The federal Clean Air Act of 1970 required EPA to assist states and localities in establishing ambient air quality monitoring networks to characterize human health exposure and public welfare effects of criteria pollutants. The 1977 federal Clean Air Act Amendments required each state to implement a visibility monitoring network to cover specified national parks and wilderness areas. The Phoenix and Tucson metropolitan areas also have year-round visibility monitoring networks to assess urban hazes. All of these networks are composed of individual monitoring sites, which are operated to collect ambient air quality data. This helps to identify causes of air pollution and provide Arizona citizens with local air quality conditions.

Table I.1. Monitoring Objectives for Air Quality Monitoring Sites

1) Determine highest concentrations expected to occur in the area covered by the network.
2) Determine representative concentrations in areas of high population density.
3) Determine the impact on ambient pollution levels of significant sources or source categories.
4) Determine general background concentration levels.
5) Determine the extent of regional pollutant transport among populated areas and in support of secondary standards.
6) Determine the welfare-related impact in more rural and remote areas (such as visibility impairment and vegetation effects).

Criteria Pollutant Monitoring Networks

The criteria pollutants are presently defined as sulfur dioxide (SO_2), total particulate lead (Pb), suspended particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and carbon monoxide (CO). Pollutants are monitored with federal reference or equivalent methods, certified by EPA. EPA redefined PM monitoring in 1987 to measure particles less than or equal to 10 microns in aerodynamic diameter (PM_{10}), and again in 1997 to measure both PM_{10} and particles less than or equal to 2.5 microns in aerodynamic diameter ($PM_{2.5}$). Networks operated to monitor the nature and causes of visibility impairment utilize some of the same sampling methods and are described in more detail later in this section. Ambient monitoring networks for air quality are established to sample pollution in a variety of representative settings, to assess the health and welfare impacts and to assist in determining air pollution

Table I.2. Measurement Scales for Air Quality Monitoring Sites

	Carbon Monoxide	Sulfur Dioxide	Ozone	Nitrogen Dioxide	Lead	Particulate Matter
Micro Scale (0 to 100 meters)	X	X	X		X	X
Middle Scale (~100 to 500 meters)	X		X	X	X	X
Neighborhood Scale (~0.5 to 4 kilometers)	X	X	X	X	X	X
Urban Scale (~4 to 50 kilometers)		X	X	X	X	X
Regional Scale (~10 to 100s of kilometers)		X			X	X

sources. These networks cover both urban and rural areas of the state. These sampling networks are designed to satisfy monitoring objectives and measurement scales defined in Tables I.1 and I.2. For each criteria pollutant, EPA specifies monitoring objectives that define the parameters over which the health exposure and public welfare are assessed, and measurement scale classifications that describe the influence of atmospheric movement at that location.

The types and scales of monitoring sites described above are combined into net-

Table I.3. Monitoring Networks Operating in Arizona

Network Operator	Geographic Area Monitored	Monitoring Objective(s) Covered	Measurement Scale(s) Covered	Pollutant(s) Monitored
ADEQ	Statewide	1,2,3,4,5,6	Micro, middle, neighborhood, urban, regional	SO_2, Pb, O_3, NO_2, CO, PM_{10}, $PM_{2.5}$
Arizona Portland Cement Company	Rillito	1,3	Neighborhood	PM_{10}
Arizona Public Service Company	Joseph City	1,3	Middle	PM_{10}
ASARCO, Inc.	Hayden	1,2,3	Middle, neighborhood	SO_2
BHP Copper, Inc.	San Manuel	1,2,3	Middle, neighborhood	SO_2
Cyprus Miami Mining Corporation	Miami	1,2,3	Neighborhood	SO_2, PM_{10}, $PM_{2.5}$
Maricopa County Environmental Services Dept.	Phoenix urban area and Maricopa County	1,2,3,4,5,6	Micro, middle, neighborhood, urban regional	SO_2, Pb, O_3, NO_2, CO, PM_{10}
National Park Svc.	National Parks and Monuments	3,4,5,6	Urban, regional	SO_2, O_3, NO_2, PM_{10}, $PM_{2.5}$
Phoenix Cement Company	Clarkdale	1,3	Neighborhood	PM_{10}, $PM_{2.5}$, Pb
Pima County Dept. of Environmental Quality	Tucson urban area and Pima County	1,2,3,4,5,6	Micro, middle, neighborhood, urban, regional	SO_2, O_3, NO_2, CO, PM_{10}, $PM_{2.5}$
Pinal County Air Qual. Control Dist.	Pinal County and Phoenix urban area	1,2,3,4,5	Middle, neighborhood, urban, regional	O_3, CO, PM_{10}, $PM_{2.5}$
Praxair, Inc.	Kingman	1,3	Middle	PM_{10}
Salt River Project	Page and St. Johns	1,3	Urban, regional	NO_2, O_3, SO_2, PM_{10}, $PM_{2.5}$
Southern California Edison Company	Bullhead City, AZ and Laughlin, NV	1,2,3,4	Neighborhood, urban, regional	SO_2, NO_2, PM_{10}
Tucson Electric Power Company	Tucson and Springerville	1,2,3	Middle, regional	SO_2, NO_2, PM_{10}, $PM_{2.5}$

