643	4,401,217	4,368,754	5,334,930
Total July-Aug.	2,594,343	2,187,964	1,990,142	2,117,991	2,144,080
% July-Aug.	51	50	45	48	40
% June-Sept.	73	72	74	71	66

Source: Pacific Northwest Region, NPS, February 1983.

TABLE IV-2

MOUNT RAINIER NATIONAL PARK VISITATION
JULY, AUGUST 1982

	July 1982	August 1982
Total for Month	424,888	480,612
Avg. Visitation per Day (M-F)	10,731	11,847
% Visitation Monday - Friday	56%	54%
Avg. Visitation per Day (Sat., Sun., and Holiday)	20,978	24,442
% Visitation Saturday - Sunday	44%	46%
% Increase Weekends vs. Weekday Rate	96%	106%

Source: Pacific Northwest Region, NPS, February 1983.

Wilderness Area Visitor Use

Annual visitor use of wilderness areas is presented in Table IV-3 (USDA, 1981b and 1981c). The visitor use data are in "visitor days" which are defined as the equivalent of 12-hour usage by one person or one-hour usage by 12 people. Monthly use patterns for 1980 for the Pasayten Wilderness were approximately 26% in July, 36% in August and 28% in September (Yenko, 1981). For Glacier Peak in 1977, the following patterns were observed: June - 10.2%, July - 27%, August - 36.7% and September 21.3%; Sunday - 17.6%, Monday - 13.8%, Tuesday - 11.6%, Wednesday - 12%, Thursday - 12.6%, Friday - 14.1%, and Saturday - 18.3% (USDA, 1981b). It can be extrapolated from these data that visitor usage in the wilderness areas is predominantly in the months of July, August, and September, and that weekend visitation is higher (per day) than weekday, on the average.

TABLE IV-3

ANNUAL VISITATION
WILDERNESS AREAS

	1977	1978	1979	1980	1981
Alpine Lakes	-	311,500	311,200	461,100	466,700
Glacier Peak	176,400	116,500	106,300	112,700	121,700
Goat Rocks	65,600	65,300	65,500	9,200	64,800
Mount Adams	55,600	58,700	50,200	(a)	40,000
Pasayten	47,200	55,500	51,500	65,000	65,100

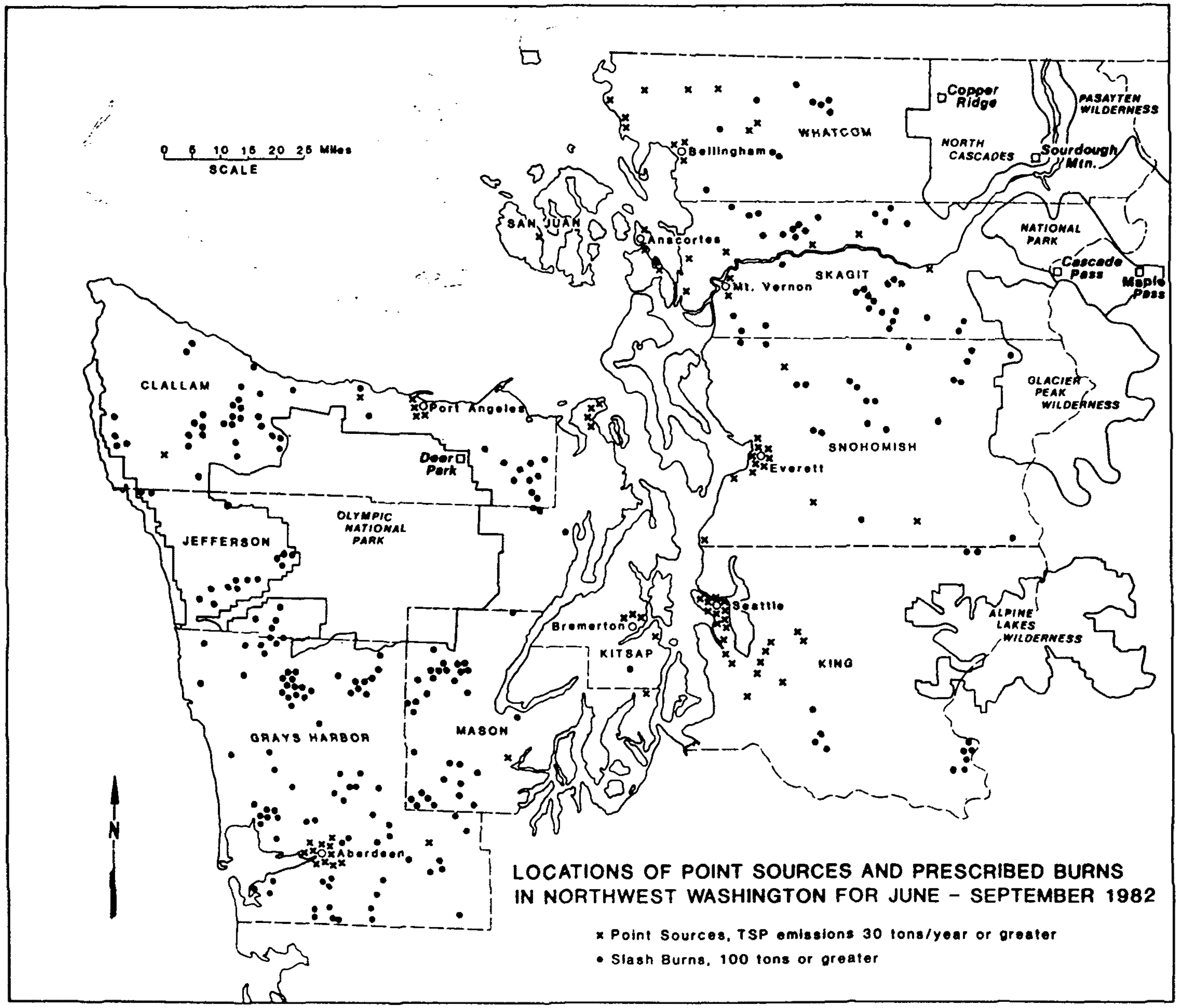
(a) - Area closed due to Mount St. Helens eruption.

SOURCE EMISSION DATA

Anthropogenic Sources

Emissions data from all regulated air pollution sources within western Washington were used to compare source contributions with periods of visibility impairment in the Class I areas. Due to the location of the national parks relative to the major air flow patterns and eastern Washington point sources (and the lack of prescribed burns during the summer in eastern Washington), only sources from the western part of the State were tabulated. For specific impairment cases, however, any source implicated by the concurrent meteorological conditions was analyzed for its contribution.

The emission information necessary to determine the source or sources contributing to visibility impairment include: the location of the source, duration of emissions, and the emission rate or quantity of emissions. This information, along with the concurrent meteorological data, is

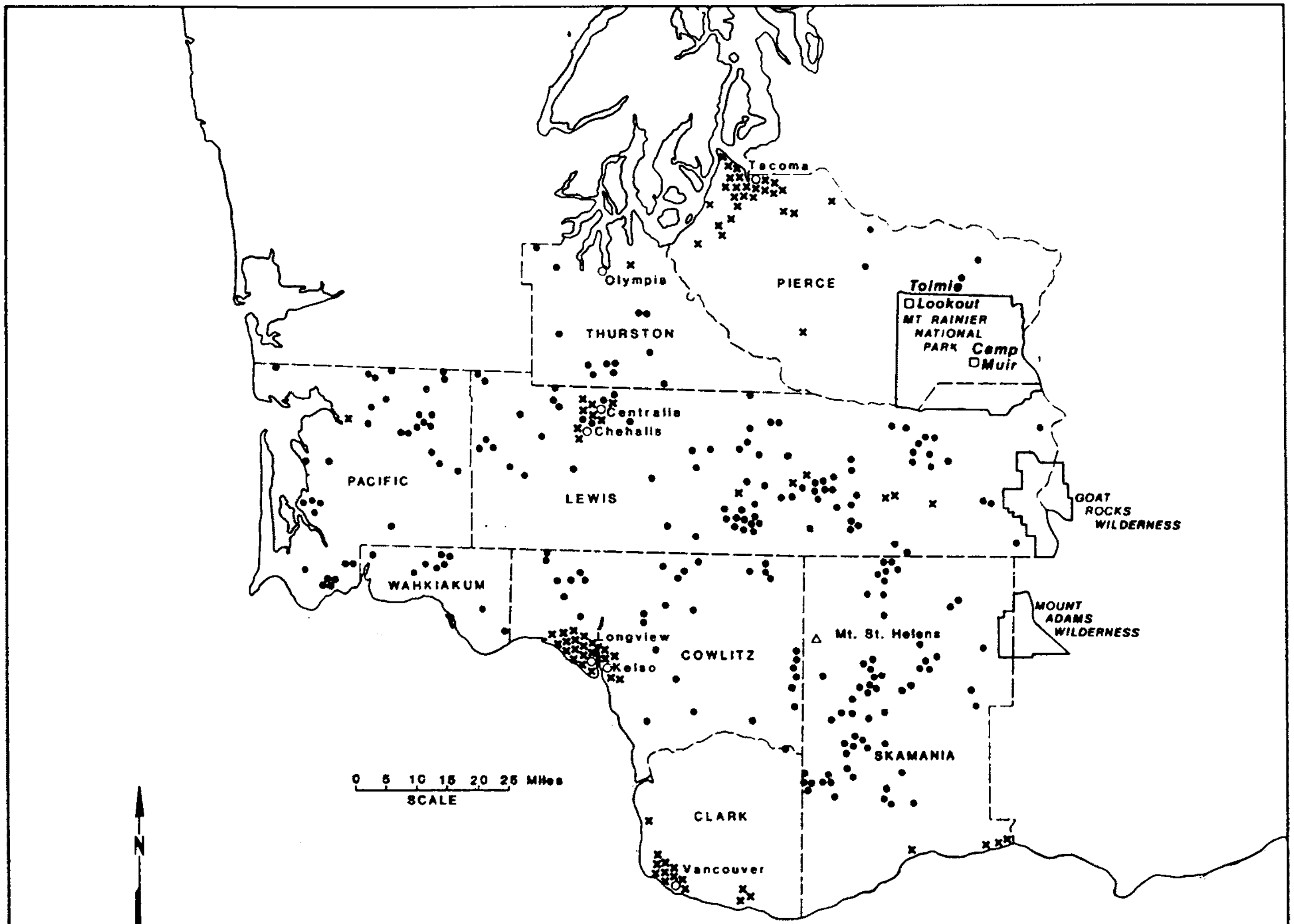


LOCATIONS OF POINT SOURCES AND PRESCRIBED BURNS IN NORTHWEST WASHINGTON FOR JUNE - SEPTEMBER 1982

× Point Sources, TSP emissions 30 tons/year or greater

• Slash Burns, 100 tons or greater

Figure IV-1



LOCATIONS OF POINT SOURCES AND PRESCRIBED BURNS IN SOUTHWEST WASHINGTON FOR JUNE - SEPTEMBER 1982

× Point Sources, TSP emissions 30 tons/year or greater

• Slash Burns, 100 tons or greater

Figure IV-2

used to determine which individual sources may have caused the recorded plume impact at a monitoring site. Emissions were tabulated for the time period that the monitoring network operates (June-September). This period corresponds to the period of highest visitor usage in the Class I areas.

The locations of all western Washington point sources (over 30 tons per year TSP emissions) and prescribed burns during the 1982 monitoring season are shown in Figure IV-1 for northwestern Washington and Figure IV-2 for southwestern Washington. Point source emissions were tabulated using the State's annual emission inventory and the seasonal activity as estimated by the owner. Point source emissions can be considered as having a constant emission rate over the time period of concern (Nelson, 1982).

For the prescribed burns shown in Figures IV-1 and IV-2, the emissions usually lasted for a period of 4 to 6 hours, with highly variable emission rates. Researchers have concluded that emissions depend on a number of parameters, e.g. fuel moisture, piling, or yarding method. For the 1982 burn season, all burns regulated by the Smoke Management Plan (SMP) were reported on a day-by-day basis. Before this season, information on completed burns was required by WDNR to be reported on at least a monthly basis (although some members of the SMP did report daily accounts). Daily accounts of burn information, including location, elevation, tonnage burned, and ignition times provided valuable information for determining sources of visibility impairment.

Total suspended particulate emission data, shown in Table IV-4, indicate that particulate emissions from point sources totaled 12,760 tons during the time period studied. Particulate emissions from prescribed fires are estimated to range from 4,907 to 19,335 tons over the same time period and area considered. Point source emissions are readily quantifiable due to well established emission factors corresponding to the fuel and raw materials consumed. For prescribed burning, however, emissions are quantified by estimating the tonnage of slash to be burned and using emission factors that range from 17 lbs/ton to 67 lbs/ton (GEOMET, 1978). Due to the great variability in factors affecting emissions from prescribed burns and the subsequent large variation in emissions from burn-to-burn, it is difficult to quantitatively estimate total slash burn emissions. In this case, however, these figures do suggest that total emissions from prescribed fires may equal or exceed those from point sources.

Natural Sources

Important natural sources of visibility impairment include atmospheric water (fog, clouds, rain, snow), wind-blown dust, forest wildfires, volcanoes, sea salt, and vegetative emissions. Within the Pacific Northwest all these sources contribute to the natural visibility levels in the Class I areas. Therefore, their impacts must be considered when evaluating visibility impairment.

The natural contribution of fog, clouds, rain, snow and other forms of precipitation can severely degrade visual air quality. The historical frequency of fogs and precipitation in the Pacific Northwest reveals that the

TABLE IV-4

TOTAL SUSPENDED PARTICULATE EMISSION DATA
POINT SOURCES, PRESCRIBED FIRES, AND WILDFIRE
WESTERN WASHINGTON
June-September 1981, 1982
(Tons TSP)

	1981			1982			
County	Point Sources(a)	Prescribed Burning(b) (low) (e)	Prescribed Burning(b) (high) (e)	Point Sources(a)	Prescribed Burning(c) (low) (e)	Prescribed Burning(c) (high) (e)	Wildfire(d)
Clallum	415	326	1,286	216	201	790	
Clark	1,700	10	40	1,760	1	6	
Cowlitz	2,546	350	1,380	2,465	829	3,266	
Grays Harbor	1,169	785	3,091	647	992	3,909	
Island	18	-	-	20	-	-	
Jefferson	289	398	1,567	287	218	859	
King	955	129	509	1,012	113	447	
Kitsap	105	9	36	122	4	17	
Lewis	572	1,097	4,320	648	785	3,093	
Mason	127	349	1,376	137	311	1,224	
Pacific	122	267	1,052	34	208	820	
Pierce	1,577	65	258	2,355	51	202	
San Juan	18	-	-	18	-	-	
Skagit	1,224	392	1,544	1,154	242	952	
Skamania	140	604	2,378	112	586	2,307	
Snohomish	690	216	851	1,070	146	575	
Thurston	15	36	141	22	84	331	
Wahkiakum	29	40	158	27	70	274	
Whatcom	1,049	41	161	838	67	263	
Total	12,760	5,114	20,150	12,934	4,907	19,335	845

(a) WEDS Encoder Report, Washington Department of Ecology, 1981, 1982.
(b) Tabulated from Washington Department of Natural Resources and Annual Report Washington Smoke Management Program, WDNR 1981.
(c) Preliminary data from Washington Department of Natural Resources, 1982.
(d) Preliminary data from Washington Department of Natural Resources, 1983, for acres consumed. Emissions derived from emission factor (EPA, 1977, AP-42) of 1,144 kg/hectare (0.51 ton/acre) for the Pacific Northwest Region.
(e) Best available range of emission factors of 17 to 67 lbs TSP/ton of fuel (D. V. Sandberg, 1975).

coastal and mountainous regions of this area have the highest frequency of occurrence (over 80 days per year) of fog and precipitation in the continental United States (Conway, 1963). Such effects are beyond human control and are seldom viewed as an aesthetic degradation of visual air quality. It should be noted that the monitoring network in each national park is recording the occurrence of these natural effects through the visual observation program.

Orgill and Schmel (1976) have analyzed the frequency of occurrence of dust storms in the continental United States based on National Weather Service observations. The forested and coastal region of the Pacific Northwest have few, if any, episodes. The only areas in the region that have a high incidence of dust are desert and agricultural regions of eastern Washington. The monthly dust frequency for the Northwest shows a summer minimum, partially due to a lull between spring and fall peaks of agricultural activity. Windblown dust emissions were not quantified for this study; however, the percent contribution of soil dust will be determined from the chemical compositional analysis of filters.

An initial attempt to inventory natural hydrocarbon emissions for vegetation has been reported by Zimmerman (1978). Plants release a number of volatile organic substances comprised primarily of ethylene, isoprene, and a variety of terpenes. Although all of these substances are photochemically reactive, the terpenes can be transformed from the vapor state into particulate matter. Based on the emissions estimates of Zimmerman (1978), the temperate rain and conifer forest regions of the Pacific Northwest have among the highest natural terpene emission densities. Terpenes from conifer needles have been shown to affect visibility by reacting rapidly with ambient ozone to form a blue haze (Rasmussen and Went, 1975). Because adequate measurements of terpene emissions from the temperate and conifer forests are not available and are difficult to estimate due to uncertainties in biomass quantities and temperature and sun conditions, it is difficult to estimate the extent of their visual impact and contribution to impairment conditions. Terpene emissions generally tend to be greatest at higher temperatures, lower elevations, and in the spring of the year. For this study terpene particulates were not separately analyzed for their contribution to impairment; however, in the chemical characterization of particulates, terpenes would contribute to the total carbon levels determined.

Due to the proximity of the Pacific Ocean and the predominant westerly weather patterns, marine aerosol can also contribute to particulate concentrations. Cooper and Watson (1979) found a 3% annual average concentration of marine aerosol in respirable particulate levels in downtown Portland, Oregon. Marine aerosol can also contribute to natural sulfur levels. A recent paper by Charlson and Rodhe (1982) suggests the possibility of enhanced natural sulfur emissions in coastal areas and of variations in emissions from regional natural sulfur cycles by a factor of five. A determination of source composition for marine aerosol by the Oregon Department of Environmental Quality (1982) found 10% of the fine composition to be sulfur. For this study, the contribution of marine aerosol will be determined from chemical compositional analysis, using literature and ODEQ values for indicator ratios (e.g., NA^+/Cl^- ratio as suggested by Core, 1981).

The two predominant natural sources of visibility impairment in the State of Washington are forest wildfires and the volcanic activity of Mount St. Helens. Since all of Washington's Class I areas are located in or near forested areas, wildfires can be a significant source of natural visibility impairment. Forest wildfires impair visibility by producing massive smoke plumes and causing haze and reduced visibility over broad regions. Data from all wildfires reported in Washington are tabulated by WDNR and include cause, location, start day and time, and total acres consumed. Wildfire total emissions data for the 1982 study period (June-September) are presented in Table IV-4.

Particulate emissions from all wildfires, 845 tons, are estimated from the total acreage consumed by wildfires. A total of 415 wildfires occurred within the area of interest during the study period (all land west of Range 19, east of the Willamette Meridian) and consumed a total of 1,655 acres (WDNR, 1983). Although a large number of fires were reported, most of them were less than one acre. Emissions were estimated using an emission factor of 1,020 lbs/acre (based on 60 tons/acre fuel consumption) reported by Vatavuk and Yamate (EPA, 1977) for wildfires in the Pacific Northwest.

A plume trajectory method, using meteorological and fire emission data, is used to determine wildfire contribution to periods of impairment. Source apportionment techniques (by chemical and statistical analysis) specifically for wildfire emissions are not possible due to the similar nature of wildfire and prescribed fire emissions. However, in filters where forestry burning is detected, the relative source strength of wildfires versus prescribed fires can be determined from the daily account of prescribed fires and wildfires, given the location, ignition time, and tonnage consumed by each.

Mount St. Helens volcanic activity has received close attention since March 1980. Many researchers have performed airborne studies of the major eruptions and their consequential effects (for example, Fruchter et al., 1980; Ogren, et al., 1980; Hobbs et al., 1981). Of particular concern to the visibility study were the volcanic activities occurring during June through September 1982. Since the major eruption activity of 1980, gas and ash emissions have been monitored by the U.S. Department of Interior (USDI) Geological Survey. The Geological Survey provided data on the daily sulfur dioxide emission rates, dates of gas and ash "bursts," fumarole gas chemistry, gas and particulate chemistry, and daily wind speed and direction measurements directly above the Mount St. Helens crater (Symonds, 1982). Information was provided from May through October 1982.

A time series representation of Mount St. Helens daily sulfur dioxide gas emissions is found in Figure IV-3. Included in the figure are the dates of ash bursts and eruptions. From the Geological Survey data, the sulfur dioxide emissions for June through September 1982 were determined to be 16,700 tons ($\pm$20%). Daily emissions for the summer ranged up to 530 tons per day. The sulfur dioxide emissions from Mount St. Helens during the same time period in 1981 totaled 31,950 tons. The 16,700 tons of sulfur dioxide emitted

during these four months in 1982 make Mount St. Helens the third largest sulfur source in the State during this time. The two larger sources are the Centralia Coal-Fired Power Plant with 18,607 tons, and the ASARCO Smelter with 30,095 tons sulfur dioxide emitted June through September. Mount St. Helens is a likely source of sulfates which contribute to visibility degradation in Class I areas (especially Mount Rainier National Park, Goat Rocks, and Mount Adams Wilderness). The contribution of Mount St. Helens will be determined from the chemical characterization of the Dog Mountain filters. A source signature for Mount St. Helens will be determined from Geological Survey data (i.e., possibly the fluorine to chlorine ratio, Symonds, 1982), or from literature values (Hobbs et al., 1982; Phelan et al., 1982).

VISIBILITY MONITORING NETWORK

The results from the visibility monitoring network are presented below on a site-by-site basis. The results from each monitoring technique are reported, except for photographic monitoring, which is covered at the end of this section.

North Cascades National Park

1. Copper Ridge

(a) Visual Observations

The Copper Ridge Lookout Station was manned by NPS back-country rangers for 68 days during the summer of 1982, from July 6 to September 11. The on-site ranger recorded visibility and meteorological conditions occurring throughout the integral vista. Of the 68 possible days, observations were taken on 42 days, a data recovery of 62%. Missing data are due to the rangers' priority of duties and are not meteorologically related; the data set is considered to be representative of the total time period.

Of the 42 observations over the three-month period, 17 (40%) were obscured due to fog and meteorological conditions (e.g. rain or snow) to one mile or less. The most distant target at this site (Mount Garibaldi, 71 miles to the northwest) was visible on 17 days, a 40% occurrence.

