Section 1. Introduction

1.1 Background and objectives

Monitoring data are a critical part of the nation's air program infrastructure. The nations ambient air monitoring networks inform the public of air quality levels and exposure, establish the compliance status of cities and other areas, track air quality trends and evaluate progress of emission control programs, and support development of emission control and air quality research programs . Monitoring programs, which are operated largely by State and local agencies and Tribal nations, are subject to continual changes in local, state, tribal, federal and academic priorities. New and revised national ambient air quality standards (NAAQS) and other regulatory needs, changing air quality (e.g., general trend toward reduced concentrations of criteria pollutants), and an influx of scientific findings and technological advancements challenge the response capability of the nation's networks. The single-pollutant measuring approach commonly administered in networks is not an optimal design for recent integrated air quality management trends such as the linkages across ozone, fine particulate matter, regional haze, air toxics, and multi-media interactions (e.g., atmospheric deposition). Indeed, the current design of the nation's networks still is based largely on the existing monitoring regulations (Code of Federal Regulations, parts 53 and 58) that were developed in the late 1970's.

The United States spends well over $200 million annually on routine ambient air monitoring programs, and the incentives for growth in ambient monitoring activities generally are clear and compelling and based on scientific findings that lead to revision of air quality standards or identification of important measurement gaps. Less clear is the justification or incentive for divesting in existing monitoring programs. Monitoring programs appear to suffer from inertia once established, and conscious downsizing efforts occur with far less frequency than recent program enhancements (e.g., PAMS, $PM_{2.5}$, air toxics). Stability in networks is a positive attribute, as considerable time spans (decadal length) often are required to detect and interpret important air quality trends. This strategy seeks to achieve an appropriate balance between needed stability and a desired improvement in response capability to scientific finding and emerging priorities. Assuming limited, at best, resource growth in monitoring programs, serious efforts must be devoted to optimizing resources to meet evolving monitoring challenges. The aggregation of so many technical, institutional, and resource issues form the backdrop for an ambient air monitoring strategy.

The goal of the strategy is to manage the nation's air monitoring networks in a manner that addresses the most pressing public health issues, optimizes efficiency, and accommodates future needs, all within the constraints of the available funding. This framework requires progress on various objectives that shape the monitoring networks, including:

1. Establishing a new air monitoring paradigm coupling a minimum level of required national monitoring with flexible state/local/tribal air monitoring networks in order to efficiently and effectively meet both national and state/local/tribal needs.

2. Providing a greater degree of timely (e.g., real-time) public air quality information, including the mapping of air pollution data, and air quality forecasts.

3. Promoting network efficiencies through the reevaluation of regulations and quality assurance procedures.

4. Fostering the utilization of new measurement method technologies.

5. Providing a mechanism for the periodic assessment, from both a national and local/regional perspective, of all air monitoring activities to help ensure the relevance and efficiency of the network. (This mechanism should provide appropriate flexibility to disinvest in monitoring activities should changing priorities so warrant.)

6. Encouraging multi-pollutant measurements, where appropriate, for better air quality management and scientific/health-based data sets.

7. Providing a base air monitoring structure which, in conjunction with special studies (not part of this strategy), could be used to support certain regulatory needs, e.g., SIP development, source apportionment, operational model evaluation, and tracking progress of emissions reduction strategies.

8. Developing and implementing a major public information and outreach program as an important cornerstone toward network changes.

9. Seeking input from the scientific community as to the merit/value of proposed changes.

10. Providing air monitoring platforms and data bases which can be used for other environmental purposes, such as area-based ecosystem assessments, global issues, diagnostic research, and biological sensing.

11. Assessing, periodically, funding levels needed to maintain support for this monitoring strategy, and incorporate recommendations into the budget planning process.

1.2 Scope

This strategy is focused largely on networks administered through the section 103 and 105 Federal Grants programs to State, local agency and Tribal nations, as well as related monitoring conducted by these organizations. These networks commonly are referred to as the National Air Monitoring Stations (NAMS), State and Local Air Monitoring Stations (SLAMS) and Photochemical Air Monitoring Stations (PAMS), as well as IMPROVE. This strategy recognizes the leveraging value of a spectrum of other air monitoring efforts, including intensive research oriented studies (NARSTO, PM2.5 Supersites, CRPAQS, PM health centers), deposition monitoring (CASTNET, IADN, NADP)

and numerous efforts conducted outside the scope of Section 103 and 105 Federal Grant programs. This admittedly "grey" description of the scope is intended to provide focus and accommodate a tractable product among those parties most closely associated with administering and operating the more routine regulatory based networks, and at the same time consider the value added of related monitoring efforts to assist in
identifying weaknesses and strengths in the nation's monitoring networks. The apparent limited scope also recognizes peripheral strategic efforts underway such as the air toxics monitoring pilot studies and data analyses projects and the PBT monitoring strategy. These efforts must be coordinated within this national strategy. One can view this current focus on the S/L/T networks as an initial stage that will be succeeded by a more inclusive assessment. Additional discussion on this broader integration is covered in Section 4.

In addition, these objectives are designed to focus on more streamlined networks with the understanding that considerable flexibility (a key operating principle of the strategy) must be provided to these Grantees to address air quality issues that can not be resolved through broad based national approaches. This strategy seeks to foster a balanced operating process that accommodates national and local level monitoring needs.

1.3 Operating Principles

What Are the Key Operating Principles that will be Followed in the Implementation of a Monitoring Strategy?

Guiding the planning process are a handful of basic principles to be adhered to throughout all monitoring strategy implementation steps. These principles emphasize the active use of data and assessments, strong interactive communications and incorporation of scientific advancements.

1. Partnership: EPA, State, local agencies and Tribes will jointly lead the planning effort underlying this strategy.

2. Flexibility by balancing national and local needs. Network design, divestment, and investment decisions must achieve a balance between prescription (consistency) and flexibility to accommodate national and local monitoring objectives, respectively. We must recognize that localized issues are "national" issues, and nationally consistent data bases serve local (State/Tribe/local agency) interests as well. A national strategy is enhanced by incorporating flexible processes to accommodate a spectrum of local and national objectives. Flexible principles must also be extended to reaching a balance between retaining valued stable network elements and introducing new elements that respond to new priorities.

3. Institutionalize Network assessments. While this document incorporates results of broad based assessment of networks, assessments, especially at the regional level, should be performed on a regular basis to ensure the relevancy and stability of network operations.

4. Demonstrate the value of data. Data should be collected only following defined plans for its use, an associated commitment to objective analysis, and an understanding that collection of data determined to be valueless should be discontinued. A realistic understanding of data usage and patience must be exercised, recognizing that beneficial returns often require several years (e.g., identifying trends) of data collection. Implicit is the understanding that challenges to data usefulness must be answered at a minimum with a defined set of analysis plans and commitments. Clearly, if data do not undergo analysis, or plans for doing so are not available, one can only assume that the data have little or no value.

5. Optimization through integration. Monitoring programs often are administered on a program by program basis, an approach that does not foster active information flow across monitoring components or the development of truly complementary networks. The administration of programs should be in step with our understanding of the scientific and logistical linkages across programs. For example, the developing air toxics program should be considered an integration of existing programs (e.g., PAMS, PM2.5, Sate/local networks) combined with new initiatives. A wealth of complementary monitoring is performed by other federal agencies (and other EPA programs) that support air quality program objectives and, in turn, benefit from the traditional program. Furthermore, several scientific disciplines (health effects, atmospheric processes

6. Effective interfacing with "science." An emphasis should be placed on more active engagement with the scientific community, and its products, recognizing the important role science plays in network design and technology and the role of networks in assisting scientific research. The perspective that a clear demarcation exists between science oriented and agency based monitoring is counterproductive to optimizing the collective value of research and air monitoring. A major cultural change that should be institutionalized is embracing the scientific community as a partner in planning and advice, as opposed to a limited role of critical review.

7. Minimize adverse program impacts. This strategy should maintain integrity of existing agency monitoring programs by emphasizing shifts in programmatic areas (e.g., PAMS to toxics, PM10 to PM coarse/toxics, etc.) and, if necessary, phase in gradual reductions in programs.

1.4 Overview of Strategic process and components.

How do all the elements tie together?

The remainder of this document addresses several operational components of the monitoring strategy. These components include:

Establishing Network objectives and priorities (Section 2)

Network Assessments (Section3)

National Network design (Section 4)

Quality Assurance review (Section 5)

Technology to deliver data (Section 6)

Monitoring methods (Section 7)

Monitoring regulations (Section 8)

Communications (Section 9)

Resources implications (Section10)

Most of these components are integrated and often co-dependent on each other as depicted in Figure 1. The basic operating principles (Section 1.2) establish important constraints. First, as a partnership among EPA and States and Tribes, considerable flexibility must be adopted in network design concepts to simultaneously recognize the need for nationally consistent data collection approaches concurrent with tailored localized programs. While certain components of the strategy can be defined as EPA or State/local/Tribe products, the development of all components benefits from input and counsel across all parties. An agreement in principle that establishes a resource balance (detailed in Section 4) to support nationally "consistent" and "local/regional" discretionary needs enables a diverse group of stakeholders to focus on a streamlined and consistent core national network design (Section 4), along with more localized networks for States, local agencies and Tribes. Second, the expectation of limited or negligible resource growth demands that the entire system be optimized and the current networks be assessed for redundant or low value sites to remove some of the existing burden to allow for a shift to identified priorities that are not being met. The national and regional assessments (Section 3) are conducted to provide broad national targets for reducing the criteria pollutant networks to redirect monitoring resources to stimulate growth in priority areas defined by the strategy (Section 2). [*For example, expanded continuous PM sampling is a priority to meet future public information needs for air quality index reporting and mapping of PM. The logical resource pool for this activity is the current PM2.5 monitoring budget, where the majority of burden addresses filter based FRM sampling. An assessment of the FRM network should uncover opportunities for reduction (following three years of data collection) to accommodate a shift toward more continuous sampling.*]

The move toward continuous PM sampling will only be effective with accompanying technical direction, information transfer technology and quality assurance (sections 5-7) that describes network

design objectives and performance specifications for continuous monitors needed to develop confidence in the linkage between established FRMs and continuous technology. Improvements in information management and transfer that emphasize remote data access and satellite support systems are needed as the motivation for increasing capacity for continuous PM monitoring is based on near real time data supply to the public. Investments in automated systems are recommended as a longer term solution to increasing efficiency of monitoring operations. In turn, the assessment results regarding the number of PM FRMs may require modifications of CFR part 58 (section 8) which established fairly rigid targets for FRM samplers. Note that the assessments only start with the national effort which are suggested to conducted every 5 years. Ongoing and future regional/local based assessments need to be institutionalized and conducted periodically (e.g., every 2 years) to ensure that the networks are not static and are producing relevant and valued information. Consequently, any modifications in regulations must incorporate sufficient flexibility to accommodate future findings from assessment efforts. Results from the assessment and design activities will require changes in EPA Grant guidance and other tools such as Regional Office Memoranda of Understandings (MOUs), in addition to potential changes in monitoring regulations.

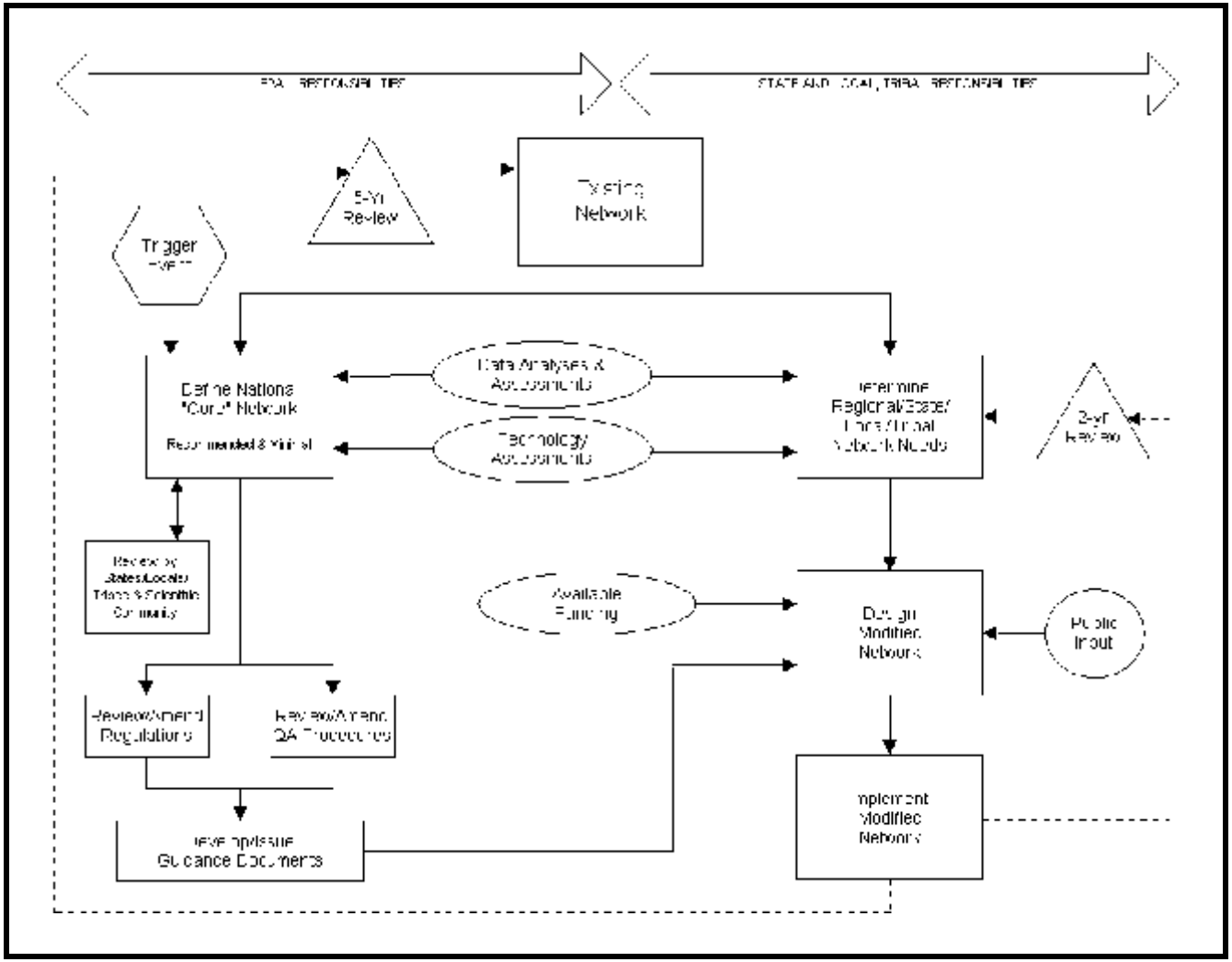

Figure 1. Information flow and integration across strategy elements indicating influence on networks.

Committee structure and Guidance

The generation of findings and recommendations within this document was guided by the National Monitoring Strategy Committee (NMSC..Attachment 1) a group of representatives from EPA, State/local agencies and Tribal nations. The NMSC provided overall direction for this strategy through a series of monthly conference calls and quarterly meeting throughout 2001 and 2002. Five technical workgroups also were established to probe more deeply into specific components of the strategy:

Two ad-hoc workgroups

1. Network Assessment workgroup (technical staff from States and EPA and Tribes to review national assessment results; culminated in July, 2001 workshop).

2. National Network design workgroup (a small subset of NMSC members developing details on proposed National Core network (NCore)..still operating.

Three formal workgroups (mix of staff from EPA, State, Locals and Tribes). These groups all met at part of major air monitoring strategy meeting in October, 2001 and are developing specific proposals on:

3. Regulatory review workgroup (developing modifications to part 58 monitoring regulations including changes in required number of criteria pollutant sites).

4. Quality Assurance workgroup (developing modifications and recommendations for improved approaches and consistency in quality assurance programs).

5. Technology (developing recommendations for accelerating dissemination of air quality data, and providing review of EPA's continuous PM implementation plan)

Two peripheral groups are linked to the strategy development.

Air Toxics Monitoring Steering Committee

A group of mostly NMSC members focusing on specific development of an air toxics monitoring program and using the overlap responsibilities to ensure integration with the National monitoring strategy.

Clean Air Scientific Advisory Committee Particulate Matter Monitoring Subcommittee

This group has been advising EPA on all aspects of PM monitoring. Over the last year an emphasis has been placed on implementing PM continuous monitoring which is a major operational element of this overall strategy.

1.5 Schedule

2001

National level network assessments and development of spatial optimization and network design tools (national assessment completed September, spatial design workshop December)
NMSC meetings and strategy development
Initial findings and status presented to STAPPA/ALAPCO (October)
Workgroup specific meetings on regulations, technology and QA
Development of continuous Implementation plan
First phase of first Regional area network assessment (LADCO/Region 5)
Draft number 1 of strategy document (October)

2002

Conceptual design for National Core network (NCore) (February)
Draft number 2 of strategy document (February)
Proposed modifications to regulations (October)
Establish CASAC subcommittee for NCore review (March)
NMSC meeting on NCore (March
NCore proposal (June)
Draft regional level assessments completed (November)

2003-2007

Implementation period

Section 2. Network Objectives, Priorities, and Design

[note to NMSC: this section was developed in June, 2001. There still exists some slight inconsistencies with the more recent (preferred) description of objectives described under NCore (section 4). Modifications will be made at a later date.]

Section 2.1 Network Objectives.

What are the objectives and priorities of the nations's ambient air monitoring networks?

The national monitoring strategy requires a clearly defined set of network objectives as a foundation for assessing current networks, establishing monitoring priorities, and to articulate a vision for future direction. These objectives are more focused on the actual use of ambient data, in contrast to the wide spectrum of objectives associated with the monitoring strategy covered in Section 1. Monitoring data provide value to air quality planning, the public and other clients such as the research, academic and industrial communities. This section describes a basic set of objective categories covering these basic needs and assigns relative priorities that indicate directions for network investment and divestment.

Objectives

Ambient data from the regulatory based networks administered through 105 and 103 are address a variety of air quality program needs that include:

- **Compliance:** Comparing air quality data to NAAQS or other benchmarks which drive regulatory actions.

- **Public awareness/population exposure**: Data to support the air quality index (AQI) and AIRNow, and population risk and exposure assessments.

- **Detecting air quality trends and evaluating progress of emissions reduction programs**: Data to detect long term air quality trends and to capture measurable ambient impacts (including emissions precursors and secondarily formed pollutants) associated with emissions reduction programs.

- **Emission strategy development**: Data to support construction of emission reduction programs (e.g., through source apportionment methods, evaluation of air quality models and emission inventories) in support of State Implementation Plans (SIPs), air toxics and environmental welfare/secondary effects programs (e.g., visibility impairment, watershed degradation). Note: This objective although similar is delineated from

objective number 3 as the types of monitoring approaches often are specific to the tool (e.g., model) being applied and in many instances emphasis is put on a short term (up to one year) period of data collection to support model application, whereas trends and program evaluation almost always demand a long term data record.

- **Research**: Data to assist research programs (e.g., develop associations between measurements and adverse health indicators, describe physical/chemical atmospheric processes). Note: Research support is not a primary objective of the nation's regulatory networks. However, the regulatory networks provide an important infrastructure that often is leveraged with other research resources that benefit air quality research and eventually regulatory programs.

Data are utilized in a variety of ways to support the objectives listed above, and several examples are provided in Table 1 to clarify the relationship of these objectives to actual data applications.

Table 1. Listing of common ambient air quality data uses associated major program objectives.
Obj 1. Comparisons with NAAQS and regional haze regulations.
Comparison with National Ambient Air Quality Standards to determine attainment/nonattainment status.
Establishing baseline and progress measures as required by regional haze regulations.
Obj 2. Public information and exposure
Public Information services, for example, reporting timely air quality data to the public (often through air quality indices) with vehicles like AIRNOW, news and weather services, and forecasting (in concert with predicted meteorology) expected high pollution events to warn the public.
Providing data base to associate possible risks related to health benchmarks for hazardous air pollutants and other metrics.
Providing data in response to Environmental Justice and related issues.
Evaluating air quality simulation models that predict concentration fields from emissions, meteorology and chemical/physical process formulations. The predicted concentration fields, in turn, drive exposure models which estimate personal exposure to specific air pollutants. Further, exposure modeling results support risk characterization (e.g., carcinogenic, cardio-pulmonary effects, etc.) of specific populations. In addition, all of the source apportionment and model system related data uses (defining background, transport, EI evaluation) described under objective 2 are applicable.
Obj 3. Trends and emissions reduction program evaluation.
Compiling trends or related information of primary pollutant and precursor species to track progress of emissions reduction strategy implementation. Various data analyses are applied ranging from general trends characterization to exercising observation and emission based models all with the general objective to address the basic question, "Have emission reduction measures been implemented as originally designed, are they effective, and what mid-course corrective steps, if any, are needed?" These applications are responsive to is sues of "accountability" raised in the recent NARSTO (North American Research Strategy for Tropospheric Ozone) critical review, and the related commentary on shortcomings in the SIP process articulated in the National Academy of Sciences (NAS) 1991 report, ***Rethinking the Ozone Problem in Urban and Regional Air Pollution***. Such uses are not limited to criteria pollutants. For example, the IMPROVE network will be utilized as the core indicator to determine effectiveness of regional haze mitigation efforts.

Meeting permitting requirements to ensure maintenance and /or progress toward prescribed impact effects
Measuring important visibility impairing species to measure progress in regional haze.
State of Environment Reports which compile criteria pollutant levels and longer term trends in quarterly in yearly (and longer) data summary reports produced by State agencies, IMPROVE, and EPA's annual Trends Report.
Obj 4. Development of emission reduction strategies.
Supporting source-apportionment and other observational based models that largely are driven by ambient data.
Evaluating air quality simulation models that predict concentration fields from emissions, meteorology and chemical/physical process formulations. The air quality model is used explicitly to develop emission control scenarios.
Defining background, regional and transported levels of pollutants that are used to delineate urban and regional pollutant signals, and to develop boundary conditions for air quality simulation models.
Evaluating emission inventories by comparing predicted emissions data with observed concentrations .
To assist in multi-media environmental impact assessments where air concentrations impact watersheds, water bodies, estuaries, soils, etc. Typically, air concentrations are required to estimate deposition loadings into other media as direct inputs into watershed/water quality models that characterize environmental conditions of those media.
Obj 5. Assist research and technical activities in atmospheric science, measurement science, health and environmental effects and exposure.
Testing and evaluation of advanced sampling methods. The phasing of new methods into routine monitoring practices has accelerated due to the rapid pace of technological development and increasing demands and new initiatives placed on the monitoring community. Examples where State and local agencies have been and will be actively engaged in methods testing include the use of continuous gas chromatographs and carbonyl sampling in the PAMS program, the early 1999 start-up period of $PM_{2.5}$ Federal Reference Methods, and the $PM_{2.5}$ speciation sampling program. While programs such as the PM Supersites are intended to assist in transitioning advanced methods to routine applications, the monitoring burden on State and local agencies has increased substantially.

Health effects research support. Although the principal objectives for most air quality data are covered in 1 -3, above, the data simultaneously can support research programs with different objectives. For example, the $PM_{2.5}$ speciation program is designed to address objectives1 and 2; however, modest refinements such as the inclusion of 10 daily sites provide potentially valuable support toward investigating the relationships of exposed populations to specific aerosol components. The more routine data bases such as the 1000 plus $PM_{2.5}$ FRM network provides a potential wealth of information toward continuing investigations associating adverse health impacts and fine mass.
Human Exposure Research Support. Core microenvironment and inhalation data collected in personal exposure research studies is a research activity beyond the scope of routine networks. However, the routine ambient data supplied by networks and other programs (e.g., Supersites, major field studies) provides a critical link from actual exposure through the atmosphere and back to original sources.
Model development and atmospheric process characterization support. Initial testing for developmental models and applied research model efforts require research grade measurements typically beyond the scope of routine programs. By themselves, research grade measurements are not capable of diagnosing model and atmospheric process behavior. The routine data provided by regulatory networks offer an infrastructure of data for advanced model applications which in combination with more advanced measurements offer the potential for comprehensive diagnostic evaluation data sets.

2.1.1 Relationship to existing Section 58 monitoring regulations.

The existing monitoring regulations list a set of objective categories located in the Code of Federal Regulations (CFR) 40 part 58, Appendix D for the State and Local Area Monitoring Stations (SLAMS), of which the National Air Monitoring Stations (NAMS) are considered a subset:

- determine highest concentrations
- determine representative concentrations
- determine impact on ambient levels due to emission sources
- determine regional transport
- determine welfare-related impacts in rural areas

In addition, the CFR lists several objectives for the Photochemical Assessment Stations (PAMS):

- NAAQS attainment and control strategy development
- SIP control strategy evaluation
- Emissions tracking
- Trends
- identifying airshed boundary concentrations
- air quality model evaluation
- ozone and air toxics exposure

These objectives for the combined NAMS/SLAMS/PAMS networks are consistent with those articulated above, illustrating stability and confirmation in the basic uses and purposes of monitoring data. Although consistencies exist between the objectives stated in Section 1.2.1 and the regulations, the revised objectives provide a more tractable and realistic group of expectations that incorporate more recent thinking on monitoring science.

2.2 What are the priorities for current and future networks?

A goal of the strategy is to take account of the current and anticipated needs that are not addressed in existing networks, and assign relative priorities across pollutant and objective categories. Monitoring priorities change over time due to scientific findings and direction from Congressional[1] and EPA Leadership. Current national monitoring program priorities include $PM_{2.5}$ and ozone (including PAMS), based on known and anticipated non-attainment areas. Air toxics is emerging as a national program priority and represents one of several challenges facing the monitoring community. Other priorities of a more localized nature include, for example, responding to public complaints, other criteria pollutant concerns (e.g., CO, SO_2), and specific source-receptor characterization needs. This

monitoring strategy is designed to produce a system capable of responding to an evolution of changing program priorities.

The NMSC has identified three general priority areas for future investment. These areas include:

1. Integrated multi-pollutant approaches to air quality monitoring in support of integrated air quality management;

2. Continuous monitoring technology, especially for particulate matter, to provide timely data to the public, and

3. Non criteria pollutant monitoring for hazardous air pollutants (HAPs)

A more pollutant specific approach for identifying priorities that help shape subsequent network assessment and design work was followed by the NMSC. Columns 2-5 in Table 2 provide a listing of general objectives cross referenced by pollutant network. Each objective approached on a single pollutant basis was assigned a relative ranking of high, medium or low with the perspective limited to the relative importance for that specified network. For example, a high weighting for lead monitoring to support compliance signifies the relative importance of meeting this objective in relation to the other four objectives for lead. That high weighting does not reflect an overall priority for lead within the more holistic view of all networks. Column 6 provides an estimate from 1 - 10 of the relative data availability on a national scale and attempts to identify those measurements that are viewed as being extremely scarce (1) to overly abundant (10), and partially supports priority setting across networks in column 7. The priority of a specific network in relation to other networks based on the NMSC's perspective is presented as a sliding scale of 1 - 10 with 1 indicating strongest need for investment. Note that these priorities share some resemblance to the data availability designations in column 6, yet the priorities also consider the NMSC's perspective on what area's regulatory monitoring should engage in. Thus, the NMSC recognizes the shortage of certain process or research oriented measurements, but assumes such activities are beyond the common scope of routine monitoring and rank lower relative to other measurements from an investment perspective. The investment/divestment rankings also do not strictly reflect "importance" as they consider both data availability (column 6) and importance. For example, ozone measurements may be just as/or more important than toxics, however the low data availability and resources in toxics elevate the need for investment.

Table 2. Network Objectives and relative investment priorities across pollutant programs.							
	Compliance with respect to NAAQS or haze regs.	**Exposure /AQI**	**Trends and emissions reduction evaluation**	**Emissions strategy development**	**Research support**	**Data[1] availability /need 1 - 10 3=minimum acceptable 5=desired**	**Priority for investment and divestment 1 - invest 10 - divest** (generally not applicable to Tribes)
	Values H, M, L reflect relative importance of each objective within given network, and do not signify relative priority across networks					note:	
Ozone and related species							
ozone	H	H	H	H	M	5	5
PAMS: O3 precursors (N)	L	L	H	H	M	7	7
PAMS: O3 precursors (VOC)	L	L	H	H	M	7	8
T high sens	L	L	M	M	M	1	4.5
T NOy	L	L	H	H	H	1	4
T chemical process parameters (NO2, H2O2, OH)	L	L	L	H	H	1	5
PM and related precursors							
PM2.5 FRM	H	M	H	M	M	8	8
PM cont. mass	M	H	H	H	H	2	3
PM2.5 spec	L	M	H	H	H	5	5
PM10 mass	M	M	H	M	L	8	8
T PM coarse	L	M	L	L	H	1	4
T PM size dist.	L	L	L	M	H	1	5

Table 2. Network Objectives and relative investment priorities across pollutant programs.							
T PM 2.5 precursor HNO3, NH3, SO2	L	L	M	H	H	1	6
Remaining criteria pollutants							
regulatory CO	H	L	M	L	L	8	9
reg NO2(NO)	H	L	L	L	L	9	9
reg SO2	H	M	L	L	L	8	9
Pb	H	L	L	L	L	8	9
Toxics							
T volatile	L	H	H	M	H	2	2
T SVOCs	L	H	H	M	H	2	2
T metals	L	H	H	M*	H	2	2
T PBTs	L	H	H	M	H	2	2
Miscellaneous							
Acid/N deposition (CASTNET)	L	L	H	M	M	5	5
visibility (camera)	H	M	H	M	L	5	5
meteorology	L	L	L	H	H	5	5
1 low values a perceived shortage of data **2 low values indicate a recommendation to invest based on a perceived shortage of data and appropriateness for "routine" networks** **notes: T yet to be developed or preliminary stage** *** rated H for mercury**							

Section 3. Network Assessments

This section includes an overview of the assessment process and National assessment results (Section 3.1 and Attachment 1), role of regional assessments (3.2) including a guidance package of tools for Regional level assessments (Attachment 2) and a draft version of the LADCO/Region 5 monitoring strategy (Attachment 3) that serves as a leading example for other assessments.

3.1 Role of assessments and National Assessment results

Results of the National ambient monitoring network assessment that was conducted as a key component of the national ambient air monitoring strategy are summarized. The national assessment was motivated by an understanding that certain aspects of the national networks largely had served their original purpose and were not optimally designed to meet current and emerging monitoring needs (e.g., continuous particulate matter and air toxics). The objectives for this assessment were twofold: first, to produce an objective evaluation of the relative value of current monitoring sites to identify broad national targets in terms of monitoring sites that could be discontinued in order to free resources to invest in new monitoring programs and second, provide a catalyst for more refined regional and local analyses that are needed to implement actual site based changes in the network and generate consensus for priority investment areas in other monitoring programs. This assessment represents the first objective comprehensive evaluation covering the majority of the nations regulatory ambient air monitoring stations operated largely by State and local agencies. All criteria pollutant networks including ozone, carbon dioxide, sulfur dioxide, nitrogen dioxide, lead, PM10, and PM2.5 were addressed in this study. The other major ambient monitoring program operated by State and local agencies, Photochemical Assessment Measurements Stations (PAMS) networks, is undergoing a parallel assessment which will be integrated with the results of criteria pollutant network assessment as part of the air monitoring strategy. Additional background regarding the national air monitoring strategy can be located at ***http://www.epa.gov/ttn/amtic/monitor.html***.

Methods

The assessment approach incorporated a combination of objective and subjective elements that were based on methodology developed by Washington University (Husar, 2000) and complemented by an ad-hoc assessment workgroup that developed a protocol (Attachment 1) and provided ongoing advice related to measures and objectives considered in the array of assessment analyses. Details regarding the method are found in ***http://www.epa.gov/ttn/amtic/monitor.html*** under *Preliminary outputs from the National Network Assessment Introduction and Explanation-File #1*. The analytical approach consisted of developing five independent measures that could be grouped to reflect the ability of a given monitoring site to meet a specified monitoring objective. The measures included:

1. Concentration
2. Spatial representation
3. Population
4. Measurement uncertainty

5. Deviation from the NAAQS

All monitoring data were ranked from highest to lowest according to these measures and aggregated in spreadsheets to allow for post processing. Data were grouped by concentration as they relate to the NAAQS (Table 1...Assessment details...). The post processing involved direct graphical displays of quartile groups for each measure on a pollutant-by-pollutant basis, and grouping of measures with variable weighting schemes (Table 2) to represent more specific monitoring objectives. The selection and weighting of these measures was documented in the protocol (Attachment 1) and refined over a series of conference calls with members of the assessment workgroup (Attachment 2). Each monitoring site for a given criteria pollutant was ranked across all monitoring sites and graphically displayed (Attachment 3) in quartiles where the upper 25% (color red) represented most important locations for the measure considered (e.g., highest 25% concentrations, 25% sites with greatest uncertainty, most populated sites) and the lower 25% (color blue) represented the least important sites based on the particular measure. Summaries of the quartile results are provided for each EPA region. In addition, the recent 5 and 10 year trend directions (up, down, not significant) for each pollutant are provided to complement the group of measures used in the assessment.

Table 2. Weighting schemes and objectives.

	Concentration	Uncertainty	Deviation from NAAQS	Area	Population
W1: equal weights	20%	20%	20%	20%	20%
W2: NAAQS Compliance	30%	30%	30%	5%	5%
W3: exposure/AQI	30%	5%	5%	30%	30%
W4: ?	50%	50%	0	0	0
W5: emissions tracking/model evaluation	20%	40%	0	40%	0

Role of the NMSC. Any combination of measures and weights can be applied to the ranked data. The weighting schemes are based on input from the assessment workgroup that were believed to reflect general objectives developed by the NMSC. The particular grouping and weighting of measures is a subjective process that requires input from the NMSC. What combinations of measures and weights that reflect the recommendations of the NMSC? Note, that any combinations of measures can be aggregated as a simple post processing exercise.

Role of EPA Regional Offices and S/L agencies and Tribes. All EPA regional offices, in conjunction with the states, tribes, and any multi-state organizations in that region, should undertake a regional/local assessment to complement this national assessment. These

regional/local assessments should be delivered to OAQPS by 9/1/02 and should include an interpretation of this national assessment as it affects their region, and proposed regional network modifications that are either consistent with this assessment or reflect more refined assessments conducted for their region. In the absence of a regional/local assessment for a given region, OAQPS may need to rely on the results of the national assessment (and, perhaps, the results of other regional/local assessments) to develop proposed network modifications for that region.

Role of EPA

The regional/local scale assessment work is not likely to address the ability of networks to characterize broad regional/national scale issues. Examples include background concentration levels and transport characterization. EPA should identify the monitoring required to meet larger scale "national" needs to ensure adequacy of monitoring and reduce the risk of removing "valuable " monitors that are undervalued from a local perspective. EPA will coordinate this design activity as part of the National Monitoring Strategy.

Summary of Results

A complete compilation of results can be located in ***http://www.epa.gov/ttn/amtic/monitor.html*** under *Preliminary outputs from the National Network Assessment Results Files #1 and #2*. This section provides a brief overview and interpretation based on those results. The results file #1 provides national maps on a pollutant-by-pollutant basis addressing each measure individually. These results are simply graphical summaries of the ranked data taken directly from the data base (***http://www.epa.gov/ttn/amtic/monitor.html*** under *Preliminary outputs from the National Network Assessment Pollutant site files in Excel format*). The results file number #2 includes mappings of the combined measures as well as additional analyses illustrating trends patterns and maps depicting sites relative to the NAAQS levels.

Caveats

It is important to remember the limitations of this national top-down analysis. As noted earlier, from a procedural perspective the national assessment must be complemented by more refined local and regional assessments to derive input form stakeholders and produce site-specific recommendations. From a technical perspective, the national top-down approach works well for certain pollutants and/or objectives, but falls short in other areas. For example, evaluating the "value" of ozone monitors located in New Jersey with Washington State monitors (and many other examples) can create an impression where ozone monitoring is only useful in high concentration regions of the country. A better approach is to review the ozone network of the Northwest and rank the value of ozone stations within particular regions where regional differences in setting the priority of monitoring objectives are expected. The national assessment is severely compromised by not considering site specific spatial scales of representation. In attempting to illustrate value of monitoring sites for model evaluation and related needs, weighting scheme W5 (Table 2) emphasized those sites located in rural or isolated urban areas with the implicit assumption that such sites represent broad spatial areas. While

this approach may work well for PM2.5 and perhaps ozone, the approach is compromised for CO and PM10 which often are sited to capture maximum local scale impacts. Again, important details simply are not captured in a broad national analysis and misleading conclusions at the site can easily occur. Sites with high concentrations generally tend to be weighted very high, a result that mistakenly could imply a lack of importance for background and related monitoring sites.

General Interpretations [Figures located in powerpoint file titled assessfigures.ppt]

Clearly, two criteria pollutants, ozone and PM2.5, dominate the nation's air quality with respect to elevated concentrations. This conclusion is reflected in the NAAQS proportion maps (Figures 1-7) When considering the suite of maps presenting quartile breakouts, one must consider that the top 25% of PM10 sites are not as valued as the top 25% ozone sites, and this logic filters through the remaining quartiles as well. These results reinforce our general understanding of the surplus of monitoring sites for criteria pollutants for which substantial progress has been achieved in reducing concentrations of CO, SO2, NO2, Pb and PM10 over the last 20 years.

Considerable attention must be paid to both the ozone and PM2.5 results due to a variety of policy and technical complexities. These results attempt to view the relative value of monitoring sites based on objective criteria that largely are decoupled from existing or future constraints due to policy considerations. For example, an ozone site rated "low" value due to some combination of measures may not be a viable candidate for removal due to established agreements requiring a monitor in a certain county, or to track a record of continued non exceedance readings to meet maintenance plan or related SIP requirements. The PM2.5 network presents a unique case where the network has just been deployed and already discussions on major modifications are taking place. The motivation for change is based on several factors including recommendations from the research community to emphasize continuous PM measurements and State and local agencies requests to reduce operational burden associated with filter based measurements. The generally observed homogeneous behavior over space and time of PM2.5 levels in broad regions of the East and Midwest suggests the network can absorb site reductions with little risk in compromising the ability to meet network data use objectives, especially with a subsequent introduction of continuous PM instruments that produce acceptable data quality.

Ozone

From a national perspective, a minor reduction of in the number of ozone sites (e.g., from urban clusters) is recommended. This reduction in the current network would not compromise our ability to address NAAQS compliance, provide input for public reporting needs (AQI, AIRNOW) or assess effectiveness of emissions control programs, including evaluation of air quality models. All of these objectives would be better served by using any resource gains from such a reduction to position ozone monitors in areas with current "high"

measurement uncertainties, locations typically outside the existing MSA of interest. The relocation should be guided by considering results of interpolated error regimes (e.g., Figure 12), air quality model output indicating expected spatial gradients and the collective knowledge of local monitoring experts that can address the logistics of site procurement and operation. Ozone assessments were performed on both 1- and 8-hour averaging periods, as well on two data bases, 1995-1997 and 1998-2000 to address policy issues associated with the both NAAQS. Obviously, the form of the NAAQS greatly impacts an interpretation of ozone compliance across the country, as the 8-hr NAAQS extends exceedance locations beyond the classic urban corridors observed for 1-hr NAAQS in the Northeast, Southwest (LA, Houston, Dallas) and Chicago (Figure 8) to broad regions throughout the East, midwest and California (Figure 1). Obviously, modifications of the ozone network must be conducted with caution given the broad spatial extent of elevated ozone levels nationally. Nevertheless, examination of the assessment results suggests areas for optimization within the ozone network which was established in large part to address the 1-hr NAAQS which resulted in a network strongly emphasizing clustering of urban sites. The newer 8-hr standard suggest that rural/regional locations take on more "relative" importance than that associated with the one hour NAAQS. In addition, an enormous body of scientific evidence and associated advice (NRC, 1991; NARSTO, 2000) as well as movement of populations away from urban centers to expanding suburbs and rural locations supports an increased emphasis on rural/regional ozone monitoring. The southeastern U.S. includes several upward moving ozone 8-hr trends over the last 10 years (Figure 9), consistent with population growth across the south. All major metropolitan areas with clustered ozone sites should consider removing those sites that provide only minimal relative value compared to other sites in the cluster. Examples include Chicago, major Eastern cities (New York, Boston, Philadelphia, Pittsburgh, Baltimore-D.C and major California cities) as depicted in Figures 10-12. Such inference should be tempered by the need to retain some core of low level background and spatial gradient sites for model evaluation and transport analyses. Consideration should be given to identifying even remote locations to provide more complete spatial detail nationally and consider enhancing partnerships with other Federal agencies (NPS, USFS) and Tribes to address areas with major geographic gaps.

PM2.5

From a national perspective, a significant reduction in the number of PM2.5 FRM monitors is recommended. This reduction in the current network would not compromise our ability to meet the principal data quality objective of addressing NAAQS compliance. It is assumed that the existing FRM network will be maintained through the end of 2002 or until three full calendar years of data are collected, whichever is later. (The only exceptions to this might be to: (1) relax the sampling frequency to 1-in-6 day at sites where the annual NAAQS is controlling, and (2) eliminate low concentration, redundant FRM monitors, if resources are needed now to support deployment of speciation or continuous monitors. After the end of 2002, or when three full calendar years of data are available, then a significant reduction in the number of FRM monitors to something on the order of 700 – 800 sites nationally should be considered. Because the FRM filter-based technology will not, however, meet the needs for timely data reporting (e.g., AQI and AIRNOW), a substantial effort must be put forth to implement continuous PM monitors that produce acceptable data quality into the network to

meet multiple data analyses[1]. Eventually, the number of integrated FRMs can be reduced further in parallel with the incorporation of PM continuous instruments that produce a successful record of meeting specified performance standards. EPA must accelerate the production of guidance for identifying redundant FRM sites for removal, the development of DQO's and performance standards that will facilitate introduction of continuous methods, and associated regulatory changes to accommodate these technical adjustments. The perspectives and recommendations presented here are based on those assessments addressing the annual PM2.5 data aggregate, as the annual standard is the dominant controlling factor throughout most of the nation. While it may appear premature to consider modifications in such a recently deployed network, a rethinking is in order given (1) the enormous operational burden placed on monitoring agencies, (2) advice and direction provided by CASAC and the NAS, and (3) recognition that any program has room for improvement. Due to the initial design objectives emphasizing "representative" siting (as opposed to capturing only "hot spot" signals) as well a generally coherent behavior of fine aerosol concentrations, the PM2.5 network provides perhaps the most statistically solid basis for conducting network assessments. As anticipated, there exist broad regions of consistent behavior of fine aerosol which implies opportunities for removing sites without compromising the ability to characterize regional and local aerosol patterns. Despite evidence indicating the potential for broad extent of PM2.5 nonattainment through the southeast and parts of the midwest (Figure 2), several potential sites should be considered for removal and/or subsequent replacement with continuous PM monitors (Figures 14 and 15). Every region of the country should review their PM2.5 FRM networks and identify "redundant" sites as candidates for removal/replacement. Although the PM2.5 sites are not as highly clustered as the those in the ozone network, population drove PM2.5 network design leading to significant urban clustering an now opportunities for site reductions. In addition, several areas of the country including New England, upstate New York, Florida and much of the north central states and west outside California do not exhibit elevated PM2.5 concentrations (Figures 2 and 16). Those areas should review their network paying careful attention to optimizing sites that emphasize characterizing background and gradient patterns and public reporting more than NAAQS compliance. EPA should provide a recommendation based on the national need for characterizing background and gradient PM2.5 levels and determine what adjustments are needed to the combined Speciation/IMPROVE and PM2.5 mass networks are needed to best serve evaluation of national air quality models.

PM10

A major reduction in the number of PM10 monitors is recommended. Only those sites that have current PM10 exceedances and violations, as well as those required as part of SIP approval conditions should remain as priority sites. Any additional PM10 monitoring should be conducted at locations collocated with a PM2.5 FRM, with suspected "elevated" PM-coarse concentrations, and with measurement technology compatible with the PM2.5 FRM. Clearly, opportunities for reduction are far greater in Eastern Regions of the country (Figure 17).

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[1] Note that the FRM network provides an excellent base for characterizing spatial patterns of PM2.5 nationally. This ability to provide such characterizations should not be compromised as modifications emerge.

Monitoring for PM10 continues at over 1000 sites nationwide with a very small number of exceedances (Figure 7) for a pollutant that is being phased out of the air program. Clearly, the consumption of resources dedicated to PM10 monitoring is not in phase with the current importance of the PM10 problem. Although EPA is likely to promulgate a coarse PM standard (PM10 - PM2.5) the variety of PM10 monitoring methods generally is not consistent with the method requirements that will emerge from a PMcoarse NAAQS.

CO

A major reduction in the number of CO monitors is recommended. Only those sites that have current CO exceedances and violations, as well as those required as part of SIP approval conditions should remain as priority sites. Existing CO monitors located in urban microscale sites should be relocated to more broadly representative urban locations. In addition, CO monitoring should be conducted using high resolution instruments in rural areas to provide regional information about CO concentrations, as may be needed to evaluate air quality models and apply observation-based methods (OBMs). The CO assessment is complicated by predominant microscale influences arising from busy traffic intersections, urban canyon effects and other factors that lead to maximum concentrations observed within the very close proximity of sites. Network design for CO should undergo a major transformation to address other data analysis needs including air model evaluation and observational based approaches (e.g., source-receptor modeling, OBMs). This shift would require investing in high resolution CO monitors capable a capturing background concentrations and locating instruments in areas representative of general background concentrations and within expected gradients. This undertaking also should be incorporated as part of the overall monitoring strategy addressing future network design.

SO2

A major reduction in the number of SO2 monitors is recommended. Only those sites that have current SO2 exceedances and violations, as well as those required as part of SIP approval conditions should remain as priority sites Any additional SO2 monitoring should be conducted at a small select number of sites to address 5 minute averaging times in response to concerns regarding short-term SO2 exposures and in rural areas to provide regional information about SO2 concentrations, as may be needed to evaluate air quality models. As a major precursor for PM2.5, very little relevant SO2 data exists that allows for evaluation of air quality models or to support observational methods that rely on formation rate principles (CO and N species are also useful). Investments in SO2 should be made in monitors capable of reading background concentrations and siting in areas with larger spatial scale representativeness collocated with other coupled atmospheric process and health related measurements.

NO2

A major reduction in the number of NO2 monitors is recommended. While there remains a need to track national trends, the network must undergo major modification to address the more important needs associated with tracking control program progress for ozone and PM2.5 and model evaluation. This suggests the need for sites in rural areas to provide regional air quality information, and to establish monitors for NO/NOy, which is a better indicator than NO/NOx. The NO2 network no longer is required for the primary purpose of

NAAQS. Changes need to be made in monitoring methods as NO2 is a poor parameter to track emissions that emerge first as NO and are gradually oxidized to an aggregate of species collectively referred to as reactive nitrogen, NOy. Technology for high resolution NOy (which simultaneously measures NO) is available and some limited progress has been made in developing an NOy/NO network, although significant QA issues associated with calibration exist. However, a network for assessing the effectiveness of major nitrogen emission reductions currently is not in place. Note that some of the existing NOx/NO monitors located in representative emission areas such as PAMS sites do provide some ability to track emissions in urban areas. Because many of the major N sources are located in non-urban locations, and the broad extent and dilution of emission plumes (and propensity for "urban" noise to wash out signals), a regional rural NOy network is probably required to detect long-term changes in N emissions associated with major utility source reductions. Note that NO2 as a measurement offers incredible value for model evaluation at the diagnostic level, as NO2 is involved as a key parameter in so many chemical pathways. Unfortunately, there does not exists an affordable solution for routine monitoring of NO2. Current NO2 measurements are influenced by measurement artifacts that generally produce a positive bias in the measurement. Fortunately, the relatively fresh emissions in urban locations where NO/NOx monitors are sited generally result in plumes dominated by NO where artifacts due to oxidized products are somewhat minimized. The use of current technology in rural locations is not appropriate as the aged plumes contain a greater percentage of oxidized N that will bias the NO2 calculation, and the concentrations in rural locations are below the resolution limits of commonly used NO/NOx monitors.

Pb

A major reduction in the number of Pb monitors is recommended. Only those sites that have current Pb exceedances and violations, as well as those required as part of SIP approval conditions should remain as priority sites. Progress in the reduction of lead concentrations is a clear air program success story. Basically, we should declare victory and limit lead monitoring to those isolated areas influenced by significant stationary sources, and maintain those sites identified by EPA to retained for long term trends.

Recommended Analysis and related activities

The national analysis served a necessary role in confirming a prevailing view of a two criteria pollutant problem, ozone and PM2.5, in the United States. Accordingly, the assessment clearly indicates that major reductions in most other criteria pollutant monitoring programs are in order. The national assessment also appears to corroborate more detailed assessment work conducted by participants in the north central states. Nevertheless, the national assessment work could be improved to better service both national and regional needs. Baesd on the July, 2001 network assessment workshop and input from the assessment workgroup a number of suggested improvements to the national assessment and advice for subsequent regional/local assessments include:

1. **Emphasize importance of regional assessments**. The national assessment results provide conclusions that may apply on a national scale, but could be

misused at a regional level. For example, clustered monitoring sites in general may produce "low value" data, yet in certain areas such data is used for an array of objectives and would be classified as "high value" when approached with a more resolved perspective.

2. **Regulatory and programmatic changes must accompany assessment results**. The assessments produce technical recommendations that could impact monitoring. Specific changes in EPA Grant guidance and monitoring regulations are needed to support investment in new monitoring programs and divestment in identified programs.

3. **Improving spatial scale representativeness of monitoring sites**. The current polygon procedure accurately portrays a nearest neighbor concept where the defined area incorporates every point closet to the monitor. This approach is analogous to identifying the closest fire station to a residence, an intuitively useful notion that associates the closet monitor in space to the enclosed population. The polygon methodology is developed solely through a geometrical construct and does not account for topographical and meteorological factors which influence actual spatial zone of representative for a particular monitoring site. Improvements in the "area" measure and those objectives that consider this measure, particularly model evaluation, would increase the applicability of the assessment at both the national and local level. Each EPA Regional Office is requested to review and rank all monitoring sites with respect to actual spatial representativeness through methodology provided by EPA Region 5. These revised rankings will be reapplied by EPA OAQPS in further iterations of the assessment requested by EPA Regional Offices. During an interim period, EPA OAQPS will rerun selected weighting schemes with a reduced emphasis on the "area" measure.

4. **Inclusion of special event data**. To retain an ideological and technically sound approach, all data sources should be utilized in the assessment. Instances where exceptional events data were excluded should be noted in tables and figures.

5. **Apply the assessment at regional scales with separate weighting schemes**. Each region/interstate group should develop a weighting scheme indicative of the objectives more closely associated with that region, and the assessment recalculated for specific regions. EPA OAQPS will perform regional assessments based on more specific input provided by EPA regional offices.

6. **Perform more critical review of results**. The reliance on graphs indicating quartile breakouts may overlook natural breaks in the data that suggest more obvious delineations for "high" and "low" value sites. In addition, some normalization could be achieved by considering values of scores as opposed to only ranked order when combining multiple measures.

7. **Identify barriers to network modifications**. This technical approach followed in the assessment does not consider potential constraints due to existing policy, monitoring regulations, community concern and other issues. These constraints should be identified to facilitate implementation of assessment findings.

8. **Consider additional measures.** Additional measures to consider include a trends indicator (e.g., longevity of monitoring record), an emissions weighting factor (e.g., relative density of emissions in vicinity of a monitoring site), a "real-time"…AIRNow benefit, and an Environmental Justice indicator (normalizing income/property levels).

9. **Include cost information**. There should be some quantification of the expected resource savings from shutting down certain monitors to identify reasonable expectations for investing in new monitoring program areas such as air toxics and continuous particulate matter. In addition, the relative "Federal" costs contributed to monitoring vary from agency to agency. There is a risk that the assessment will discourage monitoring that is funded by non traditional sources such as industry or through permit fees.

10. **Enhance Information Transfer and Technology.** The utility of monitoring data is enhanced through remote and real time access capability. The strategy should encourage greater incorporation of automated methods and information transfer. In addition, network design should be strongly linked to AIRNow by enhancing AIRNow's ability to krige monitoring data, and relying on mapping techniques to direct network design.

11. **Increase stakeholder input**. Network assessments and related strategy efforts should solicit advice from the health community (public schools of health, local health departments).

12. **Encourage alternative monitoring approaches**. The use of methods not certified as reference or equivalent offer enormous data capture potential for relatively low cost. For example, passive ozone monitoring could be used to refine ozone network design and fill in spatial/temporal gaps not provided by existing equivalent methods. Relatively low-cost nephelometers could replace PM2.5 FRMs in communities desiring monitoring coverage. Mobile approaches could also be used effectively to enhance spatial coverage.

13. **Science review**. The national assessment and related strategy should undergo scientific review by the CASAC.

14. **Transition effectively**. Build in sensible transition policies to minimize potential adverse impact on monitoring agencies and existing infrastructure.

This national level assessment has spurred the development and application several

additional network design tools, some of which are discussed in Section 3.2. EPA hosted a workshop in Decmber, 2001 dedicated to the application of spatial analysis tools for network optimiztion and air quality planning practice. Several of the concerns issued above will be addressed implicitly as the level of application and participation in this field is escalating. During 2002 and 2003 EPA will develop more specific guidance on the use of spatial fields as well as provide expectations with respect to performance specifications.

Summary of National Assessment results

The purpose of this section is to summarize the results of the monitoring network assessment that was conducted as part of the national monitoring strategy, and provide general guidance for EPA Regional Offices, States and interstate groups in conducting their assessments. Three key issues emerged from this assessment:

Investment Needs: New monitoring efforts are needed to support new air quality challenges, including monitoring for air toxics and new technology for criteria pollutants. Air toxics have emerged as a top public health concern in many parts of the country. Although guidance for deploying a national air toxics monitoring network is still under development, substantial resources appear to be necessary for this monitoring, given the cost to sample for a core set of 18 compounds for one year (i.e., about $60K per site). New technology, especially continuous measurement methods for pollutants, such as fine particles, are needed to provide more complete, reliable, and timely air quality information, and to relieve the burden of manual sampling. Resources and guidance are needed for this activity, as well.

Divestment Opportunities: To make more efficient use of existing monitoring resources and to help pay for (and justify additional resources for) the new monitoring initiatives noted above, it will be necessary to make certain cuts in the existing monitoring program. Two areas of potential divestment are suggested. First, many historical criteria pollutant monitoring networks have achieved their objective and demonstrate that there are no national (and, in most cases, regional) air quality problems for certain pollutants, including PM10, SO2, NO2, CO, and Pb. A substantial reduction in the number of monitors for these pollutants should be considered. As part of this downsizing, it may be desirable to relocate some of these shutdown sites to rural areas to provide regional air quality data. Second, there are many monitoring sites with only one (or a few) pollutants. To the extent possible, sites should be combined to form multi-pollutant monitoring stations. Any resource saving from such divestments must remain in the monitoring program for identified investment needs. A reasonable period of time must is required to smoothly transition from established to new monitoring activities.

Importance of Regional Input: The national analyses are intended to provide broad directional information about potential network changes. Regional/local analyses are a critical complement to the national analyses, and are necessary to develop specific monitoring site recommendations. To this end, EPA must allow states and regional organizations sufficient time (e.g., at least six months) to conduct adequate regional/local analyses.

3.2 Regional Assessments and guidance

As stated earlier, site specific decisions on network thinning and investments must be conducted with participating agencies. EPA has requested that each Regional Office be responsible for facilitating such assessments and producing preliminary recommendations in November, 2002. Attachment 2 provides examples of various technical applications and expectations with regard to these assessments.

Attachment 3 includes the draft strategy developed by LADCO/Region 5 which has served as a leading example for conducting these assessments. LADCO organized the first regional wide assessment of Region 5 States air monitoring networks. The process incorporated convening together monitoring and planning functions of the States, and EPA regional office staff, and developing objectives and priorities on which to base a range of decisions on investments and divestments. The process benefitted from having an NMSC member, Mike Koerber, involved (actually leading) in the meetings as well as periodic input from EPA headquarters. Attachment 3 includes the initial product from this assessment.

3.3 Policy Implications

Network assessments produce recommendations on removing or relocating samplers based largely on technical merit. In some instances, these recommendations may be in conflict with existing policy or other needs. For example, a recommendation that an ozone monitor be discontinued in a "non attainment" county due to redundancy of neighboring sampling sites raises interesting policy/technical issues. Issues such as this need to be resolved following a credible technical recommendation of network realignment. It should not be assumed that policy should override a technical recommendation, nor should technical approach override existing policy. Reasonable people should be capable of developing case by case solutions to these issues where needed. The LADCO/Region 5 monitoring strategy has accelerated this debate.

3.3.1 Preliminary suggestions on policy/assessment conflicts catalyzed by RO5 Monitoring Strategy–Ideas from Discussion (contact: John Silvasi)

OAQPS policy and technical staff developed some initial suggestions to address potential conflicts. One example suggestion included securing written agreement between States and EPA that supplementary data such as interpolated values that exhibit acceptable predictive accuracy from neighboring monitoring sites could replace data provided previously by the discontinued site. The meeting results below do not reflect EPA policy, but signify an attempt to resolve these issues in a reasonable time frames. OAPQS intends on developing consistent national level guidance for these topics.

Meeting results: On 1/9/02, several OAQPS EMAD & AQSSD representatives met to discuss the draft Region 5 monitoring strategy as it relates to ozone. Region 5 is currently revising its draft strategy. On 1/10/02, several EMAD & AQSSD representatives met to discuss the Region

5 monitoring strategy for ozone with Region 5 representatives.

Some of the problems originally identified with the elimination of monitors were discussed during both meetings (see attached table). These included effects on original nonattainment designations for the 8-hr O3 NAAQS, ability to apply the relative reduction factor process to an area with fewer monitors, photochemical grid model validation, trend retention, and reallocation of resources.

Several possible solutions were discussed to address some of these effects:

EFFECT	POSSIBLE SOLUTION
Reluctance to designate some portions of an area nonattainment if it no longer has a monitor that has recorded a violation	Obtain a written agreement in advance from the agency that is eliminating the monitor that nonattainment/attainment decisions for the county in which the monitor is located will be determined by other specified methods (e.g., modeling or krieging). Where EPA believes there is not sufficient confidence in such methods for the particular situation, the agency must agree in writing to use another indicator monitor in the area to represent the county for which the monitor is being eliminated.
Reduced number of monitors to apply relative reduction factors (RRFs) for purposes of control strategy development, demonstration of attainment, and evaluation of national measures.	For areas that experience a reduction in monitors, revise EPA guidance on attainment demonstration modeling for the 8-hr O3 NAAQS to apply the RRFs to an interpolated concentration field (developed through e.g. krieging based on remaining monitors) rather than to the limited number of remaining monitors. Standardized sets of krieging techniques* would have to be established or at least principles for krieging.
Reduced number or monitors to perform model validation.	For areas that experience a reduction in monitors, revise EPA guidance for model validation to allow model validation based on an interpolated concentration field (developed through e.g. krieging based on remaining monitors) rather than on the limited number of remaining monitors. Standardized sets of krieging techniques* would have to be established or at least principles for krieging.

EFFECT	POSSIBLE SOLUTION
An area that is once designated nonattainment may only be designated attainment if it continues to monitor in the area. Deleting a violating monitor may hamper that area's chance of showing that it has attained and may relegate the area permanently to nonattainment.	Revise EPA policy and procedures for redesignation of an area from nonattainment to attainment to allow the use of an interpolated concentration field (developed through e.g. krieging based on remaining monitors) rather than on a monitor that is eliminated as long as reliance on such methods for the particular area provides sufficient confidence in the results.

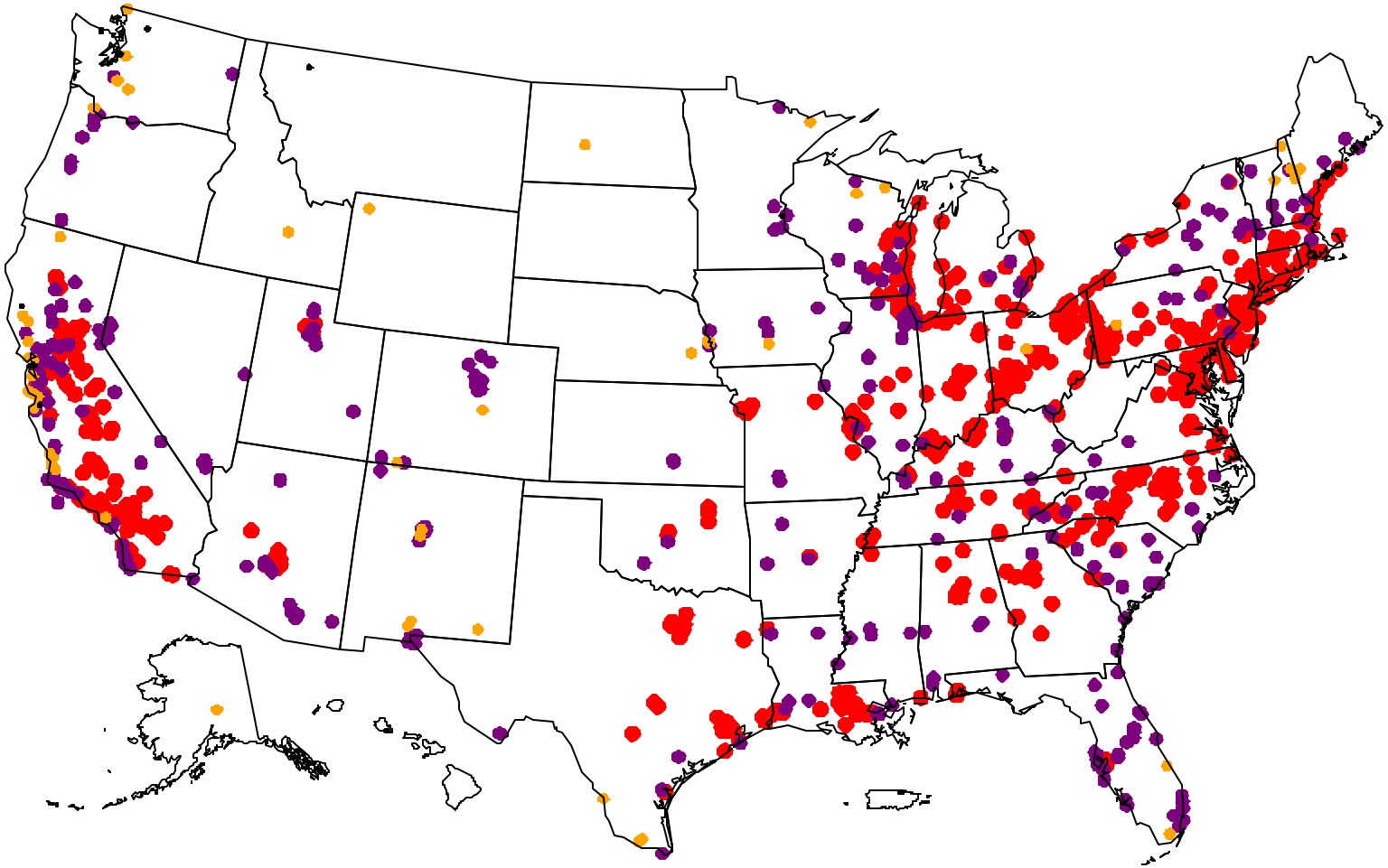
*Note that it would take probably a number of years for peer review of these changes in methodology before they could become effective.

Next steps:

1. Agree on (or modify) approaches noted above
2. Discuss with modeling group
3. Develop a draft work plan & schedule to proceed
4. Brief AQSSD/EMAD management on concepts and work plan and obtain approval to proceed

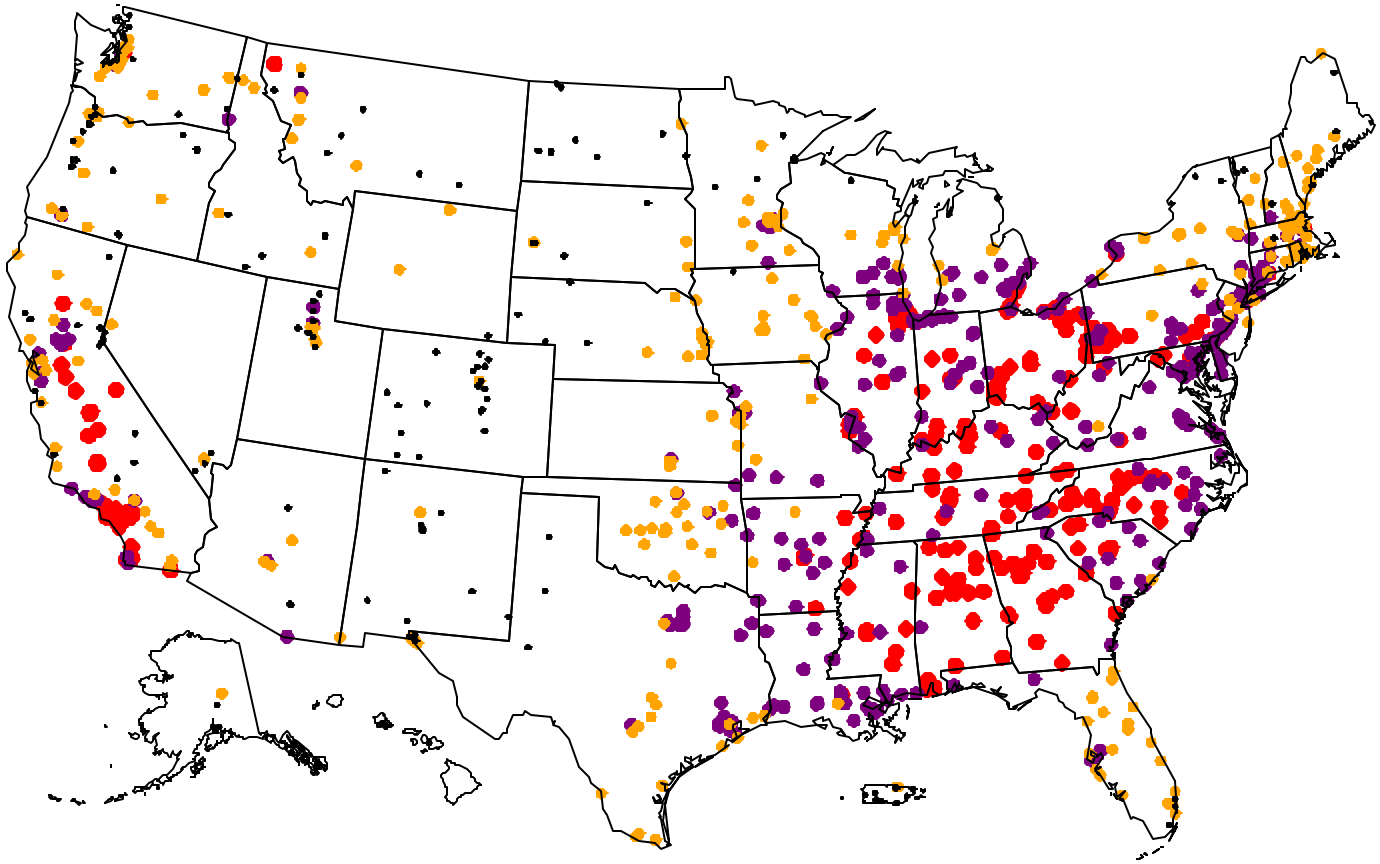
Attachment 1. National Assessment Figures

Figure 1: 98-00 8-Hour O3 4th Max - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



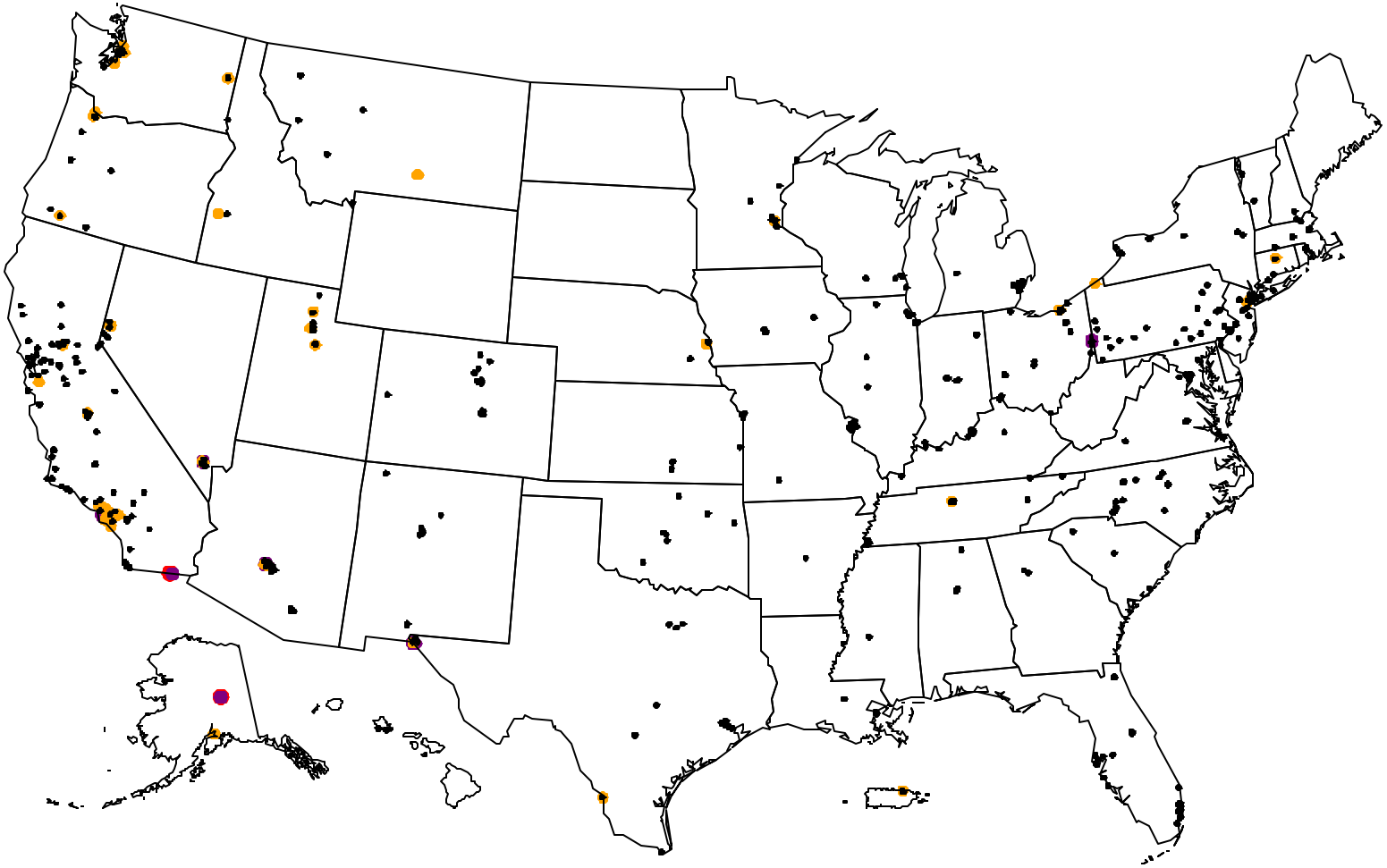
95-97 8-Hour O3 2nd Max Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

Figure 2: PM25 Annual Mean - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



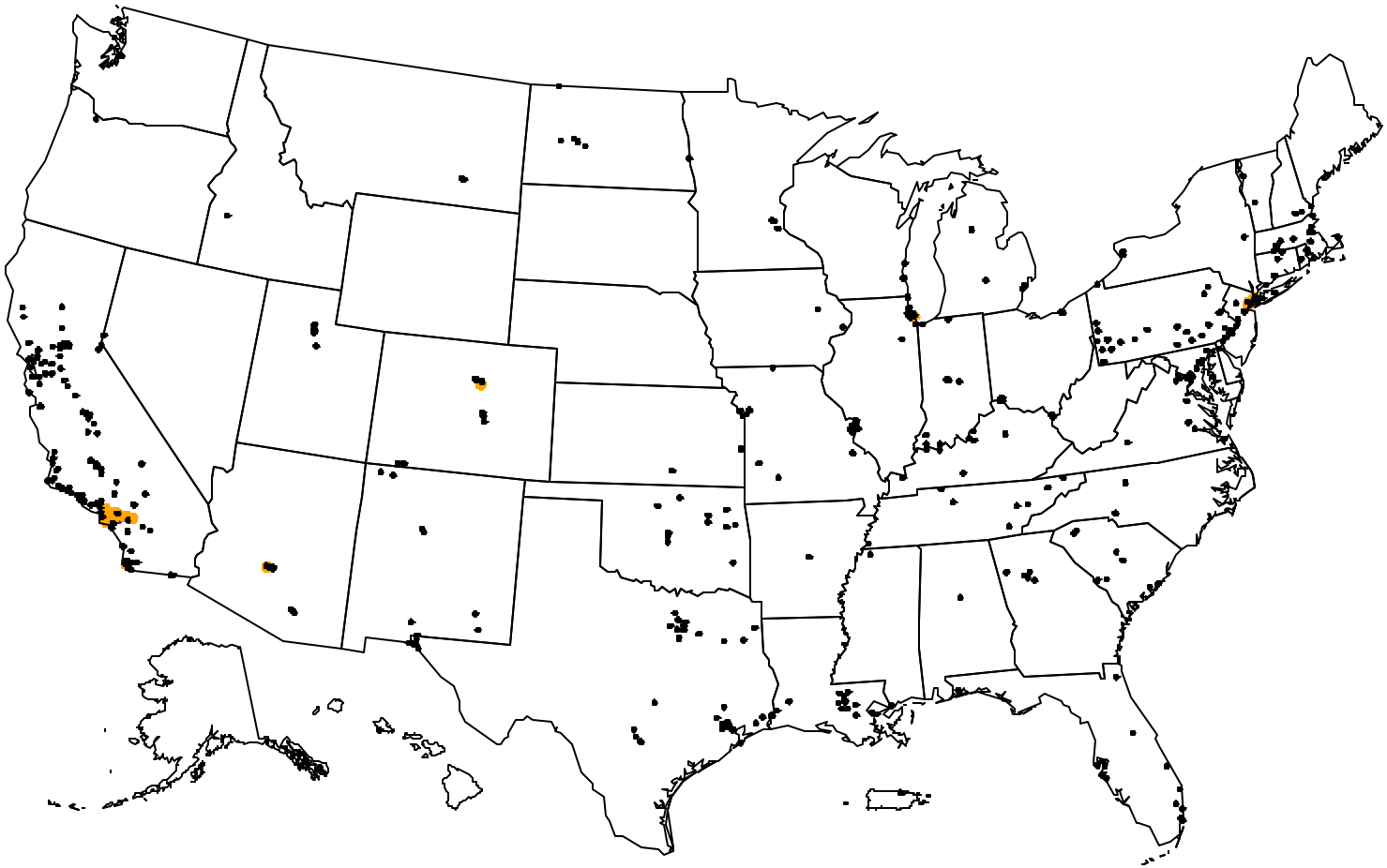
PM25 Annual Mean Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

Figure 3: 8-Hour CO 2nd Max - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



8-Hour CO 2nd Max Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

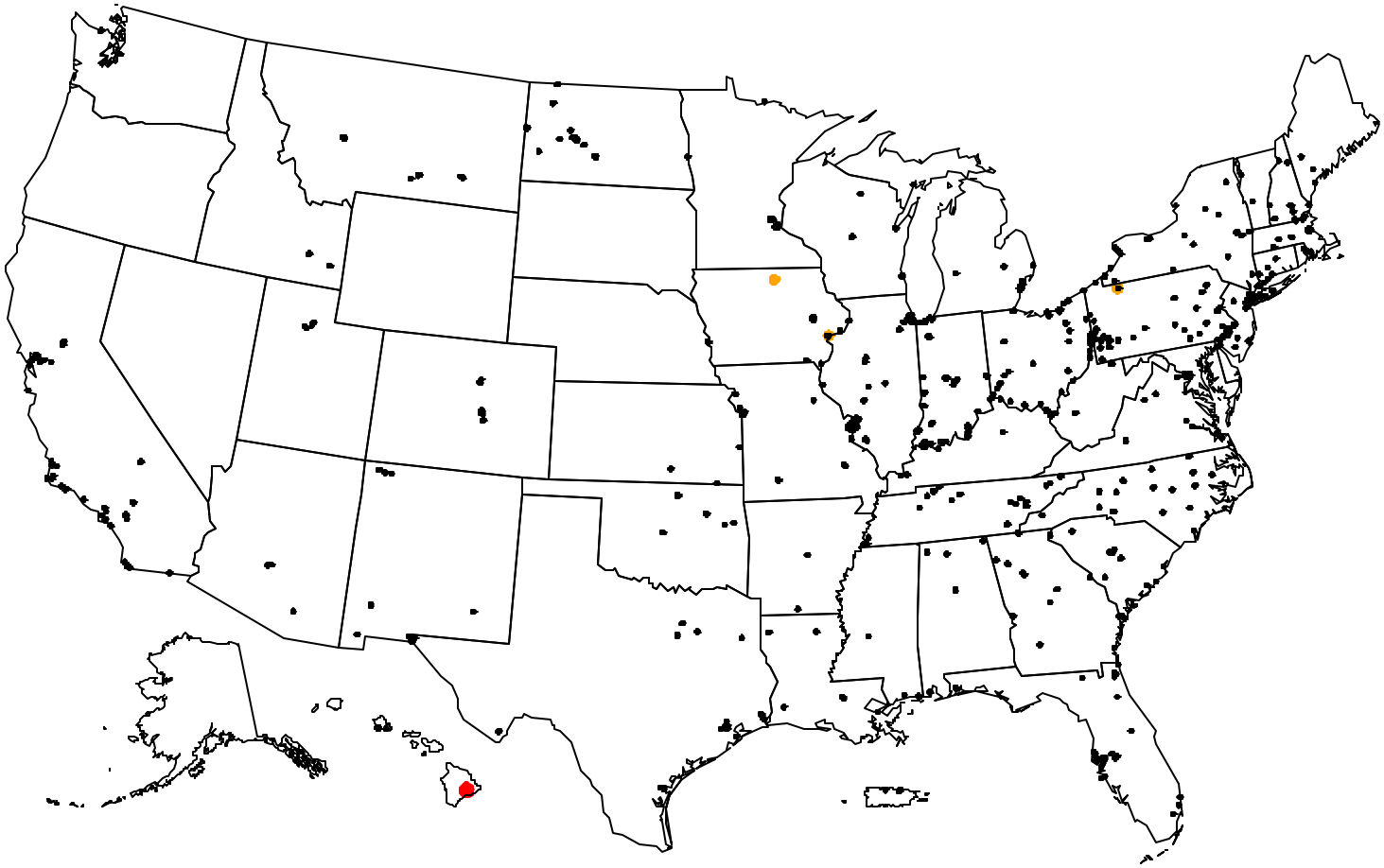
Figure 4: NO2 Annual Mean - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