works, operated by a number of government agencies and regulated companies. These networks are comprised of one or more monitoring sites, whose data are compared to the NAAQS, as well as being statistically analyzed in a variety of ways. The agency or company operating a monitoring network also tracks data recovery, quality control, and quality assurance parameters for the instruments operated at their various sites. The agency or company often also measures meteorological variables at the monitoring site.

Maricopa, Pima and Pinal counties' networks are operated primarily to monitor urban-related air pollution

Finally, special continuous monitoring for the optical characteristics of the atmosphere, and manual sampling of ozone-forming compounds and other hazardous air pollutants is done by some of the agencies. The Maricopa, Pima and Pinal counties' networks are operated primarily to monitor urban-related air pollution. In contrast, the industrial networks are operated to determine the effects of their emissions on local air quality. The National Park Service network tracks conditions in and around national parks and monuments. The state network monitors a wide variety of pollutant and atmospheric characteristics, including urban, industrial, rural and background surveillance.

Table I.3 lists the monitoring networks and their characteristics. A list of individual sites and monitoring parameters, based on the best available information at the time of publication is presented in Supplement A.

Visibility Monitoring Networks in National Parks and Wilderness Areas

Visibility monitoring networks track impairment in specified national parks and wilderness areas. These parks and wilderness areas are called Class I Areas and were designated based on an evaluation required by Congress in the 1977 federal Clean Air Act Amendments. The evaluation, which the U.S. Forest Service (USFS) and National Park Service (NPS) performed, reviewed the wilderness areas of parks and national forests which were designated as wilderness before 1977, were more than 6,000 acres in size, and have visual air quality as an important resource for visitors. Of the 156 Class I Areas designated across the nation, 12 are located in Arizona.

From the Class I Area designations EPA initiated a nationally operated monitoring network in 1987 called the Interagency Monitoring of PROtected Visual Environments (IMPROVE) program. The original purpose of the IMPROVE network was to characterize broad regional trends and visibility conditions using monitoring data collected in or near Class I Areas across the United States. The IMPROVE network was made up of approximately 30 sites at Class I areas; during 1999 and 2000 the number of sites will increase to approximately 110, with 14 planned for Arizona. ADEQ selected these additional monitoring sites in or near Class I areas in the state in order to supplement the IMPROVE network. Arizona is a member of the IMPROVE Steering Committee.

The Arizona Class I visibility network consists of a combination of visibility monitor-

Monitoring is presently conducted, or is planned to begin in the immediate future at the following sites.

Grand Canyon National Park - Hance
Grand Canyon - Indian Garden
Petrified Forest National Park
Sycamore Canyon Wilderness - Camp Raymond
Mazatzal Wilderness - Humboldt Mountain
Mazatzal/Pine Mountain Wildernesses - Ike's Backbone
Sierra Ancha Wilderness - Pleasant Valley Ranger Station
Superstition Wilderness - Tonto National Monument
Superstition - Queen Valley
Saguaro National Park - West Unit;
Saguaro National Park - East Unit
Chiricahua National Monument - Entrance Station
Galiuro Wilderness - Muleshoe Ranch
Chiricahua Wilderness - Rucker Canyon

ing sites established by ADEQ and those established by the IMPROVE committee. Monitoring is presently conducted, or is planned to begin in the immediate future at the following sites: Grand Canyon National Park – Hance, Grand Canyon – Indian Garden, Petrified Forest National Park, Sycamore Canyon Wilderness – Camp Raymond, Mazatzal Wilderness – Humboldt Mountain, Mazatzal/Pine Mountain Wildernesses – Ike's Backbone, Sierra Ancha Wilderness – Pleasant Valley Ranger Station, Superstition Wilderness – Tonto National Monument, Superstition – Queen Valley, Saguaro National Park – West Unit, Saguaro National Park – East Unit, Chiricahua National Monument – Entrance Station, Galiuro Wilderness – Muleshoe Ranch and Chiricahua Wilderness – Rucker Canyon.