The observed visual range data were used to construct cumulative frequency distributions. For all visual observation sites, distributions are presented in two ways: one distribution includes all recorded values; the second distribution uses only the data set screened for visibility obscuration due to meteorological conditions. The cumulative frequency distributions for the Copper Ridge site are shown in Figure IV-4.

The median visibility (50th percentile) values for the cumulative frequencies are, for all days, 19 miles, and for the meteorological screened data set, near 100 miles. The median value for the screened data is estimated because the farthest target was visible 65% of the non-fog/precipitation

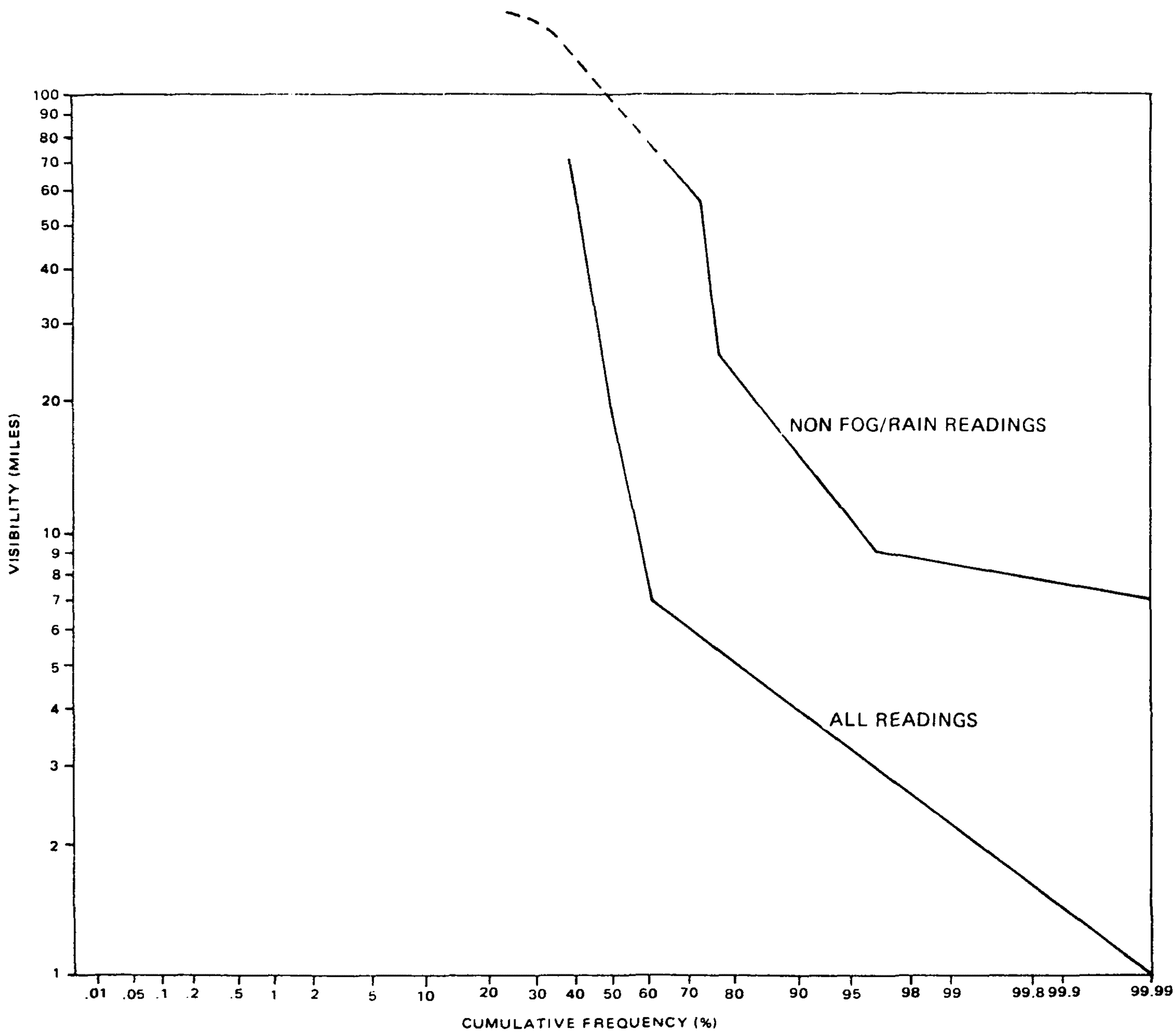


Figure IV–4. CUMULATIVE FREQUENCY, COPPER RIDGE, NORTH CASCADES NATIONAL PARK VISUAL OBSERVATIONS, JULY–SEPT., 1982.

days. To determine the median value, a set of targets considerably more distant than 71 miles would have to be available. The 90th percentile (worst case) visual ranges are: for all days - 4 miles; and for screened days - 16 miles. The 10th percentile (best case) could not be reasonably estimated from the data.

2. Sahale Arm

(a) Visual Observations

At the integral vista at Cascade Pass - Sahale Arm, the NPS backcountry rangers recorded observations on 58 days from July through mid-September. Data recovery for this site was 77%; 58 days out of 75 possible. Meteorological and visibility statistics from this site are: 18 days of fog (31%); 29 days farthest target (42 miles) visible (50% of all days and 72.5% of non-fog/precipitation days); 3 days smoke/plumes reported (7% of non-fog/ precipitation days).

The median and 10th percentile values from the cumulative frequency distribution at this site are not representative of the possible visual ranges because the location of the furthest target was only 42 miles. The 90th percentile (worst case) visual ranges found at this site are, for all days - 4 miles, and for non-fog/precipitation days - 19 miles. The cumulative frequency distribution for the observer visibility values at this site are presented in Figure IV-5.

3. Visual Observations Discussion

Visual observations from Copper Ridge and Cascade Pass/Sahale Arm indicate a significant percentage of days during the summer of 1982 when the visibility was obstructed by fog and/or precipitation. (See Table VI-5.) Fog/ precipitation was reported at Copper Ridge on 40% (17) of the 42 observation days and at Cascade Pass/Sahale Arm on 31% (18) of the 59 observation days. The percentage was higher at Copper Ridge because visual observations were not taken at this site on many clear days. This fact is indicated by the higher percentage of days on which the farthest target was visible ("far target visibility") (49%) for Cascade Pass/Sahale Arm (29 observations) vs. 40% at Copper Ridge (17 observations). Statistics are shown in Tables IV-5 and IV-6 for the number and percentage of days when the farthest target from each of the observation sites is visible. The farthest target distances varies substantially from site-to-site. However, it is meaningful to track far target visibility at each site as an indication of visibility trends. Smoke or smoke plume were sighted on 3 days from each of the North Cascades sites resulting in a 12% smoke/plume percentage for Copper Ridge and 7% for Cascade Pass/Sahale Arm.

Two important differences between the stations to consider when analyzing the data are the period of record and the view distance. Cascade Pass/Sahale Arm is much more restricted from long-range views by local topography than Copper Ridge. In spite of this significant restriction, the two stations are consistent in the number of days for which fog/precipitation are

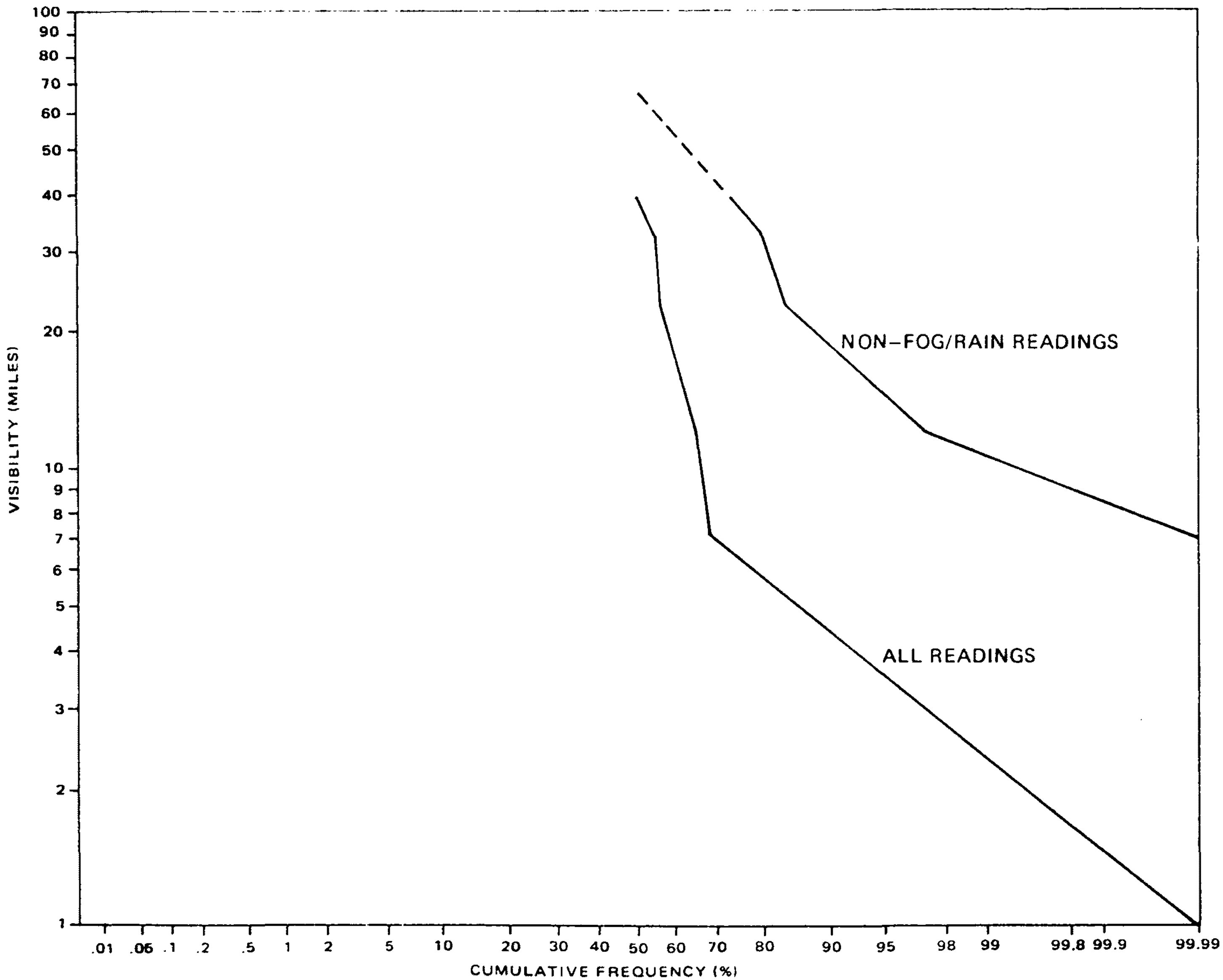


Figure IV–5. CUMULATIVE FREQUENCY, SAHALE ARM, NORTH CASCADES NATIONAL PARK VISUAL OBSERVATIONS, JULY–SEPT., 1982.

TABLE IV-5

1982 VISUAL OBSERVATION DATA,
NORTH CASCADES, OLYMPIC AND MOUNT RAINIER NATIONAL PARKS

Observation Site	Observations	Fog/Precipitation		Far Target Visibility			Smoke/Plumes Sitings	
		# Days	% Days	Target Distance (Miles)	# Days	% Days	# Days	% Non-Fog Days
North Cascades National Park								
Copper Ridge	42	17	40	71	17	40	3	12
Sahale Arm	59	18	31	42	29	49	3	7
Olympic National Park								
Blue Glacier	74	20	27	70	39	53	20	37
Lookout Rock (Summer)	109	27	25	120	73	67	12	15
Lookout Rock (Fall)	85	18	21	120	49	58	17	25
Mount Rainier National Park								
Camp Muir	78	31	40	105	24	31	13	28
Paradise	87	27	31	34	50	57	3	5

TABLE IV-6

1981 VISUAL OBSERVATION DATA,
NORTH CASCADES, OLYMPIC AND MOUNT RAINIER NATIONAL PARKS

Observation Site	Observations	Fog/Precipitation		Far Target Visibility			Smoke/Plumes Sitings	
		# Days	% Days	Target Distance (Miles)	# Days	% Days	# Days	% Non-Fog Days
North Cascades National Park								
Copper Ridge	25	3	12	71	11	44	0	-
Olympic National Park								
Blue Glacier	33	4	12	70	8	24	13	45
Lookout Rock	98	26	27	107	15	15	0	-
Mount Rainier National Park								
Paradise	85	26	31	34	23	27	7	8

reported and the number of days on which smoke was sighted. A comparison of 1981 and 1982 observation data (Tables IV-5 and IV-6) shows a consistent high percentage (44%) of far target visibility for Copper Ridge and a much lower percentage (12%) of fog/precipitation days. The small 1981 sample, 25 observations, may have been skewed toward non-fog/precipitation days.

The North Cascades National Park observer data show high percentages (ranging from 40% to 49%) of far target visibility for both years relatively low percentages (7 to 12%) of smoke sightings for 1982, and high percentages of fog/precipitation days (31 to 40%) for the summer of 1982.

4. Mount Baker Ski Area (Heather Meadows)

(a) Scattering Coefficient

An integrating nephelometer was installed and operated at this site from August until mid-October 1982. The instrument was sited at the USDA Forest Service Guard Station with cooperation and assistance from the Glacier District, Mount Baker - Snoqualmie Forest USDA Forest Service. Difficulties with calibration and quality assurance procedures associated with logistics and instrument malfunction resulted in the data falling below acceptable quality levels. For these reasons, data from this station have been omitted from the analysis.

Olympic National Park

1. Blue Glacier Site

(a) Visual Observations

At the Mount Olympus Blue Glacier site, visibility and meteorological observations were taken every day between June 28 and September 9; a 100% data recovery. Observations were taken twice daily at 0800 and 2000 hours. The observations were taken by volunteers and research staff from the University of Washington Atmospheric Science/Geophysics Department headed by Richard Marriott and sponsored by the National Science Foundation. Targets were the same as those used during the 1981 monitoring, consisting of landmarks predominantly to the northwest and northeast, and ranging to 110 miles.

For the 74-day period, 27% of all observations recorded fog or precipitation which limited visibility to 4 miles or less. On 39 days (53%), visibility was 70 miles or greater. Smoke or plumes were sighted on 20 days, 37% of non-fog/precipitation days.

For all observations, the average visibility was 40 miles; for non-fog/precipitation screened data (visibility equal to or greater than 6 miles), the average visibility was 63 miles. Visibility averaged 51 miles on days where haze/smoke were reported and for observations not obscured by fog, precipitation, smoke, or haze, visibility averaged 73 miles.

The data set from Blue Glacier was divided in four ways for cumulative distribution frequency diagrams. The first two classifications combine both observation times (a.m. and p.m.) on one diagram for all data, and also for non-fog/precipitation observations. The two other distributions represent all data (all meteorological conditions) separated by time of observation; 0800 and 2000 hours. These classifications were established to examine the relationship between time of day and visibility statistics. Results of the cumulative frequencies for the Blue Glacier are shown in Table IV-7 and in Figure IV-6.

(b) Meteorological Parameters

Research personnel at this site also recorded meteorological parameters each time visibility observations were made. The data recorded were wind speed, wind direction, relative humidity, and sky cover conditions. Instrumentation at this site included a sling psychrometer for humidity measurements and an anemometer and vane for wind and speed direction. Meteorological data were most useful for trajectory analysis to determine sources of impairment where meteorological data collected during the impairment event were used to determine specific sources or source types contributing to the observed impairment. These results are presented in the Wind Trajectory Analysis section.

2. Lookout Rock Site

(a) Visual Observations

Visual observations for the 1982 monitoring program started on June 14 at the Lookout Rock site and continued throughout the rest of the year. Observations were taken twice daily, at 0900 and 1500 hours by NPS personnel. Observations and photographs were taken using targets and procedures developed for teleradiometer monitoring at this site during 1980 and 1981. The continuation of monitoring to year's end provided some measure of seasonal variation. The monitoring seasons were classified as summer (June through September) and fall (October through December). The primary period of interest for this study was the summer season.

For the summer season, data recovery was 100% for the 109 possible days. On 73 days (67%), visibility of 120 miles (furthest target) or more was observed. On 27 days (25%), fog or precipitation reduced visibility to 6 miles or less, and on 12 days smoke or plumes were recorded (15% of non-fog days). During the fall, data recovery was 92%, 85 out of 92 days; 49 days (58%), visibility 120 miles or more; 18 days (21%), fog or precipitation reduced visibility to 6 miles or less; and 17 days (25% of non-fog days) smoke was reported. Cumulative frequencies for the Lookout Rock data set were plotted by observation times and by weather interference. Table IV-8 presents the means and percentile found from the cumulative frequency distributions shown in Figure IV-7.

TABLE IV-7

TIME OF DAY VS. VISIBILITY PERCENTILES
FOR BLUE GLACIER, OLYMPIC NATIONAL PARK
(JUNE 28 TO SEPTEMBER 9, 1982)

Visibility Percentile (Miles)

Time of Observation	All Readings				Non-Fog/Precipitation			
	Mean	(Median) 50%	(Best Case) 10%	(Worst Case) 90%	Mean	(Median) 50%	(Best Case) 10%	(Worst Case) 90%
0800	48	35	115	2	61	73	118	28
2000	39	32	115	2	56	50	120	27
Combined	43	32	115	2	59	70	120	28

TABLE IV-8

TIME OF DAY VS. VISIBILITY PERCENTILES
FOR LOOKOUT ROCK, OLYMPIC NATIONAL PARK
(JUNE 14 TO SEPTEMBER 30, 1982)

Visibility Percentile (Miles)

Time of Observation	All Readings				Non-Fog/Precipitation			
	Mean	(Median) 50%	(Best Case) 10%	(Worst Case) 90%	Mean	(Median) 50%	(Best Case) 10%	(Worst Case) 90%
0900	69	122(a)	130+(a)	2	86	170(a)	170+(a)	14
1500	75	145(a)	150+(a)	2	101	180(a)	180+(a)	32
Combined	72	130(a)	130+(a)	2	94	160(a)	160+(a)	15

(a) - Extrapolated from cumulative frequency plots.

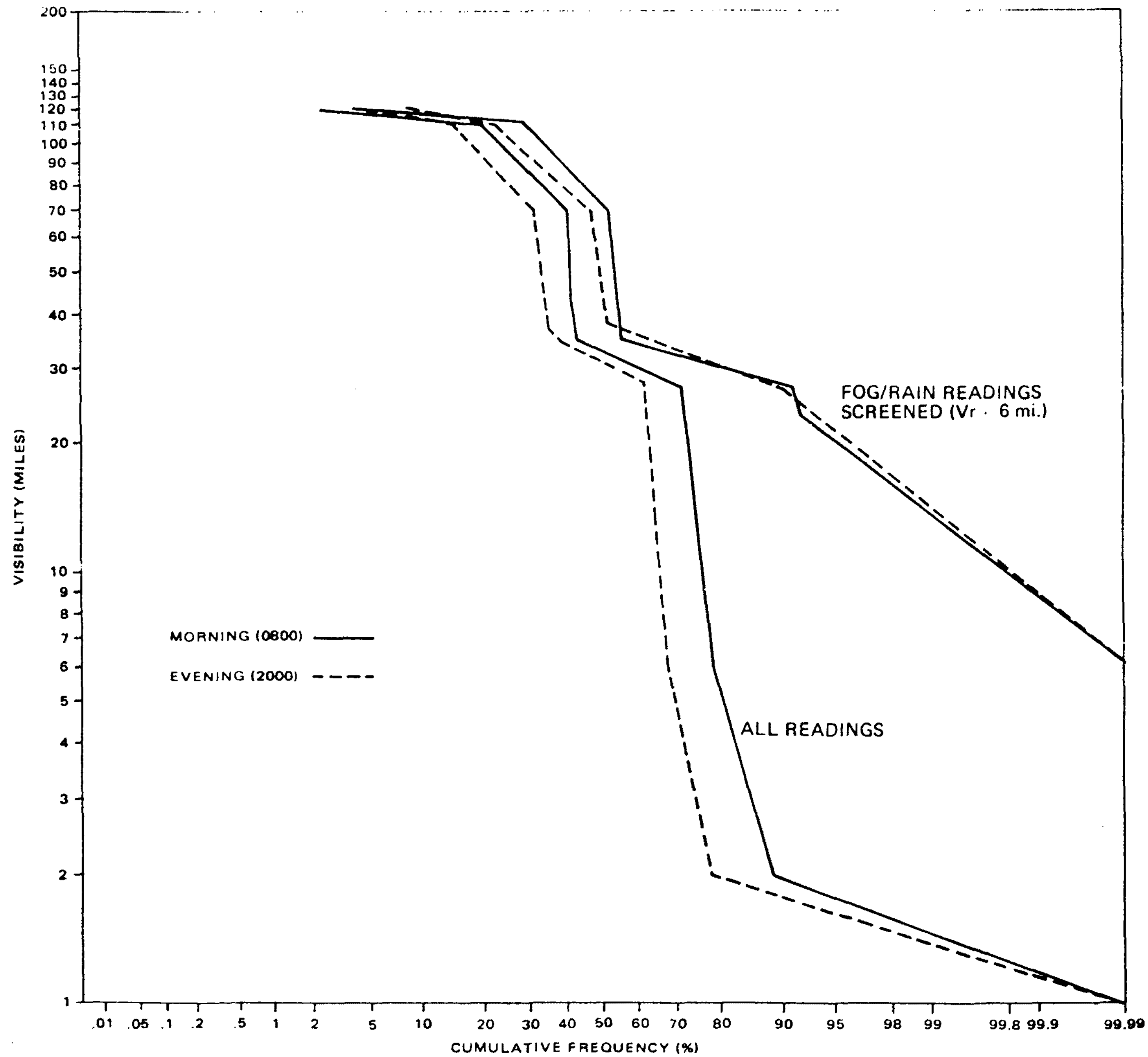


Figure IV–6. CUMULATIVE FREQUENCY, MORNING V.S. EVENING, BLUE GLACIER, OLYMPIC NATIONAL PARK VISUAL OBSERVATIONS, JUNE–SEPT., 1982.