NO2 Annual Mean Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

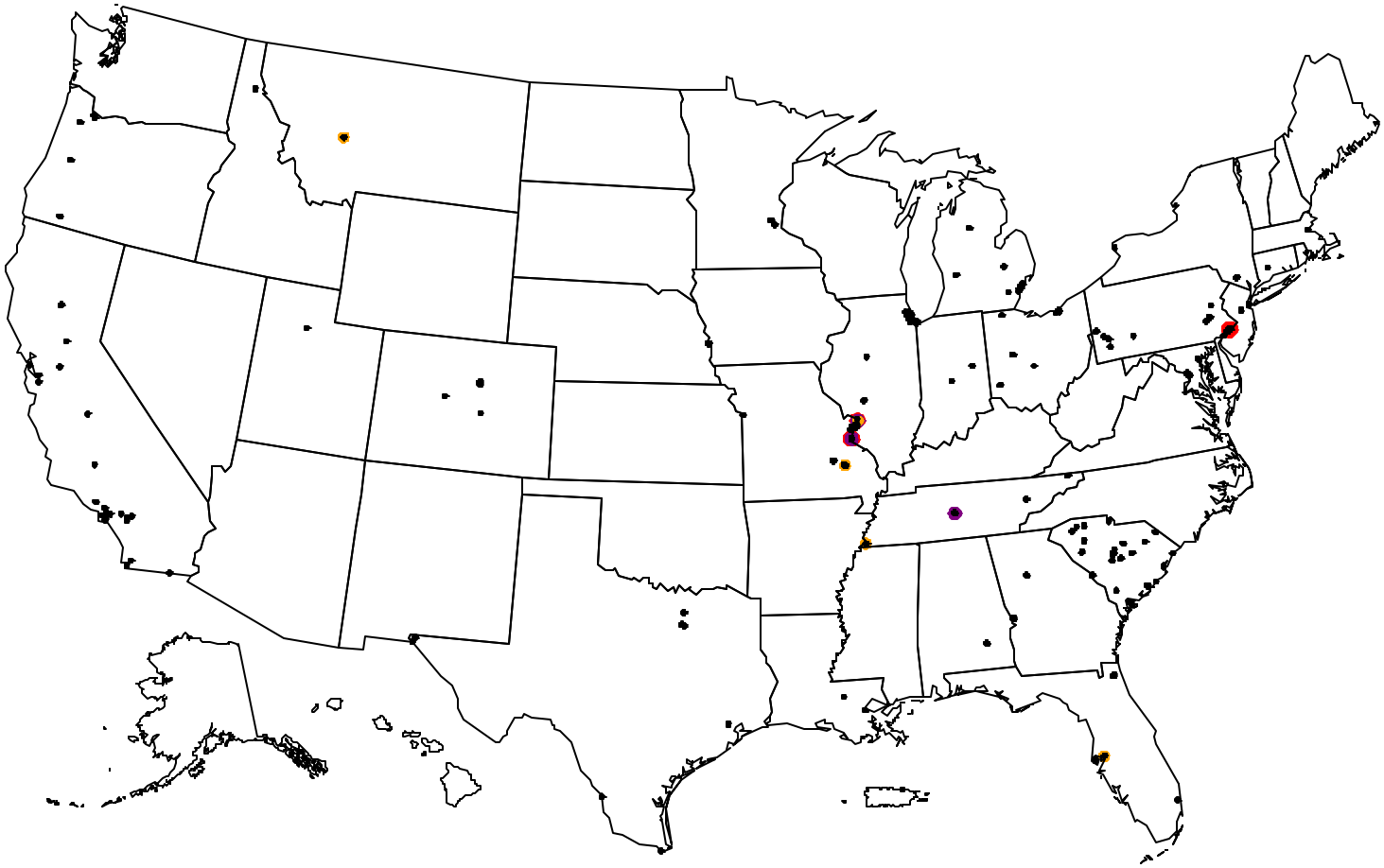
Figure 5: SO2 2nd Max - Percent of NAAQS:

Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



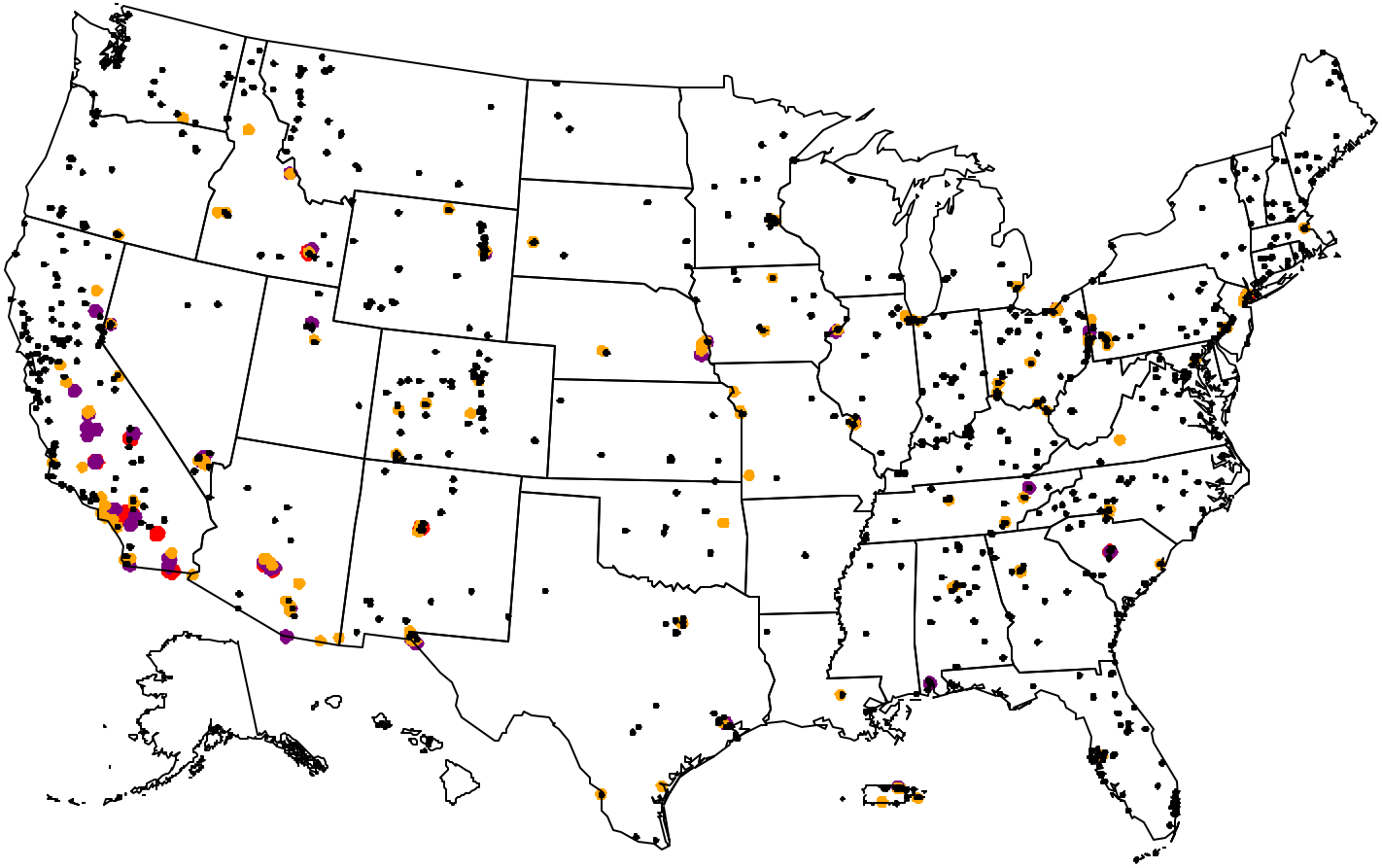
SO2 2nd Max Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

Figure 6: Pb Max Quarterly Average - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



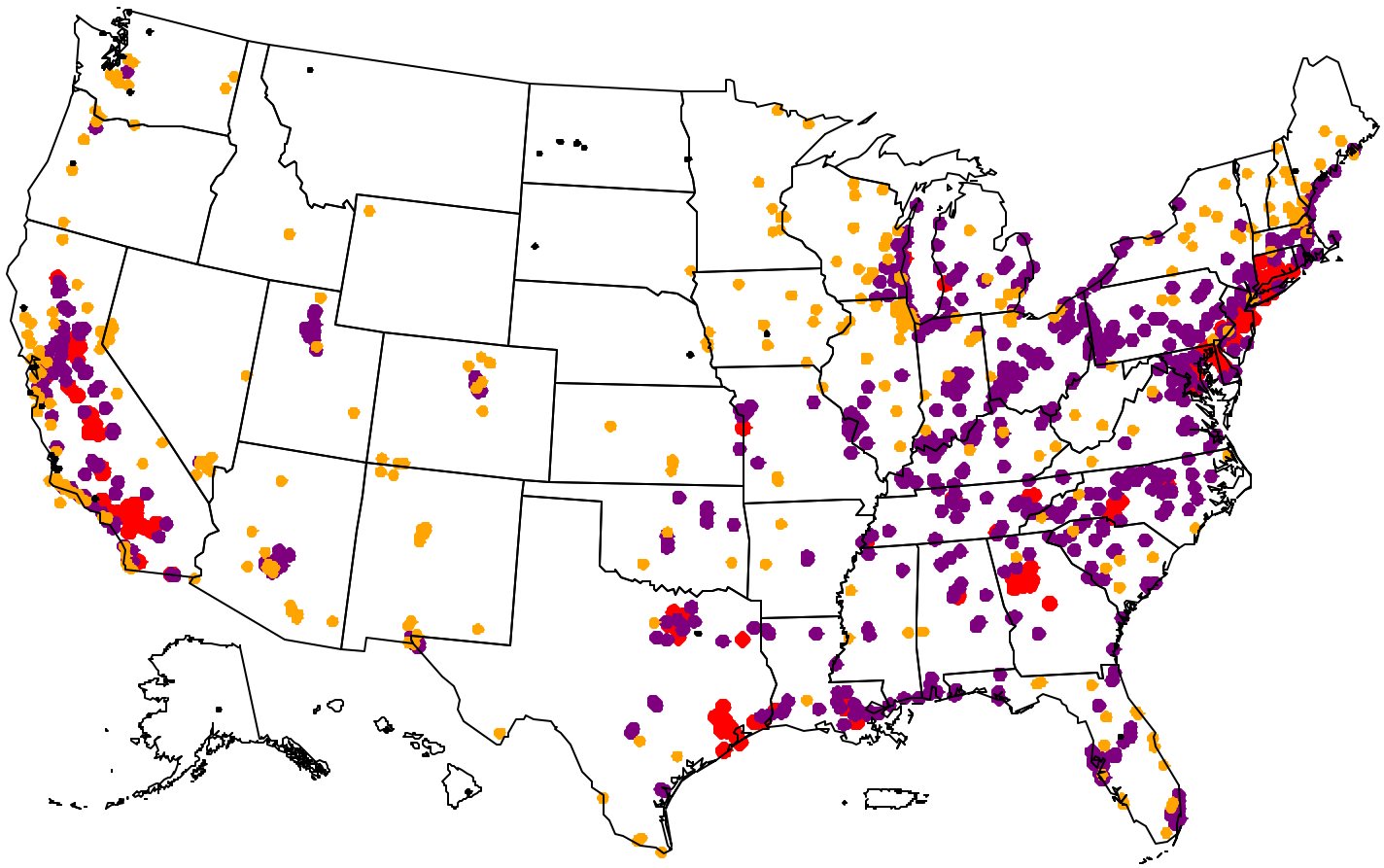
Pb Max Quarterly Average Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

Figure 7: PM10 Annual Mean - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



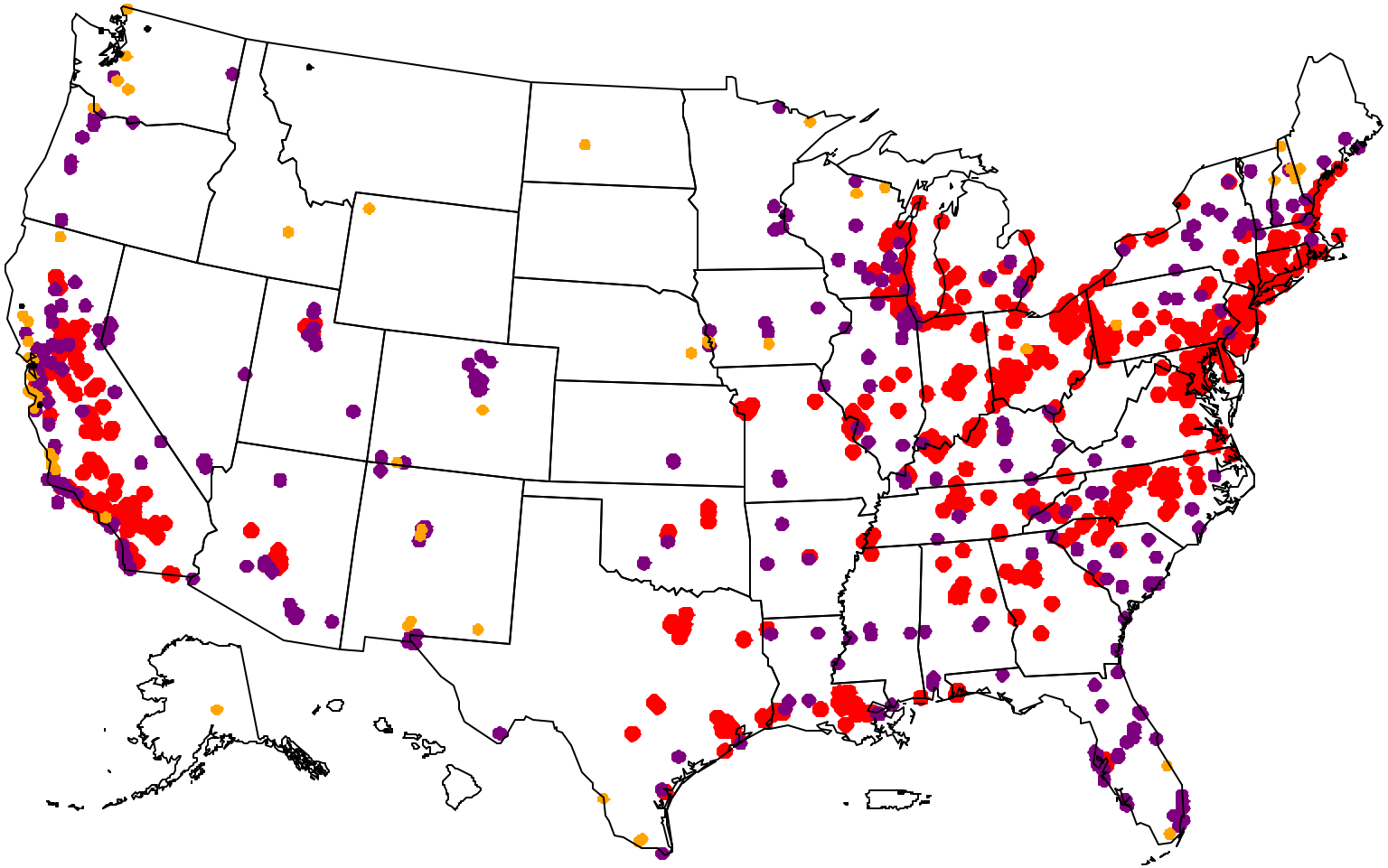
PM10 Annual Mean Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

Figure 8: 98-00 1-Hour O3 2nd Max - Percent of NAAQS:
Red= >100%, Purple= 80-100%,
Orange= 60-80%, Black= <60%



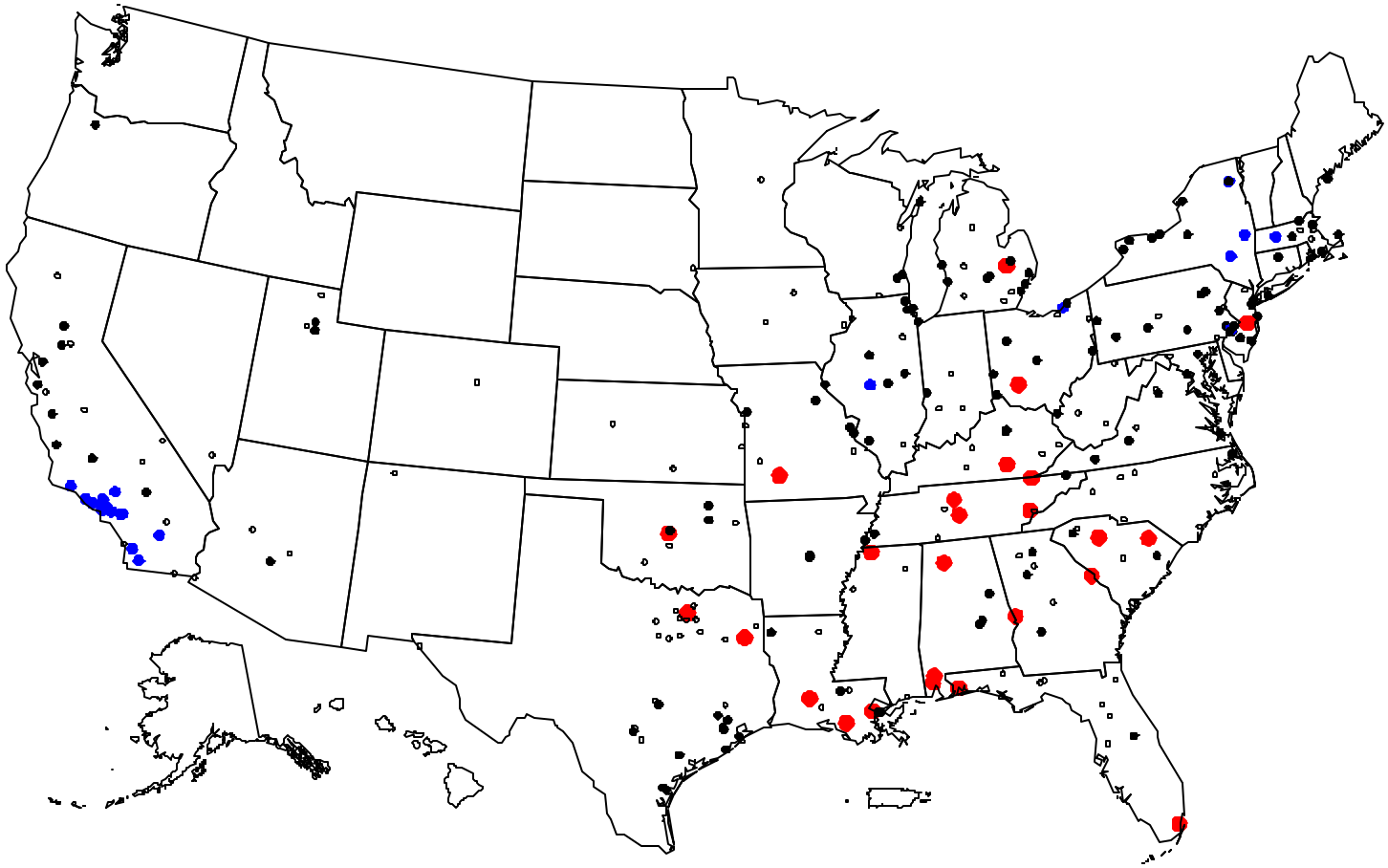
98-00 1-Hour O3 2nd Max Percent of NAAOS:Red= >100%. Purple= 80-100%. Orange= 60-80%. Black= <60%

Figure 1: 98-00 8-Hour O3 4th Max - Percent of NAAQS: Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%



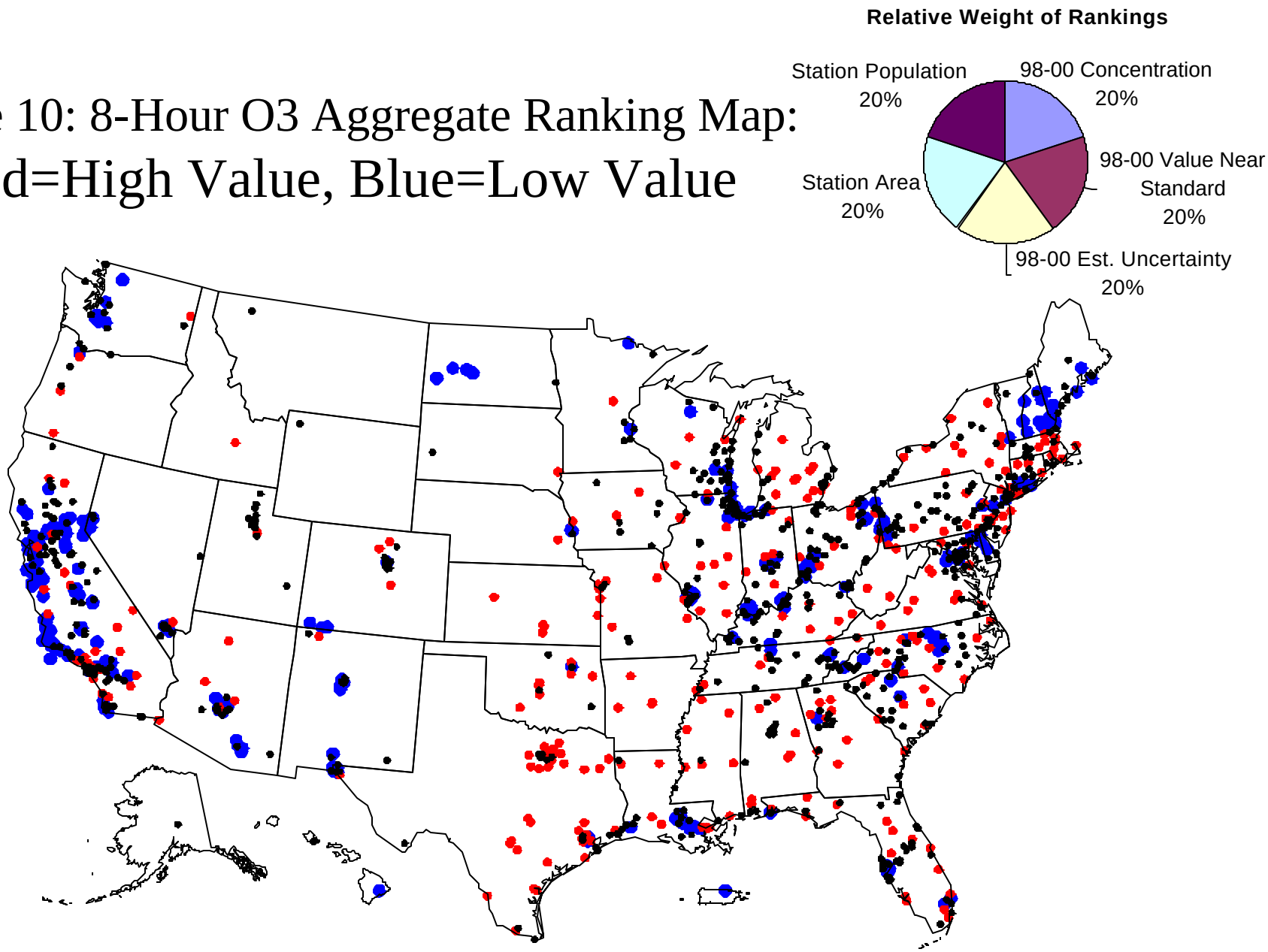
95-97 8-Hour O3 2nd Max Percent of NAAQS:Red= >100%, Purple= 80-100%, Orange= 60-80%, Black= <60%

Figure 9: 8-hr O3 10-yr Trends-Aggregate Ranked (Equal Weighting) Sites in 1st Quartile (Most Important): Red=Up, Blue=Down, Black=Not Significant



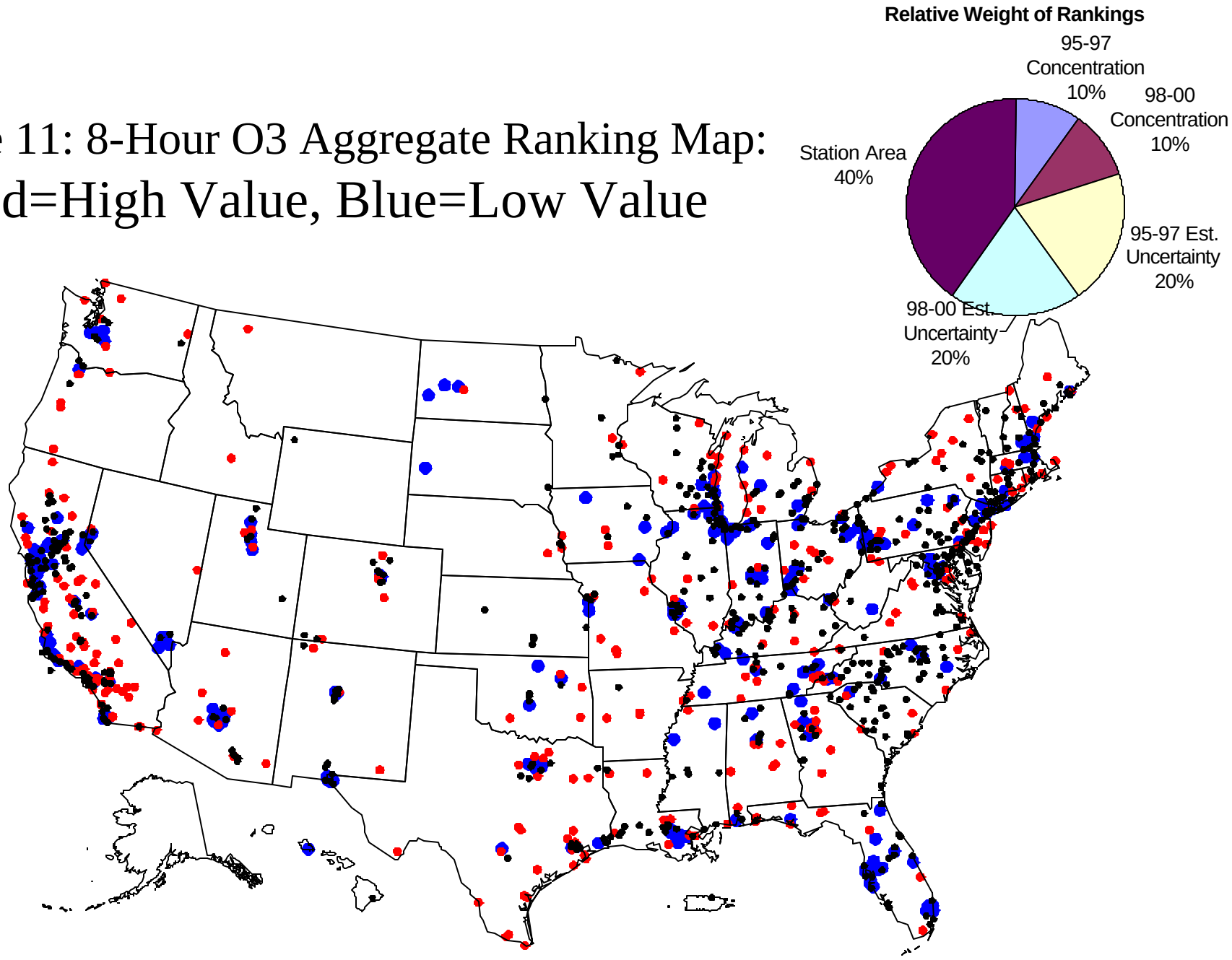
O3 8hr Trends-Aggregate Ranked Sites Above 75th Percentile:Red=Upward, Blue=Downward, Black=Not Significant, Empty=Insufficient Data

Figure 10: 8-Hour O3 Aggregate Ranking Map: Red=High Value, Blue=Low Value



O3 8hr Aggregate Ranking Map: Red=High Value, Blue=Low Value

Figure 11: 8-Hour O3 Aggregate Ranking Map: Red=High Value, Blue=Low Value



O3 8hr Aggregate Ranking Map D: Red=High Value, Blue=Low Value

Figure 12: Error mapping for ozone.

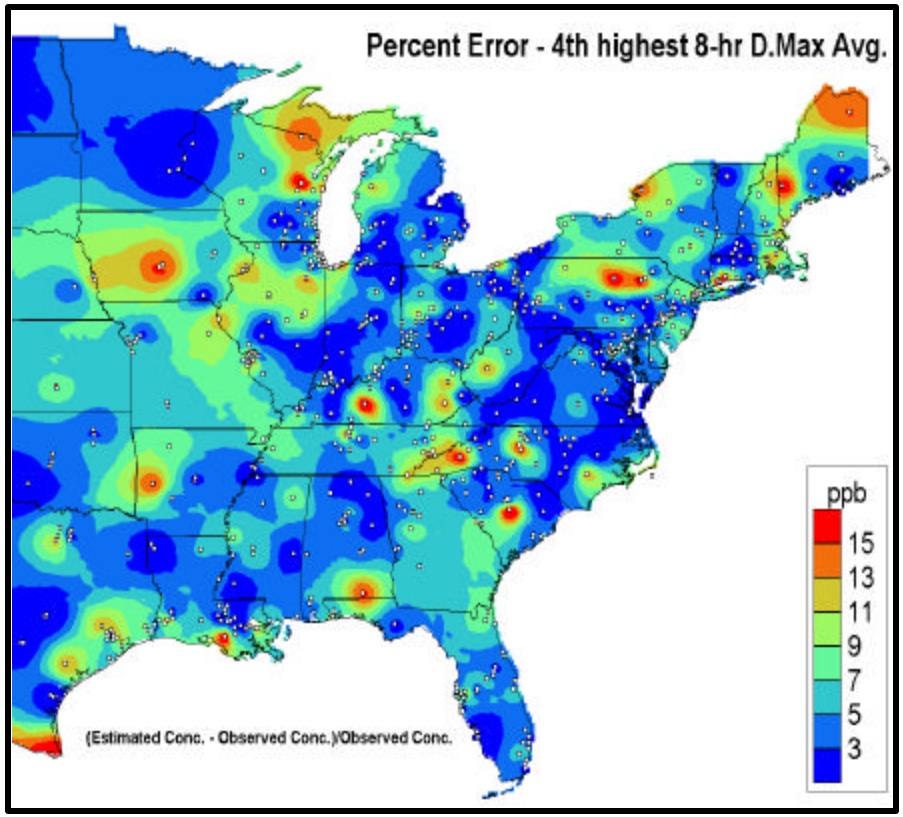


Figure 13: Regional Percent of Sites in National Quartiles

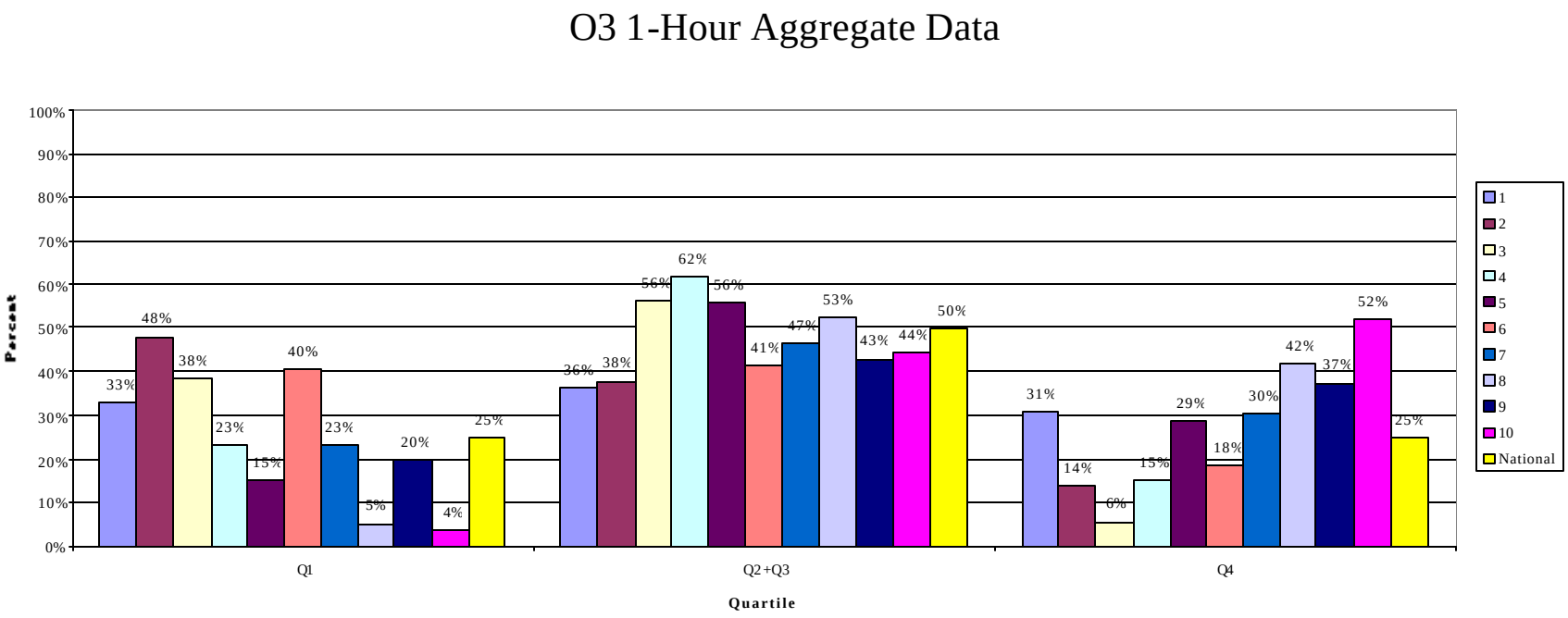
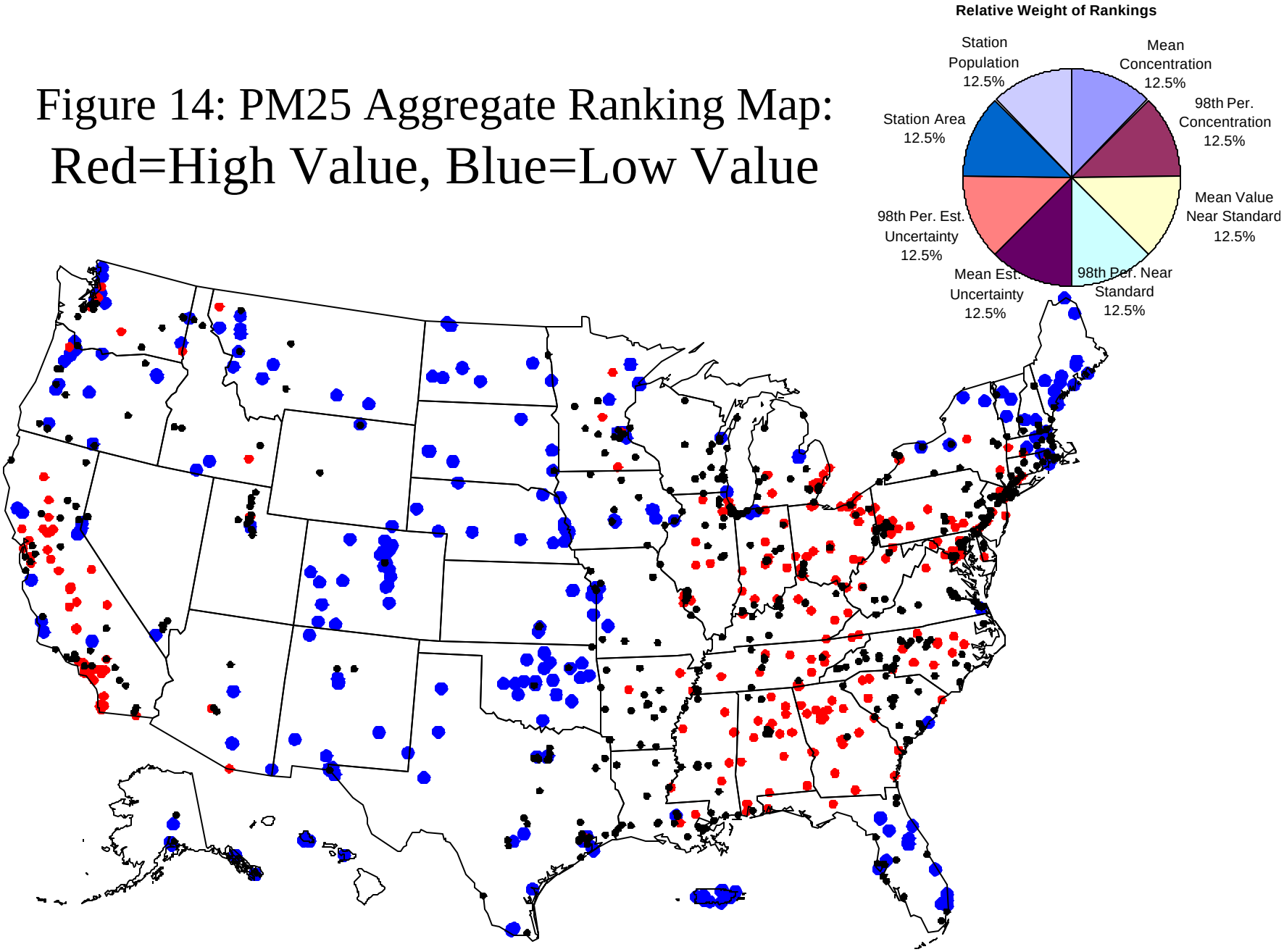
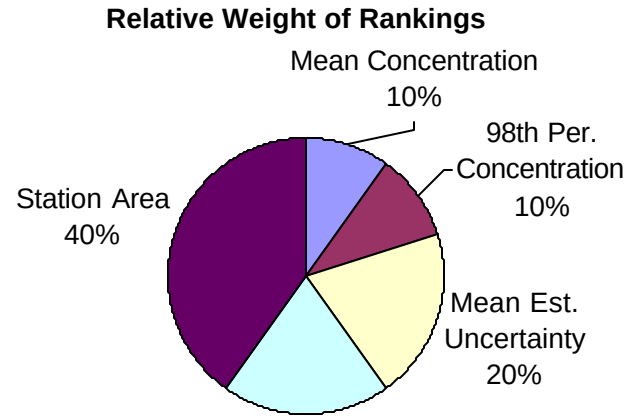


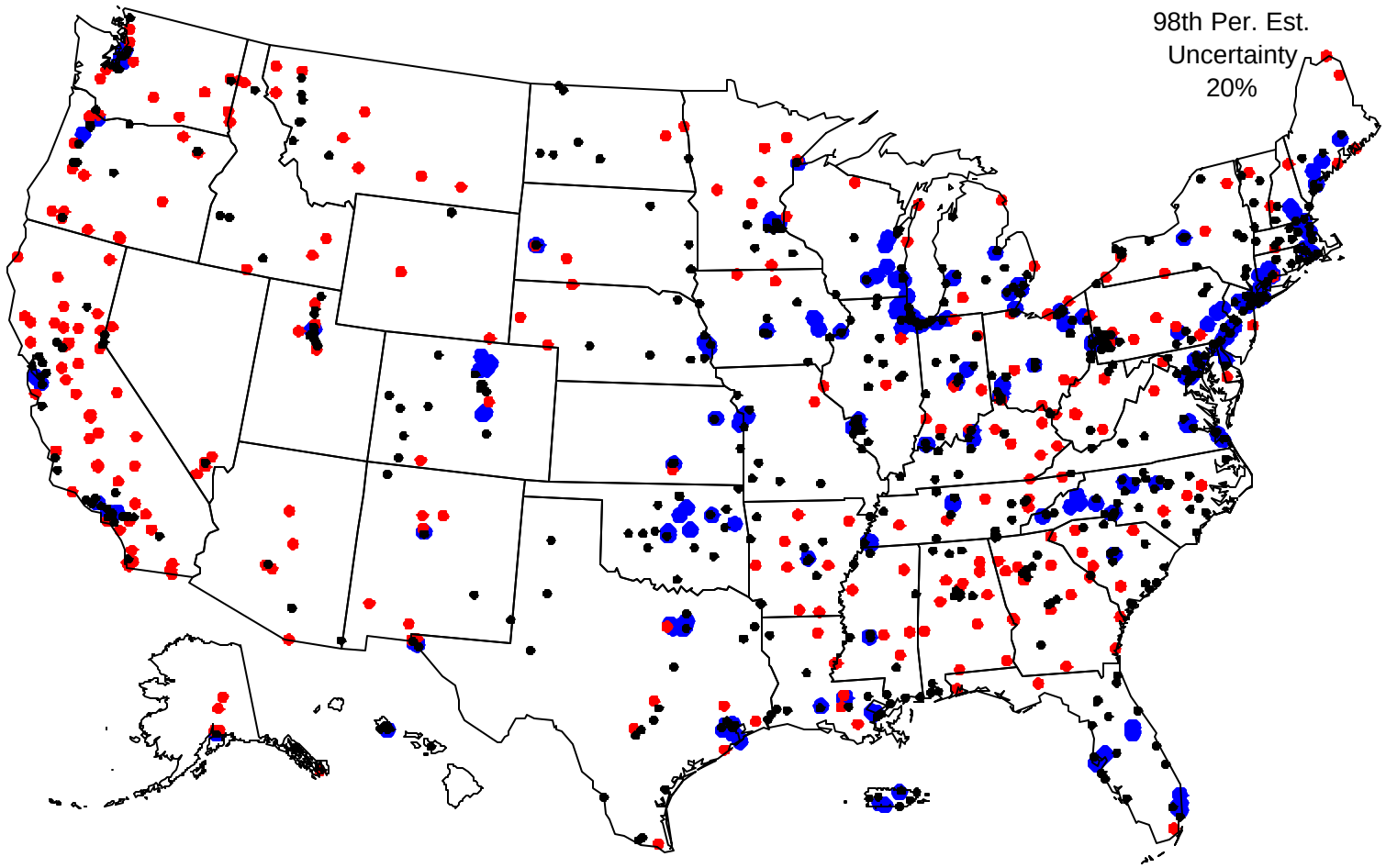
Figure 14: PM25 Aggregate Ranking Map: Red=High Value, Blue=Low Value



PM25 Aggregate Ranking Map: Red=High Value, Blue=Low Value

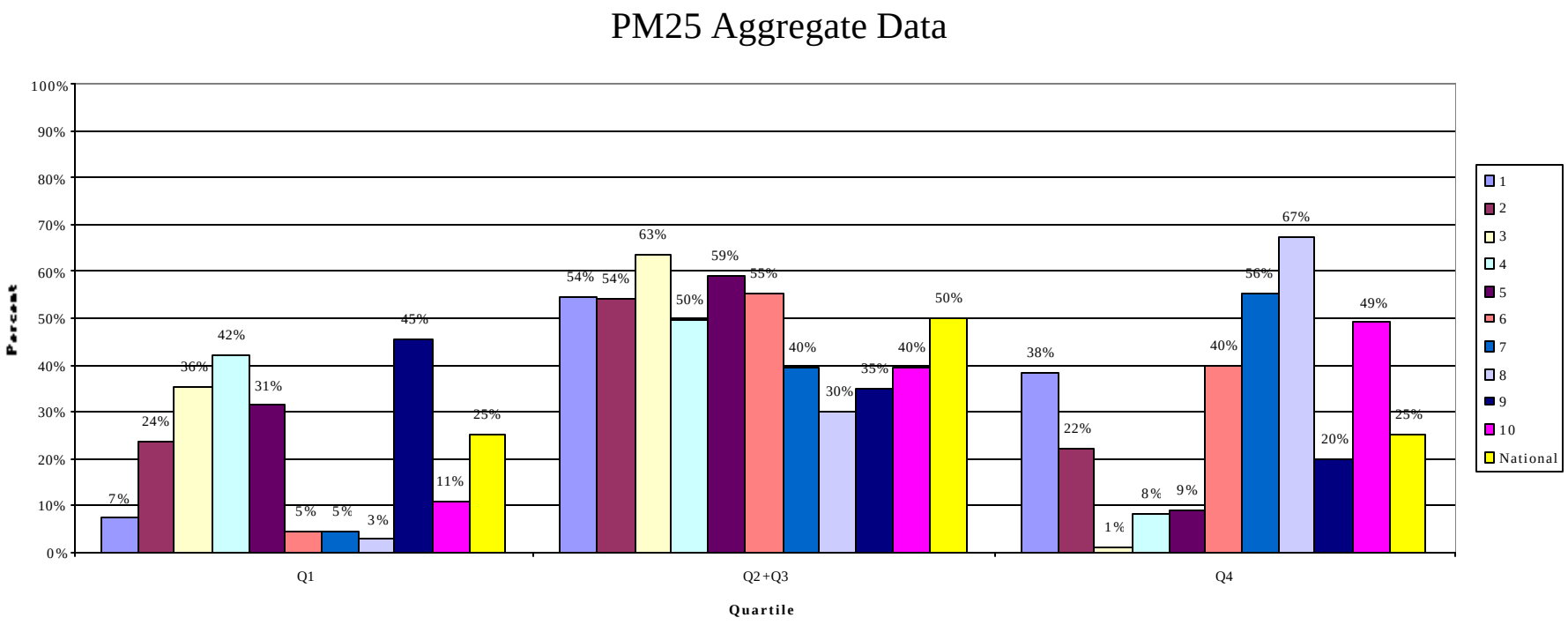
Figure 15: PM25 Aggregate Ranking Map: Red=High Value, Blue=Low Value





PM25 Aggregate Ranking Map D: Red=High Value, Blue=Low Value

Figure 16: Regional Percent of Sites in National Quartiles



Attachment 2: Network Assessment Technical Guidance - DRAFT

Table of Contents

I.	Goals and Objectives for Conducting Network Assessments	I.1
	A. Introduction and Relationship to the National Monitoring Strategy	I.1
	B. Beginning the Process	I.1
	C. Roles, Responsibilities, and Network Assessment Schedules	I.3
II.	Technical Tools	II.1
	A. National Assessment	II.1
	B. LADCO/Region 5 Approach	II.3
	C. Region 3 Approach	II.8
	D. Design Interface Tool	II.9
	E. Additional Techniques Under Development	II.10
III.	Acronyms	III.1

I. Goals and Objectives for Conducting Network Assessments

A. Introduction and Relationship to the National Monitoring Strategy

The EPA and State, local and tribal air monitoring agencies began developing a National Air Monitoring Strategy in 2000 at the urging of EPA. The genesis for the strategy came as a result of concerns about the increasing needs for air quality monitoring data for certain applications, and the pressure of these needs upon the available air monitoring resources. During this same period, the PM2.5 monitoring program deployment was nearing completion and it became evident that monitoring resources had been stretched to their maximum. Complicating this picture was the air toxics program which was looming as another air quality data need that was not being fulfilled. EPA began devoting more effort to examine the existing networks and their supporting mechanisms such as regulations, program priorities, and technologies.

EPA recognizes that some of the regulatory requirements that have remained in 40 CFR 58 for many years should be revised to reflect current program needs. The emission source distributions and levels for certain criteria pollutants, such as sulfur dioxide and carbon monoxide, have changed through the most recent years. The geographic extent of U.S. population growth into sprawling suburbs should also be taken into consideration for those parts of the network that are investigating population exposure types of monitoring. There are many reasons why EPA and its partners in the State, local and tribal agencies must continue to assess and where necessary, modify the air pollution monitoring networks to reflect our changing environment. Network assessments are the key to implementing the national monitoring strategy and to ensuring that the monitoring community uses its resources most effectively.

EPA conducted a national network assessment to start the investigation process. This national-level analysis, while informative in a general sense, was clearly not enough. The concerns of State, local, and tribal agencies could not be adequately taken into account by looking at the program's focus at a national level. This document is an attempt to prepare preliminary technical guidance for the monitoring community on some possible approaches for conducting localized network assessments. This document does not list all possible assessment methods, but it should help begin the process. This document can be expanded as newer tools are developed for this work.

B. Beginning the Process

Before beginning a review of the various approaches for network assessments, it is important to understand what is considered a network assessment and how this work might vary from what is currently done in the network review process.

The bulk of the ***network reviews*** that OAQPS has seen include a description of an agency's air monitoring program, specifically, which pollutants are measured in which locations, what changes to

sites have taken place over the most recent year(s), what new sites may need to be installed due to new requirements or losing site leases, and how these networks compare against the national air monitoring regulatory requirements for the criteria pollutants and PAMS requirements. Information on the siting criteria inspections, technical systems audits, and other quality control work is often provided in this annual network review. In some situations, agencies provide information on the size and scope of their network in the form of a printout from the Aerometric Information Retrieval System (AIRS), and in other cases, a report with maps and emissions figures are also included. The network review reporting format varies by Region and even within a Region, with the larger and more sophisticated State and local air monitoring agencies providing more detail on their networks than smaller agencies that may provide a short letter.

EPA's intention is to make the ***network assessment*** process build upon some elements of the network review by taking a more involved approach that includes reviewing the data collected by the network, discussing data needs with those who are supported by the program, and considering what level of performance can be achieved by the agency. The network assessment may be most effectively illustrated by considering the questions that should be considered.

-What are the various data collection objectives that a network should meet, at the national and local levels? EPA will revise the existing 40 CFR 58 to make the monitoring regulations more in line with data needs nationally. Regions must also consider what policy decisions must be supported in addition to the technical requirements. An example would include maintenance area monitoring requirements that are part of existing State implementation plans.

-What air pollutants are being measured and in what locations? Are the "correct" pollutants being measured in the best available locations to meet the national and State/local/tribal data needs? Does the network meet the national regulatory requirements? Are there additional State or local agency requirements that must also be addressed, and does the monitoring system meet these additional requirements?

-What data needs cannot be met due to limits in my budget/resources? It is important to understand both what can be provided by an ambient air monitoring network, and what cannot based upon existing resources.

-Are there monitors or sites in the network that would be more effectively located, or should any be removed? There are some arguments that suggest that removing samplers from a site does not save substantial resources. While it is true that the remaining monitors at that site would need to be maintained, removing unnecessary monitors would save on operator time at that site, possibly on the number of quality assurance audits, and on data management and validation.

-Are any environmental studies taking place in a monitoring agency's area that have a need for

the ambient data? How can these additional data interests be supported within available budgets? This support may vary from reconfiguring sites or collection schedules to simply making data available.

-Is the network providing data that are suitable in terms of their quality for the program needs? Are there areas where a monitoring agency needs to improve on performance? Has there been sufficient efforts to conduct technical systems audits, site inspections, and other quality assurance and quality control activities?

-Are there other data sources such as the regional haze program's IMPROVE network, the National Atmospheric Deposition Program (NADP), the Clean Air Status and Trends Network (CASTNet), or special purpose monitoring networks that may be useful to meet the agencies' data needs? Similarly, how does the State, local, and tribal agency network support these programs? Is the monitoring network design in the Region taking full advantage of these other governmental networks?

C. Roles, Responsibilities, and Network Assessment Schedules

As discussed briefly in the introduction, localized network assessments must be conducted in order for the network assessment process to be meaningful and achievable. OAQPS expects that each Regional Office will lead efforts among their State, local, and where applicable, tribal air monitoring agencies for network assessments. OAQPS will provide support and guidance when requested; however, the Regions are primarily responsible for the State and local air monitoring stations (SLAMS) networks and for the policy actions that stem from these data.

The Regions may choose to implement their network assessments over their entire geographic region by working with their monitoring agencies as a group, or individually. If the latter approach is taken, it is important that the Region consider monitoring in adjacent States or local areas that may produce data that are useful for informing a more localized assessment or data need. Both ozone and fine particles appear to drive many of the regulatory data needs; therefore, it makes technical sense that a regional approach is reasonable. OAQPS recognizes that many other factors will contribute to a Region's decision on how to most appropriately conduct their network assessments, and offers flexibility to the Regions in making this decision.

OAQPS requests that initial network assessments for the entire country be completed this year to start the process. Initial network assessment drafts should be provided by October 2002 from each Region to OAQPS. EPA does not expect that these initial draft assessments will have undergone the needed consensus building process by October; however, it is important that some effort take place this year. OAQPS expects that between October 2002 and February 2003 that Regions, States, locals, and tribal agencies will refine these initial draft assessments and complete a final network assessment by March 2003. These final network assessments should consider the technical data needs, some of the

logistical requirements for making the network changes, policy implications for any network changes, and of course, resource implications for making identified changes. Full consideration for how network changes may be realized will occur throughout 2003 as the networks are modified.

The OAQPS will review both the draft and final network assessments for national consistency issues in November 2002 and April 2003, respectively. OAQPS does not expect that each Region or monitoring agency will take necessarily the same approach toward conducting network assessments. There are a variety of approaches that could be foreseen that are equally valid. The OAQPS review will focus on the end results of these assessments and how they answer the questions listed above.

As for ongoing network assessments, OAQPS suggests a 5-year cycle for full network assessments. As with the initial assessments, the Region may choose to conduct these assessments at one time for the entire Region, or on a rotational basis. Conducting full network assessments annually is too large a burden, and not truly appropriate given that our NAAQS are generally multi-year standards that require multiple years of data at individual sites. OAQPS also recognizes that emission changes due to increasing controls are not likely to occur in a single year, and revisiting the networks over a longer period is warranted.

OAQPS intends to propose in upcoming regulatory changes that network assessments be added as a requirement. It will be important to also update language on annual reporting and certifications to reduce burden in these areas and to make better use of newer data management systems that eliminate the need for lengthly certification reports. OAQPS also proposes that deviations from national monitoring requirements are allowed for those agencies that participate in conducting an appropriate and approved network assessment that demonstrates that their alternative network meets the national needs as well as their own local needs.

II. Technical Tools

Regions and States can use any technically appropriate analytic tool or technique for their network assessments. They are encouraged to use multiple approaches. Similar results from different techniques can strengthen a case for reduced or redistributed monitoring, however, contrasting results may also be illuminating. Different approaches may yield different results because each approach probably has a slightly different objective/goal. Studying the different approaches and results will lead to a greater understanding of the various objectives and therefore lead to a network assessment most appropriate for the Region and/or State.

Several recently applied network assessment techniques, including the 'National Assessment' approach and various Regional methods, are described below. Some techniques and tools still under development are also noted. The intent of this list is not to provide all the details, rather to provide overview and motivation for the various techniques. Web links and/or contact information are provided in order for interested parties to obtain additional information. This is not an exhaustive list of methods. Also, the techniques listed below are provided for reference only. Regions / States can use these techniques, however, some may not be applicable to all areas or networks. Whatever techniques/tools are used, there should be a clear connection between the analytic results and the proposed network changes. Periodic updates to this document will highlight progress with the evolving methods and document additional illustrative Regional efforts.

A. National Assessment:

A National assessment of the criteria monitoring networks was completed in June 2001. The assessment consisted of three distinct parts: 1) an evaluation of measured concentrations as a percentage of the NAAQS, 2) a multi objective 'information value' ranking scheme which shows the relative value of each monitor according to different monitoring objectives, and 3) a trends evaluation. These pieces are described in broad terms below. The full analyses, including details of the technique, can be found at http://www.epa.gov/ttn/amtic/netamap.html. Although the National assessment was purposefully very general and did not advocate specific network cuts / changes, the approaches utilized may be appropriate for more refined, local assessments of the monitoring networks which can lead to actual network changes.

National Assessment components:

1. Evaluation of measured concentrations as a percentage of the NAAQS: An annual metric, corresponding to each criteria pollutant NAAQS, was computed for every active monitor for years 1998, 1999, and 2000. A 3-year average ('design value') of this metric was then calculated. [Note: Since $PM_{2.5}$ monitoring did not begin in earnest until 1999, a 2-yr 'design value' was used for the 2 $PM_{2.5}$ NAAQS metrics.] The 'design values' were compared to the NAAQS levels and assigned one of 4 bins:

100% or more of NAAQS, 80-100% of NAAQS, 60-80% of NAAQS, and less than 60% of NAAQS. Results were mapped and a National aggregation was bar-charted. Sites in the lower two categories, especially those 'less than 60% of NAAQS' have limited value for NAAQS usage. Although NAAQS usage is one of the central objectives of the criteria networks, other uses and objectives also exist and should be considered. The next described component of the National analyses considers multiple objectives.

2. Multi-objective 'information value' ranking scheme: Five independent measures were chosen to represent the information needs for population exposure, compliance monitoring, and tracking / model evaluation. These measures are: concentration, uncertainty (in 'design value'), deviation from NAAQS, area represented, and population represented. Each monitor was ranked (by pollutant / metric) according to those five measures. The 3-year 'design values' (computed as described above) were used in the calculations of the first three measures. A monitor's location relative to other monitors in the network was used to derive a 'sampling zone' polygon; these polygons were used to compute the latter two measures. Maps were produced for each of the five measures; the monitors in the highest ranked quartile were coded red, the monitors in the middle quartiles were coded black, and the monitors in the bottom quartile were coded blue. Hence, the red monitors were the most important (for that measure) and the blue monitors were the least important. The measure rankings were then aggregated based on several different weighting schemes and composite maps produced (using the same color scheme). Ancillary outputs such as 'Regional Breakdowns of the National Quartiles' and 'Tables of Quartile cutoffs (in measure units)' were also produced.

3. Trends evaluation: A non-parametric 'trend' routine (the same one used in the annual Trends reports) was applied to each monitor's annual metrics in 5- and 10-year cuts ('96-'00 & '91-'00). Each monitor was assigned one of 4 categories: significant upward trend, significant downward trend, no significant trend, or insufficient data. Results were summarized in pie charts. For a case study, the monitor trend information was merged with the output from #2 above and new maps produced showing the trend for specific quartiles (e.g., the blue category) of the aggregate 5-measure ranking. The rationale for this output was, even if a site is 'low value' (blue) in aggregate measure maps, you may want to keep the monitor if it has an upward trend.

Contact: Mark Schmidt (EPA-RTP, OAQPS): (919) 541-2416

B. LADCO/Region 5 Approach:

LADCO organized the first regional wide assessment of Region 5 States air monitoring networks. The assessment effort serves as a model for other regions throughout the country. The major process incorporated convening together monitoring and planning functions of the States, and EPA regional office staff, and developing objectives and priorities on which to base a range of decisions on investmets and divestments. The process benefitted from having an NMSC member, Mike Koerber, involved in the meetings as well as periodic input form EPA headquarters. Attachment 3 includes the initial product from this assessment.

In response to the ozone and $PM_{2.5}$ networks submitted to the Region by their monitoring agencies, the EPA Region 5 Air Monitoring Section reviewed the networks using a variety of data analysis techniques to determine the importance of monitoring sites. The Region 5 assessments of their ozone and $PM_{2.5}$ networks are capsuled below:

Ozone Assessment in Region 5:

Summary and Introduction

Region 5 analyzed the 1996 through 2000 daily 8-hour maximum ozone concentrations measured within the Region as well as surrounding areas to assess the current condition of the individual monitoring sites in relation to each other. The expected outcome of this analysis is a decision between the Region and the State and local air monitoring agencies as to which monitoring locations could possibly be terminated, relocated, or established.[1] To meet this objective, several analyses were conducted. The primary analyses focused on examining how relationships and concentration ratios between monitors are affected spatially between sites. The results of this analysis are intended to complement those obtained through the National Network Assessment.

Data

Hourly ozone concentrations were polled from the U.S.EPA Aerometric Information Retrieval System (AIRS) for the years of 1996 through 2000. Only data collected during the primary ozone forming months (May through September) were used for the geographic area of interest. Daily maximum 8-hour averages were calculated as prescribed in 40 CFR Part 50 Appendix H for each of the monitoring sites used in the analysis. All data regardless of flags in AIRS were included.

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[1]Tribal air monitoring activities in the Region 5 area are just beginning to be implemented, and modifications or reductions to their networks are not expected at this time. Tribal agencies will want to use these tools in future assessments after their programs have been developed.

Analyses

Ozone Correlograms

Pearson correlation coefficients (r) were calculated using SAS for every possible monitoring pair combination. A valid correlation coefficient was defined as one where there were at least 75 data points from each of the monitor pairs. Distances between sites were calculated using the following formula:

distance = arcos[cos(lat1)*cos(lon1)*cos(lat2)*cos(lon2) +
cos(lat1)*sin(lon1)*cos(lat2)* sin(lon2) + sin(lat1)* sin(lat2)]*3963.1925 miles
*1.609344 miles/km

where: lat1 and lon1 are the latitude and longitude coordinates of monitor one,
lat2 and lon2 are the latitude and longitude coordinates of monitor two,
1.609344 miles/km is the conversion factor of miles to kilometers.

Plots of the correlation between the two sites and their respective distances were created for every Air Quality Control Region (AQCR) in the Region 5 area of interest. In general, the correlation between two monitors diminishes as the distance between the monitors increases. These plots mainly were used to determine if there were any monitors which were relatively close to each another and had a relatively low correlation between their ozone measurements. This would signify that the monitor pair may be measuring concentrations unique to each site.

Plots of Correlation vs. Ratio between 2 monitors

Ratios of the concentrations between the monitor pairs used in the Correlogram analysis were calculated. Plots of the correlation of the two sites versus the ratio of the two sites were created to help determine if any highly correlated sites had significantly different concentrations.

Plots of Ratio vs. Distance between 2 monitors

Plots were created that display the ratios from the previous analysis versus the distances from the correlogram analysis. This analysis expands on the two previously described procedures to determine sites which are close to each another and may or may not have similar ozone measurements.

Summary Tables

Tables such as the excerpt below summarize the results from the Correlogram, Correlation vs. Ratio, and Ratio vs. Distance analyses.

Site 1	Site 2	Distance (km)	No. Obs.	Corr: R	Avg. Ratio	Median Ratio	Std. Dev.	Min. Ratio	Max. Ratio
170310001442011	170310032442011	18.2	759	0.81	0.86	0.89	0.22	0.16	2.07
170310001442011	170310037442011	34.7	92	0.83	1.14	1.12	0.33	0.21	2.67
170310032442011	170310063442011	15.4	747	0.69	1.97	1.71	0.95	0.75	9.25

PMF Results

Positive Matrix Factorization (PMF) was used to determine clusters of monitors displaying similar characteristics based on the concentrations measured at each site. PMF is an analysis technique similar to ordinary factor analysis except that it iteratively solves for both the factor loadings and scores and then predicts an individual monitor concentration. [See ftp://rock.helsinki.fi/pub/misc/pmf/ for details on PMF.] The factor loadings allow for the identification of groups of monitoring locations which exhibit related ozone concentrations. For this, 8-hour daily maximum ozone concentrations were used. Since this analysis requires a complete data record, missing days were estimated using a linear interpolation. Sites which had large amounts of data missing were removed from the analysis entirely.

$PM_{2.5}$ assessment in Region 5:

Summary

The purpose of this evaluation was to help the Region 5 monitoring agencies to assess the relative value of existing $PM_{2.5}$ monitors. This effort addresses the second basic objective identified in the *Regional Strategy* - identification of divestment opportunities. Parallel efforts by Region 5 and their monitoring agencies will identify areas for potential addition of $PM_{2.5}$ and other criteria pollutant monitors and will also promote expansion of the *State and Local Agency Regional Air Toxics Monitoring Network*.

Analyses

The Region 5 $PM_{2.5}$ monitors were evaluated on the basis of four decision criteria: 1) mean concentration, 2) monitor density, 3) correlation, and 4) population change. These criteria were designed to provide insight into the relative value of monitoring sites on the regional scale. The four criteria are described below and general findings are presented. This section is followed by suggestions on how to apply these findings.

Mean Concentration

A mean concentration and standard deviation were calculated for each monitor for the period of January 1999 - March 2001. Results were compiled in a spreadsheet and also mapped. Sites with fewer than 60 measurements were not evaluated (coded 'NA' on the spreadsheet). Sites were color-coded on maps and spreadsheets to indicate their relative value in terms of $PM_{2.5}$ concentration.

Region 5 monitoring sites were divided into five equally sized groups (quintiles) and color-coded as follows:

blue	6.86 - 12.21 $\mu g/m^3$ (lowest value sites)
light blue	12.24 - 14.04 $\mu g/m^3$
pink	14.05 - 15.33 $\mu g/m^3$
red	15.34 - 17.32 $\mu g/m^3$
dark red	17.34 - 20.82 $\mu g/m^3$ (highest value sites)

Please note that the same quintile color coding was used throughout the entire analyses. Monitors measuring lower $PM_{2.5}$ concentrations (with respect to the quintile ranges) are deemed less valuable than those giving higher measurements.

Site Density

Distance was measured from each individual monitor to the next nearest site, not including co-located monitors. Monitors in adjoining Regions were also considered as potential closest sites. Sites are color-coded on maps and spreadsheets to indicate their relative value in terms of site density. Monitors located closest to another site are deemed less valuable than those more isolated from other sites. Sites were divided into quintiles with blue sites having the lowest values (distance to nearest $PM_{2.5}$ site) and dark red sites having the furthest distances.

Monitor Correlation

Pearson correlation coefficients (R) were determined for each pair of monitors in Region 5 and adjoining states. The single highest correlation coefficient (R) for each monitor was identified. Results were compiled in a spreadsheet and also mapped. Sites with fewer than 60 measurements were not evaluated (coded 'NA' on the spreadsheet). Sites were color-coded on maps and spreadsheets to indicate their relative value in terms of monitor correlation. Monitors most highly correlated to another site are deemed less valuable than those with lower correlations. Dark red sites have the lowest R values and blue sites have the lowest R values.

Population Change

Percent population change (between 1990-1999) was indicated for the county in which each monitor is located. Data were obtained from the U.S. Census Bureau.

Application of Network Assessment Results

The above described decision criteria are not intended to be used independently, that is, we should not simply eliminate all low-reading monitors or cut the most highly correlated monitors in the

Region. Rather these criteria should be considered together and incorporated with other factors specific to each State and local agency. Despite the fact that the four decision criteria are quantitative in nature, it is difficult to quantitatively evaluate a group of monitors considering all four criteria simultaneously. The network reviewer may either: a) look at all decision criteria simultaneously in a qualitative way, or b) look at the criteria quantitatively in a stepwise manner as described below.

The following steps may be followed to identify the best candidates for elimination from a network. The network evaluator must first prioritize the importance of the described decision criteria. The suggested steps assume the following prioritization in decision making (criteria listed in decreasing order of importance): a) density, b) correlation, c) mean, d) population change.

1. Locate the information pertaining to the metropolitan area or State of interest on the results spreadsheet. Copy the pertinent rows into a blank spreadsheet.
2. Sort the rows based on Site Density.
3. Narrow the list by deleting the 50% of sites with the highest monitor value for Site Density, i.e., monitors which have a farther distance to the next monitor
4. Sort the remaining rows based on Correlation
5. Further narrow the list by deleting the 50% of sites with the lowest value for Correlation, i.e., monitors with lower correlations
6. From these remaining sites (the most redundant 25%), consider those with lower concentration means and lower population growth as the first candidates for network elimination.
7. Incorporate local issues and priorities in making final decisions

An alternate prioritization of the four criteria is possible, for example correlation may be considered the most important factor to consider, rather than site density. Further, the network reviewer may narrow the list to a different extent (more or less than a 50% cut in steps 3 and 5) depending on the size of the current network, the number of desired deletions, or other considerations. It is up to the monitoring agencies to decide how to best apply these results. According to the described assumptions, the sites remaining in the table may be considered the leading candidates for elimination in the Region. A portion of the table from the Region 5 analysis is shown below.

AIRS ID	Mean (µg/m^3)	Distance to Next Site	Correlation, Highest (R)	County Population Growth, Percent
1716100031	14.84	6.4	0.966	-15 to 0%
5507900592	14.54	6.9	0.971	-15 to 0%
5507900991	14.45	2.0	0.978	-15 to 0%

Agencies may wish to follow this same process on a statewide or citywide level to determine relative value of monitors on their localized scale. If multiple sites from the same area are left in the

table, the reviewer should not assume that all should be eliminated! Rather, the State should select among these sites, with the prime candidates identified as the monitors with a combination of lowest mean, highest density, and highest correlations. States may need to cycle through the entire process (including recomputation of the 4 metrics) after 'eliminating' a single or small number of monitors since the metrics and relative site values may change.

Contacts: Motria Poshyvanyk (EPA Region V, ARD): (312) 886-0267 [$PM_{2.5}$]
Mike Rizzo (EPA Region V, ARD): (312) 353-6324 [ozone]

C. Region 3 Approach

The approach to network assessment being proposed by Region III includes both the use of spatial fields and a decision making procedure (Multi-criteria Integrated Resource Assessment MIRA), developed in the Region, that allows for the simultaneous consideration of all relevant and quantifiable criteria. The approach is based upon a premise that tries to define air quality as an estimated spatial field of concentrations with a corresponding estimated field of uncertainties. The geostatistical technique of kriging is used to estimate air quality fields. The scientific merit of a given network design is judged on the certainty with which the actual concentration field can be reproduced from its measured data. The uncertainty field is constructed using modeled benchmark fields of concentrations that present a rational representation of possible future air quality, that is, air quality fields that the designed network is likely to encounter. The MIRA procedure was designed to help make informed and inclusive environmental decisions. It is a modular approach consisting of a Modular Data Collection Manager (DCM) which organizes, warehouses, and prepares data for analysis; a Geostatistical Indicators Module (GIM) that creates environmental indicators (reducing spatial maps to single indexed values for use as indicators); and a Decision Analysis Module which brings data, indicators, judgments together for holistic decision making. The general procedure Region 3 intends to use for network assessment is as follows:

1. Develop an appropriate set of modeled benchmark spatial fields.
2. Construct potential new network designs.
3. Construct a subset of concentrations from the benchmark fields based on the locations of the proposed monitoring sites.
4. Krig the concentration subsets - producing an estimate of the benchmark field.
5. Construct an uncertainty field by comparing the benchmark to the estimated benchmark fields.
6. Establish decision criteria.
7. Quantify the criteria for each network design.
8. Apply the MIRA decision approach.

Additional References:

- *Air Quality Data: A New Conceptual Approach*
  http://www.epa.gov/ttn/amtic/files/ambient/pm25/workshop/spatial/cimorelli.pdf

Contacts: Alice Chow (EPA Region III, AP): (215) 814-2144 [MIRA]
Al Cimorelli (EPA Region III, APD): (215) 814-2189 [spatial fields]
Cynthia Stahl (EPA Region III, APD): (215) 814-2180 [MIRA].

D. Design Interface Tool

The Design Interface (DI) is a software package that provides a graphical interface to evaluate alternative networks. The Design Interface makes extensive use of S-Plus which is a software package widely used by statisticians and data analysts. The existing version of DI allows users to input an arbitrary network of ambient monitors along with mathematical formulas used to describe the spatial structure of the data. From this information, the user is able to delete or add monitoring stations and display the consequences in terms of spatial predictions and uncertainties. For example, users can estimate the probability that an unmonitored area is exceeding a harmful threshold given concentration data from the network of nearby monitoring stations. Software and documentation for the current version of DI is available at the following web site: http://www.cgd.ucar.edu/stats/DI/.

EPA is upgrading DI to improve the data interface to DI so that data from AIRS and other sources can be easily inputted into the system. In addition, DI is being modified to include technical improvements and flexibility for the user in selecting network performance measures needed to evaluate alternative monitoring network designs. A feature will be added to enable users to examine and validate statistical assumptions about the spatial covariance structure and permit simple graphical display of correlation among monitors using brushing and highlighting techniques. Documentation will be significantly improved and example problems expanded to include ozone and $PM_{2.5}$ for a hypothetical planning area. Since DI is structured around the S-Plus language, users of DI must have access to S-Plus and the S-Plus spatial module. The enhanced version of DI should be available for user testing by late spring 2002.

Contact: Bill Cox (EPA-RTP, OAQPS): (919) 541-5563

E. Additional Techniques Under Development

The elements listed below came to fruition based on discussions at the Spatial Data Analysis Technical Exchange Workshop held December 3-5, 2001 in the Research Triangle Park, NC. [Presentation materials from that workshop can be found at http://www.epa.gov/ttn/amtic/spatlwrks.html.] The activities listed below will be pursued in parallel with each of the ongoing monitoring network assessments. The purpose of these elements is to establish a framework for generating reliable spatial fields. The statistical theory that is used to develop space-time models of ambient concentrations is evolving. As techniques and tools are developed, these will be made available for use in understanding airsheds, designing monitoring networks, developing control strategies, and supporting epidemiological studies.

One element is a white paper, proposed to be completed in April 2002. At the workshop, several people suggested that the participating scientists prepare a white paper describing the benefits of using interpolated spatial fields instead of using only points in space. There are several statistical papers addressing this approach. Summaries of these papers together with a discussion about the potential policy uses of spatial fields will comprise the white paper. The workshop participants agreed that this white paper could be a catalyst for getting spatial fields into the regulatory process.

The second element is a round robin by collaborators and EPA scientists to compare and contrast various techniques for developing fields of spatial predictions and associated uncertainties. Three to five emerging techniques as well as some of the techniques described in this Guidance will be part of the round robin, and each technique will be applied to the same database. The basics of the round robin include a series of objectives that get progressively harder. What is learned from each stage will hopefully be incorporated into existing tools, such as the previously mentioned Design Interface tool, so that agencies can use the tools for improved spatial prediction and network design. The series of objectives include:

1. Prediction of field of $PM_{2.5}$ 3-year average of annual average concentrations and uncertainties.
2. Prediction of field of $PM_{2.5}$ 3-year average of 98th percentiles and uncertainties.
3. Forecasting of field of daily $PM_{2.5}$ concentrations in support of public reporting.
4. Prediction of 3-year average of 4th max 8-hour average ozone concentration.
5. Multi-pollutant prediction.
6. Optimal designs.

Contacts: Shelly Eberly (EPA-RTP, OAQPS): (919) 541-4128
Ellen Baldridge (EPA-RTP, OAQPS): (919) 541-5684

III. Acronyms & Web Sites

AIRS - U.S. EPA's Aerometric Information Retrieval System (reference web site: http://www.epa.gov/airsdata.

AQCR - Air quality control region (reference 40 CFR 81)

CASTNet - Clean Air Status and Trends Network (reference web site: http://www.epa.gov/castnet)

CFR - Code of Federal Regulations

DCM - Data collection manager

DI - Design interface tool (reference web site: http://www.cgd.ucar.edu/stats/DI/)

GIM - Geostatistical indicators module

IMPROVE - Interagency Monitoring of Protected Visual Environments (reference web site: http://vista.cira.colostate.edu/improve)

MIRA - Multi-criteria integrated resource assessment, developed by EPA Region 3.

NAAQS - National Ambient Air Quality Standards (reference 40 CFR 50)

NADP - National Atmospheric Deposition Program (reference web site: http://nadp.sws.uiuc.edu)

NMSC - National Monitoring Strategy Committee (reference web site: http://www.epa.gov/ttn/amtic)

OAQPS - Office of Air Quality Planning and Standards, U.S. EPA

PMF - Positive matrix factorization (reference web site: ftp://rock.helsinki.fi/pub/misc/pmf/)

QA - Quality assurance

RTP - Research Triangle Park, North Carolina

SLAMS - State and local air monitoring stations (reference 40 CFR 58)

Attachment 3

Draft LADCO/Region 5 Air Monitoring strategy

REGIONAL MONITORING STRATEGY

The purpose of this document is to propose a strategy on how to best utilize available resources for ambient monitoring in the Region V States. The strategy reflects two basic objectives:

(1) Investment Needs: New monitoring efforts are needed to support new air quality challenges, including monitoring for air toxics and new technology for criteria pollutants.

(2) Divestment Opportunities: To make more efficient use of existing monitoring resources and to help pay for (and justify additional resources for) the new monitoring efforts, it will be necessary to make certain "cuts" in the existing criteria pollutant monitoring networks. *A fundamental assumption in this strategy is that any resource savings resulting from these cuts in a given state will be reinvested to support additional monitoring efforts within that state.*

It is expected that this document will need further review and discussion within each state and with the general public before it can be finalized.

I. CORE PRINCIPLES

The regional monitoring strategy was developed consistent with the following core principles:

- State-by-state recommendations to improve (decrease, increase, relocate, revise) existing criteria pollutant monitoring networks based on consideration of:
  - i. public information[1]
  - ii. public health/compliance with NAAQS
  - iii. strategy development (i.e., support modeling)
  - iv. trends/strategy evaluation
  - v. multi-pollutant sites (supersites)
  - vi. regional-scale (O3, PM2.5) v. local-scale (CO, SO2, Pb, PM10) pollution problems
  - vii. population-oriented sites
  - viii. over-monitoring (redundancy) and under-monitoring
  - ix. low concentrations
  - x. state rules
  - xi. population growth

[1] The states are committed to providing the public with air quality data on a near real-time basis. To this end, each state has established a web site where daily ozone data are available and has participated in USEPA's ozone mapping project, as part of EMPACT. These efforts, especially EMPACT, have been very successful. Unfortunately, USEPA will be discontinuing funding for EMPACT before the program can be expanded to deal with other air pollutants which may pose as much of a threat to public health as ozone. For example, at some locations in the Region V States, there were more days in recent years in the "unhealthy for sensitivity groups" category for PM2.5 than O3. It is, therefore, recommended that USEPA continue funding EMPACT to ensure that it will provide the public with near real-time information for all air pollutants, as appropriate.

- Establish regional air toxics monitoring network
- Not bound by Federal regulations and policies; need to change NAMS/SLAMS regulations and nonattainment policies
- Evaluate new technology
- Provide for state/local flexibility (address local needs – e.g., TSP in WI)
- Ensure adequate data quality assessments, including regionally consistent procedures for quality assurance, data validation, and data interpretation
- Address important administrative issues, including public outreach, reinvesting resource savings, preserve funding and jobs (with retraining opportunities), and a general understanding of the long-term direction of the national program

II. RECOMMENCED CRITERIA POLLUTANT MONITORING CHANGES

Based on the core principles outlined above, each state reviewed their existing criteria pollutant monitoring networks and identified proposed changes to be phased-in over the next two to three years. The proposed changes are summarized in Table 1 and Figures 1 – 7. In general, these changes reflect elimination of several existing monitors, establishment of a few new monitors, and a movement toward multi-pollutant sites. The number of monitoring sites in each state (including industrial monitors in IN and WI) before and after these proposed changes are as follows:

	O3	PM2.5 Mass	PM2.5 Cont	PM2.5 Spec	PM10	TSP	Pb	CO	SO2	NO2
IL	42/33	35/32	2/2	6/6	17/11		15/7	9/8	22/19	10/9
IN	43/35	40/30	3/3	2/7	25/22		6/6	5/4	8/7	4/4
IN-ind.	2/1				11/5		3/2	0/1	28/27	2/0
MI	25/15	27/18	10/10	9/10	9/2		10/6	7/5	7/5	4/4
MN	7/7	22/17	1/3	1/3	19/13		2/2	10/10	8/8	4/4
OH	51/40	48/46	2/2	14/14	72/33		14/5	15/10	32/19	4/3
WI	36/30	28/22	3/3	6/6	6/6	15/15	0/0	5/2	4/3	4/4
WI-ind.						16/16				
Total	204/160	200/165	21/23	38/46	148/87	15/15	47/26	51/39	81/61	30/28

(Note: numbers above reflect number of sites “before” / “after”)

Several comments on the proposed changes should be noted:

- Only minor reductions in the existing ozone networks are proposed. This is appropriate given the current widespread 8-hour ozone problem in the region. Some of the proposed changes involve relocation of monitors to rural areas to provide information on regional ozone levels.

- Only minor reductions in the existing PM2.5 FRM networks are proposed at this time. It is believed that three full calendar years of data are needed for NAAQS compliance determinations before any massive reductions are considered. It is, however, reasonable to consider at this time: (1) relaxations in the sampling frequency to 1-in-6 day at sites where the annual NAAQS is clearly controlling, and (2) elimination of low concentration, redundant FRM monitors if resources are needed now to support deployment of speciation or continuous monitors. Once three full years of data are collected, then divestment in FRMs and investment of continuous monitors should be pursued. Guidance and support is needed from EPA on moving from filter-based to continuous measurements.

- Significant reductions in PM10, Pb, CO, SO2, and NO2 networks are proposed, consistent with the absence of any regional air quality problems for these pollutants. Further reductions in the number of monitors will be considered.

- A preliminary cost analysis was performed to determine the cost savings associated with the proposed reductions. For example, it is estimated that the shutdown of 27 parameters at 22 sites in Illinois would save about $275K. Based on these approximate costs and the proposed reductions in the other states, the savings appear range from less than $100K in Minnesota to more than $500K in Ohio. While not insignificant, these savings will not be sufficient to pay for new monitoring efforts, such as a regional air toxics network.

- Several graphical analyses performed by USEPA, Region V are supportive of the proposed changes. These analyses include correlation maps for ozone and PM2.5, PMF analysis, and krieging analysis (see Figure 8). In particular, these analyses demonstrate redundancy in the existing ozone and PM2.5 monitoring networks.