Urban Haze Networks

On behalf of ADEQ, contractors conducted detailed studies of the nature and causes of urban hazes in the Phoenix area during the winter of 1989-90 and in the Tucson area during the winter of 1992-93. Each of those studies recommended long-term, year-round visibility monitoring, and ADEQ deployed instruments starting in 1993. Visibility monitoring data from the Tucson and Phoenix long-term urban haze networks are needed to provide policy makers and the public with information, track short-term and long-term trends, assess source contributions to urban haze, and better evaluate the effectiveness of air pollution control strategies.

Because the urban haze networks conduct routine special filter sampling of PM composition and variation, the data from PM_{10} and $PM_{2.5}$ samplers operated in the urban haze networks enhance other, related air quality databases in several ways: by maintaining a greater density of PM sampling sites, and expanding the coverage of existing county air pollution control agency networks into perimeter areas of urban growth; by measuring the diurnal variation and chemical composition of PM on a year-round basis; and by obtaining comparable PM_{10} and $PM_{2.5}$ concentration data by standardizing the PM_{10} and $PM_{2.5}$ instrument types used throughout the state. The Phoenix and Tucson metropolitan area networks are similar as well as to the scope and scale of the networks operated by ADEQ contractors in the Phoenix and Tucson special studies. Some of these sites are existing air pollution monitoring locations, while other, new sites have been selected and installed. The networks include $PM_{2.5}$ federal reference method sampling that began operation in January 1999.

Photochemical Assessment Monitoring Station (PAMS) Monitoring

Section 182(c)(1) of the 1990 Clean Air Act Amendments (CAAA) required the Administrator to promulgate rules for the enhanced monitoring of ozone, oxides of nitrogen (NOx), and volatile organic compounds (VOC) to obtain more comprehensive and representative data on ozone air pollution. Immediately following the promulgation of such rules, the affected states were to commence actions necessary to adopt and implement a program to improve ambient monitoring activities and the monitoring of emissions of NOx and VOC. Each State Implementation Plan (SIP) for the affected areas must contain measures to implement the ambient monitoring of such air pollutants. The subsequent revisions to Title 40, Code of Federal Regulations, Part 58 (40 CFR 58) required states to establish Photochemical Assessment Monitoring Stations (PAMS) as part of their SIP monitoring networks in ozone nonattainment areas classified as serious, severe, or extreme. The principal reasons for requiring the collection of additional ambient air pollutant and meteorological data are the lack of attainment of the National Ambient Air Quality Standard (NAAQS) for ozone nationwide, and the need for a more comprehensive air quality database for ozone and its precursors.

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Enhanced ozone monitoring will provide an air quality database that will assist air pollution control agencies in evaluating, tracking the progress of and, if necessary, refining control strategies for attaining the ozone NAAQS. Ambient concentrations of ozone and ozone precursors will be used to make attainment/nonattainment decisions, aid in tracking VOC and NOx emission inventory reductions, better characterize the nature and extent of the ozone problem, and prepare air quality trends. In addition, data from the PAMS will provide an improved database for evaluating photochemical model performance, especially for future control strategy mid-course corrections as part of the continuing air quality management process. The data will be particularly useful to states in ensuring the implementation of the most cost effective regulatory controls.

The PAMS network array for an area should supply measurements, which will assist states in understanding and solving ozone nonattainment problems. EPA has determined that for the larger areas, the minimum network that will provide data sufficient to satisfy a number of important monitoring objectives should consist of five sites:

Type 1 Site - Upwind and background characterization

These sites are established to characterize upwind background and transported ozone and its precursor concentrations entering the area and will identify those areas that are subjected to overwhelming incoming transport of ozone. The Type 1 Sites are located in the predominant morning upwind direction from the local area of maximum precursor emissions and at a distance sufficient to obtain urban scale measure-

The PAMS network array for an area should supply measurements, which will assist states in understanding and solving ozone nonattainment problems. EPA has determined that for the larger areas, the minimum network that will provide data sufficient to satisfy a number of important monitoring objectives should consist of five sites

ments. Typically, these sites will be located near the upwind edge of the photochemical grid model domain.