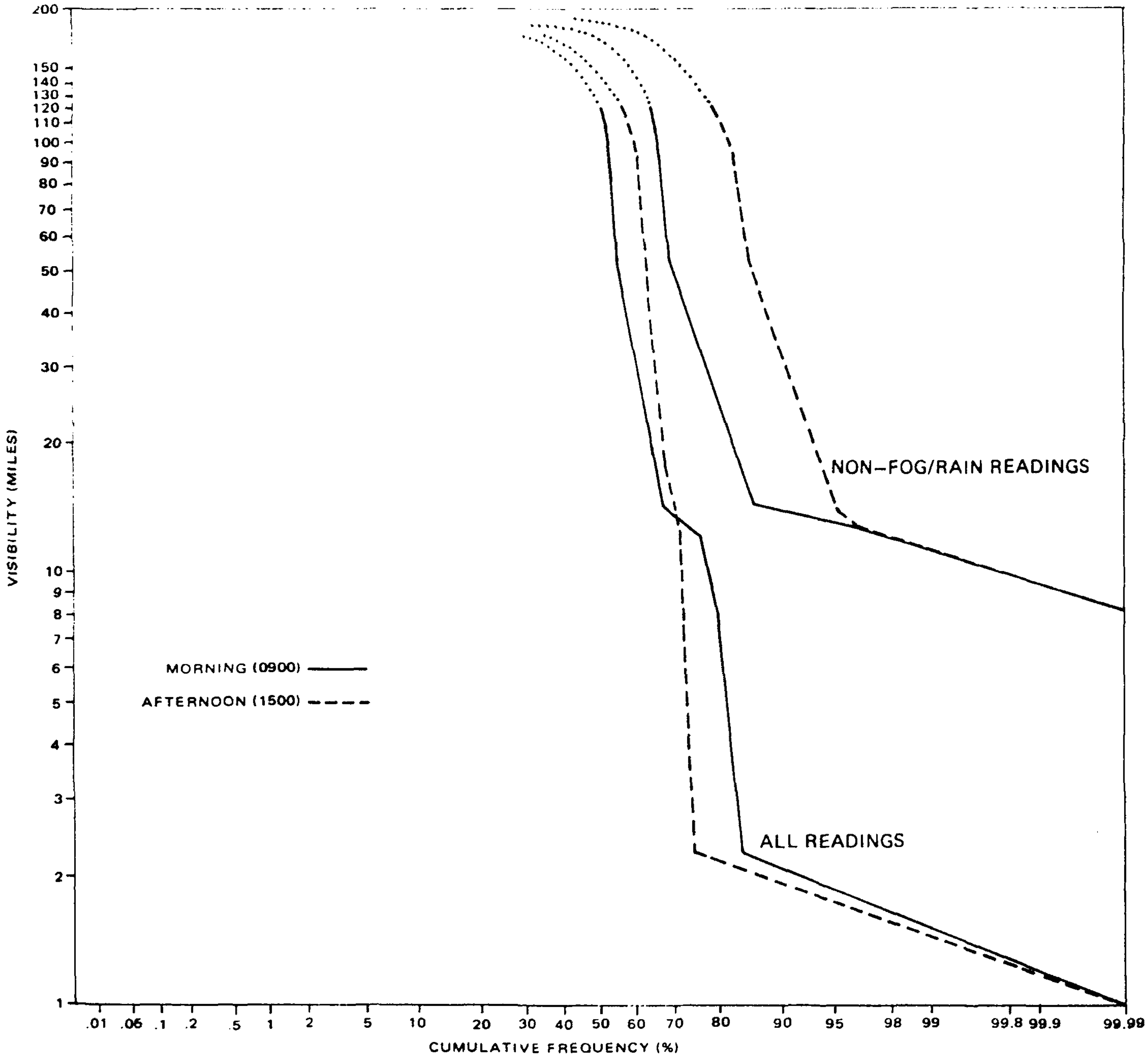


Figure IV–7. CUMULATIVE FREQUENCY, MORNING V.S. AFTERNOON, LOOKOUT ROCK, OLYMPIC NATIONAL PARK VISUAL OBSERVATIONS, JUNE–SEPT., 1982.

(b) Teleradiometer

Teleradiometer (previously telephotometer) measurements were taken at two sites within Olympic National Park during 1980, 1981, and 1982. The instrument and monitoring program was funded by the Air Quality Office of the National Park Service, and the operation was co-sponsored by the Olympic National Park and Washington Department of Ecology. All operating and data handling procedures, quality assurance, and data analysis were provided by the Air Quality Office, NPS, Environmental Monitoring Systems Laboratory, EPA, and Visibility Research Center of the John Muir Institute.

The instrument was operated at the Visitor Center, Olympic National Park (located just south of Port Angeles), and at the Lookout Rock Observation Point. The instrument was first used during spring of 1980 with continued year-round use through the fall of 1982 when teleradiometer funding from the Air Quality Office, NPS, was terminated.

At the Visitor Center, measurements were made viewing one target. The target was looking north across the Strait of Juan de Fuca to a mountain ridge in British Columbia. At the Lookout Rock site the instrument measured contrast values using five targets. Targets were located primarily in the northeast quadrant overlooking Puget Sound and the Strait of Juan de Fuca, and consisted of ridges in the foothills of the Olympics, Cascades, and Coastal Range of British Columbia.

Data from the teleradiometry monitoring at Olympic National Park are listed in Table IV-9.

3. Visual Observations Discussion

1982 Visual observation data for Olympic National Park show moderately high percentages of fog/precipitation occurrences (21-27%), high percentages of far target visibility (53-67%) and moderate to high percentages of smoke/plume sightings (15-37%). (See Table IV-5.) A higher percentage of far target visibility was observed from Lookout Rock (67%) than the Blue Glacier (53%). At the same time the number and percentage of smoke/plume sightings were much higher for the Blue Glacier than Lookout Rock. Both of these observation phenomena might be explained by location and view angles. The view angle from Lookout Rock is mostly to the east and north while the Blue Glacier, located farther south in the Olympic range, is open primarily to the north and west. The view from Lookout Rock is more likely to be affected by pollution originating from Port Angeles and the Puget Sound Basin, while views from the Blue Glacier would be more affected by smoke sources to the south and west of the Olympics.

Visual observation data for 1981 show roughly the same percentage of fog/precipitation (27%) for the Lookout Rock site and much lower percentages of far target visibility for both the Blue Glacier (24%) and Lookout Rock (15%) sites. (See Tables IV-5 and IV-6.) A lower percentage of far target visibility days was also noted at the Paradise site. The data for these three

TABLE IV-9

OLYMPIC NATIONAL PARK TELERADIOMETRY DATA (a)

Season	Data Recovery (b)		Number of Days With Observations	Avg. SVR (c)	Visibility Percentiles (Miles) (d)		
	Observer %	System %			50%	10% (Worst Case)	90% (Best Case)
Spring '80	26	13	65	140 km (88 mi)	(Insufficient Data)		
Summer '80	42	10	75	138 km (86 mi)	126 km (79 mi)	73 km (47 mi)	216 km (135 mi)
Fall '80	70	19	40	137 km (86 mi)	149 km (93 mi)	88 km (55 mi)	255 km (159 mi)
Winter '81	56	9	21	168 km (105 mi)	193 km (121 mi)	128 km (80 mi)	292 km (182 mi)
Spring '81	53	5	9	145 km (90 mi)	162 km (101 mi)	79 km (49 mi)	331 km (207 mi)
Summer '81			(Data not available from John Muir Inst. as of 2/83)				
Fall '81			(Data not available from John Muir Inst. as of 2/83)				

(a) - Source: Air Quality Office, NPS, Environmental Monitoring Systems Laboratory, EPA, and Visibility Research Center of the John Muir Institute.

(b) - The "observer" data recovery value is a measure of the diligence of the field personnel, discounting measurements not made for reasons relating to atmospheric conditions. The "system" data recovery value gives the percent of all possible measurements which result in usable data.

(c) - SVR - Standard Visual Range.

(d) - Visibility Percentiles from Cumulative Frequency Distribution.

stations show a significant number of "haze" occurrences during the summer of 1981. The lower percentages of far target visibility may be due to a higher number of general haze occurrences. The relatively low percentage of fog/precipitation days and the relatively high percentage of smoke/plume sightings at the Blue Glacier site suggests that the few observations that were taken in the summer of 1981 were skewed toward non-fog days with smoke/plume present.

1982 visibility percentile data (Table IV-10) show that visibility mean and median values were higher in the morning at Blue Glacier (view angle primarily north and west) and higher in the afternoon at Lookout Rock (view angle primarily east and north). Also, there is a dramatic increase in mean, median and worst case values for all readings for non-fog/precipitation data. The increase in visibility for best case conditions is far less dramatic. Mean, median and best case conditions are considerably higher for Lookout Rock than the Blue Glacier. However, worst case conditions are higher for the Blue Glacier for the a.m. readings.

Visibility percentile data for 1981 (Table IV-11) is fairly consistent with that for 1982 for Blue Glacier. However, the data for Lookout Rock show dramatic differences in median values between the two years. Again, these differences may be attributible to the higher number of haze occurrences in 1981.

4. Hurricane Ridge

(a) Visual Observations

An observation/photography program was started at Hurricane Ridge September 19, 1982. This site was selected to record visibilities using targets located inside the park. The targets selected at Hurricane Ridge range to 20 miles.

(b) Scattering Coefficient

The monitoring period for the nephelometer at the Hurricane Ridge site began June 22 and ended October 17. The instrument was located at the Emergency Generator Building, 200 yards north of the Hurricane Ridge Lodge.

Local pollution sources which could contribute to scattering levels at Hurricane Ridge include emissions from vehicles in the parking lot to the south and southeast of the nephelometer site, fireplaces and diesel generator fumes at the lodge, campfires and barbecues, and the emergency diesel generator. The contribution of any of these sources is considered to be short-term in nature (up to an hour) and negligible over any longer averaging period. The instrument probe was subject to some influence from trees located to the south and west. Otherwise, the instrument was well sited to measure representative pollution levels.

Data recovery for the monitoring period was 99.4%. Out of 2,797 hours of operation (117 days), only 16 hours were lost due to zero drift

TABLE IV-10

1982 VISUAL OBSERVATION
VISIBILITY PERCENTILES (MILES)

Observation Site	Time of Observation	All Readings (Mean)	All Readings (Median) 50%	All Readings (Best Case) 10%	All Readings (Worst Case) 90%	Non-Fog Precipitation (Mean)	Non-Fog Precipitation (Median) 50%	Non-Fog Precipitation (Best Case) 10%	Non-Fog Precipitation (Worst Case) 90%
Olympic National Park									
Blue Glacier	0800	48	35	115	2	61	73	118	28
Blue Glacier	2000	39	32	115	2	56	50	120	27
Lookout Rock	0900	69	122(a)	130+(a)	2	86	170(a)	170+(a)	14
Lookout Rock	1500	75	145(a)	150+(a)	2	101	180(a)	180+(a)	32
Mount Rainier National Park									
Camp Muir		49	50	135	6	74	74	145	47

(a) - Extrapolated from cumulative frequency plots.

TABLE IV-11

1981 VISUAL OBSERVATION,
VISIBILITY PERCENTILES (MILES)

Observation Site	Time of Observation	All Readings (Mean)	All Readings (Median) 50%	All Readings (Best Case) 10%	All Readings (Worst Case) 90%	Non-Fog Precipitation (Mean)	Non-Fog Precipitation (Median) 50%	Non-Fog Precipitation (Best Case) 10%	Non-Fog Precipitation (Worst Case) 90%
Olympic National Park									
Blue Glacier	1500	44	27	100	6				
Lookout Rock	1500	43	14	120+	-				

and instrument calibration. Data recovery is based on a recording day of 22 hours and does not include the twice daily one-hour clean air purge (which accounted for a total of 236 hours). This instrument proved to be quite reliable, with nearly all of the downtime related to calibration procedures. No instrument malfunctions occurred during the monitoring period.

The nephelometer data are shown in Figure IV-8, time series representations of the daily average value and daily maximum value. The values measured ranged to 25 x $10^{-5}m^{-1}$, the instrument's full-scale span. The instrument detected off-scale maximum values for eight hours during the monitoring period.

Monthly statistical parameters from the Hurricane Ridge site are presented in Table IV-12. Also presented in this table is the value for the Rayleigh scattering coefficient (blue sky, or clean air alone) at this elevation, 1.05 x $10^{-5}m^{-1}$. (NOTE: the scattering coefficient is comprised of the particle scattering coefficient, b_{sp}, which is measured by a nephelometer and the Raleigh scattering coefficient, b_{rg}, which varies with altitude; $b_{scat} = b_{sp} + b_{rg}$.) Most of the values measured at this site are near or below the value for Rayleigh scattering (median, 0.7 x 10^{-5}), signifying that typically the scattering coefficient is dominated by Raleigh scattering and not significantly influenced by pollution.

The nephelometer data also show pollution impacts to the Hurricane Ridge area. There were 15 impacts recorded greater than 5 x $10^{-5}m_{-1}$, with four over 10 x 10^{-5}. Two impacts caused the instruments to read off-scale. These two periods were also the two longest impacts. The first impact period occurred on August 19-20 and was 38 hours in duration with an average value of 11.5 x $10^{-5}m^{-1}$. The second lasted 23 hours between September 21 and 22 with an average of 11.5 x $10^{-5}m^{-1}$. The time of day the high levels were recorded was also of interest. Of 15 impacts, 9 were initiated in the afternoon.

5. <u>Visitor Center</u>

An air quality monitoring station is operated at the Visitor Center of the Olympic National Park. The operation and funding of this station is cooperatively supported by the Olympic National Park, Olympic Air Pollution Control Authority, and WDOE. Parameters measured are total suspended particulates, particle scattering, ozone, and sulfur dioxide concentrations.

This air quality monitoring station is within the Class I area; however, the station is located just outside the city limits of Port Angeles (less than 1 mile) and at an elevation near 400 feet. The measured values at this site are more representative of local pollution conditions than those in the Class I area. These data were reviewed to determine if Port Angeles pollution could influence measurements at the visibility monitoring sites, and not as representing conditions in the Park.

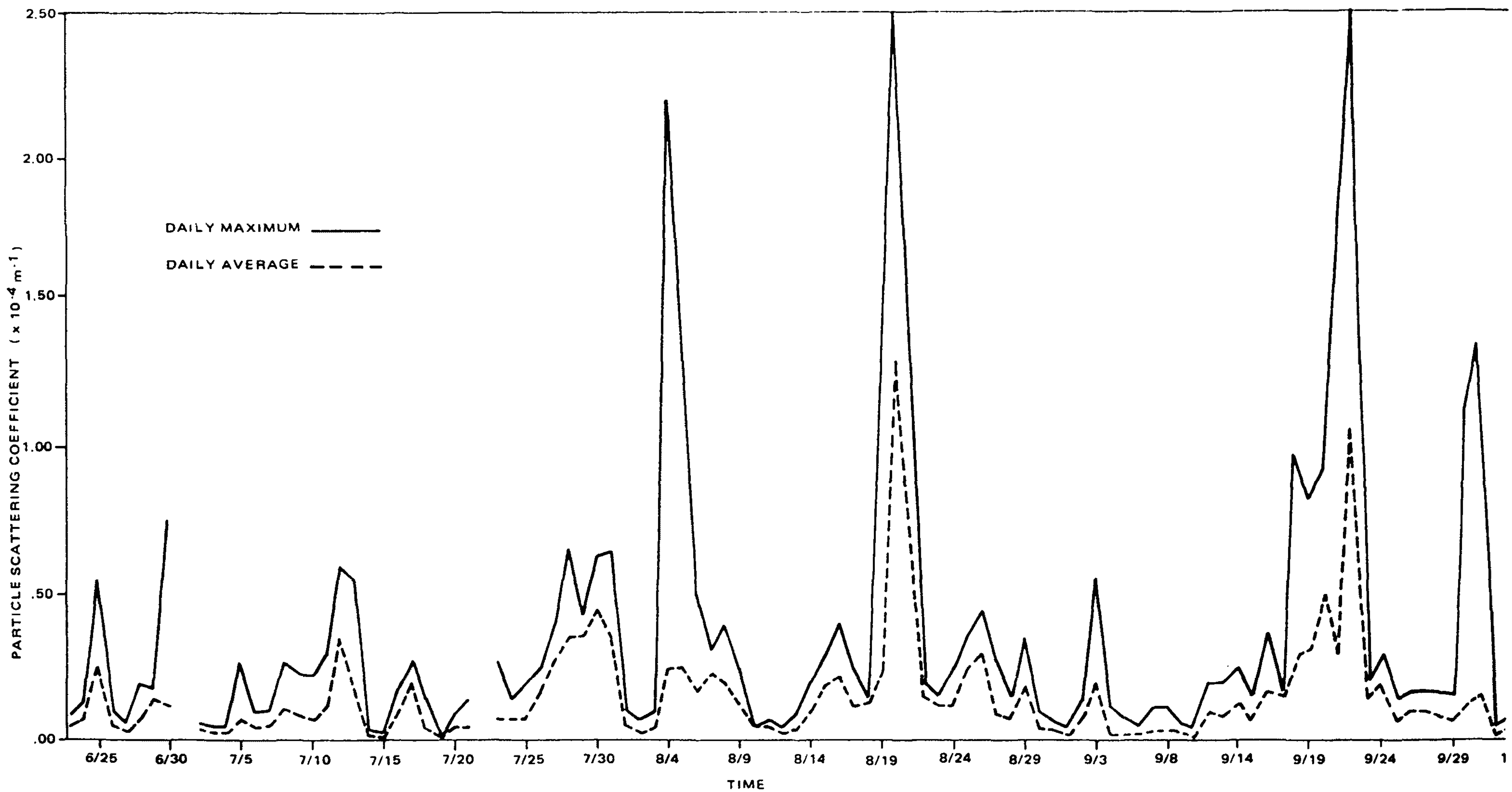


Figure IV–8. PARTICLE SCATTERING COEFFICIENT, HURRICANE RIDGE, OLYMPIC NATIONAL PARK JUNE–OCTOBER, 1982

TABLE IV-12

MONTHLY STATISTICAL PARAMETERS
FOR NEPHELOMETER VALUES

Month and Parameter	Particle Scattering Coefficient ($b_{sp} \times 10^{-5} m^{-1}$) Hurricane Ridge(a)	Paradise(b)	Dog Mountain(c)
June			
Mean	1.0	1.8	2.5
Median	0.8	1.5	2.2
Mode	0.1	2.0	2.0
Maximum	7.5	10+	20
July			
Mean	1.3	1.4	3.3
Median	0.7	1.1	1.6
Mode	0.0	1.0	1.0
Maximum	6.5	9.1	25+
August			
Mean	1.8	2.1	3.9
Median	1.1	1.5	2.5
Mode	0.3	1.0	1.0
Maximum	25+	10+	25+
September			
Mean	1.5	0.8	2.1
Median	0.8	0.7	1.3
Mode	0.2	0.4	1.0
Maximum	25+	3.3	14
October			
Mean	0.6	0.8	1.9
Median	0.3	0.4	1.2
Mode	0.1	0.1	1.0
Maximum	13.5	6.0	13
Total Monitoring Period			
Mean	1.3	1.4	2.9
Median	0.7	1.0	1.9
Mode	0.2	1.0	1.0
Maximum	25+	10+	25+
Standard Rayleigh Scattering(d)			
Clean Air Value, Elevation Corrected	1.05	1.07	1.18

(a) - Monitoring Period from June 22 to October 17, instrument span 0 - 25 x 10^{-5}.
(b) - Monitoring Period from June 9 to October 17, instrument span 0 - 10 x 10^{-5}.
(c) - Monitoring Period from June 1 to October 17, instrument span 0 - 25 x 10^{-5}.
(d) - Bodhaine, B. A. (1979).

Mount Rainier National Park

1. Camp Muir Site

(a) Visual Observations

Observations and photographs were taken at Camp Muir by NPS park rangers from June 26 until September 26, 1982. Observations were recorded on 78 of 92 possible days, an 85% recovery rate. Missing data resulted from scheduling and duty priorities and are not related to meteorological events; therefore, the 78 observations are assumed to be representative of the total sample available. During the 1982 observation period, visibility was limited to 10 miles or less (mostly less than 1/2 mile) on 31 days (40%) due to fog and precipitation. For the 47 days when visibility was not affected by fog or precipitation, average visibility was 74 miles. During 13 of the 47 days (28% of non-fog/precipitation days), plume/smoke was sighted and visibility averaged only 49 miles. For the remaining 34 clear days without weather or plume/smoke intrusions, visibility averaged 82 miles.

The Camp Muir data set is presented in Figure IV-9 as a cumulative frequency distribution. The results of the frequency distribution are shown in Table IV-13.

2. Paradise Site

(a) Visual Observations

Visual observations were taken by NPS personnel at the Paradise Visitor Center from July to the end of September. Observations were taken daily at 1300 hours. The furthest target available from Paradise is 34 miles.

The restricted target distances reduce the value of the Paradise data. A cumulative frequency distribution was not prepared for this site because of the limited target distances. Visual data collected at this station are best used to document weather, and visibility interference resulting from pollution.

The visibility averages from this site are listed in Table IV-13. Other results are: data recovery - 96% (87 observations from 91 possible days); 27 days (31%), weather interference to visibility; 50 days (57%), visibility greater than 34 miles; and 3 days (5% of non-fog days), smoke or plumes reported.

(b) Scattering Coefficient

The nephelometer at Paradise operated from June 9 to October 17. Data from this site are presented in Figure IV-10, a time series representation, and in Table IV-12 which shows statistics for each month of the data set. The data recovery at this site was 87.1%. A total of 372 hours were lost during the 131 days due to instrument zero drift and instrument or recorder malfunction.