- An additional review of the proposed changes should be conducted to address the adequacy of the regional/rural monitoring coverage, and to identify any additional opportunities for combining sites (i.e., supersites). Note, several of these supersites appear to qualify as " national core" (NCORE) sites, which are being considered in draft USEPA guidance:
    - IL – Northbrook and E. St. Louis
    - IN – Gary (IITRI) and Evansville (F.S. #17)
    - MI – Detroit (E. 7 Mile), Grand Rapids, and Seney
    - MN –
    - OH – Cleveland (14th St.), Cincinnati (Taft Rd), and Steubenville
    - WI – Milwaukee (SER Hdqs) and Mayville

- In addition to the criteria pollutant monitoring, it should be noted that the States support several other related monitoring programs. These programs include the base 9-station PAMS network:

Type	*Purpose*	*Site*
1	background	Braidwood (IL)
2	urban	Chicago - Jardine (IL)
		Milwaukee - SE Hdqs and UWM-North (WI)
		Gary - IITRI (IN)
3	peak concentration	Harrington Beach (WI)
		Northbrook (IL)
		Holland (MI)
4	downwind	Zion (IL)
		Manitowoc (WI)
	upper air	Zion (IL)

Supplemental measurements planned for 2002 and beyond include aircraft sampling in the Lake Michigan area by Wisconsin DNR and by Bob Jacko (Purdue University); aircraft sampling in other nearby areas by Bob Jacko (Purdue University); tall building measurements (Sears Tower); operation of an ozone monitor on the Badger ferry (between Manitowoc, Wisconsin and Ludington, Michigan); operation of an open path monitor at Northbrook to provide real time measurements of VOC and carbonyl; and operation of visibility cameras at several sites. Table 2 summarizes the site locations and parameters for the base and supplemental measurements.

III. REGIONAL AIR TOXICS MONITORING NETWORK

The regional air toxics monitoring network builds upon the individual state air toxics monitoring programs and an initial 5-state monitoring network. The initial 5-state network will include at least one site in Illinois, Indiana, Michigan, Ohio, and Wisconsin and will be consistent with the FY2000 Air Toxic Pilot Program. This monitoring will start in early 2002, and will collect data to assess “community-oriented” population exposures. The goals of the initial 5-state network and the proposed regional network are as follows:

- measure the same 18 “core” compounds identified for the FY2000 Air Toxic Pilot Program;
- sample on a every-sixth day schedule;
- sampling duration of 24 hours (but may be shorter or longer depending on the particular objectives and consideration of detection limits);
- similar monitor siting criteria;
- same analytical methods as in the FY2000 Air Toxic Pilot Program;
- state laboratory inter-comparisons to be conducted using split samples and canister exchanges, and the results applied to historical Region V air toxics data; and

- same quality assurance practices as in the FY2000 Air Toxic Pilot Program to be employed.

Table 3 lists the monitoring site information, pollutants to be measured, sampling schedule, and sampling/analysis methods for the initial 5-state network. It is envisioned that the regional network will expand the initial 5-state network. Note, based on the cost estimates for the initial 5-state network (i.e., about $60K/site), a regional network of say, 5 – 10 sites per state, will cost about $1.8 – 3.6M per year. Additional funding will be needed to pay for this monitoring. (Please note that these plans are subject to change based on forthcoming guidance on the national air toxics monitoring network.)

IV. RECOMMENDED REGULATION CHANGES

The elimination of several sites above will require a waiver from certain monitoring requirements in 40 CFR Part 58, Appendix D (Network Design for State and Local Air Monitoring Stations [SLAMS], National Air Monitoring Stations [NAMS], and Photochemical Assessment Monitoring Stations [PAMS]):

- Section 3.2 (SO2 Design Criteria for NAMS): waive the requirement for 2 - 4 monitors in urban areas with population > 1,000,000 and low concentrations, and for 1 - 2 monitors in urban areas with population 500,000 - 1,000,000 and low concentrations

- Section 3.3 (CO Design Criteria for NAMS): waive the requirement for a micro-scale, and/or middle or neighborhood-scale monitor in urban areas with population > 500,000

- Section 3.4 (O3 Design Criteria for NAMS): waive the requirement for a downwind monitor for all urban areas with population > 200,000

- Section 3.5 (NO2 Design Criteria for NAMS): waive the requirement for two monitors in urban areas with population > 1,000,000

- Section 4.4 (Network Design for PAMS, Minimum Monitoring Network Requirements): waive the requirement for VOC and carbonyl sampling at Type 1, 3, and 4 sites (or accept the proposed changes as part of an “alternative” network design, as provided by section 4.2)

In addition, consideration should be given to revising the minimum quality assurance requirements. For example, 40 CFR Part 58 requires bi-weekly precision checks for automated methods. A reduction in the number of checks is recommended, especially for monitors that measure concentrations below the NAAQS.

V. NEW TECHNOLOGY

The states are committed to the evaluation and deployment of new monitoring technology, especially for PM2.5 and air toxics. To this end, the following new technology is being used (or considered) by the states:

IL	OPSIS (for formaldehyde, benzene/xylene, and mercury)
	Continuous mercury monitor
	Modified auto-GC for toxics
	Diffusion tubes for toxics saturation monitoring
	Glass-lined canisters for VOCs and toxics
MI	Hexavalent and total chromium monitors
	PAHs using modified PUF sampler
	Continuous mercury with TEKRAN (w/ speciation) and LUMINEX
OH	Ammonia monitoring
WI	Ammonia monitoring
	Continuous mercury with TEKRAN analyzer

In addition, most states are establishing visibility cameras (as part of the Midwest "hazecam" network), and continuous PM2.5-mass and continuous PM2.5-speciation monitors.

VI. FEEDBACK

This document and the proposed network changes reflect the opinions of the monitoring staff in the Region V States. An important step in the development of the regional monitoring strategy is to get input from the following groups: (1) technical and regulatory staff in the States and USEPA; (2) policy types, especially state air directors; (3) stakeholders, including local government, environmental groups, and private industry; and (4) the general public. Based on this additional input, this document and the proposed network changes will be revisited.

VII. SUMMARY OF RECOMMENDATIONS

- A regional air toxics monitoring network should be established.
- States should continue to pursue new technology, especially for PM2.5 and air toxics.
- A number of changes (decreases, increases, relocations, revisions) to the existing state criteria pollutant monitoring networks are proposed.
- A public outreach effort is needed to explain and seek "buy-in" on the proposed changes to the criteria pollutant monitoring networks.
- The resource savings resulting from the proposed changes in a given state will be reinvested in that state. Note also that the resource savings will not be sufficient to pay for the regional air toxics monitoring network. Additional funding will be needed.

- USEPA should revise the NAMS/SLAMS regulations to relieve the states of certain monitoring requirements and to allow some of the proposed network changes.

- USEPA should continue funding for EMPACT to ensure that near real-time information is provided to the public for all air pollutants (especially, PM2.5), as appropriate.

Figure 1

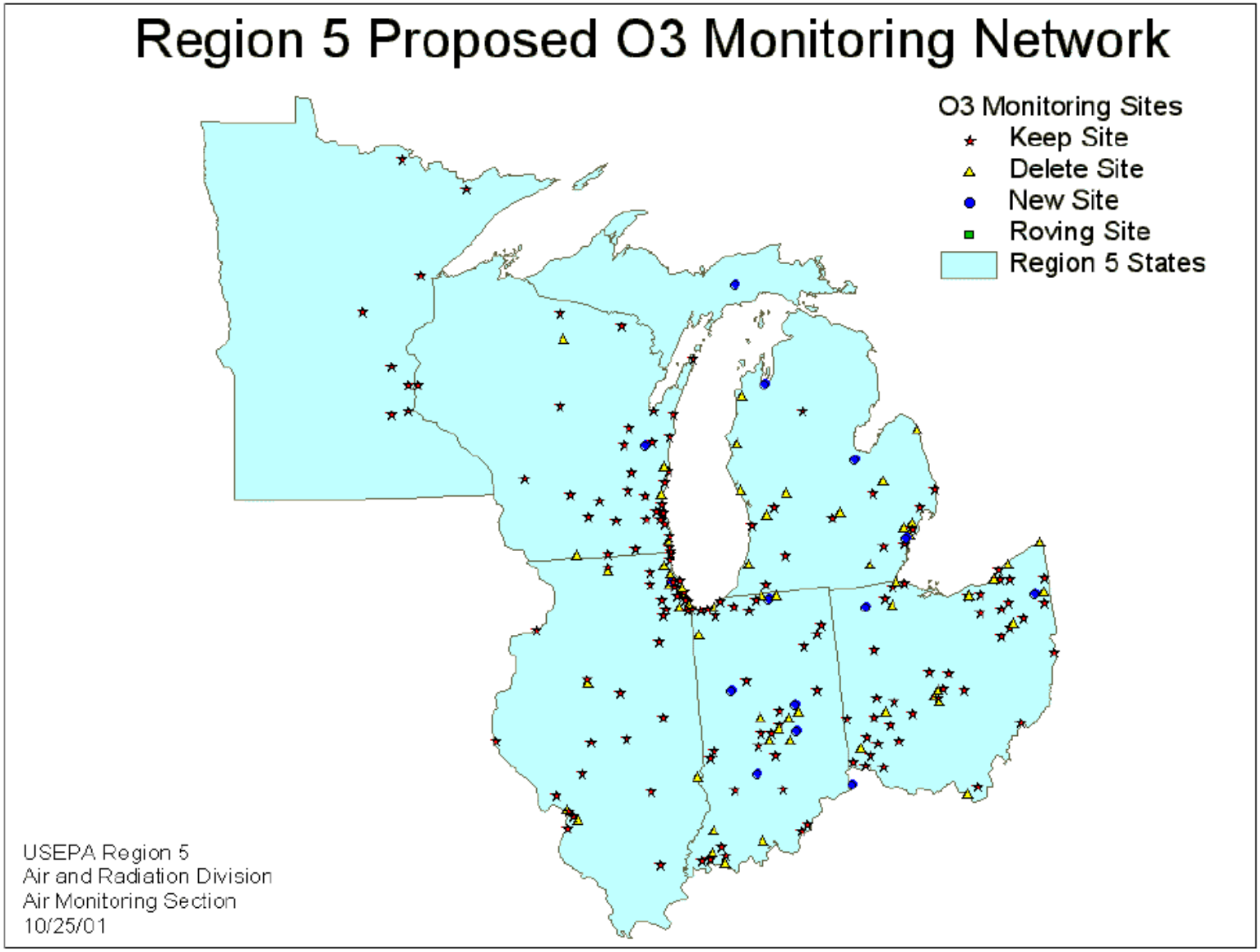

Region 5 Proposed O3 Monitoring Network
O3 Monitoring Sites
Keep Site
Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 2

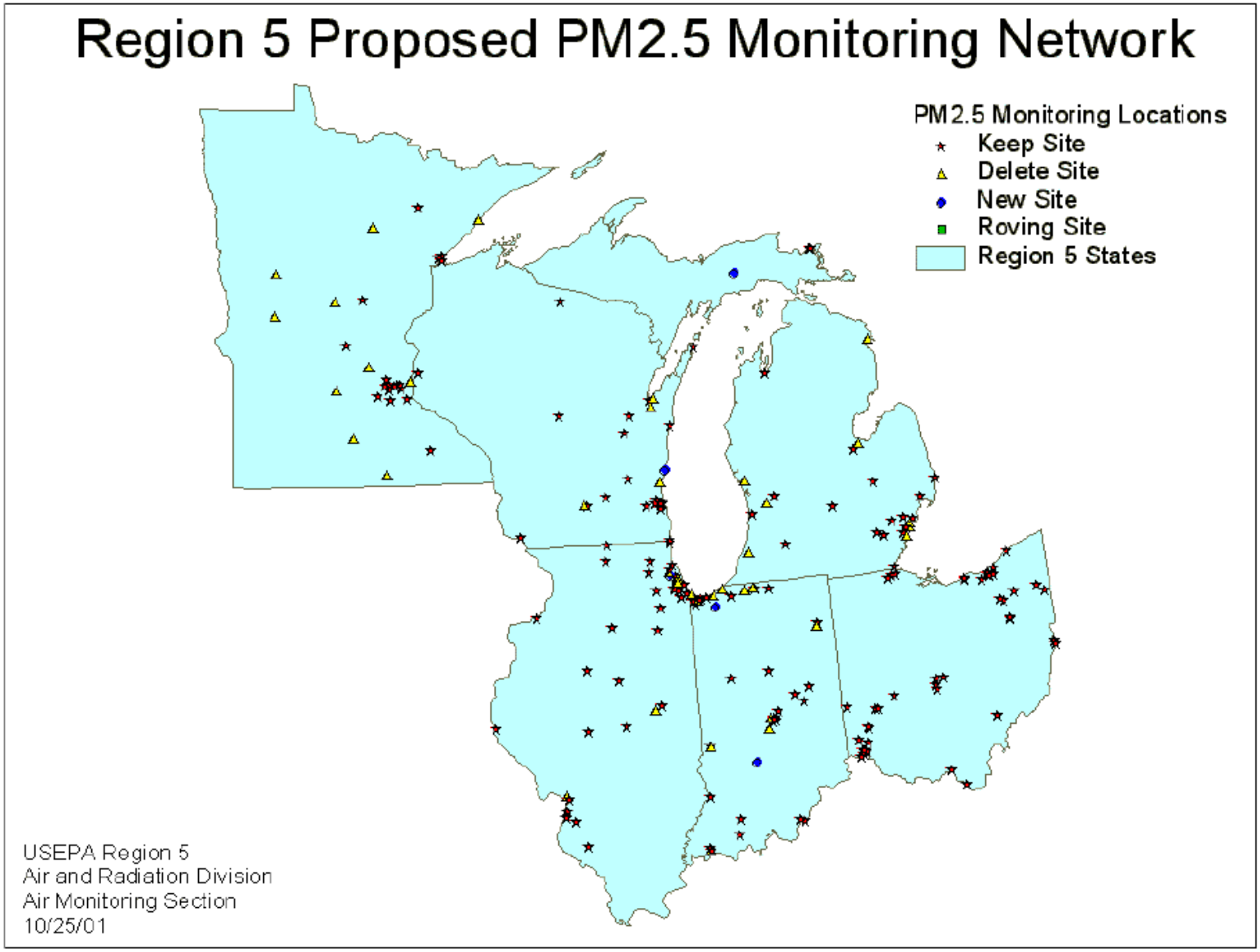

Region 5 Proposed PM2.5 Monitoring Network
PM2.5 Monitoring Locations
Keep Site
Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 3

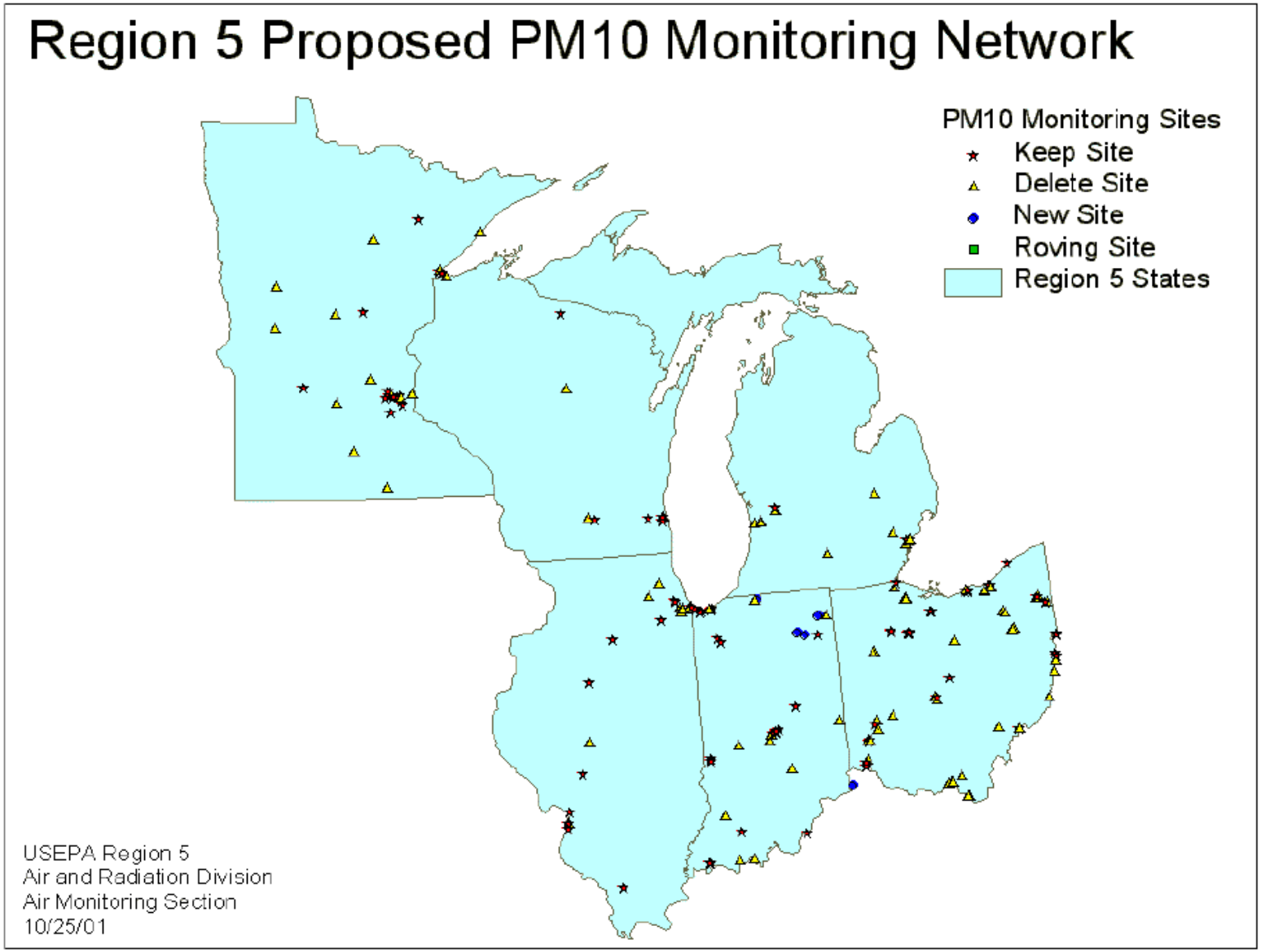

Region 5 Proposed PM10 Monitoring Network
PM10 Monitoring Sites
Keep Site
Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 4

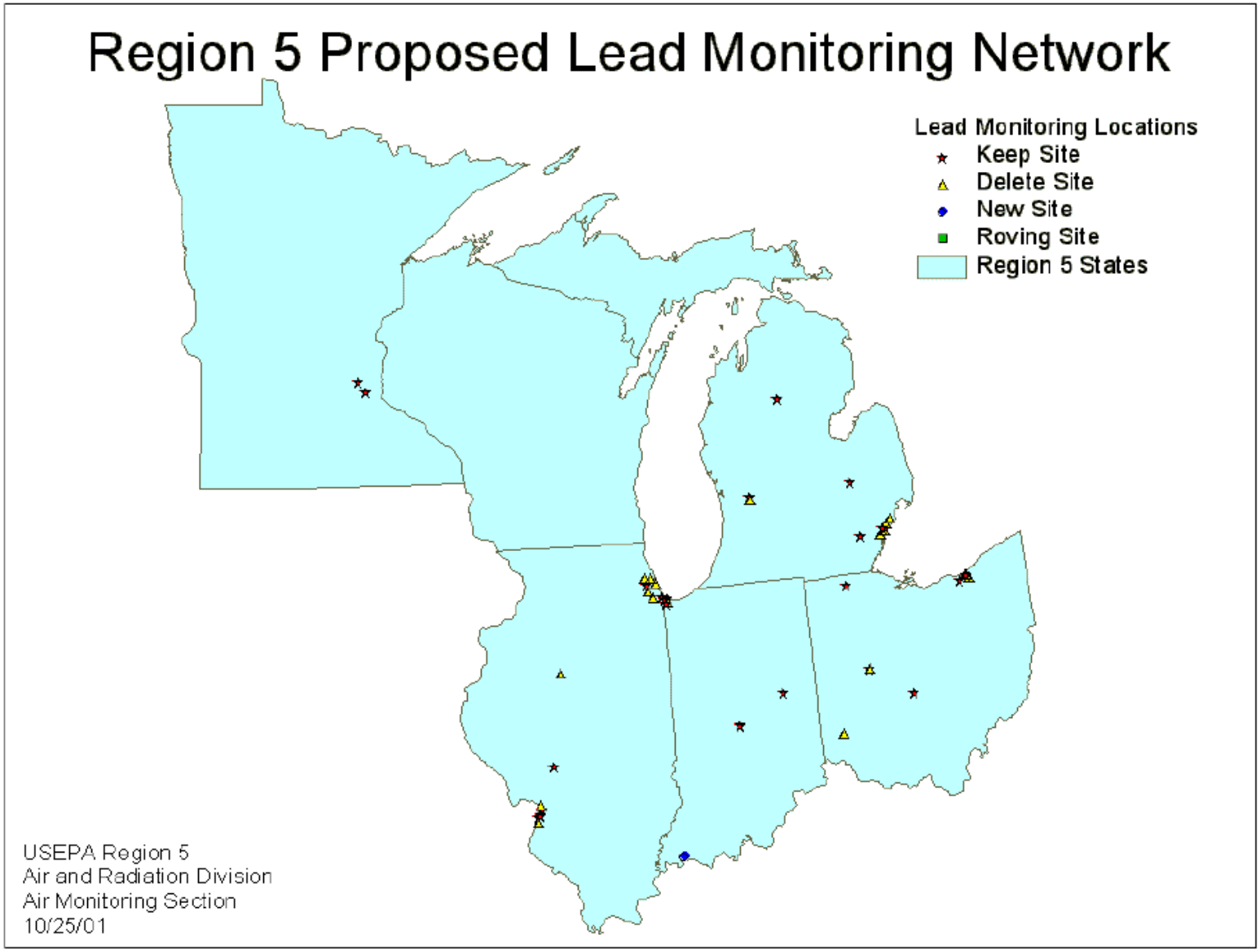

Region 5 Proposed Lead Monitoring Network
Lead Monitoring Locations
Keep Site
Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 5

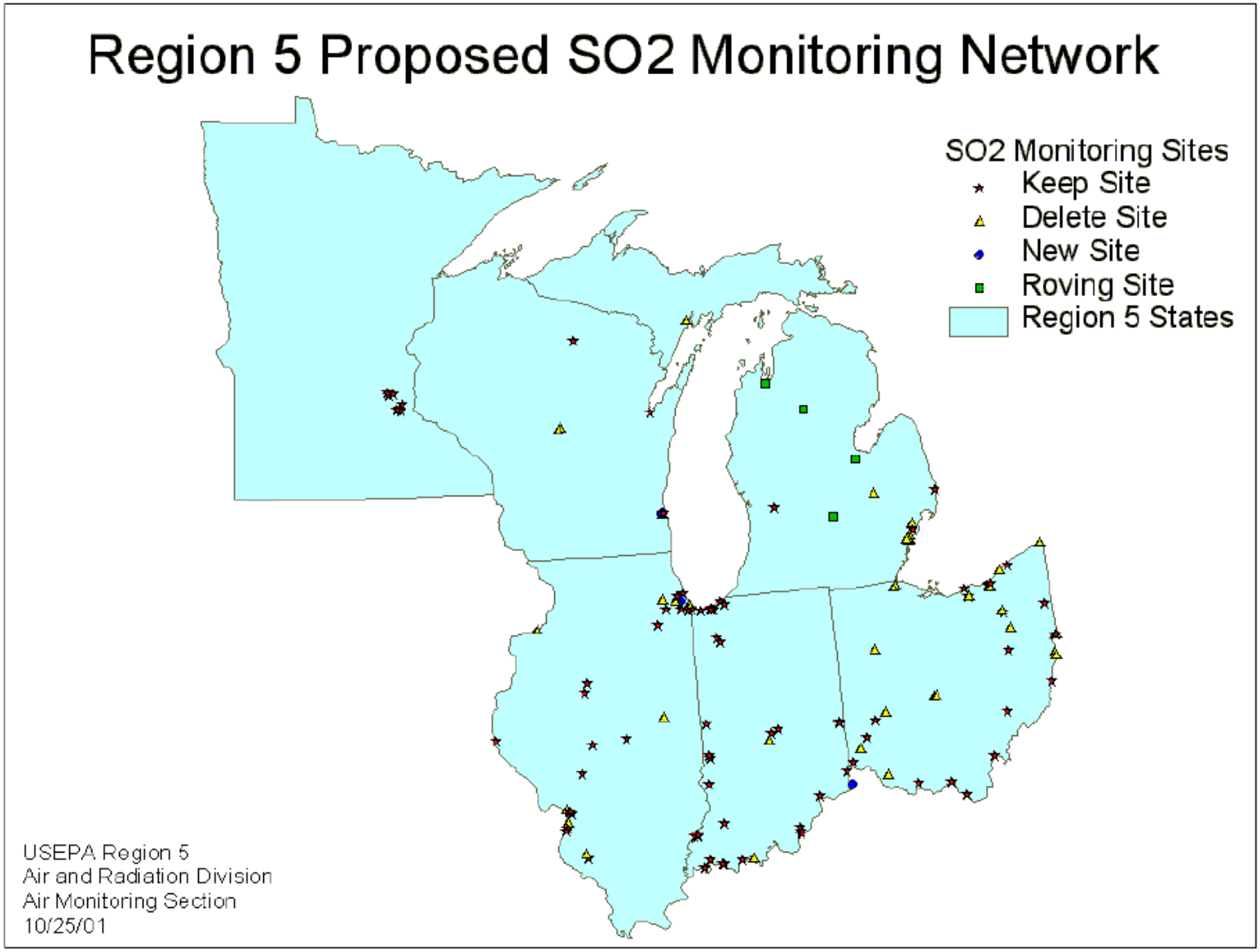
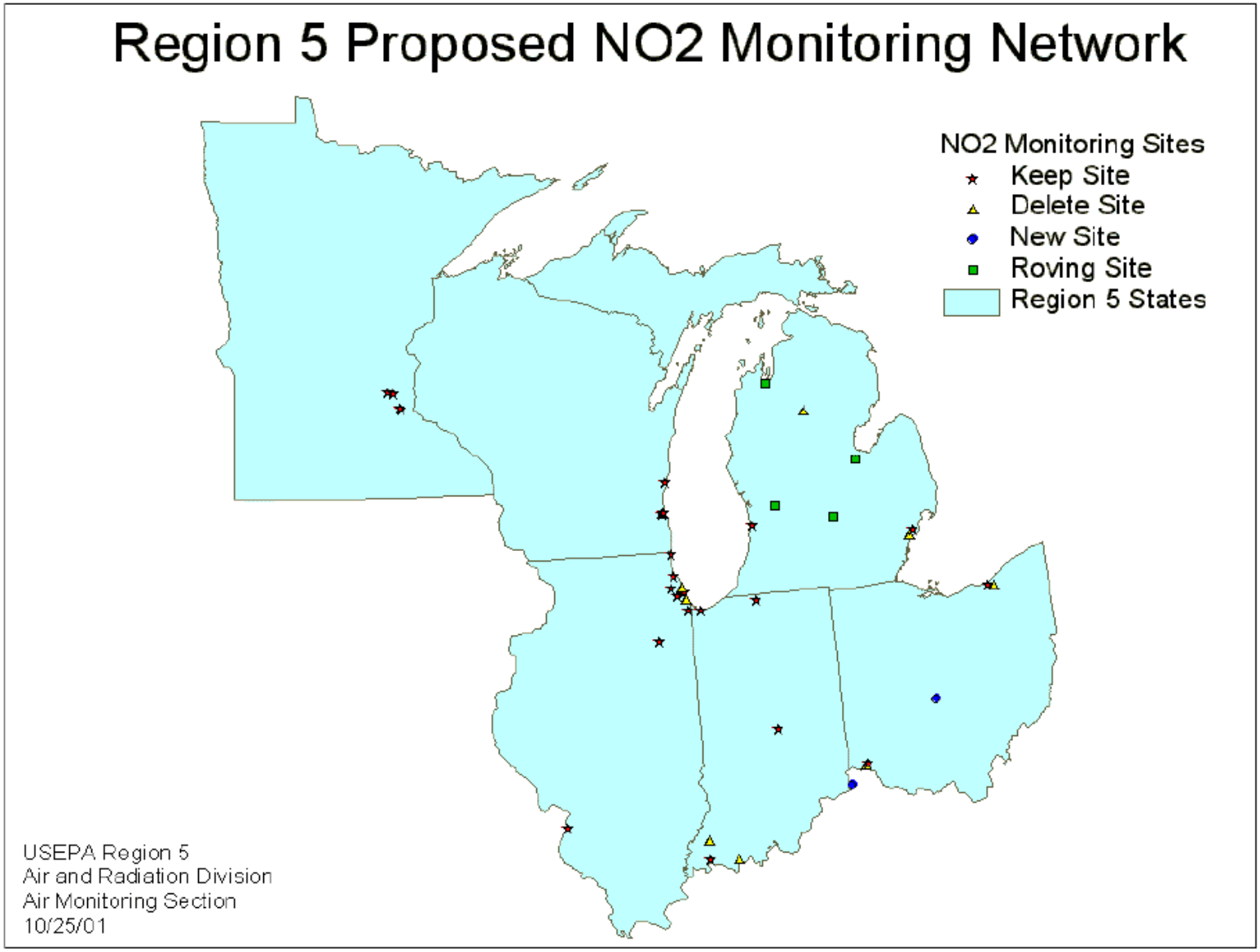

Region 5 Proposed SO2 Monitoring Network
SO2 Monitoring Sites
Keep Site
Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 6


Region 5 Proposed NO2 Monitoring Network
NO2 Monitoring Sites
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Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 7

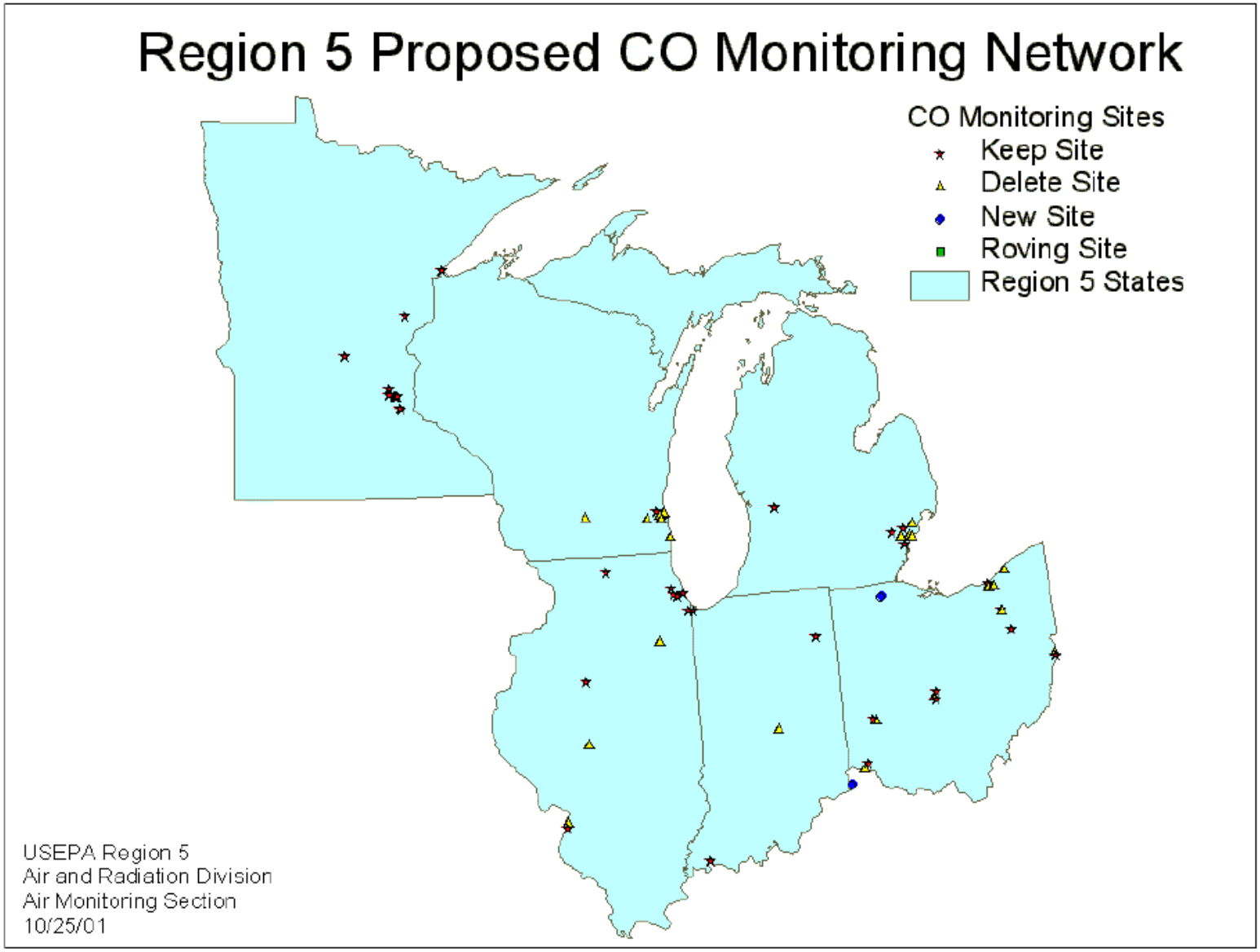
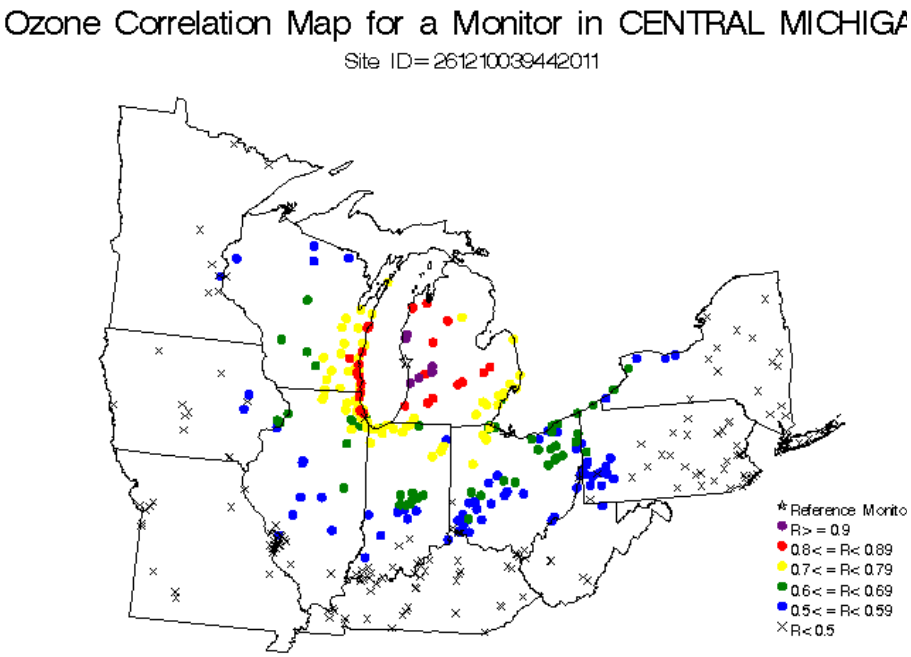
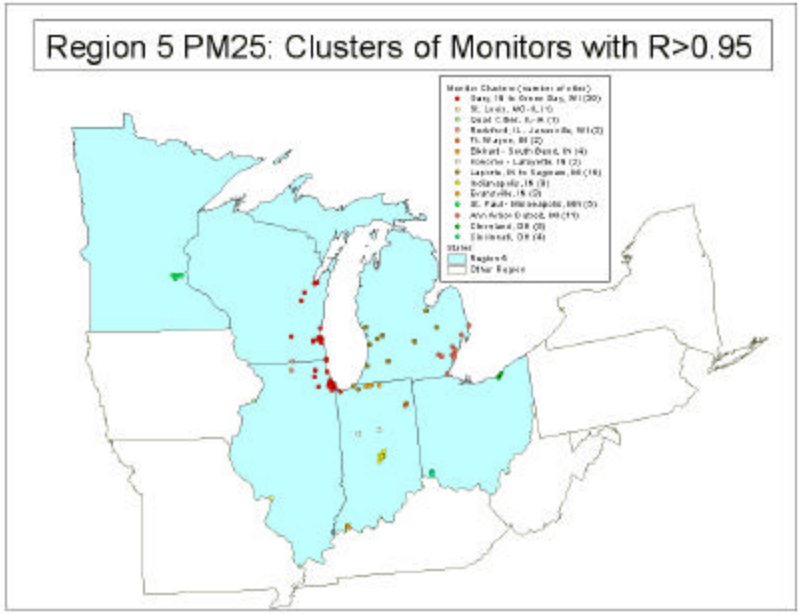
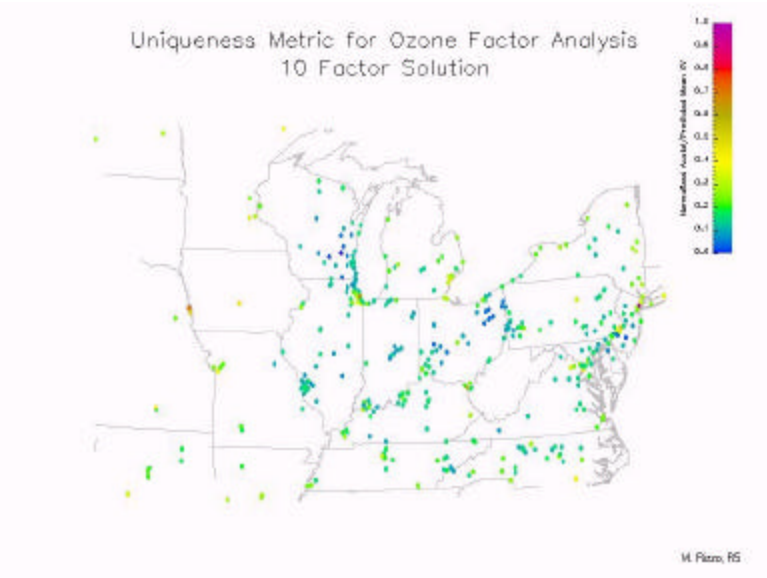

Region 5 Proposed CO Monitoring Network
CO Monitoring Sites
Keep Site
Delete Site
New Site
Roving Site
Region 5 States
USEPA Region 5
Air and Radiation Division
Air Monitoring Section
10/25/01

Figure 8. Region V Graphical Analyses







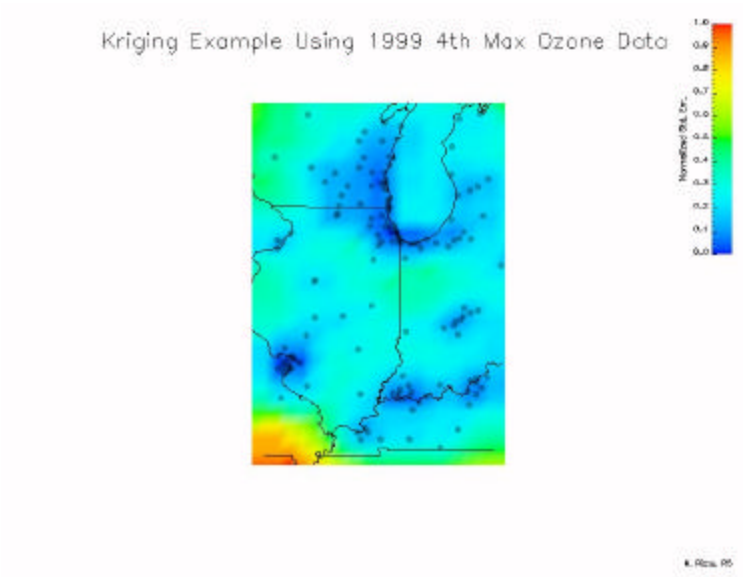


Table 2. Site-Parameter Listing for the Lake Michigan PAMS Network

Site	Type	O3	NOx	NOy	Met	VOC	Carb.	$PM_{2.5}$ Spec.	Open Path	Upper Air Met
Braidwood	1	X	X	X						
Chicago_Jardine	2	X	X		X	A	X			
Northbrook	3	X	X		X	A,t	X,t	X	X	
Zion	4	X	X,s	X	X	A	X			X
Milwaukee-SE Hdqs	2	X	X,s	X		A	X	X		
Milwaukee-UWM	2	X	X		X	t	t			
Harrington Beach	3	X	X		X	C *(24-hour sample every 6th day)*				
Manitowoc	4	X	X,s	X	X			X		
Gary-IITRI	2	X	X	X	X	A,t	X,t	X		
Holland	3	X	X	X	X			X		
WI Aircraft		X		X	X,p	C	X	X		
Jacko Aircraft		X				C	X	X		
Sears Tower		X								
Badger Ferry		X								

A = auto-GC
C = canister sampling
s = high sensitivity NOx
t = air toxics sampling (24-hour canister sample every 6th day year-round)
p = partial met (temp, rel. humidity)

Table 3. Monitoring site information, pollutants to be measured, sampling schedule, and sampling/analysis methods.

Urban Area	Monitoring Site		Pollutants to be Measured	Sampling Schedule	Sampling Apparatus/Media	Analytical Method
	Street address	AIRS ID				
Chicago, IL	Water Treatment Plant 750 Dundee Road Northbrook, IL	17-031-4201	53 VOCs, 14 carbonyls, 8 metals + continuous Hg	1 in 6 day	VOCs - summa-polished canister, Carbonyls - DNPH cartridge, Metals - TSP (hi-vol) particulate sampler using quartz filter	VOCs - TO-14a gas chromatography, Carbonyls - TO-11a high pressure liguid chromatography, Metals - atomic absorption spectroscopy
	4743 Mannheim Road Schiller Park, IL	17-031-3103	53 VOCs, 14 carbonyls, 8 metals	1 in 6 day for carbonyls + metals; VOCs collected on a limited basis (6-12 sample days selected at random)		
Indianapolis, IN	3120 E. 30th St. Washington Park Indianapolis, IN	18-097-0078	9 "core" VOCs + subset of TO15, 11 carbonyls, 7 metals	1 in 6 day	VOCs - summa-polished canister, Carbonyls - DNPH cartridge, Metals - TSP (hi-vol)	VOCs - TO-15, Carbonyls - TO-11a high pressure liguid chromatography (ERG), Metals - IO-3 - Inductive Coupled Plasma/Mass Spectrometry (RTI)
Cleveland, OH	Fire Station #22 7300 Superior Ave. Cleveland, OH (St. Clair/Superior neighborhood)	39-035-0047	71 VOCs, formaldehyde + acetaldehyde, 8 metals	1 in 6 day	VOCs - summa-polished canister, Carbonyls - DNPH cartridge, Metals - TSP (hi-vol) particulate sampler using glass fiber filter	VOCs - TO-14a gas chromatography, Carbonyls - TO-11a high pressure liguid chromatography (contract lab), Metals - acid extracttion followedby inductively coupled plasma emission spectroscopy
	Fire Station #11 7629 Broadway Ave. Cleveland, OH (Slavic Village neighborhood)	None		1 in 6 day		
	Board of Education 7733 Stone Rd Independence, OH	None		1 in 12 day		

Urban Area	Monitoring Site		Pollutants to be Measured	Sampling Schedule	Sampling Apparatus/Media	Analytical Method
	Street address	**AIRS ID**				
Detroit, MI	TBD	TBD	18 “core” compounds + other compounds measured during 2000 Detroit pilot	1 in 6 day	VOCs - summa-polished canister, Carbonyls - DNPH cartridge, Metals - TSP (hi-vol) particulate sampler	VOCs - TO-15 gas chromatography, Carbonyls - TO-11a and SW-8315 (MDEQ), Metals - Note: TSP samples to be analyzed as monthly composites.
Madison, WI	Water Reservoir Dayton & Livingston St. Madison, WI	55-025-0025	34 VOCs 13 carbonyls, total PCBs, 8 metals	1 in 6 day for VOCs + carbonyls; 1 in 12 for metals; 1/12 for PCBs (plus 1/24 from 10/15 to 3/31)	VOCs - pressurized passivated canisters, Carbonyls - DNPH coated silica gel cartridges, PCBs - quartz fiber filters with polyurethane foam back-ups using a General Metal Works PS-1 (hi-vol) sampler, Metals - quartz fiber filters using a General Metal Works TSP sampler	VOCs - TO-14 - cryogenic concentration followed by a single column gas chromatography, Carbonyls - TO-11 - solvent extracted and analyzed by high performance liquid chromatography with UV detection, PCBs - TO-4 - solvent extracted by soxhlet and cleaned extract analyzed by gas chromatography with EC detection, Metals - acid extraction followed by either Inductively Coupled Plasma Emission Spectrophotometry (ICP) or Atomic Absorption Spectrophotometry (AA) Note: Nickel and beryllium to be collected on 72-hour composites samples.

Section 4. National Core Network (NCore)

4.1 Background

The vision of the monitoring strategy includes not only the optimization of current networks through assessment activities, but also shaping ambient air monitoring networks to accommodate identified measurement needs and improved technologies. This direction must incorporate knowledge acquired in air quality research and management practices over the last two decades, and take advantage of much of the existing infrastructure of operating networks and monitoring agencies (local, state, tribal, and federal). The experience over the last 20 years suggests three basic enhancements that can be implemented in national network design:

1) allowing for **multiple and collocated pollutant measurements** to better diagnose cause effect phenomena between public health effects and air pollution and atmospheric processes,

2) characterizing **regional scale air quality** to understand the linkage between background and transport concentrations (regional, continental, global scales) as they affect rural and urban environments. This need has become increasingly important as the separation in pollutant concentrations between rural and urban air pollution levels continue to decrease,

3) **accommodating new technologies** to provide timely reporting of air quality information to the public and to improve basic characterization of physical, chemical, temporal and spatial composition of air quality.

Consistent with these enhancements, the National Monitoring Strategy Committee (NMSC), has identified the following areas for improving the monitoring program:

greater characterization of hazardous air pollutants (HAPs);
additional continuous particulate matter monitoring;
additional information transfer and delivery to the public; and
integration across pollutant programs.

Networks have evolved over time through a layering process largely in response to new ambient air quality standards (e.g., $PM_{2.5}$ program) or Clean Air Act (CAA) requirements (e.g., PAMS). Taken individually, each program design generally had a single pollutant perspective with well intentioned objectives that often were not met or communicated effectively. The monitoring strategy presents an opportunity to take a more visionary and holistic approach toward integrating traditional ambient air quality networks from multiple pollutant and objective perspectives. The importance of an appropriate balance between national and local or area- specific needs has been stressed throughout this strategy document. Networks must address both localized and national level issues, and network design features (e.g., site location, measurement parameters, sampling frequency) are subject to the

relative balance between local and national needs. The development of this National Core (NCore) network proposal addressing "national" level objectives is a useful step to identify minimum national network needs and can provide a reference mark to assess the relative balance between national and local oriented networks.

The rationale for even considering national based networks is simply a recognition that a very significant part of any "local" air pollution problems often are associated with some form of long-range transport or part of an extensive regional wide airshed problem. Similarly, a major component of emissions reduction strategies are based on national measures, examples including numerous motor vehicle regulations and major point source provisions such as Title 4 of the CAA (acid rain precursors), and nitrogen oxide SIPs in the Eastern United States and the 3- pollutant legislation (proper description?). The nature of "National" ambient air quality standards implies an understanding of the cause-effect phenomena between pollutants and adverse health impacts in many based on a rage of diverse populations and locations throughout the nation. Numerous national level modeling tools drive a range of air quality prediction and health assessments requiring consistency in measurement approaches.

We assume that the need, and therefore resources, for monitoring to characterize and assess localized air quality issues is equal or greater than that required for national needs. Therefore, the development of a national network component must be limited to allow for needed flexibility to address local issues as well as to accommodate emerging technologies and science/policy needs that often are constricted by massive infrastructures. In application, enough overlap exists between national and local design features such that a network designed for a national purpose more often than not also services a local need. For example, a national speciation trends site is used in concert with other mass and speciation sites for a more detailed local characterization of an area's particulate matter. Conversely, AIRNow incorporates numerous area specific ozone monitors to provide national and regional ozone concentration surfaces.

4.2 Attributes of Ncore

The NCore network is envisioned to be a stable long standing network that should be viewed as a "minimum" infrastructure to address major national monitoring objectives. These national objectives and other attributes are used as a starting point for design. Included are the needs to provide timely public information, develop and track progress of national level emission strategies, support health assessments underlying regular National Ambient Air Quality Standard (NAAQS) reviews and provide general characterization for air quality trends and compliance. In describing national objectives, a substantial degree of overlap with area specific objectives in aspects of network design will emerge. That is part of the overall optimization and leveraging that we strive to achieve. The scope of this activity retains the focus on traditional networks operated by State, local agencies, and Tribes. National needs beyond these that include ecosystem welfare assessments, global atmospheric transport and diagnostic research must be integrated as we attempt to leverage and

optimize national network resources, and that discussion is addressed later in this section.

Core Attributes

A. NCore would support the following national level monitoring objectives:

1. Public information.

The acquisition of real-time data from across the country (e.g., through AIRNOW) using continuous technologies for timely dissemination to the public. Such information would drive national mapping programs for $PM_{2.5}$ and ozone reported from AIRNow, support public air quality forecasts and public health advisories for various pollutants. To date, AIRNow effectively has used and evolved into a national resource built upon available data sources from an array of State and local networks designed for non-mapping purposes. By specifying mapping as a national objective, network spatial design tools can be applied to optimize the existing networks with a cohesive central mapping theme that lends itself to other applications including emission strategy development and compliance.

2. Emissions strategy development.

The development of emission reduction strategies relies on large regional to national scale air quality simulation models as one of several tools in combination with various area specific analyses. Models require evaluations which occur at different spatial scales and levels of complexity. National level models often undergo fairly routine "operational" level evaluations that rely on routinely collected data. These routine operational evaluations complement more complex diagnostic evaluations utilizing aircraft data, research grade measurements of atmospheric intermediates and sink species. In application, three types of monitoring approaches are used for model evaluation. First, the NCore component would support much of the operational evaluations of AQSMs, principally by ensuring broad and consistent geographic coverage. Second, the availability of routine data from local oriented networks and mapping related networks (e.g., AIRNow) would enhance the spatial richness of observations for evaluation purposes. Third, routine measurements from Ncore would complement intensive field campaigns that provide more complex detailed measurements (time, space and composition) for diagnostic evaluations.

Numerous source apportionment and other observation driven models attempt to use measurements directly to associate source receptor effects and infer emissions reduction approaches even in nonlinear systems. While the application of these tools tend to be area specific, the availability of NCore sites that include multiple collocated measurements will provide significant benefits and also allow for consistent national level applications.

Mapping tools delivering public information should strive to minimize concentration surface error and produce coherent pollutant concentration patterns which can guide emissions strategy

development.

3. Tracking air quality trends and emissions strategy progress

NCore would provide the primary input to track national air quality trends of a range of non criteria and precursor pollutants as reported in EPA's annual air quality trends and related reports. The NCore also would accommodate an important accountability component of air quality trends, which tend to place somewhat greater emphasis on directly emitted precursor species to determine if emission strategies are being implemented as originally intended. For accountability purposes, consideration must be given to locating some NCORE sites in rural representative locations with instrumentation capable of detecting long term emission changes associated with implementation of national programs such as Title 4, the NOx SIP calls and three pollutant (nitrogen, sulfur, mercury) initiatives.

Program tracking also would include national visibility assessments as well as a selected limited group of hazardous air pollutants (HAPs)[1] that tend to be of concern in numerous locations nationwide.

4. Support health assessments that influence periodic NAAQS reviews (i.e., 5-yr EPA review process).

Historically, much of the underlying health effects research has relied on routinely available data to associate various adverse health impacts with air quality. NCORE would provide a diversity of monitoring locations across the nation to provide a stable base of data for long term health assessments. These health assessments require basic "representative" air quality data of several common pollutants across a diversity of population and emission regimes. The NCore design will emphasize the importance of capturing diverse locations and provide a minimum group of routine collocated measurements that will assist both health assessment and emissions strategy development needs. More advanced air quality measurements would be conducted through collaborative research endeavors and not directly supported by State/local agencies and Tribes. However, where possible the development of NCORE platforms should anticipate the need for possible collaborative work ranging from toxicologists choosing to collect occasional "mega" aerosol samples to atmospheric scientists conducting research grade measurement studies. Therefore, platform capacity, space and power specifications, generally should be designed to avoid future extensive retrofitting.

5. Compliance.

NCORE will be used for basic comparisons to the NAAQS. Traditionally monitoring for

[1] The air toxics monitoring steering committee is developing a list of HAPs that will be proposed to be measured at selected trends sites, which will be incorporated into NCORE.

NAAQS comparisons has been more of a localized objective brought about by national regulations. Increasingly the extent of nonattainment for our principal criteria pollutants (PM2.5 and ozone) has become in many instances more of a regionalized issue due to numerous factors including, shifting demographics away from urban centers, widespread homogeneous behaviors of PM2.5 aerosols in many Eastern U.S. locations, and the shift to a lower concentration 8 hour ozone NAAQS. Here again, the characterization of concentration surfaces through mapping requires both national and local perspectives.

6. Research Support.

Many of the previous objectives discussed the complementary role routine networks play in supporting research. Routine data generally complement more intensive research oriented efforts spanning a range of atmospheric process and health assessment studies. While NCore design will be driven to address non research objectives, the overlap between research and regulatory needs is substantive and it is imperative that NCore be viewed as an important research resource. To that end, components of the NCORE network should facilitate collaborative work with research institutions in a manner similar to the Supersite program. Certain NCore platforms could serve an important instrument evaluation need at a national level. The NCore proposal will include some number of collocated multi-pollutant sites that serve primarily the objectives listed above. Collocation also provides opportunities for diagnosing measurement methodology issues as the more complete characterization of atmospheric chemistry provides enormous insight into likely causes of measurement artifacts. The concept is not that routine Grant programs for State/local/Tribe agencies siphon their resources to support research institutions, but rather that a greater level of complementary work across research and regulatory agencies is engendered as part of the NCORE design which provides more optimized benefits for all parties. As platform capacity is reviewed for accommodating new measurements, enhanced capacity should be built in for collaborative work where researchers may need to use platforms for short periods of time to collect large samples of aerosols for toxicological studies, or operate research grade measurements in concert with more routine instrumentation.

Other broad based national air monitoring objectives include ecosystem welfare assessments, characterization of global/continental level transport phenomena and explicit research objectives. The six objectives listed above are compatible with the existing federal grant structure where section 103 and 105 Grants are administered by EPA to State, local agencies and Tribes. Nevertheless, significant integration and optimization opportunities exist to link with these other major national objectives. The need for such integration and outreach is explored in more detail below.

Additional NCORE Attributes

The following attributes provide insight into various aspects of NCore that further guide design and subsequent implementation. Many of these attributes will be addressed in the design and related discussions below.

B. To provide a consistent national network of multi-pollutant measuring sites.

C. To provide consistent air quality information for both urban and rural areas.

D. To provide a basis from which the augmentation by state/local/tribal monitoring networks can be utilized to meet state/local/tribal monitoring priorities.

E. To accommodate the national needs for monitoring new pollutants (e.g., air toxics).

F. To maximize leveraging of existing air monitoring sites, especially those with multi-pollutant capabilities.

G. To the degree it can be accommodated, provide data and other support for essential science needs:

health/exposure and toxicological studies;
evaluation of new monitoring methods; and
characterization of atmospheric processes and source-receptor relationships (e.g., air quality model evaluation; source characterization techniques).

4.3 Attributes of the State/Local/Tribal Monitoring Networks

The development of NCore does not replace the role of localized networks, and no premise is made on the relative importance of national versus local needs . The following listing of attributes illustrates some of the major differences between NCORE and the more flexible component of State/local/T ribe networks. These attributes largely are not addressed through NCore directly, although national and local networks share common features.

A. To address state/local/tribal concerns not adequately addressed through NCORE. Examples include:

"hot spot" or mobile monitoring for air toxics,,
source-specific monitoring,
community/environmental justice concerns,
emissions reduction strategy assessments,
tracking non-criteria pollutants of concern,
NAAQS designation requests, and
enhanced monitoring as needed for local characterizations of key pollutants and/or their precursors .

B. To establish the highest priorities for state/local/tribal air monitoring needs and utilize local flexibility to shift resources to meet those needs, including the reduction of inefficient monitors and the addition of value-added monitors as necessary.

C. To utilize data collected in meeting Attribute #1, above, such that the benefits of the NCore network can be enhanced.

D. To meet federally-recommended monitoring objectives to the degree possible.

4.4 Rationale for multi-pollutant sampling and spatial mapping (with attachments)

The design process described below includes a firm recommendation for moving toward collocated multi-pollutant monitoring. Although the need for multi-pollutant measurements will emerge from design based on meeting the stated objectives, there are additional logical reasons to move towards collocated multi-pollutant monitoring:

1. Minimizing monitoring site operational expenses. A central site with several instruments requires far less travel time and site attention and maintenance than a diffuse network, assuming, of course, attendant reductions in single pollutant sites.

2. Fostering integrated air quality management. For years we have recognized the administrative burden of working in a single pollutant framework, when we understand an array of technical linkages across air pollutant categories. From an emission source perspective, mobile and stationary combustion sources simultaneously emit ozone and PM precursors as well as a host of hazardous air pollutants. Numerous chemical and physical atmospheric processes either link several pollutant categories or operate in parallel (Attachment 1 (FACA concept paper; specific references...NARSTO ozone assessment...NARSTO PM/O3 paper (spaghetti..diagram), Seinfeld paper). Examples include the shared mix of precursor (i.e., primary emissions), intermediate and sink species that link ozone and fine particulate matter (and haze); the adsorption dynamics where particles act as carriers of various hazardous air pollutants; numerous transformations where oxidant precursors (e.g., xylene, toluene, pinenes) are capable of transforming into organic aerosols, specific compounds (e.g., formaldehyde) that act as an important which is a HAP, an ozone precursor and through chemical pathways that influence particle formation. The list of examples is endless and provides a motivation for integration; however, the intention is not to imply that every aspect of air pollution is integrated. The historical emphasis on single pollutant programs needs to move toward a more integrated approaches, and air monitoring is a logical infrastructure component to help facilitate progress.

3. Addressing major objectives related to emission strategy development and NAAQS reviews (Model evaluation and health assessment examples)

   Example 1. Air Quality Model Simulation evaluation:

Air quality simulation models (AQSMs) attempt to package all of the emissions, atmospheric chemical and physical dynamics discussed above. The very structure of AQSMs therefore is based on an integrated multi-pollutant framework. Questions have been raised regarding the role of routine networks, such as NCore, in evaluating models. For example, diagnostic (e.g., stressing the model to determine if it reproduces observations for the right reasons) model evaluation require short period

intensive field campaigns incorporating vertical chemical/physical profiling throughout the troposphere and research grade measurements of complex radical and sink species all beyond the scope of S/L/T routine networks. This reality is not in conflict with the need for basic operational (e.g., does the model generally reproduce observations of important precursor and product species) evaluations of AQSMs that may span an entire year or more, and be subject to specific episodes of concern not covered in an intensive field campaign. Some of this concern is traced back perhaps to the role of ozone models in estimating the high one hour prediction. Comfort levels on model performance were focused on a few summer based high concentration episodes, and model performance during other seasons was not a priority. The change in ozone standards to a lower value eight hour average and the dominance of the annual PM2.5 standard require our models to perform well (and be evaluated) over more diverse time and meteorological regimes. Moreover, the large regional behavior of ozone and PM2.5 present national level issues that result in the AQSMs (e.g., CMA-Models 3, REMSAD) applied over large spatial domains covering the entire contiguous United States. As the models are now applied over increasingly larger spatial and time scales, the monitoring networks must adopt and provide a minimum level of support for their evaluation. Finally, an infrastructure of routine measurements even during those intensive field campaigns designed for diagnostic model evaluation are required.

Three very critical component of NCore address the model evaluation needs: spatial mapping, multi-pollutant measurements and continuos data. From an operational model evaluation perspective, models attempt to replicate major surface scale features of the primary pollutants of interest, largely PM2.5 and ozone. The emphasis on mapping as a National need for public information purposes is just as critical for AQSM evaluation, as well as other emissions strategy elements (e.g., defining planning areas and tracking progress over time) and health and exposure assessments (see below). The leveraging addition of collocated pollutants improves the ability to evaluate models by providing greater challenge to testing more than one state variable at a time. In effect, the availability of important collocated species restricts the ability to subjectively improve model performance and can serve to identify areas need for improvement. The core multi-pollutant species were chosen as key species from both model evaluation and health assessment perspectives. Finally, the emphasis on continuous data is valued from a model evaluation perspective. Although one role of a model may be to estimate an annual average, AQSMs generally calculate predictions over small time intervals and typically can provide output at one hour time intervals. The ability to test model's temporal behavior benefits both short and long term predictive ability as errors at small time scales can easily aggregate to cause problems over large time scales.

While this discussions has emphasized the use of data in evaluating model performance, a far more important integration across observations and models must be fostered through the air quality community. Calculated model concentrations and observations are all predictions, they just use different tools or formulations to arrive at the same product. A point measurement based on "measurement determined" observation is perhaps no more representative of the larger area of volume of concern than that the developed through a "model." In a sense, modeled data and measured data all are predictive results from the spatial and temporal perspective from which we interpret data. We

need to make much better progress in integrating modeling and monitoring techniques and take advantage of the maximum benefits derived from their highly synergistic usage. An opportunity now is presented to meld real time modeling data that are corrected "nudged" by the observations to produce our best and most timely representations of more complete spatial surfaces as part of future vision for linking observations and model predictions through the information transfer initiative being nationally through NCore. On a related note, the use of spatial fields have multiple benefits for air quality planning and tracking which will improve with our ability to characterize spatial fields over frequent time intervals. s we push these spatial concepts from an observations perspective, we should aggressively build our deterministic modeling capability into the process.

Other observational techniques including source apportionment models that connect emission source categories with receptors (measurements) and observational based models (OBMs) that use measurements to infer precursor control preferences (e.g., NOx or VOC for ozone; NH3 or NOx for PM) derive clear benefits from NCore multi-pollutant sites. Again, these tools as well as predictive models all together require basic inputs and checks for their operation. Collectively, with direct observations all the modeling tools applied in both traditional and unique means are used in"weight-of evidence" schemes to develop practical emission reductions strategies.

Example 2. Health and exposure assessments for NAAQS reviews

Many of the arguments for model evaluation apply to exposure and health assessments. First, we have an absolutely clear national need to maintain a minimum core network to support long term exposure and epidemiological assessments that factor into the recurring five year reviews of the NAAQS. To be clear, NCore supplies only a basic infrastructure of routine measurements. We are not undertaking personal or indoor monitoring that is necessary for exposure assessments. NCore will however provide key centralized monitoring data from which to related back to more detailed micro scale and other ambient exposure related measurements. Similarly, NCore will not collect all of the suspected particulate matter related agents hypothesized to be key players in the direct adverse health impacts associated with PM (e.g., soluble metals, ultra fines, biologicals,..). The basic goal of health assessments is to develop causative relationships between specific air pollution parameters and adverse health effects. This is best achieved by sampling a variety of pollutants over a range of diverse populations, covering different air quality conditions brought on by different climatologies and emissions patterns (i.e., mix and strengths of source types). Multiple pollutant species need to be sampled at different locations to better delineate the effects of a particular species by teasing out a range of confounding factors associated with interactive effects among different pollutants. Accordingly, NCore should measure multiple pollutants across a diverse group of platforms reflecting a range of populations, climatology and air quality composition across the United States.

4.5 Design Process

The design approach will follow a sequence of site selection steps and measurement

recommendations based on addressing the six objectives listed above. The major objective drivers for national level air quality model evaluation and health assessments suggest "representative" multi-pollutant site locations not unduly influenced by local sources with average air quality conditions for the specified area. Such locations should be optimized for representing both "typical" populations and surrounding air quality (e.g., spatial range of representativeness of 5-20 km urban locations, and > 50 km rural locations). This siting approach was largely followed in establishing the PM2.5 speciation trends sites. Note that maximum concentration locations are not emphasized in this approach. This "national" design approach may appear at odds with historical monitoring design that has focused on identifying maximum concentrations. Maximum concentrations for individual pollutants will be captured either through localized efforts (i.e., identifying a local maximum is more of a local priority than a national one) and the numerous single site recommendations to support mapping. Similarly, we need to value low concentration and rural locations. The inclusion of low concentration sites with high concentration areas provides more power for delineating cause-effect health related phenomena , and allows for more rigorous characterization of urban air quality phenomena by separating out "regional" and "background" influences. An emphasis on representative air quality supports national level objectives underlying health assessment/exposure and air quality model evaluation. From an accountability perspective, we should be concerned with progress in abating total exposure (i.e., the sum of concentrations and persons exposed) in addition to abating an isolated maximum concentrations, which may not be reflective of general exposure.

Initially, a design will be proposed that is reasonable and achievable for implementation over the next one to five years. The design will be constrained by adhering to "near zero" resource constraints and maintaining flexibility for local programs. Therefore, the five year proposal will maximize leveraging of existing networks to accommodate design recommendations. Discussion regarding longer term "ideal" design is addressed below under linkages to other programs.

Stepwise approach to five year NCORE implementation plan:

Step 1. Identify minimum site locations to support long term health assessments and exposure studies. Attachment 1 provides a description of the approach for identifying a cross section of representative locations across the United States for long term epidemiological studies. These locations in turn are compared to existing speciation sites to identify candidate sites. This procedure will yield from 40 to 80 population oriented multi-pollutant locations for consideration by the NMSC.

Step 2. Identify important regional and rural multi-pollutant sites that represent major transport corridor, concentration gradient and background locations to support evaluation of national based AQSMs. Identify existing rural site locations (e.g., IMPROVE, CASTNET, S/L/T) that offer available platforms.

Step 3. Identify siting needs to support national/regional mapping efforts such as AIRNow and other spatial design tools that interpolate observed data to produce coherent surface depictions of air quality concentrations. This applies only for relatively pervasive pollutants of national importance and would be limited to ozone and PM2.5. To date, AIRNow simply uses all available data to produce output, a procedure expected to continue. As part of this national design effort, the spatial models should be applied to determine optimal site locations to support mapping and produce a road map for future site additions and removals.

4.6 Proposed measurements and site definitions

The proposed NCORE network elements are based on the complexity and number of measurements performed at a platform. The most comprehensive multi-pollutant sites are designated Level 1 and cover a master list of species (Table 1) at 3-10 locations nationally. Level 2 stations would include the core group of continuously reading pollutant measurements as well as those additional measurements leveraged from existing networks such as the PM speciation, PAMS and air toxics programs. Level 3 three sites would largely include those single pollutant ozone and PM2.5 sites that support mapping and related spatial analysis tools. Obviously, these levels are rough guides indicating the relative level of measurement completeness located at a particular site. In particular, the level 2 stations could range from a relatively simple collection of seven core species to a most comprehensive site approaching Level 1 status by benefitting from collocation with chemical speciation, PAMS and air toxics trends sites.

4.6.1 Level 1 "Master sites"

Level 1 sites could be viewed as continuation of the Supersite program, but would provide more commonality across the sites than the current program which blend a small group of common measurements built within a series of independent hypothesis driven research programs. Operation of these future Level 1 stations would be through existing S/L/T agencies or contracted out in a manner similar to the CASTNET program. While these Level 1 sites would be "routinely" operated sites pushing the envelope on an array of measurements, collaboration with Universities and other research efforts should be facilitated through the various Grant and other efforts sponsored by government and industry groups. Assuming that the concept of Level 1 "master" sites is supported and these sites are operated by S/L/T's, eventual implementation would be channeled through a cooperative negotiation process balancing Geographic diversity with agencies willing and capable to participate. Clearly, resources beyond the current infrastructure would need to be identified for the extended set of measurements.

In addition to enhancing most data applications addressing the six national objectives, Level 1 sites offer the following benefits:

- serve as principal test locations for technologies developed by vendors and research groups,

- guarantee some level of minimal measurement for pollutants of national importance that may be perceived beyond the scope of "routine" operations. Example measurements include PM precursors nitric acid and ammonia, particulate matter, ultra fine and size distribution measurements, and real nitrogen dioxide that over time could transition into more routine Level 2 status, and

- provide centralized platforms for collaboration with more in depth atmospheric process and health related research studies.

4.6.2 Level 2 multi-pollutant site.

The majority of multi pollutant NCore sites would have Level 2 status within which the number of measurements would span a broad range from minimum "core" group to near Level 1 status dependent on the degree of collocation and leveraging from other programs. The level 2 sites are based on a "core" group of continuous measurements [$PM_{2.5}$, PM_{10}, ozone, SO_2, CO, light scattering, light absorption?] that have universal application (with the exception of light scattering) to support evaluation of national air quality models, long term health and exposure assessments, accounting for progress in national emission strategies, and source apportionment applications. A broad range of measurements would be conducted at level 2 sites dependent on the ability to collocate sites that have been (or will be) established to meet other pollutant specific programs. For example, the urban Level 2 sites would emphasize utilizing the existing 54 speciation trend sites. Discussions by the air toxics steering committee indicate a modest start of 10 air toxics trend sites measuring four HAPS, with expansion dependent on future resources. Most of these initial sites will be located at existing speciation sites, and some at sites that measure both PM speciation components and PAMS compounds. The NMSC and EPA may decide that a longer term goal is to outfit all Level 2 sites with core, HAPs, PAMS, and PM speciation. In the interest of making more immediate incremental progress that has the potential to be more comprehensive, this leveraging aspect is being strongly emphasized.

4.6.3 Level 3 single pollutant ozone and PM2.5 "adjunct" sites.

Ozone and PM2.5 are the only "national" level criteria pollutants that exhibit such widespread behavior that require national level emission strategies in concert with local programs. In addition, both pollutants exhibit reasonable degree of homogeneous behavior that is compatible with a host of spatial mapping and display techniques.

Table 1: "Master" list of measurements				
Site level {Approximate site total*}			Parameter	comments
L E V E L 1 **{3-10}**	Level 2 "core" {70-100}	Level 3 (one of) {500 -800}	***ozone***	
			PM2.5	Continuous and filter at level 2 sites; emphasis on continuos at Level 3 sites for AIRNow
			Basic Meteorology	temp, RH, atm. pressure, ws,wd [surface level]
			PM10	continuous; only filter based at critical Level 2 sites with potential NAAQS (future) violations
			light scattering	continuous; should consider continuous light absorption
			CO	requires instrument mods..
			SO2	requires instrument mods..
			NO/NOx/NOy	traditional NO/NOx in urban areas to retain trends...generally adequate given dominance (i.e., fresh emissions) of non transformed NO and NO2 in urban locations
	Level 2 core plus standard speciation {40-70}		Filter based PM2.5 speciation as in trends	every third day, 24 hr sample; major ions through IC; elements through XRF, EC and OC fractions through combustion
	core plus standard and continuous speciation {10}		daily/continuous PM2.5 speciation	includes the 10-15 continuous nitrate, sulfate and carbon measurement sites that were added to speciation trends as part of earlier agreements with NAS/CASAC

	core plus "national HAPs and standard speciation {10-25}	# sites dependent on number of HAPs trends and degree of collocation across speciation	formaldehyde	currently **proposed national HAPs** trends measurements to be collocated with PM2.5 speciation (some unknown subset of daily speciation sites included)
			benzene	
			acrolein	
			chromium	
			light absorbing aerosol	
	core plus speciation and PAMS {15-25}		VOC	**minimum PAMS** also includes Level 2 core species CO and NO/NOx/NOy; recommend both continuous TNMOC (year round to support HAPs surrogate) analyzer and mix of annual/seasonal canister or auto GC sampling for specific compounds...one type 2 site per current PAMS city
	core plus speciation plus PAMS plus HAPS {8-20}	Number of sites dependent on ability to collocate	all of above	
	Level 1 specific	Level 1 sites include alll above measurements plus next column	real NO2	not routine measurements at this time
			nitric acid	
			ammonia	
			PM size distribution	
			PM ultra fine	
			SVOC	
	* site numbers are not additive; e.g., all level 1 are part of level 2; all level 2 are part of level 3 ___instrumentation resources required...see section 4.12			

4.7 Monitoring regulations

The NMSC should advise the regulatory workgroup on what elements, if any, of Ncore need to be included in the revised part 58 monitoring regulations. Options include:

A Identify all specific required elements of NCore in part 58

B Identify certain specific aspects such as the Level 2 core measurements and associated collocation with other networks (PAMS, Speciation, air toxics), as well as other components such as linked, telemetered data, and various permutations.

C Requiring NCore in the the CFR, but referencing specific guidance on actual measurement requirements.

4.8 Relationship to existing PAMS, PM2.5, Air Toxics, and NAMS/SLAMS networks

The initial deployment phase of NCore relies on substantial leveraging from existing and emerging (e.g., air toxics) air monitoring networks. NCore would assume the "national" level or trend components of these programs.

Air Toxics. Current discussions with the air toxics steering committee indicate a relatively small trends network with 10 to 20 sites established over the next 2-3 years covering a small group of HAPs with "national" level importance (i.e., concentration predictions appearing in many places at levels of concern). More than 50% of the base air toxics monitoring resources would be dedicated to local needs. These trend sites would be located at existing (or new) PM2.5 speciation sites, some of which already exist as PAMS type 2 sites.

PM2.5 speciation

The speciation trends sites are excellent candidates to initiate siting locations for Level 2 multi-pollutant sites. The model established for the speciation program with approximately 50 national trends sites and nearly 200 S/L/T supplemental sites reflects the value associated with both local and national needs, and a blueprint for much of the development of NCore.

PM2.5 mass Recent spatial analyses of these sites are forming an important tool for larger implementation issues associated with abating PM2.5 levels throughout the United States. These sites will be assimilated into additional mapping tools

such as AIRNow to provide forecasting and timely public access to AQI related information. The transition to continuous samplers, which requires a reduction in FRM samplers, is critically important. A substantial subset of PM2.5 sites will be assimilated into Level 3 "adjunct" sites.

PAMS — A side workgroup of the regulatory workgroup has developed a set of "mimimum" PAMS recommendations (Table 2). The Type 2 PAMS sites included in this list of minimum requirements would be considered part of NCore. This revision was initiated in the January, 2000 PAMS workshop in Las Vegas and was based on redefining PAMS objectives. The PAMS principal objective now focuses on the longer term trends and accountability aspects, while playing a supporting role on other emissions strategy development objectives such as model evaluation.

Table 2. MINIMUM REQUIRED PAMS MONITORING LOCATIONS AND FREQUENCIES

Measurement	Where Required	Sampling Frequency (All daily except for upper air meteorology)[1]
Speciated VOC[2]	Two sites per area, one of which must be a Type 2 Site.	During the PAMS season: 1) Hourly auto GC, or 2) Eight 3-hour canisters, or 3) 1 morning and 1 afternoon canister with a 3-hour or less averaging time plus Continuous Total Non-methane Hydrocarbon measurement.
NOx	All Type 2 Sites	Hourly during the ozone season[3]
NOy	One site per area at the Type 3 or Type 1 Site	Hourly during the ozone season
CO (ppb level)	One per Type 2 Site	Hourly during the ozone season
Ozone	All sites	Hourly during the ozone season
Surface Met	All sites	Hourly during the ozone season
Upper Air Meteorology	One representative location within PAMS area	Sampling frequency must be approved as part of the PAMS Network Description described in 40 CFR 58.41.

[1]Daily or with an approved alternative plan.
[2]Speciated VOC is defined in the Technical Guidance Document Reference __, Target Compounds.
[3]Approved ozone season as stipulated in 40CFR58, Reference --.

NAMS/SLAMs

Components of the ozone sites in the current NAMS/SLAMS formulation will be incorporated into the Level 3 adjunct sites for ozone.

4.9 Linkage to other programs: Integration beyond traditional State/Local/Tribal Grant programs.

The clients of the S/L/T networks extend beyond the EPA air program office and their immediate grantee organizations. For this monitoring strategy to be truly national and sincere to optimization principles, there must be extended integration with other major networks and related national objectives. This integration should extend to:

- Global/continental air quality issues, including cross continental transport of ozone, PM and their precursors, persistent HAPS such as mercury, dioxins and PCBs and to characterize global warming gases (e.g., ozone, carbon dioxide) radiative losses due to light reflecting and absorbing aerosols and gases. In addition, intra continental transport issues related to fluxes across U.S/Canadian and Mexican/U.S. borders should be served as part of national monitoring strategy. Consideration should be given to an additional set of monitoring stations placed at critical locations along the coasts and borders for these purposes. Collaboration with other organizations, particularly NOAA, is suggested.

- Ecosystem and related assessments. Several national level monitoring efforts are in place or in planning potential for bidirectional benefits (i.e., two networks beenfitting each other through complementary and/or similar measurements). Examples include CASTNET and IMPROVE where both networks are used for routine evaluation of AQSMs, and visibility (IMPROVE) and atmospheric program (CASTNET) assessments benefit from State/Tribal networks operating light scattering and chemical speciation measurements. Current planning for a routine PBT monitoring strategy focused on mercury, dioxins and PCBs benefit from the existing networks through AQSM evaluation (emerging models link across most pollutant categories; mercury characterization is influenced by other species such as ozone). Advantages of leveraging operator resources and sharing platform space should be encouraged.

- Research and intensive field campaigns. Many of the more probing or diagnostic level research programs that attempt to uncover the underlying physical/chemical dynamics of atmospheric processes or characterize the more elusive or difficult specific causative factors responsible for adverse health effects are national needs. While these programs may primarily be conducted through research organizations and Universities, it is

imperative that they are perceived as integral components of the entire arsenal of technical tools used to understand, solve and account for progress in air quality management. As the monitoring strategy is integrated more completely with other research level efforts, the efforts of routine monitoring operations will reap an important side benefit of additional counsel on routine aspects of monitoring operations, a process that has worked successfully to date with the Clean Air Scientific Advisory Committee particle monitoring subcommittee (CASAC).

Recommended and ongoing actions for extended integration to these 3 needs:

1. Subject the monitoring strategy, and specifically NCore recommendations, to broader scientific review and engagement with other Federal agencies and industry. Four specific actions include:

   1) establishing a new CASAC subcommittee to review NCore and related measurement methodology issues, this action was initiated in February, 2002. This subcommittee will evaluate the NCore plan and provide counsel on the most reasonable mix of core pollutants, measurement locations and related topics;

   2) add NCore to the interagency discussions on air monitoring conducted under the Committee for Environment and Natural Resources (CENR) Air Quality Research Subcommittee (AQRS); this action was initiated in February, 2002;

   3) add NCore as an integral component to the National Research Council (NRC) - EPA PM coordination project that strives to facilitate coordination across modeling, monitoring and emissions and research and program objectives; this action will start in March, 2002

   4) add Ncore to the NARSTO agenda to initaite dialogue with industry, Canada, Mexico, as well other NARSTO entities (States, EPA, Universities); this action is scheduled for April, 2002 during the NARSTO Executive assembly meeting.

2. Foster greater integration with networks such as IMPROVE and CASTNET by utilizing a subset those platforms as NCore rural sites. Several specific tasks that attempt to identify characterize and harmonize measurement differences between IMPROVE and the PM2.5 speciation network are underway through EPA studies (OAQPS, ORD and ORIA) and Regional Planning Organization (RPO) activities. IMPROVE monitors have been added to a subset of CASTNET sites thereby providing more integration across IMPROVE, CASTNET and PM2.5 speciation. The “core” level 2 measurements should be added to some number of existing

CASTNET and IMPROVE sites to enhance rural coverage.

3. Collaborate directly with those organizations with the appropriate expertise and mission statements (e.g., NOAA) to build global and continental level monitoring needs into the national design.

4.10 Additional and future development of National Network design.

[The goal for air quality monitoring should be to provide the most comprehensive characterization of air quality over space (three dimensions), time {continuously, retrospectively and prospectively (i.e., forecasting)} and physical/chemical properties to serve a multiplicity of needs .]