Type 2a and 2b Sites: Maximum ozone precursor emissions impact

These sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions representative of the MSA/CMSA are expected to impact and are suited for the monitoring of urban air toxic pollutants. The Type 2 Sites are located immediately downwind (using the same morning wind direction as for locating Type 1 Sites) of the area of maximum precursor emissions and are typically placed near the downwind boundary of the central business district (CBD) or primary area of precursor emissions mix to obtain neighborhood scale measurements. Additionally, a second Type 2 Sites may be required depending on the size of the area, and should be placed in the second most predominant morning wind direction.

Type 3 Site: Maximum ozone concentration

These sites are intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions. Locations for Type 3 Sites should be chosen so that urban scale measurements are obtained. Typically, these sites are located 10 to 30 miles from the fringe of the urban area.

Type 4 Site: Extreme downwind monitoring

These sites are established to characterize the extreme downwind transported ozone and its precursor concentrations exiting the area and will identify those areas that are potentially contributing to overwhelming ozone transport into other areas. The Type 4 Sites are located in the predominant afternoon downwind direction from the local area of maximum precursor emissions at a distance sufficient to obtain urban scale measurements. Typically, these sites will be located near the downwind edge of the photochemical grid model domain.

The data collected at the PAMS sites include measurements of O3, NOx, a target list of VOCs including several carbonyls, as well as surface and upper air meteorology. Most PAMS sites measure 56 target hydrocarbons on either an hourly or three hour basis during the ozone season. The Type 2 Sites also collect data on three carbonyl compounds (formaldehyde, acetaldehyde, and acetone) every three hours during the ozone monitoring period. Included in the monitored VOC species are ten compounds classified as hazardous air pollutants (HAPs). All stations must measure O3, NOx, and surface meteorological parameters on an hourly basis. ADEQ has installed two PAMS monitoring sites to date; the JLG Supersite in central Phoenix (a Type 2 Site) and the Goldfield Ranch site in the far East Valley (a Type 3 Site). A time line describing proposed installation dates of additional sites is provided in Table I.4.

Annual Ambient Air Monitoring Network Review

ADEQ expanded the 1999 annual ambient air monitoring network review beyond the State and Local Air Monitoring Stations (SLAMS) to include all state networks. The Code of Federal Regulations (CFR), Title 40, Section 58.20(d), requires states to complete and submit to EPA an annual network review.

Table I.4. PAMS Installation Time Line

Type of PAMS	*Ozone Season*	*Proposed Installation*
Type 1	2001	Palo Verde – Wintersburg Area
Type 2	1999	Supersite – 17th Ave. and Campbell, Phoenix
Type 2a	2002	Rio Salado – Rio Salado Park Area
Type 3	2000	Goldfield Ranch – Saguaro/Apache Lake Area
Type 4	2003	Tonto – Tonto National Monument

At 40 CFR Part 58, states are required to establish air quality surveillance systems in their SIP. The air quality surveillance systems consist of various sites designated as SLAMS, National Air Monitoring Stations (NAMS) and Photochemical Assessment Monitoring Stations (PAMS). In order to provide a complete review of the air monitoring network, ADEQ chose to include additional stations classified as Special Purpose Monitoring Stations (SPM), which includes Urban Haze monitoring sites and IMPROVE sites, ADEQ visibility stations located in or near mandatory Class I areas, and source-oriented monitoring sites operated independently by the permittee.

The annual network review determines conformance with the requirements of 40 CFR Part 58, Appendix D (Network Design Criteria) and Appendix E (Probe and Path Siting Criteria) for sites classified as SLAMS, NAMS, PAMS and SPM. Class I monitoring sites are subject to specific siting and operational guidance developed by the IMPROVE Steering Committee. Results of the annual network review are used to determine how well the network is achieving its required air monitoring objectives, how well it meets data users needs, and how it should be modified (through termination of existing stations, relocation of stations, establishment of new stations, monitoring of additional parameters, and/or changes to the sampling schedule) in order to continue to meet its objectives and data needs. The main purpose of the review is to improve the network to ensure that it provides adequate, representative, and useful air quality data.