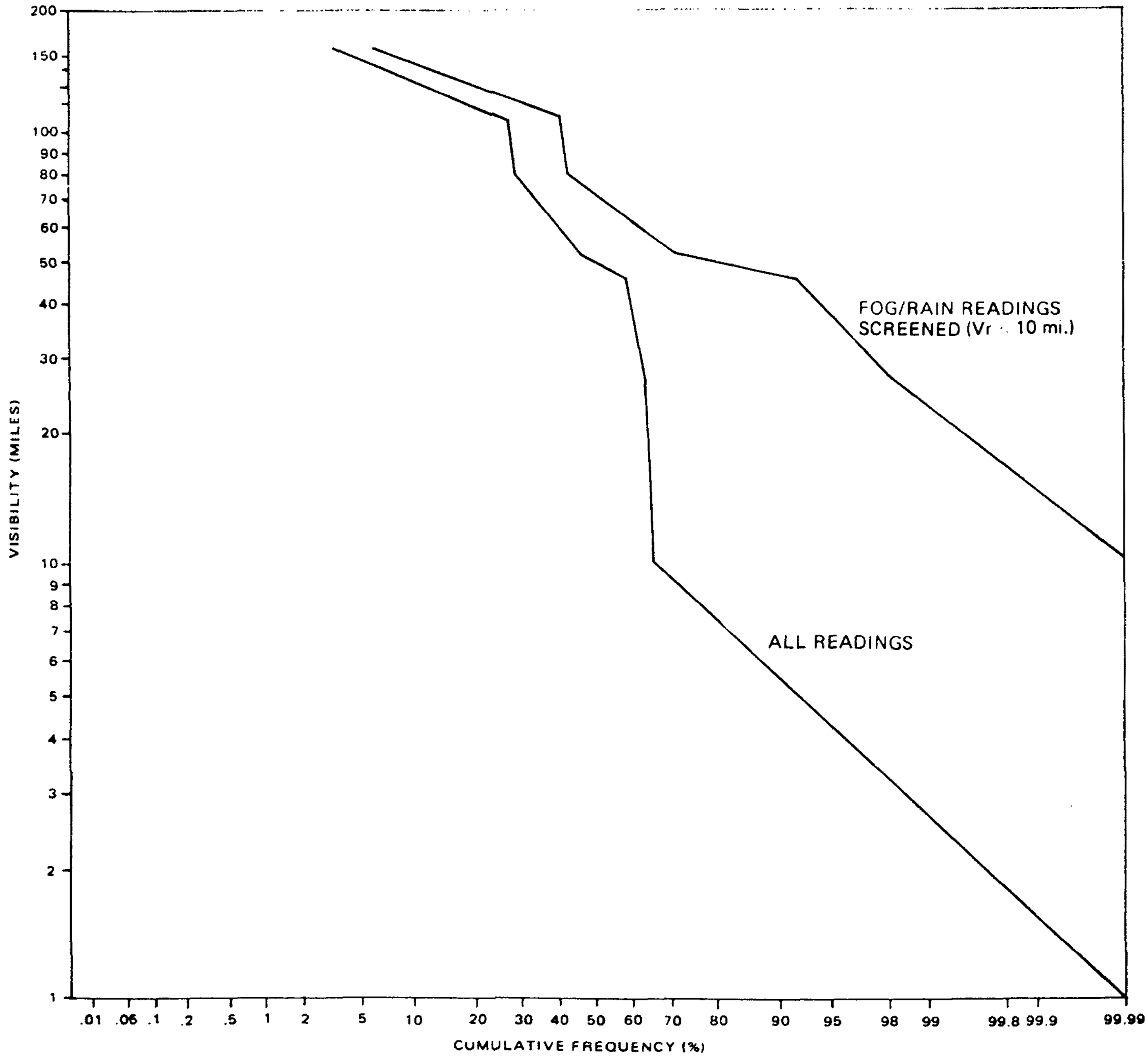


Figure IV–9. CUMULATIVE FREQUENCY, CAMP MUIR, MT. RAINIER NATIONAL PARK VISUAL OBSERVATIONS, JUNE – SEPT., 1982.

TABLE IV-13

MOUNT RAINIER VISUAL OBSERVATION
VISIBILITY PERCENTILES, 1982

Visibility Percentile (Miles)

Site	All Readings				Non-Fog/Precipitation			
	Mean	(Median) 50%	(Best Case) 10%	(Worst Case) 90%	Mean	(Median) 50%	(Best Case) 10%	(Worst Case) 90%
Camp Muir(a)	49	50	135	6	74	74	145	47
Paradise(b)	22	-	-	-	31	-	-	-

(a) - June 26 to September 26.
(b) - July 1 to September 29.

The instrument in operation at Paradise was the most sensitive of the nephelometers with a full-scale reading of 10 x $10^{-5}m^{-1}$. This range proved to be adequate; a full scale of 25 x $10^{-5}m^{-1}$ would be consistent with other nephelometers used for visibility monitoring and would result in fewer off-scale readings. (The Paradise instrument measured off scale 12 hours.) The highest monthly average value occurred during August and the lowest in October. The values measured at Paradise (median 1.0 x $10^{-5}m^{-1}$) indicate a usual pristine air space. The clean-air Rayleigh coefficient of 1.1 x $10^{-5}m^{-1}$ and particle scattering coefficient measured combined for a median value for the scattering coefficient at Paradise of 2.1 x $10^{-5}m^{-1}$.

The nephelometer data show evidence of impacts to the air space within Mount Rainier National Park. Periods of high particle scattering coefficient were recorded during 1982 monitoring. The selected criterion established for indicating the presence of a possible plume impact was an hourly average b_{sp} value of 5 x $10^{-5}m^{-1}$ occurring for two continuous hours or longer (the mean b_{sp} value for the monitoring period was 2 x $10^{-5}m^{-1}$). The cause of these impacts will be determined by reviewing concurrent source, chemical composition of filters, and meteorological data.

During the 1982 monitoring period, 14 periods of high particle scattering coefficient measurements were recorded. These impact periods lasted an average of 5 hours (minimum 2 hours, maximum 16 hours). Within four of these periods, peak values exceeded the scale of the instrument. No marked increase in humidity values were noticed during periods of higher scattering; for the monitoring period, no correlation between scattering and humidity was found.

The time of day during which the high particle scattering coefficient impacts occurred was also of interest. For the 14 occurrences, four events began between the hours of midnight and noon and 10 between noon and midnight. Afternoon, the period of the day when the majority of events began, is also the time of day when relative humidities are usually the lowest. The 50% cumulative frequency for the hourly average value is 1.8 x $10^{-5}m^{-1}$, and for daily maximum 3.7 x $10^{-5}m^{-1}$. The average value for the monitoring period was 1.4 x $10^{-5}m^{-1}$.

(c) Meteorological Parameters

Measurements of wind speed, wind direction, and relative humidity were taken at the Paradise Ranger Station. The instruments were operated during this time period for the visibility study; normal operation occurs November through April for avalanche control purposes. The Park Service is responsible for the siting, maintenance, and calibration of the instruments.

Wind and humidity data provide support information for the visibility monitoring at the Paradise and Camp Muir sites. The data are primarily used with the Paradise nephelometer data (instruments are located approximately 1/4 mile apart). Wind and humidity data assist in determining source contributions for impacts recorded on the nephelometer. Of specific interest was the relationship of humidity levels to particle scattering at this site.

The wind data show the results that would be expected due to the topographical influences at Paradise. Paradise is at the eastern end of the Nisqually drainage valley and has the Tatoosh Range to the south and Mount Rainier to the north. Winds at Paradise are predominantly from the west (42%) due to the synoptic weather patterns and drainage effects. Winds from the north occurred almost 30% of this time period, most likely due to downslope winds from Mount Rainier. Winds from the south were rare (2%), and minimal from the east, 11%. Wind speeds reflected the weaker summer fronts and localized mountain-valley winds. Speeds of 0 to 5 mph occurred 53% of the time, and 5 to 10 mph 30% of the time.

The relative humidity levels at this site were high. Humidities over 90% occurred 41% of the time and over 60% of the recorded humidities exceeded 70%. The lowest humidity value recorded was 21% for three hours; values below 40% occurred 10% of the time.

3. Visual Observations Discussion

Visual observations from Mount Rainier National Park show a high percentage of fog/precipitation days (31%-40%), a high percentage of far target visibility days (31-57%), a high percentage of smoke/plume sightings from Camp Muir (28%) and a low percentage of smoke plume sightings from Paradise (5%).

The number of fog/precipitation days is consistent between Camp Muir and Paradise (fog/precipitation percentages are also consistent with those from the North Cascades National Park). The number and percentage of far target visibility days are much higher for Paradise than Camp Muir. This difference is primarily related to the view distance; the maximum view distance from Paradise is 34 miles while the view distance from Camp Muir exceeds 100 miles. View distance and view angle also contribute to the much larger number and percentage of plume sightings from Camp Muir than Paradise. Camp Muir is located at 10,000 feet with an unobstructed view to the east, south and west. Paradise is located at elevation 5400 and where views are restricted by local topography to short ranges, except for 34 miles to the west.

The 1981 visual observation data for Paradise show numbers and percentages of fog/precipitation consistent with the 1982 Paradise data. In 1981 far target visibility was recorded for half as many days as in 1982. Again, this difference could reflect the higher number of hazy days during the summer of 1981. Four more smoke/plume sightings were reported in 1982 than 1981 from the Paradise site, a slightly higher percentage of smoke during non-fog days.

4. Dog Mountain

(a) Scattering Coefficient

The nephelometer at this site was installed on June 1 and operated through the remainder of 1982. The monitoring period used for this report is

June to October 17. Data from this site are shown in Figure IV-10, a time series representation of the scattering coefficient shown with a time series of fine particulate mass (described below), and the monthly particle scattering statistics are shown in Table IV-12.

A data recovery of 80.4% was accomplished at this site. A total of 591 hours of data were lost during the 137 days monitored. Instrument zero drift resulted in data loss, and a lamp burnout accounted for a lost week of data.

The nephelometer recorded numerous plume impacts (Figure IV-10). The frequent occurrence of impacts and the high particle scattering values measured at this site occur because Dog Mountain is located along the Cowlitz Valley in eastern Lewis County, a western Washington county in which the high tonnage of slash is burned.

All values were higher at this site than at the Paradise or Olympic sites; clearly this site is impacted more by pollution than sites within Class I areas. Impacts at this site are positively correlated with those recorded by the Paradise nephelometer and with impairment observed at Camp Muir. Those impacts corresponding with impairment at Mount Rainier National Park were analyzed for source contribution.

(b) Fine Particulate Mass (fpm)

For the 1982 monitoring, 156 24-hour samples were taken between May 19 and October 25. Glass fiber and cellulose acetate filters were both used in 1982, while during 1981 only glass fiber filters were used. Data recovery was 97.5% for this instrument; the sampler was inoperable for only four days.

The fpm data are plotted with the scattering coefficient in Figure IV-10 and with emission source information (slash burns and Mount St. Helens) in Figure IV-3. For the 156 filters the fpm has the following statistical characteristics: mean 9.6 ug/m^3, standard deviation $\pm$12.0 ug/m^3, maximum value 112.8 ug/m^3 on July 20, and minimum value of less than 1 ug/m^3 on 12 occasions. Monthly averages were distributed as follows: May 19 to June 30 - 8.5 ug/m^3; July - 14.3 ug/m^3; August - 13.2 ug/m^3; September - 6.1 ug/m^3; and October - 5.1 ug/m^3.

The Dog Mountain filters were measured for fine particulate mass, fine particulate concentration, and the particle absorption coefficient (b_{ap}) by the integrating plate method (Lin et al., 1973). The scattering coefficient (b_{sp}) was available from the nephelometer measurements.

Thirty filters selected from the 1982 sample underwent additional chemical analysis to determine the chemical composition of the fine particulate mass collected. The techniques used are presented in Section III, Table III-2. In addition, nine filters from the 1981 sample were analyzed by the Oregon's DEQ Laboratory for eight elements and chemical species (Br^-, Cl^-, $SO_4^=$, NO_3^-, NA^+, K^+, NH_4^+, and carbon).

Photographic Monitoring

1. North Cascades National Park

(a) Copper Ridge

The photographic program at this site did not start until September 5, 1982, due to a shortage of cameras, and only continued for a few days.

(b) Cascade Pass/Sahale Arm

No photographic data were obtained at this site during 1982 because equipment was not available.

2. Olympic National Park

(a) Blue Glacier

The photographic/observation program started on June 28. Photographs were taken on 33 of the 74 days between June 28 and September 9. Visibility photographs were taken primarily on the 20 days when smoke was reported from this site. Two examples appear on the following page. Photo No. 1 was taken looking southwest toward Mount Tom on July 24, 1982. The impairment description sheet for that day describes the layered haze as smoke originating from either a slash burn or a forest fire. Photo No. 2 was taken looking in the same direction on August 6, 1982. The following information was taken from the August 6 impairment description sheet: "At 1730 smoke reached Mount Olympus area. Summit pinnacle hazy and strong smell of smoke. Day previously was crystal clear with excellent visibility. Communication with Hoh Ranger Station indicated major slash burns in Sams River and Clearwater River Valley." NOTE: The impairment recorded in these photographs occurred within the park boundaries.

(b) Hurricane Ridge

An observation/photography program began on September 17, 1982 at Hurricane Ridge. Data from this site are used to track visibility changes within Olympic National Park.

(c). Lookout Rock

Photographic monitoring at Lookout Rock is part of a national visibility photographic monitoring network operated by the NPS. Photographs have been taken at this site from 1980 through 1982. From 1980 through 1981 simultaneous teleradiometer data were also recorded. This station has the most photographic data available for long-range tracking purposes. This information is presently being archived and analyzed by the NPS. Estimates of visual range using these photographs are expected from the Air Quality Office, NPS, by April 1983.

Photo No. 1 - Southwest from Blue Glacier.
2000, July 24, 1982.

Photo No. 2 - Southwest from Blue Glacier.
2000, August 6, 1982.

3. Mount Rainier National Park

(a) Camp Muir

An observation/photography program was carried out at Camp Muir from June 26 to September 2, 1982. Photographs were not taken on days when the visibility was obscured by clouds or fog. Camp Muir is an optimum location for an observation/photography monitoring station because it is an integral vista viewpoint, it is manned by park personnel during the summer, and has long-range views to the east through south to west unrestricted by topography. Photographs taken during 1982 are being archived for use in long-term tracking. Examples of photographs from Camp Muir include: Photo No. 3 - view towards Mount St. Helens obscured by large slash burn on August 18 and Photo No. 4 - same view earlier that day before impact occurred.

(b) Paradise

A photography program supplementing daily observations was started at the Paradise site on July 4, 1982. The photographs are also being archived for use in long-range tracking. Photographs from the Paradise station may be more useful for localized effects and impacts to the park itself since the view distance from Paradise is severely restricted by local topography. An example of localized impacts is shown in Photo No. 5, taken on August 18. In-park impacts were also recorded from Camp Muir and the Paradise nephelometer on this date.

4. Flights

In addition to the stationary sites, aerial photographs were taken on June 11, July 26, and August 19. Photo No. 6 was taken during the June 11 flight which was made to assess pollutant dispersion from a large burn of blowdown resulting from the Mount St. Helens eruption. The flight on July 26 was made to document the impact on Mount Rainier National Park of a burn near Randle. This flight was made in response to visitor complaints from Paradise. The August 18 flight was taken to observe projected impacts on Olympic National Park from slash burns and stationary sources to the south.

Supporting Data

Regional and site-specific meteorological data were used during impact analysis to help determine impairment sources. Data used included: sounding data from WDOE station at Portage Bay, National Weather Service stations at Salem, and Quillayute; National Oceanic and Atmospheric Administration satellite photos and weekly weather updates; Geological Survey daily accounts of Mount St. Helens emissions and winds near the 9000-ft level above the crater; and observation data from western Washington airports and from the Southwest and Yakima Air Pollution Control Agencies.

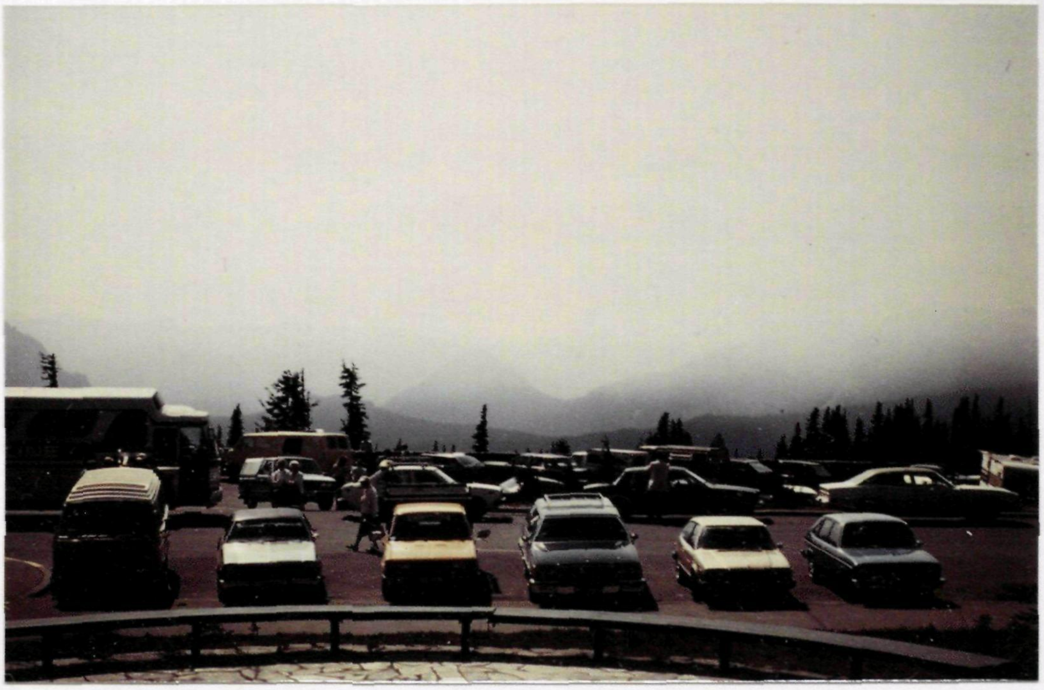


Photo No. 5 - Local impact as viewed from Paradise
Visitor Center. 1500 August 18, 1982.

Photo No. 6 - Aerial photography flight. June 11, 1982.

Photo No. 3 - South from Camp Muir. 1500 August 18, 1982.

Photo No. 4 - South from Camp Muir earlier the same day. 0900 August 18, 1982.

Source Apportionment

1. 1981 Studies

Filter samples were collected and optical scattering measured at the Dog Mountain site in the summers and early falls of 1981 and 1982. To investigate the causes and extent of visibility degradation in and near national forest and park lands, one approach to data analysis is to seek possible correlations between visibility degradation and chemical tracers associated with distinguishable sources (Harrison et al., 1982). Seven glass fiber filter samples collected in 1981 on days of reduced visibility were analyzed. These samples were examined for the ionic species: Cl^-, BR^-, NO_3^-, $SO_4^=$, Na^+, K^+, NH_4^+, and for elemental carbon. All Br^- analyses showed levels below a threshold of 2 micrograms per filter. The remaining analyses are tabulated in Table IV-14, with entries normalized by collected air volumes, together with the optical scattering coefficient, b_{sp}, and the total fine particulate mass. These data were then processed by computing a crossed-correlation matrix. The resulting matrix is shown in Table IV-15.

The data set is very small, and the standard error associated with each of these correlations is large, about 0.5. It appears, however, that significant intercorrelations are present in the lower right-hand corner of the correlation matrix.

The correlation matrix is next processed by a conventional eigenvector-eigenvalue rotation. This process discovers a sequence of normalized, orthogonal, linear combinations of the observables which successively accounts for as much as possible of the total variance of the combined data set.

The first vector (column) of Table IV-16 accounts for 6.236/9.000 = 69% of the variance; the second for 1.778/9.000 = 20%, etc. Only these two account for more variance than could be attributed to correlations with random variables. Inspection of the first column shows that it is about equally loaded with all the observables, except the first two, namely Cl and NO_3. The second column picks these two for heavy loadings. This separation reveals that Cl, a tracer of oceanic origin, and NO_3, a tracer primarily of cities (but also possibly of the Centralia power plant) fluctuates more or less coherently, but incoherently with everything else. This separation implies that those materials associated with optical scattering at the Dog Mountain site, on the days sampled, are likely NOT of urban or maritime origin.

Despite the large standard errors of Table IV-15, the correlation matrix has been further processed by a factor analysis. This process seeks linear combinations of the correlants which:

a. are orthogonal;

b. account for most of the variance of the correlation matrix; and

TABLE IV-14

FPM COMPOSITIONAL DATA, DOG MOUNTAIN, 1981

(Units of cols 1-7 are nanograms^{m}, col 9 is micrograms/m^3
units of b_{sp} are reciprocal meters, times 10,000.)

Cl	NO_3	SO_4	Na	K	NH_4	C	b_{sp}	fpm
35.0	366.8	3,082.2	299.8	30.4	860.0	5,570.8	7.5	13.5
36.7	172.4	1,747.3	261.3	26.5	330.7	2,051.5	4.0	3.5
28.1	194.2	5,360.3	503.5	74.7	1,608.1	7,275.9	8.2	19.6
25.5	38.6	972.2	292.4	13.1	98.8	1,118.8	0.1	5.5
24.3	220.8	4,719.3	445.4	75.1	1,517.5	11,699.5	11.9	34.7
33.4	443.8	2,893.7	401.1	72.9	845.6	12,490.3	7.9	32.8
31.7	325.8	2,491.7	350.0	53.3	760.0	8,166.7	7.5	21.8

TABLE IV-15

THE CORRELATION MATRIX, 1981 FILTERS

	Cl	NO_3	SO_4	Na	K	NH_4	C	b_{sp}	fpm
Cl	1.000	0.528	-0.326	-0.516	-0.258	-0.344	-0.160	-0.108	-0.309
No_3	0.528	1.000	0.231	0.159	0.465	0.287	0.688	0.577	0.581
SO_4	-0.326	0.231	1.000	0.894	0.825	0.993	0.628	0.831	0.631
Na	-0.516	0.159	0.894	1.000	0.907	0.900	0.699	0.688	0.727
K	-0.258	0.465	0.825	0.907	1.000	0.860	0.900	0.842	0.891
NH_4	-0.344	0.287	0.993	0.900	0.860	1.000	0.698	0.877	0.704
C	-0.160	0.688	0.628	0.699	0.900	0.698	1.000	0.856	0.987
b_{sp}	-0.108	0.577	0.831	0.688	0.842	0.877	0.856	1.000	0.836
fpm	-0.309	0.581	0.631	0.727	0.891	0.704	0.987	0.836	1.000

c. are loaded with as few individual tracers as possible.

A variety of factor rotations have been explored which produce results typical of those summarized in Table IV-17.

For clarity in Table IV-17, the smaller and less significant loadings have been suppressed. The first column reveals that most of the variance is associated with sulfate salts of NH_4, Na, and K, and that these correlate with the nephelometric optical scattering. The second column again picks up the Cl and NO_3. The third, which may only be marginally significant, puts the carbon in the same pocket as the total mass loading of fine particles and, possibly, also associates these with potassium and the optical scattering coefficient.

The tentative conclusions are:

a. Most of the optical scattering sampled at the Dog Mountain site on the selected days was associated with sulfate aerosols.

b. These were not of oceanic or city origin.

c. Carbonaceous aerosols correlated with total fine particulate mass and contributed significantly to optical scattering. That the carbon did NOT correlate with SO_4 indicates that the origins (or sink mechanisms) of these two tracers differ.

(NOTE: The reader is cautioned that the data set is slim and the risk of overinterpretation is large.)

2. <u>1982 Studies</u>

The method of factor analysis appears promising and present applications of this method are being conducted on filters collected during 1982 monitoring. The data base has been extended by analyzing a larger number of filters, and for a wider set of tracers, in particular metals such as manganese (which is a useful tracer of coal combustion), copper, arsenic, and antimony (which are tracers of smelter operations), and lead (which is a city and highway tracer). These additional tracers may facilitate estimates of the relative contribution from different sources to the degradation of visibility observed within the Camp Muir viewshed. The data base assembled for the filters sampled in 1982 is presented in Tables III-2 and III-3.