The NCore proposal presents a logical, inexpensive intermediate step toward implementing more far reaching and innovative approaches in monitoring. In reality, there are very few bold proposals in NCore, which really is more a series of necessary, pragmatic adjustments to our current networks. There must be an exploration of expanding the use of simplified and complex technologies into the system, including simple and inexpensive passive samplers that flood an area to fill important spatial gaps and support network design through evaluation of spatial analysis methods. Advanced optical technologies that characterize air quality over extended paths would be consistent with the emphasis on measuring "representative" air quality in response to national objectives. Can we do better than just "leveraging" existing networks and settling for a small number of comprehensive multi-pollutant sites? Or, should we build in a future design that is more directly need based. How do we anticipate future needs? In one sense the NCore design is purposefully presented as a "minimum" to prevent stagnation and allow for accommodation of new needs and technologies.

A detailed future vision for air monitoring will not be presented at this time and more forward looking perspectives and direction should emerge from the outreach and integration tasks described above. The goal for air quality monitoring should be to provide the most comprehensive characterization of air quality over space (three dimensions), time (continuously) and physical/chemical properties. To reach that goal, the following attributes should be associated with a more innovative future for air monitoring:

1. Multi-pollutant sites as a standard rather than the exception. Air quality is complex and we need a far more comprehensive measurements approach to convey true ambient air characteristics.

2. Measurement technology (simple and complex) that allows for efficient, accurate and comprehensive air quality characterizations to realize the first attribute. Advances in miniature technologies that incorporate the near equivalent of a continuous gas

chromatograph housed on a microchip, the multiple chemical/physical (continuous aerosol chemistry and size characteristics) processing capabilities of single particle analyzers that are deployed in Supersites, the use of optical path instruments to sample representative volumes, and the expansion of remote Satellite sensing capability.

3. Models and measurements need to be coupled dynamically to realize the future goal.

The geometric increases in computational capacity are now (or will be shortly) available to produce near real time output of predictive concentrations. This discussion on monitoring should be extended to incorporate modeling directly and in a manner analogous to the Four Dimensional Data Assimilation (FDDA) meteorological models where observed data iteratively "nudge" predictive values closer to observations with ne result being a detailed spatial output grounded on observations. The future of a system like AIRNow should evolve along the following lines:

current: real time view of ozone mapped data across most of the United States

next 1- 5years with NCore: real time view of ozone and PM2.5 mapped data and other "level 2 core pollutants at specific points

next 5-10 years: real time view of complete spatial fields reflecting integrated observations/predictions for a list of pollutants outputted from models, combined with an analysis system integrating meteorological and satellite air quality data imagery with the capbility of air quality forecasting over the entire nation.

4. Extend the current engineering design approach through a more idealized scientific approach utilizing the outreach and integration and review process established (CASAC, NARSTO, CENR). This will require an investment from (as well as to) the research community.

4.11 Implementation schedule

2002-2003 Establish initial NCore sites through leveraging existing networks and initial deployment of air toxics trend sites

Undergo CASAC review of NCore plan and adjust as needed.

Resources (from available instrumentation and new purchases) permitting, initiate deployment of "core" measurements and platform enhancements at type 2 sites.

2003-2005 Resources permitting, complete deployment of Level 2 sites, including linked telemetering system.

Establish and deploy Type 1 master sites.

Complete development of future blueprint for "idealized" design and network structure.

2005-2010 Expand NCore as per idealized design and resource constraints

4.12 Resource implications

The working assumption for NCore is based on protecting and even enhancing the degree of flexibility S/L/T agencies have in conducting monitoring to meet their identified needs. There are some very moderate resources to be allocated that have emerged from the network assessments that indicate reductions of traditional criteria pollutant monitoring sites. While we are advocating establishment of new multi-pollutant sites through NCore, we also are encouraging investments into air toxics and continuous PM monitoring. While some of the investments in these two areas are distinctly part of NCore, in many cases, especially for air toxics, the investment largely serve local needs. The divestment from existing programs is not sufficient to completely meet all the investment needs for air toxics, continuous PM (and eventually coarse) and NCore. Therefore, two very important implementation tasks need to be followed. First, as described above, maximum leveraging and optimization of existing networks must drive the initial implementation of NCore over the next one to five years. This includes strong encouragement or perhaps requirement through regulations to collocate new air toxics trend sites at speciation sites and, where available, PAMS sites as well. Second, modest investments from EPA must be contributed to catalyze NCore.

The resource estimates below assume the strawman measurements list, and approximately 50 urban and 20 rural Level 2 sites. Note that the operations and maintenance costs of the elements below largely are assumed to be covered under current salary structures (i.e., the divestments in criteria pollutants allow for manpower shifts to other monitoring needs).

Note: these resource needs have not been reviewed by the NCore subcommittee. They are included here to indicate that a costs is associated with NCore components. Additional costing must be performed.

NCore Resource Needs (all $ are State and Tribal Assistance Grants (STAG) unless noted as EPM/S&T. Assumptions: Measurements as per Table 1. 50 urban and 20 (10/10 split...across S/L/Ts and Fed. agencies) rural Level 2 sites.

1. Modifications and training for converting available sulfur dioxide and carbon monoxide samplers for measuring "average" air quality. Each sampler would require ~ $2,000 for needed modifications. Assuming 60 sites and 2 samplers per site requires approximately a one time ***$240,000*** investment.

2. Purchase of ~ 50 continuous PM 10 instruments; 50* $20K/site = ***$1,000,000*** (divestments from PM2.5 and PM10 to finance some part). [***note, 1. collocating continuous PM2.5 and PM10 is an explicit attempt to develop a data base to build the case for using continuous methods for future PMcoarse needs, 2. Continuous PM2.5 monitors available from existing program***].

3. Purchase of nephelometers; 60 sites*$6,000/site = one time ***$360,000*** investment. [Should consider continuous light absorbing instrument purchases as well].

4. Specific to rural Level 2 [all of these sites could be operated by S/L/Ts; the NCore subcommittee recommended that EPA /Fed. take responsibility for some rural monitoring during the Las Vegas meeting]:

   10 S/L/T sites: Purchase of approximately 10 NO/NOy instruments for rural locations for one time ***$250,000*** investment and operation by S/L/Ts.

   Enhance 10 existing CASTNET and IMPROVE sites to add level 2 core species. Assume approximately $200,000/site, includes instruments, shelter/power enhancements for ***$2,000,000*** total EPA EPM/S&T (operation and maintenance through collaborating groups).

5. Monitoring platform enhancements (space, power) for S/L/T's, 20K/site @ 60 sites; ***$1.2M***

6. Installation of Information transfer technology hardware and software and data base expansion and incorporation of continuous Level 2 and Level 3 data into AIRNow. Estimate unknown, assume **~ *$1.9M*** (see section 6).

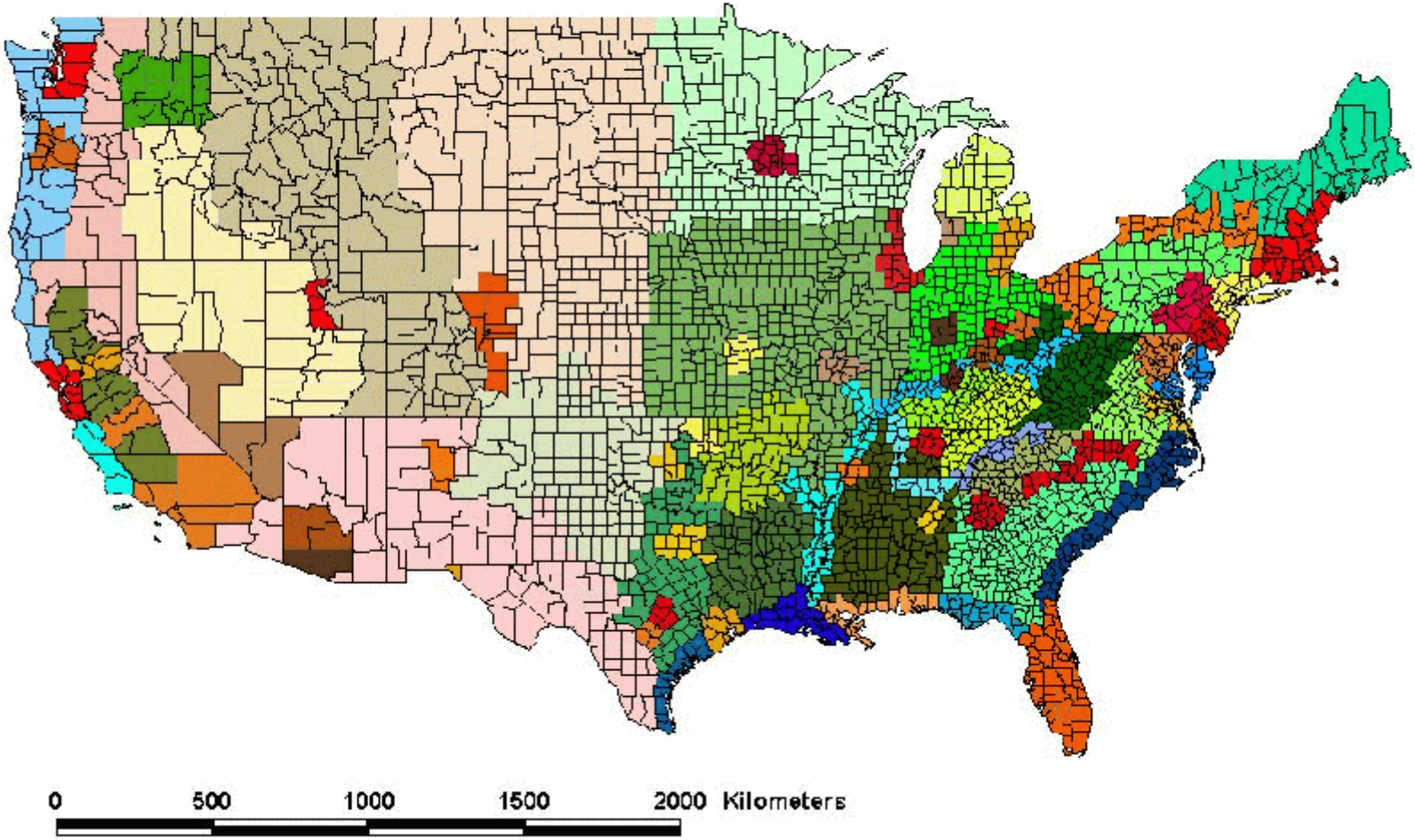
7. Routine operation and maintenance of NCore level 2 sites. These costs are assumed to be within the zero sum assumption. That is, the divestment in criteria sites and filter based measurements should be commensurate with additional operational burdens associated with Level 2 sites.

8. Level 1 site establishment and operation. **More detailed analysis required.** Assume one time investment of 500,000/site and annual $300K operating and laboratory

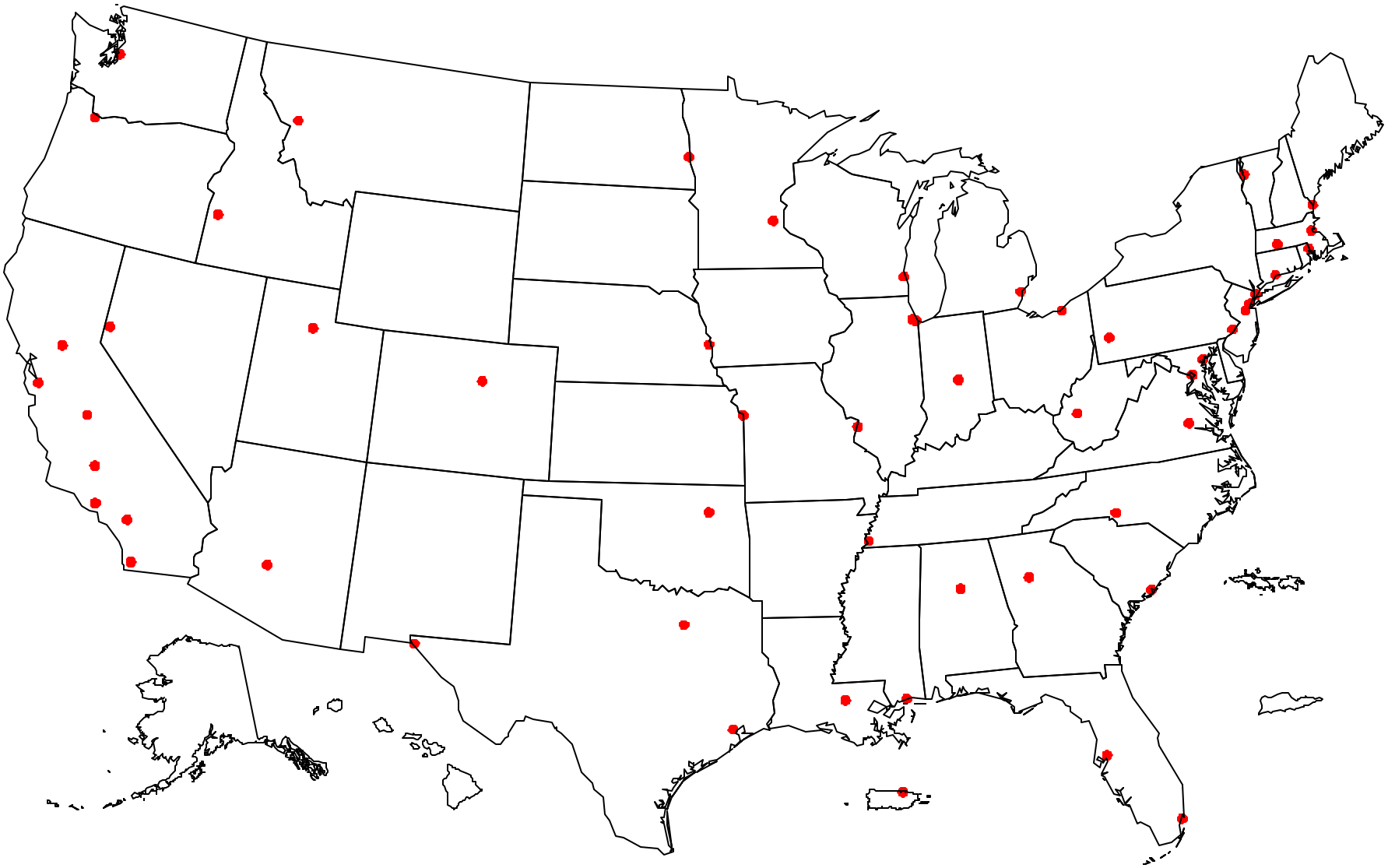
analysis expense. At 5 sites, initial outlay of ***$2.5M*** and annual expense of ***$1.5M*** covered by EPM/S&T

Total: ***$9.45M*** one time expense; ***$300K*** additional operating expense (obvious cost reductions through scling back, assuming future implementation)

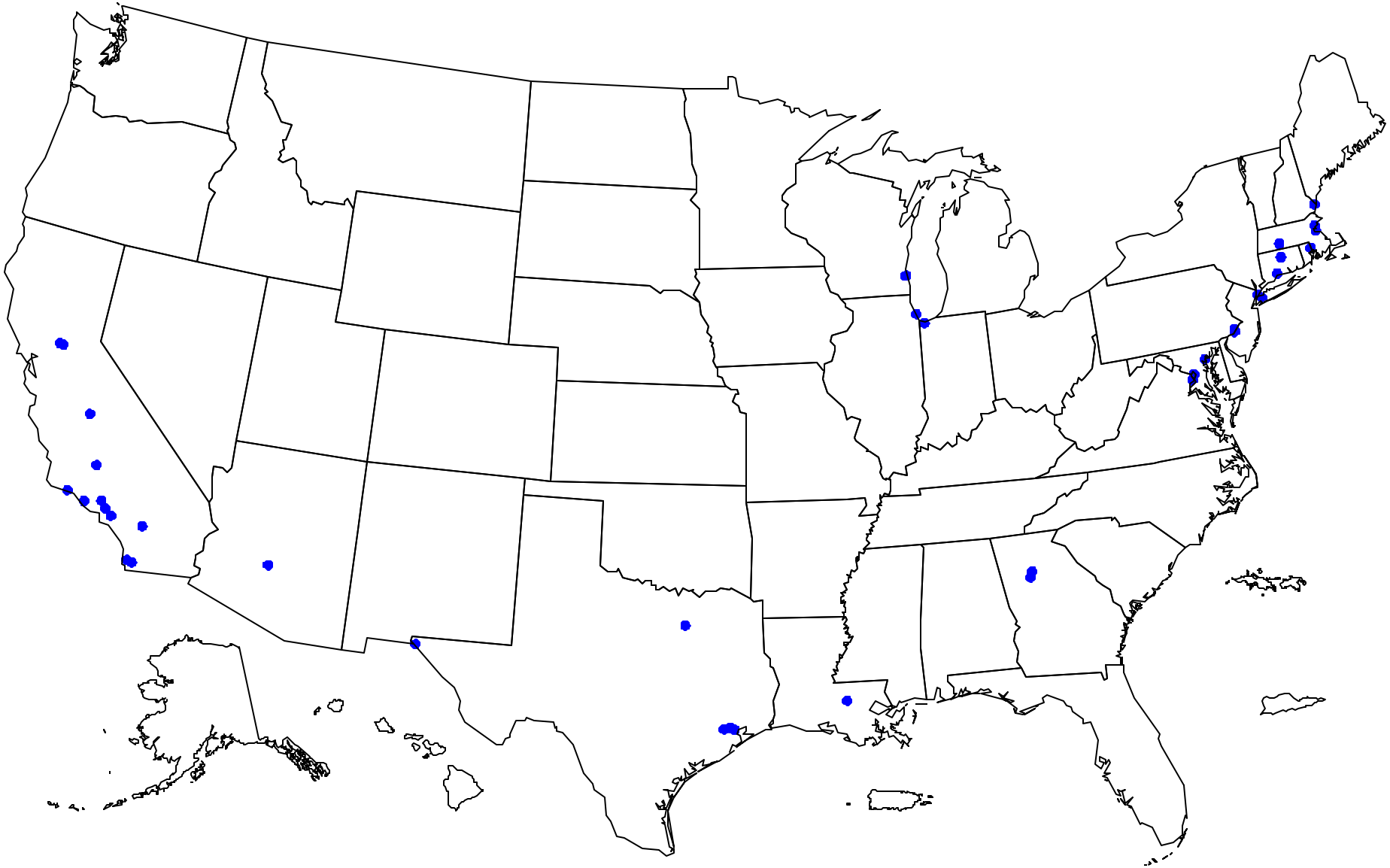
Figure 1: Population-based Air Quality Regions



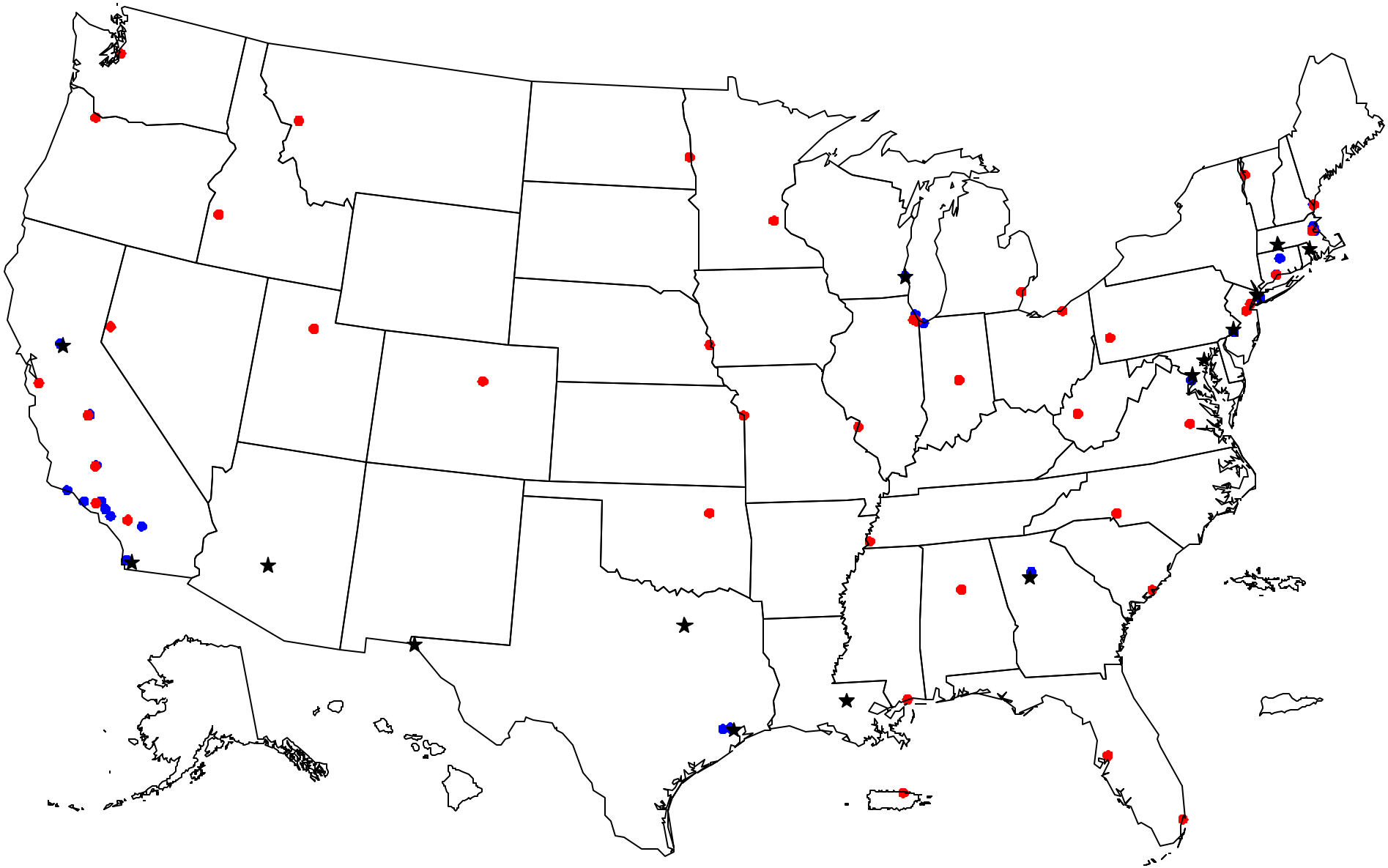
Speciation 'Trends' Sites



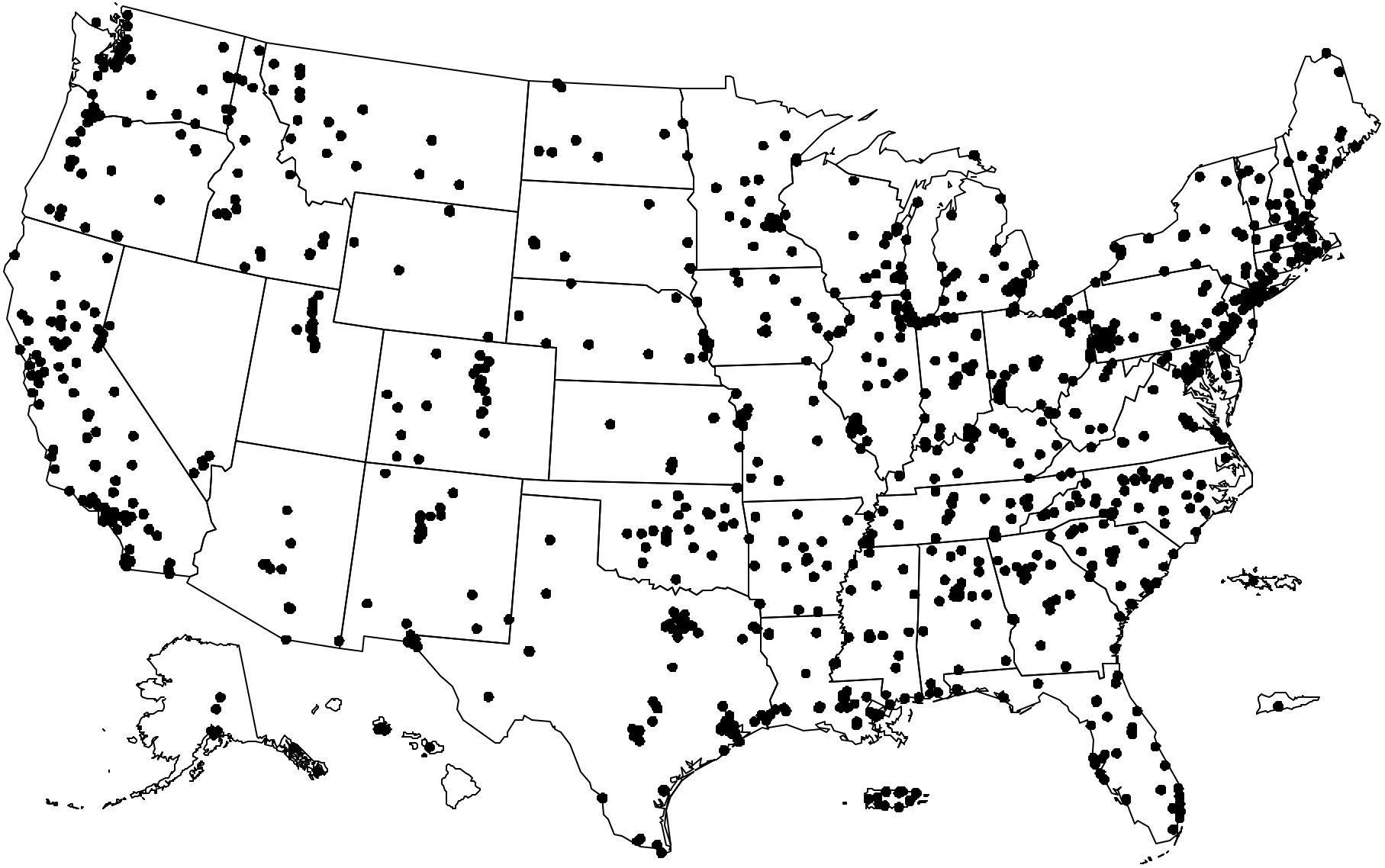
PAMS 'Type 2' Sites



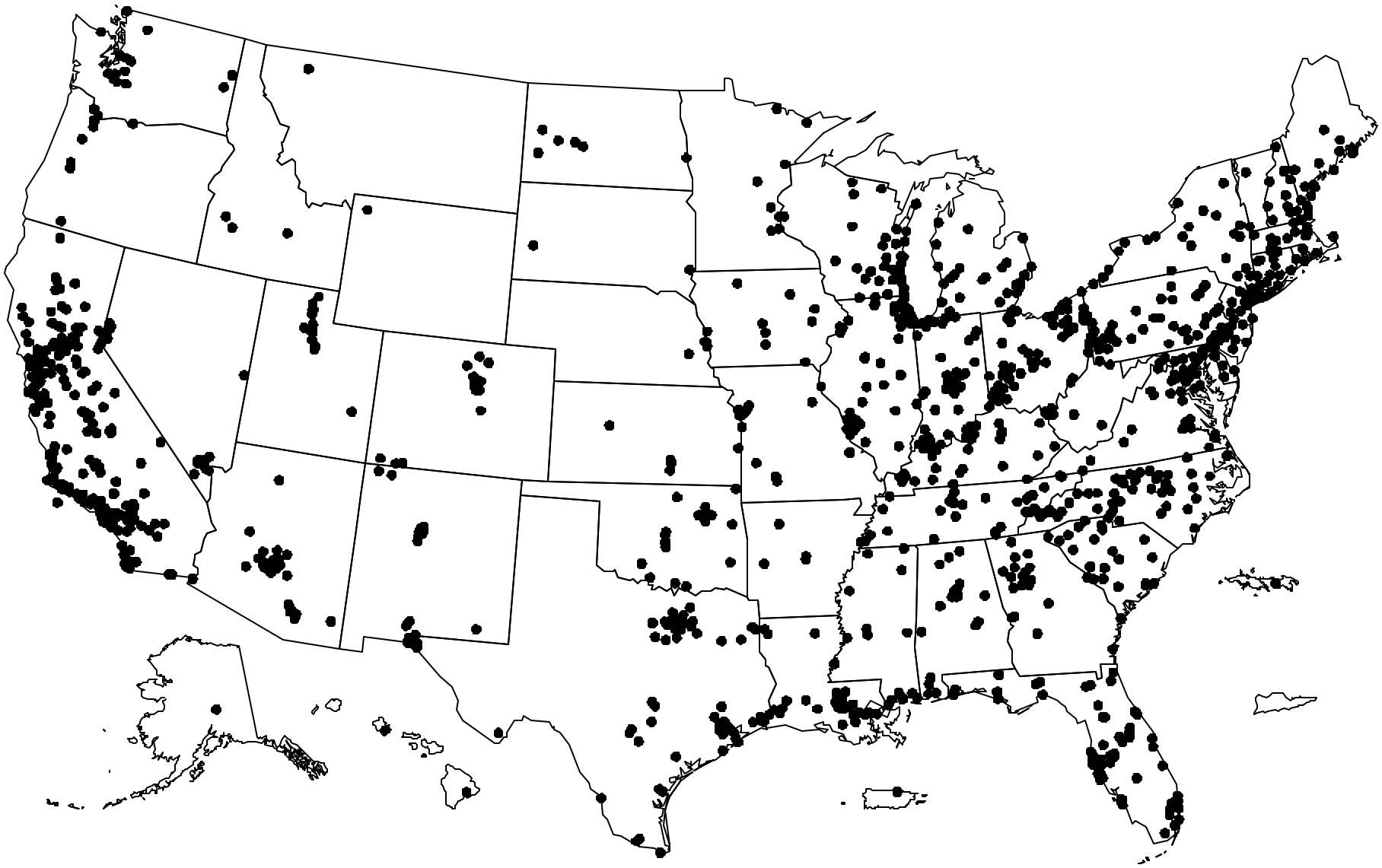
Speciation 'Trends' & PAMS 'Type 2' Sites



$PM_{2.5}$ Sites

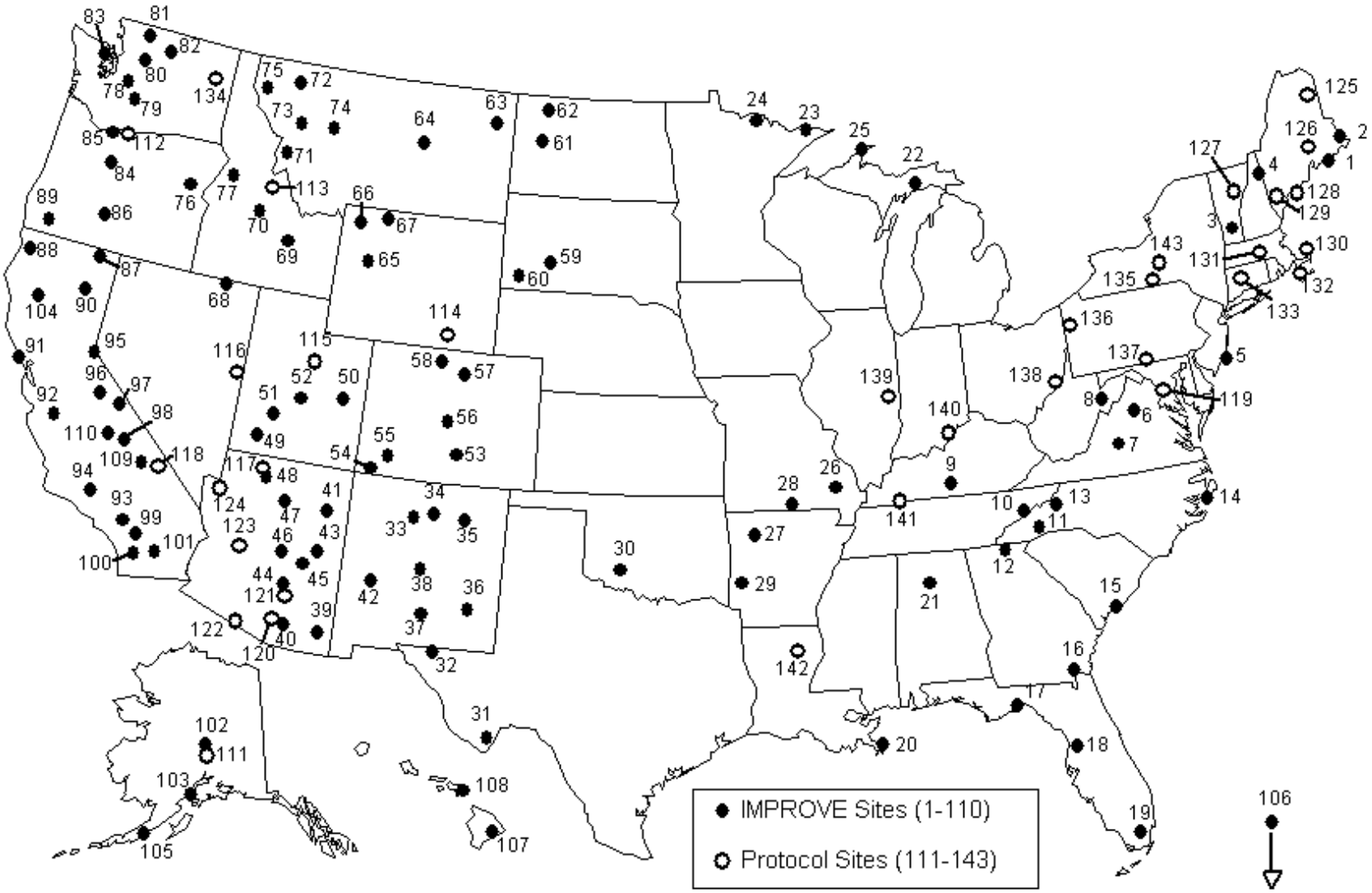


Ozone Sites

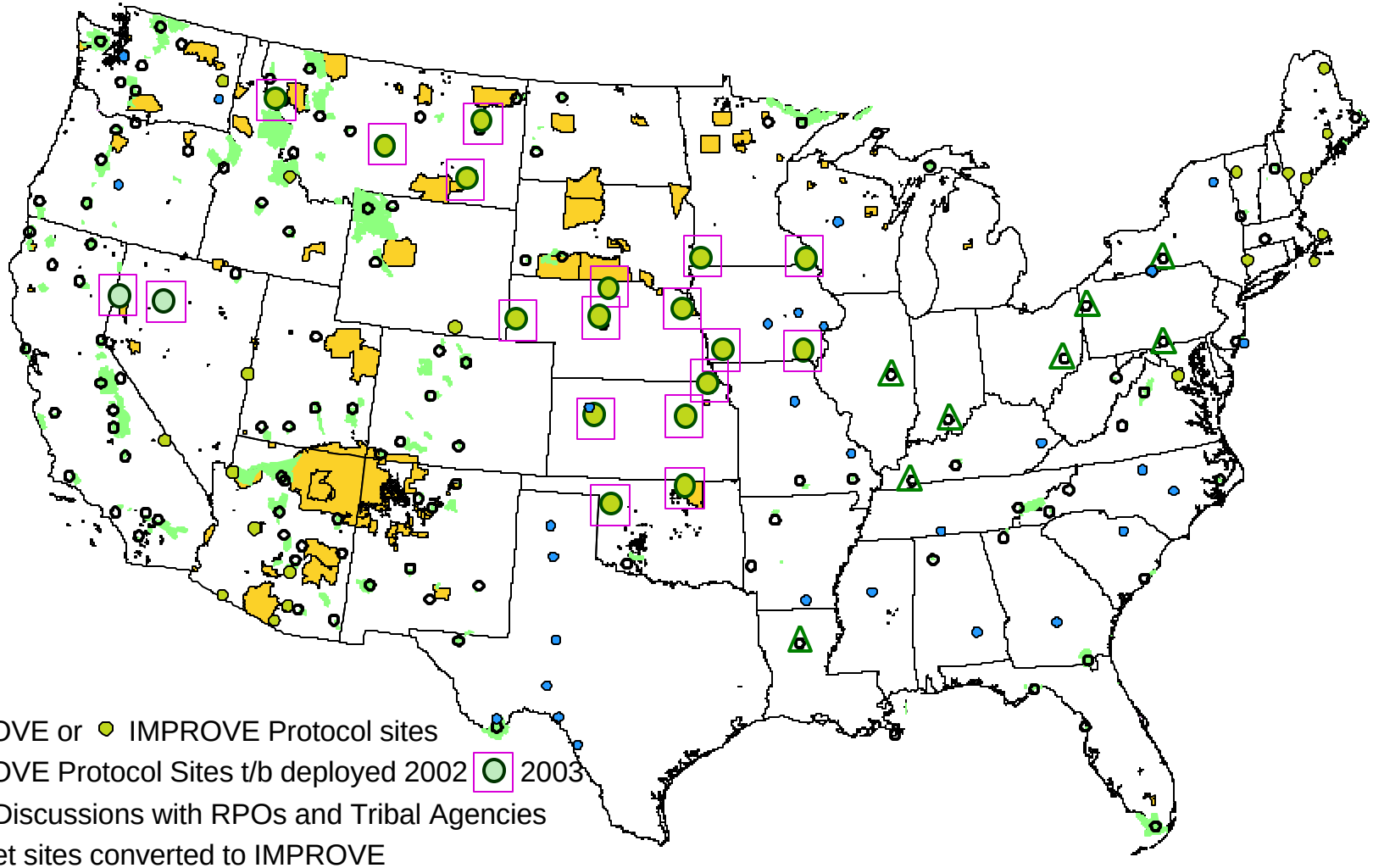


CASTNet Sites

IMPROVE (rural sites)



Current/Planned IMPROVE, IMPROVE Protocol & Rural Supplemental $PM_{2.5}$ Speciation Sites



IMPROVE or IMPROVE Protocol sites

IMPROVE Protocol Sites t/b deployed 2002 2003

From Discussions with RPOs and Tribal Agencies

Castnet sites converted to IMPROVE

Supplemental Speciation Sites

Class I Areas

Tribal Lands

1/02

Air Quality Monitoring in Support of Epidemiology

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ORD / NHEERL / HSD / EBB

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Air Quality Monitoring in Support of Epidemiology

Epidemiologic studies of the health effects of ambient particulate matter have been enormously important in determining the real health effects of real-world exposures to ambient particulate matter and co-pollutants among real human populations with the relevant range of variations in sensitivity. While some studies have generated their own air quality monitoring data, many epidemiologic studies have relied entirely on routinely collected air quality data supplied by a compliance-oriented air quality monitoring system. The health-based nature of the current air quality standards for particulate matter suggest a strengthening of this link between epidemiologic studies and compliance-oriented air quality monitoring systems.

By analogy, police officers are required to do more than simply find and arrest the bad guys. Police officers are expected to be on the watch for hazardous situations, such as adverse road conditions (exposure assessment); to assist citizens by summoning emergency services (health assessment); and to be particularly active in situations where these two conditions coincide, such as a hurricane warning (risk assessment and communication). Compliance-oriented air quality monitoring systems should also be designed to maximize their utility for these ancillary functions.

The choices involved in the determination of routine air quality monitoring systems will have important consequences for future epidemiologic research, for future risk assessments and for future regulation. The early choice of a 2.5 micron cut-point for fine particulate matter by research scientists has had important and unforeseen consequences for the air quality standard. The decisions now being made regarding compliance-oriented air quality monitoring systems will shape future epidemiologic research. For example, if the proposed air quality monitoring system cannot distinguish between the source contributions of gasoline and diesel vehicles, then many future epidemiologic studies will not be capable of making any distinction between these sources.

Types of Epidemiologic Studies

Various non-epidemiologists have complained about the inability of epidemiologists to clearly indicate their needs for air quality monitoring systems. Each epidemiologist seems to be describing an entire different set of research requirements. This apparent lack of consensus among epidemiologists is primarily a reflection of the differing exposure assessment requirements of different epidemiologic study types.

Epidemiologic studies of the health effects of ambient particulate matter fall into several distinct study types. Each type of study requires air quality data over different frequencies of measurement, different durations of measurement, different levels of geographic scope, and different levels of geographic detail. These epidemiologic studies fall into four broad categories: unenumerated open-cohorts ("time-series studies"), prospective closed-cohorts with repeated measurements, closed-cohorts analyzed for the timing of a health event ("case-crossover studies") and closed-cohorts analyzed for survival.

Unenumerated open-cohorts

Epidemiologic studies of unenumerated open-cohorts have played a key role in identifying fine particulate matter as an important public health problem. Since mortality and hospitalization records are routinely collected by public health authorities, these studies only require the addition of routinely collected daily data on weather and on ambient concentrations of particulate matter and co-pollutants. These studies have been conducted throughout the world under a large number of climatic conditions and sources of particulate matter.

The sample size of these studies is generally one or more well-defined urban areas each with a population of 100,000 or more persons followed over years of daily observations. While early studies

were limited to single cities, the most extensive study was Jon Samet and colleagues' analysis of 90 U.S. cities (1). These 90 cities covered a broad range of city sizes: 3 cities were over 5 million, 20 cities were between 1 and 5 million, 35 cities were between ½ and 1 million, and 32 cities were under ½ million population. With the increase in the number of cities considered in a single study, researchers have gained an ability to examine the determinants of city-to-city variability in the exposure-response relationship.

The frequency of air quality measurements required for these studies depends on the time resolution of the health data. Since mortality and hospitalization data is available as daily counts, the ambient air quality measurements should be conducted at least daily at fixed locations with a minimum of missing data. The timing of missing air quality values must not be related to both air quality levels and health effects. Even routine one-in-six or one-in-three day sampling introduces an unacceptable pattern of missing values into the data and severely limits the analysis of the delayed (or lagged) health effects of particulate matter.

The duration of air quality measurements required for these studies depends on the size of the observed population and the natural variability of air quality levels. For most populations in a single urban area, air quality measurements must be continued for extensive periods of time (years or decades) in order to gain sufficient statistical power in terms of person-time of observation. However, a national network of monitoring stations representing the exposures of large numbers of individuals combined with daily source apportionment might be able to generate annual reports on the relative toxicity of different sources of particulate matter.

The geographic scope of air quality measurements required for these studies depends on the geographic scope of the health data system. While the scope of a hospital-based record system is limited by the size of the individual hospital's catchment area, mortality records and federally-assisted hospital care

records are national in scope. A more extensive air quality monitoring network will (a) increase the total size of the population under study, (b) increase the number of study cities, (c) increase the statistical power to detect the relative health effects of various pollutants, (d) increase the ability of the study to understand the effects of various combination, and (e) increase the ability of the study to examine effect modifiers such as personal characteristics, behaviors, and situations, such as age, preexisting conditions, smoking status, and air conditioning. A nation-wide air quality monitoring system that captures the day-to-day variability in air quality levels for the entire U.S. population would permit an extension of these studies.

The geographic detail of air quality measurements required for these studies depends on the small-scale spacial variability of the pollutant under study and the geographic detail of the health data. Due to privacy concerns, health data are generally not available at less than the county or city level. Fortunately for these studies, the exposure data do not need to reflect the mean exposure of specific individuals or their total exposures to ambient and non-ambient particulate matter. The exposure data must only capture the day-to-day variability in ambient air quality levels for the population as a whole. Methodological issues concerning the use of a single central-site monitor to represent the exposures to particulate matter over broad geographic areas have been largely resolved by recent exposure assessment research.

Prospective closed-cohorts with repeated measurements

Epidemiologic studies of prospective closed-cohorts with repeated measurements of symptoms and physiological parameters ("panel studies") in both field and clinical settings have been instrumental in developing our understanding of the biologically plausible modes of action for particulate matter. By allowing each subject to serve as their own control, these studies have considerable statistical power to detect the determinants of the day-to-day variability of health. The physiological parameters have included

pulmonary function (2), heart rate and heart rate variability (3), and biomarkers such as fibrinogen, C-reactive protein and plasma viscosity (4).

The sample sizes of these studies are generally of the order of 60 people followed three times each week for four- week periods, but a recent German study followed about 60 people monthly for an entire year. In the U.S., these studies tend to be of limited duration due to the costs of repeated measurements and subject boredom. However, both the National Cooperative Inner-City Asthma Study and the subsequent Inner-City Asthma Study used an interesting variant of this study design with rotating panels of study subjects each of whom were on study daily for two week periods spaced at six-month intervals (5). By dividing their subjects into 12 groups, the investigators were able to maintain a study of children under observation daily for 18 months.

The frequency of air quality measurements required for these studies depends on the time resolution of the health data. Since the timing of the health measurements is often under the control of the investigator, these studies have investigated the health effects of exposures one to four hours prior to the health examination. Continuous or hourly data on air quality will be of great utility to these studies.

The duration of air quality measurements required for these studies depends on the period of observation of the health effects. In most studies involving intensive physiologic measurements, the duration of observation is relatively brief, four to eight weeks. For the rotating panel design, the period of health observation was over 18 months. The air quality monitoring system should not be reduced in frequency or geographic detail during such studies.

The geographic scope of air quality measurements required for these studies depends on the geographic scope of the study population. These epidemiologic studies are general conducted with health

measurements performed at a single location, but successful studies have been conducted with subjects scattered over a single community. As with the open-cohort studies, the exposure data must capture the short-term variability in air quality levels for the study population as a whole. The exposure data do not need to reflect the mean exposure of any individual or the total exposures to ambient and non-ambient particulate matter.

The geographic detail of air quality measurements required for these studies depends on the small-scale spacial variability of the pollutant under study. For pollutants with low small-scale variability, such as fine particulate matter, central site measurements generally are sufficient, while for pollutants with considerable small-scale variability, such as ultrafine particulate matter, air quality measurements should be conducted near to the location where the health measurements are performed or where the study subjects reside.

Closed-cohorts with timing of a health event

Epidemiologic studies of closed-cohorts based on the timing of a health event are generally distinguished from the prospective cohorts with repeated measures in that either a) the subjects are identified by the occurrence of a rare health event such as a myocardial infarction (6) or b) the health data is generated by the recording of a rare health event such as the discharge of an implanted cardiac device (7). In both cases, the analysis concerns the exact timing of the health event and proceeds using a case-crossover method.

While only a few epidemiologic studies have been conducted using this study design, the research potential of such studies is great. The clinical significance of either a myocardial infarct or a device discharge is obvious. Given that these are rare health events, these studies are generally conducted in a

retrospective manner with the acquisition of exposure data from a routine monitoring system after the occurrence of the health event.

The frequency of air quality measurements for these studies depends on the time resolution of the health data which can be quite precise when recorded by an implanted cardiac device. While routine hospital data does not have sufficient time resolution, recent studies have relied on interviews with heart attack survivors to establish the timing of the onset of symptoms. Due to the significance of the cardiac event and the important of prompt care, the timing of the onset of symptoms is often well remembered by the survivor. Continuous or hourly data on air quality will be of great utility to these studies.

The duration of air quality measurements required for these studies depends on the need to collect a sufficient number of health events for analysis. Since the required time period can easily cover several years, a stable air quality monitoring system that can provide extensive historic data will greatly facilitate these studies.

The geographic scope of air quality measurements required for these studies depends on the geographic scope of the study population. While these studies generally are conducted in a few hospitals or a single clinical practice, the study subjects may come from relative large catchment areas encompassing entire urban areas. As with the open-cohort studies, the exposure data must capture the short-term variability in air quality levels for the study population as a whole. The exposure data do not need to reflect the mean exposure of any individual or the total exposures to ambient and non-ambient particulate matter.

The geographic detail of air quality measurements required for these studies depends on the small-scale spacial variability of the pollutant under study. For pollutants with low small-scale variability, such

as fine particulate matter, central site measurements generally are sufficient. However, a recent study found that cardiac events were more strongly associated with nitrogen dioxide than with fine particles (7). This finding suggests that pollutants with greater small-scale variability, such as ultrafine particulate matter, may be producing this health effect. Furthermore, these studies should be capable of ascertaining the location of each study subject at the time of the event which would permit the use of very fine geographic detail on air quality.

Closed-cohorts analyzed for cumulative incidence (survival)

Epidemiologic studies of closed-cohorts analyzed for cumulative incidence of a health event over time have shown the most adverse effects of long-term exposures to particulate matter. In adult cohorts, these studies follow the survival of a well-characterized cohort of subjects in communities with differing long-term air quality exposures. In cross-sectional studies of children, these studies collect information on children's health status during the time preceding the survey.

The two major adult survival studies have been the Dockery and colleagues study of 8,111 adults followed for 14 to 16 years in six U.S. cities (8) and the Pope and colleagues study in 151 U.S. cities using the American Cancer Society cohort of 552,138 adults followed for nine years (9). While Dockery and colleagues' study in six U.S. cities was supported with research-oriented air quality monitoring, the Pope and colleague's study relied entirely on routine compliance-oriented air quality monitoring. Follow-up of these cohorts has continued through 2000 and will be continued as these cohorts advance in age.

Examples of the many children's cohorts include Harvard Six-Cities Studies (10), the Harvard 24-Cities Studies (11, 12), the Kanawha Valley Health Study (13), and the Southern California Children's Health Study (14, 15). The Harvard studies dealt with large-scale differences on long-term exposures

across different communities, while the other two studies dealt with intra-urban gradients of air pollutants. In all cases, limited air quality monitoring was used to infer long-term exposure histories for these children.

The frequency of air quality measurements required for these studies are less intensive than for the other study types. Monthly averages should be sufficient for this type of study, so long as the measurements are sufficiently frequent to capture the average ambient air quality during the month. One-in-three day air quality monitoring may be sufficient, but one-in-six day monitoring may not be adequate for the calculation of monthly averages.

The duration of air quality measurements required for these studies is considerably more extensive than for the other study types. In order to adequately capture the long-term exposure history of study subjects, the air quality monitoring data must capture a considerable portion of their lifetime. The nine to 16 years of follow-up in the cited studies still required the assumption that the relative rankings of the cities with respect to air quality during the follow-up period correctly represented the relative rankings of long-term exposures for the subjects.

The geographic scope of air quality measurements required for these studies is also greater than for the other study types. Due to the high geographic mobility of the U.S. population, a single location cannot adequately represent many individuals' long-term exposures. A nation-wide air quality monitoring network that captures the ambient air quality exposures of a substantial portion of the U.S. population would be necessary for these studies.

The geographic detail of air quality measurements required for these studies needs to adequately characterize individuals' long-term exposures to ambient pollutants. Since healthy adults tend to travel around within their local communities, intra-community geographic detail may be less important for this type

of study. However, given the broad, national scope proposed for such a study, regional geographic detail is very important. Increased geographic detail may be required for communities with local heavy industry and within a complex urban setting such as the U.S. Eastern Megalopolis. The most important requirement for this type of study is that the exposure assessment methods must be standardized across all monitoring locations. Variations in monitoring methods could result in false associations between health and air quality.

Epidemiologic study requirements for air quality monitoring

The requirements for air quality monitoring differ greatly across the various epidemiologic study designs (table 1). This table clarifies the differing requirements expressed by epidemiologists for routine air quality monitoring systems. The exposure assessment requirements for epidemiologic studies differ greatly according to the type of studies under consideration.

Table 1. Summary of air quality monitoring requirements by type of epidemiologic study.

	Unenumerated Open-Cohorts	Closed-Cohorts with repeated measures	Closed-Cohorts analyzed for event timing	Closed-Cohorts analyzed for cumulative incidence
Frequency	Daily	Hourly	Hourly	Monthly
Duration	Years to Decades	Weeks to Years	Years	Decades
Geo. Scope	Urban Centers	Limited	Urban Centers	U.S. Population
Geo. Detail	County	Study site	County	Regions

The maximum requirements for a comprehensive air quality monitoring system are clearly quite daunting: hourly data collected for decades to capture both the short-term and long-term exposures of populations ranging from a few study subjects to the U.S. population as a whole and from regional to neighborhood levels of detail.

Compliance-oriented air quality monitoring systems alone cannot fully meet the needs of epidemiologic studies. Research-oriented air quality monitoring and air quality models will be required to supplement the compliance-oriented systems. However, research-oriented air quality monitoring is an expensive and difficult component of prospective epidemiologic research. Epidemiologic research on the long-term exposures of adults requires the assessment of exposures over decades with a real premium on routine and geographically extensive compliance-oriented air quality monitoring systems.

Combination of monitoring and modeling

Environmental epidemiologists are accustomed to using limited environmental measurements in the context of a model. Often these models are very naive and simplistic, such as assuming that central site monitoring can well capture the ambient exposures of an extended population over a wide geographic area and that measurements conducted over limited periods can adequately capture past exposure gradients. Nevertheless, epidemiologic studies utilizing these simple models have been very successful in elucidating the health effects of environmental exposures. More sophisticated models have not always shown a clear advantage in statistical power over the simpler models, since model precision often comes at substantial cost and a reduced sample size. However, by using appropriate air quality models and geographic information systems, a compliance-oriented air quality monitoring system with limited direct measurements could be used to provide more intensive research data.

The <u>frequency</u> and <u>geographic detail</u> do not need to be the same for each air quality monitoring parameter. Since many parameters are highly correlated, air quality models may allow the imputation of values across different levels of frequency and geographic detail. For example, a temporal air quality model could permit the pairing of (a) a device measuring hourly light scattering or beta-emission attenuation that

provides a high-frequency estimate of $PM_{2.5}$ with (b) a lower-frequency (24-hour), but more accurate gravimetric measurement of $PM_{2.5}$. Similarly, a spatial air quality model could permit the imputation of exposures to ultra-fine particulate matter from (a) costly ultra-fine measurements at a few locations, (b) co-pollutants measured at more locations with greater geographic detail, and (c) distance to and traffic density on nearby roadways. Spatial air quality models may also permit measurements of specific pollutants conducted at differing locations to be integrated into a common model.

The interaction between geographic scope and geographic detail is particularly relevant for the assessment of long-term exposures. A nation-wide system for exposure assessment (scope) will require the identification of a sufficiently large number of geographic regions so that long-term average air quality levels are relatively uniform across the area (detail). An illustrative attempt at the delineation of population regions across the U.S. is included as Appendix A. For some study designs, these regional averages could be supplemented by information on the subject's residential location with the study region.

Geographic information systems have great potential for application to these problems. In principle, the residential location of most study subjects may be ascertained to specific street addresses which may be mapped to census and traffic engineering data. Data from the U.S. Decennial Census can provide information on neighborhood characteristics including population density and type of housing. Routinely collected traffic engineering data can provide the location of major highways and traffic density for most urban areas. In addition to this information on these mobile and area sources, the locations and emissions of point sources would complete the source profile. The locations of and data from compliance-oriented air quality monitoring stations would complete the geographic information system.

The precision required for a national air quality exposure assessment system should be defined in terms of the relative error for specific proportions of the U.S. population. A small proportion (less than 1 percent) of the study population could have their exposures greatly misclassified (greater than 20 percent) without introducing a important bias into an epidemiologic study, provided that the exposure misclassification was unrelated to their health status after adjustment for age and other measurable characteristics.

Conclusions

Compliance-oriented air quality monitoring has played and will continue to play a major role in determining the ability of epidemiologists to assess the health effects of ambient pollutants. Any new system should be national in scope with carefully standardized measurements, with an ability to provide hourly data and monthly averages, and with sufficient geographic detail to permit accurate community-level exposure estimates. The monitoring system must be coupled with a research-oriented modeling system that will permit increased time and spatial resolution for less frequent and more widely spaced monitors.

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Air Quality Monitoring in Support of Epidemiology

Appendix A:

Population-based Air Quality Regions

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December 31, 2001

Appendix A: Population-based Air Quality Regions

The 281,421,906 residents of the United States (April 1, 2000) are unevenly spread over an area of 9,628,382 square kilometers (km^2) divided by civil jurisdictions into 3,111 counties and equivalent entities. No air quality monitoring network can fully capture the ambient air concentrations of criteria air pollutants in the vicinity of their 105,480,101 occupied housing units. This problem of air quality exposure assessment for the U.S. population can be reduced to a more manageable scope by a geographic information system that combines direct monitoring at a comprehensive network of air quality monitoring stations with sophisticated models. As an aid to this process, the entire area of the U.S. must be divided into a limited number of smaller, more tractable air quality regions. This document is an initial attempt at a population-based approach to the designation of air quality regions.

The densest concentrations of the U.S. population are found in 253 Metropolitan Statistical Areas (MSA) and 19 Consolidated Metropolitan Statistical Areas (CMSA) designated and maintained by the White House Office of Management and Budget (OMB) in the Federal Information Processing Standard (FIPS) 8-6. The 19 CMSA's are divided into 76 Primary Metropolitan Statistical Areas (PMSA). These MSA's/CMSA's range in population from the 21,119,865 residents of the New York–Northern New Jersey–Long Island, NY–NJ–CT–PA CMSA to the 57,813 residents of the Enid, OK MSA and contain 81 percent of the U.S. resident population. The MSA's and the non-metropolitan counties and equivalent entities form the elemental units of the designated air quality regions. In several policy statements, OMB has indicated that all Federal Agencies should utilize these MSA's. These designated air quality regions are therefore aggregates of well-defined statistical entities.

For the purposes of designating air quality regions, this process of aggregation from MSA's does lead to certain unusual features on a map. For example, the county of San Bernardino, CA is part of the Los Angeles–Riverside–Orange County, CA CMSA even though much of the county's area lies east of the Sierra Nevada mountains. The central point for the weighted population distribution within San Bernardino (the population centroid) lies near the western edge of the county. The overwhelming majority of the residents of San Bernardino county are properly characterized by their inclusion in the Los Angeles–Riverside–Orange County, CA CMSA.

The current version of these air quality regions (figure 1) does not cover Alaska (626,932 residents) or Hawaii (1,211,537 residents). The Commonwealth of Puerto Rico is not included in the U.S. population totals or in the current air quality regions. In future versions, Alaska probably should be divided into two or more air quality regions, while Hawaii and Puerto Rico probably should be single air quality regions.

Air Quality Considerations

These population-based air quality regions have been assembled with a basic knowledge of the general determinants and levels of criteria air pollutants, but not on the basis of specific air quality measurements. In each region, air quality sources will be a combination of (a) the long-range transport of primary and second pollutants, (b) the atmospheric generation of secondary pollutants from transported and locally-generated primary pollutants, (c) area sources, (d) local mobile sources, and (e) local point sources. The first two source categories will result in regional-scale increases in air pollutant concentrations, while population-exposures to air pollutants from the other three source categories may be more greatly affected by proximity to the source.

Ideally, each air quality region should be small enough so that the region's population experiences similar exposures to the regional-scale sources of air pollution. However, considerable variations may still exist in population exposures to air pollutants from local sources. Air quality regions that would be small enough to ensure complete uniformity of population exposures to pollutants from all sources would be too numerous to permit the development of a workable exposure assessment system.

The exposure of the air quality region's residents to regional-scale exposures to air pollutants may be determined from direct monitoring. The determination of population exposures to local sources, such as mobile sources, will require a combination of direct monitoring and modeling. The air quality models will need to take into consideration each resident's proximity to major roadways, the density and type of traffic on these roadways, and the density of smaller roadways in the neighborhood. These small-scale

considerations may be more important in air quality regions with considerable variation in the density of population, housing units, and roadways.

Types of Air Quality Regions

The 23 **major urban regions** consist of one or more undivided MSA's or CMSA's. These major urban areas range in size from the 21,104,292 residents of the New York City air quality region to the 2,566,053 residents of the Richmond to Norfolk air quality region. In a few instances, one or more adjoining non-MSA counties have been included to preserve the contiguous nature of these major urban areas. The combined populations of these 23 major urban regions (139,682,947 residents) is nearly half of the entire U.S. population.

The 21 **city regions** consist of MSA's with populations between 750,000 and 2,500,000 residents that are not part of larger urban areas. A few of the small MSA's within the following rural regions may deserve promotion to city areas if local conditions warrant their increased monitoring. An example of such a city is the El Paso, TX MSA that is located just north of the major Mexican city of Ciudad Juarez (over 2,000,000 residents). The combined populations of these 21 city regions (23,392,084 residents) is eight percent of the U.S. population.

The 17 **rural regions** consist of less urban counties and equivalent entities, but may include isolated MSA's of less than 750,000 residents. The designation of these rural regions followed to general boundaries of the State Economic Areas delineated by the U.S. Bureau of the Census in the 1950's. The Appalachian rural regions follow the boundaries established by the Appalachian Regional Commission, but

this region was divided into five air quality regions to allow for regional-scale differences in air pollutant concentrations. These rural regions contain small MSA's which are listed in the definition of each region.

The 4 **valley regions** consist of rural regions along major waterways in the eastern U.S. Historically, narrow river valleys have been a major factor in locally high air pollutant concentrations and in major air pollution disasters such as occurred in Denora, PA. These valley regions may include isolated MSA's of less than 1,000,000 residents.

The 7 **coastal regions** consist of counties within 10 km of the coast lines of the U.S. and outside the major urban areas. Unlikely narrow river valleys, coastal regions have generally low air pollutant concentrations due to on and off shore breezes and other routine meteorological conditions. The major urban areas of the northeastern U.S., Houston, TX and Pensacola to New Orleans are not included as coastal regions.

The 7 **extremely low-density regions** consist of rural regions with population densities less than 7 residents per km^2. Due to the low population density, air quality monitoring is a very inefficient means of estimating population exposures. Fortunately, air pollutant concentrations tend to be very low in these regions. Only four of the MSA's in these low-density regions have more than 240,000 residents: the Albuquerque, NM MSA (712,738 residents); the Boise City, ID MSA (432,345 residents); the Reno, NV MSA (339,486 residents); and the Lubbock, TX MSA (242,628 residents).

Major Urban Regions

The **New York City** air quality region (21,104,292 residents) consists of the New York–Northern New Jersey–Long Island, NY–NJ–CT–PA CMSA excluding Litchfield county, CT (26,829 km^2 with 787 residents per km^2). This CMSA includes the following 15 PMSA's: Trenton, NJ (350,761 residents); Bergen–Passaic, NJ (1,373,167 residents); Jersey City, NJ (608,975 residents); Middlesex–Somerset–Hunterdon, NJ (1,169,641 residents); Monmouth–Ocean, NJ (1,126,217 residents); Newark, NJ (2,032,989 residents); New York, NY (9,314,235 residents); Newburgh, NY–PA (387,669 residents); Dutchess County, NY (280,150 residents); Nassau–Suffolk, NY (2,753,913 residents); New Haven–Meriden, CT (542,149 residents); Stamford–Norwalk, CT (353,556 residents); Bridgeport, CT (459,479 residents); Danbury, CT (183,303 residents in Fairfield county); and Waterbury, CT (187,200 residents in New Haven county). In order to preserve county boundaries in the New England area, this region does not include any portion of Litchfield county, CT: 34,677 residents of the Danbury, CT MSA and 41,784 residents of the Waterbury, CT MSA.

The **Washington/Baltimore** air quality region (7,608,070 residents) consists of the Washington–Baltimore, DC–MD–VA–WV CMSA (24,825 km^2 with 307 residents per km^2). This CMSA includes the Baltimore, MD PMSA (2,552,994 residents), the Washington, DC–MD–VA–WV PMSA (4,923,153 residents) and the Hagerstown, MD PMSA (131,923 residents).

The **Philadelphia** air quality region (6,188,463 residents) consists of the Philadelphia–Wilmington–Atlantic City, PA–NJ–DE–MD CMSA (15,483 km^2 with 400 residents per km^2). This CMSA includes the Atlantic–Cape May, NJ PMSA (354,878 residents), the Philadelphia, PA–NJ PMSA (5,100,931 residents), the Vineland–Millville–Bridgeton, NJ PMSA (146,438 residents), and the Wilmington–Newark, DE–MD, PMSA (586,216 residents).

The **Boston/Providence/Hartford** air quality region (10,320,465 residents) consists of 31 counties along the Atlantic coast from Hartford, CT to Portland, ME (43,225 km^2 with 239 residents per km^2) including the Boston–Worcester–Lawrence, MA–NH–ME–CT CMSA. The Boston–Worcester–Lawrence, MA–NH–ME–CT CMSA includes the following 10 PMSA's: Boston, MA–NH (3,406,829 residents); Brockton, MA (255,459 residents); Fitchburg–Leominster, MA (142,284 residents); Lawrence, MA–NH (396,230 residents); Lowell, MA–NH (301,686 residents); Manchester, NH (198,378 residents); Nashua, NH (190,949 residents); New Bedford, MA (175,198 residents); Portsmouth–Rochester, NH–ME (240,698 residents); and Worcester, MA–CT (511,389 residents). Six smaller MSA's that lie north of the New York City region have been joined into this air quality region including the Providence–Fall River–Warwick, RI–MA MSA (1,188,613 residents), the Hartford, CT MSA (1,183,110 residents), the New London–Norwich, CT–RI MSA (293,566 residents), the Springfield, MA MSA (591,932 residents), the Barnstable–Yarmouth, MA MSA (162,582 residents), and the Portland, ME MSA (243,537 residents). In order to preserve county boundaries in the New England area, the borders of these MSA's and PMSA's have been expanded to include the non-MSA portions of the counties in which they lie. Thus, this region includes all of Litchfield county, CT: 34,677 residents of the Danbury, CT PMSA and 41,784 residents of the Waterbury, CT PMSA.

The **Albany to Niagra** air quality region (4,435,206 residents) consists of a band of seven MSA's running west from the Pittsfield, MA area to the Niagra Falls, NY area (43,315 km^2 with 102 residents per km^2). These MSA's from east to west include the Pittsfield, MA MSA (84,699 residents plus 50,254 residents of Berkshire county, MA who reside outside the MSA), the Albany–Schenectady–Troy, NY MSA (875,583 residents), the Glens Falls, NY MSA (124,345 residents), the Utica–Rome, NY MSA (299,896), the Syracuse, NY MSA (732,117 residents), the Rochester, NY MSA (1,098,201 residents), and the Buffalo–Niagra Falls, NY MSA (1,170,111 residents).

The **Scranton–Harrisburg** air quality region (3,407,205 residents) consists a band of six MSA's (24,504 km^2 with 139 residents per km^2) that are located just west of the Philadelphia and New York regions. These MSA's include the Scranton–Wilkes-Barre–Hazleton, PA MSA (624,776 residents), the Allentown–Bethlehem–Easton, PA MSA (637,958 residents), the Reading, PA MSA (373,638 residents), the Harrisburg–Lebanon–Carlisle, PA MSA (629,401 residents), the Lancaster, PA MSA (470,658 residents), and the York, PA MSA (381,751 residents). This region also includes Monroe county, PA (138,687 residents); an isolated, non-MSA county just northeast of the Allentown–Bethlehem–Easton, PA MSA.

The **Pittsburgh to Cleveland** air quality region (7,087,165 residents) consists of a contiguous band of eight MSA's/CMSA's from Pittsburgh, PA to Cleveland, OH (36,562 km^2 with 194 residents per km^2). These MSA's include the Pittsburgh, PA MSA (2,358,695 residents), the Sharon, PA MSA (120,293 residents), the Steubenville–Weirton, OH–WV MSA (132,008 residents), the Wheeling, WV–OH MSA (153,172 residents), the Canton–Massillon, OH MSA (406,934 residents), the Erie, PA MSA (280,843 residents), the Youngstown–Warren, OH MSA (594,746 residents), and the Cleveland–Akron, OH CMSA. The Cleveland–Akron, OH CMSA includes the Akron, OH PMSA (694,960 residents) and the Cleveland–Lorain–Elria, OH PMSA (2,250,871 residents).

The **Toledo–Detroit–Flint** air quality region (6,074,631 residents) consists of the Toledo, OH MSA (618,203 residents) and the Detroit–Ann Arbor–Flint, MI CMSA (20,631 km^2 with 294 residents per km^2). The Detroit–Ann Arbor–Flint, MI CMSA includes the Ann Arbor, MI PMSA (578,736 residents), the Detroit, MI PMSA (4,441,551 residents), and the Flint, MI PMSA (436,141 residents).

The **Milwaukee–Chicago–Gary** air quality region (10,847,112 residents) consists of the Chicago–Gary–Kenosha, IL–IN–WI CMSA and the Milwaukee–Racine, WI CMSA (22,742 km^2 with 477 residents per km^2). The Chicago–Gary–Kenosha, IL–IN–WI CMSA includes the Gary, IN PMSA (631,362 residents), the Chicago, IL PMSA (8,272,768 residents), the Kankakee, IL PMSA (103,833 residents), and the Kenosha, WI PMSA (149,577 residents). The Milwaukee–Racine, WI CMSA includes the Milwaukee–Waukesha, WI PMSA (1,500,741 residents) and the Racine, WI PMSA (188,831 residents).

The **Minneapolis–St. Paul** air quality region (2,968,806 residents) consists of the Minneapolis–St. Paul, MN–WI MSA (16,349 km^2 with 182 residents per km^2).

The **Richmond to Norfolk** air quality region (2,566,053 residents) consists two contiguous MSA's in central Virginia (13,845 km^2 with 185 residents per km^2) including the Richmond–Petersburg, VA MSA (996,512 residents) and the Norfolk–Virginia Beach–Newport News, VA–NC MSA (1,569,541 residents).

The **Raleigh to Greenville** air quality region (4,901,184 residents) consists of a band of four contiguous MSA's running from central North Carolina to the western tip of South Carolina along two interstate corridors (36,347 km^2 with 135 residents per km^2). These four MSA's include the Raleigh–Durham–Chapel Hill, NC MSA (1,187,941 residents), the Greensboro–Winston-Salem–High Point, NC MSA (1,251,509 residents), the Charlotte–Gastonia–Rock Hill, NC–SC MSA (1,499,293 residents), and the Greenville–Spartanburg–Anderson, SC MSA (962,441 residents).

The **Atlanta** air quality region (4,112,198 residents) consists of the Atlanta, GA MSA (15,880 km^2 with 259 residents per km^2).

The **Florida Peninsula** air quality region (14,520,138 residents) consists of 40 counties in the Florida peninsula (96,957 km^2 with 150 residents per km^2). This air quality region includes 13 non-MSA counties in the Florida peninsula south of Gainesville, FL and 15 MSA's: Jacksonville, FL (1,100,491 residents); Gainesville, FL (217,955 residents); Dayton Beach, FL (493,175 residents); Ocala, FL (258,916 residents); Orlando, FL (1,644,561 residents); Melbourne–Titusville–Palm Bay, FL (476,230 residents); Lakeland–Winter Haven, FL (483,924 residents); Tampa–St. Petersburg–Clearwater, FL (2,395,997 residents); Sarasota–Bradenton, FL (589,959 residents); Punta Gorda, FL (141,627 Residents); Fort Myers–Cape Coral, FL (440,888 residents); Naples, FL (251,377 residents); Fort Pierce–Port St. Lucie, FL (319,426 residents); West Palm Beach–Boca Raton, FL (1,131,184 residents); and Miami–Fort Lauderdale, FL (3,876,380 residents).

The **Pensacola to New Orleans** air quality region (3,528,105 residents) consists of a band of five contiguous MSA's running along the Gulf coast from Pensacola, FL to New Orleans, LA (34,896 km^2 with 101 residents per km^2). These MSA's include the Pensacola, FL MSA (412,153 residents), the Mobile, AL MSA (540,258 residents), the Biloxi–Gulfport–Pascagoula, MS MSA (363,988 residents), the Baton Rouge, LA MSA (602,894 residents), and the New Orleans, LA MSA (1,337,726 residents).

The **Houston** air quality region (4,669,571 residents) consists of the Houston–Galveston–Brazoria, TX CMSA (20,201 km^2 with 231 residents per km^2). The Houston–Galveston–Brazoria, TX CMSA includes the Brazoria, TX PMSA (241,767 residents), the Galveston–Texas City, TX PMSA (250,158 residents), and the Houston, TX PMSA (4,177,646 residents).

The **Dallas/Fort Worth** air quality region (5,221,801 residents) consists of the Dallas–Fort Worth, TX CMSA (24,060 km^2 with 217 residents per km^2). The Dallas–Fort Worth, TX CMSA includes the Dallas, TX PMSA (3,519,176 residents) and the Fort Worth–Arlington, TX PMSA (1,702,625 residents).

The **St. Louis** air quality region (2,603,607 residents) consists of the St. Louis, MO–IL MSA (16,733 km^2 with 156 residents per km^2).

The **Front Range (Denver)** air quality region (3,573,008 residents) consists of a band of five contiguous MSA's running just east of the front range of the Rocky Mountains (47,364 km^2 with 75 residents per km^2). These MSA's include the Cheyenne, WY MSA (81,607 residents), the Fort Collins–Loveland, CO MSA (251,494 residents), the Denver–Boulder–Greeley, CO CMSA, the Colorado Springs, CO MSA (516,929 residents), and the Pueblo, CO MSA (141,472 residents). The Denver–Boulder–Greeley, CO CMSA includes the Boulder–Longmont, CO PMSA (291,288 residents), the Denver, CO PMSA (2,109,282 residents), and the Greeley, CO PMSA (180,936 residents).

The **Phoenix–Mesa** air quality region (3,251,876 residents) consists of the Phoenix–Mesa, AZ MSA. The Phoenix–Mesa air quality region includes over 37,212 km^2 (87 residents per km^2) due to the large size of Arizona counties, but most of the population resides in a denser urban core.

The **Los Angeles/San Diego** air quality region (19,187,478 residents) consists of the San Diego, CA MSA (2,813,833 residents) and the Los Angeles–Riverside–Orange County, CA CMSA (98,535 km^2 with 195 residents per km^2). The Los Angeles–Riverside–Orange County, CA CMSA includes the Los Angeles–Long Beach, CA PMSA (9,519,338 residents), the Orange County, CA PMSA (2,846,289 residents), the Riverside–San Bernardino, CA PMSA (3,254,821 residents), and the Ventura, CA PMSA (753,197 residents). The effective population density of this urban region is understated due to the inclusion of two large counties: San Bernardino and Riverside.

The **San Francisco** air quality region (7,039,362 residents) consists of the San Francisco–Oakland–San Jose, CA CMSA (19,058 km^2 with 369 residents per km^2). The San Francisco–Oakland–San Jose, CA CMSA includes the Oakland, CA PMSA (2,392,557 residents), the San Francisco, CA PMSA (1,731,183 residents), the San Jose, CA PMSA (1,682,585 residents), the Santa Cruz–Watsonville, CA PMSA (255,602 residents), the Santa Rosa, CA PMSA (458,614 residents), and the Vallejo–Fairfield–Napa, CA PMSA (518,821 residents).

The **Seattle–Tacoma** air quality region (3,554,760 residents) consists of the Seattle–Tacoma–Bremerton, WA CMSA (18,528 km^2 with 192 residents per km^2). The Seattle–Tacoma–Bremerton, WA CMSA includes the Bremerton, WA PMSA (231,969 residents), the Olympia, WA PMSA (207,355 residents), the Seattle–Bellevue–Everett, WA PMSA (3,554,760 residents), and the Tacoma, WA PMSA (700,820 residents).

Large City Regions

The **Portland** air quality region (2,265,223 residents) consists of the Portland–Salem, OR–WA CMSA (18,153 km^2 with 125 residents per km^2). The Portland–Salem, OR–WA CMSA includes the Portland–Vancouver, OR–WA PMSA (1,918,009 residents) and the Salem, OR PMSA (347,214 residents).

The **Cincinnati** air quality region (1,979,202 residents) consists of the Cincinnati–Hamilton, OH–KY–IN CMSA (9,932 km^2 with 199 residents per km^2). The Cincinnati–Hamilton, OH–KY–IN CMSA consists of the Cincinnati, OH–KY–IN PMSA (1,646,395 residents) and Hamilton–Middletown, OH PMSA (332,807 residents).

The **Sacramento** air quality region (1,796,857 residents) consists of the Sacramento–Yolo, CA MSA (13,488 km^2 with 133 residents per km^2).

The **Kansas City** air quality region (1,776,062 residents) consists of the Kansas City, MO–KS MSA (13,945 km^2 with 127 residents per km^2).

The **Provo–Salt Lake City** air quality region (1,702,450 residents) consists two contiguous MSA's that are located in northern Utah (10,908 km^2 with 156 residents per km^2). These MSA's include the Provo–Orem, UT MSA (368,536 residents) and the Salt Lake City–Ogden, UT MSA (1,333,914 residents).

The **Indianapolis** air quality region (1,607,486 residents) consists of the Indianapolis, IN MSA (9,276 km^2 with 173 residents per km^2).

The **San Antonio** air quality region (1,592,383 residents) consists of the San Antonio, TX MSA (8,607 km^2 with 185 residents per km^2).

The **Las Vegas** air quality region (1,563,282 residents) consists of the Las Vegas, NV–AZ MSA. The Las Vegas air quality region includes over 101,830 km^2 (15 residents per km^2) due to the large size of Nevada counties, but most of the population resides in a denser urban core.

The **Columbus** air quality region (1,540,157 residents) consists of the Columbus, OH MSA (8,211 km^2 with 188 residents per km^2).

The **Austin–San Marcos** air quality region (1,249,763 residents) consists of the Austin–San Marcos, TX MSA (10,999 km^2 with 114 residents per km^2).

The **Nashville** air quality region (1,231,311 residents) consists of the Nashville, TN MSA (10,576 km^2 with 116 residents per km^2).

The **Memphis** air quality region (1,135,614 residents) consists of the Memphis, TN–AR–MS MSA (7,855 km^2 with 145 residents per km^2).

The **Grand Rapids** air quality region (1,088,514 residents) consists of the Grand Rapids–Muskegon–Holland, MI MSA (7,302 km^2 with 149 residents per km^2).

The **Oklahoma City** air quality region (1,083,346 residents) consists of the Oklahoma City, OK MSA (10,998 km^2 with 99 residents per km^2).

The **Louisville** air quality region (1,025,598 residents) consists of the Louisville, KY–IN MSA (5,324 km^2 with 193 residents per km^2).

The **Dayton** air quality region (950,558 residents) consists of the Dayton–Springfield, OH MSA (4,274 km^2 with 222 residents per km^2).

The **Fresno** air quality region (922,516 residents) consists of the Fresno, CA MSA (20,659 km^2 with 45 residents per km^2).

The **Birmingham** air quality region (921,106 residents) consists of the Birmingham, AL MSA (8,198 km^2 with 112 residents per km^2).

The **Tucson** air quality region (843,746 residents) consists of the Tucson, AZ MSA. The Tucson air quality region includes over 23,627 km^2 (36 residents per km^2) due to the large size of Arizona counties, but most of the population resides in a denser urban core.

The **Tulsa** air quality region (803,235 residents) consists of the Tulsa, OK MSA (13,203 km^2 with 61 residents per km^2).

The **El Paso** air quality region (679,622 residents) consists of the El Paso, TX MSA (2,543 km^2 with 267 residents per km^2).

Rural Regions

The **Northern New England** air quality region (2,241,468 residents) consists of 42 counties (149,718 km^2 with 15 residents per km^2) north of the Boston/Providence/Hartford and Albany to Niagra air quality regions. This rural air quality region includes the Bangor, ME MSA (90,864 residents), the Lewiston–Auburn, ME MSA (90,830 residents), and the Burlington, VT MSA (169,391 residents).

The **Northern Appalachia** air quality region (3,588,349 residents) consists of 55 counties (107,402 km^2 with 33 residents per km^2) of the Appalachian Region in New York and Pennsylvania north of the Mason-Dixon line (aside from one rural county in southwestern Pennsylvania). This rural air quality region includes the Jamestown, NY MSA (139,750 residents), the Elmira, NY MSA (91,070 residents), the Binghamton, NY MSA (252,320 residents), the Williamsport, PA MSA (120,044 residents), the State College, PA MSA (135,758 residents), the Johnstown, PA MSA (232,621 residents), and the Altoona, PA MSA (129,144 residents).

The **Central Appalachia** air quality region (2,537,893 residents) consists of 87 counties (98,645 km^2 with 26 residents per km^2) of the Appalachian Region in Ohio and in Maryland, West Virginia and Virginia south of the Mason-Dixon line (aside from one rural county in southwestern Pennsylvania). This rural air quality region includes the Cumberland, MD–WV MSA (102,008 residents) and the Charleston, WV MSA (251,662 residents).

The **South Central Appalachia** air quality region (1,566,683 residents) consists of 71 counties (65,669 km^2 with 24 residents per km^2) of the Appalachian Region in eastern Kentucky and Tennessee. This rural air quality region contains no MSA's.

The **Southeastern Appalachia** air quality region (2,154,049 residents) consists of 54 counties (53,304 km^2 with 40 residents per km^2) of the Appalachian Region in western North Carolina and northern Georgia. This rural air quality region includes the Hickory–Morganton–Lenoir, NC MSA (341,851 residents), the Asheville, NC MSA (225,965 residents), and the Athens, GA MSA (153,444 residents).