During 2000, ADEQ plans to develop monitoring plans for each ambient monitoring program (e.g. NAAQS, PAMS, Urban Haze, Class I Area Visibility) that will define specific program goals and objectives. The initial monitoring plans will utilize inventories and recommendations made in the annual network review. The monitoring plans will then go through a review every two to three years considering factors such as data results and completeness, site representativeness, and data representativeness. The monitoring plan review will also tabulate network review results accumulated over the prior three-year period and will recommend changes to the monitoring plans and instrument or operating requirements.

Monitoring Methods

The gaseous criteria pollutants, SO_2, O_3, NO_2, CO, and optical characteristics of the atmosphere (total light extinction, light absorption by gases, light scattering by particles, and light absorption by particles) are monitored with continuous analyzers that take approximately one pollutant sample per second.

The gaseous criteria pollutants, SO2, O3, NO2, CO, and optical characteristics of the atmosphere (total light extinction, light absorption by gases, light scattering by particles, and light absorption by particles) are monitored with continuous analyzers that take approximately one pollutant sample per second. These values are then averaged on an hourly basis, and recorded to the correct number of significant digits, based on the form of the air quality standards and the detection limits of the instrument. In most cases, the hourly data are summarized into the appropriate multi-hour averages. Regular checks of the stability, reproducibility, precision, and accuracy of these instruments are conducted by either the agency or company network operators. Precision and accuracy of ambient data are assessed across an entire network, using statistical tests required by EPA.

Particulate lead (Pb), PM_{10} and $PM_{2.5}$, are usually sampled for 24 hours, from midnight to midnight on every sixth day. Ambient air is drawn through an inlet of a specified design, at a known flow rate, using a calibrated timer, onto a filter that collects all PM less than a diameter specified by the inlet design. Pb, PM_{10}, and $PM_{2.5}$ samples are then processed in the same manner; the filters are weighed before and after the sample period to determine the difference in mass and then integrated with flow rate and timer data to arrive at a mass per unit volume concentration. In the case of Pb, the filter is then subjected to chemical analysis to determine the amount of Pb particulate and integrated with the flow rate and timer information to calculate the concentration. These data are then summarized into the appropriate quarterly or annual averages. These samplers are also certified as Federal Reference or Equivalent Methods. Regular checks of the stability, reproducibility, precision, and accuracy of the samplers and laboratory procedures are conducted by either the agency or company network operators. Again, precision and accuracy of ambient data are assessed across an entire network, using statistical tests required by EPA.

Visibility monitoring methods are generally divided into three groups: optical, scene, and aerosol (PM). Monitoring of visibility requires qualitative and quantitative information about the causes of haze (what is in the air, e.g., the formation, transport and deposition of pollutants), and the nature of haze (what are the optical effects of those pollutants to the observer). Optical monitoring is discussed above. Scene conditions of visual air quality associated with hazes are recorded with a color video camera, which utilizes a super-VHS format and is programmed to advance at the rate of one frame every four minutes during daylight hours. The video recording system is set to start just before sunrise, and to stop just after sunset, for each day. Scene information can also be obtained from 35 millimeter slides, taken at the same times each day, to establish baseline conditions, and track variation in haze.

In monitoring visibility it is also essential to collect and analyze particulate samples, to define and understand the chemistry of aerosols present before, during, and after haze events. The chemical speciation data can be used to determine the contributions of each source category to the observed optical haze data. From these filter data, the chemical components are used to calculate light extinction for the filter sample period and compared with continuous measurements as a check. Finally, the samplers used in the urban haze networks also monitor compliance with PM_{10} and $PM_{2.5}$ air quality standards, and provide information on the categorical source contributions to observed PM_{10} and $PM_{2.5}$ concentrations. Sampling frequency for PM in the urban networks is generally every sixth day, and every third day in the ADEQ and IMPROVE Class I Area networks. Sampling every day at all monitoring sites is cost prohibitive and very personnel intensive with current particulate sampling technologies.

To more fully understand the causes of hazes often associated with certain atmospheric conditions, it is necessary to monitor certain meteorological parameters. For these reasons, each network includes meteorological data such as temperature, relative humidity, wind speed and direction.

Finally, to more fully understand the causes of hazes often associated with certain atmospheric conditions, it is necessary to monitor certain meteorological parameters. For these reasons, each network includes meteorological data such as temperature, relative humidity, wind speed and direction. Routine measurements of upper air temperature and water vapor are not made in the Phoenix area but information from the twice daily rawinsonde launches by the National Weather Service at Tucson and Flagstaff as well as Las Vegas, NV and El Paso, TX are used to characterize the air masses over Arizona.