Results of the 1982 filter analysis for source apportionment determination are not available. The laboratory chemical analyses have not been completed at the time of this writing. Publication of the completed analysis will be included in future visibility data reports by the WDOE. The first publication of 1982 results using a factor analysis approach for source apportionment of impairment sources, however, will be included in the thesis of Pam Jenkins, Atmospheric Sciences - University of Washington, expected June 1983.

TABLE IV-16

EIGENVALUES AND VECTORS, 1981

Eigenvalues --								
6.236	1.778	0.658	0.229	0.091	0.007	0.000	0.000	0.000
Vectors								
-0.121	0.640	0.480	-0.268	0.371	0.240	-0.212	-0.095	0.154
0.198	0.632	-0.065	-0.038	-0.667	-0.259	0.152	-0.042	-0.138
0.355	-0.175	0.480	0.079	-0.171	0.535	0.196	0.003	-0.502
0.358	-0.264	0.085	-0.555	-0.189	-0.177	-0.646	-0.036	-0.038
0.387	0.007	-0.045	-0.444	0.444	-0.343	0.561	-0.038	-0.140
0.371	-0.147	0.377	0.160	-0.170	-0.055	0.197	0.003	0.776
0.365	0.202	-0.374	-0.009	0.114	0.338	-0.096	0.731	0.118
0.370	0.133	0.151	0.618	0.324	-0.421	-0.326	0.001	-0.229
0.365	0.103	-0.469	0.088	0.097	0.381	-0.079	-0.672	0.126

TABLE IV-17

FACTOR LOADINGS, 1981

Eigenvalues	6.17	1.45	.55
Cl	-	.76	-
NO_3	-	.70	-
SO_4	.99	-	-
Na	.89	-	-
K	.85	-	.83
NH_4	.99	-	-
C	-	-	.99
B_{sp}	.84	-	.76
Fpm	-	-	.99

Trajectory Analysis

During the 1982 study period, daily upper air wind speed and direction were estimated for western Washington. Data utilized in the analysis included upper air data from Quillayute, Salem, and Portage Bay. Weather maps and satellite photos were also analyzed. The resulting wind fields were then used to project plume travel resulting from pollution sources such as slash burns, or locate the sources responsible for the numerous impacts recorded during the study period by instrument monitoring and visual observations.

This trajectory method proved to be accurate in locating the responsible source when the wind field was steady with a moderate wind. For those impacts determined to be from slash burns, it was also possible by "working backward" from impact time to estimate the ignition time of the burn very closely to the actual reported time. Under ideal steady wind field conditions, the relationships between recorded impact and responsible source was evident even for sources greater than 50 miles upwind.

One example of a wind trajectory analysis is the impact to Dog Mountain and Paradise, August 27-28, 1982. The b_{sp} values for both sites remained low until a sudden increase occurred at 1500 PST for the Dog Mountain site and 3 hours later at the Paradise site. The Dog Mountain values increased over 600%, reached a peak value at 1830 PST, and then decreased to pre-impact level by noon the next day. Paradise values went off scale on the more sensitive instrument used at that site and dropped back to normal levels by afternoon of the next day. Meteorological analysis indicated a weak onshore gradient with upper air flow from the southwest at around 10 mph. The smoke management forecast was for southwest winds at 12 mph for 3,000 feet and west at 12 mph for 5,000 feet. Therefore, wind field analysis indicates a probable source of some magnitude southwest of the site. Two slash burns, located 42 miles to the south-southwest of Dog Mountain and 75 miles west-southwest of Paradise, were ignited at 1035 PST and 1220 PST.

The first burn at T9N R2W was 1,200 tons. The second, ignited 2 hours later, was 930 tons. Assuming an average wind speed of 12 miles per hour and working backwards from impact times for the two sites using distances of 42 and 75 miles, an estimated ignition time was arrived at 1130 from the Dog Mountain impact and 1230 for the Paradise site. The above analysis does not consider lag time between ignition time and plume development and elevation gain of from 1500 feet for Dog and 5000 feet for Paradise.

Trajectory analysis became less reliable during periods of low wind speeds and stable air conditions. Under such conditions, usually associated with high pressure systems lasting several days, the nephelometer trace would show a slow increase to moderate levels corresponding to a general haze build-up. As the high pressure system moves on and westerly flow begins, values would peak as the accumulated haze impacted the monitoring stations (Dog Mountain or Paradise). Values would then drop to near zero levels as the weather system brought in a clean air mass. During periods experiencing wind shifts due to major weather systems, trajectory analysis became difficult but still possible if sufficient meteorological data were available.

In 1981 and 1982 numerous visual impairment impacts were recorded at the monitoring sites by nephelometers. Visual observations confirmed most all impacts with reports of smoke layers or distinct plumes. Impacts are defined as a sudden increase in b_{sp} values to at least double the levels recorded immediately prior to the impact, and exceeding a threshold level. The following number of impacts were recorded at the various sites using two different threshold values:

Site	Number of Nephelometer Impacts 1981	1982
Dog Mountain ..	17(a), 7(b)	50(a), 18(b)
Paradise	20(a), 6(b)	15(a), 5(b)
Hurricane Ridge	No Data	15(a), 4(b)

(a) - Greater than $5 \times 10^{-5} m^{-1}$.
(b) - Greater than $10 \times 10^{-5} m^{-1}$.

DISCUSSION

Visual Observations

Visual observation, a successful monitoring technique, can be used for long-term tracking and, in some cases, source identification. This method can be used to determine:

1. the variance of meteorological conditions, including the number of occurrences of natural obstructions to visibility such as fog and precipitation and the pattern of those occurrences;

2. the number of smoke/plume sightings;

3. the number of haze occurrences and the pattern of those occurrences; and

4. the number of days that long-range targets are visible.

Conditions recorded visually during the summers of 1981 and 1982 show the following:

	1981 2 Stations	1982 6 Stations
Meteorological Obstructions	29%	33%
Far Target Visibility	21%	49.5%
Range of Smoke/Plume Sightings for Non-Fog Days	0-8%*	5-37%

*The value for the Blue Glacier was 45% but the data were skewed to clear days with plume sightings.

The percentage of meteorological obstruction was similar for the two years (29 and 33%). However, the values for far target visibility were quite different (21 and 49.5%). Part of the difference between these two percentages may be explained by the greater number of hazy days reported during the 1981 summer. Haze levels depend not only on pollution source strengths but also upon meteorological patterns, including lengths of stagnation periods, wind speeds and inversion heights.

Meteorological variables affect the distribution of pollutants and their effects on visibility. Long-term monitoring is needed on a yearly basis to provide a data base and to assure the accurate accounting of changes. Observations taken by NPS (or volunteer) personnel at 7 sites, with no direct cost to the visibility study, provided a useful source of information with a data recovery of 62% to 100%.

Observation data were used in two ways: First, the type and frequency of meteorological conditions limiting or otherwise affecting visibility was noted. Tabulations for each site included days of meteorological impairment (e.g. fog, rain, snow), days with the farthest target visible, and days where pollutant-caused impairment in the distinct form of plumes or smoke were observed. Hazes, either a low valley or general type, was noted; they were not tabulated due to the difficulty of distinguishing the type and extent of impairment. Second, the data provide a distribution of the visual range values in the form of a cumulative frequency. The median value of each data set corresponds to a cumulative frequency of 50% and it is also an approximation of the geometric or arithmetic mean. For the cumulative frequency distribution, the 10th percentile is assumed to be "best" conditions and the 90th percentile as representative of the "worst" conditions.

These transformations of visual observation data reduce the variance of the data resulting from individual subjectivity. These two analyses have also been used in a number of other visibility studies (Trijonis, 1979; Trijonis, 1982; Gins et al., 1981; and Malm et al., 1981). Trijonis (1979) concluded that airport observation data, when plotted as cumulative frequency, yielded results that were consistent from site-to-site and showed remarkable agreement to measurements taken by photographic photometers and integrating nephelometers.

Because standard observation practices used at the visual observation sites were similar to those used at airports and other weather stations, consistent techniques could be applied to determine the statistical distribution of the data and to calculate visibility percentiles. These techniques have been described by Trijonis (1979 and 1982). These techniques have been applied to all visual observation data sets. Trijonis (1979) has shown that these techniques produce consistent results from site-to-site even if the various stations have visibility markers at different distances.

Basically, these techniques require that visibilities reported by the observer be routine values, taken using a standard procedure at a standard time; non-routine or special observations can produce anomalies in the data.

The data set must also systematically account for occasions when a target cannot be seen, thus allowing the distribution to be weighted in proportion to the frequency with which visually impaired days occur.

At two locations, the farthest target was 40 miles or less (Paradise - 34 miles, and Sahale Arm - 40 miles) and was reported on over 50% of the time. Because the data set lacked resolution at these locations, the use of visual range values was eliminated; however, meteorological observations were useful. Observation sites with target distances of near 70 miles or greater are needed to provide a sufficient data base for visual range statistics.

Photography

Photographic monitoring provides a means of documenting visual range observations and recording impairment conditions and sources. Photographic and visual observation data in combination can provide information that cannot be detected with any other monitoring technique. Due to the expansive view at integral vistas a point measurement (particulate sampler or nephelometer) or path measurement (teleradiometer) cannot always be indicative of conditions within a view. Views from integral vistas are primarily comprised of mountainous or forested areas. Figures IV-1 and IV-2 present the point sources and prescribed fires within Washington which were considered as contributing to visibility impairment during June-September 1982. Except for the Deer Park - Hurricane Ridge Integral Vista, no point source plume is distinctly visible at an integral vista. The source emission locations which can be detected from integral vistas are limited to those occurring in forested areas. Both photographic and visual observation data are necessary for interpretation because of the varying locations and occurrences of prescribed fires near the Class I areas.

Studies performed by the NPS at the Grand Canyon National Park and reported by Malm (1983) conclude that because of the circumstances of smoke intrusion and the difficulty of locating a representative sampling site, monitoring smoke intrusions must rely on visual observations and color photography. The results of the Camp Muir monitoring support the conclusions reached by Malm (1983).

Nephelometer

Four nephelometers were operated during the 1982 season, but data from only three were used in the analyses. The modified nephelometers (MRI Model 1560, by A. P. Waggoner, University of Washington - for Project VIEW) were effective for measuring aerosol particle scattering extinction at the usually pristine levels of Class I areas (at or below Rayleigh scatter). The instruments recorded impact duration, magnitude, and frequency. Scattering measurements along with the fine particulate mass and chemical analysis from the Dog Mountain site related particle scattering to a likely cause.

The instrument measures optical properties at a point which may limit its applications to cases where there is spatial uniformity of atmospheric optical properties. Errors and deficiencies in nephelometer measurements have been reported by Waggoner (1980, 1981). The errors of particular concern are those relating to humidity effects. Errors may be introduced by differences in humidity inside the instrument relative to ambient conditions, and during fog conditions when particles larger than 3 um dominate optical properties. In fog the angular integration suffers from truncation at low scattering angles and will underestimate the actual scattering coefficient up to a factor of two. Effects of increased aerosol scattering noticed with increased relative humidities, as reported by Covert et al. (1972), also are of concern due to high frequency of occurrence of humidities over 70% at the monitoring sites. At the Paradise site, fog conditions occurred on 31% of the days and humidity exceeded 70% for 60% of the time.

High humidities at the Paradise site have not significantly affected the particle scattering coefficient. This lack of interference is probably due to the low concentrations of pollutants (sulfates) present. Many studies have shown sulfate to be positively correlated to scattering coefficient (Hidy et al., 1975; Waggoner et al., 1976; Patterson and Wagman, 1977), and negatively correlated to visual range (Trijonis and Yuan, 1977). Low scattering coefficients measured during fog conditions are not of consequence because fog is a natural impairment.

Particulate Monitoring

The fpm measurements provided a basis for source apportionment studies through chemical analysis and defined levels of fine particulates at the Dog Mountain site. The filter media used allowed for analyses of elements and species of concern by x-ray fluorescence, flame ionization or ion chromatography. A superior method would have been to sample glass fiber and cellulose acetate filters simultaneously to yield both carbon and elemental/chemical species data for any particular day. Although only one type of filter was used per day, the results provide adequate information for source classification attempts. Resources were not available to sample both filter types daily.

At the Dog Mountain site, the maximum fpm measurement was 112.8 ug/m and measurements over 20 ug/m^3 occurred on 18 days. This maximum value indicates that the secondary 24-hour TSP standard of 150 ug/m^3 was probably exceeded on that day. The high levels of fpm measured at this site suggest that the secondary particulate standard could be exceeded.

Previous Pacific Northwest studies by Waggoner and Weiss (1979) in both urban and rural sites indicate that fine and coarse particle concentrations are not well correlated. Measured fpm levels of over 40 ug/m^3 at 7 urban and rural sites recorded during the present study also indicate relatively small differences in fine particulate mass loadings exist between rural and urban sites. These findings suggest fine particulate aerosols, are a regional effect, coarse particulate levels vary site-by-site, and fine and coarse particulates have different responsible sources.

Measurement of coarse particles or TSP is suggested at the Dog Mountain site. Results indicate that the secondary TSP standard, 150 ug/m^3, could be violated at this site, and that the coarse particulate levels and sources are of concern. The highest 24-hour measurement equals 75% of this standard, i.e. 113 ug/m^3 was consumed by fpm alone. A recent study by Pitchford (1982) concludes that coarse particulates contribute from 30% to 80% of particle-related optical extinction. Although Pitchford worked in the southwest where the atmosphere is generally uniform with regard to light scattering particles over distances as great as 100 km, the study of coarse particulates should be considered for Washington even though regional homogeneity is not as prevalent.

CORRELATIONS

Results from the nephelometer and particulate monitoring showed that fine particulates dominate light scattering at the Dog Mountain site. 1982 results found a correlation of 0.82 between light scattering and fpm levels measured at Dog Mountain. The correlation found between these variables during 1981 was 0.92. A decrease in correlation was also found between nephelometers at Dog Mountain and at Paradise. The 1981 correlation was 0.80; the value found for 1982 is 0.52. The reduction in correlation values indicates a decrease in homogenity of the pollution in the air space between the two years. Regional pollution impacts apparently occurred less frequently within this area in 1982 than 1981. This difference in regional haze was also noted in the visual observation data.

Conclusions drawn from the visual observation data indicate a higher occurrence of haze in 1981 than in 1982. Weather patterns in 1981 were characterized by a series of high pressure ridges interspersed by periods of stagnation. In 1982 the frequency of such events was lower.

The emissions from point sources and prescribed burns did not significantly vary between 1981 to 1982. Point source particulate emissions increased 1.4%, and particulate emissions from prescribed fires decreased 4.0%. Sulfur dioxide emissions from point sources varied insignificantly between 1981 and 1982; however, in 1982 sulfur dioxide from Mount St. Helens decreased by nearly 50% from the 1981 level (31,950 tons to 16,700 tons, emissions, June -September).

The reduction in sulfur dioxide emissions and increase in stable atmospheric conditions in 1982 may be responsible for much of the observed difference in results between the 1981 and 1982 monitoring. The differences observed also show the value of continuing yearly monitoring since meteorological conditions affecting visibility levels have been shown to vary from year-to-year.

Fpm levels measured at Dog Mountain were also correlated to emission sources. Near this site the most prevalent emissions are those from prescribed burning and Mount St. Helens. No correlation was found between daily

Mount St. Helens SO_2 and ash emissions and the corresponding 24-hour average fpm or scattering levels measured at Dog Mountain during 1982. Mount St. Helens' contributions to scattering levels, fpm, and reduced visibility are more likely caused by sulfates originating from its SO_2 emissions. For the seven 1981 filters of reduced visibility days that were chemically analyzed, all had significant sulfate loadings. The contribution to visibility degradation from Mount St. Helens is not directly related to the daily sulfur dioxide emissions, but to the sulfates originating from these emissions. Sulfate conversion is dependent on a number of factors, including meteorological variables, residence time, and solar radiation. The interactions of these factors with SO_2 emissions result in varying sulfate levels which are best determined by chemical analyses. A moderate correlation of 0.62 was found between fpm and the tonnage of prescribed burns in southwest Washington (Cowlitz, Lewis, Skamania and Pacific Counties). This value does not take into consideration wind direction, proximity to the site and source-receptor lag time, all of which could increase the correlation value.

Figure IV-3 compares a time series of fpm levels with the daily tonnage of slash consumed in southwest Washington and Mount St. Helens sulfur dioxide emissions. The fpm levels are correlated with the tonnage of slash burned. Of 31 occasions when fpm exceeded 15 ug/m^3, only 6 are not associated with a concurrent peak of slash burning. If wind direction and distance were considered on a case-by-case basis for each burn, the correlation between fpm and tonnage would most likely increase.

SECTION V

CONTROL STRATEGIES

SECTION V

CONTROL STRATEGIES

SUMMARY OF WASHINGTON SIP REVISION

Federal visibility regulations require states to revise their SIP's to establish long-range goals, to establish a planning process, and to implement procedures assuring visibility protection for mandatory Class I Federal areas. WDOE's SIP revisions implement new programs and procedures that will assure visibility protection to the state's national parks and wilderness areas. The control strategies include amendments to regulations for existing and future stationary sources and the development of programs and procedures for prescribed burning.

Existing stationary facilities need to be reviewed for further pollution control if impairment of visibility in Class I areas or associated integral vistas determined by the FLM or the State, is identified by the State as being attributed to that stationary facility. The required level of control is BART for existing stationary sources.

Any new source in the State requiring a construction permit will be required to do a screening analysis to determine whether or not it will degrade the visibility in any Class I area. If degradation is indicated, a permit will be denied unless mitigating procedures are adopted. This screening procedure will be incorporated into WAC 173-403, General Regulations for Air Pollution Sources.

The control strategies for prescribed burning include scheduling of burns and a reduction in total emissions. Prescribed burning that could impact Class I areas will be restricted during visibility-important days (weekend days from July 1 through Labor Day). Western Washington forest managers have established an objective of reducing total emissions from prescribed burning by 35% by 1990. WDOE believes this figure to be a reasonable objective that, combined with burn scheduling, should provide adequate protection. Progress evaluations will be conducted every third year to assure that reasonable progress is being achieved by these control strategies.

WDOE has concluded that a long-term monitoring network is essential for tracking changes in visual air quality, identifying impairment sources, and evaluating the success of the control strategies. Therefore, a long-term visibility monitoring strategy, as well as a process for documenting and evaluating progress, is outlined in the proposed SIP revision. The proposed revision to the Washington SIP for visibility protection is presented in Appendix B. This proposed revision was submitted to the FLM's for comment on March 3, 1983.

INTERAGENCY COORDINATION

Local, state, and Federal agencies provided valuable input into program development, resource support, and contributed toward the formulation of long-range control strategies.

Resource Support

Monitoring equipment was loaned to the State by the Oregon DEQ, the EPA, and PSAPCA. A fine particulate sampler was loaned by the Oregon DEQ, four nephelometers by EPA, and strip chart recorders by the Puget Sound Air Pollution Control Authority.

Clean air purges for the nephelometers were leased from Dr. Alan Waggoner of the University of Washington. Dr. Waggoner initially serviced and calibrated the nephelometers and repaired them, when necessary. The Washington State Patrol and the Department of Transportation provided access to the Dog Mountain site. Meteorological data taken at Paradise were made available to WDOE by the NPS. Observation and photographic monitoring at Camp Muir, Paradise, Sahale Arm, Copper Ridge, Lookout Rock, and Hurricane Ridge were accomplished by NPS personnel. Visual observations and photography on the Blue Glacier were provided by Rich Marriot and his staff sponsored by the National Science Foundation. Permission to use the Mount Baker site was obtained from the USDA Forest Service, Glacier District.

Two local agencies, Yakima County Clean Air Authority, and the Southwest Air Pollution Control Agency recorded visibility observations.

Program Development

Several meetings were held to develop a consistent monitoring effort between Washington and Oregon. Attended by representatives from Oregon DEQ, the NPS, the USDA Forest Service, WDOE and R. W. Beck and Associates, these meetings involved discussions of the monitoring plans, the use of consistent techniques, statistical analyses, and data reduction techniques. It is proposed that a meeting be held after the 1982 data have been analyzed to assess the current monitoring techniques used.

Meetings were held with Shirley Clark of the Pacific Northwest Regional Office of the NPS to coordinate the monitoring program in the three national parks. The success of the observation/photography network was largely due to the enthusiastic support by Ms. Clark and the NPS observers. Communication between USDA Forest Service and WDOE representatives on initiating visibility monitoring in the State's five wilderness areas has begun. The USDA Forest Service has expressed interest in establishing a network of well-instrumented, first-order stations.

Two field trips were taken by interagency personnel to observe monitoring sites, instrumentation, and data acquisition techniques. On September 22, 1982, representatives from EPA, WDOE, NPS, and R. W. Beck and

Associates observed the monitoring program in Olympic National Park, which included the Visitor Center, Lookout Rock, and Hurricane Ridge sites. On October 11, 1982, representatives from R. W. Beck and Associates joined a group from Oregon DEQ to observe the instruments and monitoring techniques at the Mount Hood visibility sites.

On October 7, 1982, a field trip was taken to observe slash utilization efforts by the USDA Forest Service in the Mount Baker - Snoqualmie Forest. Utilization efforts at this site concentrated on making yarded material available to woodcutters and chipping for hog fuel. Utilization has provided increased employment opportunities both within and without the Forest Service. Utilization advantages include decreased smoke emissions, free or low cost firewood and decreased planting costs due to increased natural reforestation. For utilization efforts to become more of an established pattern, utilization opportunities must be analyzed at the time of timber sales.

In addition to the informal meetings described above, three formal visibility meetings were held during 1982. The first was a meeting held on August 5, 1982 to discuss smoke management strategy. The meeting was attended by representatives from WDOE, NPS, USDA Forest Service, EPA, WDNR, the forest industry, and R. W. Beck and Associates. Each of the agencies presented its views on smoke management strategies for visibility protection. The presentations were followed by a discussion centering on the draft position paper presented by WDNR representing IFA, WFPA, USDA Forest Service, and WDNR.

A public meeting sponsored by the Washington Air Quality coalition was held on October 15, 1982. Mr. Darrell Weaver of WDOE was asked to present the WDOE proposed visibility strategies. This was followed by an open discussion and suggestions for future public participation. The meeting was attended by representatives from WDOE, the Mountaineers, the Sierra Club, the Washington Environmental Council, the American Alpine Club, the National Park Service, Olympic Park Associates, Issaquah Alps Association, Puget Power, American Lung Association, R. W. Beck and Associates, and the University of Washington.

On November 10, 1982 a public information meeting was held for the purpose of presenting the visibility regulations, the FLM's positions, WDOE's proposed strategy, and for taking public comment. Statements presented by the FLM's are presented in Appendix C. Presentations and comments from this meeting were considered in drafting the SIP revision.