The **Bluegrass** air quality region (1,410,263 residents) consists of 41 counties (37,115 km^2 with 38 residents per km^2) in western Kentucky and Tennessee. This rural air quality region includes the Lexington, KY MSA (479,198 residents) and the Clarksville–Hopkinsville, TN–KY MSA (207,033 residents).

The **Piedmont** air quality region (2,093,921 residents) consists of 61 counties (59,493 km^2 with 35 residents per km^2) central Virginia and eastern North Carolina. This rural air quality region includes five MSA's: Charlottesville, VA (159,576 residents); Roanoke, VA (235,932 residents); Lynchburg, VA (214,911 residents); Danville, VA (110,156 residents), and Rocky Mount, NC (143,026 residents).

The **Southeast** air quality region (6,697,074 residents) consists of 171 counties (203,124 km^2 with 33 residents per km^2) from central North Carolina to eastern Alabama. This rural air quality region includes 13 MSA's: Goldsboro, NC (113,329 residents); Fayetteville, NC (302,963 residents); Florence, SC (125,761 residents); Columbia, SC (536,691 residents); Sumter, SC (104,646 residents); Augusta–Aiken, GA–SC (477,441 residents); Athens, GA (153,444 residents); Macon, GA (322,549 residents); Albany, GA (120,822 residents); Columbus, GA–AL (274,624 residents); Auburn–Opelika, AL (115,092 residents); and Dothan, AL (137,916 residents).

The **South Central** air quality region (4,419,205 residents) consists of 127 counties (205,746 km^2 with 22 residents per km^2) in western Alabama and Tennessee and eastern Mississippi. This rural air quality region includes 6 MSA's: Gadsden, AL (103,459 residents); Anniston, AL (112,249 residents); Montgomery, AL (333,055 residents); Tuscaloosa, AL (164,875 residents); Jackson, MS (440,801 residents); Hattiesburg, MS (111,674 residents); and Jackson, TN (107,377 residents).

The **West South Central** air quality region (2,723,327 residents) consists of 71 counties (141,131 km^2 with 19 residents per km^2) in northwestern Louisiana, eastern Texas and southwest Arkansas. This rural air quality region includes six MSA's: Alexandria, LA (126,337 residents); Monroe, LA (147,250 residents); Shreveport–Bossier City, LA (392,302 residents); Texarkana, TX–Texarkana, AR (129,749 residents); Longview–Marshall, TX (208,780 residents); and Tyler, TX (174,706 residents).

The **Eastern Mid-West** air quality region (6,486,226 residents) consists of 114 counties (128,926 km^2 with 50 residents per km^2) in western Ohio, Indiana, and southern Michigan. This semi-rural air quality region includes 15 MSA's: Mansfield, OH (175,818 residents); Lima, OH (155,084 residents); Jackson, MI (158,422 residents); Lansing–East Lansing, MI (447,728 residents); Kalamazoo–Battle Creek, MI (452,851 residents); Benton Harbor, MI (162,453 residents); South Bend, IN (265,559 residents); Fort Wayne, IN (502,141 residents); Elkhart–Goshen, IN (182,791 residents); Muncie, IN (118,769 residents); Kokomo, IN (101,541 residents); Lafayette, IN (182,821 residents); Terre Haute, IN (149,192 residents); and Bloomington, IN (120,563 residents).

The **Central Mid-West** air quality region (11,927,428 residents) consists of 363 counties (569,631 km^2 with 21 residents per km^2) in Illinois, southern Wisconsin, Iowa, Missouri, northern

Arkansas, and eastern Kansas and Nebraska. This rural air quality region includes 22 MSA's: Champaign–Urbana, IL (179,669 residents); Decatur, IL (114,706 residents): Bloomington–Normal, IL (150,433 residents); Peoria–Perkin, IL (347,387 residents); Springfield, IL (201,437 residents); Davenport–Moline–Rock Island, IA–IL (359,062 residents); Rockford, IL (371,236 residents); Janesville–Beloit, WI (152,307 residents); Madison, WI (426,526 residents); Dubuque, IA (89,143 residents); Cedar Rapids, IA (191,701 residents); Iowa City, IA (111,006 residents); Waterloo–Cedar Falls, IA (128,012 residents); Des Moines, IA (456,022 residents); Sioux City, IA–NE (124,130 residents); Omaha, NE–IA (716,998 residents) Lincoln, NE (250,291 residents); St. Joseph, MO (102,490 residents); Columbia, MO (135,454 residents); Wichita, KS (545,220 residents); Topeka, KS (169,871 residents); Lawrence, KS (99,962 residents); and Jonesboro, AR (82,148 residents).

The **North Michigan** air quality region (1,458,632 residents) consists of 39 counties (58,549 km^2 with 25 residents per km^2) in Michigan north of a line between Grand Rapids and Flint. This rural air quality region includes the Saginaw–Bay City–Midland, MI MSA (403,070 residents).

The **Upper Mid-West** air quality region (5,549,381 residents) consists of 178 counties (422,834 km^2 with 13 residents per km^2) in the Michigan peninsula, northern Wisconsin and Iowa, Minnesota, and the eastern edges of North and South Dakota along the Red River. This rural air quality region includes 12 MSA's: Sheboygan, WI (112,646 residents); Green Bay, WI (226,778 residents); Appleton–Oshkosh–Neenah, WI (358,365 residents); Wausau, WI (125,834 residents); Eau Claire, WI (148,337 residents); La Crosse, WI (126,838 residents); Rochester, MN (124,277 residents); St. Cloud, MN (167,392 residents); Duluth–Superior, MN–WI (243,815 residents); Grand Forks, ND–MN (97,478 residents); Fargo–Moorhead, ND–MN (174,367 residents) and Sioux Falls, SD (172,412 residents).

The **Central Texas / Oklahoma** air quality region (2,212,566 residents) consists of 71 counties (151,668 km^2 with 15 residents per km^2) in central Oklahoma and Texas. This rural air quality region includes five MSA's: Enid, OK (57,813 residents); Waco, TX (213,517 residents); Killeen–Temple, TX 312,952 residents); Sherman–Denison, TX (110,595 residents); and Bryan–College Station, TX (152,415 residents).

The **Ozark Plateau** air quality region (2,404,760 residents) consists of 65 counties (124,454 km^2 with 19 residents per km^2) in northwestern Arkansas, eastern Oklahoma, and southwestern Missouri. This rural air quality region includes 4 MSA's: Fort Smith, AR–OK (207,290 residents); Fayetteville–Springdale–Rogers, AR (311,121 residents); Joplin, MO (157,322 residents); and Springfield, MO (325,721 residents).

The **California Central Valley** air quality region (3,226,466 residents) consists of 24 counties (96,804 km^2 with 33 residents per km^2) in the central valley of California. This rural air quality region includes six MSA's: Bakersfield, CA (661,645 residents); Visalia–Tulare–Porterville, CA (368,021 residents); Merced, CA (210,554 residents); Modesto, CA (446,997 residents); Stockton–Lodi, CA (563,598 residents); Yuba City, CA (139,149 residents); Chico–Paradise, CA (203,171 residents); and Redding, CA (163,256 residents).

The **Columbia Plateau** air quality region (1,060,554 residents) consists of 17 counties (61,251 km^2 with 17 residents per km^2) in western Washington. This rural air quality region includes the Spokane, WA MSA (417,939 residents) and the Richland–Kennewick–Pasco, WA MSA (191,822 residents).

Valley Regions

The **Ohio Valley** air quality region (1,500,130 residents) consists of the 45 counties (41,769 km^2 with 36 residents per km^2) along the Ohio River Valley from the Steubenville, OH MSA to the Mississippi River. This region includes the Parkersburg–Marietta, WV–OH MSA (151,237 residents), the Huntington–Ashland, WV–KY–OH MSA (315,538 residents), the Evansville–Henderson, IN–KY MSA (296,195 residents) and the Owensboro, KY MSA (91,545 residents), but does not include the Cincinnati, OH, MSA or the Louisville, KY–IN MSA.

The **Upper Tennessee Valley** air quality region (1,846,978 residents) consists of 25 counties (23,363 km^2 with 79 residents per km^2) in eastern Tennessee and southwestern Virginia along the Tennessee River. This region includes the Johnson City–Kingsport–Bristol, TN–VA MSA (480,091 residents), the Knoxville, TN MSA (687,249 residents), and the Chattanooga, TN–GA MSA (465,161 residents).

The **Lower Tennessee Valley** air quality region (1,002,471 residents) consists of 21 counties (29,193 km^2 with 34 residents per km^2) in Alabama and western Tennessee along the Tennessee River. This region includes the Huntsville, AL MSA (342,376 residents), the Decatur, AL MSA (145,867 residents), and the Florence, AL MSA (142,950 residents).

The **Lower Mississippi Valley** air quality region (1,733,195 residents) consists of 54 counties (78,284 km^2 with 22 residents per km^2) from southern Illinois and Missouri to the Gulf of Mexico along the Mississippi River and a portion of the lower Red River in Arkansas. This region includes the Little

Rock–North Little Rock, AR MSA (583,845 residents) and the Pine Bluff, AR MSA (84,278 residents), but does not include the Memphis, TN–AR–MS MSA or the Lafayette, LA MSA.

Coastal Regions

The **Mid-Atlantic Coast** air quality region (801,504 residents) consists of 21 counties (18,776 km^2 with 43 residents per km^2) in eastern Virginia and on the DelMarVa peninsula that are bounded by the Richmond–Petersburg, VA MSA, the Washington–Baltimore, DC–MD–VA–WV CMSA, and the Philadelphia–Wilmington–Atlantic City, PA–NJ–DE–MD CMSA. This region includes the Dover, DE MSA (126,697 residents).

The **Southeast Coast** air quality region (2,770,723 residents) consists of 48 counties (71,641 km^2 with 39 residents per km^2) along the Atlantic coast from North Carolina to Georgia. This region includes the Greenville, NC MSA (133,798 residents), the Jacksonville, NC MSA (150,355 residents), the Wilmington, NC MSA (233,450 residents), the Myrtle Beach, SC MSA (196,629 residents), the Charleston–North Charleston, SC MSA (549,033 residents), and the Savannah, GA MSA (293,000 residents).

The **East Gulf Coast** air quality region (713,116 residents) consists of 18 counties (31,225 km^2 with 23 residents per km^2) along the Gulf coast in the Florida panhandle. This region includes the Tallahassee, FL MSA (284,539 residents), the Panama City, FL MSA (148,217 residents), and the Fort Walton Beach, FL MSA (170,498 residents).

The **Central Gulf Coast** air quality region (1,481,780 residents) consists of 19 counties (40,488 km^2 with 37 residents per km^2) along the Gulf coast from the New Orleans to the Houston. This region includes the Houma, LA MSA (194,477 residents), the Lafayette, LA MSA (385,647 residents), the Lake Charles, LA MSA (183,577 residents), and the Beaumont–Port Arthur, TX MSA (385,090 residents), but does not include the Houston–Galveston–Brazoria, TX MSA or the New Orleans, LA MSA.

The **Western Gulf Coast** air quality region (996,651 residents) consists of 13 counties (28,138 km^2 with 35 residents per km^2) along the Gulf coast of Texas from Houston to the Mexican border. This region includes the Victoria, TX MSA (84,088 residents), the Corpus Christi, TX MSA (380,783 residents), and the Brownsville–Harlingen–San Benito, TX MSA (335,227 residents).

The **California Coast** air quality region (1,101,024 residents) consists of 4 counties (27,653 km^2 with 40 residents per km^2) along the Pacific coast of southern California. This region includes the Salinas, CA MSA (401,762 residents), the San Luis Obispo–Atascadero–Paso Robles, CA MSA (246,681 residents), and the Santa Barbara–Santa Maria–Lompoc, CA MSA (399,347 residents).

The **North Pacific Coast** air quality region (2,056,047 residents) consists of 28 counties (128,492 km^2 with 16 residents per km^2) along the Pacific coast from the Canadian border to northern California. This region includes the Bellingham, WA MSA (166,814 residents), the Corvallis, OR MSA (78,153 residents), the Medford–Ashland, OR MSA (181,269 residents), and the Eugene–Springfield, OR MSA (322,959 residents).

Extremely Low-density Regions

The **High Plains** air quality region (2,021,475 residents) consists of 223 counties (858,648 km^2 with 2.4 residents per km^2) east of the Rocky Mountains from southern Colorado to the Canadian Border. This region includes the Billings, MT MSA (129,352 residents), the Casper, WY MSA (66,533 residents), the Rapid City, SD MSA (88,565 residents), and the Bismark, ND MSA (94,719 residents).

The **Great Plains** air quality region (2,070,401 residents) consists of 126 counties (381,355 km^2 with 5.4 residents per km^2) in northern Texas, eastern Oklahoma, southwest Kansas, southeastern Colorado, and northeastern New Mexico. This region includes the Abilene, TX MSA (126,555 residents), the Amarillo, TX MSA (217,858 residents), the Lubbock, TX MSA (242,628 residents), the Wichita Falls, TX MSA (140,518 residents), and the Lawton, OK MSA (114,996 residents).

The **Southwest** air quality region (4,478,318 residents) consists of 97 counties (687,524 km^2 with 6.5 residents per km^2) from southern Texas, through New Mexico and Arizona, to southern California. This region includes eight MSA's: McAllen–Edinburg–Mission, TX (569,463 residents); Laredo, TX (193,117 residents); San Angelo, TX (104,010 residents); Odessa–Midland, TX (237,132 residents); Las Cruces, NM (174,682 residents); Sante Fe, NM (147,635 residents); Albuquerque, NM (712,738 residents); and Yuma, AZ (160,026 residents).

The **Rocky Mountains** air quality region (2,206,886 residents) consists of 118 counties (717,574 km^2 with 3.1 residents per km^2) along the Rocky Mountains from southern Colorado to the Canadian Border. This region includes the Grand Junction, CO MSA (116,255 residents), the Pocatello, ID MSA (75,565 residents), the Missoula, MT MSA (95,802 residents), and the Great Falls, MT MSA (80,357 residents).

The **Great Basin** air quality region (1,235,556 residents) consists of 43 counties (457,727 km^2 with 2.7 residents per km^2) from northern Arizona through eastern Nevada and western Utah into southwestern Idaho and western Oregon. This region includes the Flagstaff, AZ–UT MSA (122,366 residents) and the Boise City, ID MSA (432,345 residents).

The **Coastal Range** air quality region (1,280,350 residents) consists of the 31 counties (257,711 km^2 with 5.0 residents per km^2) from California to Washington along the Sierra Nevada, Coastal and Cascade mountain ranges. This region includes the Reno, NV MSA (339,486 residents) and the Yakima, WA MSA (222,581 residents).

Section 5. Ambient Air Quality Monitoring Quality System Strategy

5.1 Introduction

Since the implementation of the ambient air monitoring program there has been little change to the QA regulations and the resultant quality system for the program. As new monitoring programs were developed (i.e, $PM_{2.5}$) new regulations were added but little thought was given to a review of the over all system for ensuring the quality of the nations data.

Within the same period of time changes within monitoring and QA have taken place.

- The National Performance Audit Program saw a reduction in funding which resulted in fewer audits being distributed.
- Monitoring technology has changed make instruments more reliable and stable.
- New QA processes like data quality objectives, performance based measurement systems and data quality assessment have been developed.
- EPA QA Policy has been revised in areas like the development of quality management plans and quality assurance project plans.

With the re-thinking of our process for monitoring should come a re-thinking of our processes of ensuring the quality of our data. This section will address a strategy for the review and if necessary re-development of a quality system that is germane, flexible where necessary and responsive to changes in the monitoring program.

The Quality System An important concern in any organization that is collecting and evaluating environmental data must be the quality of the results. A quality system must be developed and documented to ensure that the $PM_{2.5}$ monitoring results:

- meet a well-defined need, use, or purpose;
- satisfy customers expectations;
- comply with applicable standards and specifications;
- comply with statutory (and other) requirements of society, and
- reflect consideration of cost and economics.

A quality system is defined as a structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, and implementation plan of an organization for ensuring quality in its work processes, products, and services. The quality system provides the framework for ***planning, implementing, assessing, and reporting*** worked performed by the organization and for carrying out required QA and QC.

The development of a quality system requires a coordinated effort between “stakeholders”; EPA Headquarters, the EPA Regions, and the State, local, Tribal (SLT) monitoring community. As the strategy is presented, roles and responsibilities of the stakeholders will be identified and discussed.

5.2 Quality System Review/Improvement Process

The goal for this QA Strategy is to take a philosophical look at QA with the premise "what is an appropriate quality system elements and activities for an ambient air monitoring program". Once this is determined, any monitoring program would address the quality system elements/activities in an appropriate manner for their objectives, thereby creating some flexibility in the approach to data quyality (graded approach to QA).

Taking the lead from the Monitoring Strategy activities, it was felt that the best way to improve the Ambient Air Monitoring Program quality system was to throughly review the current program in light of new quality assurance concepts and policy. This review had supporting goals to:

- Develop an understanding and respect of the various stakeholder goals for collecting ambient air monitoring data and the various levels of acceptable data quality
- Provide a structure in which the elements vital to a healthy QA program are intimately tied to the monitoring program (i.e., are funded commensurate with ambient air monitoring)
- Provide an integrated (SLT/Region/Headquarters) approach to ambient air quality monitoring quality system development and implementation
- Review and solidify roles and responsibilities
- Move towards the development of performance based measurements and assessments to identify acceptable data quality
- Eliminate redundancies to improve cost efficiencies
- Establish a graded quality system approach to allow resource prioritization toward measurement systems that are classified as critical
- Provide a through review of regulations in order to identify requirements and those that could be considered guidance
- Revise regulations (CFR) and Guidance (Red Book Vol II) to the new recommendations
- Create an atmosphere of stakeholder cooperation and commitment to implementing the quality system
- Establish a phased approach toward implementation, with a flexible time line to assure that each step is thoroughly completed.

In order to accomplish these goals a QA Strategy Workgroup was developed. This Workgroup is composed of EPA Headquarters, EPA Regions and SLTs. Representatives for the SLTs were selected through STAPPA/ALAPCO activities.

The Workgroup created a list (see Table 1) separating the current QA activities into the three elements: 1) planning, 2) implementation, and 3) assessment/reporting. Each Worgroup member then selected one "Breakout Workgroup", based on the 3 elements/activities. Each Breakout Workgroup had a mix of Headquarter, EPA Region and SLT personnel. In order to address each QA activity in a consistent manner, a Ambient Air Monitoring Quality System Activity Information Form was developed. Figure 1 represents the information that will be collected for each activity. This process will

provide a record of the evaluation of each QA activity, provide information for a final report, and provide the direction to implement the changes in both regulation and guidance documentation (Redbook.).

Table 1 QA Element and Activity List

Quality System Elements	Activities and Questions
Planning	**Activities** < Data Quality Objectives < Regulation Development < Quality Management Plans < QA Project Plans and SOPs < Guidance Documents -Network Design -Methods -QA Manuals
Implementation	**Activities** < Training < Internal Quality Control Activities -precision checks (automated/manual) -verification/calibration (zero/span checks, flow rate checks etc) - QC described in CFR and guidance (MQO tables in Redbook APP 3) -standards certification -instrument and equipment maintenance < Record keeping < Data verification/validation
Assessment/ Reporting	**Activities** < Site Characterizations < Performance Evaluations (NPAP, PEP, Region/SLT Performance audits) < Management Systems Reviews < Technical Systems Audits < Data Quality Assessments < QA Reports < P&A Reports

In addition to the separate activities, overarching issues will be discussed such as:

< Moving to a performance based measurement system (DQO driven)
< Ensuring QA is looked at as a cost of doing business–"bundling" monitoring and QA resources more tightly togther.
< Looking at graded approaches to QA.

All Workgroup activities and conference call notes will be posted on AMTIC http://www.epa.gov/ttn/amtic/qaqcrein.html. The Workgroup meeting the week of Oct 23 -25 was used to provide consensus on the element activities, or to finish them, and discuss development of the QA Strategy Report.

Ambient Air Monitoring Quality System Activity Information Form

Quality System Element:_____ (Planning, Implementation, Assessment/Reporting)

Quality System Activity:_____

Activity Description:

Definition
Actions covered under this description
What is the function or use of this activity?
Is the activity important? (what does it get us)
Is there a product? Who is the major user of the product or information
Is this a new activity? What activity does it replace or enhance?
Brief description of current activities
Who is responsible for the activity (currently)

Pros and Cons of the activity as it's currently implemented:

Ways of improving the activity:

Who should be providing (responsible for) this activity?

Are changes to regulation or guidance required?

Figure 1. Ambient Air Monitoring Quality System Activity Information Form

5.3 Recommendations for Change

This section provides recommended changes to the quality system based upon the QA Workgroup activities and acceptance of the QA Strategy Report. The QA Strategy Workgroup successfully accomplished its workshop goals. The Workgroup felt that the overall objective of the QA Strategy is:

To develop a Comprehensive Ambient Air Monitoring Quality System with these characteristics:

- ***Performance based***
- ***Workable***
- ***Common sense***
- ***Good science***
- ***Flexibility***

- ***Defendable and comparable***
- ***Balance w/legalities***
- ***Cover both spectrums of air program expertise***
  - ***specifics for those who don't want to/can't follow flexible approach, and***
  - ***tools to support flexibility***
- ***Implementable***

The products of the Workshop are the refinements to the activity forms (Attachment 1) and a list of recommendations/action items to help effect change for improvements to the Quality System (Attachment 2). The remainder of this section will summarize these recommendations using the following categories.

- Performance Based Measurement Processes
- Roles and Responsibilities
- Funding/Resource Issues
- Regulation Changes
- Training and Guidance
- Data Certification
- Quality Management Plans (QMPs) and QA Project Plans (QAPPs)
- Quality Control
- Site Characterization
- Performance Evaluations
- Data Quality Assessments
- Data Validation/Verification

Performance Based Measurement Process (PBMS)

The QA Workgroup made a recommendation to utilize the concept of performance based measurement process as the primary tool for selection or identification of appropriate methods for ambient air monitoring. PBMS is a set of processes wherein the data quality needs, mandates or limitations of a program or project are specified and serve as criteria for selecting appropriate methods to meet those needs in a cost-effective manner. PBMS can be achieved by using the data quality objective (DQO) process early in the planning process. DQOs need to be developed in concert with the setting of the attainment standards since population and measurement uncertainty may dictate where the NAAQS is set and what error can be tolerated. DQOs would then set the stage for the development of federal reference method acceptance criteria that would be in step with the DQO. As an example, the DQOs developed for the $PM_{2.5}$ are now being used to determine the "acceptability" of continuous $PM_{2.5}$ monitors.

OAQPS would be responsible for developing DQOs for federally mandated data collection efforts. DQOs for other data collection activities (i.e., DQOs for non-trends speciation sites) would be the responsibilities of the SLTs. Relative to the NCore, it would appear that monitoring for comparison to

the NAAQS would be included in NCore. Therfore, DQOs would be developed by OAQPS for monitoring to fulfill this objective.

The performance based approach that lends itself to flexibility will put more responsibility on the SLTs for developing quality systems. Therefore, there will be a greater importance and emphasis on QA project plans. Recommendations for this category include:

Complete DQOs for other criteria pollutants -Prioritize this activity to ozone and toxics (if necessary). If a coarse particulate matter standard is coming along, get ahead of the curve for this DQO. As time allows, utilize the DQO process to establish DQOs for the other criteria pollutants.
.

Link DQOs more directly to Federal Reference Method and Equivalency Program - It is important to continue implementation of the Federal Reference Method and Equivalency Program but the acceptance criteria should be linked to the DQOs.

Use of a graded approach to QA - Not all ambient air monitoring data are used for comparison to the NAAQS. Therefore some monitoring objectives may not call for quality systems and quality assurance documentation (QAPPS) to meet the stringent requirements for NAAQS comparison purposes.

No network deployment until full testing of monitors - The Workgroup felt that more "real-world" testing of monitoring equipment needs to occur prior to implementation of new monitoring programs. This will help identify monitor problems and will supply information on population and measurement uncertainties. It was felt that the NCore sites (all or a selection) might be used for testing purposes.

Provide more ambient air specific training on the DQO process

Provide a vehicle for statistical support on DQOs- OAQPS will establish a contract vehicle that would allow SLTs to tap into statistical help as it relates to DQOs.

Roles and Responsibilities

As the Workgroup proceeded through the elements they identified what organization (OAQPS, EPA Regions, or SLTs) was responsible for each endeavor. The activity forms in Attachment 1 summarize, in general terms, roles and responsibilities. More details of this information will be developed as the specific elements are addressed in the QA Handbook Volume II (Redbook).

One issue that was raised at the Workshop was identifying a QA manager for each SLT monitoring organization. The Workgroup mentioned that within the SLT organization there needs to be a group or resource that understands QA and the quality system and is empowered to implement the quality

system. The Workgroup will identify a minimum level of responsibilities for this individual in order to ensure consistency in implementing the ambient air quality system.

Funding/Resource Issues

The Workgroup felt that QA activities needed to be intimately tied to the monitoring process so that costs for the quality system increase/decrease commensurately with monitoring costs. Resource and funding related action items include:

Provide a reasonable estimate of the "cost of QA" - Identify quality system elements for a "typical" SLT monitoring organization and provide an estimate of the costs of an adequate quality system. Use these estimates to provide a percentage of monitoring costs that should be allocated to the implementation of a quality system.

Ensure grant funds available for QA training - Similar to funding for AIRS training, the Workgroup thought QA training was important and in many cases funding is not made available. As the Workgroup develops their "cost of QA" they will pursue a mechanism similar to that which makes AIRS training available. Additional information on training is included in the section specific to this topic.

Provide Contractual Support - The Workgroup suggested OAQPS provide a mechanism for SLTs to tap into statistical expertise for development of data quality objectives, data quality assessments and other statistically related assessments.

STAG Resources for NPAP - The Workgroup endorsed the use of STAG resources to cover the NPAP program. STAG funds currently pay for the $PM_{2.5}$ Performance Evaluation Program (PEP). The NPAP program is currently being re-invented to a through-the-probe audit process. The added costs to each State to implement this new program is about 11K. More information on this suggestion is included in the performance evaluation section.

Regulation Changes

Regulation for the Ambient Air Monitoring Program quality system can be found primarily in 40 CFR Part 58 Appendix A and B. These two appendices were the focus of the Workgroup. However, quality control criteria can also be found in 40 CFR Part 50 that describe the method requirements.

As mentioned in the introduction, the QA Strategy Workgroup spent most of its time identifying the important elements of a quality system and did not get into any details of a particular pollutant or method. Therefore, this section will not contain specific regulation changes to a particular pollutant but will provide recommendations at a broader scale. Recommendations and action items include:

Reducing confusion between requirements and guidance- In general anything in regulation identified as a "must," "shall" or "will" is considered mandatory. Guidance documents usually

supplement the regulation by providing additional information. Guidance documents may provide additional "suggested" methods, quality control samples or acceptance criteria that are not found in CFR and are therefore not mandatory. However there have been cases where CFR requires that guidance documents be followed. This has added some confusion to the traditional use of regulations and guidance documentation.

Define graded approach in CFR- EPA has endorsed using a graded approach for QA; meaning tailoring your quality system and QA project plan development to the objectives for which the data are being collected. For example, developing a quality system for data that will be used to make regulatory decisions would need a "more stringent" quality system than an air monitoring program for environmental education purposes. The Workgroup will try to define and utilize the graded approach as it relates to the collection of ambient air data for different monitoring objectives. The approach needs to provide balance between monitoring objectives and data comparability among programs with similar objectives.

Combine Part 58 Appendix A and B- Since most of the requirements for Appendix A (SLAMS) and Appendix B (PSD) are the same, the Workgroup agreed that the appendices could be combined.

Review the requirements, focusing on the "musts" -The Workgroup had the general opinion that if performance based measurement systems were going to work, performance goals (DQOs) were needed and that quality control (QC) samples would be used to evaluate the achievement of the goals. However, the frequency of implementing the requirements and some of the actual acceptance criteria may not be required in CFR. These specifics would be included in guidance documents. Therefore, organizations with sophisticated QA programs would have the flexibility to develop their quality systems with minimal hindrance in requirements while organizations that had less sophisticated programs or expertise could use the guidance to develop their quality systems. Allowing this type of flexibility will put much more emphasis on the development, approval and use of QA project plan documentation and oversight activities.

Revise CFR to provide for quarterly data certifications - Due to the emphasis on real-time reporting, it was felt that data quality validation and evaluation is occurring earlier in the monitoring process than in the past. In addition, the QA Reports distributed by OAQPS (i.e., CY99 and CY00 $PM_{2.5}$ QA Reports) have limited usefulness due to the fact that the data is not evaluated until after it is officially certified (6 months after the calendar year in which it was collected). The Workgroup felt that certifications could occur sooner and proposed a quarterly certification process. More information on this recommendation is provided later in this report.

Training and Guidance

The Workgroup had a number of recommendations and actions items related to training and guidance documents. The majority of these are in attachment 1. Some significant recommendations include:

Place more emphasis on training- There was a sense that QA training has been neglected. It was suggested that mechanisms for achieving training be included in the grant requirements (funds should be set aside in grant process), identifying specific training in QAPPs, or as part of technical systems audits recommendations.

Development of "certification/accreditation" programs- One way to place more emphasis on training was to establish a national accreditation process to certify personnel in the following categories:

Upper Management - QA 101, basic QA concepts
Ambient Air Monitoring Manager
Site Operator
Calibrators
QA Technician
Laboratory Scientist
QA Manager
Information Manager

This accreditation process would foster a level of consistency across the nation. SLT organizations need to be creative in how they use and benefit from the accreditation process.

Combining all guidance into one document - The Workgroup identified a problem with locating various guidance documents and recommended the development of one document that would combine all the guidance necessary for ambient air monitoring and associated quality assurance. It was suggested that the QA Handbook Volume II (Redbook) be the home for the various guidance.

Annual QA Conference - The workgroup suggested that a QA meeting be held annually (similar to the AIRS Training). It was suggested that this QA meeting coincide with the National QA Conference in order to take advantage of the training modules put on by EPA Quality Staff at the National Meeting. OAQPS has submitted an abstract for a ambient air data quality objective/data quality assessment workshop for the National Meeting the week of April 8, 2002 in Phoenix in order to secure a room. We hope to be able to use the room for the remainder of the day to discuss progress on the QA Strategy. In 2003, OAQPS will work with the Quality Staff to secure additional rooms and time for an annual ambient air QA meeting.

Web-based training - OAQPS will pursue the use of web-based training courses.

Develop a generic QAPP - Take the G-5 EPA QAPP Guidance and develop a generic ambient air monitoring QAPP software product that would allow the SLTs to input the correct information into each section for their particular monitoring program.

Poll for guidance- The Workgroup endorsed polling the SLTs to determine what guidance is needed. It was suggested that STAPPA/ALAPCO could help develop/implement this poll.

Data Certification and Quicker Data Access on AIRS

Due to the more recent emphasis on real-time reporting of data, the real-time review/verification/validation of data has become equally important. Many Workgroup members questioned the current requirement for certification of a calendar years worth of data six months after the end of the previous calendar year. It was felt that due to real-time data reporting, a good majority of data verification/validation has been automated or is already occurring sooner and that delays in getting data into AIRS in many cases is simply because the regulations allow it. OAQPS does not write their QA Reports until after certification (similarly, the Trends Reports are developed on certified data). The SLTs thought that the QA Report would have more value if it reported sooner which would require earlier certification of data. A number of recommendations on this topic include:

Provide more automated requirements for data review/verification/validation - The workgroup endorsed the capital expenditure of information capture and transfer technologies (data loggers, telemetry, automated quality control) for automatic transfer of routine and quality control information to central facilities. Included in this would be quality control systems for automating various QC checks like zero/span checks or bi-weekly precision checks.

Provide for quarterly certifications- instead of waiting till 6 months from the end of the calendar year, provide a mechanism for certification on a quarterly basis.

Certified/uncertified data flagging - Data qualifiers are not used for the majority of the SLAMS pollutants, meaning that SLT personnel wait for data to be validated before uploading to AIRS. Since many SLTs use data qualifiers on their local sites to inform data users that the real time data is not validated, maybe AIRS data could be initially uploaded as "unqualified" and on a quarterly basis, based on suggestion above, have this qualifier removed. This would allow OAQPS to develop generic data evaluation/validation reports (see below) on AIRS that could be used/or modified by the AIRS user community rather than having SLTs develop their own reports.

Development of QA/QC evaluation reports - The Workgroup suggested the generation of various validation/evaluation program and reports to reduce the burden on data validation personnel and provide for quicker certification.

Quality Management Plans (QMPs) and QA Project Plans (QAPPs)

Two of the major QA documentation requirements for EPA funded programs are quality management plans (QMPs) and project specific QA project plans (QAPPs). EPA provides some flexibility on how these documents are prepared. For example, small local agencies may be able to combine their QMP and QAPP into one document. However, there are also some discrepancies among the EPA Regions on the detail and approval process of QMPs and QAPPs. Since the

objectives for SLAMS monitoring is similar in all parts of the country, there should be some consistency in the preparation/review/approval requirements for QMPs and QAPPs for the ambient air monitoring program. The QA Workgroup will try to find this balance.

As mentioned earlier, if the performance based measurement process is to be successful, the responsibility of creating an adequate quality system will be the responsibility of the SLTs and not mandated in CFR. The QAPP documents this quality system will become a more important document to SLTs since it will indicate how the organization plans on meeting, with the use of various quality control measures, the performance goals. The goal of the QA Workgroup is to foster this paradigm shift.

Quality Control Activities

The majority of the day-to-day QA activities at the SLT monitoring organization involve implementing or assessing quality control information; whether it be zero/span checks, collocated precision or running field trip or lab blanks. Each method contains a list of required and suggested quality control samples to judge data acceptability of a phase (sampling) of the measurement system or the total measurement system. The Workgroup made the following recommendations:

Use the performance based measurement system principal to develop the necessary quality control samples in the regulations without mandating frequency and acceptance criteria - CFR should identify the types of QC samples that will provide assessments of attaining the DQOs. As can be shown with the $PM_{2.5}$ DQO Software tool, various combinations of uncertainty (precision, bias etc.) effect the attainment of the data quality objectives. CFR would be revised to identify the uncertainties that needed to be measured as well as the confidence one wanted in the estimate of those uncertainties. The SLTs would then be responsible for developing a quality system that would measure, assess, and control these uncertainties. Therefore, the SLTs would determine how frequently they needed to perform various QC checks and what the appropriate acceptance criteria should be. OAQPS, using the data in AIRS could also assess data uncertainty to determine if an SLT had developed a quality system that was "in control". For organizations with less QA resources or experience, guidance documents would continue to be developed that would provide the suggested acceptance criteria and QC sample frequencies.

Site Characterizations

Site characterizations are a type of audit to ensure that samplers or monitors at the monitoring site meet the applicable siting criteria for SLAMS, NAMS and PAMS which are specified in 40 CFR Part 58 Appendix E. The on-site visit consists of the physical measurements and observations such as: height above ground level, proper spacing from various instruments, or distance from obstructions and roads. Recommendations and action items for site characterization include:

Setting minimal levels and tracking - The Workgroup will review the requirements for the frequency of such characterization and recommend a change (if necessary). In addition, the

Workgroup suggested better tracking of this information to ensure they are being performed. AIRS has an area that can be used for this tracking activity.

Ensure updates made in AIRS - Information from inspections (monitors or sampling equipment added to site, Lat/Long changes) that reflect a needed change in the site record in AIRS are not always getting revised. There needs to be some method of ensuring information found during site characterization gets corrected in AIRS in a timely manner.

Development and use of site characterization form- The Workgroup felt that a site characterization form and possibly software could be developed and distributed to provide some consistency in performing site characterizations.

Site characterization training- It was suggested that a training module be developed for the performance of site characterizations.

Speed up approvals for discontinuing sites- The Workgroup mentioned that SLTs submit paperwork for discontinuing sites that do not get approved for a considerable length of time. OAQPS needs to review this process.

Performance Evaluations

Performance evaluations (PE) are a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst or laboratory. The types of audits in this category include: the National Performance Audit Program (NPAP), Standard Reference Photometer Program (SRP), PM2.5 Performance Evaluation Program (PEP), as well as any SLT's audit programs. Recommendations included:

Avoid redundant programs - It is known that the goals of the NPAP program are similar to the goals of various SLT programs (i.e., the CARB through-the-probe audit program). In order to avoid performing multiple PEs and reduce QA costs, the Workgroup recommended defining an "acceptable" PE program and determining which SLT are performing these. NPAP would not have to include these sites within their PE network other than to establish some level of consistency/equivalency.

Combining NPAP and PEP Program- The Workgroup endorsed the revision of NPAP to a through-the-probe audit approach and agreed that the STAG funding mechanism of the current $PM_{2.5}$ PEP could be enhanced to include NPAP.

Revise requirements for industry to contribute payments to NPAP- In the past, the NPAP, which was required under the PSD requirements, provided audits to industry for free. It was suggested that a mechanism for industry payment could be added to the requirement.

Update guidance and practicability of the SRP. The SRP guidance has not been revised for a considerable length of time. Due to the stability of new ozone instruments, and jargon (definitions of primary and transfer standards etc.) that needs be revised, it was felt that the SRP program guidance needed updating.

Implement PAMS audits prior to ozone season.- The Workgroup felt that the PAMS audits should be scheduled from January to April or within some time frame that information could be evaluated and corrective actions take place prior to ozone season.

Data Quality Assessments

A data quality assessment (DQA) is a statistical evaluation of a data set to establish the extent to which it meets user-defined application requirements (i.e., DQOs). Historically, DQAs have received little attention in the ambient air monitoring community. With a move towards performance based measurements systems and DQOs., there will be more emphasis on DQAs. Recommendations from the Workgroup include.

OAQPS responsibility for DQAs - The Workgroup concluded that OAQPS should be responsible for the development of DQAs for all federally required data at the reporting organization level. Assessments at the site specific level or for objectives other than federal (i.e., non-trends speciation sites) would be the responsibility of the SLTs and be described in their QAPP.

Development of DQA tools - Similar to the $PM_{2.5}$ DQO software that is being modified as a DQA tool, as DQO development on the other criteria pollutants move forward (recommendation in another section above) DQA tools will also be made available. It is anticipated that these tools would be integrated with AIRS.

Data Validation/Verification

Similar to data quality assessments, there has not been much emphasis on data verification or validation techniques. Recommendations included:

Utilize advancements in technology - Earlier suggestions to increase the use of automated information transfer and quality control systems include the use of various automated data evaluation processes to provide for more real-time consistent screening and data verification/validation activities. Real-time data transfer technology would allow personnel at centralized offices to implement various verification/validation techniques, identify problems and take corrective actions in a more real-time mode.

Validation templates - The Workgroup suggested the continued development of data validation templates similar to the one developed by the $PM_{2.5}$ Data Validation Template Workgroup. This would allow for some level of consistency across the ambient air monitoring program.

Validation programs on AIRS- The Workgroup suggested the development of data verification/validation techniques on AIRS. This could be accomplished but may have limited benefit if data does not get reported to AIRS for some considerable period of time.

5.4 Summary and Next Steps

The Workgroup and results of the workshop produced a large lists of recommendations and action items for improvements to the ambient air monitoring quality system. The workgroup compiled a list of these (~85) suggestions and voted on their priority (high-1, medium - 2, low -3), whether the improvement could be made with little or no additional resources (Y or N) and the time frame on when the recommendation should be implemented (within 1 year -1, within 2 years-2, or 3 or greater years - 3). Attachment 2 provides the listing of these recommendations in order of priority first, and time frame second.

The QA Workgroup's efforts, as described in this draft report, will be distributed and reviewed by the Monitoring Strategy Steering Committee and the external monitoring community. Comments from these groups will be reviewed and incorporated into a final report which, once endorsed, will be implemented based on priorities, time frames and available resources . A time line and implementation plan for QA improvements would be developed upon approval of the final report.

The QA Workgroup will continue to meet as an entity for change and improvement. The Workgroup realizes that it will need to enlist other volunteers to chair specific priority projects. It hopes to utilize the STAPPA/ALAPCO process to invite other SLTs organization to participate on the improvement of the quality system.

Attachment 1

Ambient Air Monitoring Quality System Activity Form

The following form was used by the QA Strategy Workgroup to identify and review the quality system activities related to the Ambient Air Monitoring Program. The Workgroup created a list separating the current QA activities into the three elements: 1) planning, 2) implementation, and 3) assessment/reporting. Each Workgroup member then selected one "Breakout Workgroup", based on the 3 elements/activities. Each Breakout Workgroup had a mix of Headquarter, EPA Region and SLT personnel. During Breakout Workgroup Conference calls, the Breakout Workgroup discussed the activity and completed the form. This information was reviewed during the Oct 23-25, 2001 QA Strategy Meeting in RTP, NC. The following Element/Activities can be found:

Element	**Activity**	**Page**
Planning	Systematic Planning	1
Planning	Regulation Development	4
Planning	Quality Management Plans	6
Planning	QA Project Plans & SOPs	8
Planning	Guidance Documents	11
Implementation	Training	13
Implementation	Data Verification/Validation	16
Implementation	Internal Quality Control	20
Implementation	Record Keeping	23
Assessment/Reporting	Site Characterization	26
Assessment/Reporting	Performance Evaluations	28
Assessment/Reporting	PSD network for NPAP	31
Assessment/Reporting	Technical Systems Audits	33
Assessment/Reporting	Data Quality Assessments	35
Assessment/Reporting	QA Reports	37
Assessment/Reporting	P & A Reports	39
Assessment/Reporting	Quality System Audits	41

Meeting Date: September 12, 2001

Agenda: Planning Activity I - Data Quality Objectives

Attendees: Dennis Mikel, Mike Papp, Terry Rowles, Alissa Dickerson, Melinda Ronca-Battista, and Rachael Townsend

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Quality System Element: **Planning**

Quality System Activity: **Systematic Planning Process**

Activity Description:

Quality System Activity: DQO Process, including gathering information on costs of different options, assessment of the impacts of options, evaluating their implications in terms of decisions, and writing and revising associated documentation at several iterations of the process.

Definitions: **Data Quality Objectives (DQO) Process** - A systematic strategic planning tool based on the scientific method that identifies and defines the type, quality, and quantity of data needed to satisfy a specified use. DQOs are the qualitative and quantitative outputs from the DQO Process.

Data Quality Objectives (DQOs) — The qualitative and quantitative statements derived from the DQO Process that clarify study's technical and quality objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

When the DQO Process is not applicable (i.e, the objective of the program is estimation, research, or any other objective that does not select between two opposite criteria), a systematic method for defining performance criteria must be used.

Activities covered under this description:

- This element applies to all data collection activities, although the EPA's graded approach to QA allows simplified DQO processes for small data collection activities. Current DQO guidance does not, however, adequately delineate those cases when a simplified DQO process can be used and what would be acceptable for such a simplified process. The only exception is for training or demonstration projects, where the data will not be used for any purpose. In these cases, the use of the equipment is the point of the exercise.
- The national program of data collection and analysis for the purpose of comparing to the NAAQS requires a rigorous DQO process for all pollutants for which there is a standard. This effort must come from OAQPS and should be completed as soon as possible.
- Tribe, State and local agencies should retain the flexibility to develop their own DQOs.

However, DQOs for data used to compare to national standards may continue to be used as de facto allowable bias, precision and LLD values in those cases when data may eventually be used to compare to national standards. Because of this, and for EPA to adhere to its own written policies, it is imperative that OAQPS fund and complete the DQO process for all criteria pollutants.

< The DQO process may result in performance specifications, rather than equipment specifications. This will increase flexibility and may reduce overall costs.
< Metadata guidance should be prepared, so that all data incorporated into national or regional estimates from different organizations has associated information such as precision, bias, and LLD.
< Resources and funding from both EPA OAQPS and EPA Regions should be provided to Tribal, State, and local agencies in the form of training and contract support for these agencies to develop DQOs.

What is the activity's function or use:

< To ensure that the data are appropriate to be used for the objectives of the data collection effort.

Is there a product? Who is the major user of the product or information:

< The product is documentation in the form of a QA Plan or manual that includes Data Quality Objectives and other sections that were prepared using EPA guidance. The user is anyone who uses that data for any purpose.

Brief description of current activities:

< Tribe, State, and local agencies develop DQOs now, usually using guidance from EPA. EPA-funded projects receive different levels of technical review, due to differences among EPA regions and different priorities for different individuals.
< Tribe, State, and local agencies comply with extremely specific requirements for PM2.5 measurements, while other criteria pollutants, for which no national DQOs were developed, are measured without the same level of consistency in detail.

Who is responsible for the activity (currently):

< OAQPS is responsible for developing DQOs for Federally required data. Tribes, State, and local agencies are responsible for developing their own DQOs for other data uses.

Is the activity important?(what does it get us):

< The DQO process, whether simplified or extensive, is mandatory to ensure the data can answer the questions being asked. In addition, knowing the quality of the data allows users to determine if other, un-anticipated questions, can be answered by the data. Without measured

quality in terms of bias, precision, and LLD the data may be easily misused.

Pros and Cons of the activity as it's currently implemented:

Pros:
- Significant flexibility for Tribe, State, and local agencies, except for PM2.5, which is extremely prescriptive.
- Improved compatibility of objectives and measurement methods.

Cons:
- Inconsistency among Tribe, State, and local agencies for small-scale projects.
- Potential misuse of data.

Ways of improving the activity:

< OAQPS needs to develop DQOs for the NAAQS. In addition, there should be a project to evaluate converting the DQOs for PM2.5 to include performance-based standards.
< Complete DQOs for other criteria pollutants. Prioritize this activity to ozone and toxics (if necessary). If a coarse particulate matter standard is coming along, get ahead of the curve for this DQO.
< Link DQOs more directly to Federal Reference Method and Equivalency Program
< Use of a graded approach to QA - Not all ambient air monitoring data are used for comparison to the NAAQS. Therefore some monitoring objectives may not call for quality systems and quality assurance documentation (QAPPS) to meet the stringent requirements for NAAQS comparison purposes
< Provide more ambient air specific training on the DQO process
< Funding should be provided to Tribe, State, and local agencies to develop DQOs
< Provide a vehicle for statistical support on DQOs. OAQPS will establish a contract vehicle that would allow SLTs to tap into statistical help as it relates to DQOs.

Who should be providing (responsible for) this activity?

< All Tribe, State, and local agencies can develop their own DQOs; however, it is incumbent upon a national organization such as OAQPS to develop the national DQOs.
< In order that DQO development be adequately conducted by tribes, states, and locals, the EPA should provide adequate resources. These would include at least Level of Effort contracting for DQO development assistance and training in DQO development specific to air programs.

Does it require changes to regulation or guidance?

Both regulation and guidance should be changed to reflect

1. the DQOs developed by OAQPS for criteria pollutants, and
2. performance-based DQO statement for PM2.5 and other pollutants as an alternative acceptable approach to ensuring adequate data quality.

Meeting Date: September 26, 2001

Agenda: Planning Activity II - Regulation Development

Attendees: Mark Shanis, Terry Rowles, Chris Hall and Rachael Townsend

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Quality System Element: **Planning**

Quality System Activity: **Regulation Development**

Activity Description:

Quality System Activity: Writing, presenting, and revising regulations that specify how the air quality measurements must be made in order to conform to the assumptions made in the DQO process and produce results of the type and quality needed by the decision makers.
Definition:

Portions of 40 CFR 58 Appendix A, which include:

1. General Information
2. Quality System Requirements
3. Reporting
5. Calculations

Activities covered under this description:

< Writing, presenting, and revising regulations that specify how the air quality measurements must be made, analyzed, and reported.

What is the activity's function or use:

< Codify the specifics of quality systems nation wide.

Is there a product? Who is the major user of the product or information:

< Guidance and requirements in 40 CFR that guide quality systems.

Brief description of current activities:

< EPA takes the initiative, review through STAPPA/ALAPCO, proposed for CFR, then promulgated.

Who is responsible for the activity (currently):

< EPA (OAQPS) and designees.

Is the activity important?(what does it get us):

- Important and required.

Pros and Cons of the activity as it's currently implemented:

Pros: - consistency

Cons: - costly and time consuming to implementers

Ways of improving the activity:

- Revision of 40 CFR 58 App. A. and Combine Part 58 Appendix A and B- Since most of the requirements for Appendix A (SLAMS) and Appendix B (PSD) are the same, the Workgroup agreed that the appendices could be combined.
- Address how the regulation process will be affected including the DQO process.
- DQOs are not addressed in the CFR (guidance or required; at what level is it required or appropriate?).
- Review the requirements, focusing on the "musts" - If performance based measurement systems were going to work, performance goals (DQOs) were needed and that quality control (QC) samples would be used to evaluate the achievement of the goals. However, the frequency of implementing the requirements and some of the actual acceptance criteria may not be required in CFR. These specifics would be included in guidance documents. Therefore, organizations with sophisticated QA programs would have the flexibility to develop their quality systems with minimal hindrance in requirements while organizations that had less sophisticated programs or expertise could use the guidance to develop their quality systems.
- Ensure CFR clearly discriminates between requirements and what is guidance; this is made more confusing when guidance documents are referenced in the CFR as a requirement.
- Adjust regulation for guidance on how and when organizations can collapse QMP and QAPP.
- Identify methods to develop the guidance for small organizations and projects, such as those who can collapse the QMP and QAPP.
- The graded approach need to be addressed in the CFR, including specific criteria for different levels of QAPPs with examples.
- Develop a tool to identify each requirement, provide management with use and value information, and access the requirement within the regulation development process to make modifications useful to management during the process. (During processing and development of regulations, include tools for management to understand and ensure communication with technical staff on how it relates to their job. Make sure management have understanding on how to use and importance.)
- Revise CFR to provide for quarterly data certifications

Who should be providing (responsible for) this activity?

- EPA (OAQPS), assisted by affected organizations among Tribes, States, and local agencies.

Meeting Date: September 19, 2001

Agenda: Planning Activity II - Regulation Development (discussion to continue Sept. 26)
(See the attached excerpts from 40 CFR Appendix A with requirements highlighted.)

Planning Activity III - Quality Management Plans

Attendees: Norm Beloin, Mike Papp, Terry Rowles, Alissa Dickerson, Melinda Ronca-Battista, and Rachael Townsend

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Quality System Element: **Planning**

Quality System Activity: **Quality Management Plans**

Activity Description: Defining and requiring content for QMPs.

Definition: **Quality Management Plan (QMP)** — A formal document that describes the quality system in terms of the organization's structure, the functional responsibilities of management and staff, the lines of authority, and the required interfaces for those planning, implementing, and assessing all activities conducted.

Activities covered under this description:

< Defining and requiring content for QMPs.

What is the activity's function or use:

< defines the quality system for the entire organization
< provides a description of the organization and its mission
< describes the organization's management responsibilities
< helps ensure consistency between programs within the organization
< serves as an audit tool

Is there a product? Who is the major user of the product or information:

< QMP guidance published by EPA's Office of Environmental Information, in the form of guidance document EPA QA/R-2 (August 1994); note that this was revised in the spring of 2001 but the changes were very minor (EPA/240/B-01/002). QMPs are developed and revised by most larger monitoring organizations.

Brief description of current activities:

- Revisions to EPA QA/R-2 are not scheduled.
- Revisions to QMPs by Tribal, State, and local organizations.

Who is responsible for the activity (currently):

- EPA's OEI and/or OAQPS, in terms of issuing guidance for QMPs, and the organizations themselves who write and use their own QMPs.

Is the activity important?(what does it get us):

- valuable to organization, particularly States and other large monitoring organizations; see bullets above.

Pros and Cons of the activity as it's currently implemented:

Pros:- see bullets above
Cons:- QMPs are often not distributed to all staff

- no guidance on when the QMP and QAPP can be combined into one document(for smaller organizations)
- no clear guidance on how to ensure independence of QA review in small organizations
- no clear guidance on the use of the graded approach
- no resources are available in many organizations for QMP preparation

Ways of improving the activity:

- Increase consistency between EPA Regional offices on how they review QMPs.
- Revise EPA QA/R-2 with the substantive changes discussed here.
- Define needs for QMPs for all agencies.

Who should be providing (responsible for) this activity?

- EPA's OEI or a separate document from OAQPS with assistance from affected organizations.

Does it require changes to regulation or guidance?

- Yes, changes to EPA QA/R-2 or the issuance of a separate document is required.

Meeting Date: September 26, 2001

Agenda: Planning Activity IV - QAPPs and SOPs

Attendees: Terry Rowles, Melinda Ronca-Battista, Dennis Mikel, Alissa Dickerson, Rachael Townsend

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Quality System Element: **Planning**

Quality System Activity: **QA Project Plans and SOPs**

Activity description: Requiring and specifying content for QAPPs and SOPs.

Activities covered under this description:

Definition: **Quality Assurance Project Plan (QAPP)** — A formal document describing in comprehensive detail the necessary QA, QC, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria..
Standard Operating Procedure (SOP)-A written document that details the method for an operation, analysis, or action with throughly prescribed techniques and steps, and that is officially approved as the method for performing certain routine or repetitive tasks.

What is the activity's function or use:

< Guidance for QAPPs is used by Tribe, State, and local agencies to understand and adhere to the EPA requirements.

Is there a product? Who is the major user of the product or information:

< EPA QAPP guidance is used by Tribe, State, and local agencies to develop their required QAPPs, as well as EPA regions in their review of submitted QAPPs. Note that the QAPP guidance document (QA/R-2) was revised in the spring of 2001 but only very minor changes were made (EPA/240/B-01/002).

Brief description of current activities:

< No work is now being conducted by OAQPS or the EPA OEI to prepare or revise guidance for QAPPs.

Who is responsible for the activity (currently):

< OAQPS is the only entity that has the jurisdiction and resources for revising or producing air

monitoring-specific QAPP guidance.

Is the activity important? (what does it get us):

< Revising the QAPP guidance is very important. As it now stands, Tribe, State, and local air departments, especially those in small organizations, are often put in the position of either hiring contractors to produce the statistical evaluation of DQOs or copying DQOs from other groups or projects. Both of these options often produce QAPPs which are not helpful. Revising the current QAPP guidance will bring increased respect for and use of QAPPs and DQOs as sensible, integrated parts of the project. As DQO development becomes a common element of QAPPs, related issues may require changes in QAPP guidance.

Pros and Cons of the activity as it's currently implemented:

Pros: - The model PM2.5 QAPP is thorough and widely used.
S The general QAPP guidance is useful for large-scale projects for large organizations.

Cons: - The QAPP guidance does not include provision for small organizations, or for those projects for which a statistical treatment of DQO options is not relevant.

Ways of improving the activity:

Current guidance for QAPPs and SOPs should be modified as follows:

< Guidance should be provided for those cases when a new statistical derivation of DQOs is not necessary, for example, when a Tribe, State, or local organization is using DQOs already developed by OAQPS for the NAAQS, or when extremely simple conclusions are to be drawn from the results. This guidance should provide clear and simplified treatment of the statistics of DQOs, such as that provided for radiological measurements in the Multi-Agency Radiological Survey and Site Investigation Manual (MARSSIM, downloadable documents at: www.epa.gov/radiation/marssim/). A decision tree to facilitate the choice of options would be useful.
< Develop a generic QAPP - Take the G-5 EPA QAPP Guidance and develop a generic ambient air monitoring QAPP software product that would allow the SLTs to input the correct information into each section for their particular monitoring program
< As part of reference method designation process, make vendors develop adequate SOPs that could be made available for monitoring agencies to modify.
< Guidance to EPA regions on the need for consistency in the review of QAPPs should be issued as soon as possible. Regions now differ widely on their priorities and expectations regarding QAPPs, and this adds confusion and delay to the project approval process.
< Guidance for QAPPs should clearly state that QAPPs that are for projects covered by a QMP do not need to duplicate information in the QMP or applicable SOPs.

Who should be providing (responsible for) this activity?

- OAQPS is the only entity that can initiate this activity.

Does it require changes to regulation or guidance?

- Guidance should be modified or a second QAPP guidance document issued.

Meeting Date: October 4, 2001

Agenda: Planning Activity V - Guidance Documents, such as Network Design and Technical Methods

Attendees: Chris Hall, Dennis Mikel, Mike Papp, Norm Beloin, Alissa Dickerson, and Rachael Townsend

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Quality System Element: **Planning**

Quality System Activity: **Guidance Documents, such as Network Design and Technical Methods**

Activities described: Researching, writing, revising, and obtaining approval for guidance that assists those trying to adhere to the requirements of the regulations. Documents provide non-mandatory information including examples.

Activities covered under this description:

- Writing of new guidance documents, technical methods and network design
- The red books and methods associated with the red books
- Guidance documents on siting criteria

Activities not being done:

- Data quality assessment guidance
- Data validation guidance
- Data acceptance guidance
- Guidance on what level of quality is needed for AQI decisions (real -time-data)

What is the activity's function or use:

- Help define/expand regulations
- Should provide a strongly recommended way of doing the work
- Clarify what is required in the regulation
- Provide some consistency across the nation for monitoring programs

Is there a product? Who is the major user of the product or information:

- Guidance documents and technical documents, including new methods are used by Tribal, State and local agencies as well as data users, like health effects users.

Brief description of current activities:

- Siting guidance
- Production of guidance documents
- Documents are reviewed periodically

Who is responsible for the activity (currently):

- EPA (OAQPS)

Is the activity important?(what does it get us):

- Same as function of activity stated above.

Pros and Cons of the activity as it's currently implemented:

Pros: - Pro-active approach to upgrading these documents

Cons: - Have not had enough time to work on; a number of guidance documents are outdated.
- Don't have formal program to review relevance of guidance
- No single way to access all of the guidance documents

Ways of improving the activity:

- Need more state and local involvement during the early development.
- State and locals need to have a full time person for QA for the air monitoring programs.
- Define or clarify attributes or responsibilities of QA person or manager.
- Get more state and locals in on which documents are more important to them, to prioritize which are more important to them to get revised and updated.
- QA forum for continued support and exchange of information.
- Combining all guidance into one document - It was suggested that the QA Handbook Volume II (Redbook) be the home for the various guidance.

Who should be providing (responsible for) this activity?

- EPA Headquarters

Does it require changes to regulations?

- No, except for 40 CFR Part 58, App. A, Section 2.2 which states that PAMS must be consistent with EPA guidance.

Meeting Date: September 12, 2001

Agenda: Implementation– Training

Attendees: Tom Parsons, Donovan Rafferty, Jerry Sheehan, Andy Johnson, Rayna Broadway, Anna Kelly, Mark Shanis, Mike Papp

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Quality System Element: **Implementation**

Quality System Activity: **Training**

Activity Description:

Definition: **None**

Actions covered under this description:

- Sampling equipment or measurement device operation, calibration and maintenance
- Laboratory analysis calibration
- Sample chain of custody, preparation, analysis, archiving
- Quality assurance activities - performance evaluation, auditing, data quality assessment
- Information manager

What is the function or use of this activity?

- Ensure that a consistent methodologies are followed that allows for the collection of data of acceptable quality.

Is the activity important?

- Yes- Provides some assurance of data comparability within and between monitoring organization and allows for the transfer of knowledge and experience

Is there a product?

- Yes-More experienced staff and data of acceptable quality

Is this a new activity?

No.

Brief description of current activities

- On the job training - SLT one-on-one or group training

- Regional training (NESCAUM, MARAMA, WESTAR, TAMS)- various training activities put on by regional organization.
- Air and Waste Management Association (AWMA)- training put on a national or specialty conferences
- Vendor training - training put on by vendors which can be incorporated into the purchase of equipment.
- Air Pollution Distant Training Network (APDLN) provide remote televised training which also allow for real-time questions
- Air Pollution Training Institute (APTI)
- Redbook (self instruction)
- The web sites, especially AMTIC

Who is responsible for the activity-

- The responsibility for training occurs at all levels.

Pros and Cons of the activity as it's currently implemented:

Pros - On the job training is probably the most important training technique. Some SLT have good training programs

-APDLN for $PM_{2.5}$ was successful at providing a good general level of training for the program.

Cons - Training is not mandatory so some people do not take training when it would be advantageous

- Funds are not always available remote training if it is needed
- When SLT resources are tight training is one of the first things to be cut
- Although on the job training has advantages, the downside is there's not much standardization in that process and a newer agency or one that has lost its core personnel to attrition can't count on OJT.

Ways of improving the activity:

- Develop web- based training courses
- Place some important training in regulation
- Development of some type of Ambient Air Monitoring Training Certification Program for:

  - Upper Management
  - Ambient Air Monitoring Manager-
  - Site Operator
  - Calibrators
  - QA Manager
  - QA Technician
  - Laboratory Scientist
  - Information Manager

- Tie career growth to training
- Try to include vendor training as part of equipment purchases
- Combining all guidance into one document. Revise the Redbook.
- Annual QA Conference - The workgroup suggested that a QA meeting be held annually (similar to the AIRS Training). It was suggested that this QA meeting coincide with the National QA Conference in order to take advantage of the training modules put on by EPA Quality Staff at the National Meeting.
- Recognize that QA within a state agency may have more than one training need

Does is require changes to regulation or guidance

Regulation:

- Need to decide if certain training should be requirement.
- May include in regulation that training is important and records should be kept of training.

Guidance:

- May want to improve Redbook guidance on training to include certification proposal.

Meeting Date: September 20, 2001

Agenda: Implementation– Data Verification/Validation

Attendees: Tom Parsons, Rachael Townsend, Donovan Rafferty, Rayna Broadway, Anna Kelly, Mike Papp

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Quality System Element: **Implementation**

Quality System Activity: **Data Verification/Validation**

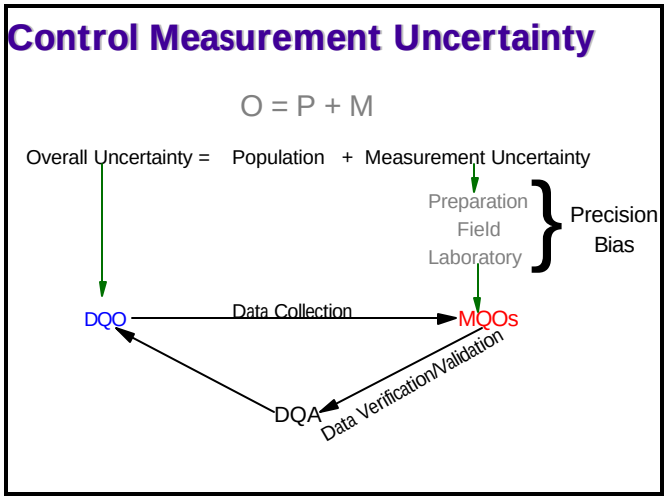
Activity Description:

Definition: **Verification** - Confirmation by examination and provision of objective evidence that specified requirements have been fulfilled. In design and development, validation concerns the process of examining a result of a given activity to determine conformance to the stated requirements for that activity. (ANSI/ISO/ASQC A8402-1994).

Validation- the process of substantiating specified performance criteria. confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. (ISO 8402)

Actions covered under this description

- Verification of data entry (100% checks, double entry techniques etc.)
- Using QC information to determine the validity of samples.
- Using range checks or internal consistency checks to determine erroneous data.
- Using automated flagging and data quality systems to identify outliers or erroneous data for possible invalidation



What is the function or use of this activity?

The figure can be used to illustrate where validation occurs. DQOs are developed that define the acceptable overall data uncertainty. Measurement quality objectives are developed that help assure that activities occurring at various phases of the measurement process (field, lab etc.) Maintain an acceptable level of data quality. Therefore the MQOs are identified as the various QC samples or QC activities

undertaken to “ensure “ the DQOs are met. Data verification/ validation is the process of taking this information to ensure that data of unacceptable quality is identified and appropriately handled so that it cannot effect the decision making process.

Is the activity important? (what does it get us)

- YES

Is there a product? Who is the major user of the product or information

- The “final” product is data of acceptable quality in a final data base. The major user of the QC data are the quality assurance personnel who need this “meta-data” to help determine data validity.

Is this a new activity? What activity does it replace or enhance?

- No, this is not a new activity. It does not replace any activity; it enhances the usefulness of the resultant data.

Brief description of current activities

- In general, the current activity is very similar among most SLTs. Various quality control information is required or suggested to be collected during monitoring activities. These include:

  - zero/span checks
  - weekly/biweekly precision checks
  - Collocated precision
  - equipment stability information (flow, temp pressure)
  - shelter or laboratory information (temp, humidity etc.)
  - Contamination information (field notes, field/trip/lab blanks)
  - performance evaluations
  - calibration information
  - field notes - (sampler issues, damage, contamination etc)

However how this data is used in the validation process may differ among SLTs.

- Once the data is entered to AIRS there is additional QA reports that are run that can also help in the final validation of data.

Who is responsible for the activity (currently).

- SLTs

Pros and Cons of the activity as it's currently implemented:

Pros
- Some organizations have developed procedures for the consistent verification/validation of data
- Real time data reporting has helped to initiate verification/validation screening tools. Although these tools do not provide full validation of data, they do provide an early review of information.
- The $PM_{2.5}$ Data Validation Template helped provide some consistency in data verification validation among SLTs

Cons -
- There is no consistency in data verification/validation techniques among SLTs.
- Local site information could be very helpful in the validation process (events) but in many cases this information is not recorded and therefore not available.
- Resources in some SLTs not available for timely validation
- Present verification techniques taking too long, meaning corrective action is not taken as soon as possible.
- Due to the diverse use by SLTs information management systems, there is currently no easy way to develop automated validation techniques (at a headquarters level) in a cost effective manner.

Ways of improving the activity:

- Technology is available for more real time validation that could free up resources for other activities: This could start with:
  - Use of data logging, telemetry or "lease-lines" to get data into information management systems and validation systems more quickly.
  - Use of computer technology by the site operator to access data that has been reviewed at the "central office" in order to implement corrective actions in a more real time mode
  - Use of the new AIRS system to develop more data assessment/validation techniques that could then be consistently used by all SLTs.
- Continue the development of Validation Templates for the other criteria pollutants
- Development of QA/QC evaluation reports - The Workgroup suggested the generation of various validation/evaluation program and reports (on AIRS or standalone) to reduce the burden on data validation personnel and provide for quicker data certification.
- Certified/uncertified data flagging - Data qualifiers are not used for the majority of the SLAMS pollutants, meaning that SLT personnel wait for data to be validated before uploading to AIRS. Since many SLTs use data qualifiers on their local sites to inform data users that the real time data is not validated, maybe AIRS data could be initially uploaded as "unqualified" and on a quarterly basis, based on suggestion above, have this qualifier removed. This would allow OAQPS to develop generic data evaluation/validation reports (see below) on AIRS that could be used/or modified by the AIRS user community rather than having SLTs develop their own reports.

Who should be providing (responsible for) this activity?

- SLTs

Does this require changes to regulation or guidance?

- If data validation is tied to performance (DQOs) process (see figure) then some regulations changes may occur if QC criteria are changed or removed.
- Guidance in Redbook could be changed to reflect validation templates

Meeting Date: October 9, 2001

Agenda: Implementation– Internal Quality Control Activities

Attendees: Tom Parsons, Donovan Rafferty, Jerry Sheehan, Andy Johnson, Rayna Broadway, Anna Kelly, Mark Shanis, Mike Papp

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Quality System Element: **Implementation**

Quality System Activity: **Internal Quality Control Activities**

Activity Description:

Definition: the overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the needs of users. The aim is to provide quality that is satisfactory, adequate, dependable, and economical.

Actions covered under this description

- See Redbook Measurement Quality Objective Forms (Appendix 3 in Redbook)
- Zero/Span checks
- Accuracy audits
- Verification checks (flow rate, temp, pressure, time)
- Calibrations
- Recertifications (SRP program, primary standards and transfer standards) gases, other QC instruments
- Precision checks (automated and collocated)
- Detection limit tests
- NPAP/State Audits (may also be included under performance evaluation)
- Routine instrument maintenance

What is the function or use of this activity?

- Ensure sampling, measurement equipment, or environmental monitoring conditions (shelters, labs) are operating within acceptable ranges to produce data of know and acceptable quality.

Is the activity important? (what does it get us)

- Yes quality control activities provide data users with checks at enough frequency to maintain "control" over data quality at various phases (sampling, preparation, analysis) of the measurement process.

Is there a product? Who is the major user of the product or information

- In most case there is not a product other than routine data of acceptable quality. However, some of the major quality control samples are reported to AIRS and can be used to provide a measure of precision and bias for reporting agencies. Products such as control charts etc. can also help to document data of acceptable quality.

Is this a new activity? What activity does it replace or enhance?

- No it's not a new activity

Brief description of current activities

- Activities defined in Redbook

Who is responsible for the activity (currently)

- In most case State/local/Tribes are responsible for these activities

Pros and Cons of the activity as it's currently implemented:

Pros- The current QC check requirements and guidance do seem to provide an adequate evaluations of data quality

Cons
- Some organizations may feel "audited to death". There may be some redundancies with our various auditing activities such as NPAP, State and internal auditing functions
- Some QC checks have "lost there value" due to the improvements of monitoring technology.
- Reducing frequencies of some checks may have the potential for invalidating more data.

Ways of improving the activity:

- Automate measurement systems as much as possible. Providing state of the art measurement, data logging/data transfer and QC systems will provide coast savings in the long run and provide for QC at higher frequency at no additional cost.
- Automate zero/span - Some organizations may still be performing these manually and at less frequency than recommended.
- Through-the-probe zero/span/precision checks - have checks cover entire inlet/manifold systems
- Develop QC checks based on system performance. Some checks, due to better, more stable equipment may not need to be checked as frequently as required or suggested.
- Have vendors of new instruments be required to develop adequate SOPs as part of the reference and equivalency process (may need to be added to SOP form).

Who should be providing (responsible for) this activity?

- State/local/Tribal monitoring agencies will maintain responsibility for this activity.

Does is require changes to regulation or guidance?

- Unsure at present- a thorough review of QC requirements in CFR and guidance should be implemented.

Meeting Date: October 16, 2001

Agenda: Implementation– Record Keeping

Attendees: Tom Parsons, Andy Johnson, Don Gourley, Anna Kelly, Mike Papp

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Quality System Element: **Implementation**

Quality System Activity: **Record Keeping**

Activity Description:

Definition: a written, documented group of procedures describing required records, steps for producing them, storage conditions, retention period and circumstances for their destruction or other disposition.

Actions covered under this description

< Storage of pertinent ambient air monitoring program documents and records at State/local/Tribal organization, EPA Regions and Headquarters.

What is the function or use of this activity?

< To document or provide supporting documentation of the quality/validity of ambient air monitoring data and adherence to ambient air monitoring requirements.

Is the activity important? (what does it get us) - YES

< provides for a repository of pertinent program information.(current and historical)
< provides documentation of data validity

Is there a product? Who is the major user of the product or information

< Products are the records/documents. The user is the organization collecting the information and potentially organizations required to review the records during auditing activities or challenges to the data validity.

Is this a new activity? What activity does it replace or enhance?

< No, not a new activity.

Brief description of current activities.

Workgroup used Section 5 "Documentation and Records" of the Quality Assurance Handbook for Air Pollution Measurement Systems (Volume II Part 1) as a source of information on this subject. The table below, which is in the section, was reviewed to determine whether the categories and record types were appropriate and comprehensive.

Categories	**Record/Document Types**
Management and Organization	State Implementation Plan Reporting agency information Organizational structure of monitoring program Personnel qualifications and training Quality management plan Document control plan Support contracts
Site Information	Network description Site characterization file Site maps/pictures
Environmental Data Operations	QA Project Plans Standard operating procedures (SOPs) Field and laboratory notebooks Sample handling/custody records Inspection/maintenance records
Raw Data	Any original data (routine and QC)
Data Reporting	Air quality index report Annual SLAMS air quality information Data/summary reports Journal articles/papers/presentations
Data Management	Data algorithms Data management plans/flowcharts
Quality Assurance	Control charts Data quality assessments QA reports System audits Network reviews

A number of points were made during the discussions;

- Some organizations have data archive requirements for much longer than the statute of limitations described in Section 5 of the Redbook (3 years).
- It appeared that resources needed for records archive and storage were adequate.
- The Breakout Group felt the table sufficiently covered the records and document types for the ambient air monitoring program. However certain records (i.e., record types in management and organization) may be the responsibility of management levels outside the monitoring organization.

- A monitoring organization may be responsible for data collection activities implemented by organizations outside of the immediate office (contractors or other local organizations) . We may need some additional guidance on what would need to be archived.

Who is responsible for the activity (currently)

- organizations responsible for ambient air data collection activities

Pros and Cons of the activity as it's currently implemented:

Pros-

Cons ! some organizations may not have a central filing capability. Therefore, individuals are filing and archiving information for which they are immediately responsible. During personnel turnover there is a possibility that this information gets discarded.

NOTE: This situation occurred with the CY2000 PM2.5 network where a significant amount of QC data disappeared when a site operator was removed from his/her position

- There may be discrepancies within organizations documentation (QMP/QAPPS/PPG) with regards to record keeping. Monitoring organization must ensure there is consistency among these various documents.

Ways of improving the activity:

- Centralize filing systems - it appeared that organizations are moving in this direction.
- Review Table 5-1 in Redbook- ensure agreement on record types.

Who should be providing (responsible for) this activity?

- Organization dependent.

Does it require changes to regulation or guidance?

- No change in regulation; may be modification to guidance

Other issues:

- Need to check on the defensibility of electronic data.

Meeting Date: September 13, 2001

Agenda: Assessment/Reporting -Site Characterization

Attendees: Mike Miguel, Michael Papp, Mark Shanis, Richard Heffern

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **Site Characterization**

Activity Description

Definition: Applicable siting criteria for SLAMS, NAMS and PAMS are specified in 40 CFR Part 58 Appendix E. The on-site visit itself consists of the physical measurements and observations needed to determine compliance with the Appendix E requirements, such as height above ground level, distance from trees, paved or vegetative ground cover, etc

What is the function or use of this activity?

< The function of the site characterization is to ensure national uniformity of parameter specific air monitoring activities.

Is the activity important? (What does it get us)

< Yes, the activity is important and it allows one to determine if the network conforms to the regulations.

Is there a product? Who is the major user of the product or information?

< Yes, there is a product (report) and all levels of government use the information.

Is this a new activity? What activity does it replace or enhance?

< No, it enhances the overall consistency of air monitoring data.

Brief description of current activities.

< States/local conduct site evaluations of their air monitoring networks once a year. The Regions usually conduct site evaluations during a technical system audit and only conduct a percentage (5%) of a air monitoring network.

Who is responsible for the activity (currently).

- OAQPS, Regions and States are responsible for this activity.

Pros and Cons of the activity as it's currently implemented:

Pros:
- Aids the Regions and State/local to evaluate the air monitoring networks.
- Provides uniformity
- Some states have a Website for current site activities.

Cons
- No consistent documentation of site evaluations
- Most States do not have a website for current site activities.
- No consequences for not conducting site evaluations (No comparison between AIRS an hard copy in the files)

Ways of improving the activity:

- Conduct polls of the Regions and State/locals on who is conducting site evaluations.
- Setting minimal levels and tracking - review the requirements for the frequency of such characterization and recommend a change (if necessary).
- Ensure better tracking of this information to ensure they are being performed. AIRS has an area that can be used for this tracking activity.
- Ensure updates made in AIRS - Information from inspections (monitors or sampling equipment added to site, Lat/Long changes) that reflect a needed change in the site record in AIRS are not always getting revised. There needs to be some method of ensuring information found during site characterization gets corrected in AIRS in a timely manner.
- Development and use of site characterization form- A site characterization form and possibly software could be developed and distributed to provide some consistency in performing site characterizations.
- Site characterization training- It was suggested that a training module be developed for the performance of site characterizations.
- Speed up approvals for discontinuing sites- SLTs submit paperwork for discontinuing sites that do not get approved for a considerable length of time. OAQPS needs to review this process

Who should be providing (responsible for) this activity.

- The Regions and the States should be responsible for this activity.

Does this require changes to the regulation or guidance?

- No

Meeting Date: September 26, 2001

Agenda: Assessment/Reporting - Performance Evaluations

Attendees: Danny France, Matt Plate, Mark Shanis, Mike Miguel, Richard Heffern, Rayna Broadway, Vic Guide, Rachael Townsend, Scott Hamilton

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **Performance Evaluation** (NPAP, PEP, Ozone Verification)

Definition: a type of audit in which the quantitative data generated in a measurement system are obtained independently and compared with routinely obtained data to evaluate the proficiency of an analyst or laboratory.

What is the function or use of this activity?

< To ensure the quality of data collect and resolve any significant quality assurance problems.

Is the activity important? (What does it get us)

< The activity is important. It allows for the intercomparability of data sets and identification of problem areas.

Is there a product? Who is the major user of the product or information.

< Uniform data on a national level. All levels of the government/tribes and industry are major users of this information.

Is this a new activity? What activity does it replace or enhance?

< No. The performance evaluation program enhances the overall quality system on the nation's air monitoring program.

Brief description of current activities.

< State/locals and PSD networks participate in the NPAP and PEP. Most tribal agencies do not participate in the programs.

Who is responsible for the activity (currently) ?

< OAQPS, Regions and States are responsible for the activity.

Pros and Cons of the activity as it's currently implemented.

Pros: ! It enhances the overall consistency of air monitoring data.
! Some states like the program as it is.

Cons: ! Very little return for the VOCs and Carbonyl for the PAMS.
! Some states have such small air monitoring programs it is impossible to have adequate separation QA and monitoring staff. In this case, independence is not achieved.
! To much duplication in the program.
! Need more flexibility in the program.
! Regulatory guidance in certifying ozone transfer standards is 20 years old.

Ways of improving the activity:

< PAMS NPAP should be conducted in the January to March time frame so that potential problems can be rectified prior to the ozone season.
< Less compounds could be included in the PAMS NPAP audits. Participants would prefer if higher quality standards (NIST) are utilized with less compounds.
< It was suggested that ambient air comparisons be used to compare between lab results. This is already being done at some Regions.
< Headquarters should certify auditors for parameters. This is being done for PM2.5.
< Eliminate duplication in the NPAP program. EPA could certify States that do have a PE program in place, conduct round robin with labs.
< Combining NPAP and PEP Program- Revise NPAP to a through-the-probe audit approach. STAG funding mechanism of the current $PM_{2.5}$ PEP could be enhanced to include NPAP.
< Revise requirements for industry to contribute payments to NPAP- In the past, the NPAP, which was required under the PSD requirements, provided audits to industry for free. It was suggested that a mechanism for industry payment could be added to the requirement
< The current regulation require transfer standards to undergo a 6-certification at the beginning of each ozone season (provided the previous 6-days certification lapsed) and then a 1-day recertification at the end of 90 days. This poses a problem in some areas which have to ship ozone standards. The current frequency may be overkill. The group commented that this would depend on the situation. For example, if a reporting organization was experiencing discreprencies or other QA/QC problems, the frequency may need to be increased so that the problem could be resolved. Conversely, if a reporting organization was running smoothly with audits, calibrations and span checks showing expected results, then this frequency may be too much. The group concluded that the 90-day frequency seems to be appropriate but is subjective.
< Update guidance and practicability of the SRP. The SRP guidance has not been revised for a considerable length of time. Due to the stability of new ozone instruments, and jargon (definitions of primary and transfer standards etc.) that needs be revised, it was felt that the SRP program guidance needed updating.
< PM2.5 PEP comments: Alaska commented that the PEP auditor need to space out audits throughout the year. It was suggested that the quarterly audits may be too many. The

frequency of could be determined by the success (or failure) of the previous audit.

Who should be providing(responsible for) this activity?

< OAQPS , Regions and the States should be responsible for this activity.

Does the activity require changes to regulation or guidance?

< Current regulatory guidance used in certifying ozone transfer standards may need to change.

Meeting Date: October 10, 2001

Agenda: Assessment/Reporting - PSD networks participation in NPAP

Attendees: Danny France, Matt Plate, Mark Shanis, Michael Papp, Mike Miguel
Scott Hamilton, Richard Heffern, Rayna Broadway

Quality System Element: **Assessment/Reporting**

Quality System Activity: **PSD networks participation in NPAP**

What is the function or use of this activity?

< The function of the PSD networks participation in the National Performance Audit Program is to ensure that the ambient air data collected is of a known quality.

Is the activity important? (What does it get us)

< Yes, the activity is important and it gives us a picture of an industry's quality system.

Is there a product? Who is the major user of the product or information?

< Yes, there is a product (report) and OAQPS, Regions and the States will use the information.

Is this a new activity? What activity does it replace or enhance?

< No, this is not a new activity and the NPAP will provide a assessment of an industry's air monitoring network.

Brief description of current activities.

< Most States require that the industries participate in the NPAP.
< Some PSD networks ambient air data is submitted to AIRS.

Who is responsible for the activity (currently).

< OAQPS , Regions and States are responsible for this activity.

Pros and Cons of the activity as it's currently implemented:

Pros: ! Aids State/local to evaluate the industries air monitoring networks.
! Industries are requesting to participate in the NPAP.

Cons ! No mechanism in place to receive money from industry for their participation in the NPAP.
! Funds being cut from the NPAP, therefore industry participation is lessen.

Ways of improving the activity:

< There should be a mechanism in place to allow industry to pay for their participation in the NPAP.

Who should be providing (responsible for) this activity.

< OAQPS , Regions and the States should be responsible for this activity.

Does this require changes to the regulation or guidance?

< Yes.

Meeting Date: October 10, 2001

Agenda: Assessment/Reporting - Technical Systems Audits

Attendees: Danny France, Matt Plate, Mark Shanis, Michael Papp, Mike Miguel, Scott Hamilton, Richard Heffern, Rayna Broadway

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **Technical Systems Audits**

Activity Description:

Definition: a thorough, systematic on-site, qualitative review of facilities, equipment, personnel, training, procedures, record keeping, data validation, data management, and reporting aspects of a total measurement system

What is the function or use of this activity?

< The function of the Technical System Audits (TSA) are to promote national uniformity in the evaluation of state and local agency monitoring programs and agencies performance.

Is the activity important? (What does it get us)

< Yes, the activity is important and it gives us a picture of an agencies overall performance.

Is there a product? Who is the major user of the product or information?

< Yes, there is a product and all levels of government use the TSA report.

Is this a new activity? What activity does it replace or enhance?

< No, this is not a new activity and the TSA will promote the uniformity of the air monitoring program.

Brief description of current activities.

< Most Regions and some states conduct TSA's. There may be a need to conduct TSA's of Tribal organizations.

Who is responsible for the activity (currently).

< The Regions and States are responsible for this activity.

Pros and Cons of the activity as it's currently implemented:

Pros: ! Promote uniformity in the evaluation of the State/local agencies.
! TSA's can identify problem areas.

Cons ! Some Regions and States are not conducting TSAs

Ways of improving the activity:

< There should be a minimum level of tracking TSAs. (Maybe in the new AIRS)
< Develop TSA Teams (Regions, State/local)
< Conduct TSA of Tribal air monitoring programs.
< Collect the various audit forms being used in the nation in one place and make available to the air monitoring community.

Who should be providing (responsible for) this activity.

< The Regions and States should be responsible for this activity.

Does this require changes to the regulation or guidance?

< No.

Meeting Date: October 3, 2001

Agenda: Assessment/Reporting - Data Quality Assessment

Attendees: Danny France, Matt Plate, Shelly Eberly, Mike Miguel, Don Gourley, Rayna Broadway, Vic Guide, Kuenja Chung, Richard Heffern, Michael Papp, Regina Charles

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **Data Quality Assessment**

Definition: the statistical evaluation of a data set to establish the extent to which it meets user-defined application requirements (i.e., DQOs).

What is the function or use of this activity?

< To ensure the quality of data collected can be used to make a decision with a desired confidence.

Is the activity important? (What does it get us)

< The activity is important. It gives us a statistical evaluation of data.

Is there a product? Who is the major user of the product or information.

< Yes, there is a product and OAQPS and the regions are the major users.

Is this a new activity? What activity does it replace or enhance?

< Yes, data quality assessments enhances the overall quality system on the nation's air monitoring program

Brief description of current activities.

< All levels of government perform data quality assessments, but not from a statistical standpoint.

Who is responsible for the activity (currently) ?

< OAQPS and Regions are responsible for the activity.

Pros and Cons of the activity as it's currently implemented.

Pros:! Summary on information for criteria pollutants available in AIRS.
! Good DQOs will help develop good DQAs.

Cons:! Not many DQAs performed from a statistical standpoint.

Ways of improving the activity:

< Provide real time feedback.
< Provide statistical assessments (maybe available in new AIRS).
< Development of DQA tools - Similar to the $PM_{2.5}$ DQO software that is being modified as a DQA tool, as DQO development on the other criteria pollutants move forward (recommendation in another section above) DQA tools will also be made available. It is anticipated that these tools would be integrated with AIRS

Who should be providing(responsible for) this activity?

< OAQPS responsibility for DQAs - The Workgroup concluded that OAQPS should be responsible for the development of DQAs for all federally required data at the reporting organization level. Assessments at the site specific level or for objectives other than federal (i.e., non-trends speciation sites) would be the responsibility of the SLTs and be described in their QAPP.

Does the activity require changes to regulation or guidance?

< Yes

Meeting Date: October 3, 2001

Agenda: Assessment/Reporting - QA Reports

Attendees: Danny France, Matt Plate, Shelly Eberly, Mike Miguel, Rayna Broadway, Vic Guide, Kuenja Chung, Richard Heffern, Michael Papp, John Gourley, Regina Charles

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **QA Reports**

Definition: Documents describing a quality system for a particular project or program for a particular period of time and the resultant data quality. The term is used as a catch all for various types of reports including reports on results of performance evaluations and systems audits, results of periodic data quality assessments, and significant quality assurance problems and recommended solutions

What is the function or use of this activity?

< The function of the QA Reports are to provide an overall assessment of the air monitoring program to management.

Is the activity important? (What does it get us)

< Yes, the activity is important. QA reports give us the ability to identify problem areas in our air monitoring system.

Is there a product? Who is the major user of the product or information?

< Yes, there is a product and all levels of government use the QA reports.

Is this a new activity? What activity does it replace or enhance?

< No, this not a new activity and it will enhance the quality of air monitoring data collected in the nation.

Brief description of current activities.

< Most States/locals, Regions and OAQPS use QA reports.

Who is responsible for the activity (currently)

< OAQPS, Regions and States/locals are responsible for the activity.

Pros and Cons of the activity as it's currently implemented:

Pros: ! QA reports used by all levels of government.
! QA reports improves the quality system of an agency.

Cons: ! PSD QA reports should be assess.

Ways of improving the activity:

< Need to assess the system audits of contractors (especially PSD).

Who should be providing (responsible for) this activity?

< Headquarters, Regions, State/locals/Tribal should be responsible for this activity.

Does this require changes to the regulation or guidance?

< Yes

Meeting Date: October 3, 2001

Agenda: Assessment/Reporting - P&A Reports

Attendees: Danny France, Matt Plate, Shelly Eberly, Mike Miguel, Rayna Broadway, Vic Guide, Kuenja Chung, Richard Heffern, Michael Papp, John Gourley, Regina Charles

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **P&A Reports**

Definition: Reports describing the achievement of the precision and accuracy requirements for the Ambient Air Quality Monitoring Program.

What is the function or use of this activity?

< The function of the P&A Reports are to provide an overall assessment of air monitoring data.

Is the activity important? (What does it get us)

< Yes, the activity is important. P&A reports give us the ability to identify problem areas in our air monitoring system.

Is there a product? Who is the major user of the product or information?

< Yes, there is a product and all levels of government use the P&A report.

Is this a new activity? What activity does it replace or enhance?

< No, this not a new activity and it will enhance the quality of air monitoring data collected in the nation.

Brief description of current activities.

< Most States/locals, Regions and OAQPS use P&A reports.
< Tribes need to use precision and accuracy reports.

Who is responsible for the activity (currently)

< OAQPS and the Regions are responsible for the activity.

Pros and Cons of the activity as it's currently implemented:

Pros: ! Summary information for precision and accuracy data is available in AIRS
! P&A Reports used by all levels of government.

Cons ! PSD networks should have P&A Reports.
! P&A probability limits should be reviewed.

Ways of improving the activity:

< Correct problems of uploading precision data in AIRS.
< Burden reduction of precision and accuracy checks should be addressed in the regulations.
< Improve cooperation from States/locals/tribes in getting precision data into AIRS.
< Include frequency of audits in the QAPP.

Who should be providing (responsible for) this activity?

< Headquarters, Region, State/locals should be responsible for this activity.

Does this require changes to the regulation or guidance?

< Yes

Meeting Date: October 10, 2001

Agenda: Assessment/Reporting - Quality System Audits

Attendees: Danny France, Matt Plate, Mark Shanis, Michael Papp, Mike Miguel, Scott Hamilton, Richard Heffern, Rayna Broadway

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Quality System Element: **Assessment/Reporting**

Quality System Activity: **Quality System Audits**

Definition: the qualitative assessment of a data collection operation and/or organization(s) to establish whether the prevailing quality management structure, practices, and procedures are adequate for ensuring that the type and quality of data needed and expected are obtained

What is the function or use of this activity?

< The function of the Quality System Audit (QSA) is a process of qualitatively assessing the effectiveness of management practices in applying QA/QC to environmental data operations.

Is the activity important? (What does it get us)

< Yes, the activity is important and it gives us a picture of an agency quality system.

Is there a product? Who is the major user of the product or information?

< Yes, there is a product (report) and OAQPS, Regions and the States will use the information.

Is this a new activity? What activity does it replace or enhance?

< Yes, this is a new activity and the QAS will provide a assessment of an agency's Quality Management Plan.

Brief description of current activities.

< OAQPS and some Regions have conducted QSAs.

Who is responsible for the activity (currently).

< OAQPS, Regions and States are responsible for this activity.

Pros and Cons of the activity as it's currently implemented:

Pros:! Aids management to evaluate the entire agency's program concerning a quality system.

Cons ! No joint audit form (TSA and QSA audit form).

Ways of improving the activity:

< There should be development of an audit form to include TSA and QSA .

Who should be providing (responsible for) this activity.

< OAQPS , Regions and the States should be responsible for this activity.

Does this require changes to the regulation or guidance?

< No.

Attachment 2
QA Strategy Action Item/Recommendations Voting Results

As a result of the QA Workshop (Oct 23-25, 2001) the QA Workgroup produced a large lists of recommendations and action items for improvements to the ambient air monitoring quality system. The Workgroup compiled a list of these suggestions and voted on their priority (high-1, medium - 2, low -3), whether the improvement could be made with little or no additional resources (Y or N) and the time frame on when the recommendation should be implemented (within 1 year -1, within 2 years-2, or 3 or greater years -3). Attachment 2 provides the listing of these recommendations in order of priority (first), and time frame (second). QA Workgroup members voting on this list included State, local and Tribal monitoring agencies (12), EPA Regions (4) and EPA OAQPS (2)

QA Strategy Action Item/Recommendations Voting Results		
Priority	**Time**	**Recommendation/Action Item**
1.17	1.69	State and locals need to have a full time person for QA for the air monitoring programs
1.22	1.78	OAQPS needs to develop DQOs for the NAAQS. In addition, there should be a project to evaluate converting the DQOs for PM2.5 to include performance-based standards.
1.24	1.47	Have vendors of new instruments be required to develop adequate SOPs as part of the reference and equivalency process (may need to be added to SOP form).
1.28	1.50	National air monitoring QA conference (annually) to help consistency (fund through 105, like AIRS conf.)
1.31	2.00	Use of automated zero-span, precision checks to validate data
1.35	1.18	Correct problems of uploading precision data in AIRS.
1.39	1.81	Need DQOs to do DQA - Work on priority DQOs
1.39	1.85	Getting DQO tool working with AIRS
1.41	1.71	Review grant process to tie QA costs to monitoring costs
1.41	2.03	Continue the development of Validation Templates for the other criteria pollutants
1.44	1.90	Development of critical review criteria in AIRS
1.47	1.76	Get more state and locals in on which documents are more important to them, in order to prioritize revisions
1.47	1.80	Provide real time feedback.
1.47	1.97	Redbook needs updating -- have calls with states and regions
1.47	2.12	Training for TSAs, DQAs, and data validation
1.50	1.44	QA forum for continued support and exchange of information.
1.50	1.47	PAMS NPAP should be conducted in the January to March time frame so that potential problems can be rectified prior to the ozone season.
1.53	1.74	Ensure grant funding is available for QA related training
1.53	2.15	Use of the new AIRS system to develop more data assessment/validation techniques that could then be consistently used by all SLTs.
1.56	1.33	Define or clarify attributes or responsibilities of QA person or manager
1.56	1.72	Clear discrimination between guidance and regulation
1.56	1.94	Training for managers so they understand components/need for QA
1.56	2.47	Automate measurement systems as much as possible. Providing state of the art measurement, data logging/data transfer and QC systems will provide coast savings in the long run and provide for QC at higher frequency at no additional cost.
1.59	1.63	Recommendations for NPAP program: eliminate duplication in the program, EPA could certify states that do have QA in place, conduct round robin with labs
1.59	1.65	Need to work out details of graded approach.
1.59	1.79	Ensure AIRS summarizes data as DQOs indicate
1.59	1.81	Review each methods and QA for "musts" and "shalls". Identify "musts" in regulation without describing frequency or acceptability.
1.59	2.03	Provide statistical assessments (maybe available in new AIRS)
1.59	2.15	Combine all guidance into one document (Redbook)
1.61	1.53	Improve cooperation from States/locals/tribes in getting precision data into AIRS.
1.63	2.38	Use of data logging, telemetry or "lease-lines" to get data into information management systems and validation systems more quickly.
1.64	1.69	Audit PAMS and get results out before ozone season.
1.65	1.74	Develop audit teams from SLT and Regions in order to share experience/knowledge
1.65	1.82	Update SRP guidance and make practical
1.65	1.91	Develop a template QAPP (fill in the blanks) -- generic for any air program, not just criteria pollutants – needs to handle graded approach
1.66	2.09	Need a mechanism to ensure corrective action from evaluation and updates in AIRS
1.67	2.00	Development of auditing QA software tool
1.67	2.14	Incorporate spatial representativeness (or lack thereof) into DQOs
1.68	2.06	Streamlining audit programs (audit auditors?), SRP & NPAP
1.69	1.85	NPEP funding through STAG is appropriate
1.69	1.94	Develop QC checks based on system performance. Some checks, due to better, more stable equipment may not need to be checked as frequently as required or suggested.
1.72	1.97	Burden reduction of precision and accuracy checks should be addressed in the regulations.

QA Strategy Action Item/Recommendations Voting Results		
Priority	**Time**	**Recommendation/Action Item**
1.75	1.60	There should be a mechanism in place to allow industry to pay for their participation in the NPAP (PSD)
1.76	1.29	Electronic record keeping -- check with OEI to see if electronic files are acceptable (legally defensible?)
1.76	1.76	Guidance to EPA regions on the need for consistency in the review of QAPPs
1.76	1.85	Develop training on how to conduct TSA. Minimal steps to take during TSA. Include in Redbook
1.76	2.00	Certification/accreditation program - hierarchical approach -- OAQPS-Regions-State/local
1.76	2.09	Conduct TSA of Tribal air monitoring programs.
1.76	2.21	Provide statistical assessments (maybe available in new AIRS)
1.76	2.34	Through-the-probe zero/span/precision checks - have checks cover entire inlet/manifold systems
1.78	1.67	Expand AMTIC Web links to training
1.81	2.23	Use of computer technology by the site operator to access data that has been reviewed at the "central office" in order to implement corrective actions in a more real time mode
1.88	1.71	Guidance for QAPPs should clearly state that QAPPs that are for projects covered by a QMP do not need to duplicate information in the QMP or applicable SOPs.
1.88	1.91	Define needs for QMPs for all agencies.
1.88	2.19	Review and develop "minimal" TSA form in Redbook
1.89	1.97	Contractual mechanisms to provide support, such as DQO/DQA statistical support
1.90	1.61	Less compounds could be included in the PAMS NPAP audits. Participants would prefer if higher quality standards (NIST) are utilized with less compounds.
1.93	2.07	Develop documentation for states that opt out of NPEP
1.93	2.25	Revise EPA QA/R-2 with the substantive changes discussed in Workshop. Will not revise R2; will create ambient air specific R2.
1.94	1.78	Definition/interpretation of primary and transfer standards
1.94	2.06	Can flagging help get data in sooner? Flag data in AIRS as "unvalidated" for use more real time, then pull "unvalidated" flag off quarterly or yearly
1.97	2.14	Guidance on timeliness and consistency in performing site evaluations
2.00	1.88	Collect the various audit forms being used in the nation in one place and make available to the air monitoring community.
2.00	2.19	Set minimal level of conducting site evaluations (Redbook)
2.00	2.26	Develop the guidance for small organizations and projects, such as those who can collapse the QMP and QAPP
2.06	1.63	Look to see if there is a requirement for a central filing systems -- QA order 5360.1???
2.06	2.03	Recommendations/guidance for central filing system (Redbook) including what should be in those filing systems
2.07	1.90	Perform survey to determine "acceptable" PE programs in order to avoid redundancy.
2.11	2.03	Place some important training in regulation
2.11	2.06	What is reporting organization? Does this need to be re-defined or should the definition be strictly adhered
2.11	2.33	Develop web- based training courses
2.11	2.47	OAQPS oversight is very helpful -- site visits annually for some (maybe with MSR)
2.12	2.21	Develop combo TSA, QSA audit form
2.12	2.24	The graded approach needs to be addressed in the CFR, including specific criteria for different levels of QAPPs with examples
2.12	2.31	Increase consistency between EPA Regional offices on how they review QMPs.
2.13	1.57	Review Table 5-1 in Redbook- ensure agreement on record types
2.18	1.82	Conduct polls of the Regions and State/locals on who is conducting site evaluations
2.19	2.16	There should be a minimum level of tracking TSAs. (Maybe in the new AIRS)
2.21	2.32	Tools to help w/DQAs, beginning with annual/3-year reports.
2.27	1.87	Revise CFR to quarterly certifications
2.29	2.21	APDLN - more hubs, e.g., Alaska, Guam
2.61	2.33	Combine 58 Appendix A and B

Section 6. Technology Section National Monitoring Strategy

Introduction

One of the major focuses of the National Monitoring Strategy is to identify the areas of Technology that are well suited to improve the efficiency and scope of products delivered by State and local air monitoring agencies. To provide input on the areas of technology that should be considered and how they might best be implemented, an ad-hoc workgroup of State, local, Tribal, and EPA representatives was formed. This workgroup met in a series of teleconference calls followed by a 3 day face to face meeting in October of 2001. Areas considered include all hardware and software used in the monitoring, calibration, logging, transfer, storage, validation, and reporting of ambient air data. Through the conference calls and face to face meetings, 3 specific areas of technology were identified as most pressing for technology investment:

- PM Continuous monitoring;
- Data transfer and access of ambient monitoring data;
- Tools and training that support real-time or near real time public reporting of data.

There are many other technology needs within the ambient air monitoring programs, such as ozone QA optimization, use of web camera technologies, and toxics monitoring. These needs should also be considered, however each has its own special issues. These issues will be discussed in this section and other section of this strategy. For example, ozone QA optimization is expected to also be addressed in the QA section of the strategy.

In order for each of these investments to be successful not only is there a financial commitment necessary, but also a dedicated approach of eliminating barriers to technology investment. For example, in order to invest in PM continuous monitoring there needs to be a regulatory mechanism to allow for substitution of some of the FRMs with continuous monitors. Also, there may be provisions in the current regulations and guidance that are preventing the implementation of some of these technologies. Therefore, the workgroup is providing the following recommendations as mechanisms to accommodate the investment of these new technologies:

- support for a hybrid network of PM monitors that provides for a substantial divestment of filter based monitoring and investment in continuous monitoring;
- a thorough examination of ozone monitoring quality assurance that would result in recommendations leading to greater efficiency in ozone monitoring QA;
- an examination of available telemetry systems to optimize data access and transfer;

- support for investment in data management systems at the State and local agency level that could lead to more efficient processing of data; and

- accommodation for each of these areas to be included in the grant process so that available grant monies can be used for these investments.

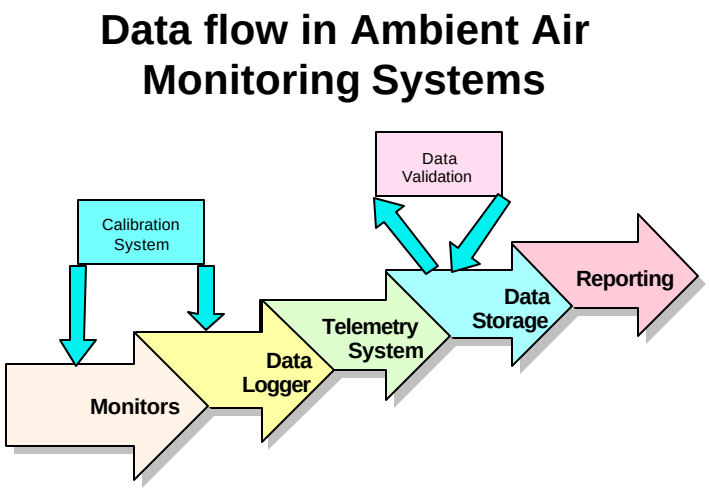
While the recommendations above may go a long way towards fostering implementation of appropriate technology investment, the list cannot comprehensively address every need in the immediate future or longer term. State, local, and Tribal monitoring agencies along with EPA should continue to define areas that are best suited for technology investment.

1. Introduction

The National Monitoring Strategy seeks to provide the direction for an ambient air monitoring network that can more responsive to current and future needs of the network. This section of the strategy focuses on areas of the ambient air monitoring program that are ripe for investment in new technologies. The purpose of these investments would be to increase the efficiency and timeliness of data for existing monitoring as well as to add monitoring for high priority areas not adequately being addressed. The section attempts to identify some specific areas of investment as well as a process by which new technologies could potentially be introduced into routine monitoring networks.

2. State of Technology in Ambient Air Monitoring

The technologies used in the ambient air monitoring program cover all hardware and software used in the measurement, calibration, logging, transfer, storage, validation, and reporting of data. Figure 2-1 illustrates the flow of data from where it is produced to where it ends up being reported. Many of the areas identified are already using state of the art technologies. For instance, much of the gaseous criteria pollutants are measured using continuous monitors with automated features for calibration and data output. However, other areas such as data transfer are relying on technologies that may be outdated. In some cases a technology may be somewhat antiquated; however, because it is operating smoothly and



satisfying the needs of the data users, it may not be an opportune area for investment.

3. Areas of Investment

This section identifies each specific area of investment for the ambient air monitoring program. Any one air monitoring program may or may not already have invested in these areas. These areas have been identified due to either the heavy burden of already doing the work or because they are areas that data users have identified as needed

3.1 Monitoring

In general, continuous methods should be emphasized over manual methods. This is important for several reasons. On the resource side, continuous instruments are usually much less resource intensive to operate, provide more useful data for assessment of air quality throughout a day, have a higher sample frequency, provide for greater precision due to reduced human intervention, are easier to automate with respect to data delivery, and their data are easier to validate. The descriptions below provide the specific monitoring areas of investment being considered in this strategy.

3.1.1 PM Continuous Methods

A strong push for PM continuous methods is a major component of this strategy. EPA has developed an ambitious continuous monitoring implementation plan taht was borne out of requests from S/L agencies (specifically through SAMWG) and from the CASAC subcommittee on PM monitoring. Attachment 1 provides the basic plan, now under revision after discussions during the January, 2001 Some of the major features of the PM continuous monitoring strategy included:

- support for a hybrid network of several hundred PM continuous monitors with a few hundred FRM samplers;

- using performance based criteria developed in the Data Quality Objective (DQO) process to determine the acceptability of PM continuous monitors in the individual networks that they are used; and

- a parallel approach for approval and applicability of methods with one option being more rigid and allowing approval of a continuous method for all monitoring objectives and a more flexible approach that allows for using these monitors for all monitoring objectives except the first order of comparison to the NAAQS.

The end goal of the PM continuous monitoring strategy is to have a PM monitoring network

that can meet multiple monitoring objectives at lower cost.

3.1.2 Ozone Methods

Although a large network of Ozone monitors exists in the United States, there may be opportunities to make better use of the Ozone network. This could be potentially involve several specific areas of technology associated with ozone monitoring identified below:

- As described in other sections there may be a large opportunity to divest of some redundant urban monitoring and relocate those monitors in areas outside the urban environment in order to detect the spatial gradient of ozone. This is expected to be largely accomplished through the assessments performed across Regional areas. This becomes a technology issue in that any relocated or new ozone monitoring needs to be implemented in a manner that minimizes the ongoing operational costs.

- Performing a comprehensive review of how ozone monitoring quality assurance is performed. This should examine the regulations as identified in 40 CFR Part 58, Appendix A and the QA guidance in the Red book. A review of how State and local agencies are performing QA in their agencies should also be performed. The review should provide recommendations for areas of divestment and investment in ozone monitoring quality assurance.

3.1.3 Web Camera Technologies

Many State and local air monitoring agencies have successfully implemented web cameras to illustrate the visual quality of the air. For example, the CAMNET site (http://www.hazecam.net/) implemented by NESCAUM provides web accessible images of urban and rural scenic vistas at several sites throughout the northeast. The images have been used with air pollution data to communicate visibility and air quality. The relatively low cost of the technology combined with an effective medium for distribution of the data on State and local agency web sites makes for an efficient way to communicate air quality to the public. With the growing interest in reporting and forecast ambient air quality to the public the web cameras have become an important tool in supplementing these reports.

3.2 Information Technology

The areas of information technology currently run in most State and local agencies may be the most ripe for new investment. This is largely due to both the need for a national network of air monitoring that can be available in real-time to support public information needs of the data and the substantial areas of improvements that have been made in information technology since most air monitoring stations were implemented. Although commercially available information technologies may

be substantially more efficient than what are currently being used by many State and local agencies, there are a number of issues to consider such as: making the best choice for investment - as today's technology may be outdated soon, costs of technical support, and how easy would it be to move to another generation of this technology once the current generation is outdated.

3.2.1 Instrument to Datalogger

Most continuous monitors have the ability to output data at least two ways. For realtime or near realtime monitors, analog outputs usually have a DC voltage corresponding to a range of the concentrations. For example, in an Ozone monitor a 0 to 5 volt output might correspond to a 0 to 500 part per billion range. The analog output is fed into a datalogger that has been programmed to receive the DC voltage and interpret it as a concentration of Ozone. A RS 232 or other output may also be employed. These outputs can carry a substantial amount of information beyond the concentration value. For instance: operating temperature; light intensity, if applicable; and concentration range may all be carried in addition to the actual concentration. Despite the wealth of information that can be carried across an RS232 connection, these connections are rarely used. The primary reasons for using DC voltage outputs over RS232 connections are the simplicity of receiving the concentration data by DC voltage and the lack of standard formats for the fields among vendors for the RS232 connections. Despite not using these other data available via the RS232 connection, some of the information may actually be very useful for validating data and remote troubleshooting of instruments. With the cost of storing data becoming cheaper having an archive of these data may be an effective way to improve this component of the ambient air monitoring program. In order to move from a network where most sites are connected by DC voltage to something that provides for more information, a number of issues need to be worked through. For instance, providing the data in a common format from multiple vendors manufacturers would allow for data loggers to be easily adopted to receive data from any of these monitors. Also, an examination of the existing and up and coming direct connections should be made (USB, ethernet, FireWire)

3.2.2 Datalogger to Database

Once data are on the datalogger at the ambient air monitoring station they need to be sent to servers where they can be summarized and disseminated to data users. In most cases this will occur by using a server at the office of the State or local agency. The frequency of the transfers are usually dictated by the needs of the data user. For public information use data may need to be sent to the server every hour of even more frequent. The conventional way to get data from the monitoring stations has been to poll each of the stations individually. With more widespread availability of the internet, pushing data from monitoring sites on a regular basis will be especially effective in mapping and public reporting of data.

3.3 Reporting

The need to provide data to a number of users will require multiple reports of the information. For example, the public may need a near real time simple message that the air is clean or moderate. A health researcher or modeler may want a very detailed accounting of the available data in the shortest time intervals possible. Regulatory users generally want the data in the form that they can be compared to the NAAQ.S

3.3.1 Public Reporting

The area of public reporting for air monitoring data may the provide the largest number of users of data. This area has been growing rapidly in the last few years as a result of the increased availability of air quality reporting, especially for ozone. This is expected to continue for other pollutants, specifically PM public reporting is expected to increase as more agencies bring their PM continuous instruments on-line and EPA's AIRNOW program accepts and reports PM monitoring data.

3.3.2 AIRS Reporting

Air monitoring data is to be supplied to AIRS after it has been validated at the State or local Agency level. In early 2002, EPA will be implementing its new AIRS system. The new system is expected to have a lot more functionality than the previous main-frame system. This will be especially useful to casual users of the data who were previously unable to access air monitoring data from the main frame system.

4.0 Implementation Approaches

In order to assure that new technologies are appropriately integrated into all ambient air monitoring programs a phased in approach should be taken that allows for sufficient time and refinement of the technologies. This phased in approach should be coordinated with various stakeholders of the ambient air monitoring program. The sections below describe the applicability of testing each potentially new technology and who should be responsible for testing or implementing this phase of testing.

5.0 Issues

Despite the need to invest in many areas of the ambient air monitoring program, investing blindly may never result in an improved system. Some concern that have been brought to the attention of the Technology workgroup from both within the group and external to it are identified below. As appropriate, some possible solutions to each of these issues are also presented:

- Making the right choice for a technology. For any one type of technology there may be several choices to consider. The most cost effective choice right now may be outdated

in a year. Making the right choice needs careful consideration and even then the choice may still not be correct.

- Transition from current to new technology. Need to consider things such as downtime of systems and contingency plan if new systems fail.

- Training of Staff. New technologies may require a higher level of expertise than the old system it was replacing. Need to adequately plan for major shifts in technology.

- Technical service. Need to consider what, if any service plan would accompany any new technology. This may affect the true cost of the technology. Also, need to consider the responsiveness of technical service.

- Use of proprietary software. Need to consider the issues regarding the use of software that is not in the public domain.

- Ability to transfer to new technologies at a future time. Agencies need to be careful to select technologies that do not prevent them from selecting a newer technology down the road.

- Identification of appropriate technical specifications to be included on purchase requests so that air monitoring agencies make the right purchase of equipment. This is especially important regarding technologies that may have similar features; however, the lower cost product is inferior and leads to substantial problems to the end user. If purchasing agents are given an appropriate amount of detail in the technical specification selection of the inferior technology may be avoided.

6.0 Recommendations

The Technology workgroup has several recommendations to include in the National Monitoring Strategy. Although many of the details are described above this section summarizes those recommendations is a concise manner:

- Support for a hybrid network of PM monitors that provides for a substantial divestment of filter based monitoring and investment in continuous monitoring;

- A thorough examination of ozone monitoring quality assurance that would result in recommendations leading to greater efficiency in ozone monitoring QA;

- An examination of available telemetry systems to optimize data access and transfer;
- Support for investment in data management systems at the State and local agency level that could lead to more efficient processing of data;
- Accommodation for each of these areas to be include in the grant process so that available grant monies can be used for these investments.

DRAFT

Revision 1

January 23, 2002

CONTINUOUS MONITORING IMPLEMENTATION PLAN

Table of Contents

Abbreviations and Terms

Executive Summary

Section 1. Introduction

Section 2. $PM_{2.5}$ Continuous /FRM Relationships

Section 3. Enhanced Correlated Acceptable Continuous Methods (CAC)

Section 4. Regional equivalent Method (REM)

Section 5. Network design

Section 6. Performance Standards for Continuous Monitoring.

Section 7. Data transformation policy and guidance

Section 8. Guidance for developing boundaries for regional equivalent areas

Section 9. Monitoring methods guidance and support

Section 10 Linkage to national monitoring strategy

Section 11. Regulatory Changes and Schedule

Section 12. Summary of Issues and Action Items

Attachment A. $PM_{2.5}$ Continuous/FRM Analysis

Attachment B. PM2.5 Data Quality Objectives

Attachment C. DQO guidance for AQI applications

Attachment D. Draft National Air Monitoring Strategy

List of Abbreviations and Terms

AQI	Air Quality Index - An numerical and color coded index for reporting timely air quality to the public for five major pollutants: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide.
Bias (total)	The systematic or persistent distortion of a measurement process which causes errors in one direction.
BAM	Beta Attenuation Monitor - A monitor that uses a source and detector of emitted beta particles to determine the collection of particulate matter.
CAC	Correlated Acceptable Continuous *(as currently applied)* - A continuous PM2.5 monitor collocated with a FRM having sufficient comparability to allow for a reduction in sample frequency of the FRM from daily to one in three days.
CAMM	Continuous Ambient Mass Monitor - A monitor that measures changes in pressure drop across a filter tape with particulate matter collected on it to determine the concentration of fine particulate.
CASAC	Clean Air Science Advisory Committee - A group charged with statutorily mandated responsibility to review and offer scientific and technical to the Administrator on the air quality criteria and regulatory documents which form the basis for the National Ambient Air Quality Standards.
DQO	Data Quality Objectives - Are qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential errors, that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
FEM	Federal Equivalent Method - A method for measuring the concentration of an air pollutant in the ambient air that has been designated as an equivalent method in accordance with 40 CFR Part 53.
FRM	Federal Reference Method
Measurement Precision (total)	A measure of the mutual agreement among individual measurements of the same property, usually under prescribed similar conditions, expressed generally in terms of the standard deviation.

Primary Monitor	Identifies one instrument as the sanctioned monitor for comparison to the NAAQS when there are multiple instruments measuring the same pollutant at the same site.
REM	Regional Equivalent Monitor - A potential new type of equivalent monitor being proposed in this document that would be limited geographically in its approval to where its performance has been successfully demonstrated.
SAMWG	State Air Monitoring Working Group
SES	Sample Equilibration System - A technology utilizing a Naphion® dryer that allows sample flow streams to be conditioned to low humidity and temperature.
STAPPA/ALAPCO	State and Territorial Air Pollution Program Administrators / Association of Local Air Pollution Control Officers
TEOM	Tapered Element Oscillating Microbalance - A particulate matter continuous monitor that utilizes an inertial balance which directly measures the mass collected on a filter by measuring the frequency changes on a tapered element.

Executive Summary

An enlarged continuous PM monitoring network will improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and decrease the resource requirements of operating a large network of nearly 1200 filter-based particulate samplers. This document provides recommended directional guidance to move forward in deploying a valued continuous PM monitoring program operated by State and local agencies and tribal governments. A range of topics are addressed, including relationships between continuous and filter-based measurements, performance analyses of collocated continuous and filter based samplers, recommended performance criteria, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

This plan proposes a hybrid network of filter based and continuous mass samplers. The hybrid network would include a reduced number of existing FRM samplers for direct comparison to the NAAQS and continuous samplers that meet specified performance criteria related to their ability to produce sound comparisons to FRM data. Two approaches for integrating continuous mass monitors are proposed to maximize flexibility for agencies; an expanded use of Correlated Acceptable Continuous Monitors (CAC), and a new Regional Equivalent Monitor (REM) program. The CAC approach would enable agencies to address any monitoring objective, other than ***direct*** comparisons to NAAQS for attainment and non-attainment designations, while the REM approach would serve any monitoring objective.

In either approach, if data produced by a continuous monitor differ from that produced by the filter-based method, then monitoring agencies should seek to optimize the continuous method to reduce those differences. If all established means to optimize the continuous method have been exhausted, and the differences in data from the filter-based method and continuous monitor are still not acceptable, then the continuous data should be adjusted to be more comparable to that of the filter-based method. Only simple adjustments will be allowed for the REM whereas any type of adjustment will be allowed for the CAC. At sites operating a continuous instrument that is not collocated with a filter-based instrument, assumptions will have to be made about the adjustment that is appropriate to produce data that is comparable to a filter-based sampler. The general approach proposed in this document is to determine geographical regions within which one adjustment is appropriate for all of the continuous measurements. There is flexibility in the adjustments and regions associated with a CAC, whereas the adjustments and regions associated with the REM will be restricted and subject to an independent review through EPA's Office of Research and Development or a similar entity.

Two performance criteria are proposed to determine whether the adjusted continuous measurements are sufficiently comparable to be integrated into the $PM_{2.5}$ network. These criteria are bias (relative to a filter-based method) between -10% and +10% and precision less than 20% coefficient of variance (CV). These criteria are the result of a data quality objective (DQO) analysis that is based on data from the existing $PM_{2.5}$ network and based on the assumption that the annual

$PM_{2.5}$ air quality standard is the principal decision driver. Also, the DQO result is conservative in that the goals guarantee decision error rates for the "worst case" scenarios. In cases that are not "worst," the DQO approach allows for additional flexibility beyond the stated bias and precision goals. These performance criteria preferably would be demonstrated by monitoring agency staff under actual operational conditions, a departure from the very tightly controlled approach used for national equivalency demonstration, and validated periodically in recognition of changing aerosol composition and instrument performance.

Recommended changes in the PM monitoring regulations are proposed that will reduce the number of required FRM samplers nationally, a divestment needed to generate operational resources to stimulate deployment of continuous mass samplers.

Many of the proposals in this document require additional work before formal guidance can be completed. Some of the additional work includes increasing the number of sites with collocated FRM and continuous samplers in order to characterize relationships between sampling methods and the spatial extent of those relationships. Such characterization is necessary for initial and ongoing integration of the continuous monitors into the entire $PM_{2.5}$ mass network. The final section of this document lists the areas requiring additional work.

Section 1. Introduction

This document presents a proposal for enhancing the continuous particulate matter monitoring in the air monitoring networks operated by State and local agencies and tribal governments. The document addresses a range of topics including recommended performance requirements, regulatory modifications, and identification of outstanding technical issues and actions to be taken in the near future.

EPA is working with the Clean Air Science Advisory Committee (CASAC) technical subcommittee on particle monitoring; State and local agencies and tribal governments; and consortiums of State and local agencies on a strategy to enhance deployment and utility of continuous fine particulate mass monitors. This document is an important step in this cooperative effort as it provides a basis for comment on our intended approaches. Clearly, a substantial subsequent guidance development effort will be required to implement the directions in this proposal. Comments are welcome from all interested stakeholders on this document as well as the national air monitoring strategy it is intended to support.

The reader should be aware that the concepts and elements incorporated in this plan are singularly and collectively complex therefore creating a communications challenge. Other approaches were considered, but the potential drawbacks of a simplistic approach were not acceptable. That is, it would have been easy to develop a rigorous non-flexible program easily communicable but conveying little motivation for deployment. Similarly, a program without constraints would likely compromise data quality and interpretability. Thus, a decision was made to accommodate both flexibility and data comparability at the expense of developing and communicating a complex program.

The development of "acceptable" relationships between a Federal Reference Method (FRM) measurements and continuous monitors is stressed throughout this document. The reason for this is that so many objectives relate to the FRM measurement (e.g., NAAQS comparisons, air quality index reporting, air quality model application). In many instances, there is no technical reason to expect comparability between disparate measurement approaches. Such comparability is desired given the utility of relating continuous measurements to a wealth of existing FRM data and to incorporate a reference marker. The downside of this approach is that the value of an FRM measurement is assumed or inferred to be greater than that of a candidate method, when in some cases the candidate method may better reflect "true" characteristics of an aerosol. This topic is addressed in more detail in Section 7.

Background

EPA is motivated to develop the continuous monitoring program by the need to improve public data reporting and mapping, support air pollution studies more fully by providing continuous (i.e., hourly) particulate measurements, and to decrease the resource requirements of operating a large

network of filter-based particulate samplers. This document also addresses an important gap in technical guidance for the continuous particulate matter program, created in part by a strong emphasis to date on compliance (Federal Reference Method) and chemical speciation sampling.

Approximately $170 million has been directed toward the deployment and operation of the $PM_{2.5}$ network since July 1997, and the $PM_{2.5}$ network continues to operate at a cost of $42 million annually. The majority of the annual expenses are for the operation and maintenance of the federal reference method samplers, $26.5 million. The introduction of continuous particulate matter monitors capable of addressing multiple objectives with reduced operator burden could produce desired network efficiencies. For example, the cost of operating a federal reference method sampler on a one-in-three day schedule for a year is approximately $19,000 (including operations, maintenance, data management, filters, and quality assurance audits). The cost of operating one of the available continuous (hourly) particulate matter samplers is approximately $8,000. EPA does not expect that all federal reference method samplers will be replaced; however, significant resources can be impacted by the use of more continuous samplers in lieu of some federal reference methods.

Assessments of existing criteria pollutant networks are being conducted as part of a separate but parallel National Air Monitoring Strategy effort. These assessments are providing direction for reducing the current number of $PM_{2.5}$ federal reference methods based on observed spatial redundancy (due to relatively broad homogeneous fine aerosol behavior throughout the eastern United States) and related factors. Such divestment in filter based methods is needed to support integration of a more comprehensive continuous mass network, as well as preparing for future coarse particulate monitoring requirements. This comprehensive air monitoring strategy also has defined progress in continuously operating PM monitors as a priority for implementation.

Over the last four years many monitoring agencies have expressed a strong desire for the development and acceptance of continuous methods for use as compliance samplers (i.e., federal equivalent methods). This sentiment has been expressed in a number of venues including the Air and Waste Management Association PM2000 conference; through the STAPPA/ALAPCO Monitoring Committee and the Standing Air Monitoring Work Group (SAMWG); and the CASAC Technical Subcommittee on Particle Monitoring. The CASAC Technical Subcommittee on Particle Monitoring met on January 22, 2001 in a workshop session dedicated to continuous particulate matter monitoring. This document provides further details on EPA's proposal to enhance continuous PM monitoring as a follow-up to that CASAC workshop. The approach utilizes the data quality objective process to develop continuous monitor performance specifications. State and local agencies and tribal governments would have a set of parallel options through a new Regional Equivalent Method program and an modification of the existing Correlated Acceptable Continuous monitors provision.

The principal challenge implied within this document is maintaining an acceptable balance between data quality and technological progress. The promulgation of the 1987 PM_{10} standards included a performance-based approach to the acceptance of PM_{10} methodology. The current $PM_{2.5}$

monitoring network has achieved relatively high data quality[1] due in large measure to the requirement of design-based methods (i.e., monitors with virtually identical components) and a thorough quality assurance program that followed through on a cycle of planning (data quality objectives), implementation (field/laboratory quality control), data assessment and reporting tasks. Risk in compromising data quality will emerge as an assortment of technologies are accommodated in the network. Consequently, the success of this program will rely not only on the initial data quality objective planning steps, but through a commitment to conducting the remaining quality assurance tasks and retaining the flexibility to take appropriate action in the use of data when systematic failures are encountered within the quality assurance system.

Document Layout

Section 2 examines the available collocated federal reference method and $PM_{2.5}$ continuous monitoring data. This examination illustrates both the successes and challenges of implementing PM continuous monitors. Section 3 and 4 detail the applicability of the correlated acceptable continuous (CAC) monitors and the regional equivalent monitors (REM) including testing requirements and the approval process. Section 5 focuses on network design emphasizing the suggested hybridization of federal reference method and continuous particulate monitors, and proposing a new minimum number of required $PM_{2.5}$ federal reference method sites. Section 6 provides the performance standards for using PM methods and a description of the data quality objective process utilized to derive the goals for precision and bias. The data quality objective process recognizes a number of variables such as measurement precision, population precision, sample bias, sample frequency, a 3-year standard, and sample completeness in order to predict the confidence in a decision around the annual average. Section 7 addresses the use of statistical transformations for each category of continuous methods. The use of such transformations need careful consideration in terms of number of variables, frequency of adjusting, and spatial scale of applicability. Section 8 provides some initial thoughts on developing boundaries for approval of methods across a spatial scale. This section details how a number of inputs such as aerosol composition using both monitored data and modeled data as well as overlaying this output with natural geographic boundaries, such as how State lines or city boundaries may be used. Section 9 provides design guidance on continuous monitoring methods. Section 10 identifies how this effort to enhance a network of continuous particulate monitors is linked to the national monitoring strategy. Section 11 provides a summary of the potential regulatory changes and schedule necessary to implement this plan. Section 12 provides a repository of issues and action items.

Applicability

The scope and intention of this document is focused on addressing continuous particle mass

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[1]"CY 2000 Quality Assurance Report of the $PM_{2.5}$ Ambient Air Monitoring Program," U.S.EPA Office of Air Quality Planning and Standards, October 2001.

monitors that provide in-situ sampling/analysis capability producing outputs that can be aggregated upward to one-hour reporting periods (e.g., TEOMs and beta attenuation gauges). The approaches proposed rely on the use of the data quality objective process to produce quantitative performance standards. This process would in concept accommodate alternative particulate matter measurement approaches beyond the more traditional continuous mass methods, assuming performance standards are achieved. Such acceptable examples that might provide a useful alternative to the federal reference method include the use of a continuous speciation monitor alone (e.g., sulfate only) or in combination with multiple speciation monitors (e.g., carbon, nitrate and sulfate), or other filter based methods that do not have current equivalency status (e.g., dichotomous sampler). The principles described in this document are not applicable to measurement systems beyond particulate matter (e.g., utilizing particulate matter measurements to replace ozone or other discrete gaseous measurements).

Section 2. $PM_{2.5}$ Continuous/FRM Relationships

Introduction

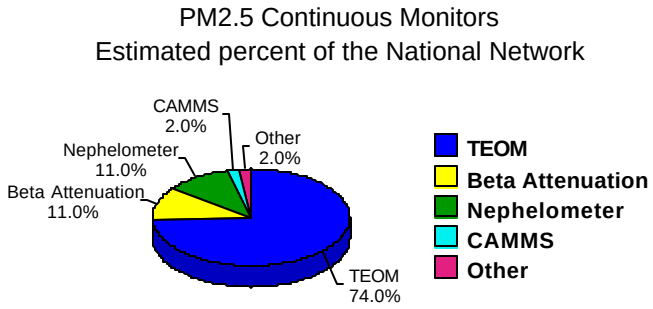
This section represents an initial effort to compile relational analyses between continuous and FRM data. Relationships between $PM_{2.5}$ continuous and FRM monitors are synthesized from a number of sources, including routinely collected data provided by State and local agencies and data from available field studies. The task of comparing $PM_{2.5}$ continuous data with FRMs was accomplished by averaging the hourly continuous mass data between midnight to midnight, to parallel the FRM operations. General information is provided first with a number of analyses presented later in this section. A more detailed set of analysis are presented in Attachment A.

General Summary

Continuous monitors track FRM data with varying degrees of success across the country, with a mix of seasonal and geographical patterns affecting behavior. Analyses to date are somewhat limited by the availability of relatively few formal field studies, and the current (and temporary) situation where only one $PM_{2.5}$ continuous method (the TEOM[2] operated at 50C) has been widely deployed (Figure 2-1). Despite these limitations, there is an emerging understanding that the best $PM_{2.5}$ continuous monitor choice may vary from one monitoring agency to the next. TEOMs operated at 50C appear to predict FRM measurements in locations where volatile losses are minimal. Examples include sites with sulfate dominated aerosols in the Southeast (the Carolinas and Georgia) throughout the year and northeastern and upper Midwest (Iowa and Michigan) locations during the summer. The prevalence of winter month underestimates in certain areas suggests that the TEOM operated at 50 C exacerbates volatile losses during cool conditions when the difference between operational and ambient temperature is greatest. Converting the 50C TEOM to a 30C TEOM with a Sample Equilibration System (SES) should reduce cool season volatile losses. Analyses comparing collocated 50 C and 30 C TEOMs with the SES and FRMs at sites in North Carolina and New York State indicate improved comparability to the FRM for the 30 C TEOM with the SES.

[2]Manufactured by Rupprecht & Pataschnick.

Figure 2-1 Percent of PM2.5 Continuous Methods used Nationally



The beta attenuation monitor (BAM)[3] is operated at several locations (second in number to the TEOM) throughout the western United States with a limited number of new locations in the east. The California Air Resources Board and other organizations sponsored a field study of several major $PM_{2.5}$ commercially available monitors indicating high performance of the BAM conducted during relatively volatile aerosol conditions.[4] EPA's Environmental Technology Verification Program (ETV) included two test sites; one in Pittsburgh, PA in the summer of 2000; and one in Fresno, CA in the winter of 2000-2001. This verification program included a number of $PM_{2.5}$ continuous monitors being deployed by State and local agencies including the BAM, the TEOM operated at 50C, the TEOM operated with the sample equilibration system at 30C, and the CAMMS[5]. While the verification reports do not offer conclusions as to the performance of the monitors, inspection of these reports indicates that the Met One BAM performed consistent at both test sites. The final verification reports from these field studies are available from the U.S. EPA web site.[6]

The Nephelometer is used at many sites in the Pacific Northwest. This monitor can have

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[3]Manufactured by Met One Instruments.

[4]Reference the CARB report here.

[5]Manufactured by Thermo Andersen.

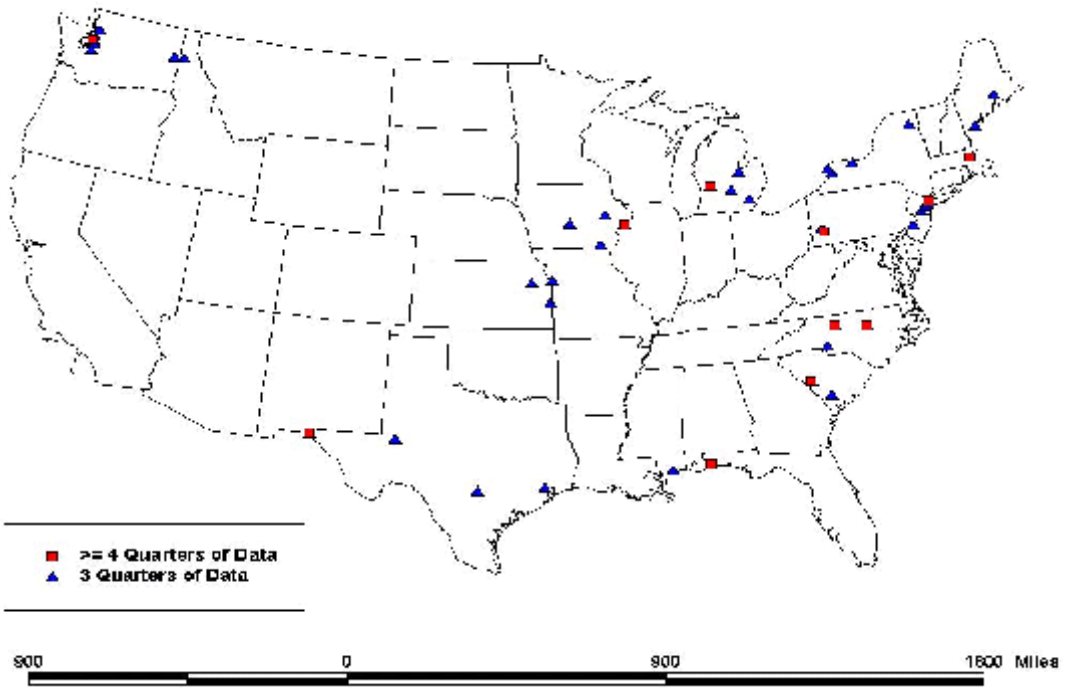
[6]Environmental Technology Verification Statements and Reports:
http://www.epa.gov/etv/verifrpt.htm#07

advantages over PM2.5 continuous methods with respect to its ease of operation. However, Nephelometers can have problems with high humidity and care should be taken to assure sample streams are conditioned so as not to have moisture interfere with the scattering output. There are several manufacturers of Nephelometers, so care also needs to be taken when comparing data from a monitor at one site to another. Although Nephelometers do not provide for a direct output of fine particualte concentration, they can be useful when calibrated against filter based methods to provide for diurnal and day to day signal of fine particulate.

Analysis of the Variety of Relationships for 47 Collocated $PM_{2.5}$ Continuous and FRM Sites

The AIRS database included 11 sites with at least a years worth of collocated $PM_{2.5}$ continuous monitoring and FRM data based on a Spring, 2001 retrieval. An additional 36 sites were included for analyses if they had at least 3 quarters of data with at least 11 valid collocated pairs per quarter for a total of 47 sites (Figure 2-2) forming the basis for the analyses presented in this section.

Figure 2-2 Map of 47 Sites used in $PM_{2.5}$ Continuous Monitors Analyses



Intercomparisons of FRMs and $PM_{2.5}$ Continuous Monitoring Data:

Of the 11 sites with at least 4 quarters of complete data, 8 sites used TEOM monitors with the factory installed correction factor applied for the entire data set. This factory installed correction factor adds 3 ug to the intercept and 3% to the slope for data coming from a TEOM. A table summarizing the range of concentration values from each of the FRM and continuous monitors at these sites is provided

below:

Table 2-1 Concentration Ranges for 8 Sites with Collocated PM2.5 FRM and TEOM Monitors

MSA	Site ID	N	Primary Monitor Type	Concentration Range of Data (µg/m^3)						
				Mean	SD	Min	Q1	Median	Q3	Max
Aiken, SC - Augusta, GA	450370001	144	Continuous	14.50	6.42	1.37	9.85	13.46	18.88	34.75
			FRM	14.49	6.55	2.40	9.75	13.00	18.00	34.20
Davenport, IA - Moline - Rock Island, IL	191630015	453	Continuous	12.00	6.49	2.92	7.26	10.53	15.30	48.81
			FRM	12.81	7.31	2.30	7.30	11.50	16.90	46.70
Winston - Salem, NC	370670022	525	Continuous	16.23	8.05	2.66	10.29	14.45	20.95	64.02
			FRM	16.89	8.70	1.60	10.60	15.00	21.70	69.70
New York, NY	360050110	295	Continuous	15.40	9.26	4.69	8.85	12.85	19.24	85.38
			FRM	15.21	9.17	3.60	8.30	12.30	20.00	53.00
Pensacola, FL	120330004	214	Continuous	14.41	6.74	-17.7	9.90	13.02	17.94	45.83
			FRM	14.03	6.89	1.00	8.60	12.70	18.41	49.30
Pittsburgh, PA	420030064	344	Continuous	16.68	12.00	1.21	7.27	13.19	22.50	68.92
			FRM	20.87	13.39	3.10	11.00	17.20	26.55	78.50
Raleigh-Durham, NC	371830014	389	Continuous	15.02	6.89	2.78	10.00	13.66	18.98	45.88
			FRM	15.59	7.52	3.00	10.10	14.40	20.00	52.80
Seattle, WA	530330057	340	Continuous	13.30	6.39	3.38	9.08	11.87	15.48	44.42
			FRM	12.64	7.25	2.80	7.80	10.95	15.40	46.90

Inspection of Table 2-1 indicates that most of the sites appear to produce similar PM2.5 concentrations regardless of whether an FRM or TEOM is used. Only the Pittsburgh, PA site showed a large discrepancy between the mean of the FRM and PM2.5 continuous monitor. Due to this discrepancy, the Allegheny County monitoring staff were contacted to confirm the operation of the TEOM and use of default corrections factors. While the operation of the instrument was determined to be correctly identified, it was mentioned that the site is located in a community orientated location in close proximity to a large local source.

Scatter plots were produced for each of the 11 sites with at least a years worth of complete data. Data were plotted for each day where both a FRM value and a corresponding average 24-hour continuous $PM_{2.5}$ value were available. Separate plots for linear and log-normal concentrations were plotted for each site. The scatter plots can be separated into several categories: scatter plots with good agreement most of the time - illustrated by most points being on a straight line (Figures 2-3 through 2-6 and 2-9); scatter plots with a small but discernable amount of spread about the best fit line - as illustrated by a mild spread about the best fit line (Figures 2-7 and 2-8); scatter plots with good agreement part of the time and poor agreement in others - illustrated by a large increasing spread with concentration (Figures 2-10 and 2-11); and scatter plots that do not appear to correspond well with any pattern - illustrated by a large spread about the 1:1 relationship regardless of the concentration (Figures 2-12 and 2-13).

These first four figures represent sites in the southeastern United States where the $PM_{2.5}$ continuous monitor appears to track the FRM reasonably well:

Figure 2-3 Raleigh-Durham, NC

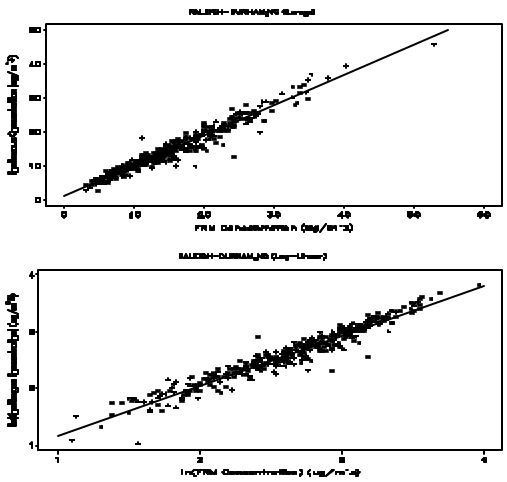


Figure 2-4 Winston-Salem, NC

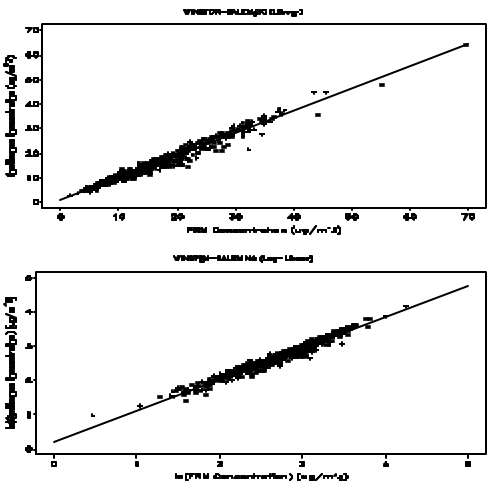


Figure 2-5 Aiken, SC - Augusta, GA

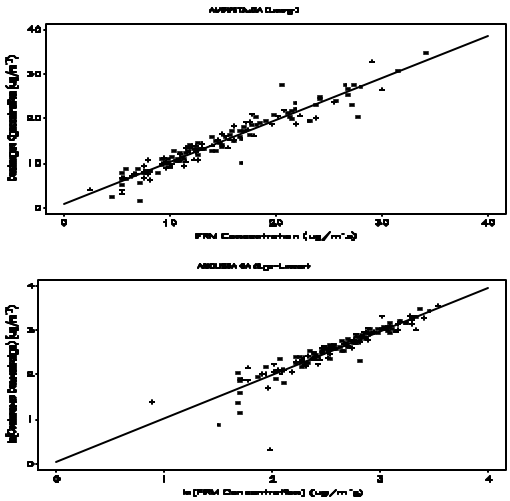
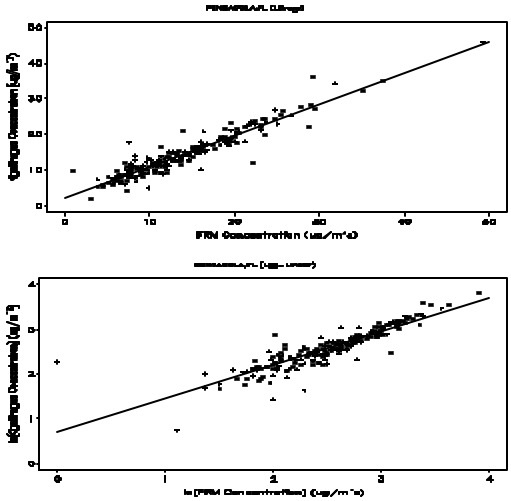


Figure 2-6 Pensacola, FL



The following scatter plots represent cities in the Northeast with some discernable spread about the best fit line, but not severely distorted.

Figure 2-7 New York, NY

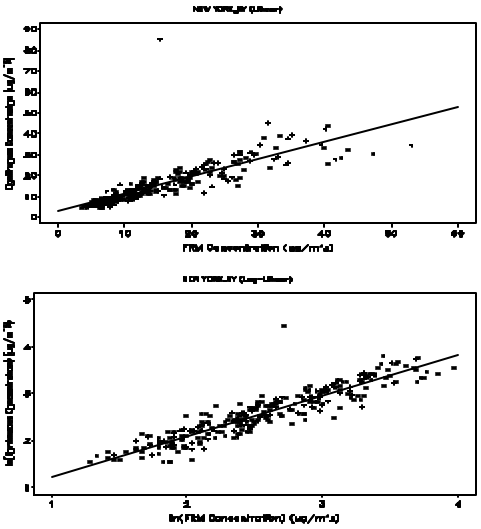
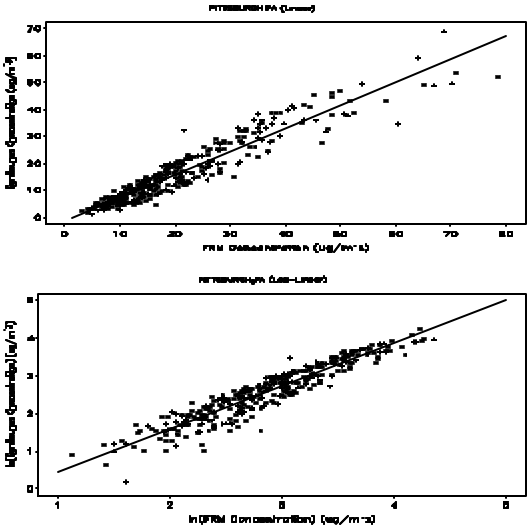
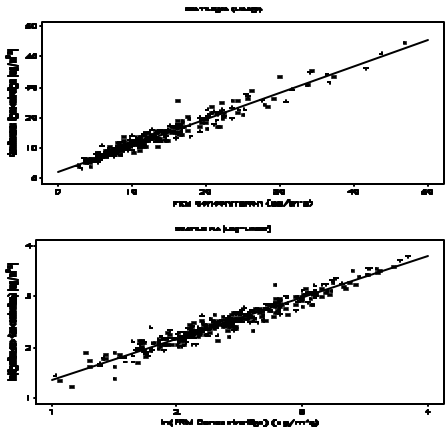


Figure 2-8 Pittsburgh, PA



The following figure is from a northwest site. The scatter plot shows a good fit about the best fit line.

Figure 2-9 Seattle, WA



These figures, using data from sites in the upper mid-west, represent a clear spread with concentration. This is likely an effect of seasonal aerosol changes.

Figure 2-10 Davenport, IA

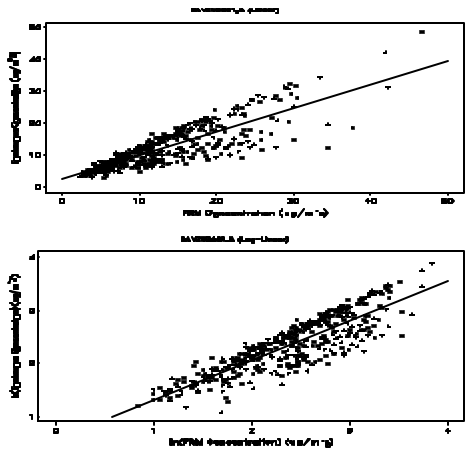
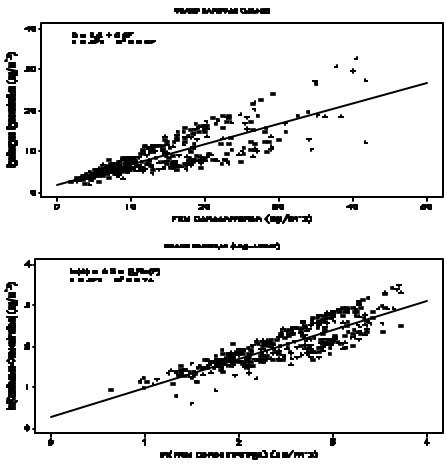


Figure 2-11 Grand Rapids, MI



These figures represent data from air sheds where the TEOM and FRM do appear to correspond well.

Figure 2-12 El Paso, TX

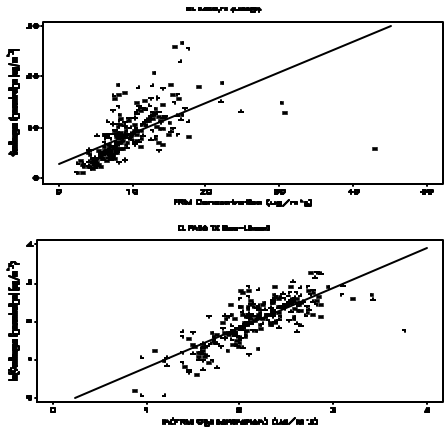
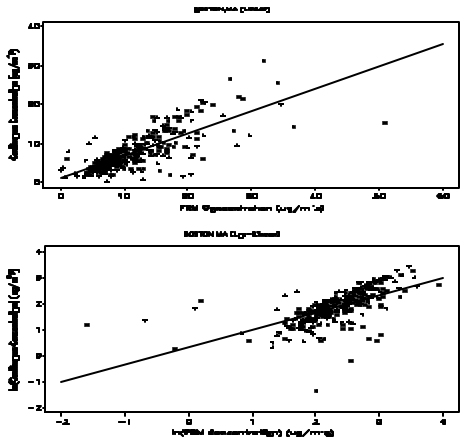


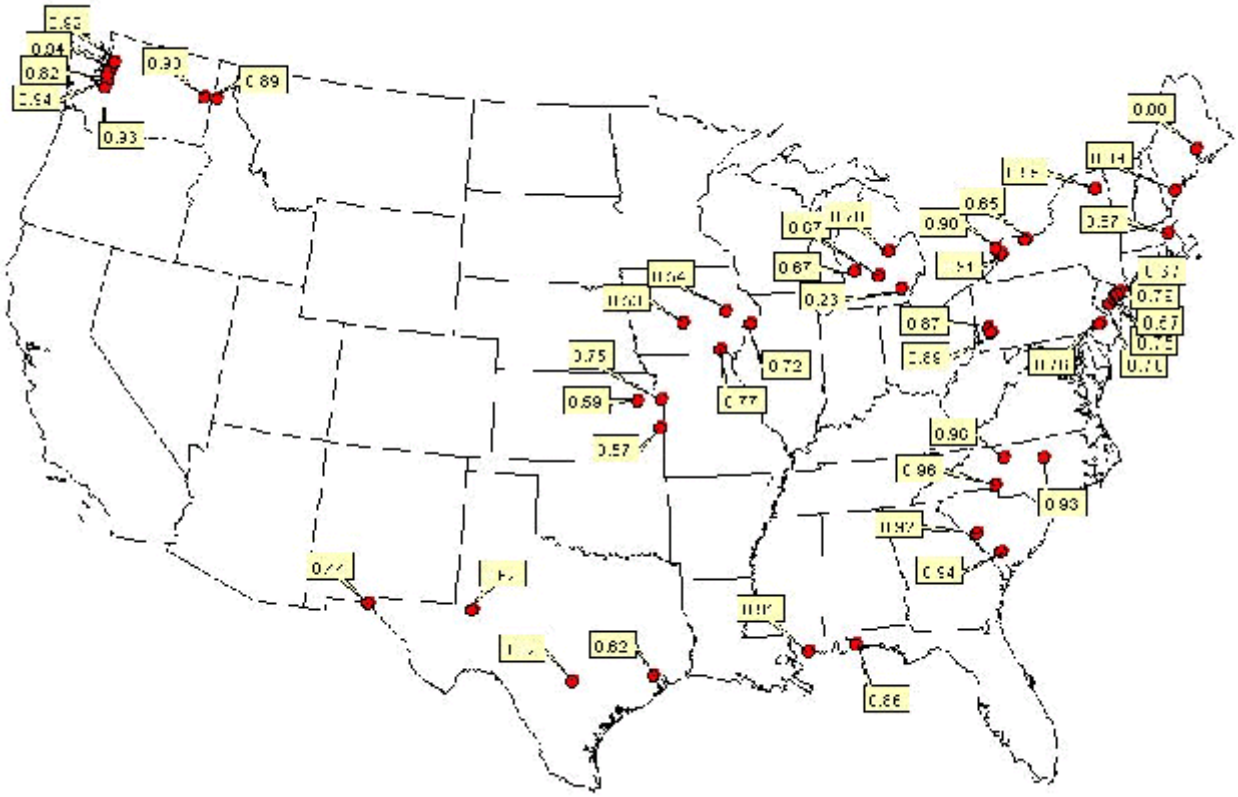
Figure 2-13 Boston, MA



Correlation between $PM_{2.5}$ Continuous Monitors and FRMs

Another way to look at the data is to evaluate the goodness of fit between a model using $PM_{2.5}$ continuous data to explain FRM measurements. The map below (Figure 2-14) illustrates the correlation coefficient (R^2) at each of the available 47 sites. All 47 sites are able to be used because a linear model will not affect the correlation regardless of whether a site specific model is used, the standard correction factors are applied or no model is used at all. The map also indicates that geographical area plays a large role in how high a correlation coefficient is observed. This is likely due to the aerosol encountered at specific sites, the concentration of fine particulate and an effect of the season. Areas exhibiting high correlation include the Southeast, Northwest and selective locations of the Northeast. Areas with poor correlation are likely the result of either regional scale winter time volatilization as demonstrated in Iowa and Kansas or micro-scale to urban-scale influences of local sources such as in Boston and El Paso.

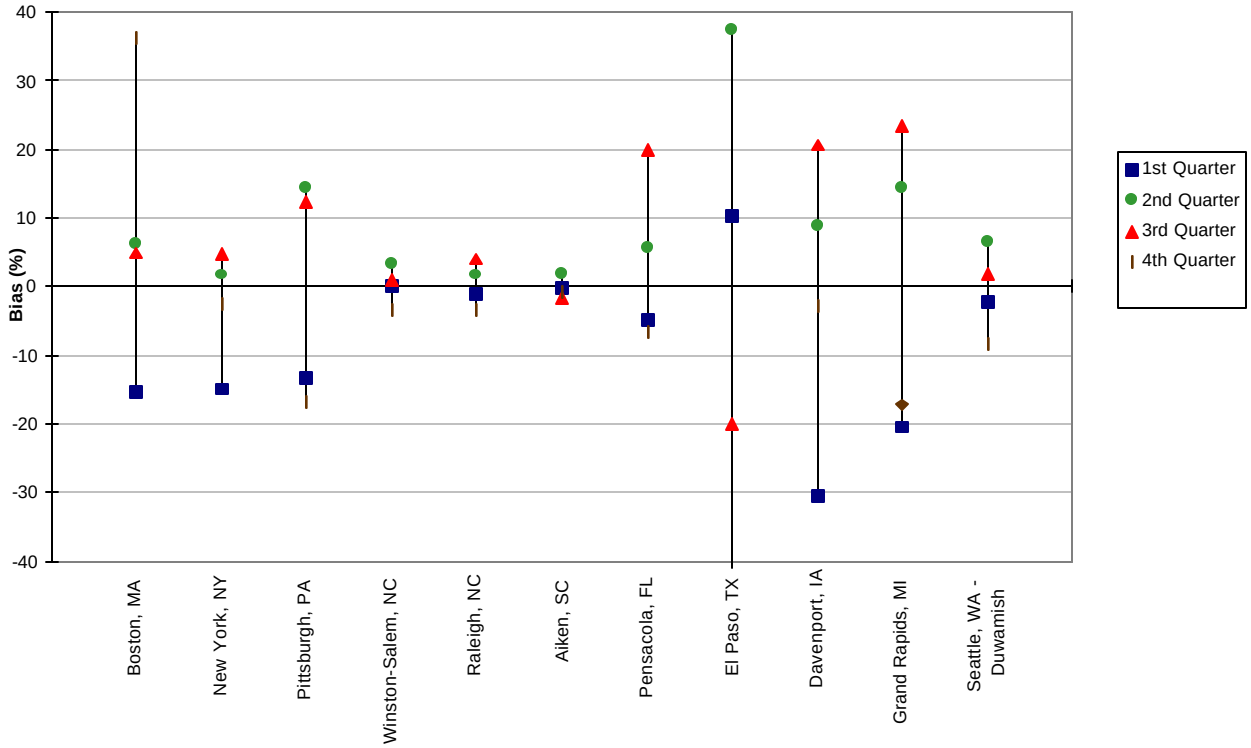
Figure 2-14 Correlation between FRMs and $PM_{2.5}$ Continuous Monitors



Bias by Season

In many air sheds across the United States the species and concentration of the aerosol encountered varies by season. Changes in the species and concentration of the aerosol can lead to changes in performance of a $PM_{2.5}$ continuous monitor. In the illustration below the spread of bias is presented for those sites with at least 4 quarters of complete data. Bias data were calculated by comparing the FRM and collocated continuous monitoring data for days when both instruments produced a valid 24 hour value. Since some monitoring agencies choose to use a standard correction factor in the reporting of their data while others did not, each set of data was first fit to it's own linear model and then the bias were calculated by quarter. Additional graphics depicting the bias by quarter for those sites without 4 complete quarters are available in attachment 1. The tighter the fit between season the better the opportunity to use that continuous instrument to produce FRM-like measurements. Generally, cooler quarters produced the largest negative biases. This is likely due to the larger difference between the operating temperature of the TEOM and the ambient temperature of the atmosphere. The relatively high operating temperature of the TEOM during these cooler months leads to evaporation of a portion of the aerosol that are collected on a filter based sampler.

Figure 2-15 PM2.5 Bias Data for TEOM Monitors by Quarter



Analysis of the Acceptability of the Relationship relative to the Data Quality Objective Process and Class III equivalency.

In the section above, a few of the sites appeared to have $PM_{2.5}$ continuous monitors that are replicating the FRM measurements very well with other sites not performing well and many sites in between. A site may be expected to replicate the FRM very well by virtue of having a scatter plot close to unity, a high correlation coefficient and a low bias. But with a variety of performances across sites, at what level should a site be considered acceptable? In this section data from 160 collocated FRM/FRM sites and 47 collocated $PM_{2.5}$ continuous/FRM sites are compared to various levels of the Data Quality Objective (DQO) process and the equivalency criteria. For the DQO criteria, precision and bias statistics are determined for each site and results are presented as a function of the percentage

of sites that satisfied the criteria. For the equivalency criteria, linear regression is performed for each site and results are presented as a function of the percentage of sites that satisfied the criteria.

Table 2-2 Percentage of Collocated Sites meeting individual DQO and Equivalency Criteria

Criteria	160 Collocated FRM/FRM (% of sites meeting criteria)	47 Collocated FRM/Continuous Sites (% of sites meeting criteria)
Data Quality Objective		
Bias 5%	86.9	34.0
Bias 10%	97.5	53.2
Precision 5%	28.1	0.0
Precision 10%	68.8	12.8
Precision 20%	NA	61.7
Equivalency		
Slope (1±0.05)	77.5	91.5
Intercept (±1 µg)	82.5	97.9
Correlation ($0.97)	66.2	10.6

Interpreting Table 2-2 leads to several observations:

- Evaluations of the collocated FRM/FRM sites against the existing goals of ±10% bias and ±10% precision, indicate that precision is the limiting factor. Most (97.5%) of the sites meet the bias goal and 68.8 % meet the precision goal. As will be demonstrated in section 6, bias strongly influences the uncertainty of a 3 year mean, while precision has little effect due to the large number of samples in 3 years of data. Therefore, we have confidence that the FRM network is performing well, as indicted by 97.5% of the sites meeting the bias statistic.

- Evaluating the FRM/FRM sites against the existing criteria for Class III equivalency[7] indicates that correlation is the limiting factor with 66.2% of the sites passing. That's

[7] 40 CFR 53

important since we believe we have a well-operating $PM_{2.5}$ FRM network; however, over one-third of the sites would fail the Class III equivalency testing criteria. If a collocated network of FRM cannot largely meet the equivalency criteria, it will be very difficult for a network of FRMs collocated with $PM_{2.5}$ continuous monitors to meet this criteria.

- Evaluations of the collocated FRM/continuous sites against the existing goals of ±10% bias and ±10% precision indicate that precision is also the limiting factor with 53.2 % of the sites meeting the bias goal and only 12.8 % meeting the precision goal. As mentioned above and demonstrated in section 6, bias strongly influences the uncertainty of a 3-year mean, while precision has little effect due to the large number of samples in 3 years of data. If the precision goal could be reduced to ±20%, then 61.7% of the sites in the analysis would have satisfied this criteria. Although an even less stringent precision goal could potentially be chosen, bias has now become the limiting factor for performance of the continuous monitors. While precision could potentially be relaxed and we would still have a high degree of confidence in the 3 year annual mean, the need to monitor for other monitoring objectives necessitates controlling precision to some degree. A detailed explanation of the DQO process will be explained in section 6.

- Evaluating the FRM/continuous sites against the existing criteria for Class III equivalency indicates that correlation is the limiting factor with 10.6% of the sites passing. If it can be demonstrated that the continuous monitors are producing FRM-like measurements that meet the goals established in the DQO process rather than the equivalency criteria, than the correlation criteria becomes irrelevant.

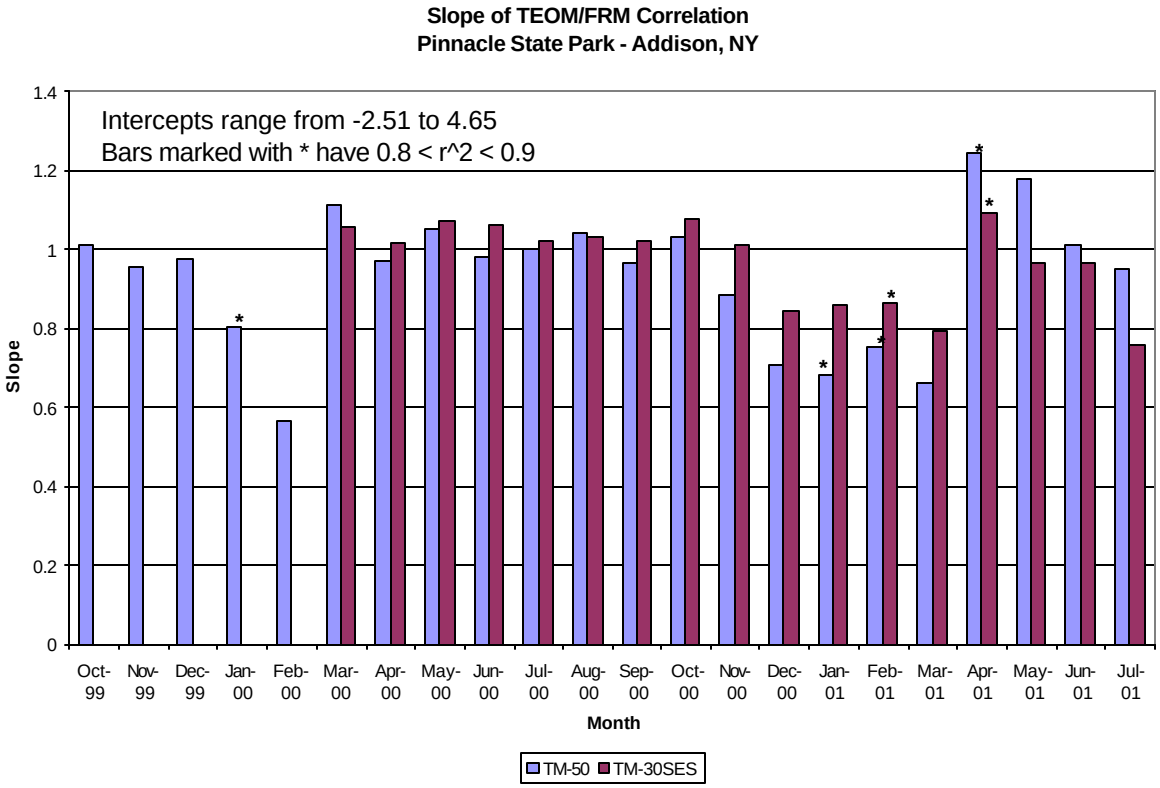
Note: In addition to this analysis the EPA has produced assessments of the quality of the $PM_{2.5}$ monitoring program for the currently operating FRMs for calendar year 1999 and 2000. The calendar year 1999 report is final and can be reviewed on-line at the EPA web site: http://www.epa.gov./ttn/amtic/. The calendar year 2000 report is in review and a draft copy can be obtained from the same web address.