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

SECTION VI

CONCLUSIONS AND RECOMMENDATIONS

Visibility protection is needed for the mandatory Class I Federal areas in the State of Washington. This protection is not only required to protect the parks and wilderness areas from future degradation, but also to remedy effects already noted. Results from visibility monitoring in 1981 and 1982 show that vistas lying completely within Class I areas as well as integral vistas viewed from within Class I areas have already been subjected to impairment.

Based on preliminary analysis, two sources contributing to visibility impairment have been identified. The first is prescribed slash burning. Because all Class I areas in the State are encompassed by forests, prescribed burning has a major impact on visual quality within such areas. Prescribed burning has been identified by both photographic and visual observations as degrading visual quality of vistas seen within and from the national parks. The impact to visual range can be estimated from nephelometer measurements. These impacts can be traced to forestry burning through trajectory analysis and analysis of filter data. Strategies to decrease the impact of forestry burning need to be implemented and enforced to ensure meeting the national visibility goal. The second identified source is beyond control. The analysis from Dog Mountain filters shows that a likely contributor to the sulfate levels at that site is Mount St. Helens.

The State's overall control strategy is a three-way directional approach for visibility protection: (1) NSR for proposed sources and source modifications; (2) BART for existing sources; and (3) smoke management for slash burning. The next level of effort needs to be directed toward developing practical and environmentally sound procedures to implement these regulations and programs. In addition, results from two summers of monitoring have underlined the usefulness of various monitoring techniques. In future years the need is to incorporate these successful techniques into a practical, consistent, long-term monitoring network that can be used to define impairment levels, identify sources, and track visibility changes. Monitoring results have shown yearly fluctuations in visibility and air quality levels due to variations in regional and local meteorology and source emissions.

It is recommended that the monitoring program be continued, refined, and expanded. The monitoring network should be run yearly to avoid the possibility of judging progress by monitoring atypical years. Several promising monitoring techniques have been developed and used during the 1981-1982 monitoring program; some further refinement of these techniques and expansion of the network would enhance data reliability. Expanding the filter analysis would increase the frequency and accuracy of source identification. It would be particularly useful to expand this program to other Class I areas. A consistent regional visibility monitoring network should be developed with the defined objectives of evaluating visibility levels, identifying sources, and tracking changes in the visual air quality. This network should be expanded to include representative sites in all Class I areas.

The control strategies need to be implemented and monitored to ensure reasonable progress toward the national visibility goal. After the BART regulation is established, for any existing impairment the Federal Land Manager or State identifies the State needs to assess the contribution of existing stationary sources to visibility degradation, identify contributing sources, if any, and perform a BART analysis on those identified. NSR procedures need to clearly set forth the level of analysis required and the responsibilities of the WDOE, local agencies and the operator of any new source.

The smoke management program needs to be refined to include effective measures to meet SIP requirements for defining emissions and to encourage slash utilization. Increasing utilization requires a knowledge of workable methods and a willingness to change traditional patterns. Recent research has shown that successful burning can be accomplished over a wider variety of temperature and moisture conditions than previously recommended (Sandberg and Ward, 1982). If more burn days and acceptable burning conditions are available, scheduling will be less of a hardship on the forest industry and emissions can be lowered in Class I areas during the visitor season (July-September). Scheduling can decrease adverse impacts on visitor-important days.

In conclusion, the continuation, refinement, and expansion of the long-term monitoring network and the implementation of defined and workable procedures for BART, NSR, and smoke management strategies are needed to ensure reasonable further progress toward attaining the national visibility goal.

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APPENDIX A

1982 VISUAL OBSERVATION DATA

Impairment Description Sheet

1. Date:

2. Time:

3. Photograph taken and recorded? Yes No Frame No. _______

4. Impairment Description:

a. Type (check box that applies)

- [ ] Distinct Plume
- [ ] Layered Haze
- [ ] General Haze

b. Border of Haze/Plume:
Is there a border between discolored air and clear air at or near horizon? (In other words, can you distinguish a layer of discolored air?)

Please Circle number that applies:

0	1	2	3	4	5	6	7
View Blocked	No Border						Sharp Border

c. Color (check box that applies)

- [ ] Colorless
- [ ] Light White or Grey
- [ ] Dense White or Grey
- [ ] Light Brown or Yellow
- [ ] Dense Brown or Yellow
- [ ] Other (please describe) ______________________

____

5. Possible Source: If any of the following are present in the view, please indicate by checking as many as apply:

- [ ] Visible Emissions from Recreational Sources (campfires, road dust, vehicle Emissions, etc.) general direction _____
- [ ] Visible Emissions for forestry burning, smoke or smoke plumes. general direction
- [ ] Industrial or stack emissions general direction _______
- [ ] General haze from direction of Urban Areas, general direction _____
- [ ] Haze or Smoke from forested areas, general direction _______
- [ ] Low valley haze or fog, general direction ________
- [ ] Other, (please describe)

6. Extent of Impairment

- [ ] Below vista targets, in valleys.
- [ ] Obscurring vista targets, All targets or targets Nos. _______
- [ ] Above vista targets or outside target view range
- [ ] Is the impairment more intense in a distinct direction? Yes No
- [ ] If yes, in what general compass direction __________________________

7. Remarks and Follow up Comments.

Name of Vista: Camp Muir - South Washington

Photograph Date: 9-9-80　　Time: 3:00 pm　　Camera Data: 35 mm/50 mm lens

View Direction: SE, S, SW　　View Angle: From 100 to 230

Observation Point: Camp Muir

Can Also Be Viewed From Observation Points:

Ricksecker Point
Paradise
Box Canyon
Backbone Ridge
Sunrise Point

PHOTOGRAPH INTERPRETATION

KEY	Feature	Distance	Focal Point
A	Cascade Crest	15 mi.	Yes
B	Goat Rocks	27 mi.	Yes
C	Cowlitz Drainage	10 mi.	No
D	Mt. Adams	45 mi.	Yes
E	Tatoosh Range	6 mi.	Yes
F	Mt. St. Helens	51 mi.	Yes
G	Nisqually River	7 mi.	No
H	Tum Tum	9 mi.	No
I	Mt. Wow	10 mi.	No
	Mt. Hood	105 mi.	
	Mt. Jefferson	155 mi.	

VISIBILITY OBSERVATIONS FROM CAMP MUIR SITE

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
June 26	1300	0	overcast, fog, rain	fog	
June 27	1300	2/3	undercast to 9000'	clouds	
June 29	1300	2/3	overcast, fog, lt. rain	clouds	
June 30	1300	2/3	clouds, fog	clouds	
July 1	1300	51	low clouds, sunny above 8000'		
July 2	1300	0	clouds, fog, lt. snow	fog	
July 3	1300	2/3	clouds, fog, high winds	clouds & fog	
July 4	1300	45	cloud cover, sunny above 9000'		
July 5	1323	45	cloud cover, sunny above 9000'		
July 6	1320	2/3	clouds, fog, windy	fog & clouds	
July 7	1308	1/2	clouds, fog	fog	
July 8	1300	155	clear	Mt. Jefferson visible	
July 9	1500	0	clouds, fog	fog	
July 10	900	51	haze	hazy, but visible	
July 10	1500	45	haze, clouds	smoke	B
July 11	1500	27	clouds	clouds	
July 12	1500	51	clouds to S-SW	clouds	
July 13	1500	0	fog, clouds	fog	
July 14	1500	2/3	fog, clouds	fog	
July 15	1530	2/3	fog, clouds	fog	
July 16	1500	105	clear		
July 17	1500	27	clouds to S		
July 18	1500	105	clouds below 9000'		
July 19	1415				B
July 19	1500	51	clouds below 7000'	smoke seen from 1400 on	B
July 19	1630				B
July 20	1500	10			
July 21	1500	105	partly cloudy below 8000'	clear above clouds	
July 22	1243	155		smoke column rising from 208°	B
July 22	1410			greater amount of smoke	B
July 22	1500	51	low clouds patches, generally clear	no longer see Mt. Hood	
July 22	1656	45		no longer see Mt. St. Helens	B,D
July 23	1500	155	clear		
July 24	1500	105	clear		
July 25	0900	45	generally clear, some haze	hazy to the W, blocking Mt. St. Helens	D
July 25	1500	105	clear, some haze		
July 26	1508	105	clear, calm, high clouds	smoke S-SW, Mt. St. Helens blocked	
July 27	1504	51	clear, calm, high clouds	hazy, small burn to SW	

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 29	1510	105	clear, calm, high clouds		
July 30	1500	51	partly cloudy	hazy above 7000'	
July 31	1500	51	cloud level 7000'		
August 1	1500	105	cloud level 8000'		
August 2	1500	0	cloud level 10000'	fog	
August 3	1500	0	cloud level 10000'	fog	
August 4	1500	45	partly cloudy		
August 5	0900	105	clear		
August 5	1500	45	generally clear	yellow SW haze blocking Hood and St. Helens	D
August 5	1600	25	haze blocking Goat Rock, Adams		D
August 6	1418	105		burn at 196° blocking SW view	B
August 7	1500	45	generally clear	heat haze	
August 8	1500	45	partly cloudy		
August 9	1500	15	partly cloudy		
August 10	1500	0	clouds, fog		
August 11	1500	0	clouds, fog		
August 12	1500	105	partly cloudy	cloud layer 9000'	
August 13	1500	0	clouds, fog, mixed rain and snow		
August 14	1500	80	low clouds		
August 15	1500	27	fog		
August 16	1500	0	partly cloudy		
August 17	1500	0	fog		
August 18	0900	105	low haze	smoke column rising at 200°	B
August 18	1500	45	generally clear	thick smoke haze, slash burn, SW view blocked	B
August 19	1500	51	generally clear	low valley haze	
August 20	1500	51	generally clear	slight haze	
August 21	1500	51	clear, low haze		D,F
August 22	1500	105	clear, low haze	low valley haze	
August 23	1500	105	clear		
August 24	1500	105	clear		
August 25	1600	51	haze	Adams, St. Helens barely visible through haze	
August 26	1500	105	low haze, generally clear	haze below 8000' to S-SW	
August 27	1500	105	clear, low clouds		
August 28	1500	105	clear, scattered clouds		
August 29	1500	0	fog		
August 30	1500	0	fog		
August 31	1500	2/3	low clouds, fog		

VISIBILITY OBSERVATIONS FROM CAMP MUIR SITE

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Sept. 1	1500	105	clear	valley haze	
Sept. 1	1600	--			D,F
Sept. 2	1500	51		low, thick haze	
Sept. 3	1500	1/4	clouds, rain		
Sept. 4	1500	1/4	fog		
Sept. 5	1500	105	clouds to W	steam from St. Helens lava dome	
Sept. 6	1500	1/4	cloud level 9500'		
Sept. 7	1500	105	clear, scattered cloudy		
Sept. 17	1600	51	clear, some haze	smoke and haze from slash burn	B
Sept. 18	1500	51	overcast		
Sept. 19	1500	1/4	fog		
Sept. 25	1500	0	cloud level 9400'	can see Hood from 9000'	
Sept. 26	1500	0	snow, winds from SE		

Data Summary

Data recovery, 85%, 78 observations out of 92 possible days
31 days, 39%, fog/clouds with low visibility (less than 10 miles)
47 non-fog days, 60%, average visibility 74 miles
13 days smoke reported, 28% (of non-fog days), average visibility 49 miles
34 days no fog or smoke, average visibility 82 miles

*A Visible emissions from recreational sources (campfires, road dust, vehicle emissions, etc.)

B Visible emissions for forestry burning, smoke or smoke plumes

C Industrial or stack emissions

D General haze from direction of urban areas

E Haze or smoke from forested areas

F Low valley haze or fog

VISIBILITY OBSERVATIONS FROM PARADISE SITE, MOUNT RAINIER NATIONAL PARK

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 1	1310	34+	high clouds	cloud level 7000'	
July 2	1315	34+	variable clouds, low fog	cloud level 10000'	
July 3	1500	0	fog		
July 4	1505	34+	high clouds	cloud level 7000'	
July 5	1515	34+	high clouds	cloud level 8000'	
July 6	1500	34+	cloud bank moving in	cloud level 10000'	
July 7	1500	0	cloudy	fog	
July 8	1500	34+	clear		
July 9	1515	34+	clear		
July 10	1530	34+	clear		
July 11	1515	34	clear, some haze		
July 12	1500	34	hazy		
July 13	1500	0	foggy		
July 14	1530	29	storm moving in		
July 15	1500	0	foggy, mixed rain and snow		
July 16	1500	34	clear	low clouds - S	
July 17	1500	17	clear, some haze		
July 18	1520	17	high clouds	cloud level 7000'	
July 19	1510	34	high clouds		
July 20	1520	34	scattered clouds	few cumulus clouds	
July 21	1515	34	high clouds		
July 22	1500	34	clear		
July 23	1515	34	generally clear, some haze	slash burn, pink/yellow haze	
July 24	1500	34	clear		
July 25	1530	34	clear		
July 26	1620	34	clear	south haze	
July 27	1610	34	haze to south		
July 28	1500	17	haze to south	high clouds	
July 29	1550	34	clear, fog in valleys	hot	
July 30	1500	4.3	fog to 5200'		
July 31	1500	0	no visibility	cloud level 6600'	
August 1	1500	0	foggy, light rain		
August 2	1500	0	foggy, light rain		
August 3	1500	34	high clouds	cloud level 10000'	
August 4	1500	34	clear		
August 5	0945				D
August 5	1700	34	clear, haze to south		
August 6	1500	34	clear, heavy haze to south	slash burn and uncontrolled park fire	B,P

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
August 7	1600	34	mostly clear	gray haze moving W	
August 8	1515	34	high clouds, haze		
August 9	1500	0	blowing fog		
August 10	1500	0	misty/thick fog		
August 11	1500	0	misty/thick fog		
August 12	1500	0	misty/thick fog		
August 13	1500	0	misty/thick fog		
August 14	1500	34	clear	low clouds in S	
August 15	1505	34	clear		
August 16	0900				D,F
August 16	1430	34	clear	clouds moving in	
August 17	1510	34	clear	haze in valley	
August 18	1500	11.5	clear and sunny	smokey	E
August 19	1515	34	clear	hazy	
August 20	1500	34	clear	hazy to SW	
August 21	1500	34	clear	blue/grey haze to S	
August 22	1515	34	clear		
August 23	1510	34	clear	slight haze	
August 24	1430	34	clear		
August 25	1515	34	clear		
August 26	1515	16	clear	hazy to S	
August 27	1530	34	clear	hazy to S	
August 28	1630	34	clear		
August 29	1500	0	foggy, light rain		
August 30	1500	0	foggy		
August 31	1505	17	high clouds	cloud level 7000'	
Sept. 1	1430	34	clear	hot	
Sept. 2	1430	34	clear		
Sept. 3	1500	0	foggy		
Sept. 4	1500	0	foggy		
Sept. 5	1500	34	clear		
Sept. 10	1500	0	foggy, windy	3" snow	
Sept. 11	1500	0	foggy, rainy		
Sept. 12	1500	0	foggy, rainy		
Sept. 13	1500	34	clear		
Sept. 14	1530	34	clear, windy		
Sept. 15	1700	34	light, high clouds		
Sept. 16	1515	34	clear	occasional small cumulus	
Sept. 17	1500	34	clear		
Sept. 17	1900				B,E
Sept. 18	1700	17	clear	grey/blue haze in S	
Sept. 19	1500	11.5	variable clouds		
Sept. 20	1500	3.8	foggy		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Sept. 21	1500	17	variable clouds		
Sept. 22	1530	34	clear	blue haze in S	
Sept. 23	1500	34	clear	slight haze	
Sept. 24	1500	0	rain		
Sept. 25	1500	3.8	rain		
Sept. 26	1500	0	rain, fog		
Sept. 27	1500	0	rain, fog		
Sept. 28	1500	0	rain, fog		
Sept. 29	1500	0	rain, fog		

Data Summary

Note: At the Paradise, Mount Rainier site the farthest visible target is 34 miles. Visual range determinations, therefore, will not be concluded at this site.

Data recovery, 96%, 87 observations from 91 possible days
50 days, 57%, visibility greater than 34 miles
27 days fog/clouds, 31%, with low visibility
3 days smoke reported, 5% of non-fog days

VISIBILITY OBSERVATIONS FROM COPPER RIDGE LOOKOUT, NORTH CASCADES NATIONAL PARK

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 6					
July 7	1030	19	partly cloudy	10000' ceiling; cumulus	
July 8	1200	9	clear; scattered clouds	cumulus	
July 9	1300	58	clear	slight haze to W	
July 10	1100	71+	clear		
July 11	0900	71+	clear	light valley fog	
July 17	1000	71	clear	scattered cumulus	
July 18	0930	0	grey, cloudy		
July 19	1015	0	grey, cloudy		
July 20	1700	0	heavy fog, rain		
July 21		0	heavy fog, mixed rain & snow		
July 22	1130	0	heavy fog		
July 23	1030	71+	clear		
July 24	1300	71+	clear		
July 25	0830	71		high cirrus	
July 25	1700	71+	clear	hazy to NW	
July 26	1900	71	clear	hazy to NW	
July 27	1750	58	clear	slash burn to NW	
July 30	2000	0	heavy fog		
August 1	1300	0	heavy fog		
August 2	1300	0	heavy fog		
August 5	0900	25	high cloud ceiling		
August 6	1300	71+	clear		
August 7	1300	71+	clear		
August 8	0900	71+	high cloud ceiling		
August 8	1700	71+	high cloud ceiling		
August 9	1700	0	heavy fog		
August 10	1000	0	heavy fog		
August 21	1400	71+	clear		
August 22	1400	71+	clear		
August 23	1200	71+	clear		
August 24	1700	71+	clear		
August 25	1700	9	clear	poor visibility due to slash burns in S & W	
August 26	1700	19	clear	hazy due to slash burn	
August 27	1700	0	fog		
August 28	1100	7	overcast		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Sept. 4	1330	0	fog, light rain		
Sept. 5	1300	9	heavy cumulus clouds		
Sept. 6	1330	71	heavy cumulus, stratus clouds		
Sept. 7	1300	4	fog, overcast		
Sept. 8	1200	4	fog, overcast		
Sept. 9	1300	0	snow		
Sept. 10	1330	0	snow		
Sept. 11	1300	0	snow		

Data Summary

Data recovery, 62%, 42 observations out of 68 possible days
17 days, 40%, visibility greater than 70 miles
17 days, 40%, fog with low visibility

VISIBILITY OBSERVATIONS FROM SAHALE ARM, NORTH CASCADES NATIONAL PARK

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 2		0	fog, rain		
July 3		0	fog, rain		
July 4		0	fog, rain		
July 5	1700	0	low clouds		
July 6	1700	13	broken cloud cover		
July 7		0	fog, rain		
July 8	1700	34	broken sky cover		
July 9	1700	13	broken sky cover		
July 10	1700	40+	clear		
July 11	1700	40+	clear		
July 12	1700	7	hazy		
July 13	1700	0	foggy		
July 14	1700	0	foggy		
July 15	1700	0	foggy		
July 16	1700	23	high clouds	slight haze	
July 17	1700	40+	slight haze		
July 19		0	fog, clouds, rain		
July 20		0	fog, clouds, rain		
July 21		0	fog, clouds, rain		
July 22	1700	13	broken cloudiness		
July 23	1700	40+	clear	slight haze to W	
July 24	1900	40+	clear	slight haze to W	
July 25	1830	40+	clear	slight haze	
July 30		0	no visibility due to weather		
July 31		0	no visibility due to weather		
August 1	1400	13	rain		
August 2	1500	13	rain		
August 3	1500	34			
August 4	1800	40+			
August 5	1900	40+	clear		
August 6	1900	40+	clear		
August 7	1800	40+	clear		
August 8	1800	40+	clear		
August 13	1500	0	fog, low clouds		
August 14	1500	0	fog, low clouds		
August 15	1500	13	broken low-level cloudiness		
August 16	1700	34	broken cloud layer		
August 17	1900	40+	clear	hazy to W	B

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
August 18	1800	40+	clear	hazy to W	D
August 19	1800	40+	clear	slight haze to E	D
August 20	1800	40+	clear	slight haze	D
August 21	1900	40+	clear with haze		D
August 22	1800	40+	clear with haze	haze to W	D
August 23	1900	40+	clear with haze		D,F
August 24	1800	40+	clear with haze		D,E
August 25	1700	40+	partly cloudy	blue smoke layer to W; brown haze to east	D,E
August 28	1800	40+	clear		
August 29	1800	40+	cloudy		
August 30	1800	40+	cloudy		
Sept. 1	1700	40+	clear with haze		
Sept. 2	1700	40+	clear		
Sept. 3	1800	40+	clear		
Sept. 4	1900	0			
Sept. 5	1600	0			
Sept. 6	1800	40+	clear		
Sept. 10	1400				
Sept. 11	1600	0			
Sept. 12	1300	40+	clear		
Sept. 13	1800	40	clear		

Data Summary

Note: At the Sahale Arm observation site, the farthest visible target is 40 miles. Visual range determinations, therefore, will not be made to this site.