Analysis of Collocated TEOMs with a FRM

In New York State two sites have operating collocated TEOMs with a FRM. Additionally, a site in Raleigh North Carolina also has two TEOMs and a FRM. At each site one of the TEOMs is run with an operational temperature of 50C, while the other is operated at 30C and utilizing a Sample Equilibration System (SES). Data are compared to the operating FRM at the sites, which for all 3 locations is a R&P 2025 FRM. The site with the longest record of data is located at Pinnacle State Park in Addison, NY. This site is located in a rural area of New York's Southern Tier. The illustration below provides some indication of the improvement a TEOM operated at 30 degrees C with a SES can have over operating the conventional TEOM at 50 C. The improvement is most pronounced in the cold weather months of November through March. A table summarizing regressions for all 3 sites by

month is available in attachment A.

Figure 2-16 Slope of TEOM/FRM at Pinnacle State Park, NY



Data courtesy of New York State Department of Environmental Conservation and University of Albany, Albany NY.

Conclusion

Although this analyses is very limited it's becoming clear that some areas of the country may already be operating PM continuous monitors that produce data with similar quality to that of the FRM. If a mechanism to approve the use of these continuous monitors could be made where the performance of the instrument is defined to be acceptable than a large resource savings may be gained by divesting of some of the FRM operations. Other areas of the country may not be producing PM2.5 continuous data that could be used to replace the FRM. For these areas, agencies may need to pursue improvements to their instrumentation or new technologies altogether. Comparing the performance of sites that have a collocated FRM/FRM pair with a collocated FRM/continuous pair to the expected equivalency criteria revels that the correlation statistic (r^2 $0.97) would be the limiting factor for either FRMs or continuos monitors to meet equivalency. If this is the case than an evaluation of the expected statistical criteria for equivalency of a continuos monitor should be made. Section 6 of this document

examines the performance standards of PM2.5 continuous monitors in detail.

Section 3. Enhanced Correlated Acceptable Continuous Methods (CAC)

A provision to enhance the existing provision for Correlated Acceptable Continuous (CAC) monitors is being proposed in concert with a new Regional Equivalent Monitor (REM) program to provide agencies with options to enhance their network of PM continuous monitors. Rationale based on data comparability for selecting the CAC or REM vehicle is discussed in Section 5 and 6. The basic premise of a revised CAC is to provide flexibility in method selection for PM monitoring sites that are not needed for direct comparison to the NAAQS and for sample frequency relief. These sites would be allowed to use CAC monitors if they meet specified performance criteria. While the current provisions for CAC(s) only allow for a reduction in sample frequency of the accompanying FRM/FEM, the provision under consideration would also allow for a continuous monitor to be approved for use without the collocation of a FRM at sites that are not required for the NAAQS. This additional flexibility is being considered for CAC monitors since no agencies have yet to have a CAC approved and it would be better to enhance the usefulness of CACs rather than to have another provision in the regulation. This approach would potentially be targeted for those agencies that need to monitor for a number of monitoring objectives other than NAAQS attainment decisions. Thus while the CAC cannot be used for attainment decisions - it can be used to meet all other applicable monitoring objectives such as: public reporting, trends, mapping, and exposure. By allowing a portion of the currently required FRM sites in a network to be substituted with continuous monitors meeting performance based criteria, the monitoring agencies can realize a reduction in resource requirements while maintaining data delivery with an acceptable defined level of quality. Also, some of the remaining FRM sites would be collocated with the same continuous methods as the CAC's to provide the performance data for ongoing assessment of the continuous method. These revised CACs would be different than the conventional Federal Equivalent Methods (FEMs) in that they could only replace a limited number of sites and the CAC met the performance criteria specified in Section 6 - Performance Standards for Continuous Monitoring. CACs would be different from REMs in that they could not be used for direct attainment decisions and there would be much more flexibility in the use of data transformations as described in Section 7 - Data Transformation Policy and Guidance. This section describes the current provisions for CAC monitors and lays out the potential scope of using CACs in a revised network.

Performance Criteria

There are two types of performance criteria to consider. The first criteria to consider are the performance standards for acceptance of a method. These criteria are provided for in section 6 and are primarily based upon the goals for measurement uncertainty as developed in the data quality objective process for the $PM_{2.5}$ monitoring program. Since the CAC is not used for regulatory decision making the specific criteria for precision and bias at a site or network of sites will remain "goals" and not requirements. The second type of criteria are for on-going evaluation that the method is providing data of sufficient quality for its intended monitoring objective. These criteria are the same performance standards developed for measurement uncertainty in the $PM_{2.5}$ monitoring program and are also presented in section 6 of this document.

Testing Requirements

There are a number of testing requirements that need to be considered. These testing requirements are intended to be designed so that State and local agencies can readily implement a field testing program to pursue a CAC for use in their network. The table below identifies the suggested criteria and rationale for CACs:

Table 3-1 Test Specification for $PM_{2.5}$ CACs

Testing Requirement	Suggested Criteria for CACs	Rational for Criteria
Number of Test Sites	1 on a site by site basis or minimum of 2 for a network (see Table 3-2 below)	Need to demonstrate that the method can meet performance criteria at a specific site or multiple locations in a State or local network.
Number of FRMs per site for generating baseline data in testing	1 - However strongly suggest locating test sites at collocated FRM precision sites to assure control of FRMs and to have high sample completeness	Precision of FRM can be assumed from FRM network precision statistic
Number of Candidate Samplers	2 for first CAC site, 1 each for each additional site tested.	Need to have collocated candidate CACs in order to calculate measurement precision of the continuous method for at least one site in the network.
Number of hours to make a valid 24 hour sample for comparison to the FRM	18	75% completeness of the 24 hour period
Length of testing	All 4 seasons - however testing can begin and end at any point during the year	Need to assure that changes in aerosol or meteorology related to changes in season can meet performance requirements.
Number of data pairs - Primary Monitors, both the FRMs and the candidate CACs	90 per site with at least 20 per season See reference in section 7	Expected to be similar to 1 in 3 day sample frequency at 75% completeness for four seasons
Number of data pairs - Collocated FRMs	As found in network	Use existing collocated FRM precision sites
Number of data pairs - Collocated candidate CACs	- 60 sample pairs - At least 15 sample pairs per season	Based upon 90% confidence that the precision statistic is within 15% of the true precision. Since these are continuous methods may expect to have a substantially large data set.

Range of concentrations for siting	As found in the area of consideration.	Need to evaluate method under the conditions in which it will operate.
Range of concentrations for use in data set when determining performance of methods	May (but not required to) exclude values where the FRM concentration is below 6 ug/m^3. Exclusion of values due to low concentrations does not result in failure of completeness requirements	As concentration values approach 0, biases can appear large. By focusing on the values that are above 6 ug/m^3 estimates of the performance of the candidate methods are more stable.

Guidance for Developing Boundaries for Applicability of CAC

Section 8 of this document provides the detail for how the appropriate geographic size is determined for use of an approved CAC.

Number of test sites for Collocated Acceptable Continuous monitors

The number of test sites for CACs depends on a number of factors such as whether one site or a network of sites is being considered for approval of a CAC and the homogeneity of the aerosol across the area of consideration. At a minimum, 2 sites are to be tested to support a candidate CAC across a network. The following table details how many sites are to be tested assuming the aerosol is homogeneous across an area in which it is being tested:

Table 3-2 Test Site Specifications for $PM_{2.5}$ CACs

Geographical Area of Consideration for CAC	Number of Test Sites
One MSA	2
Multiple MSA's in the same air district or State	1 for each MSA up to the first 3 MSAs, plus at least 1 site in a rural county.
Multiple States	1 for each MSA up to the first 2 MSAs, plus at least 1 site in a rural county. For each additional State add 1 urban and 1 rural site.

Note: if the aerosol is expected to vary according to the guidance provided for in section 8, then apply test sites as if each State or air district were performing testing separately. This will ensure that for each type of aerosol encountered a minimum number of sites are tested.

Review Procedures

Since the monitoring objectives for CACs do not include direct comparison to the NAAQS, the approval procedures for use of a method should be streamlined. Thus the review procedures should be included in the annual network review that is submitted by the State, local or Tribal Agencies to the Region. The Region would work to determine that the performance criteria have been appropriately addressed and the continuous method is suitable for inclusion in the network. Since many agencies potentially seeking the CAC approach for relief from FRM sampling are expected to be substantially below that standard, the Regions should work towards approval of the CACs where they make sense and not prevent their approval if a specific goal is not met. For instance, one way for Regions to make a good decision on the approval of a CAC is to utilize the DQO tool that has been developed with inputs of a number of variables and see if the uncertainty around the NAAQS would be worse or better. If the goals for measurement uncertainty are ± 10% bias and 20% CV and the agency has a bias of 5% and CV of 23% with their continuous method, then the uncertainty around the NAAQS may actually be better.

Ongoing Evaluation of Method Performance

Since the CAC is not to be used for direct comparison to the NAAQS, the specific QA/QC requirements of the $PM_{2.5}$ quality system do not apply in a strict sense. However, since the data are to be used for a number of other important monitoring objectives the $PM_{2.5}$ quality system does apply in a qualitative sense. This means that agencies must develop appropriate measures to determine precision and bias estimates for the CAC monitors used in their network, but they are not held to specific numbers as if they were regulatory monitors. Additionally, the CACs should be appropriately addressed in the monitoring agencies Quality Assurance Project Plan (QAPP). Agencies should be evaluating the quality of their network on an ongoing basis and work to resolve problems as they are encountered.

Potential Use of CACs in $PM_{2.5}$ Monitoring Networks

The expected outcome of having a CAC approved for use at a site or in a monitoring network is that it can be used in combination with a limited number of FRMs as part of a “hybrid” network. Section 5 of this document lays out the detailed network design of a potentially revised network.

Section 4. Regional Equivalent Monitors

A provision to allow for Regional Equivalent Monitors (REMs) is proposed to enhance the network of PM continuous monitors. The basic premise of a REM is that when a $PM_{2.5}$ continuous method meets the precision and bias performance criteria identified in section 6 and the testing specification described below within the geographic area that it is used, then this method may be used anywhere in the network for which it is approved. The spatial extent of the approval of the method would be based upon a number of factors such as number and location of sites tested and homogeneity of the aerosol in the network. This flexibility is being considered since some methods are expected to work well in replicating FRM measurements across specific agencies networks across all seasons, but not in every network in the country. Approved REMs would be allowed to be used for attainment decisions as part of a "hybrid" network of $PM_{2.5}$ FRMs and continuous monitors as described in section 5 - Network Design. For implementation purposes REMs are different than the conventional Federal Equivalent Methods (FEMs) in that they are only for use in the specific geographic area of approval and a minimum network of FRMs must be retained for operation in each network in which they are used. When FRMs are collocated with REMs, the FRM is identified as the *Primary* monitor, meaning it is the monitor to be used for comparison the NAAQS at that site. REMs are different from Correlated Acceptable Continuous (CAC) monitors in that data from REMs are used for direct comparison to the NAAQS, while data from CACs are not. Since the data from REMs are used for comparison to the NAAQS, there is much more control on the approaches for data transformations, as described in section 7. This section describes the test specifications and approval process for REMs.

Performance Criteria

There are two types of performance criteria to consider. The first criteria to consider are the performance standards for acceptance of a method. These criteria are provided for in section 6 and are primarily based upon the goals for measurement uncertainty as developed in the data quality objective process for the $PM_{2.5}$ monitoring program. The second type of criteria are for on-going evaluation that the method is providing data of sufficient quality for its intended monitoring objective. These criteria are the same performance standards developed for measurement uncertainty in the $PM_{2.5}$ monitoring program and are also presented in section 6 of this document.

Testing Requirements

There are a number of testing requirements that need to be considered. These testing requirements are intended to be designed so that State and local agencies can readily implement a field testing program to pursue a REM for use in their network. The table below identifies the required criteria and rationale for REMs:

Table 4-1 Test Specification for $PM_{2.5}$ REMs

Testing Requirement	Suggested Criteria for REMs	Rational for Criteria
Number of Test Sites	Minimum of 2 (see Table 4-2 below)	Need to demonstrate that the method can meet performance criteria at multiple locations in a State or local agency network.
Number of FRMs per site for generating baseline data in testing	1- However strongly suggest locating test sites at collocated FRM precision sites to assure control of FRMs and to have high sample completeness	Precision of FRM can be assumed from FRM network precision statistic
Number of Candidate Samplers	2 for first REM test site, 1 for each additional site	Need to have collocated candidate REMs in order to calculate measurement precision of the continuous method for at least one site in the network.
Number of hours to make a valid 24 hour sample for comparison to the FRM	18 - valid hourly values within the midnight to midnight period.	75% completeness of the 24 hour period.
Length of testing	All 4 seasons - however testing can begin and end at any point during the year.	Need to assure that changes in aerosol or meteorology related to changes in season can meet performance requirements.
Number of data pairs - Primary Monitors, both the FRMs and the candidate REM	90 per site with at least 20 per season. See reference in section 7	Expected to be similar to 1 in 3 day sample frequency at 75% completeness for four seasons
Number of data pairs - Collocated FRMs	As found in network	Use existing collocated FRM precision sites
Number of data pairs - Collocated candidate REMs	- 60 sample pairs for the REM - At least 15 per season for the REM.	Based upon 90% confidence that the precision statistic is within 15% of the true precision. Since these are continuous methods may expect to have a substantially large data set.
Range of concentrations for siting	As found in the area of consideration.	Need to evaluate method under the conditions in which it will operate.
Range of concentrations for use in data set when determining performance of methods	May (but not required to) exclude values where the FRM concentration is below 6 ug/m^3. Exclusion of values due to low concentrations does not result in failure of completeness requirements	As concentration values approach 0, biases can appear large. By focusing on the values that are above 6 ug/m^3 estimates of the performance of the candidate methods are more stable.

Guidance for Developing Boundaries for Applicability of Regional Equivalent Monitors

Section 8 of this document provides the detail for how the appropriate geographic size is determined for use of an approved REM.

Number of Test Sites for Regional Equivalent Monitors

The number of test sites for REMs depends on a number of factors such as the area of consideration for approval of a REM and the homogeneity of the aerosol across the area of consideration. At a minimum, 2 sites are to be tested to support a candidate REM. The following table details how many sites are to be tested assuming the aerosol is homogeneous across an area in which it is being tested:

Table 4-2 Test Site Specification for $PM_{2.5}$ REMs

Example Geographical Area of Consideration for REM[8]	Number of Test Sites
One MSA	2
Multiple MSA's in the same air district or State	1 for each MSA up to the first 3 MSAs, plus at least 1 site in a rural county.
Multiple States	1 for each MSA up to the first 2 MSAs, plus at least 1 site in a rural county. For each additional State add 1 urban and 1 rural site.

Note: if the aerosol is expected to vary according to the guidance provided for in section 8, then apply test sites as if each State or air district were performing testing separately. This will ensure that for each type of aerosol encountered a minimum number of sites are tested.

Review Procedures

The approval of a "Regionally" equivalent monitor should follow the same process for review and approval of other federal equivalent methods. This process works through the Office of Research and Developments National Exposure Research Laboratory (NERL) Reference and Equivalency program. That program receives, reviews and provides feedback to vendors and other parties that have applied for equivalency. Once all the criteria have been appropriately addressed and the candidate method has been determined to meet the appropriate performance criteria the Reference and Equivalency program makes a recommendation that the method be approved as "equivalent". Once approved by EPA management as "equivalent" a notice is published in the Federal Register indicating

[8] The example presented at best reflects a minimum requirement. Definition of extent of regional applicability is addressed more completely in section 8 and is a topic requiring significant development.

that this status has been achieved. Any geographic limitations to a methods approval would also be included in this notice.

Ongoing Evaluation of Method Performance

Since the REM is to be used for NAAQS decision making all applicable elements of the $PM_{2.5}$ quality system are to be applied to its use. This means that REMs are to be collocated with both FRM and the same continuous method as the primary monitor as well as being subject to performance evaluation audits defined in Appendix A of Part 58. Additionally, the CACs should be appropriately addressed in the monitoring agencies Quality Assurance Project Plan (QAPP). If for three consecutive years the REM does not meet the DQOs and a examination of the data indicates that the uncertainty in decision errors is increasing, then the monitoring agency should - **NOT SURE WHAT THE CONSEQUENCE SHOULD BE.** Would like to have agencies work through a solution.

Potential Use of Regional Equivalent Monitors in $PM_{2.5}$ Monitoring Networks

The expected outcome of having a REM approved for use in a monitoring network is that it can be used in combination with a limited number of FRMs as part of a "hybrid" network. Section 5 of this document lays out the detailed network design of the a potentially revised network.

Section 5 - Network Design

Introduction:

The $PM_{2.5}$ monitoring program has been implemented with a heavy emphasis on Federal Reference Method (FRM) samplers in order to support comparing mass data to the National Ambient Air Quality Standards (NAAQS). Approximately 1143 (July 11, 2001 AIRS) monitoring sites in the United States are now operational with FRM samplers. The entire $PM_{2.5}$ network includes components for chemical speciation and advanced measurements (Attachment B). Only the FRM or Federal Equivalent Method (FEM) can be used for direct comparisons to the NAAQS. This plan proposes a more balanced hybrid network of filter based and continuous mass samplers, assuming that data analysts would incorporate filter based and continuous methods (seamlessly) when utilizing network data for broad scale spatial applications such as positive matrix factorization (PMF) and air quality model evaluation. This hybrid network would include a reduced number of existing FRM samplers for direct comparison to the NAAQS and continuous samplers that meet specified performance goals related to their ability to produce sound comparisons[9] to FRM data. Two approaches described in sections 3 and 4 for integrating continuous mass monitors are proposed to maximize flexibility for agencies; an expanded use of Correlated Acceptable Continuous Monitors (CAC), and Regional Equivalent Monitors (REMs). The CAC approach would enable agencies to address any monitoring objective, other than ***direct***[10] comparisons to NAAQS for attainment and non-attainment designations, while the REM approach would serve any objective.

There is an unknown amount of degraded data quality risk associated with moving from the current design based system to one relying on performance based specifications. Therefore, this hybrid network will maintain a core of FRMs to maintain an ability to quantify the relationship between FRMs and continuous samplers for continuity to both the historical record as well as ongoing and prospective use of continuous methods. The remaining network of FRMs might constitute 30% to 50% of the current network. A large network of continuous monitors meeting performance criteria would eventually be in place to improve the data base for: public reporting of Air Quality indices (AQI) and mapping through AIRNow; supporting health effects and exposure studies addressing short term exposures; evaluating air quality models and emission inventories, and supporting compliance needs related to direct comparisons with the NAAQS and delineating the spatial extent of attainment/nonattainment areas.

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[9] Comparability between FRMs and continuous samplers is desired, based on the extensive FRM network available. This practical need also recognizes inherent differences between measurement principles of integrated and continuous methods and does not assume any one type of measurement best represents true atmospheric aerosols conditions. Further discussion on incommensurabilities between measurement systems is provided in section 7.

[10] Data from CACs would be expected to be incorporated in as yet undetermined weight-of-evidence analyses to define boundaries of non-attainment/attainment areas.

Minimum number of Federal Reference Method (FRM) Samplers

A separate but parallel effort is underway to better identify redundant monitoring for all pollutants as part of the National Monitoring Strategy (see section 10). This national strategy supports an investment in continuous PM monitors balanced by a divestment in $PM_{2.5}$ FRM sampling. Progress in enhancing PM continuous monitoring requires a burden reduction in FRM sampling. Currently, nearly 1100 FRM samplers operate across the United States, and an additional 200-300 IMPROVE and continuous samplers. The spatial richness this network should not be severely compromised; however, areas of redundancy are evident based on a variety of national and regional based assessments that illustrate broad expanse of homogeneous aerosol behavior. A reduction in required FRM samplers is possible using network assessment processes to determine effective numbers of samplers across regional and urban spatial scales. Nationally, we are suggesting that a minimum of 300-500 FRM/FEMs be retained to ensure consistency with the existing network, and provide the primary regulatory base of data. A total of approximately 600 equivalent samplers (including FRMs, FEMs and REMs) for direct comparisons to the NAAQS are recommended. The network size of approximately 600 is based on several data analyses. One analysis shows that the large spatial patterns in $PM_{2.5}$ are nearly identical whether using 300 or 1200 monitoring locations in an area that covers much of the eastern United States. A second analysis indicates that several urban areas are likely over-sampled by approximately 25-35%. Perhaps as many as 1000 (or more) $PM_{2.5}$ mass (FRM and continuous) sites nationally are needed for spatial characterization, but request that actual number of sites be a function State/local agency discretion as agencies must balance several competing monitoring priorities. Note, that this approach while increasing flexibility could have unintended negative consequences by accommodating too many diverse methods that do not relate well with each other. Agencies are encouraged to strive for consistency in deploying their continuous PM network and consider not only consistency of methods within an agency, but attempt to harmonize technology across regional areas.

Table 5-1 summarizes the applicability of each monitoring method category to the type of site in the network. Tables 5-2 and 5-3 include examples of revised network requirements for $PM_{2.5}$ samplers. Specific modifications to the $PM_{2.5}$ monitoring regulations are being addressed through a workgroup of state/local agency, Tribal nation, and EPA representatives (see section 11).

Table 5-1 PM Method Applicability

Method	Required Sites for NAAQS						
	< 80% of NAAQS	80% to 120% of NAAQS	>120% of NAAQS	Sites that are currently required but are not required in a future network.	Current Supplemental Sites	Background and Transport Sites	Speciation and IMPROVE
FRM/FEM	T	T	T	T	T	T	
REM	T • With 30% FRM collocation in network	T • With 30% FRM collocation in network	T • With 30% FRM collocation in network	T	T	T	
CAC	T • With 100% FRM Collocation in network FRM operates 1-6		T • With 100% FRM Collocation in network FRM operates 1-6	T	T	T •	
IMPROVE						T	T
Speciation						T •	T
Existing Continuous mass PM					T		

T The method category in the row is applicable for the monitoring objective in the column.
• This symbol indicates a change to the monitoring regulation is needed

Method Applicability Summary

FRM/FEM/REM - These methods can be used at a required site, regardless of the concentration; at any current or future supplemental sites; and at any background or transport sites. REMs would be required or have at least 30% collocation with FRMs when they are sited at required sites. The FRM would be the primary sampler when collocated with an REM.

CAC - This monitor could provide relief up to 3 new ways:

To convert a site from a filter based sampler to a CAC:

1.) At current supplemental, background, and transport sites CAC monitors may be used as the primary monitor. Collocation at these sites would follow the provisions of Appendix A; which is expected to be 15% collocation with the first collocated monitor being an FRM and the next one being of the same make and model as the CAC.

2.) The minimum number of required sites is to be reduced in Appendix D of Part 58. There is an expectation that there will be more sites operating than the minimum number required. For sites that are no longer required to be operated; but the agency still intends to operate the site to meet other monitoring objectives, the agency may choose to operate the site with a CAC. Appendix A collocation requirements would apply for these CACs. Moreover, it is feasible that revised monitoring regulations may require a similar total number of monitors currently required or operating (i.e., 850 to 1100) with a subset required to have reference/equivalent status and the remainder being satisfied by an equivalent/reference or CAC designation.

To provide additional sample frequency relief:

3.) For required reference/equivalent sites (current or future) that are either substantially above or below the NAAQS, the CAC may be operated to provide a signal of PM provided it is collocated with a FRM operating on at least a 1 in 6 day schedule. The FRM maintains the status as the primary monitor.

The conventional sample frequency relief for a CAC would still apply:

A FRM site that is required to operate daily may have its sample frequency reduced to 1 in 3 provided it is collocated with a CAC regardless of the concentration or NAAQS status.

Table 5-2 Network Design Criteria for $PM_{2.5}$ Required SLAMS

Network Design Criteria	Current Network	Example Revised Network
Required minimum number of sites at State and local Air Monitoring Stations (SLAMS)	Approximately 850* * 100 are for background and can use IMPROVE samplers	Assuming ~600 sites are reasonable we envision a hybrid network of FRM and continuous methods meeting acceptable performance standards. A minimum of ~ 30% of each monitoring agencies future network would be required to remain as FRMs.
Scale of representativeness - Annual Average	Neighborhood or Urban Scale with FRM or FEM	Neighborhood or Urban Scale with FRM/FEM or hybrid network of FRM and continuous monitors meeting performance based criteria
Scale of representativeness - Daily Average	Micro, Neighborhood, Urban Scale	Micro, Neighborhood, Urban Scale. For sites that are expected to only have a violation of the daily standard, but not the annual average, site with a FRM/FEM. Collocated with a Continuous monitor, if needed
Community Monitoring Zones	Optional	Consider deleting this provision since no agencies are using

Section 6 - Performance Standards for Continuous Monitoring

Introduction

The current paradigm for a $PM_{2.5}$ continuous monitor to receive an federal equivalent monitor designation requires field tests at multiple locations over an entire year with the field data being able to meet conservative test specifications that include slope, intercept, and R^2. If a candidate method meets all the criteria, then it receives an "equivalency" designation for use anywhere in the national network, even if it has not been tested in all areas. The assumption is that the method will perform as intended in all areas if it meets strict test specifications at a limited number of sites covering a range of environmental and aerosol conditions. Also, once a method receives an equivalency designation, no additional field tests are required to ensure that the equivalency holds through time.

The approach presented in this section is to link the testing requirements and the ongoing performance requirements to the Data Quality Objectives (DQOs). The DQOs provide a level of uncertainty in the data that is acceptable, given the intended use of the data. Methods that meet or exceed the DQOs can be used in the networks in which they were tested, provided they continue to meet the DQOs through time.

The PM2.5 Data Quality Objective was developed for comparison of values around the 3-year annual average NAAQS since it was found to be the more restrictive standard (i.e. any violation of the daily standard would in almost all cases be in violation of the annual standard). Therefore, use of the DQO for continuous monitoring, at present, is limited to comparisons against this objective. OAQPS is pursuing development of a DQO controlling data quality around the daily standard.

Background and Rationale

$PM_{2.5}$ DQO Process

DQOs are qualitative and quantitative statements that clarify the monitoring objectives, define the appropriate type of data, and specify the tolerable levels of potential decision errors that will be used to determine the quality and quantity of data needed to support decisions (i.e., NAAQS comparisons). A more complete description of the $PM_{2.5}$ DQOs and how they were derived is presented in Attachment B.

DQOs for $PM_{2.5}$ were developed during the months from April to July of 1997. A number of assumptions were made in order to generate realistic error rates. Table 6-1 provides a listing of these assumptions. In 2001, EPA reassessed the assumptions underlying the 1997 DQOs. In almost all cases, the assumptions made in the 1997 process held true in the 2001 evaluation.

The $PM_{2.5}$ DQOs were generated using conservative but realistic assumptions. For example,

the DQOs were generated assuming a sampling frequency of every 6 days with 75% completeness. This is the lowest sampling frequency allowed in the Code of Federal Regulation. A 95% confidence limit around the annual mean at this sampling frequency would be "wider" than a 95% confidence limit for an every day sampling frequency at 90% completeness. In all cases, the assumptions in Table 6-1 are close to the extremes of realistic and allowable data. Assumptions in bold are variables that will be discussed later in this section.

Table 6-1 2001 DQO Assumptions

1. **Bias is -10% or + 10%**
2. **Precision is 10%**
3. Annual NAAQS is controlling standard
4. No spatial uncertainty and each monitor stands on its own (no spatial averaging)
5. **1 in 6 sampling with 75% completeness (144 days)**
6. 3-year annual average is truth, (every day sampling and 100% comp.) up to bias and measurement variability
7. **Lognormal distribution for population variability, 80% CV**
8. Normal distribution for measurement uncertainty
9. **Seasonal ratio (ratio of avg conc for highest season to lowest season) = 5.3**
10. **No auto correlation in daily concentrations**
11. Bias and measurement variability (precision) applies to entire 3 years
12. Type I and type II decision errors set to 5%

Figure 6.1 provides the power curve based on the 2001 assumptions shown in Table 6-1. A power curve is an easy way to display the potential of decision errors based upon the choice of various assumptions that affect data uncertainty. The gray zone is the range of concentrations for which the decision errors are larger than the desired rate of 5%.

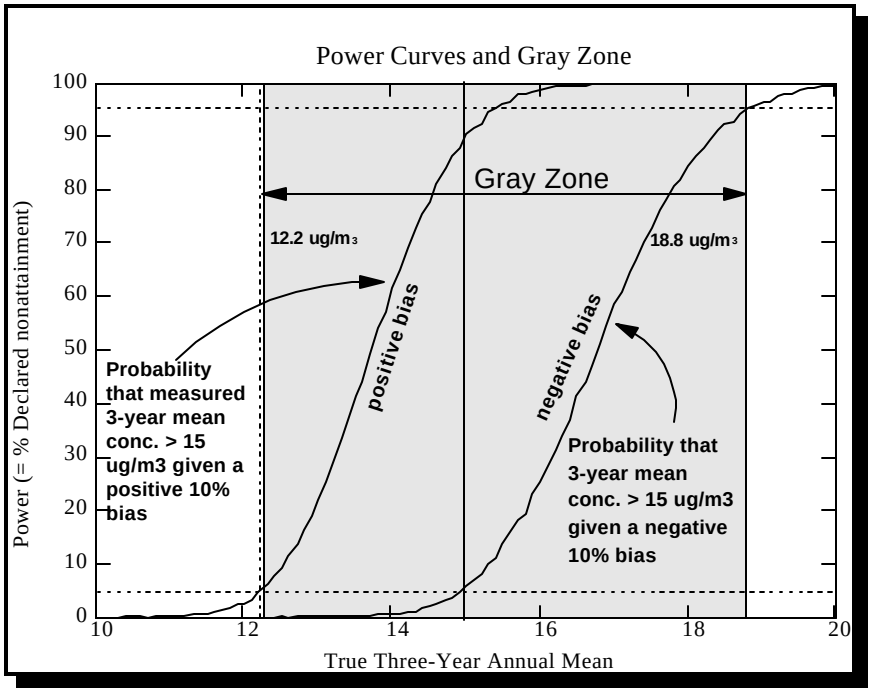


Figure 6.1 Power curve based on 2001 assumptions

Based on the 2001 assumptions, the gray zone is 12.2 to 18.8 µg/m^3. This means that if all the 2001 assumptions hold, the decision maker has a 5% chance of observing a 3-year mean concentration that is greater than 15 µg/m^3 even though the true mean concentration is 12.2 µg/m^3. As has been mentioned, the 2001 assumptions are realistic but conservative. For example the CY00 $PM_{2.5}$ QA Report

demonstrates that the precision and bias estimates at a national level are well within the DQOs. Assumptions that are "better" than those listed in Table 6-1 will tend to decrease the width of the gray zone. Figure 6.2 provides an example of the power curve/gray zone changes for a simple change in sampling frequency from 1 in 6 day (green/solid) to 1 in 3 day (blue/dots) to every day (red/dashed); all the other 2001 assumptions remain the same. Higher sampling frequencies result in narrower gray zones, meaning that decision errors are reduced.

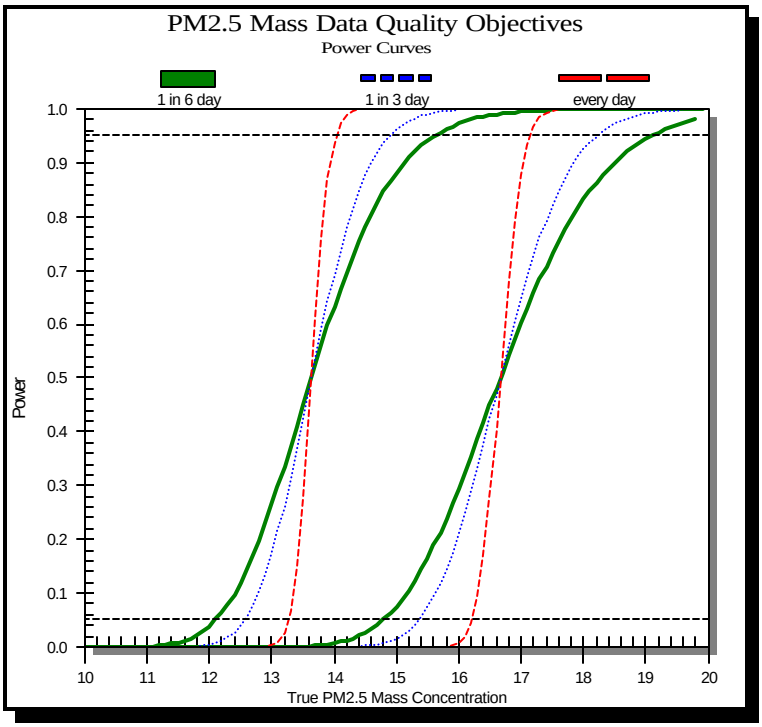


Figure 6.2. Power curve changes due to changes in sampling frequency

Because there is potential for the assumptions to vary, OAQPS commissioned the development of a software tool to help Headquarters and State, local and Tribal organizations determine the potential for decision errors based on assumptions relevant for sites within their network. Figure 6.2 is generated using this tool and allows for multiple scenarios (power curves) to be reviewed on one table. The assumptions listed in bold in Table 6-1 can be changed to suit a particular network. This tool is being finalized and should be available by December, 2001. Furthermore, the tool will be useful for making decisions about the acceptability of REMs or CACs within a network.

The DQO evaluation showed that sampling frequency, population variability (assumed to be lognormally distributed with a CV of 80%), and measurement bias play a significant role in the width of the gray zone. Measurement precision did not have a significant effect on the gray zone which suggests more imprecision could be tolerated with little effect on decision errors (when evaluating an annual mean developed with 3 years of data).

CONCLUSIONS FROM DQO TOOL

The $PM_{2.5}$ mass DQOs were developed for making good decisions about the 3-year average of annual means, since it was assumed that the annual standard was the controlling standard. In particular, they were developed to evaluate the chance of concluding an average concentration was above 15 : g/m^3, when in truth it was not, and the chance of concluding an average concentration was below 15 : g/m^3, when in truth it was not. Due to the number of measurements that go into the 3-year

average of annual means (at least 144), it is easy to see why measurement precision does not have a large influence on the size of the gray zone of the power curve. If, however, the DQO tool displayed the power curves for the daily standard (the 3-year average of the annual 98th percentiles), it is likely that measurement precision would be important for the decision errors, since the extremes of distributions are less robust than the centers. Recent evaluations of the continuous monitors have shown precision estimates comparable to the FRMs.

Data uses that involve no averaging, such as real-time reporting, are even more sensitive to measurement imprecision. Thus, caution should be exercised in drawing conclusions from the DQO power-curve tool. The tool has been designed for specific data uses, namely, evaluating decision errors associated with the $PM_{2.5}$ standards and is based on specific assumptions. If the assumptions are not appropriate or if the data use is different than comparison to the standards, the power curves and gray zones likely do not reflect the true decision errors.

The DQO tool is being enhanced to present both forms of the standard to ensure that decision errors are acceptable for both standards. This tool will be available for monitoring agency use in CY02. In addition, we hope to be able to develop a report in AIRS that would automatically generate the DQO assumptions listed in Table 6-1 by a variety of data aggregation schemes (i.e., reporting organization, by a collection of sites etc.)

Acceptable Performance Criteria for Continuous Monitoring Using Power Curve Tool

Figure 6.1 set up the most extreme case that is tolerated in the $PM_{2.5}$ DQO, based on the assumptions in Table 6-1. The DQOs have associated with them a gray zone which will be used to develop acceptable bounds for the quality of the data required (REM) or recommended (CAC) for the continuous monitoring program. An important note is that the data for which the quality is being evaluated is not the raw data produced by the continuous monitors. Rather it is the continuous data that has been transformed, using a statistical model, to be FRM like.

Subsequent discussions will include the terminology of “simple” transformations and “complex” transformations. For this document, the definition of a simple transform is one in which the FRM data are the response variable (also called the dependent variable) and the only explanatory variable (also called the independent variable) allowed is the continuous data, summarized to the daily level. Thus, simple transforms are of the form $Y = a + bX$, where Y is the FRM data and X is the continuous data. The transformation is still considered to be simple if the natural logarithms of X and Y are used instead of the raw data. The definition of a complex transformation is one in which the FRM data are the response variable and any variable is included as an explanatory variable. Minimally, the continuous data are an explanatory variable. Again, complex models may be based on the raw data from the monitors or based on their natural logarithms.

The following table describes some of the fundamental differences between a REM and CAC, as pertains to data use, allowable transformations, and data quality requirements or goals.

REM	CAC
Assumptions: Will be used in comparison to NAAQS Must have FRMs in Network Can only include simple transformations Must meet **1-3 day** DQO (gray zone) but specifically meet 10% bias DQO	***Assumptions:*** Will not be used in comparison to NAAQS Must have FRMs in Network Can include complex transforms Should meet **1-6 day** DQO (gray zone) but specifically meet 10% bias DQO

Developing performance criteria using the power curve tool is a multi-step process. The first step is to collect information from the CAC/REM network. The second step is to develop a transformation that produces FRM-like data from the CAC/REM (details of which are provided in Section 7). The third step is to determine the spatial extent for which the transformation is appropriate (details of which are provided in Section 9). The fourth step is to determine reasonable values for the highlighted parameters in Table 6-1. The values should be reflective of the entire spatial extent of the CAC or REM network being evaluated. The last step is to use the DQO software tool to determine the gray zone that results from the values from the previous step. If the bias is within -10% and +10% and the gray zone is within 12.7 and 18.1 : g/m^3 (the gray zone for an FRM that operates every third day), then the continuous sampler meets the requirements for being a REM. If the bias is within -10% and +10% and the gray zone is within 12.2 and 18.8 : g/m^3 (the gray zone for an FRM that operates every sixth day), then the continuous sampler meets the goals for being a CAC.

Figure 6.3 provides an example of the power curve for a 3-year mean based on the following data quality input parameters

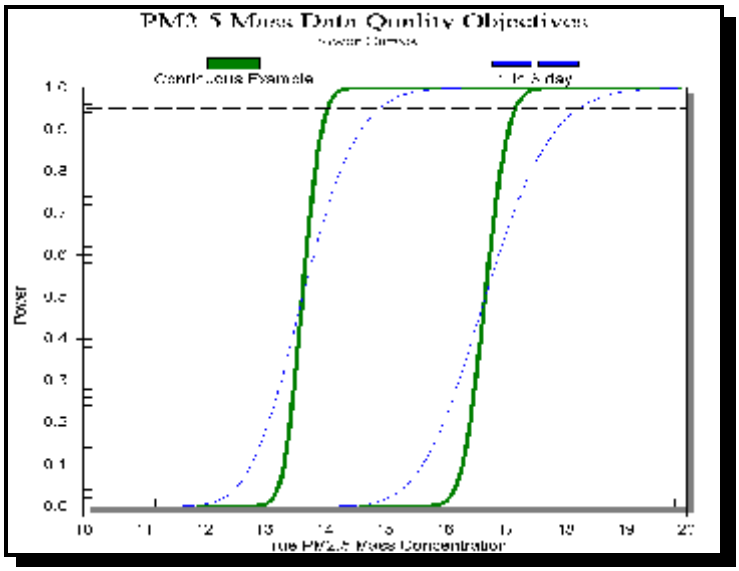


Figure 6.3. Example continuous monitoring network power curve relative to 1 in 3 day power curve.

<	bias	10%
<	completeness	75%
<	sampling frequency	every day
<	measurement CV	30%
<	population CV	80%
<	Seasonal ratio	5.3

The resultant gray zone is 13.2 µg/m^3 (lower left line green solid) and 17.1 µg/m^3 (upper right line green solid which is within the 1-3 day DQO of 12.7 (lower left blue dashed) and 18.1 (upper right blue dashed). Therefore, this example continuous monitoring network could be considered acceptable for CAC or REM designation.

Simplified Performance Criteria for Continuous Monitoring

Organizations may use the DQO process described above to determine levels of measurement imprecision that can be tolerated but still provide data of a quality to support decisions about comparison to the NAAQS. For organizations not interested in using the DQO tool to develop gray zones applicable to specific areas, the DQOs are set to 20% CV and bias within -10% and +10%. REMs are required to meet these objectives whereas it is highly recommended that CACs meet these objectives.

Summary of Performance Criteria for $PM_{2.5}$ Methods

When discussing performance criteria, it's important to clarify the difference between acceptance of a method in the designation process and the on-going performance based goals. The acceptance of a method in the designation process is associated with the Reference and Equivalency program defined in 40 CFR Part 53. This process is purposely strict in order to assure the quality of data when subsequently designated methods are used throughout the country. Table 6-2 summarizes each category of existing and potentially revised methods with criteria for acceptance of the method and criteria for the on-going evaluation of the performance of that method.

Table 6-2. Performance Specifications for PM2.5 Methods

Category of Method	Requirements for Acceptance of Method	Existing Performance Goal for Acceptable Measurement Uncertainty	Future Performance Goal for Acceptable Measurement Uncertainty
FRM	Many design and performance criteria. Precision for field testing: < 2 µg/m³ when concentration is <40 µg/m³ (24 hour sample) or <30 µg/m³ (48 hour sample); Rpj <5% for concentration > 40 µg/m³ (24 hour sample) or >30 µg/m³ (48 hour sample).	10% coefficient of variation (CV) for total precision and +/- 10 percent for total bias.	No Revision
FEM	Across a limited number of field test sites depending on class of equivalency: Slope of 1+/- 0.05 Intercept of 0 +/- 1 µg R^2 $ 0.97	10% coefficient of variation (CV) for total precision and +/- 10 percent for total bias.	No Revision.

REM	Within each network that is being considered: 20 % coefficient of variation (CV) for total precision and +/- 10 percent for total bias.	NA	Utilize 1 in 3 day DQO/Powercurve or simplified approach of 20% coefficient of variation (CV) for total precision and +/- 10 percent for total bias.
CAC	Within each network that is being considered: 20 % coefficient of variation (CV) for total precision and +/- 10 percent for total bias. (Goal, not requirement.)	NA	Utilize 1 in 6 day DQO/powercurve or simplified 20% coefficient of variation (CV) for total precision and +/- 10 percent for total bias. (Goal, not requirement.)

Section 7. Data Transformation Policy and Guidance

Variations in $PM_{2.5}$ measurements attributed to methodological differences should be minimized to support consistent data analysis across temporal and spatial regimes. For example, it would be erroneous to infer that 20% of the $PM_{2.5}$ measured in an urban area is due to local sources based on a comparison of the concentrations measured by monitors in an urban area to concentrations from upwind sites, if the instrumentation at the upwind sites are biased low by 20%, relative to the instrumentation used in the urban area. Realistically, $PM_{2.5}$ measurements should "look" like measurements taken by an FRM. This is because of the richness of the available FRM data base and due to the difficulty in ascribing a "reference" check for aerosol measurements.

Non-FRM samplers generally operate at a higher temporal resolution than FRMs and many will operate where there is no FRM, thus helping to fill spatial gaps in the FRM network. However, to be able to use data from multiple types of $PM_{2.5}$ mass monitoring networks (FRM, non-FRM) in the same analysis, the data must be comparable. Comparable means that if the various samplers were spatially and temporally interchanged, approximately the same concentrations would be measured. To achieve comparability, it is possible to transform, using statistical models, non-FRM data to look like FRM data or vice versa. Due to the interest in FRM-like concentration surfaces, the remainder of this section will only address transforming data from non-FRM samplers to produce FRM-like measurements.

Due to the inherent differences in measurement principles between FRM and PM continuous monitors there may be biases between the measurements obtained from an FRM and continuous monitor. If the bias is consistent through time and across space, a standardized correction factor could be used to produce FRM-like measurements from the continuous monitors. However, since mass concentration and composition and environmental conditions vary, a standard correction may not be practical on a national scale but may be achievable on a more regional scale. This section provides information about the development of transformations to produce FRM-like measurements from continuous measurements.

Based on preliminary analyses summarized in Section 2, developing a statistical model to relate concentrations from continuous samplers (predominantly TEOMs) to FRM samplers is achievable, although the complexity of the model varies by location and may vary through time. The complexity likely is a function of the stability of the composition of the aerosol, the stability of the meteorology (temperature and humidity), and the continuous monitoring methodology. The following guidance for developing transformations is based on the experience gained in analyzing the limited collocated FRM/continuous database to date. The database is limited due to temporal representativeness (at best 2 years since the FRM network was deployed in 1999), spatial representativeness (continuous samplers have been and continue to be deployed predominantly in large urban areas), and non-FRM sampling techniques. The database is predominantly based on data reported to AIRS. Prior to 2000, it was not possible to determine whether the data from a continuous monitor was reported after being adjusted by "correction" factors. Beginning in 2000, AIRS method codes were expanded so that it would be possible to determine whether correction factors had been applied, although it is not possible

to specify the form or parameter estimates of the adjustment. These new method codes appear not to be accurate for all sites, as seen in Section 2, making it a further challenge to determine appropriate transformations.

A balance between forcing a particular measurement principle to mimic another (i.e., the FRM) is a significant complication that must be recognized in this task. The practical needs for data analysts demand some level of comparability. However, there is intrinsic value in the very differences that emerge between measurement systems due to the complex character of aerosols. The intention clearly is not to define the FRM as truth, but rather to recognize the practicality of the existing network. These considerations of basic measurement principles are embodied in this transformation guidance. Where relationships between two measurement systems exhibit simple linear and constant character, one can probably assume the difference in measurement approach does not result in a significantly different indicator of ambient aerosol. Such simple relationships are the foundation for accommodating REMs that can be compared to the NAAQS. On the other hand, more complex relationships between a candidate system and the FRM suggest that a significantly different aerosol property is being accounted for (likely varies over time or space) in one system relative to the other. This does not mean one system is superior to the other, but reasonable judgement suggests a limit to forcing a system to mimic the FRM for regulatory use, but to accommodate the system for other data uses within the limits of data comparability guidelines. This latter approach reflects the concept underlying the expanded use of CACs.

The guidance on transformations will be broken into two sections, one for the CAC and one for the REM. The guidance for acceptable transformations for REMs will be very strict and limited to simple transformation models. Acceptable transformations for CACs will be less strict. For either case, recall that the performance criteria presented in Section 6 is based on the transformed continuous measurements. Note that if the performance criteria are met with the raw continuous measurements, then no transformation is required. That is, transformations need not always be developed.

Regardless of whether the continuous sampler is a CAC or REM, measurements should be reported to AIRS. Given that data users might not understand the differences in the sampling methodologies, it is recommended that the data be entered AFTER applying a transformation to produce FRM-like measurements. However, it will be important for other data uses to know what transformations have been applied. EPA will be investigating possible ways to include the transformation information in AIRS so that it will be possible to “back out” the transformation and have the original, non-FRM measurements.

Transformation Guidance for CAC

Even though the data from a CAC will not be used for direct comparison to the NAAQS, they should meet the DQOs, as described in Section 6. Although this is not a requirement, it is strongly recommended for comparability of measurements across the network. The data used for evaluation in the DQO process are those that have been transformed to be FRM-like; that is, the DQOs are not necessarily based on the raw data from the non-FRMs. This section describes the process for developing the transformations for CACs. The rationale and details for the selection of many of these criteria are included in the EPA document *Reporting an Air Quality Index (AQI) Using Continuous $PM_{2.5}$ Data: Data Quality Objectives (DQOs) and Model Development for Relating Federal Reference Method (FRM) and Continuous $PM_{2.5}$ Measurements (Attachment C).*

Step 1. Create daily non-FRM measurements. If the non-FRM data are collected more frequently than daily, the sub-daily intervals should be averaged before comparing to the FRM data. At least 75% of the sub-daily intervals should be valid to consider the average to be valid. Also, the sub-daily intervals to be averaged should be those that most closely span midnight to midnight, the operating interval of the FRMs.

Step 2. Determine if there are sufficient data to develop statistical model. The model to relate the non-FRM and FRM data should be based on data from all four seasons and have at least 104 valid pairs of data, approximately evenly distributed through each season. It is recommended that each season have at least 20 valid pairs. If there are not more than 100 valid pairs approximately evenly distributed through the seasons, it is recommended that additional data be collected. The 100 pairs need not be from only one year.

3. Develop a statistical model. The statistical model relating the non-FRM and FRM data should have the FRM data as the response variable (also called the dependent variable) and minimally must include the non-FRM measurements from *Step 1* as an explanatory (independent variable). The number and type of explanatory variable allowed in unlimited. The model can be based on the data as is or can be based on the natural logarithms of the data. The final R^2 between the measured and predicted FRM measurements should be 0.80 or greater.

4. Spatial extent for use of one transformation. Section 8 describes the process for determining the area within which one transformation may be used for all of the continuous samplers, regardless of whether the continuous sampler has been previously collocated with an FRM.

5. On-going evaluation of transformation and its spatial extent. The statistical model should be revisited every 3 years, or more frequently if there is reason to believe a change in the relationship between the non-FRM and FRM may have occurred. Possible reasons for such changes include, but are not limited to, a change in sampling methodology, change in aerosol composition due to control strategies, or different meteorological regimes than what was observed during the development of the statistical model. If a new statistical model is more appropriate, that model should be used from that

date forward. That is, one model would be used up to one date and the next model would be used for subsequent dates.

Transformation Guidance for REM

The data from REMs must meet the DQOs, as described in Section 6. The data used for evaluation in the DQO process are those that have been transformed to be FRM-like; that is, the DQOs are not necessarily based on the raw data from the non-FRMs. This section describes the requirements for the transformations. Because the data are intended to be used for NAAQS comparisons, the allowable statistical models and parameter estimation will be explicitly defined. The reason for this specificity is to ensure that two independent data analysts will produce the same transformation and hence will produce the same FRM-like concentrations. Most of the details of this guidance are unknown at this time, due to limited data, but the issues that need to be addressed and a time line for addressing them is included. The guidance components are as follows.

Step 1. Manipulation of non-FRM data, prior to development of statistical model. This section will detail how data are aggregated to produce a daily number to be used to compare to the FRM. Issues to address will include handling of missing data, producing averaging periods that are approximately midnight to midnight, and handling of negative or zero concentrations prior to aggregation. Data completeness will also be addressed. Likely, at least 75% of the sub-daily intervals should be valid to consider the average to be valid.

Step 2. Identification of pairs to use in development of transformation model. This section will address the number of required valid pairs, temporal representativeness of those pairs (e.g., whether highest and lowest seasons are sufficient or if every season must be represented), range of concentrations spanned by the pairs (need a good spread so that the model is appropriate and can be used for prediction through wide range of concentrations), handling of negative or zero concentrations, handling of concentrations less than some cutoff value (e.g., minimum detection limit), identifying and handling influential pairs.

Step 3. Development of statistical model. This section will detail how the statistical model relating FRM and aggregate non-FRM collocated data is to be developed. The only model allowed will be one for which the aggregate non-FRM data is the only explanatory variable and the FRM data is the response variable, that is, only a slope and intercept will need to be estimated. Issues include whether the raw or natural logarithm of the raw data are to be modeled, the required R^2 between the measured and predicted FRM measurements, the equations for estimating the slope, intercept, and R^2 especially if seasons are not equally represented in the data set (that is, should the estimates be weighted).

Step 4. Inferences to be drawn from the statistical model. This section will discuss how to determine the spatial representativeness of the model (what is the area that can use the same transformation, which will be discussed in Section 8) and the temporal representativeness of the model (for how long is the model valid). When a transform is found to be no longer appropriate, what is done

with the previously transformed data? Is the old transformed used until up to one date and then the new transform used for subsequent dates?

Step 5. On-going evaluation of statistical model and its spatial extent. At least 30% (rounding up) of the non-FRM sites must be permanently collocated with FRMs to provide the data needed to evaluate regularly the reasonableness and consistency of the transforms. The collocated sites should be distributed to represent different composition and meteorological regimes. Issues to cover include the frequency at which the transformation is formally evaluated to determine whether it is still appropriate. For example, it would not be practical to have a transformation that is changed every month or quarter, but the transformation should be reviewed at some frequency.

Due to the numerous issues to developing statistical models, EPA will establish a panel to recommend solutions to the various issues listed above. The panel will be comprised of people conversant in statistics, ambient air monitoring, and air quality management. Solutions to these issues and final guidance on the development of transformations for regulatory data use are expected to be completed by the end of calendar year 2003.

Section 8. Defining Regional Applicability

The basic relationship between a continuous monitor and an FRM should be similar throughout a given "region" of application, especially with respect to bias. This reasoning is the foundation for the new regional equivalent method approach which assumes consistent monitor behavior can be achieved within a "region" despite inconsistencies nationally. Sections 3 and 4 provided example requirements (2 sites per MSA) for demonstrating consistency. The determination of regional applicability should be based first on technical considerations related to the homogeneity of aerosol composition and meteorology. This section addresses candidate approaches to determine regional applicability, and is intended to raise the understanding of this topic for further development of applications guidance.

Operationally, only one transformation model would be applied within the region of consideration. Determining the region in which the use of one transform is appropriate, meaning that all the sites within the region will meet the bias and precision requirements (REM) or goals (CAC), can be approached in two ways. One approach is to establish regions a priori where the regions explicitly cover specific land masses in the United States. For example, regions may be the interior southeast, the east coast, Florida, the industrial belt, the Midwest, the western coast, the arid southwest, Alaska, the Rocky Mountain states, and the humid northwest coastal area. The testing requirements for a candidate method would have to be met throughout one or more of these previously established regions. If one of the sites does not meet the testing requirements, then the method can not be used within that region. Such an approach implies knowledge about areas in which a particular type of continuous methodology and the FRMs have similar relationships. As shown in Section 2, knowledge based on the analysis of ambient measurements does not currently exist due to lack of data, especially data from emerging continuous monitoring methodologies. However, as more ambient measurements are collected for the various continuous monitoring methodologies, environmental conditions, and particulate composition and size distributions, such regions may become more clearly defined. ***This approach could be acted on by establishing a panel of experts charged with developing these regions.*** EPA and other organizations (monitoring agencies, Tribal nations, Regional Planning Organizations, RPO's) would address logistical and administrative complications associated with multiple monitoring organizations operating in a defined "region".

A second approach is to allow any size and shape of region. The State/local/tribe, RPO, or vendor interested in using a particular type of continuous instrument would specify the boundary of the region and then follow the testing requirements or goals to prove whether one transformation would be adequate for the entire region. That is, the domain of the region is flexible. However, once the testing has been completed for a specific domain, the domain remains fixed until on-going evaluations indicate the performance criteria are no longer being met throughout the region.

Both approaches will be pursued. It will be strongly encouraged that potential continuous monitoring methodologies be deployed at a core set of sites where the data from these sites will help to determine potential regions for the first approach. Until there are sufficient data to determine appropriate regions, the second approach will be used.

Definition of Regionality of Transformation

For a specific type of continuous monitoring methodology, given a sufficiently dense monitoring network of these monitors collocated with FRMs, it would be possible to develop a surface of the bias between the two types of instruments. In some places the bias might be small while in other places the bias might be large. In some places the bias might be negative and in others, it might be positive. Hopefully, the surface of biases would be smooth, that is, it would gradually change from one location to the next. Given such a smooth surface, it would be possible to produce FRM-like measurements at any location, even if there were no collocated FRM.

A difficulty with this construct of a surface of biases is that there is not a sufficiently dense network with which to build a surface for any large geographical area, especially for each type of continuous monitoring methodology. However, understanding this surface is the basis for being able to know sizes of regions. Collection of data with which to build such a surface is an important step to understanding regionality and is described below.

A surface of biases implies that the transformation to generate FRM-like measurements from continuous data would vary from site to site. Implementing site-specific transformations likely would prove to be intractable for a large number of sites, especially if the transformation is considered to be part of the method. One way around this problem is to use one transformation over an area where the biases are "similar." Specifically, the definition of the regionality of a transformation is that geographical area in which it is possible to use one statistical model to estimate FRM-like measurements and those FRM-like measurements meet the performance criteria specified in Section 6. Determining regions for which biases are "similar" also hinges on a dense data base of collocated FRMs and continuous instruments.

Data Collection to Support Definition of Regionality of Transformations

At least 100 sites of collocated continuous monitors and FRMs will be established as part of a National Core (NCore) network. These collocated sites will provide the data necessary to understand and monitor the temporal and spatial relationships between FRMs and continuous samplers. Characteristics of the sites include: (1) FRMs should operate at least every third day, (2) monitors should operate year-round and every year, (3) speciation trends sites are ideal given that the speciated data may help better understand the relationships, and (4) sites upwind of the speciation trends sites are also ideal, as the upwind sites likely have different compositions due to urban/rural gradients. The database generated by these sites will be regularly analyzed to determine if and how the FRM-continuous relationships vary spatially and temporally and how those relationships may change over time as compositions change due to implemented control strategies.

Until such time that a priori regions are defined, the regions may be any size and shape and the following guidance is applicable.

Regionality of Transformations for CAC

If the data from the non-FRMs are intended to be used for non-regulatory purposes, it is important that the data be comparable to the data produced by FRMs. However, since the data will not be used for direct comparison to the NAAQS, there is more flexibility in determining the regions within which one transformation is applicable.

Step 1. Develop transformations for each collocated site within the region of interest, based on the guidance provided in Section 7.

Step 2. Determine whether the transformations are statistically equivalent. For the sites that are equivalent, pool their data together to estimate one transformation. This one relationship should be used at each of the sites that was considered equivalent and may be used at other continuous sites for which there is no collocated FRM, provided that the sites operate the same type of non-FRM sampler using the same standard operating procedures, have similar chemical composition, and are exposed to similar meteorology. For examples, it would be inappropriate to apply a relationship established at a site running a TEOM to a site running a BAM, to apply a relationship established at a population-oriented site without any nearby sources to a site impacted by a large local source, or to apply a relationship established at an inland site to a coastal site. Sites that are not statistically equivalent to others should be considered unique, meaning that the transformation for the site should not be applied to any other site.

Step 3. On-going evaluation. It is recommended that at least 10% of the non-FRM sites be collocated with FRMs for at least 1 year of every 3 years and that the regionality be re-evaluated every 3 years. This recommended level of collocation on a permanent basis generally is met or exceeded in current networks.

Regionality of Transformations for REM

Following the approaches for CAC and REM discussed in Sections 3-7, the approval process for regional applicability for REMs would incorporate an as yet undetermined independent review procedure and more formalized demonstration of meeting performance and test requirements. The development of a review panel or board was raised above, and such an approach might be necessary given the probability of several unique cases and the desire to maintain equity in approval nationally.

Alternatively, due to the lack of understanding of the regionality of a relationship between data produced by FRMs and non-FRMs, the size of the region within which a continuous monitor can be considered for equivalency will be no larger than a site. As the data from the core sites becomes available and some understanding of the relationships grows, the size of potential regions will be reconsidered. Given that the continuous monitoring technology is changing and as a result few locations have at least a year of collocated measurements collected using the most-current SOPs, it is premature to propose an approach for using one

transformation over an area larger than an site. Too little is known about the potential gradients in the bias surface at this time.

Section 9. Monitoring Methods Guidance and Support

Despite a substantial allocation of resources in overall PM monitoring implementation, very little methods development work has been performed in the area of $PM_{2.5}$ continuous monitors. This lack of development combined with requirements for lengthy field testing in multiple sites and high statistical correlations for designation as a $PM_{2.5}$ Federal Equivalent Method (FEM) have resulted in no applications for designation of continuous $PM_{2.5}$ monitors as FEM.

Introduction:

During the planning stages of the $PM_{2.5}$ monitoring program there was little emphasis on development of PM continuous methods by EPA. There were no nationally coordinated field testing programs to assess the usefulness of continuous methods over a variety of locations and aerosols. A guidance Document was written in 1998 compiling the available field testing on PM continuous methods to date; however, this document offered little insight on planning a long term strategy of using $PM_{2.5}$ continuous methods for regulatory purposes. Additionally, EPA never actually proposed or promulgated Class III equivalency criteria that would provide the testing requirements for $PM_{2.5}$ continuous methods. Since no criteria have ever been proposed there has never been an opportunity for the various stakeholders in the monitoring community to provide comments on the usefulness of the Class III equivalency testing criteria. There is an expectation that the equivalency criteria for Class III designations would be at least as strict as the Class II criteria. But since these criteria have never been published by EPA there is no clear path for acceptance of $PM_{2.5}$ continuous methods. Without EPA directly involved in developing PM continuous methods, vendors have been left to pursue improvements on their own. While some vendors have been successful at improving their methods by working directly with the States, these methods have not been appropriately tested on a national scale. For instance, the California Air Resources Board (CARB) has been working with the Met One Beta Attenuation Monitor over the last few years, yet very little data exists on this method collocated with FRMs in any east coast States. Also, Rupprecht & Patashnick Company have commercialized the Sample Equilibration System (SES) as an add on to the TEOM PM continuous monitor to allow for operation of this instrument at lower temperatures; however, little information is known about the long-term usefulness of the SES. The result of all of this is that there are no designated equivalent methods for $PM_{2.5}$ continuous monitors. Also, little information is available in the form of peer reviewed field studies over a variety of methods and locations. Despite all these issues there is still a great deal of information to glean from monitoring agencies and vendors on how these methods may be best suited for implementation in routine regulatory networks. This section attempts to summarize a number of points in how to best set-up and operate $PM_{2.5}$ continuous monitors. Many of these suggestions have already been incorporated into commercially available monitors. None of the suggestions should be considered as "required" since ultimately the best measures of success are performance of the $PM_{2.5}$ continuous monitor with respect to its ability to reproduce itself (measurement precision) and comparison to a FRM (bias).

Recommendations for Design and Operation of $PM_{2.5}$ Continuous Methods

In order to design an appropriate configuration for a $PM_{2.5}$ continuous monitor many issues need to be addressed. This section attempts to provide the general specifications for $PM_{2.5}$ continuous methods. A detailed accounting comparing the FRM design and performance specifications with applicability to a generic $PM_{2.5}$ continuous monitor follows.

Comparing FRM and Continuous Methods for Design and Performance Criteria

The Federal Reference Method is based upon both design and performance criteria as identified in 40 CFR, Part 50, Appendix L. Design criteria are applicable to components of the reference method such as the inlet and second stage separation device. Performance criteria are applicable to things such as the control of flow rate and maximum allowable temperature difference between the filter and the ambient temperature. For any potential continuous method to be used in the routine regulatory network only performance criteria with respect to the comparison of collocated FRM and continuous data are to be used. However, the performance of a continuous method may be expected to be optimized by adhering to as much of the reference method as practical. In reality, many aspects of the design and performance of the FRM will not be included in a continuous methods operation due to the measurement principle of the instrument or other factors. For instance, much of the laboratory FRM criteria are not practical since there is not expected to be any pre or post-sampling gravimetric analyses in the traditional sense. This section discusses the current understanding of the FRM design and performance criteria that may be applicable to a potential continuous method for use in a regulatory network. Also, where applicable, alternatives to the design and performance criteria of the FRM are included as may be appropriate for use with continuous methods. This section is intended to provide information on how a continuous method might best be designed so that resulting data mimic that of the FRM. Due to the inherent operation of any one continuous method, many of the FRM design and performance criteria may not be suitable for inclusion in its design; therefore, none of the FRM criteria are required. Also, improvements to a design or performance criteria of the FRM are encouraged where appropriate in order for resulting PM continuous data to match that of the FRM.

General Specifications

There are many specifications listed in the FRM as detailed in 40 CFR, Part 50, Appendix L. Among the general specifications, a number of items may be applicable to PM continuous monitoring. This section details those general provisions of the FRM that should be included in the design of a PM continuous method:

- *Pollutant* - Fine particulate matter having an aerodynamic diameter less than or equal to a nominal 2.5 micrometers in the ambient air. Surrogates of this are possible if they result in meeting the necessary performance standards identified in section 6 of this document.

- *Units* - Provide for data to be reported in units of micrograms per cubic meter. This may be calculated directly or indirectly through use of other inputs.

- *$PM_{2.5}$ measurement range* - Provide for a lower and upper concentration limits that allow for meaningful comparison to the FRM. While the FRM is estimated to have a lower concentration limit of at least 2 ug/m^3 and upper concentration limit of at least 200 ug/m^3, continuous methods may be able to operate over an even wider range of concentrations. Most importantly, PM continuous methods need to provide concentration values in the environments they operate in. For instance, in an extremely dirty environment, a continuous method may be able to operate above 200ug/m^3, if designed appropriately. Similarly, when a continuous method is operated at a very clean site the performance of the instrument should be able to discern changes in ambient $PM_{2.5}$ even over very low concentrations.

- *Sample Period* - Provide for a sample period that can be used to calculate the midnight to midnight 24-hour average $PM_{2.5}$ concentration. For all other criteria pollutant continuous data the reported averaging period is usually 1-hour. Depending on the precision of the PM continuous instrument shorter or longer averaging periods may be necessary in order to have a meaningful averaging period. Therefore, 1-hour averages should be capable of being reported; however shorter or longer averaging periods may be necessary depending on the measurement precision of the instrument.

- *Accuracy and Precision* - Because of the size and volatility of the particles making up ambient PM vary over a wide range and the mass concentration of particles varies with particle size it is difficult to define the accuracy of $PM_{2.5}$ measurements in an absolute sense. The accuracy of $PM_{2.5}$ measurements is therefore defined in a relative sense, referenced to measurements provide by the FRM. Section 6 defines the performance standards for $PM_{2.5}$ continuous methods.

Design Criteria

Design criteria for the FRM are largely associated with the inlet and separation device to obtain the desired size selection of aerosol in the sample stream. Many of these criteria can be applied to a potential continuous method. Most of the commercial vendors of PM continuous methods have already incorporated these design criteria into their instruments. The table below describes the various design criteria for the FRM and their applicability to PM continuous methods. Also, where appropriate, alternatives to the FRM design criteria are offered:

Design Areas	Section of Appendix L	FRM specification	Applicability to Continuous Methods
Inlet Assembly	7.3.2	PM_{10} head with dimensions as described in figures L-2 through L-18	This should be applicable to most PM continuous methods
Downtube	7.3.3	With dimensions as described in figure L-19	This may or may not be applicable to a PM continuous method. A downtube may not be needed if there is sufficient clearance for the PM 10 head above the monitor. Also, there needs to be a provision for a leak check adapter to be attached at the point where the PM_{10} heads attaches if the downtube is not utilized.
Impactor	7.3.4	WINS with dimensions as described in Figures L-20 through L-24.	The WINS may be used or alternatively the Sharp Cut Cyclone (SCC) or newer generation of SCC or other cyclone providing an appropriate $PM_{2.5}$ separation may be used. The SCC is expected to maintain an appropriate separation of coarse and fine particulate over a longer period of time than the WINS making it more suitable for use with $PM_{2.5}$ continuous monitors.
Filter Holder Assembly	7.3.5	Many specifications as described in the text and with dimensions as detailed in Figures L-25 through L-29.	Most of the filter holder assembly design specifications will not be applicable to PM continuous monitors. Some of the important areas to strive for in the design of a PM continuous method include: - providing for a uniform face velocity of the sample stream during sample collection. - preclude significant exposure of the filter (or surrogate collection device) to possible contamination.
Flow Rate Measurement Adapter	7.3.6	As described with the dimensions in Figure L-30	Ideally, this would be the same so that flow rate adapters would be interchangeable between FRMs and continuous methods.

Surface Finish	7.3.7	Anodized aluminum for all internal surfaces exposed to sample air prior to the filter.	Ideally continuous methods will also have anodized aluminum for all internal surfaces exposed to sample air prior to the filter or surrogate collection device. This is especially important to note for the Sharp Cut Cyclone; if used, since it is not part of the FRM.
Sampling Height	7.3.8	2 meters ± 0.2 meters	Ideally, the sample inlet on a continuous method would meet this.

Performance Specifications

Performance specifications for the FRM are largely associated with maintaining the flow rate within an acceptable range and the operational conditions for which the instrument should be capable of operating in. Most of the flow rate performance specifications for the FRM should be applicable to continuous methods; however, the operational conditions for which an instrument should be capable of operating in may or may not be applicable to any one continuous method. Many of these performance criteria can be applied to a potential continuous method. Most of the commercial vendors of PM continuous methods have already incorporated these performance criteria into their instruments. The table below describes the various performance specifications for the FRM and their applicability to PM continuous methods. Also, where appropriate, alternatives to the FRM performance specifications are offered:

Performance Specification Area	Section of Appendix L	FRM specification	Applicability to Continuous Methods
Sample Flow Rate	7.4.1	16.67 L/min measured as actual volumetric flow rate at the temperature and pressure of the sample air entering the inlet.	Generally applicable with the exception of any potential use of nephelometers. This flow rate is necessary if a PM_{10} size selective inlet is used as well as for most second stage separators.
Leak Test Capability	7.4.6	Provide for an convenient external leak test capability	Generally applicable.
Range of Operational Conditions	7.4.7	Ambient Temperature -30 to +45 C Ambient Relative Humidity 0 to 100 percent Barometric Pressure 600 to 800 mm Hg	Generally applicable as a starting point for design of an instrument; however, some continuous instruments may need to be located in an environmentally controlled shelter in order to have operate correctly. Some instruments may not meet all of these specifications which may limit their use geographically.
Ambient Temperature and Barometric Pressure Sensors:	7.4.8 and 7.4.9	Capable of operating over the range of operating conditions	Applicable for the operation of the continuous instruments in the range of environmental conditions they will encounter.
Filter Temperature Control	7.4.10	The sampler shall provide a means to limit the temperature rise of the sample filter from isolation and other sources to no more than 5C above the temperature of the ambient air surrounding the sampler.	It is desirable to minimize the temperature difference between the ambient air and the location where sample are collected and analyzed in a continuous method to provide for minimal volatilization of PM; however, in some cases heating may be necessary due to moisture interference or other reasons. Each potential continuous method should be designed to optimize this temperature difference with respect to avoiding moisture interference, PM volatilization, and stable measurement readings.

Filter Temperature Sensor	7.4.11	Capable of operating over the range of operating conditions	Generally applicable. However, may not always be required depending on the measurement principle of the continuous method.
Clock/timer system	7.4.12	Capable of maintaining local time and date including year, month, day of month, hour, minute, and second to an accuracy of ± 1.0 minute per month.	Generally applicable.
Outdoor Environmental Enclosure	7.4.14	Suitable to protect the instrument	Generally applicable for those instruments intended to be located outside. Not necessarily applicable to those instruments intended to be located in a station trailer or other environmentally controlled housing
Electrical Power Supply	7.4.15	105 to 125 volts AC (RMS) at a frequency of 59 to 61 Hz.	Generally applicable.
Data Output Port Requirements	7.4.17	Standard RS-232C	The Standard RS-232C data output connection can be utilized. Additionally, it is strongly encouraged to have a provision for an analog output that can be conveniently connected to a typical data logger utilized by ambient air monitoring agencies. For example, 0 - 10mV, 0-100mV, 0-1V, 0-5V, or 0-10V.

Section 10. Linkage to national monitoring strategy

The EPA in partnership with it's principal grantees; States, local agencies and Tribes, are formulating a national air monitoring strategy that strives to enhance the overall effectiveness of major regulatory based monitoring efforts throughout the nation. The continuous PM monitoring plan addressed here is a major sub-component of this more comprehensive air monitoring strategy. A brief overview of the air monitoring strategy with selected attachments is provided to understand the larger context of the of role of continuous PM monitoring in the nation's reshaping of air monitoring

The monitoring strategy includes establishing a future direction for the shape and scope of air networks throughout the United States. This direction must incorporate knowledge acquired in air quality research and management practices over the last two decades, and take advantage of the much of the existing infrastructure of operating networks and monitoring agencies. The experience over the last 20 years suggests three basic enhancements in national network design:

1) ***multiple and collocated pollutant measurements*** to better diagnose cause effect phenomena in health association and atmospheric process characterization efforts,

2) ***regional scale air quality characterization*** to understand the linkage between background and transport concentrations (regional, continental, global scales) as they impact both rural and urban environments, an increasingly important need as the separation between rural and urban air pollution levels continues to decrease.

3) ***accommodating new technologies*** to provide timely reporting of air quality information to the public and to improve basic characterization of physical, chemical, temporal and spatial composition of air quality.

Consistent with these enhancements, the strategy has identified needed improvements to the monitoring program:

- characterization of hazardous air pollutants (HAPs)
- continuous particulate matter monitoring
- information transfer and delivery
- integration across pollutant programs; and

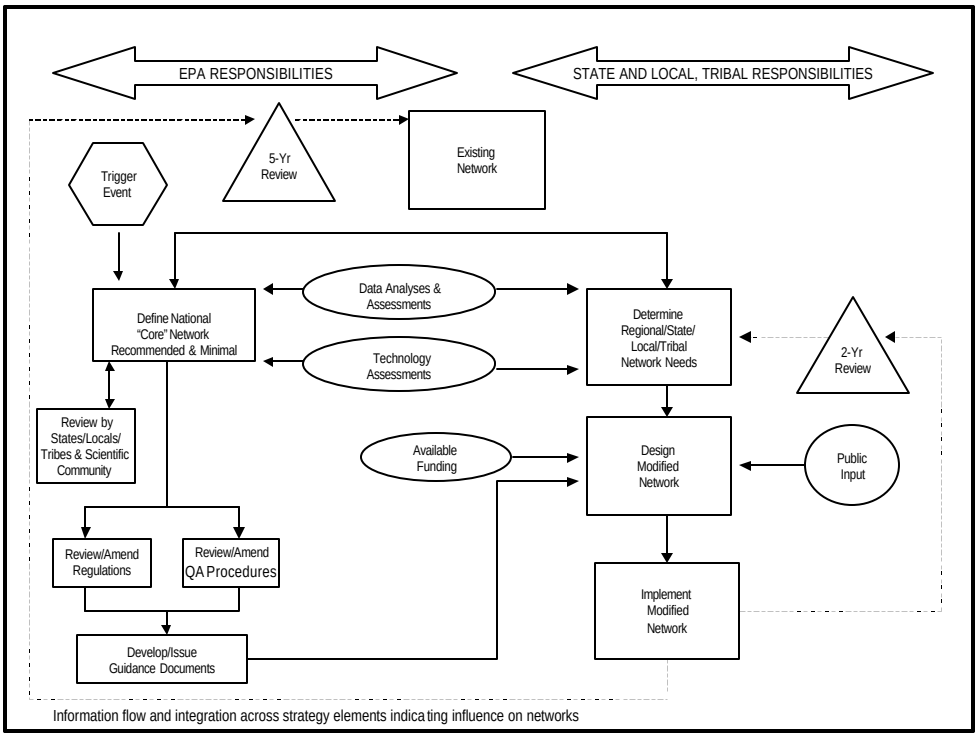
divestment in much of the existing criteria pollutant monitoring networks.

The strategy is challenged to create adequate flexibility for States, Tribes and local agencies to address area specific problems and simultaneously yield a core of consistent measurements nationally within an anticipated flat resource allocation. This strategy is being guided by the National Monitoring Steering Committee (NMSC), which combines a combination of monitoring and air program management leadership from States, local agencies, Tribes and EPA. The NMSC will be delivering

the strategy, which is largely a set of directional and specific recommendations for change in monitoring nationwide for broader public and scientific review in early 2002. Several efforts are underway to evaluate the effectiveness of existing networks and provide a vision for future operations, including:

- Development of network objectives and priorities to guide future investments and divestment;
- a network design proposal for nationally consistent multi pollutant measurement stations;
- National and regional based assessments of existing criteria pollutant networks that attempt to identify existing opportunities for criteria monitoring divestment;
- modifications of existing regulations and quality assurance practices to implement the recommendations emerging from the assessment; and
- accommodation of advanced monitoring and information transfer technologies to enhance scientific value of data collected and dissemination of public information.

Figure 1 illustrates the information flow across these various components.



This PM continuous monitoring implementation plan provides a test case for this important fifth element of the air monitoring strategy, and the ability to implement continuous monitors is impacted by all of the strategy elements. The broader vision for a PM network includes an integrated hybrid network of filter based and continuously operating samplers. The current $PM_{2.5}$ network of

approximately 1100 integrated samplers (FRMs) and nearly 200 "uncoordinated" continuous samplers should evolve into a system of perhaps 700- 1000 $PM_{2.5}$ samplers with a more even distribution (e.g., 50-50) of integrated and continuous methods. The continuous methods must be integrated to ensure data compatibility with the current FRM network . Currently, EPA provides only limited specification on operational guidance or performance expectations for continuous samplers, which limits the ability to utilize many of the existing continuous monitors to support an array of spatially oriented data uses such as model evaluation and PMF applications. Currently, only a very small fraction of continuous monitors enhance the spatial depth of the existing FRM network The challenge in this strategy is to maximize the benefit of continuous samplers so that data analysts are not constantly confronted with screening out instrument types for non regulatory use. This goal is challenged further by an existing inventory of diverse methods using various measurement principles, and the recognition that the measurement from an integrated sampler in many instances has several inherently different (and meaningful) physical and chemical features with respect to a filter measurement.

Assuming no new resource initiative for PM monitoring, resources for the enhancement and integration of continuous monitors will largely come from the existing resource base. This assumption implies a substantial reduction of FRM operations to free resources for operation of continuous samplers. The assessment work (element 3) to date has identified several areas where there is redundancy of samplers and therefore the potential for a reduction of FRM monitors. EPA needs to develop specific guidance for selecting candidate sites for removal based on the assessment and related spinoff products. Such guidance would incorporate design objectives that seek to eliminate sampling redundancy through correlation or related analysis, and enhance spatial coverage through mapping and kriging approaches. EPA will deliver this guidance in mid-2002. Meanwhile, a set of specific recommendations to modify existing PM monitoring regulations will be delivered as part of the strategy in early 2002. These modifications will reduce the number of required $PM_{2.5}$. FRM sites to free operational resources and enable agencies to invest in continuous methods. The recommended revisions must address the performance expectations and test requirements for Regionally Equivalent Monitors (Section 4) and lay out the basic network design framework (Section 5) expected for an integrated $PM_{2.5}$ system.

The NMSC has identified a national need to move toward a multi pollutant network that emphasizes hazardous air pollutants, continuous PM and advanced information transfer technology. In addition to addressing methods, the technology component (element 5) of the strategy provides the rationale and approach for enhancing information transfer and data analysis to increase data usage. The network design effort (element 2) is recommending a set of National Core (NCore) multi pollutant monitoring sites located in major metropolitan areas and selected rural environments. The goals of these sites include assistance for health and exposure studies, air quality management and monitoring m methods. The research community should realize long term benefits from these goals, which are similar to the objectives being addressed in the existing Supersites program. The use of these NCore sites to serve as multi pollutant methods platforms that collocate continuos and integrated PM measurements is critical to the long term integration of continuous and filter based methods. The relationship between a continuous sampler and an FRM is impacted by composition and meteorology which vary in time and space. The NCore platforms could maintain system integration by supporting iterative review of the statistical relationships between collocated integrated and continuous methods as aerosol composition changes arise from future demographic shifts and implementation of emission reduction strategies.

Section 11. Regulatory Changes and Schedule

There are a number of federal regulations that are used to provide the framework for ambient air quality monitoring. These regulations cover the sampling and analytical methods used, how new methods are approved, quality assurance and control procedures, and basic monitoring objectives for certain air pollutants. A great deal more technical information is provided in guidance documents and through the Internet.

Guidance documents are relatively easy to modify as new procedures and technologies appear within the monitoring community. Federal regulations are not particularly easy to modify; however, periodic reviews and revisions are necessary in order to create an air monitoring system that is responsive to current environmental data needs. Along with a variety of topics, we intend to review and modify our regulations to incorporate more continuous particle techniques as part of a larger overall national monitoring strategy. We also intend to establish mechanisms for incorporating continuous techniques by using guidance documents whenever possible.