Data recovery, 77%, 58 observations out of 75 possible days
29 days (50%) visibility greater than 40 miles
18 days (31%) fog and low visibility
3 days smoke reported, 7% of non-fog days

VISIBILITY OBSERVATIONS FROM LOOKOUT ROCK, OLYMPIC NATIONAL PARK

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
June 14	0859	13	cloudy		
June 14	1506	18	cloudy	hazy	
June 15	0849	120	scattered, high clouds		
June 15	1445	120	scattered clouds	distant haze	
June 16	0845	120	high, scattered clouds	slight haze	D
June 16	1440	120	sunny, scattered clouds	haze over straits	
June 17	0845	120	clear, sunny	haze over straits	D
June 17	1457	120	clear, sunny	distant haze	D
June 18	0855	18	clear, sunny	valley, strait haze	
June 18	1450	120	clear, sunny		
June 19	0845	120	clear, sunny	haze over straits	
June 19	1450	18	clear, sunny	valley, strait haze	
June 20	0830	120	clear, sunny	fog on straits	C
June 20	1450	120	clear, sunny		
June 21	0927	120	broken clouds	low fog, distant haze	C,D
June 21	1505	120	cloudy	fog over straits	D
June 22	0855	120	sunny; scattered clouds	light haze, low fog	C
June 22	1507	120	sunny; scattered clouds	light haze	
June 23	0855	120	clear, sunny	low fog, haze	C
June 23	1500	120	sunny; high scattered clouds	low fog, haze	C
June 24	0850	120	high, scattered clouds	heavy haze to NE	D
June 24	1455	120	clear	light to heavy distant haze	D
June 25	0839	120	overcast, rain	heavy valley haze	
June 25	1505	13	overcast	fog on straits	
June 26	0900	2.3	rain, heavy cloud cover	dense fog	
June 26	1500	0	rain, heavy cloud cover	dense fog	
June 27	0855	0	complete cloud cover	dense fog	
June 27	1457	120	light rain, cloudy	valley and strait fog	
June 28	0840	0	dense fog		
June 28	1507	120	overcast	heavy fog	
June 29	0840	120	overcast	heavy haze	D
June 29	1455	120	scattered clouds	haze over straits and valleys	C
June 30	0911	2.3	overcast	dense fog	
June 30	1454	0	overcast	dense fog	
July 1	0910	0	fog		
July 1	1430	0	fog		
July 2	0900	0	fog		
July 2	1446	0	fog, rain		
July 3	0905	0	fog		
July 3	1500	0	fog, rain		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 4	0905	120	sunny; scattered clouds		D
July 4	1500	120	heavy cloud cover		
July 5	0900	0	dense fog cover		
July 5	1500	0	overcast, fog, light rain		
July 6	0850	120	overcast, light fog		D
July 6	1458	18	overcast, rain, light fog		
July 7	0900	120	overcast		
July 7	1457	0	overcast, fog		
July 8	0900	120	overcast	heavy haze	C
July 8	1505	120	scattered, low clouds	haze on vistas	C
July 9	0900	120	sunny	valley haze	C
July 9	1500	120	scattered clouds	smoke, haze from burn	D
July 10	0906	120	cloud cover, fog	haze on valleys and straits	D
July 10	1504	120	warm, scattered clouds	valley haze	C
July 11	0900	120	warm, scattered clouds	distant and valley haze	
July 11	1503	120	warm, cloudy	strait and horizon haze	
July 12	0900	120	clear, warm	slight fog, haze	
July 12	1500	120	sunny, hot	slight distant haze	
July 13	0900	52	overcast	distant and valley haze	
July 13	1500	0	rain, overcast, fog		
July 14	0900	120	scattered clouds, cold, windy		
July 14	1501	120	broken clouds, windy, cool	light haze	G, smoke
July 15	0900	8	overcast, rain, fog		
July 15	1503	13	overcast, heavy, fog		
July 16	0900	18	heavily overcast		
July 16	1505	120	overcast, low clouds	general haze	
July 17	0905	18	broken clouds	lower valley haze	
July 17	1501	120	scattered clouds, sunny, warm	valley and distant haze	
July 18	0905	13	overcast, fog patches	valley haze	
July 18	1505	120	overcast		
July 19	0900	0	fog		
July 19	1500	0	fog		
July 20	0900	0	fog, rain		
July 20	1510	0	fog, mist		
July 21	0900	120	scattered clouds, cool	strait and distant haze	
July 21	1504	8	fog, mist		
July 22	0900	18	clear, distant fog		
July 22	1506	120	scattered clouds	vista and valley haze	C
July 23	0900	18	scattered clouds, sunny, warm	low fog	C
July 23	1512	120	clear, sunny, warm	valley, strait, distant haze	
July 24	0904	120	clear, sunny, warm	valley, strait haze	
July 24	1505	120	clear, sunny, warm	vista haze	
July 25	0929	120	clear, sunny, warm	valley, strait haze	C
July 25	1543	120	clear, sunny, warm	valley haze, some fog	D

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 26	0900	120	clear, sunny, warm	low fog	
July 26	1506	120	clear, sunny, warm	heavy haze	D
July 27	0900	18	clear, hot, scattered clouds	ground fog	D
July 27	1502	120	clear, hot, sunny	fog on straits and distant vistas	D
July 28	0900	13	scattered clouds, hot, sunny	heavy ground fog	
July 28	1502	120	cloudy; warm and foggy		
July 29	0900	2.3	scattered clouds, sunny, hot	valley and distant fog	
July 29	1500	107	clear, sunny, hot	heavy fog to NE	
July 30	0900	13	scattered clouds, sunny		
July 30	1500	52	overcast	heavy haze to NE	
July 31	0900	0	complete fog cover		
July 31	1500	0	complete fog cover		
August 1	0900	0	complete fog cover		
August 1	1500	0	complete fog cover		
August 2	0900	18	sunny	low clouds, ground fog	
August 2	1500	0	fog, light rain		
August 3	0900	0	fog, heavy mist		
August 3	1455	120	overcast	valley haze	
August 4	0900	120	sunny, scattered clouds	light haze	
August 4	1504	120	cloudy	strait, valley haze	
August 5	0900	120	high clouds	very dense, smoke-like haze	
August 5	1500	18	sunny, high clouds	heavy horizon haze	
August 6	0900	18	clear	heavy distant haze	
August 6	1500	18	clear	very dense haze	
August 7	0905	120	clear, foggy	low valley haze	
August 7	1506	120	clear, hot	some haze	
August 8	0811	120	overcast, foggy	low valley haze	
August 8	1500	120	overcast, foggy	valley haze	
August 9	0910	13	high scattered clouds, fog	hazy	
August 9	1502	7.8	cloudy, fog, rain		
August 10	0900	13	cloudy, low fog		
August 10	1500	0	dense fog		
August 11	0900	120	scattered clouds, warm	fog in patches	
August 11	1500	0	cloudy, foggy		
August 12	0900	0	overcast, foggy		
August 12	1500	0	overcast, fog, mist		
August 13	0900	0	heavy fog		
August 13	1500	0	heavy fog		
August 14	0914	120	sunny, scattered clouds	valley and vista haze	D
August 14	1505	120	overcast, haze, fog		G, smoke plume

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
August 15	0908	120	sunny; high, scattered clouds	vista and valley haze	
August 15	1508	120	cloudy	vista and valley haze	
August 16	0900	120	scattered clouds, sunny	light haze	
August 16	1500	120	scattered clouds, sunny	light strait haze	C
August 17	0900	18	clear	distant haze and fog	
August 17	1500	120	warm; scattered clouds	distant haze	
August 18	0900	120	clear	distant, strait heavy haze	
August 18	1510	120	clear, sunny		
August 19	0904	120	clear, sunny	strait, valley haze	
August 19	1506	120	partly cloudy, sunny	valley haze	
August 20	0906	120	sunny, partly cloudy	haze over target areas	
August 20	1505	120	sunny, scattered clouds	general haze over targets	
August 21	0908	120	sunny, partly cloudy	valley, target haze	
August 21	1504	120	sunny, hot, clear	target haze	
August 22	0907	120	sunny, clear, hot	target haze	
August 22	1506	120	mostly clear, sunny, hot	heavy haze	
August 23	0900	120	clear, sunny	distant haze	
August 23	1508	120	clear, sunny, hazy	valley haze	
August 24	0900	120	clear, sunny, hazy	distant haze	D
August 24	1506	120	clear, sunny, hazy	heavy haze over distant targets	
August 25	0900	120	clear, sunny, hazy		D
August 25	1508	120	clear, sunny, hazy	target, valley haze	
August 26	0900	1.4	sunny, foggy		
August 26	1500	0	fog		
August 27	0900	0	fog		
August 27	1500	15	high fog, overcast		
August 28	0910	18	low hanging clouds		G, smoke plume
August 28	1508	18	overcast, fog	strait, valley haze	
August 29	0912	120	overcast	light valley haze	
August 29	1506	120	overcast	valley, vista haze	
August 30	0900	107	cloudy		
August 30	1500	0	rain, fog	complete cloud cover	
August 31	0900	120	clear	fog in patches	C
August 31	1507	120	mostly cloudy	valley haze	G, smoke plume
Sept. 1	0900	120	clear	heavy fog in places	
Sept. 1	1506	120	scattered clouds	valley haze	
Sept. 2	0900	120	cloudy, warm	dark haze over strait	
Sept. 2	1500	120	clear, hot	heavy brown haze on strait	B
Sept. 3	0900	120	cloudy, warm	ground fog over strait	
Sept. 3	1500	0	fog		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Sept. 4	0910	18	partly cloudy	patches of ground fog	
Sept. 4	1459	0	overcast	dense fog	
Sept. 5	0906	120	scattered clouds	fog, haze on straits	
Sept. 5	1505	120	clear, sunny, few clouds	light valley haze	
Sept. 6	0900	120	partly cloudy		
Sept. 6	1508	120	partly cloudy	valley, vista haze	
Sept. 7	0900	0	dense fog		
Sept. 7	1457	0	dense fog		
Sept. 8	0900	0	dense fog		
Sept. 8	1516	120	cloudy, hazy		
Sept. 9	0900	120	cloudy	fog in patches	
Sept. 9	1509	120	partly cloudy		
Sept. 10	0846	120	partly cloudy, cold	light vista, strait haze	
Sept. 10	1500	120	partly cloudy, cool	light strait haze	
Sept. 11	0905	18	cloudy, cool, windy	fog in patches	
Sept. 11	1456	0	cloudy, dense cloud cover		
Sept. 12	0904	1.4	cloudy, fog, rain		
Sept. 12	1506	120	partly cloudy	valley, horizon haze	
Sept. 13	0915	107	sunny, cold, clear	strait fog	
Sept. 13	1505	120	scattered clouds, sunny	valley, target haze	
Sept. 14	0908	120	clear, sunny, warm	light vista haze	D
Sept. 14	1507	120	clear, sunny, hazy		
Sept. 15	0840	120	cloudy, cool	light vista haze	
Sept. 15	1454	120	partly cloudy	light valley, vista haze	
Sept. 16	0840	91	clear, sunny	heavy, distant haze	
Sept. 16	1445	120	clear, sunny	heavy brown haze on vista	D
Sept. 17	0905	120	sunny, clear	distant, heavy haze	D
Sept. 17	1450	120	sunny, clear	distant, heavy haze	D
Sept. 18	0905	18	sunny, scattered clouds	heavy distant haze	D
Sept. 18	1456	91	sunny	heavy distant haze	D
Sept. 19	0906	18	cloudy	light to dense haze	D
Sept. 19	1458	18	cloudy	haze, fog on strait	D
Sept. 20	0838	8	cloudy, rainy, fog	strait fog, valley haze	
Sept. 20	1458	0	cloudy, foggy		
Sept. 21	0830	8	scattered clouds, fog		
Sept. 21	1505	0	cloudy, foggy		
Sept. 22	0840	0	dense fog		
Sept. 22	1510	8	partly cloudy	light to heavy fog	
Sept. 23	0840	13	sunny, clear	haze in places	D
Sept. 23	1515	91	sunny, clear	dark brown haze on vistas	D
Sept. 24	0905	13	rain, fog		
Sept. 24	1455	0	dense fog		
Sept. 25	0904	13	overcast, fog		
Sept. 25	1503	120	partly cloudy, fog, haze		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Sept. 26	0857	0	overcast, fog		
Sept. 26	1459	0	partly cloudy	fog in patches	
Sept. 27	0850	18	sunny, clear, some fog		
Sept. 27	1459	0	overcast, foggy		
Sept. 28	0840	120	sunny, clear	distant fog, light haze	
Sept. 28	1509	120	broken clouds	light haze, some fog	
Sept. 29	0840	120	sunny, clear, low fog	some light haze	
Sept. 29	1457	120	sunny, clear	horizon fog, valley haze	E
Sept. 30	0840	120	sunny, clear	light fog, haze	
Sept. 30	1445	120	sunny, clear	light distant haze	
Oct. 1	0840	18	sunny, clear	fog on distant vistas	
Oct. 1	1450	120	cloudy	distant fog	
Oct. 2	0908	120	partly cloudy	valley, vista haze	E
Oct. 2	1458	0	overcast, rain, fog		
Oct. 3	0905	120	scattered clouds, sunny	light valley, vista haze	E
Oct. 3	1501	120	cloudy	fog, haze in patches	D,G, smoke plumes
Oct. 4	0855	18	partly cloudy, sunny	haze and strait fog	
Oct. 4	1455	15	partly cloudy	fog and low valley haze	
Oct. 5	0840	91	sunny, scattered clouds	distant and strait fog	
Oct. 5	1505	120	mostly cloudy	haze, fog in valleys, near vistas	G, smoke plumes
Oct. 6	0840	120	cloudy, rain, overcast	light haze over strait	
Oct. 6	1500	0	cloudy, rain, fog	all vistas fogged in	
Oct. 7	0850	120	foggy, cloudy, clear to NE		
Oct. 7	1440	120	partly cloudy	fog on some vistas	
Oct. 8	0842	18	partly cloudy, misty	distant and strait fog	
Oct. 8	1440	18	cloudy, misty	distant and strait fog	
ct. 9	0907	15	partly cloudy	valley, strait fog	
Oct. 9	1500	0	cloudy, foggy	all vistas fogged in	
Oct. 10	0909	120	sunny, scattered clouds	haze and ground fog, some vistas	
Oct. 10	1457	120	sunny, clear	dark haze, fog in some areas	
Oct. 11	0845	120	sunny, clear	dark distant haze	
Oct. 11	1450	120	sunny, warm, clear	dark distant haze	E
Oct. 12	0845	107	sunny, clear	dark distant haze	
Oct. 12	1505	120	sunny	dark distant haze	E
Oct. 13	0845	120	sunny, clear	dark haze, fog on strait	
Oct. 13	1508	120	sunny	dark haze over distant targets, straits	
Oct. 14	0840	91	sunny, clear	heavy dark haze on horizon	
Oct. 14	1440	107	sunny, clear	dark haze on straits and horizon	

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Oct. 15	0851	13	sunny, clear	distant, strait fog	
Oct. 15	1520	0	dense fog, cloudy		
Oct. 16	0903	18	cloudy, fog	ground fog, haze	D
Oct. 16	1502	0	cloudy, foggy		
Oct. 17	0902	120	partly cloudy, sunny	light haze and ground fog	
Oct. 17	1505	120	cloudy	light haze on all vistas	D,G, smoke plumes
Oct. 18	0940	91	sunny, clear	heavy low fog	
Oct. 18	1506	120	sunny, partly cloudy	valley, vista haze	
Oct. 19	1504	120	sunny, scattered clouds	light vista, valley haze	
Oct. 20	1507	120	cloudy, foggy	smoke to east	G, smoke plumes
Oct. 21	0848	18	rain, cloudy	light to heavy fog	
Oct. 21	1510	52	rain, cloudy	distant fog	E
Oct. 22	0845	8	rain, cloudy, windy		
Oct. 22	1500	120	scattered clouds	light fog on strait	E
Oct. 23	0910	120	mostly clear, scattered clouds	light haze, fog patches	G, smoke plumes
Oct. 23	1510	120	cloudy, light rain	fog patches	G, smoke plumes
Oct. 24	0902	120	cloudy, rain	light fog patches	
Oct. 24	1507	120	cloudy, light rain	light haze straits, distant horizons	D,G, smoke plumes
Oct. 25	0849	120	cloudy, rain	light distant, strait haze, fog	
Oct. 25	1504	120	cloudy, light rain	fog, haze, smoke in valley	G, smoke plumes
Oct. 26	0840	18	cloudy, rain, fog		
Oct. 26	1501	13	rain, cloudy	light to heavy fog all vistas	
Oct. 27	0834	18	cold, cloudy	fog on distant vistas	
Oct. 27	1507	120	cloudy, fog	heavy haze on distant vistas	G, smoke plumes
Oct. 28	0845	120	light rain, cloudy	distant fog	
Oct. 28	1500	8	cloudy, rain	heavy fog	
Oct. 29	0833	0	cloudy, mist	dense fog	
Oct. 29	1440	0	cloudy, mist	dense fog	
Oct. 30	0902	18	partly cloudy, foggy	light haze on vistas	
Oct. 30	1500	120	cloudy, light fog	haze on vistas	C
Oct. 31	0909	120	cloudy, rain, fog	light valley and distant haze	D
Oct. 31	1459	120	partly cloudy, sunny	haze in valleys, vistas	D
Nov. 1	0845	52	sunny, partly cloudy		
Nov. 1	1456	2.6	cloudy, foggy		
Nov. 2	0845	7.8	cloudy, foggy		
Nov. 2	1502	0	cloudy, foggy		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Nov. 3	0845	120	cloudy	light haze on distant vistas	
Nov. 3	1515	120	cloudy, foggy		
Nov. 4	0845	18	cloudy, rain, low fog		
Nov. 4	1509	120	partly cloudy, foggy		G, smoke plumes
Nov. 5	0910	18	cloudy, rain, fog		
Nov. 5	1500	18	rain, fog, cloudy		
Nov. 6	0902	18	snow, cold	low cloud cover	
Nov. 6	1459	120	overcast, rain fog		
Nov. 7	0901	120	overcast, rain	valley ground fog and haze	D
Nov. 7	1454	120	partly cloudy, sunny	haze on targets	
Nov. 8	0830	120	sunny, clear	light haze on straits	
Nov. 8	1456	120	sunny	haze on straits, vistas	G, smoke plumes
Nov. 9	0840	120	sunny, clear	light haze	
Nov. 9	1505	120	sunny, light haze		D
Nov. 10	0845	120	sunny, clear	distant fog	
Nov. 10	1506	120	sunny	dark grey haze in distance	G, smoke plumes
Nov. 11	0835	18	fog, cloudy	dark haze all vistas	
Nov. 11	1455	2.6	cloudy, foggy		
Nov. 12	0826	18	cloudy, foggy	light haze some vistas	
Nov. 12	1505	0	dense fog		
Nov. 13	0909	18	sunny, foggy	light haze	
Nov. 13	1450	0	cloudy, foggy		
Nov. 14	0905	15	sunny, scattered clouds	fog, haze obscured distant vistas	
Nov. 14	1450	91	sunny, fog, haze		D
Nov. 15	0911	18	partly cloudy	distant fog	
Nov. 15	1450	2.3	cloudy, foggy		
Nov. 16	0840	18	rain, fog, cloudy		
Nov. 16	1459	18	partly cloudy, sunny	light haze on straits, valley and vistas	
Nov. 17	0840	15	rain, fog, cloudy		
Nov. 17	1501	0	dense fog cover		
Nov. 18	0840	1.4	foggy, cloudy		
Nov. 18	1453	2.6	snow, fog, cloudy		
Nov. 21	0925	18	cloudy, foggy, cold	haze in valley	
Nov. 22	1450	120	sunny, cold	dark haze distant horizon	D
Nov. 23	1500	120	clear, sunny	haze on vistas, straits	D
Nov. 24	0845	107	clear, low fog		
Nov. 24	1508	107	clear, foggy	smoke, haze over strait and valley	
Nov. 27	0908	120	rain, fog, cloudy		
Nov. 27	1447	18	rain, fog, cloudy		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Nov. 28	1445	120	cloudy, foggy		D
Nov. 29	0840	7.8	partly cloudy, foggy		
Nov. 29	1452	0	cloudy, foggy		
Nov. 30	0835	120	clear, distant low clouds		
Nov. 30	1445	120	cloudy, light fog	haze, fog on straits and vistas	
Dec. 1	0835	107	clear, light fog, distant clouds		
Dec. 1	1455	120	cloudy, foggy	light fog, haze over straits, vistas	D,G, smoke plumes
Dec. 2	0830	18	cloudy, light haze		
Dec. 2	1505	18	cloudy, light fog		
Dec. 3	0830	0	dense fog cover		
Dec. 4	0902	120	sunny, partly cloudy		
Dec. 4	1450	120	partly cloudy	light fog, haze in valleys, straits	G, smoke plume
Dec. 5	0905	107	low clouds, fog		
Dec. 5	1450	0	dense fog cover		
Dec. 7	1502	91	cloudy, foggy		
Dec. 8	1500	120	cloudy, foggy	dark grey, haze/fog over coastal areas, distant horizon	
Dec. 10	1515	120	cold, clear	brown haze on horizon	
Dec. 11	1458	91	cloudy, foggy	haze in valley	
Dec. 12	1446	13	cloudy, foggy		
Dec. 13	0845	120	cold, clear	light haze	
Dec. 13	1440	18	cloudy, foggy	light haze	G, smoke plumes
Dec. 14	0850	120	cold, cloudy, light fog		G, private burn
Dec. 14	1459	18	rain, fog, cloudy		G, smoke plumes
Dec. 18	1445	120	rain/snow, cloudy		
Dec. 20	1445	0	cloudy, foggy		
Dec. 21	1440	120	cloudy, foggy	haze, fog in valleys, straits, horizon	
Dec. 22	1431	120	partly cloudy		
Dec. 23	1440	120	clear, distant low clouds	light haze on strait	
Dec. 24	0907	18	partly cloudy		
Dec. 24	1430	120	clear, distant cloud cover	distant light haze	
Dec. 26	1435	18	foggy, some sun		
Dec. 27	1445	120	sunny, clear	light distant haze	
Dec. 28	0815	120	sunny, clear, low distant clouds	distant heavy haze	
Dec. 28	1402	120	sunny, low distant clouds	light haze on vistas	
Dec. 29	1415	107	mostly clear		
Dec. 30	0916	107	sunny, clear, low fog		
Dec. 30	1350	120	sunny, clear, distant fog	valley and strait haze	
Dec. 31	0907	107	sunny, clear, distant fog	valley and strait haze	
Dec. 31	1350	107	cold, high clouds, low fog		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Jan. 1	0917	107	cloudy, foggy	light fog, haze to east	
Jan. 1	1347	120	cloudy, foggy	inland fog, haze	
Jan. 2	1447	18	partly cloudy, foggy	light haze, fog in valley	
Jan. 3	0916	18	cloudy, distant fog		
Jan. 3	1412	120	cloudy, windy, foggy		
Jan. 4	0959	0	dense fog cover		

Data Summary (June 14, 1982 to September 30, 1982)

Data recovery, 100%, 109 observation days out of 109 possible days
73 days, 67%, visibility 120 miles at one or both of the daily observations
27 days, 25%, fog with low visibility
12 days smoke reported, 15% of non-fog days

Data Summary (October 1, 1982 to December 31, 1982)

Data recovery, 92%, 85 observation days out of 92 possible days
49 days, 52%, visibility 120 miles at one or both of the daily observations
18 days, 20%, fog with low visibility
17 days smoke reported, 19% of non-fog days

*A Visible emissions from recreational sources (campfires, road dust, vehicle emissions, etc.)

B Visible emissions for forestry burning, smoke or smoke plumes

C Industrial or stack emissions

D General haze from direction of urban areas

E Haze or smoke from forested areas

F Low valley haze or fog

G Other

VISIBILITY OBSERVATIONS FROM THE SNOWDOME, BLUE GLACIER, OLYMPIC NATIONAL PARK

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
June 28	0830	27	broken clouds	clouds, fog obscured visibility	
June 28	2100	70	scattered clouds		
June 29	0800	70	overcast	marine stratus obscured visibility	
June 29	1500	0	broken clouds, fog		
June 29	2000	6	broken clouds	clouds, fog obscured visibility	
June 30	0800	45	overcast	fog, stratus obscured visibility	
June 30	2000	110	clear	fog, stratus obscured visibility	
July 1	0800	70	overcast	fog, stratus obscured visibility	
July 1	2000	6	overcast	fog, clouds obscured visibility	
July 2	0800	2	overcast	fog, clouds obscured visibility	
July 2	2000	2	overcast, rain, fog	fog, clouds obscured visibility	
July 3	0800	2	overcast, fog		
July 3	2000	0	overcast, drizzle, fog		
July 4	0800	70	scattered clouds	clouds obscured visibility	
July 4	2000	0	overcast, fog		
July 5	0800	0	overcast, fog		
July 5	2000	70	overcast, rain	clouds obscured visibility	
July 6	0800	70	broken clouds, rain showers	clouds, rain obscured visibility	
July 6	2000	70	overcast	clouds obscured visibility	
July 7	0800	2	overcast	clouds obscured visibility	
July 7	2000	0	broken clouds	clouds, fog obscured visibility	
July 8	0800	110	clear		
July 8	2000	27	scattered clouds	clouds obscured visibility	
July 9	0800	110	scattered clouds	some haze	
July 9	2000	2	scattered clouds	clouds obscured visibility	
July 10	0800	110	overcast	clouds obscured visibility	
July 10	1500	110	overcast	some haze to W	B
July 10	2000	120	overcast	smoke, haze all quadrants	B, burn
July 10	2100			strong smoke smell	B, burn
July 11	0800	70	overcast	light haze in valleys	
July 11	1715			haze and smoke to the N and W	E
July 11	2000	70	overcast	smoky haze	
July 12	0800	27	mostly clear	smoky haze obscured visibility	E
July 12	1500	27	broken clouds	smoky haze obscured visibility	
July 12	2000	27	broken clouds	smoky haze	
July 13	0800	6	overcast, fog, mist	clouds, fog obscured visibility	
July 13	2000	0	overcast, fog, rain		
July 14	0800	0	thick fog, snow		
July 14	2000	0	thick fog, snow		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
July 15	0800	0	thick fog, snow		
July 15	2000	27	overcast	fog in valleys	
July 16	0800	27	clear, sunny		
July 16	2000	35	scattered clouds	haze obscured visibility	E
July 17	0800	27	broken clouds	clouds obscured visibility	
July 17	2000	6	overcast	fog in valleys	
July 18	0800	27	clear	fog in valleys	
July 18	2000	110	clear	haze, fog in valleys	F
July 19	1500	110	scattered clouds	clouds in valleys	
July 19	2000	27	clear		
July 20	0800	2	overcast, fog, light rain		
July 20	2000	2	broken clouds, fog		
July 21	0800	2	overcast, fog		
July 21	2000	70	clear		
July 22	0800	110	clear		
July 22	2000	110	clear		
July 23	0800	110	clear		
July 23	2000	110	clear		
July 24	0800	70	clear		
July 24	2000	70	clear	smoke north of Mt. Tom	E
July 25	0800	70	clear	moderate smoke to W	
July 25	2000	70	clear	light haze all quadrants	
July 26	0800	27	clear, coastal fog	moderate smoke and haze, all quadrants	
July 26	2000	70	clear, coastal fog	moderate smoke and haze, all quadrants	
July 27	0800	27	scattered clouds	smoke, haze	
July 27	2000	27	scattered clouds	smoke, haze	
July 28	0800	27	scattered clouds		
July 28	2000	27	broken clouds	smoke, haze	
July 29	0800	27	scattered clouds		
July 29	2000	27	scattered clouds		
July 30	0800	6	broken clouds	haze	
July 30	2000	27	scattered clouds		
July 31	0800	27	clear		
July 31	2000	6	clear		
August 1	0800	27	clear		
August 1	2000	0	fog		
August 2	0800	2	overcast, drizzle, fog		
August 2	2000	2	overcast, rain, fog		
August 3	0800	6	clear, stratus to 6,000'		
August 3	2000	0	overcast, fog		

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
August 4	0800	70	clear		
August 4	2000	6	clear, stratus in valleys		
August 5	0800	110	overcast		
August 5	1515			low valley haze and fog	F
August 5	2000	38	broken clouds		
August 6	0800	110	scattered clouds		
August 6	1630			visible burn in Hoh Valley, to SSW	B
August 6	2000	6	partial obscuration	strong smoke smell, thick smoke	B
August 7	0800	24		valley haze all quadrants	
August 7	2000	35		valley haze all quadrants	
August 8	0800	27	overcast	stratus in valleys	
August 8	2000	27		stratus in valleys	
August 9	0800	27			
August 9	2000	3			
August 10	0800	6	light rain	valley clouds	
August 10	2000	2	light rain, fog		
August 11	0800	3	broken clouds		
August 11	2000	0	fog		
August 12	0800	0	fog		
August 12	2000	0	fog		
August 13	0800	0	scattered clouds, fog		
August 13	2000	0	fog, partial obscuration		
August 14	0800	110		valley stratus	
August 14	2000	2	clear above 6,500'		
August 15	0800	70		clouds in valleys	
August 15	2000	0	overcast		
August 16	0800	35	broken clouds		
August 16	2000	38	scattered clouds	stratus in valleys	
August 17	0800	110	broken clouds		
August 17	1700			visible burn in a.m., general haze in p.m.	B,E
August 17	2000	110	scattered clouds		
August 18	0800	110	clear		
August 18	1500			haze to the W	E
August 18	2000	110	clear	visible smoke from slash burn	
August 19	0800	70	clear	thick smoke to NW	
August 19	1500			hazy to the W	E
August 19	2000	70	scattered clouds	smoke to 8,000' to E	
August 19	2015			layered haze S to NE	E
August 20	0800	27	scattered clouds	most targets obscured by smoke	
August 20	0815			visible smoke to W, hazy in others	B
August 20	1500	27		visible smoke to W, general haze	B,E
August 20	2000	35	scattered clouds	thick smoke obscured targets	

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
August 21	0800	27	clear	thick smoke in all valleys	
August 21	1500	27		haze in all directions	E
August 21	2000	70	clear	smoke in valleys	
August 22	0800	70	clear, coastal fog	smoke in valleys	
August 22	1550			haze to the W, blocking W view	E
August 22	2000	70	clear	smoke, haze in valleys	
August 23	0800	70	clear	light haze in valleys	
August 23	2000	70	clear	light haze in valleys	
August 24	0800	110	clear	light haze in valleys	
August 24	1700			haze to W, blocking views to W and N	E
August 24	2000	110	clear	light haze to W	
August 25	0800	70	scattered clouds, light fog	light haze	
August 25	1500	27		haze from W, blocking 6 targets	E
August 25	2000	27	scattered clouds, light fog	haze in valleys	
August 26	0800	27	scattered clouds, light fog	haze in valleys	
August 26	2000	27	clear, fog in valleys		
August 27	0800	27	clear	stratus in valleys	
August 27	2000	0	overcast, fog		
August 28	0800	0	overcast, fog		
August 28	2000	27	clear, clouds in valleys		
August 29	0800	110	overcast		
August 29	2000	0	overcast, fog, drizzle	targets obscured by fog	
August 30	0800	0	overcast	targets obscured by fog	
August 30	1500	0	overcast, fog, light rain	targets obscured by fog	
August 30	2000	0	overcast, fog, light rain	targets obscured by fog	
August 31	0800	70	scattered clouds		
August 31	1500	27	scattered clouds		
August 31	2000	70	overcast		
Sept. 1	0800	110	scattered clouds		
Sept. 1	1300	120	scattered clouds		
Sept. 1	2030	120	clear		
Sept. 2	0800	120	scattered clouds	haze, smoke layers to W	
Sept. 2	0900				unknown
Sept. 2	1500	120	clear	pronounced haze, smoke to W	unknown
Sept. 2	2010	70	clear	pronounced haze, smoke to W	slash burn
Sept. 3	0800	27	overcast	haze, smoke in valleys	
Sept. 3	2000	0	overcast, fog, light rain		
Sept. 4	0800	0	overcast, light rain		
Sept. 4	2000	0	overcast, fog		
Sept. 5	0800	110	clear		
Sept. 5	2000	27	clear	targets obscured by clouds	
Sept. 6	0800	120	clear		
Sept. 6	2000	0			

Date	Time	Prevailing Visibility (miles)	Meteorological Conditions	Remarks	Possible Source Visual Impairment*
Sept. 7	0800	27	overcast	targets obscured by clouds	
Sept. 7	2000	35			
Sept. 8	0800	27	clear		
Sept. 9	0800	0	broken clouds	targets obscured by clouds	

Data Summary

June 28 to September 9, 1982
Data recovery, 100%, 74 observation days out of 74 possible days
39 days, 53%, visibility 70 miles or greater at one or more observations
16 days, 22%, fog with low visibility at all observations
20 days smoke reported, 34% of non-fog days

*A Visible Emissions from Recreational Sources (campfires, road dust, vehicle emissions, etc.)

B Visible Emissions for forestry burning, smoke or smoke plumes

C Industrial or stack emissions

D General haze from direction of Urban Areas

E Haze or smoke from forested areas

F Low valley haze or fog

APPENDIX B

REVISION TO THE WASHINGTON STATE IMPLEMENTATION PLAN:

WASHINGTON STATE'S VISIBILITY PROTECTION PROGRAM

APPENDIX C

FEDERAL LAND MANAGER STATEMENTS

Appendix C

UNITED STATES DEPARTMENT OF THE INTERIOR, NATIONAL PARK SERVICE

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

Mr. Darrell Weaver
Office of Air Programs
Department of Ecology
Mail Stop PV-11
Olympia, WA 98504

Dear Mr. Weaver:

We have reviewed the Revision to the Washington State Implementation Plan for Visibility Protection and find that it is satisfactory with respect to the goals and policies of the National Park Service. We believe the proposed plan also meets the procedural requirements included in the Federal requirements for State visibility plans (40 C.F.R. §§ 51.300 - 51.307).

We are aware of the conflicting interests which this plan covers and feel that a reasonable initial compromise has been reached. The proposed weekend burning restriction and the reduction of emissions represent definite steps toward improving visibility in class I areas. However, continual evaluation and assessment during the implementation of the plan will be critical to its success. We encourage the State of Washington to continue the monitoring program and to evaluate visibility annually to ensure that progress is being made.

With respect to "integral vistas," the State has proposed to adopt the vistas preliminarily identified by the National Park Service in a proposed rulemaking published in 1981. The National Park Service has not made final determinations on these vistas, and the integral vista aspect of visibility impairment is currently under reconsideration by the Environmental Protection Agency and under judicial review in the courts. By adopting the proposed plan, the State would be electing to consider integral vistas on its own initiative. As proposed under the plan, the State would be required to consider the effect of emissions from new and existing sources on integral vistas and balance protection of these vistas with other relevant considerations such as economic and energy effects.

The National Park Service supports your proposed plan, and appreciates your proposal for the protection of the visibility aspects of the class I park areas in Washington. We look forward to continued involvement in the monitoring program and annual evaluations as the plan is implemented.

Sincerely,

G. Ray Arnett
Assistant Secretary for
Fish and Wildlife and Parks

Appendix C

UNITED STATES DEPARTMENT OF AGRICULTURE, FOREST SERVICE

Testimony Relative To:

THE FEBRUARY 22, 1983
REVISION TO THE WASHINGTON STATE IMPLEMENTATION
PLAN
WASHINGTON STATE'S VISIBILITY PROTECTION PROGRAM*

I appreciate this invitation for a second opportunity to comment on the Washington State Visibility Protection Program. As before, because strategies advanced by the State Implementation Plan (SIP) Revision include important restrictions on prescribed burning, I want to deal in some depth with that activity. I would also like to discuss additional visibility protection concerns raised by the proposed Plan. Thus, because of the limited time for oral testimony, I intend to cover only those elements we believe call most for clear public understanding regarding Forest Service relationships to, support for, and reservations about, the SIP Revision. Suggestions of an editorial or technical nature will be supplied separately. While specifically directed to the narrative portion of the plan, my comments bear upon the consequent proposed amendments to the Washington Administrative Code.

I have referred to both support for and reservations about the proposed Plan. I want to assure you that we view positively the new SIP. There can be little question that Washington State is providing for application of the best available technology to meet the National Visibility Protection Goal and related mandates of Congress. Particularly important and reassuring to us is the paragraph at the bottom of page 13 of the text. There, reference is made to investigations of more sophisticated methods. Provision is then made for replacing or supplementing control strategies advanced with the SIP Revision when equal or better performance is demonstrated. Further on I will cover some specifics regarding attainable sophistication, but now want to proceed with comments in the same sequence as in the furnished text.

I would like to begin with Section III - Definitions. I believe that the key term, "Visibility Important Day" should be defined in this Section. The remainder of my comments depend mainly upon interpretation of "visibility importance," found in the next to last paragraph on page 13, and upon note (1) to figure 2.

My comments on Section V - Control Strategies are identified with individual subsections.

In Subsection A - Best Available Retrofit Technology there seems to be a conflict which, while apparently editorial, is worth noting. Subsection A is technically correct regarding the lack of any identified sources, but the preceeding Section IV (page 8, paragraph 3), identifies certain stationary source types. Even though the Section IV identifications may be sketchy, there is an indication that a part of the assessed visibility impairment is left unaddressed. Contributions from several small stationary sources may in total be equal to, or more important than, impairment by an individual, larger source. In suggesting a revision to account for impairment by the combined impact from all permanent sources, I recognize the monitoring and modeling difficulties. I also venture to speculate that public perception, and even some studies, are flawed by lack of accounting for the combined impact of less readily identified sources.

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* Testimony of James C. Space, Deputy Regional Forester, Pacific Northwest Region, United States Department of Agriculture, Forest Service, at the Washington State Department of Ecology Public Hearing in Seattle, Washington on April 12, 1983.

In Subsection B - New Source Review no reference is made to visibility protection for Integral Vistas, at this time a requirement of the Federal regulations relative to new sources [40CFR §51.307(b)(1)].

Subsection C - Prescribed Burning and Wildfires deals first with differences between categories of fires. It is important to this hearing record to elaborate on the discussion in the proposed Plan.

First, let's look at the basic similarities of prescribed fires of the two types: planned ignitions and unplanned ignitions. In both types the result is change in the vegetative mantle. Both are viewed as Mankind's way of carrying out to our own purposes that which would have occurred in nature. This view applies equally to fires prescribed in wilderness to maintain natural fuel loadings or to restore ecosystems, and to those which are prescribed in residues following timber harvesting. If we had no need for the fibre in the trees we harvest, natural processes, including fire, would have continued to replace timber stands with successive vegetational mantles.

Next, let's look at an environmentally important difference between planned and unplanned ignitions. Because we have less opportunity to schedule unplanned ignitions, rapid changes in weather affecting atmospheric dispersion are more likely and there is greater risk of unsatisfactory air quality and visual impact. I will later make a suggestion addressing the challenge which this poses.

The reference to wildfire suppression in the proposed Plan (last paragraph, page 12) also calls for a bit of elaboration to be understood in terms of U.S. Department of Agriculture, Forest Service policy. We are aggressive in taking initial action on all fires except where prior planning has provided that fires from unplanned ignitions, as discussed above, may be prescribed. It would be poor management, however, to expend huge sums to immediately attempt to suppress some fires escaping initial attack. Further, when our suppression forces are taxed, we must sometimes prioritize the timing and extent of initial attack. I believe that the proposed Plan does not intend that this policy be changed, although it would be possible to reach such an interpretation from the referenced statement.

Further, for the hearing record, I would like to mention that recent history confirms a decline of air pollution from major wildfires in the Northwest. But recent history can be misleading. To benefit air quality, we are today foregoing treatment (thus leaving untreated fuel) or prescribing conditions which will lower emissions, as well as burning under conditions which favor smoke dispersion (like an unstable atmosphere). Less easily controlled fire is often a consequence. A higher risk of fires escaping could then combine with a drier climatic cycle to result in an increase in major conflagrations. These are technical matters for which each fire organization must lay plans, but it would be irresponsible if we did not mention here that increased risk-taking is involved in these strategies.

I would like to turn now to consideration of Subsection 1. Controlling Emissions. I have said earlier that we support the SIP revision, and reaffirm that statement here. Our positive position is based on two precepts: A) that the public wishes to provide for increased visibility protection even though costs and risks of doing so will be greater; and B) that in providing for application of the best available technology, the SIP revision recognizes that improvements are possible.

In regard to costs, the proposed Plan contains a statement (page 13, paragraph 3) concerning enhancement of the economic benefits to tourism. This hearing record should show that economic benefit to tourism is not without tradeoff. Based upon work by Sandberg and Schmidt (1982), our best estimate of current costs of operating changes to manage smoke from prescribed fires is $14.02 per acre. From the same reference, overall costs of smoke management on all Western Oregon and Western Washington National Forests currently total an estimated $26 per acre, or approximately $2 million per year. To arrive at a projection of the added costs that the SIP revision strategies may bring about, I'd like you to look first at a general map showing the proximity of the National Forests to Class I Federal Areas being afforded visibility protection.

The cost impact of the SIP revision 10-mile and 30-mile lines of demarcation for different restrictions is made most clear when you examine closely an area like the Olympic Peninsula. There the Class I Olympic National Park is surrounded by, and mixed with, the relatively narrow band of the Olympic National Forest. Added costs to manage prescribed fire smoke within this narrow National Forest band (much of it just about 10 miles wide) are expected to be greatest in the cost elements Sandberg and Schmidt identified as: "Work Plan Changes;" and "Extra Work." By assuming a simple proportion to be representative of the change from 7-day to 5-day opportunities to burn, we arrive at a projected added cost of $ 4.40 per acre. With this cost borne by the timber being harvested, a reduction in Federal and County revenues will be experienced.

Anywhere within the 30-mile line of demarcation some cost impact is also possible for other land ownerships. A competitive disadvantage is thus imposed upon the timber industry in this area. Similar costs borne by the U.S. Government and the Counties, or passed on to industry and ultimately to the consumer, will be experienced on forest lands surrounding other Mandatory Class I Federal Areas.

Other potential costs must also be considered. Those values used above do not include the cost of lost production (for example, through changes in site productivity where the restrictions make necessary the use of machines that result in soil compaction, or through time lost in growing a new crop of trees). Neither do they include costs like those of tree planting stock grown in the nursery and left unused because of lost opportunities to burn on "Visibility Important Days." These increased costs may be borne by the industry or passed on to the taxpayer, depending on circumstances.

In regard to possible improvements, I promised early in this testimony to deal more specifically with attainable sophistication in the management of smoke. We believe that the SIP revision offers the currently best available technology in a straight forward, easy to follow manner. We also believe that in critical areas like the Olympic Peninsula referred to above, it will be desirable, and soon be possible, to apply a much more sophisticated technology to smoke management.

A Smoke Management Screening and Approval Process Handbook documenting application of the latest state of knowledge is now roughly 80 percent complete. Programming for the first generation of an automated approach that will make the process easy to use is now approximately 50 percent complete. Field trials of the process are targeted to begin on the Olympic National Forest in August of this year. In the past few weeks, we have seen promising results from the first trial runs of the process using climatological data with the burns actually conducted in 1982. The results compare decision outcomes between the proposed SIP revision strategies and the process under development. I think it is safe to say we can meet the requirement of "equal or better performance."

Our goal is to complement the Cooperative Smoke Management Program administered by the Washington State Department of Natural Resources, and recognized as a vital component of the proposed SIP Revision. We intend that the Screening and Approval Process will be applied on the National Forests in any locale where its use will help to hold down both tangible and intangible costs. By "intangible" I mean such costs as impaired weekday visibility, increased smoke in areas not being afforded protection by the proposed SIP revision or other special smoke management measures, and such costs as the potential to lose opportunities to maintain desired components within wilderness ecosystems. These are high aspirations, and we can expect to see an evolution through several generations of the process.

I have earlier promised to make a suggestion regarding smoke from both planned and unplanned ignition prescribed fires for maintaining wilderness ecosystems. I suggest that by treating both categories of ignition the same, and by merely limiting the extent of total visibility impact within the Mandatory Class I Federal Areas, we can achieve both visual quality and desired ecosystems, themselves part of the view. Criteria in the Screening and Approvals Process discussed above are intended to accomplish this.

Also under Subsection C - Prescribed Burning and Wildfires a continuing commitment is made to reducing the amount of fuel that will be consumed, and thus a reduction in total emissions. I am confident that each of the activities outlined by the proposed SIP revision will lead to this goal. Individual specialists in the Forest Service Pacific Northwest Region have been assigned to develop strategies that will be in direct support to the cooperative effort outlined by the proposed Plan. Emphasis in these assignments is on further improvements in utilization of trees being harvested. Among the activities listed in the proposed Plan is one in particular I would like to underscore: "Continued refinement of burning techniques..." The technology for reducing smoldering combustion will alone deal with one of the most troublesome aspects of burning residues. Scientists in the Pacific Northwest Forest and Range Experiment Station who are working to make this technology available should be sought out by anyone interested in applying what has been learned to date.

The final area of Forest Service concern to be covered here is in Section VI - Long-Term Visibility Monitoring Strategy. This is a highly technical area in which we will encourage our own specialists to continue to work with the Washington Department of Ecology to arrive at the most sound plan. Limited dollars and personnel suggest we will have to prioritize this work. I do not see the need for a longstanding program in any one Class I Area. We are particularly concerned that monitoring sites for wilderness be within wilderness, despite inconveniences of access and meeting the need for virtually no impact. We presently see automation of the Photographic Visibility Monitoring Technique as most adaptable to wilderness needs.

These comments have been aimed at achieving clarity in our relationship to the State Visibility Protection Program. I do not view even the more critical comments, such as the matters of costs or risks, as reason to fall back from the position of support the Forest Service is expected to provide. I can reaffirm our continued support for the Cooperative Smoke Management Program administered by the State Department of Natural Resources, and am inviting both that Department and the Department of Ecology to monitor or participate in the field trials and further developmental work on the Smoke Management Screening and Approval Process.

In closing I want to thank personally each of the State and other cooperating organization specialists who have worked to formulate an approach acceptable to the individuals and organizations it affects. I believe you have been successful. With implementation, we can expect to meet better the Federal Land Manager responsibilities mandated by Congress to the Department of Agriculture, Forest Service.

Reference Cited

SANDBERG, DAVID V. and R. GORDON SCHMIDT, 1982. Smoke management costs for forest burning. Paper presented at the Air Pollution Control Association Pacific Northwest International Section Annual Meeting, Vancouver, B.C., Canada, November 15-17, 1982. 10 pp.