Specific Regulations to be Reviewed:

There are three main regulatory "Parts" of the Code of Federal Regulations (CFR) that we will investigate in our work to modify the monitoring regulations. These regulations are all part of CFR Title 40 which deals with the environment. Specifically:

40 CFR 50[11] Appendices: National Primary and Secondary Ambient Air Quality Standards (NAAQS), Appendix L. This regulation provides us with the NAAQS and the federal reference methods for measuring each air pollutant with an established standard. We are NOT going to modify the national ambient air quality standards with this regulatory review. Reviews and, if needed, revisions of the NAAQS occur in separate formal processes. We do want to review a portion of the minor requirements in the Appendix L portion of this regulation which describes the reference method for measuring $PM_{2.5}$. The overall reference method will not be modified; however, we do want to examine some of the requirements for reporting supplementary data on the samplers' performance. We have successfully completed two annual quality assurance reports on the $PM_{2.5}$ FRM network operation, and we believe that we can reduce the amount of supplementary data being reported to EPA, specifically in Table L-1. This is a small change; however, it may provide some relief to State, local, tribal, and other monitoring agencies' data managers.

40 CFR 53 Ambient Air Monitoring Reference and Equivalent Methods. This regulation provides air quality monitoring instrument manufacturers with the application and testing requirements for reference and equivalent methods that must be followed in order to have their sampler/analyzer approved for regulatory use. The EPA's Office of Research and Development (ORD) is currently responsible for these approvals. This regulation describes the

[11]Regulations are cited in documents using the format "Title# CFR Part#".

complexities of how new criteria pollutant methods can be formally introduced into the ambient air monitoring network. EPA is a strong proponent of this formal process given the policy and financial impact that decisions using data from federal reference and equivalent methods can carry. We will review this regulation; however, changes to it may or may not be taken in this package. The particulate matter National Ambient Air Quality Standard is being reviewed separately by the EPA. This separate process will also be used to promote continuous particulate matter monitoring technologies within our regulations.

The EPA's ORD has established a Reference and Equivalent Method Board that includes members from OAQPS and ORD. This Board's function has been to review new and modified proposals for fine particulate matter monitoring candidate methods, and to provide broader program input into the approval process. OAQPS proposes to expand the role for this Board to include identifying how to incorporate regional equivalency into the existing reference and equivalent method testing program prior to any actual regulatory change. This approach may need to take the form of a pilot project initially. We will also need to examine our regulatory authority for making such a change. There is a precedent for approving regionally based equivalency within the particulate matter program, specifically with the approval of the Oregon DEQ Med-Vol sampler. It will be necessary to follow-up with any regional equivalency process with formal regulatory changes to Part 53.

40 CFR 58 Ambient Air Quality Surveillance. This regulation is a primary focus of our efforts to both incorporate new technologies and to provide data as outlined in the national monitoring strategy. Nearly all data collection and reporting requirements, all the quality assurance requirements, the NAAQS pollutant network design criteria, the air quality index reporting, and annual data certification requirements are included within this regulation. This regulation describes how the Clean Air Act air monitoring authority has been interpreted and implemented by the EPA and our State and local agency partners for air pollutants with established NAAQS. Tribal agencies are not regulated under this provision; however, the technical requirements within should be familiar to any tribal agency that plans to conduct monitoring.

We expect to change the 40 CFR 58 regulations to allow more flexibility in designing the particulate matter monitoring network. One of these changes would include modifying the existing correlated acceptable continuous (CAC) particulate matter monitoring approach to allow for a more network-based approach rather than only the site-by-site approach as defined currently. The original CAC provisions were developed prior to the full deployment of sequential federal reference methods (FRMs) for fine particles as a way to provide sampling frequency relief from daily sampling. Since the sequential FRMs have been available and are working, the CAC provision has largely been ignored by air monitoring agencies. EPA will modify this provision so that it will provide a better mechanism for incorporating continuous particle monitors into the network.

Participants in the Regulatory Review

We have solicited input from a variety of parties for this regulatory review process. Through the larger air monitoring strategy, we have created a National Monitoring Strategy Committee that is providing advice and recommendations for the national air monitoring program. Some of these

recommendations will be realized only after regulatory change has taken place. The NMSC has been discussed in section 10 of this document.

We have also created three separate work groups, one each for the subjects of regulatory review, quality assurance, and technology. These work groups were established to make some concrete progress on the program changes needed to realize the national monitoring strategy goals. The quality assurance group will provide recommendations for changes to the quality assurance provisions of the monitoring regulations as well as all existing quality assurance practices; and the technology work group will make recommendations for use in the methods sections of the regulations and in technical guidance used by monitoring agencies. The regulatory review work group must take information from all of these parties, in addition to the NMSC and the work group's own recommendations, and develop an appropriate regulatory package.

The NMSC and the three work groups include representatives from the EPA OAQPS, the ten EPA Regional Offices, State agencies, local agencies, and tribal governments. All regulatory changes will undergo public review and comment inherent within the regulatory modification process. EPA will also work through existing mechanisms such as the STAPPA/ALAPCO Monitoring Committee and the Standing Air Monitoring Work Group (SAMWG) to communicate with stakeholders on these regulatory changes.

Schedule

Regulatory changes typically take a minimum of 18 to 24 months to complete, including the original proposal package preparation, publication and comment periods, reviewing and responding to comments, and finalizing a package for publication.

Cost estimates are generally prepared for a rule-making action such as the one. A complete funding review of air monitoring grant funds will also be needed, but this should be part of the overall monitoring strategy implementation, and not tied as directly to this package.

Key Milestones (later milestones are subject to change):
October - NMSC recommendations on the national network.
October 23-25 - Monitoring Strategy Workshop
December 1 - Draft rule-making language prepared for work group review.
January - External scientific review of monitoring strategy
June 2002 - Proposal in the Federal Register
July-September 2002 - Public comment period
October - December 2002 - Review public comments, prepare responses
January 2003 - Final regulatory package published in Federal Register

Section 12. Summary of Issues and Action Items

This document serves as a bridge between initial concepts for integrating continuous PM monitors presented at the meeting with the Clean Air Science Advisory Committee's Subcommittee on Particle Monitoring in January, 2001 and comprehensive guidance for monitoring agencies. There remain numerous details not addressed at this time that should be addressed to ensure a satisfactory outcome. These issues and other areas of concern include:

- ***Complex program***. The concepts and elements incorporated in this plan are singularly and collectively complex therefore creating a communications challenge. Other approaches were considered, but the potential drawbacks of a simplistic approach were not acceptable. That is, it would have been easy to develop a rigorous non-flexible program easily communicable but conveying little motivation for deployment. Similarly, a program without constraints would likely compromise data quality and interpretability. Thus, a decision was made to accommodate both flexibility and data comparability at the expense of developing and communicating a complex program.

- ***Annual standard versus daily***. The DQO analyses performed to date have assumed that the annual standard is the driving standard. Since the annual standard involves the average of three numbers, each of which is based on at least 44 numbers but usually more than 60, it is clear why decision errors are not very sensitive to measurement imprecision and why it is proposed that the measurement precision performance criterion be 20% CV. DQOs based on the daily standard, which involves the average of 3, annual 98th percentiles, may show that decision errors are sensitive to measurement imprecision. Additional analyses will be performed to assess the importance of measurement imprecision for decision errors associated with the daily standard. Similarly, analyses will be performed to assess the importance of measurement imprecision for decisions made with non-aggregated data, such as AQI reporting.

- ***Rescinding REM certification based on future poor performance***. The REM program is based on demonstrating an acceptable level of comparison between FRM and continuous samplers. This relationship may change as a result of atmospheric changes due to deployment of emission mitigation strategies. Guidance, albeit complex, will allow for a non static relationship. Nonetheless, this potential for aerosol change will require iterative evaluation of instrument performance that is likely, in some instances, to show that a previously approved REM fails performance goals.

- ***Guidance for developing and approving regional equivalent domains***. The information in this document can be applied in a somewhat straightforward manner for approving an instrument for CAC or REM purposes at an individual site. The larger goal is to broaden this acceptance to a "region" where the meteorological and aerosol composition characteristics exhibit consistent behavior and hence throughout which the continuous and FRM methods exhibit similar relationships. Regionality is further complicated by administrative and demographic issues (e.g., multiple monitoring agencies and State boundaries intersecting within a given "region"). This topic has not been adequately addressed in this document and requires

additional effort. The overall complexity of regionality and the use of transformation models might suggest development of a review board to handle REM requests on a case by case basis.

- ***Reliance on FRM measurements as an indicator***. The underlying approaches require comparability of continuous and FRM measurements. The reason for this is that so many objectives relate to the FRM measurement (e.g., NAAQS comparisons, AQI, air quality model application). In many instances, there is no technical reason to expect comparability between disparate measurement approaches. Such comparability is desired given the utility of relating continuous measurements to a wealth of existing FRM data and to incorporate a reference marker. The downside of this approach is that the value of an FRM measurement is assumed or inferred to be greater than that of a candidate method, when in some cases the candidate method may better reflect "true" characteristics of an aerosol.

- ***Specific Guidance on Performance Specifications***. Sections 5 - 8 introduce performance specifications for bias and precision, but several specific details are not addressed. For example, how is bias measured? What is the statistic as well as what is the source of the data to be used in the statistic? Are bias estimates based only on existing collocated instruments or is an independent audit required? How are bias and precision treated on a regional basis, does the failure of one site constitute failure for a region, or are all estimates averaged across a region? What is the appropriate frequency for checking bias and precision? These unique considerations warrant development of a dedicated Quality Assurance program for CAC and REM applications.

- ***Data interpretation and management***. Transformed data are to be submitted to AIRS. How do analysts gain access to raw non-transformed data? Transformation models are based on 24-hr comparisons, yet transformed data will be reported continuously, which may create odd results in discrete hourly reporting. Coding specifications for CAC and REM need to be developed.

- ***Demonstration of performance***. The bias and precision estimates are based on existing network performance. This implies that the testing to meet such specifications should be conducted under conditions consistent with routine operations. This approach should not be interpreted as excluding desired vendor participation. Responsibilities for conducting testing, developing transformations and communicating performance results requires further effort.

- ***Consistency with FEM***. The current Class III equivalency requirements appear to be more strict than what a FRM can meet. That is, the imprecision in the FRM is such that the R^2 requirement can not be met, not because of the challenging instrument, but because of the instrument being used as the standard. This inconsistency needs to be addressed. In doing so, it may make it possible for an instrument to acquire a Class III equivalency.

ATTACHMENT A – $PM_{2.5}$ Continuous /FRM Analysis

TO BE PROVIDED AT A LATER DATE

Attachment B. DRAFT TECHNICAL REPORT

Data Quality Objectives (DQOs) for $PM_{2.5}$

for

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Quality Planning and Standards
Emissions, Monitoring, and Analysis Division (MD-14)
Research Triangle Park, North Carolina 27711

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Contract No. 68-D-98-030
Work Assignment 4-08

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1
- 1.1 Data Quality Objectives 1
- 1.2 Data Uncertainty 2

2.0 THE $PM_{2.5}$ DQOS 5
- 2.1 The DQO is Based on the Annual Arithmetic Mean NAAQS 5
- 2.2 The Distribution of the Measurement Error 6
- 2.3 Errors Can Occur When the Estimated 3-Year Average Differs from the Actual, or True, 3-Year Average 7
- 2.4 The Limits on Precision and Bias Are Based on the Smallest Number of Sample Values in a 3-Year Period 7
- 2.5 The Error Limits Were Set at 5 Percent 7
- 2.6 Measurement Imprecision Was Established at 10 Percent Coefficient of Variation (CV) 8
- 2.7 Assumptions About the Underlying Variability of the Day-to-Day PM Concentrations 8

3.0 THE MODELING PROCESS 13
- 3.1 Gray Zone Boundary Cases 13
- 3.2 Modeling 14

REFERENCES 17

APPENDIX A: ASSUMPTIONS AND INPUT CRITERIA FOR THE DQOS FOR AMBIENT AIR MONITORING OF PM2.5 . . . . . A-1

List of Tables

Table 1: Distribution of ratios of highest to lowest monthly or bimonthly mean at a site 9
Table 2: Distribution of CVs about monthly and bimonthly means 9
Table 3. Summary of Case 1 and 2 parameters 14
Table 4. Maximum decision error rates 16

List of Figures

Figure 1. Effect of positive bias on the annual average estimate, resulting in a false positive error 2

Figure 2. Effect of negative bias on the annual average estimate, resulting in a false negative error 2

Figure 3. Annual arithmetic mean and 24-hour 98th percentiles from AIRS data (extracted on April 4, 2001) 5

Figure 4. Comparison of normal and lognormal density functions at low measurement error (10 percent CV) 7

Figure 5. Comparison of normal and lognormal density functions at higher measurement errors (50 percent CV) 7

Figure 6. $PM_{2.5}$ concentrations showing a sinusoidal seasonal pattern along with the DQO sine curve that is associated with these data 10

Figure 7. The data example and curve plotted against the number of days into the year 11

Figure 8. Simulated $PM_{2.5}$ data for every third day with a long-term mean of 16.3 : g/m^3 and a population CV of 80 percent 12

Figure 9. Power curves for 75 percent complete 1-in-6-day sampling with 10 percent measurement CV and +/- 10 percent bias 15

DRAFT TECHNICAL REPORT

DATA QUALITY OBJECTIVES (DQOS) FOR $PM_{2.5}$

1.0 INTRODUCTION

An important concern in any organization that is collecting and evaluating environmental data must be the quality of the results. A quality system [1] must be developed and documented to ensure that the $PM_{2.5}$ monitoring results:

- meet a well-defined need, use, or purpose;
- satisfy customers expectations;
- comply with applicable standards and specifications;
- comply with statutory (and other) requirements of society; and
- reflect consideration of cost and economics.

The development of a quality system for $PM_{2.5}$ requires a coordinated effort between EPA and the State and local monitoring community and tribal organizations. Elements of the quality system include planning, implementation, and assessment. As part of the planning effort, EPA is responsible for developing National Ambient Air Quality Standards (NAAQS), defining the quality of the data necessary to make comparisons to the NAAQS, and identifying a minimum set of QC samples from which to judge data quality. The State and local organizations are responsible for using this information to develop and implement a quality system that will meet the data quality requirements. Then, it is the responsibility of both EPA and the State and local organizations to assess the quality of the data and take corrective action when appropriate. This document describes the approach used in developing a quality system for the $PM_{2.5}$ monitoring program. It is based on both the initial DQO development done in 1997, prior to the network establishment, and an assessment of the major assumptions that went into that development using 1999 and 2000 data from the network. Following the planning, implementation, and assessment theme, the discussion includes the:

1. development of data quality objectives (DQOs);
2. identification of the types and frequencies of QC samples, based upon the DQOs, to evaluate and control measurement uncertainty;
3. data quality assessment (DQA) process used to compare measurement uncertainty to the DQO; and
4. consequences of failing to meet the DQOs.

1.1 Data Quality Objectives

DQOs are qualitative and quantitative statements derived from the DQO Process that clarify the monitoring objectives, define the appropriate type of data, and specify the tolerable levels of measurement errors for the monitoring program [2]. By applying the DQO Process to the development of a quality system for $PM_{2.5}$, the EPA guards against committing resources to data collection efforts that do not support a defensible air quality management program. The DQO Process that follows illustrates the steps taken to assess the quality of data needed for making comparisons to the $PM_{2.5}$ NAAQS. The focus of this document is the annual NAAQS based on the 3-year annual arithmetic mean concentration. Throughout this document, the term *decision maker* will be used. This term represents individuals that are the ultimate users of ambient air data and, therefore, may be responsible for: setting the NAAQS, developing a quality system, evaluating the data, or making comparisons to the NAAQS to determine if a standard is or is not violated. The DQOs will be based on the data requirements of the decision maker(s).

In order to understand the DQO Process, a discussion on data uncertainty will follow, which will lead into the discussion of the $PM_{2.5}$ DQO.

1.2 Data Uncertainty

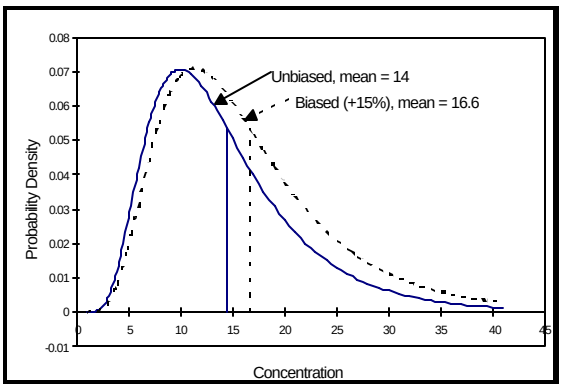

Figure 1. Effect of positive bias on the annual average estimate.

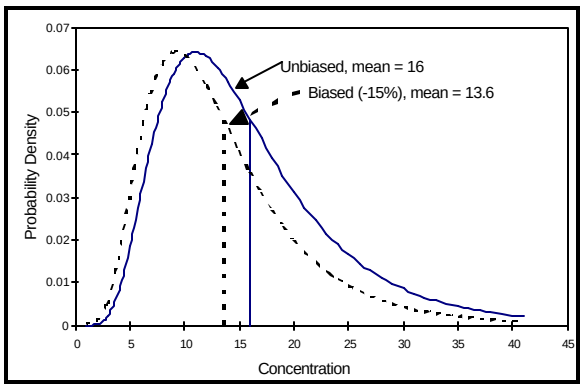

Figure 2. Effect of negative bias on the annual average estimate

Decision makers need to feel confident that the data used to make environmental decisions are of adequate quality. The data used in these decisions are never error free and always contain some level of uncertainty. Because of these uncertainties or errors, there is a possibility that measurements may yield annual averages above 15.0 : g/m^3 when the average is actually below 15.0 : g/m^3 (false positive error as illustrated in Figure 1) or below 15.0 : g/m^3 when actually the mean is above 15.0 : g/m^3 (false negative error as illustrated in Figure 2). Therefore, decision makers need to understand and set limits on the probabilities of these types of uncertainties in these data.

The DQO defines the acceptable level of data uncertainty. The term "uncertainty" is used as a generic term to describe the sum of all sources of error associated with a given portion of the measurement system. The estimate of the overall uncertainty that the decision makers are willing to accept leads to the DQO. Overall data uncertainty is the sum of **total population uncertainty** and **total measurement uncertainty**.

Total Population Uncertainty is defined as the natural spatial and temporal variability in the population of the data being evaluated. Population uncertainty can be controlled through the use of statistical sampling design techniques, the proper placement of ambient air quality monitors, spatial averaging (as allowed by the $PM_{2.5}$ NAAQS), and maintaining sampling frequency and completeness standards. Since the population of concern for the $PM_{2.5}$ NAAQS violation decision is a single instrument (each instrument can effect the attainment/nonattainment decision), the population uncertainty would be the uncertainty over the 3-year averaging period. During the development of the NAAQS, population uncertainty, due to temporal variability, was incorporated into the standard by stating that 3 complete years of data determines compliance with the NAAQS, even though the expected value may be different. Therefore, temporal variability would be considered completely accounted for, as long as every day sampling was implemented. However, 1-in-6-day sampling and 1-in-3-day sampling, or any deviation from every day sampling, have an impact on uncertainly that must be understood, and, if possible, quantified.

Total Measurement Uncertainty is the total error associated with the environmental data operation. The environmental data operation for $PM_{2.5}$ represents various data collection activities or phases including: the initial weighing of the filters (and the conditions in which they are weighed), the transportation of the filters, the calibration of the instrument and its maintenance, the handling and placement of the filters, the proper operation of the instrument (sample collection), the removal, handling and transportation of the filter, the storage and weighing of the sampled filter, and, finally, the data reduction and reporting of the value. At each phase of this process, errors can occur that, in most cases, are additive. The goal of a QA program is to control total measurement uncertainty to an acceptable level through the use of various quality control and evaluation techniques. In a resource constrained environment, it is most important to be able to calculate/evaluate the total measurement uncertainty and compare this to the DQO. Various phases (field, laboratory) of the measurement system can be evaluated, subject to the availability of resources.

Two data quality indicators are most important in determining total measurement uncertainty:

- **Precision** - a measure of mutual agreement among individual measurements of the same property usually under prescribed similar conditions. This is the random component of error. Precision is estimated by various statistical techniques using some derivation of the standard deviation. For the $PM_{2.5}$ DQO, the coefficient of variation (CV) is used, which is the standard deviation divided by the mean, multiplied by 100.

- **Bias** - the systematic or persistent distortion of a measurement process that causes error in one direction. Bias will be determined by estimating the positive or negative deviation from the true value as a percentage of the true value.

Accuracy has been a term frequently used to represent closeness to "truth" and includes a combination of precision and bias error components. For $PM_{2.5}$, the term accuracy will be used when measurement uncertainty cannot be separately associated with precision or bias.

2.0 THE $PM_{2.5}$ DQOS

The $PM_{2.5}$ DQOs were developed to reduce the probability of decision errors by controlling precision, bias, and sampling representativeness. The development was based on a series of assumptions and input criteria. These key assumptions are discussed below. The main assumptions that are data driven were compared with 1999 and 2000 data from the $PM_{2.5}$ mass network. The key inputs from decision makers have been reviewed by decision maker representatives. The power curves in Figure 9 and the error rates in Table 4 incorporate any modifications to the items below as indicated by this review. See Appendix A for additional assumptions and input criteria.

2.1 The DQO is Based on the Annual Arithmetic Mean NAAQS

The $PM_{2.5}$ standards are a 15 $:g/m^3$ annual average and a 65 $:g/m^3$ 24-hour average. The annual standard is met when the 3-year average of annual arithmetic means is less than or equal to 15 $:g/m^3$. Due to rounding, the 3-year average does not meet the NAAQS if it equals or exceeds 15.05 prior to rounding. The 24-hour average standard is met when the 3-year average 98th percentile of daily $PM_{2.5}$ concentrations is less than or equal to 65 $:g/m^3$.

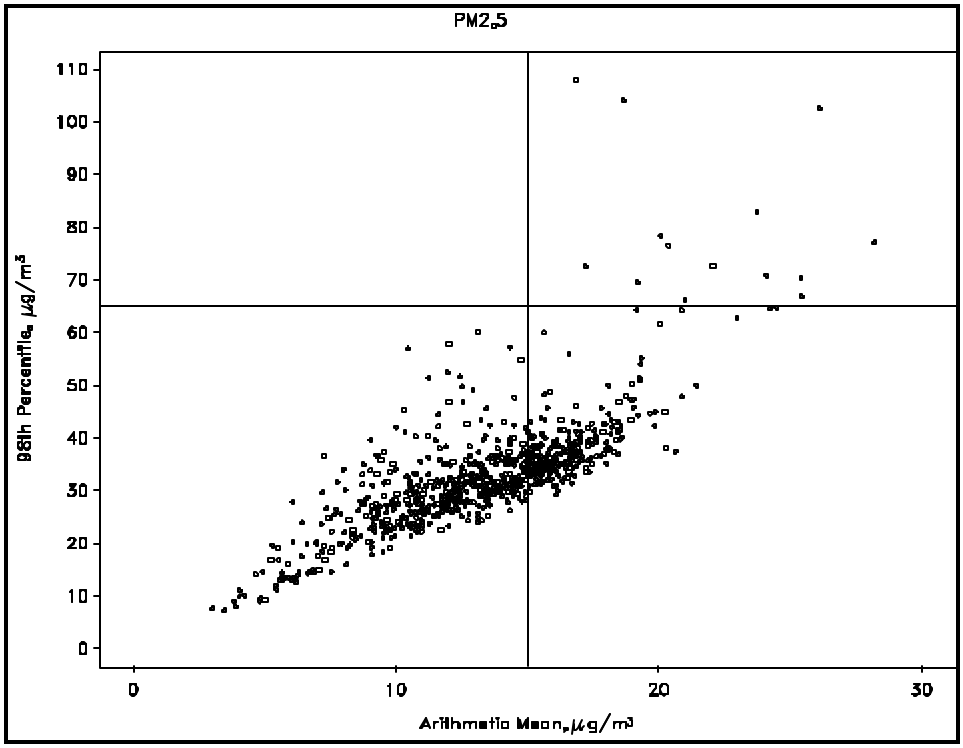

Figure 3. Annual arithmetic mean and 24-hour 98th percentiles from AIRS data (extracted on April 4, 2001)

The original $PM_{2.5}$ DQOs were developed using some $PM_{2.5}$ information (a total of 47 single-year estimates of the annual average and the 24-hour 98th percentile) as well as available PM_{10} information. In order to review and revise these standards, two years of AIRS $PM_{2.5}$ data (extracted on April 4, 2001) were investigated. These data represent the first two years of the mass network. Identifying sites with 90 or more observations in the year 2000 (which represented the first full year of data collection) yielded 757 measurements of annual averages and 24-hour 98th percentiles. These points are plotted in Figure 3. Figure 3 does not display estimates derived according to the standard, as the averages represent one-year averages as opposed to three-year averages, but it does indicate the relative importance of the two standards. Points to the right of the vertical line may be viewed as exceeding the annual average standard. Approximately 34 percent of the annual average measurements exceeded the standard. Only 14 measurements or about 2 percent exceeded the 65 $:g/m^3$ 24-hour standard.

2.2 The Distribution of the Measurement Error

Error in environmental measurements is often assumed to be normal or lognormal. Figures 4 and 5 attempt to illustrate what happens to the normal and lognormal distribution functions for the same median concentration at two values for measurement error (CV's of 10 percent and 50 percent). In the case of $PM_{2.5}$, the measurement error is expected to be in the range of 5 to 10 percent of the mean, as shown in Figure 4, where normal or lognormal errors produce close to identical results. Therefore, due to these comparable results and its simplicity in modeling, the normal distribution of error was selected.

Additionally, measurement error is assumed to be independent from day to day. It is also assumed that the standard deviation of the measurement error is assumed to be proportional to the true concentration being measured . The first of these assumptions is quite reasonable to expect. The second may not be entirely true. However, as long as the measurement error is less than the amount implied by a 10 percent CV, the decision errors will be controlled at the desired levels.

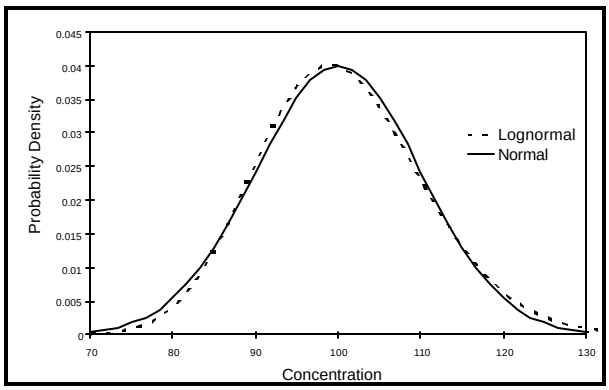

Figure 4. Comparison of normal and lognormal density functions at low measurement error (10 percent CV)

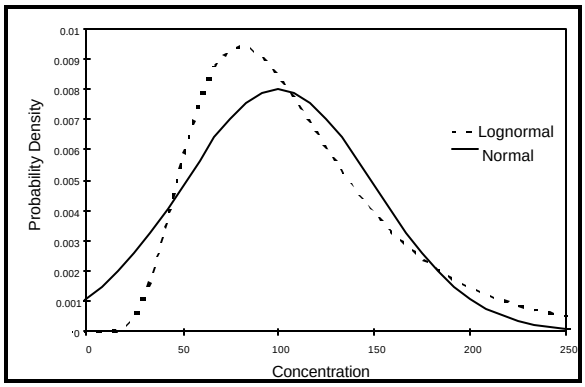

Figure 5. Comparison of normal and lognormal density functions at higher measurement errors (50 percent CV)

2.3 Errors Can Occur When the Estimated 3-Year Average Differs from the Actual, or True, 3-Year Average

Errors in the estimate are due to population uncertainty (sampling less frequently than every day) and measurement uncertainty (bias and imprecision). The false positive error occurs whenever the estimated 3-year average exceeds $15.0 : g/m^3$ and the actual 3-year average is less than $15.0 : g/m^3$ (Figure 1). The false negative error occurs whenever the estimated 3-year average is less than $15.0 : g/m^3$ and the actual 3-year average is greater than $15.0 : g/m^3$ (Figure 2).

2.4 The Limits on Precision and Bias Are Based on the Smallest Number of Sample Values in a 3-Year Period

Since the requirements allow 1-in-6-day sampling and 75 percent data completeness each quarter, the minimum number of values in a 3-year period is 144. It can be demonstrated that obtaining more data, either through more frequent sampling or the use of spatial averaging, will lower the rate of errors at the same precision and bias acceptance levels. It is assumed that any missing values are random and, thus, unlikely to have significant impact on precision and bias levels.

2.5 The Error Limits Were Set at 5 Percent

For the two cases in Section 3, the decision maker will make the correct decision at least 95 percent of the time if precision and bias are maintained at the acceptable levels and the completeness criteria are satisfied. For cases that are less "challenging" (i.e., have annual average values that are farther from 15.0 : g/m^3 or are made from less variable data), the decision maker will make the errors less often. Sampling more frequently will also reduce the probability of making an error. Finally, if precision and bias prove to be lower than the values used in the DQO development, the decision maker can expect errors less than 5 percent of the time.

2.6 Measurement Imprecision Was Established at 10 Percent Coefficient of Variation (CV)

The original DQO analysis reviewed available AIRS data and other $PM_{2.5}$ studies to determine that it was reasonable to allow measurement imprecision at 10 percent CV. While measurement imprecision has relatively little impact on the ability to avoid false positive and false negative errors, it is an important factor in estimating bias. CV's greater than 10 percent make it difficult to detect and correct bias problems. The DQOs are developed assuming a worst case scenario with respect to the bias, in that the bias is always assumed to be in the direction that would result in a decision error.

Other assumptions made concerning precision and bias include the assumption that they will be constant throughout the 3-year period. Similarly, it is assumed that precision and bias are checked sufficiently often to detect significant deviations from the DQOs.

2.7 Assumptions About the Underlying Variability of the Day-to-Day PM Concentrations

For the original DQOs, PM_{10} data from AIRS were reviewed to find a reasonable statistical model for $PM_{2.5}$. These analyses led to choosing a sinusoidal model for the long-term seasonal pattern. The review of the 1999 and 2000 $PM_{2.5}$ network data indicates that this is a reasonable choice for the cases with the largest amount of natural variation.

Specifically, the original DQOs were based on assuming a mean sinusoidal seasonal pattern for the $PM_{2.5}$ concentrations such that the:

- ratio between the high and the low points of the curve was 5.63;
- random population variation about the mean seasonal curve has a normal distribution with a standard deviation that is proportional to the seasonal mean;
- random population variation about the mean seasonal curve has a CV of at most 50 percent; and
- natural day-to-day variation about the sine curve is statistically independent.

Each of these assumptions were meant to reflect a worst case scenario with respect to the assumption's influence on the decision error rates.

A subset of the 1999 and 2000 network data was extracted from AIRS on April 4, 2001 to investigate the original DQO assumptions. The data were limited to sites with an annual mean between 10 and 20 micrograms per cubic meter. This was done mainly to represent the range that is most important to the DQOs. Also, the relative variability (CV) that can be measured could easily be biased by sites with the more extreme means. Next, completeness criteria were applied to ensure representativeness of the results. (See below.) Tables 1 and 2 show the distribution of two of the key characteristics in the DQO development, the ratio of highest to lowest mean values and the CV about those means.

Table 1: Distribution of ratios of highest to lowest monthly or bimonthly mean at a site

		Monthly	Bimonthly
	# of sites	289	292
	Mean	2.07	1.76
	Minimum	1.24	1.11
Percentile	90.0	2.60	2.12
	91.0	2.65	2.36
	92.0	2.79	2.38
	93.0	2.87	2.49
	94.0	3.01	2.57
	95.0	3.70	3.17
	96.0	4.41	3.36
	97.0	4.61	3.90
	98.0	5.25	4.03
	99.0	6.05	4.69
	Maximum	6.54	4.89

Table 2: Distribution of CVs about monthly and bimonthly means

		Monthly	Bimonthly
	# of Estimates	3,398	1,752
	Mean	49.6	50.7
	Minimum	16.1	22.9
Percentile	10.0	34.6	37.6
	25.0	40.4	42.8
	50.0	48.1	49.4
	75.0	56.3	56.9
	90.0	66.6	64.7
	95.0	73.7	70.5
	96.0	75.4	72.3
	97.0	78.2	75.9
	98.0	83.8	79.1
	99.0	93.5	89.8

To estimate the ratio of the high and the low means throughout the year and to estimate the variability about those means, monthly and bimonthly averages were considered. Technically, the DQO parameters of interest are daily means and the CV's about those means. These cannot be directly estimated without multiple measurements for each day of the year taken over many years. However, since the assumed sinusoidal behavior does not change much over the period of 1 to 2 months, the data were aggregated to monthly and bimonthly levels. Hence, the ratio of the highest to lowest points on the sine curve is approximated by the ratio of the highest monthly (bimonthly) mean to the lowest. Similarly, for each site and month (or consecutive 2-month period) a CV could be calculated for the period.

For the monthly averages, a site's data were used when there were at least 11 months, each with at least 10 valid measurements. For the bimonthly averages, a site was considered if there were at least 19 valid measurements in each of the six two-month intervals. A site's ratio was then the ratio of the maximum monthly mean (or bimonthly mean) to its minimum monthly mean (or bimonthly mean). The distribution of these ratios is included in Table 1. For each site and month or bimonthly period, a CV was also estimated. Table 2 contains the distribution of CVs about the means. The DQOs need to guard against the most variable cases, so the highest portion of the distribution is most important to this work. However, since the original DQOs were based on a CV of 50 percent, Table 2 indicates that some of the middle portion of the distribution of CVs is important as well.

These analyses show that the ratio of maximum to minimum used in the original DQOs was slightly higher than would be necessary as an estimate of the worst case scenario for the seasonal variability. From the distribution shown in Table 2, it was concluded that the estimate for the upper bound on the CV used in the original analyses was too low. A ratio of 5.3 and CV of 80 percent were chosen to represent the worst case for use in the DQOs and the case studies below (compared to 5.63 and 50 percent, respectively, in the original DQOs).

Figures 6 and 7 show an example of the $PM_{2.5}$ data extracted from AIRS for a fixed site. The mean of the data from this site for the time period shown (January 1999 through November 2000) is 16.3 : g/m^3. A sine curve with a mean of 16.3 and a ratio of 5.3 between the highest and lowest points on the curve would be given by

$$16.3 + 11.125 \sin(2 \text{ B } D / 365 + \text{phase shift}) \quad .$$

The curve shown in Figures 6 and 7 is

$$16.3 + 11.125 \sin(2 \text{ B } D / 365 + 1.9) \quad ,$$

where D is the number of days into the 3 year cycle. The phase shift 1.9 was chosen to minimize the square error between the sine curve and the data values. Figure 7 has the same data and curve plotted against the number of days into the year rather than the number since January 1, 1999.

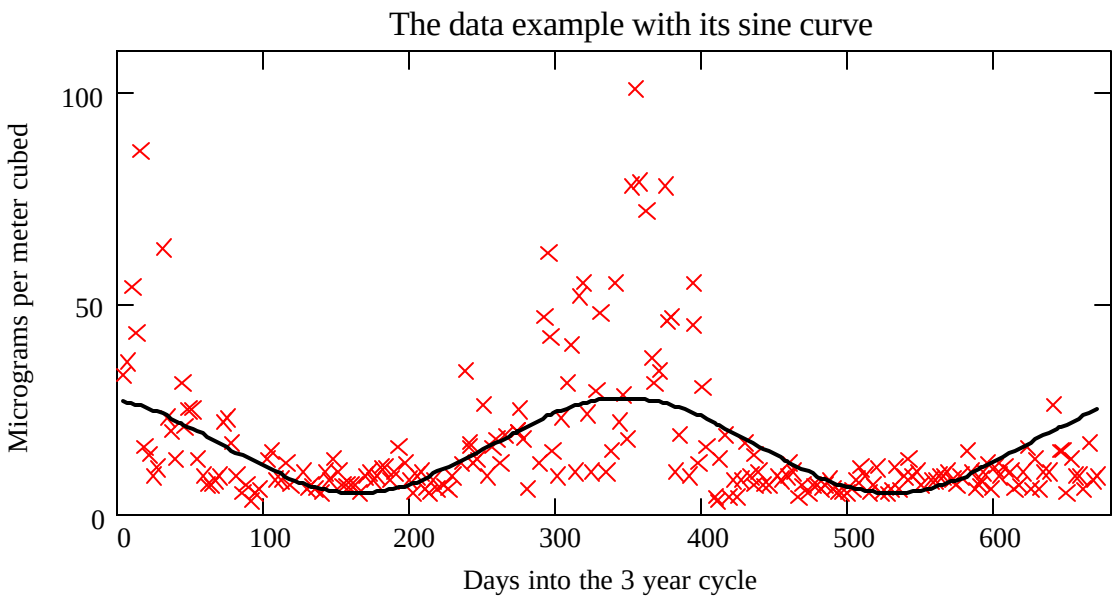

Figure 6. $PM_{2.5}$ concentrations showing a sinusoidal seasonal pattern along with the DQO sine curve that is associated with these data

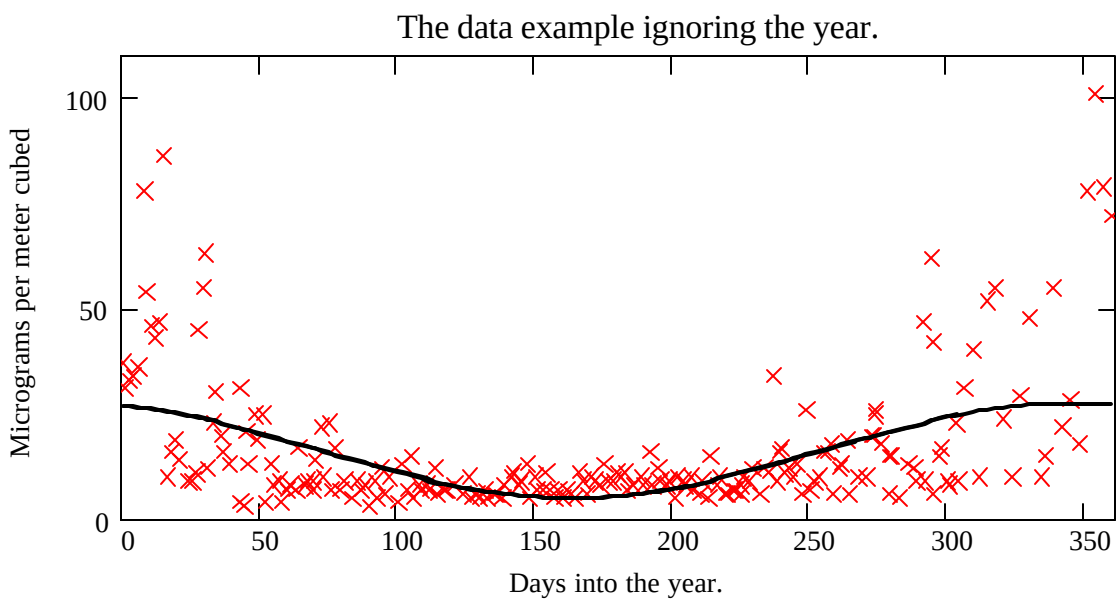

Figure 7. The data example and curve plotted against the number of days into the year

The figures show several key points that the DQO model is designed to simulate. First, the data exhibits seasonal variation. For this particular site, the ratio of the highest monthly mean to the lowest is 5.2. The periods with the highest means have much more variability. The variability "about" the sine curve is not symmetric; the deviations above the curve extend further away from the curve than the deviations below the curve. In fact, if the sign of the deviations from the curve were reversed there would be many negative values. There is also a considerable amount of day-to-day variation. After accounting for the sinusoidal seasonal variation and subtracting out a measurement error CV of 10 percent, the remaining variation is just over 80 percent.

Sinusoidal simulation models were also considered as starting points for developing DQOs. The following model mimics the situation in Figure 7 except for the phase shift[1].

C_D = concentration on Day D = [16.3 + 11.125 sin(2 B D / 365)]* $*_D$,

D = 1,2,... is the number of days into the 3-year cycle ,

where $*_D$ is a random factor that is log-normally distributed with mean one and standard deviation equal to 80 percent. Figure 8 illustrates this function together with simulated $PM_{2.5}$ levels for three years. (Compare with the real data in Figures 6 and 7.) The long-term average concentration is 16.3 : g/m^3. A station having $PM_{2.5}$ levels following this model would virtually always be in a true state of non-attainment, based on the average of three years' data with no measurement system error.

In revising the DQOs, instead of assuming a normal distribution about the sinusoidal curve, a lognormal distribution was utilized. The lognormal distribution does not produce negative values and is skewed. (See Figure 2.) The original DQOs were based on a normal distribution about the sine curve with a CV of 50 percent. This produced very few negative values that were ignored. However, using a normal distribution with a CV set at 80 percent would have resulted in negative numbers more than ten percent of the time. Hence, the lognormal distribution was chosen to more realistically simulate the natural variation about the sine curve.

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1 For modeling purposes, the phase shift is not important since complete years will be used.

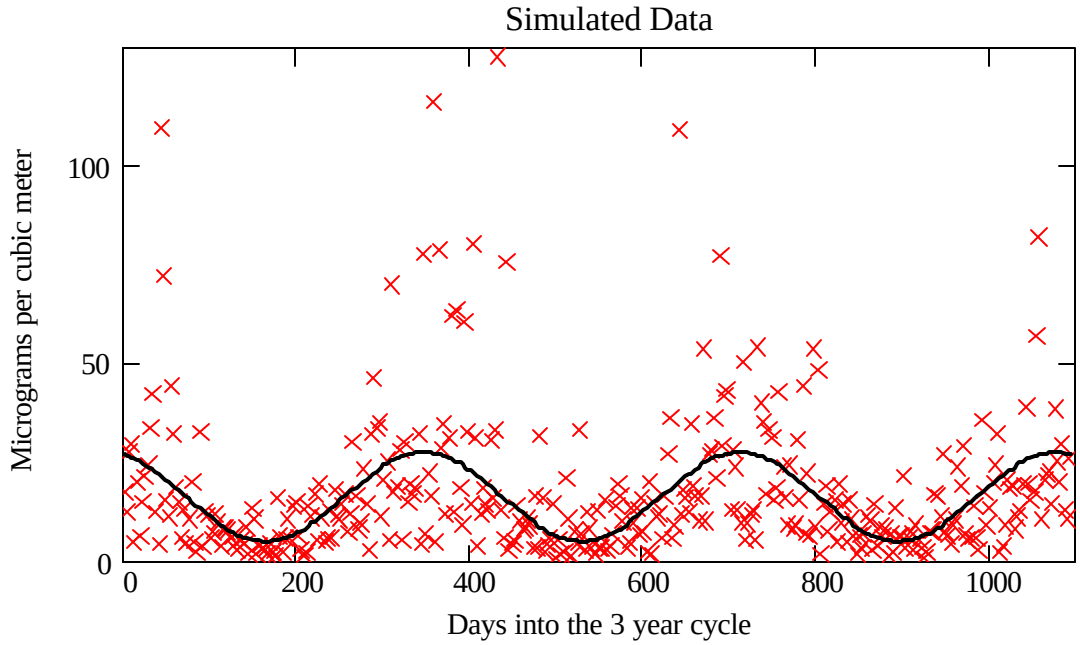

Figure 8. Simulated $PM_{2.5}$ data for every third day with a long-term mean of 16.3 :g/m³ and a population CV of 80 percent

3.0 THE MODELING PROCESS

The relationship of the DQO assumptions and input criteria to the decision error rates was established by Monte Carlo simulation of both the true 3-year annual mean concentrations and the 3-year mean sample mean concentration. A true 3-year mean concentration establishes the correct attainment/nonattainment decision. The sample mean determines the decision.

Each of the items listed in Section 2 impacts the output of this process. The two key outputs are power curves and the associated gray zone. The power curves relate the true 3-year means to the probability of a measured annual mean being above 15.0 : g/m³. The gray zone is the range of 3-year annual means about the standard where the decision error rate is unavoidably higher than the 5 percent limit set in Section 2.5.

3.1 Gray Zone Boundary Cases

The following two examples illustrate the process used to investigate the effects on ~~decision~~ error rates of various values of precision, bias, and sampling frequency. They show the extremes where the 5 percent error rate is met. As mentioned above, less "challenging" cases, such as cases with means that are further from the NAAQS standard, will have lower error rates.

Case 1: Suppose a site has a true three-year mean of 12.2 :g/m³.

The correct measurement is an annual mean below 15.0 :g/m³. The probability of the false positive error for sampling every sixth day depends on the measurement system bias and precision. (See Table 4.) As stated in Section 2.6, the data in Table 4 show that precision alone has little impact on error, but is an important factor for determining the bias, which is an important factor in error rates. Figure 9 illustrates the power curves associated with 75 percent complete 1-in-6-day sampling, a population CV of 80 percent (about the sine curves), a measurement CV of 10 percent, and biases of +/- 10 percent. The actual mean obtained from sampling would likely differ from 12.2 because of sampling error (not sampling every day), measurement error, and measurement bias. However, the probability that these factors would combine to yield a mean of at least 15.05 :g/m³ is only 5 percent.

Case 2: Suppose a site has a true three-year mean of 18.8 :g/m³.

The correct measurement is an annual mean above 15.0 :g/m³. The probability of the false negative error for sampling every sixth day depends on the measurement system bias and precision. (See Table 4.) As stated in Section 2.6, the data in Table 4 show that precision alone has little impact on decision error, but is an important factor for determining the bias, which is an important factor in decision error. Figure 9 illustrates the power curves associated for 75 percent complete 1-in-6-day sampling, a population CV of 80 percent (about the sine curves), a measurement CV of 10 percent, and biases of +/- 10 percent. The actual mean obtained from sampling would likely differ from 18.8 because of sampling error (not sampling every day), measurement error, and measurement bias. However, the probability that these factors would combine to yield a mean of less than 15.05 :g/m³ is only 5 percent.

Combinations of precision and bias that yield error probabilities around 5 percent were considered acceptable. After reviewing Cases 1 and 2, and based upon the acceptable decision error of 5 percent, the DQOs for acceptable precision (10 percent CV) and bias (± 10 percent) were chosen.

Table 3. Summary of Case 1 and 2 parameters

	3-Year Mean	Correct Decision	Incorrect Decision	Tolerable Error Rate
Case 1	12.2 ug/m^3	Attainment	F(+) = nonattainment	5 %
Case 2	18.8 ug/m^3	Nonattainment	F(-) = attainment	5 %

3.2 Modeling

The probability estimates in Table 4 and the power curves in Figure 9 are developed by modeling 3-year sets of data similar to that shown in Figure 8, except all 3*365 days are generated. For a given long-term expected mean between 10 and 20, many sets of data representing a true 3-year set of data are generated. Each set of random data determines a true 3-year mean that is rounded to the nearest tenth and is either in attainment (at most 15.0) or out of attainment (over 15.0). Then associated with each these data sets, a random set of 144 days is selected such that 12 days are selected from each quarter from a 1-in-6-day sampling scheme. To these values, normally distributed random measurement error and both a positive and negative bias are added. The random measurement error has a mean of 0 and a standard deviation that depends on the magnitude of the particulars day's true value (10 percent for the power curves). This generates a set of sampled data values and a sample mean. Finally, the power curve is generated by repeating this process for a range of long-term expected means. Power is calculated as the percent of the time that sample means from a fixed true 3-year mean are over 15.05.

The power curves show the probability or percent of the time that a measurement of an annual mean is above 15.0 : g/m^3 under different conditions. Power curves are the standard statistical tool for comparing the effects of various input parameters on decision errors. The curves shown in Figure 9 and the error rates in Table 4 are based on the assumptions and input criteria discussed in Section 2. In particular, the key assumptions are a long-term sinusoidal daily mean with ratio of 5.3 between the high and low points of the curve, a lognormal variation about the sine curve with a CV of 80 percent, 75 percent complete 1-in-6-day sampling, normal measurement error with a 10 percent standard deviation, and bias of +/- 10 percent.

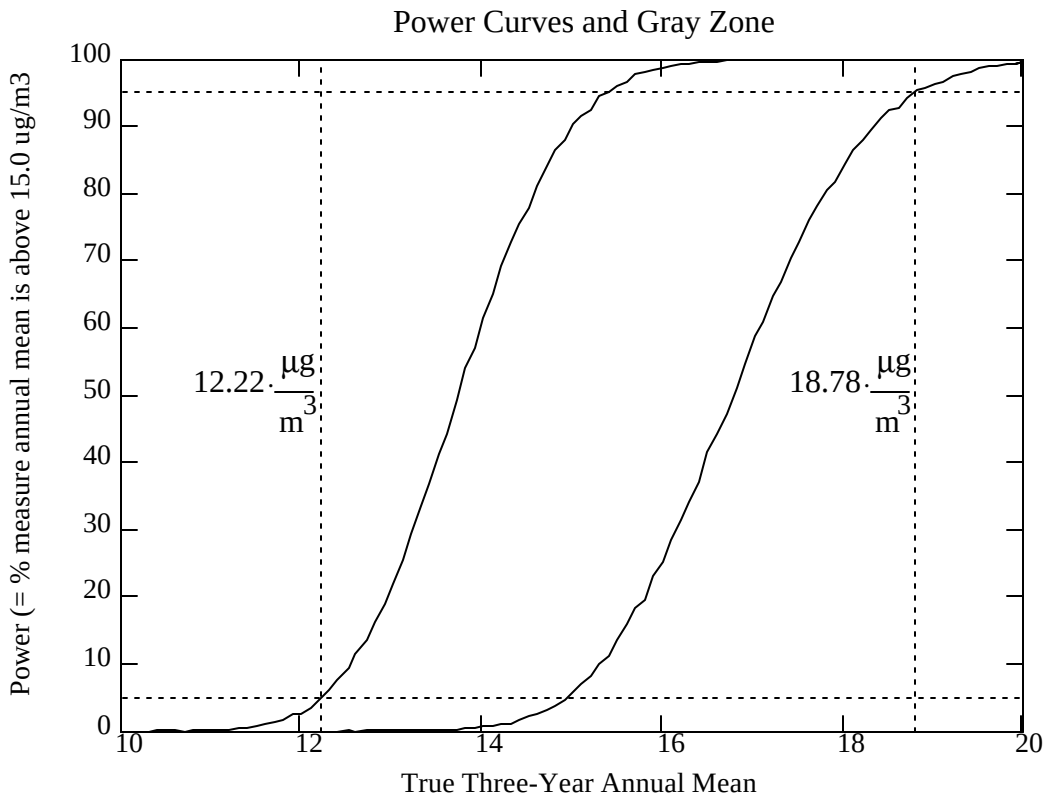

Figure 9. Power curves for 75 percent complete 1-in-6-day sampling with 10 percent measurment CV and ± 10 percent bias.

Table 4. Maximum error rates

Absolute Bias *	Measurement CV	Error rate at 12.2 mg/m^3	Error rate at 18.8 mg/m^3
5	0	1%	1%
5	10	1%	1%
5	80	8%	8%
5	100	10%	12%
10	0	5%	5%
10	10	5%	5%
10	80	15%	17%
10	100	18%	21%
15	0	15%	21%
15	10	15%	21%
15	80	26%	31%
15	100	28%	34%

* The bias is taken in the direction that causes the most error.

The Data Quality Objectives Process sets concrete goals to produce sufficient, high quality data for decision makers and data user needs. The process needs to continue throughout the data collection cycle. Assumptions made in the process need to be checked and, if necessary, updated as the data are collected. For $PM_{2.5}$ monitoring program, the combination of at most a 10 percent measurement CV and at most an absolute bias of 10 percent have been chosen to ensure that at most 5 percent decision errors will occur outside the range of 12.2 to 18.8 : g/m^3 for a 1-in-6-day sampling scheme. The key assumptions that went into the original choice of 10 percent measurement CV and 10 percent absolute bias have been checked against the 1999 and 2000 data from the network The basic structure of the assumptions has been left intact, but some of the particular parameters have been modified to more realistically model the network data.

REFERENCES

[1] American National Standard, Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs, ANSI/ASQC E4-1994, American Society for Quality Control, 1994

[2] Guidance for the Data Quality Objectives Process, U.S. Environmental Protection Agency, Quality Assurance Management Staff, EPA QA/G-4, March 14, 1994.

[3] Guidance for the Data Quality Assessment Process EPA QA/G-9, U.S. Environmental Protection Agency, QAD EPA/600/R-96/084, July 1996.

[4] Rhodes, R.C., "Guideline on the Meaning and Use of Precision and Accuracy Data Required by 40 CFR Part 58, Appendices A and B." EPA60014-83-023, U.S. Environmental Protection Agency, Research Triangle Park, N.C. 27711, June 1983.

[5] "Model Quality Assurance Project Plan for the $PM_{2.5}$ Ambient Air Monitoring Program at State and Local Air Monitoring Stations (SLAMS)," Quality Assurance Guidance Document, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, EPA 454/R-98-005, April 1998.

APPENDIX A:

ASSUMPTIONS AND INPUT CRITERIA FOR THE DQOs FOR AMBIENT AIR MONITORING OF $PM_{2.5}$

APPENDIX A: ASSUMPTIONS AND INPUT CRITERIA FOR THE DQOS FOR AMBIENT AIR MONITORING OF $PM_{2.5}$

The DQO process clarifies the monitoring objectives of a network to ensure that the data collected is of the appropriate type, quantity, and quality to meet program goals. The process necessarily makes various assumptions about the nature of the data to be collected in order to quantitatively bridge the decision goals with the required quantity and quality of monitoring data. A key part of the DQA process is then to assess these assumptions, once monitoring data are available. AIRS $PM_{2.5}$data from 1999 and 2000 were used to review the assumptions made in developing DQOs for the $PM_{2.5}$ NAAQS compliance. The NAAQS $PM_{2.5}$ standards are met if:

1. The 3-year average of the annual arithmetic means of the daily $PM_{2.5}$ concentrations is less than or equal to 15 micrograms per cubic meter; and
2. The 3-year average 98th percentile of the daily $PM_{2.5}$ concentrations is less than or equal to 65 micrograms per cubic meter.

Both the original DQO process and an outline for the DQA are documented. EPA developed a model Quality Assurance Project Plan QAPP for states to follow. This included a general DQO development that was intended to be used nationwide to provide for uniform data quality. Section 7 of the Model QAPP documents the DQOs and Section 24 outlines an assessment plan for checking some of the assumptions made in the DQO development. Included in this outline is a list of seven assumptions and input criteria statements used in the DQO development. They are enumerated in the Model QAPP as:

1. The DQO is based on the annual arithmetic mean NAAQS.
2. Normal distribution of measurement error.
3. Decision error can occur when the estimated 3-year average differs from the actual, or true, 3-year average.
4. The limits on the precision and bias are based on the smallest number of required sample values in a 3-year period.
5. The decision error limits were set at 5 percent.
6. Measurement imprecision was established at 10 percent coefficient of variation (CV).
7. Achievement of bias and precision limits.

Further examination of the DQOs shows that there are some additional assumptions that should be verified. (Or verify that there is negligible impact from making an incorrect assumption.) These are enumerated with some comments below.

1. The DQO is based on the annual arithmetic mean NAAQS.

   The review of the 1999 and 2000 data shows that annual arithmetic mean is the more stringent requirement for the network. However, since the main calculations in the DQO development are done via Monte Carlo simulation, it is not necessary to make this assumption. Using Monte Carlo simulation, DQOs for the 98th percentile could be included as well. This was not done because, compared to the annual mean, the quality of the estimate of the 98th percentile will be much more dependent on the distributional assumptions made in the simulations.

2. Normal distribution of measurement error.

   The statement and the suggested check in the Model QAPP is concerned only with the distributional nature of the measurement error. There is an additional implied assumption that is directly tied to this assumption, namely:

   > The measurement error standard deviation is assumed to be proportional to the true concentration..

3. Error can occur when the estimated 3-year average differs from the actual, or true, 3-year average.

   This is a fundamental assumption of the process. The assumption is that the methods described for calculating the error rate are realistic.

4. The limits on the precision and bias are based on the smallest number of required sample values in a 3-year period. In particular, it is assumed that 75 percent of 1-in-6-day sampling is both sufficient and attainable.

   It is also assumed that the missing values are completely at random. It is, of course, assumed that the missing values are independent of the daily value. However, the missing data could be random, but clustered because the completeness requirement is applied quarterly, any clustering is unlikely to have a significant impact.

5. The decision error limits were set at 5 percent.

   This is an input criteria needed to carry out the calculations being made. It is not necessary that both the false positive error rate and the false negative error rate be the same, but this was the case that was chosen by decision makers.

6. Measurement imprecision was established at 10 percent coefficient of variation (CV).

   This input criteria statement has the implied assumption is that a 10 percent CV is attainable. (And, as noted above, it makes sense to measure the precision in terms of a percent of the mean.)

7. Achievement of bias and precision limits.

   As with Assumption 6, the DQO was developed assuming that an absolute bias of 10 percent was achievable. There is also the underlying assumption that the bias should be measured as a percent of the mean rather than as an absolute bias. The DQOs are developed assuming a worst case scenario with respect to the bias. (The bias is always assumed to be in the direction that would result in a decision error.)

8. There is a mean seasonal pattern to the PM concentrations that can be adequately described by a sinusoidal curve such that the ratio of the high to the low in this pattern is 5.3 (this is assumed as a worst case).

   The original value of 5.63 was reduced to 5.3 based on the review of the 1999 and 2000 data. (See Section 2.7 and Table 1 in the main text.)

9. The random population variation about the mean seasonal curve is log-normal with a standard deviation that is proportional to the seasonal mean.

   The original DQO development assumed normally distributed variation. This was changed to lognormal to more realistically model the data in the Monte Carlo simulations.

10. The random population variation about the mean seasonal curve has a CV of at most 80 percent.

    This was increased from 50 percent based on the review of the 1999 and 2000 data. (See Section 2.7 and Table 2 in the main text.)

11. The precision and bias will be constant throughout the 3-year period (or at least consistently within their respective limits).

12. The precision and bias are checked sufficiently often to detect significant deviations from the DQOs.

13. The day-to-day values (of the truth) are assumed to be independent.

The review of the network data found that this is NOT true across the network. However, it is nearly true; the minimum correlation between daily values is about 0.3. To model the worst case for the decision maker, values close to 0 (=uncorrelated) should be used. Incorporating a small amount of correlation into the DQO modeling has very little effect on 1-in-6-day sampling. The effect would be more pronounced on a DQO based on 1-in-3-day sampling or daily sampling.

14. The measurement error is assumed to be independent from day-to-day.

This is much the same as saying that the bias is consistent. In particular, it is assumed that the sampler will not be high for a couple of months, then low for a while, and average out to some acceptable bias.

Attachment C. DQO Guidance for AQI Applications

See: http://www.epa.gov/ttn/amtic/files/ambient/monitorstrat/aqidqorept.pdf

ATTACHMENT D - Draft National Monitoring Strategy

See: http://www.epa.gov/ttn/amtic/stratdoc.html

Section 7: Monitoring Methods and Issues

Background/Introduction

The strategy goal is to manage the nation's air monitoring networks such that critical and stable network elements, as well as changing priorities, can be accommodated in a framework that is scientifically sound and resource optimized to address national and local interests. This framework requires progress on various aspects, as outlined in Section 1, that shape the monitoring networks, including the incorporation of emerging technological and scientific advances in measurement techniques to support these monitoring efforts. Several different measurement techniques are needed to support the existing monitoring program efforts. The list of measurements is provided in Table 1 of Section 4 and includes mostly those that are required with some recommendation on additional measurements.

This information supports the overall Monitoring Strategy approach by providing a general understanding of, and issues related to, routine and new technologies currently available to provide the measurements outlined in the strategy. Its goal is to help provide insight to those deciding how these measurements will be obtained. An attempt is made to strike a balance between the routine, easy-to-use, "tried and true" and the new, commercially available, continuous, and maybe not yet full demonstrated, technologies. Recognizing that other techniques may be applicable to the measurements discussed, the methods provided here are those used in current EPA monitoring networks. This discussion does not include PM mass and PM continuous measurements.

This section is organized by measurement or category of pollutant(s) and provided in the same order as listed in Table 1 of Section 4. A short description of the basic operating principle is provided along with any anecdotal information or known issues related to making these measurements.

Methodology

It is important to distinguish between "routine" and "non-routine" methods for monitoring. Routine methods are thought to be fully field demonstrated, tested and routinely used in networks such as the National Ambient Air Quality Standard (NAAQS) networks. Routine methods are those that are usually simple to implement, use and maintain, stable in operation and do not require significant resources to operate. Non-routine methods are considered less "rote", more research-oriented, more difficult to maintain and requires a specially trained or skilled operator. Non-routine methods may also be new technologies that have not yet been fully field tested or evaluated.

Particulate Matter

$PM_{2.5}$ Chemical Speciation - Elements, ions, and carbonaceous aerosols and organic PM

The most commonly applied aerosol analyses methods can be divided into the following categories: mass, elements, ions, and carbon. It is possible to obtain several different analytes from the same substrate, but not possible to obtain all desired chemical species from a single substrate; therefore, the appropriate filter media, sampling hardware, and analysis methods must be combined. The analysis

techniques performed on a particular filter type may vary depending on the specific sampler type and configuration used for sample collection. The following sections outline the filter analysis methods for the chemical species categories of elements, ions, and carbonaceous aerosols used for the PM Speciation program. Mass is not addressed in this discussion.

Elements

To date, several analytical methods have been used to determine the elemental composition of particulate matter. X-Ray Fluorescence (Dzubay and Stevens, 1975; Jaklevic et al., 1977) and Proton Induced X-Ray Emission (Cahill et al., 1990) have been used extensively in the analysis of ambient aerosols for both the Chemical Speciation and IMPROVE programs because they are non-destructive, have multi-element capabilities, and are relatively low cost.

Energy-dispersive x-ray fluorescence (EDXRF) by Method IO-3.3 (U.S. EPA, 1997d) is used for the National Chemical Speciation program to characterize the elemental composition of the aerosol deposits on Teflon® filters. EDXRF determines the concentration of approximately forty elements (from sodium through lead on the periodic table); however, for typical atmospheres, the analysis is most useful for half of these elements, including aluminum, silicon, sulfur, chlorine, potassium, calcium, titanium, vanadium, chromium, manganese, iron, nickel, copper, zinc, arsenic, selenium, bromine, cadmium, and lead. Since sample filters often contain very small amounts of particle deposits, preference is given to methods that can accommodate small sample sizes and require little or no sample preparation or operator time after the samples are placed into the analyzer. X-ray fluorescence (XRF) meets these needs and leaves the sample intact after analysis so it can be submitted for additional examinations by other methods as needed.

This method was developed using the Kevex spectrometer. EPA has experience in the use of the Kevex spectrometer associated with various field monitoring programs involving analysis of filterable particulate matter for metals over the last two decades. This method can be applied to PM_{10}, $PM_{2.5}$ and PMcoarse (2.5-10 :m) aerosols particles captured on membrane filters for research purposes in source apportionment. The samplers which collect these particles are designed to separate particles on their inertial flow characteristics producing size ranges which simplify x-ray analysis. The instrument is a commercially available Kevex EDX-771 energy dispersive x-ray spectrometer which utilizes secondary excitation from selectable targets or fluorescers and is calibrated with thin metal foils and salts. Spectra are acquired by menu-driven procedures and stored for off-line processing. Spectral interferences are corrected by a subtractive coefficient determined during calibration.

The type of filter on which the sample is collected is very important for XRF analysis. In general, thin membrane filters (Teflo® and Nuclepore®) are required so that the background is low and penetration of particles into the matrix of the filter is small. Thick depth filters such as quartz or glass fiber not only have high background, but also allow particles to penetrate into the matrix of the filter - a condition that the spectral processing system cannot accommodate. Some internal contaminations consisting of Sn, Ni, Cu and Fe are present which sometimes appear in

blanks. Routine analysis of blanks with samples will provide the magnitude of the correction necessary to compensate for this bias. An inherent problem with a helium atmosphere is the diffusion of He through the detector window causing detector degradation and necessitating replacement. A lifetime of 3 to 4 years is expected. Due to the potential for x-ray leaks around the anode area of the x-ray tube, the head must be shielded with additional lead cladding to prevent unwanted excitation of internal parts. This leak poses no threat to personnel, but can cause high background when operating at the maximum voltage. The additional shielding also proves very effective at improving detection limits.

To obtain the greatest efficiency and sensitivity, XRF typically places the filters in a vacuum which may cause volatile compounds (nitrates and organics) to evaporate. As a result, species that can volatilize such as ammonium nitrate and certain organic compounds can be lost during the analysis. The effects of this volatilization are important if the filter is to be subjected to subsequent analyses of volatile species.

Ions

Ionic species (sulfate, nitrate, ammonium, sodium, and potassium) can represent a large fraction of fine particulate matter, thus their determination is important. Polyatomic ions such as sulfate, nitrate, and ammonium are quantified by ion chromatography (IC). Simple ions, such as chloride, and fluoride may also be measured by IC along with the polyatomic ions. When the aerosol deposit is suspected of being acidic, its hydrogen ion content can be determined by a pH electrode or by micro titration. It is important to keep the filter away from ammonia sources, such as human breath, to minimize neutralization of the acidic compounds.

Ion chromatography is a form of liquid chromatography that uses ion-exchange resins to separate atomic or molecular ions based on interaction with the resin. IC can be used for anions and cations by employing separate columns. All ion analysis methods require a fraction of the filter to be extracted in deionized distilled water and then filtered to remove insoluble residues prior to analysis. The extraction volume should be as small as possible to avoid over-diluting the solution and inhibiting the detection of the desired constituents at levels typical of those found in ambient $PM_{2.5}$ samples.

Sulfate is one of the most robust particulate matter species because it remains stable during and after sampling. Sulfate is collected on PTFE or nylon filters and aqueous extracts of these filters analyzed using IC. It is important to utilize the appropriate denuder for SO_2 gas while making particulate sulfate measurements using nylon filters and to maintain the denuder for optimal efficiency while in use. Particulate sulfur is also routinely analyzed using XRF. The typical mass ratio of [(sulfate by IC)/(sulfur by XRF)] is about 3, which indicates that almost all of the fine particle sulfur is in the form of sulfate.

Accurate measurement of particulate nitrate requires the removal of gas phase nitric acid prior to particle collection. It also requires the collection of nitrate on a nylon filter, which binds the nitric acid molecules produced during the volatilization of the collected particulate ammonium nitrate. Nylon filters are slightly alkaline and can collect nitrate quantitatively. Aqueous extracts of the nylon filters are analyzed using IC to determine the nitrate concentration. Removal of the gaseous nitric acid is achieved

by using diffusion denuders coated with alkaline substances (e.g., sodium carbonate or magnesium oxide) or the use of unanodized aluminum inlets. Previous methods, which have used PTFE or glass fiber filters for nitrate collection, are negatively biased due to ammonium nitrate loss during and after sampling. Loss of ammonium nitrate can be caused by the presence of ammonium bisulfate and similar incompletely neutralized forms of sulfuric acid collected on the filter media (Koutrakis et al., 1992). The equilibrium between particle ammonium nitrate, gaseous ammonia, and nitric acid can also be perturbed by changes in relative humidity and temperature. In addition, nitrate can be lost after sampling during sample transport and storage. To date, there is no agreement among different studies regarding the extent of nitrate loss. This disagreement stems from the fact that these results correspond to a variety of locations, meteorological conditions, and sampling methods. If the speciation sampler relies upon metallic denuders which may be used for long periods of time (e.g., more than a couple of weeks, as with the IMPROVE network), the capacity of these denuders should be determined through laboratory and field studies.

Aqueous extracts of PTFE or nylon filters are analyzed using IC to determine ammonium concentrations. Ammonium sulfate salts are very stable, so ammonium losses during sampling and storage are negligible. However, ammonium nitrate, which is an important constituent of fine particle mass, is unstable and can volatilize during both sample collection and storage as discussed above. The extent of dissociation of ammonium nitrate depends on many parameters, including temperature, relative humidity, and face velocity of the collecting filter.

Similarly, as for the rest of the ions, aqueous extracts of PTFE or nylon filters are analyzed using IC to determine the concentrations of potassium and sodium. Many precautions must be taken during the filter preparation, sampling, transport, and analysis to minimize sodium contamination of the samples. Otherwise, both laboratory and field blanks will be highly variable and sampling precision poor.

Carbonaceous Aerosols

Three classes of carbon are typically measured in ambient aerosol samples collected on pre-fired quartz-fiber filters: 1) organic, volatilized, or non-light absorbing carbon; 2) elemental or light-absorbing carbon; and 3) carbonate carbon. Carbonate-source carbon [i.e., potassium carbonate (K_2CO_3), sodium carbonate (Na_2CO_3), magnesium carbonate ($MgCO_3$), calcium carbonate ($CaCO_3$)] may be specifically determined from a second filter section after acidification. Without acidification, the determination of carbonate carbon is not specific and is detected as either organic or elemental carbon.

Two thermal-optical methods are currently in use for the analysis of carbonaceous aerosols, they are the NIOSH thermal optical transmittance (TOT) and DRI/OGC (Desert Research Institute/Oregon Graduate Center thermal-optical reflectance (TOR) methods. The NIOSH method has typically been used for analysis of diesel particulate. The DRI/OGC method has historically been used for the EPA IMPROVE (Interagency Monitoring of Protected Visual Environments) program for visibility in federal class I areas. The measurement principal is fundamentally the same; however, the methods differ with respect to analysis time, temperature profile (temperature vs. time), types of carbon speciated, and the

pyrolysis correction technique. The pyrolysis correction feature allows correction for the "char" that forms on the filter during analysis of some materials (e.g., cigarette and wood smoke). Correction for pyrolysis is made by continuously monitoring the filter transmittance or reflectance throughout the analysis.

The measurement of organic and elemental carbon is operationally-based and dependent on the specific analytical technique used. Because elemental (EC) and organic carbon (OC) are defined operationally, the details of the measurement method must be rigorously prescribed. Only one organic and one elemental carbon fraction are reported in NIOSH 5040 (total carbon is the sum of these two) and carbonate carbon as simple carbonate (i.e., not a bicarbonate) is estimated by integrating the carbonate peak (typically the fourth peak in 'thermogram'). In contrast, four types of organic carbon and three types of elemental are defined by the TOR technique. In both instances, different classes of carbon are evolved from the sample during the analysis. In the case of Method 5040, the division into two fractions reflects the purpose of the method (i.e., occupational monitoring of diesel particulate). For other applications (e.g., source apportionment), additional fractions may be appropriate provided that the applied temperature program is repeatable over time. Otherwise, the information will not be meaningful because non-constant analytical parameters can affect the classification of carbon types.

Currently, there are currently no reference standards or standardized method for distinguishing between organic and elemental carbon; therefore, differing results can be obtained for the same sample depending on the analytical method operating parameters used. The fact that a method is operationally-based does not mean it is not well-characterized or reasonably accurate. When the definition of an analyte is based solely on optical and thermal properties, the analysis is by definition an operational one. In this case, the carbon in widely different types of carbon-containing materials is collectively measured as either "organic" or "elemental" depending on these properties. A single standard is not appropriate when analytes are defined as such. Instead, the relative accuracy of different thermal methods is better addressed by examining the accuracy of total carbon measurements and ensuring that pyrolyzable organic materials used for calibration (e.g., sucrose) have no or little elemental carbon content.

Organic PM --- Semi-volatile Organic Aerosols

Particle-phase organic matter is an aggregate of thousands of individual compounds. Due to the number of organic compounds present, characterization analysis of the organic chemical composition of $PM_{2.5}$ presents a difficult challenge. No single analytical technique can characterize the multitude of organic carbon compounds present. Identification of the ideal denuder, filter media combination, sorbents and development of routine sampling and analytical methods for semi-volatile organic aerosols is complicated due to the number and variety of semi-volatile organic aerosol compounds in the atmosphere and their varying absorptive properties.

The collection of particulate organic matter can be accomplished using particulate sampling instruments equipped with quartz fiber or Teflon®-impregnated glass fiber filters. However, since many organic compounds are distributed between the gas and particle phases, additional sampling techniques are

required to measure the particle phase semi-volatile organics. This methodology is susceptible to negative (desorption of semi-volatile compounds from the particles on the filters) and positive (adsorption of gases by the filter material) artifacts. Considerable experimental and theoretical effort has been expended to understand and correct for these vaporization and adsorption effects. Denuder technology has been employed to provide a less artifact-encumbered approach for accurate determination of semi-volatile species because the gas phase is removed prior to the particulate phase (Gundel et. al 1995). A sorbent or denuder after the filter may also be employed to collect any semi-volatile material desorbed from the filter.

Positive and negative artifacts are of most concern, but there is disagreement as to the cause and extent to which they bias organic PM measurements. The estimate of artifact contributions to OC mass measurement range from -80% for volatilization bias to +50% for adsorption bias (Eatough et al.1990 and Turpin et al. 1994). Phase distributions of semi-volatile organic compounds depend not only on vapor pressure and temperature, but also on sampling conditions such as face velocity, pressure drop across the filter and sampling duration. Partitioning of organic compounds between the gas and adsorbent phases depends on atmospheric temperature, available surface area for adsorption, partitioning constant (e.g., vapor pressure), and the presence of other competing adsorbates such as water vapor (Turpin 2000). These factors can introduce substantial uncertainty in the measurements.

The amount of organic matter or OC found on the primary sampling filter is subject to many sample collection effects. Volatilization is expected to vary with pressure, since pressure drop across the filter varies with face velocity; therefore, the OC collected is expected to vary with face velocity. The variation in OC affected by face velocity and pressure drop has been studied (McDow and Huntzicker 1990, Turpin et al.1994, McDow 1999, U.S. EPA 2001). Adsorption artifacts are expected to be a function of filter type (quartz), face velocity and sampling duration. Bias introduced by adsorption of OC is greater for rural versus urban samples due to the reduced final sample concentration. The effect of this bias can be reduced by increasing the sampling volume under these conditions. Stripping of gases upstream of the sampling filter by denuders may disturb the gas-particle equilibrium of the organics, providing a driving force for volatilization. Thus, volatile losses from a filter downstream of a denuder may be greater than the volatile losses experienced by an undenuded filter. If used, the efficiency of the denuder must be known. In a system where the denuder efficiency is <100 %, corrections must be made to account for the gas phase organics passed through the denuder. It is important to determine the denuder collection efficiency for the compounds of interest over the range of conditions likely to be encountered during sampling. When sampling without a denuder, the gas phase is expected to be in equilibrium with particle phase during and after sampling. Volatilization from, and adsorption to, organic PM collected in undenuded filter samples is only expected due to changes in atmospheric concentrations or pressure (change in equilibrium) during sampling (Turpin 2000).

For quantitation of individual organic compounds the denuder, filter, and sorbent is extracted individually with a suitable organic solvent (or a combination of solvents). The extract is then analyzed

by high-resolution gas chromatography (HRGC) and gas chromatography with mass spectrometry or GC/MS (or with other specific detectors). Combined GC/Fourier transform infrared (FTIR)/MS techniques or high performance liquid chromatography (HPLC)/MS techniques are also used.

Detailed organic chemical composition of particulate-phase samples requires the analysis of several calibration standard mixtures (Rogge et al. 1991) to cover the range of compounds that may be of interest as a result of the hundreds of organic compounds that may be associated with both the gas and particle phases in the atmosphere. The availability and cost of acquiring and synthesizing the numerous analytical standards required for this analysis is problematic. Where calibration materials are not available for all target analytes, compounds that most closely match in volatility and retention time characteristics are often used. National Institute of Standards and Technology (NIST) standard reference material (SRM) 1647 has also been used as a calibration material (Zielinska et al. 1998).

$PM_{2.5}$ Continuous Speciation - nitrate, sulfate, carbon, polycyclic aromatic hydrocarbons (PAHs)

Nitrate - Ambient Particulate Nitrate Monitor

The R&P Series 8400N Particulate Nitrate monitor is a semi-continuous technique involving wet impaction and flash vaporization (at 350°C) of particles in nitrogen followed by NO_x ($NO + NO_2$) measurement via a chemiluminescent NO_x analyzer with a molybdenum converter. The monitor uses an activated charcoal denuder, a humidifier to grow particles, and an impaction/flashing strip. The measurement includes nitrate contained in the form of NH_4NO_3, KNO_3, and $NaNO_3$. The resolution of reported values is ±0.2 µg/m^3. The time resolution is 10 minutes (8 minutes for sample collection and 2 minutes for analysis). Stolzenburg and Hering (2000) measured the particle collection efficiency of this technique to be between 95 and 100% for particles above 0.1 µm. Evaporative losses for ammonium nitrate were found to be 2 ± 4%. Calibration includes the use of a zero nitrogen and NO span gas in nitrogen to calibrate the chemiluminescent NO_x analyzer and the calibration of the NO_x analyzer is automated. Collection flow rate calibration and leak checks can be performed. Liquid calibration is done with solution of NO_3^- as KNO_3 . The monitor requires very frequent maintenance to replace the flashing strips.

Sulfate - Ambient Particulate Sulfate Monitor

The R&P Series 8400S Particulate Sulfate monitor is a semi-continuous technique involving wet impaction and flash vaporization (at 600°C) of particles in air followed by SO_2 measurement using a fluorescence SO_2 analyzer. This monitor is very similar to the nitrate monitor discussed above except sulfate versus nitrate is measured. It uses an activated charcoal denuder, humidifier to grow particles and an impaction/flashing strip. The measurement resolution is 0.2 µg/m^3 and the time resolution of measurements is 4 minutes. The instrument is calibrated using zero nitrogen and SO_2 span gas in air. Collection flow rate calibration and leak checks can be performed for quality control and the calibration of the SO_2 analyzer is automated. Liquid calibration is done with a solution of SO_4^- as Na_2SO_4. As with the nitrate monitor, the sulfate monitor requires very frequent maintenance to replace the flashing strips.

Black Carbon - Aethalometer

Particulate matter aerosol is collected by the Andersen Aethalometer on a quartz filter tape as a focused spot . The light attenuation through the sample spot and a blank reference are used to determine light absorption. The absorption is converted to black carbon (BC) using an absorption coefficient. A specific attenuation of 16.6 m^2/g is the default used by the vendor to calculate BC and 12.6 m^2/g is recommended as the attenuation value for EC.. When the material collected on the spot reaches a certain value, the tape advances automatically. Both dual beam (325 and 880 nm) and multi-beam (350, 450, 571, 590, 660, 880, and 950 nm) instruments are available. Data are downloaded directly to an on-board 3.5-inch floppy disk. A detection limit of 0.05 $\mu g/m^3$ BC for a 5 minute average is reported. A time resolution of 2 seconds to 60 minutes is possible, depending on the ambient concentration; 10 minutes is typical (vendor default). Only calibration of the collection flow rate is possible using a NIST-traceable device. This monitor requires very little maintenance and can perform for months with little operator involvement. Since no BC or EC particulate standards are available for use in calibrating this monitor, only flow rate calibration is possible. During operation, there are regular, short intervals of missed data during the period when the tape is advancing.

Organic and Elemental Carbon Analyzer

The R&P 5400 carbon analyzer provides an automated thermal CO_2 method. Carbon is collected on a stainless steel impaction plate (0.14µm cut point and flow rate of 16.7 L/min). The carbon is then oxidized at elevated temperatures. The temperature profile is defined by the user. A non-dispersive infrared (NDIR)-CO_2 detector measures the amount of carbon released during oxidation. Organic and elemental carbon (OC/EC) are determined by the use of an intermediate oxidation temperature (default of 340°C). The EC measurement is obtained by the difference between the total carbon measurement and the "low temperature" organic carbon measurement provided by the instrument. Data can be download through an RS232 connection to a laptop computer with DOS or Windows-based software. The detection limit is 0.2 $\mu g/m^3$ for 2 hour resolution. The time resolution is a minimum of 1 hour, 2 hour nominal, depending on the ambient concentration. An elevated baseline operation temperature of 50°C may volatilize OC. This instrument has been shown to provide relatively good correlation with filter-based methods, but low recovery of OC and TC. The 5400 collection flow rate is calibrated with a flow standard. The CO_2 detector is calibrated using zero and CO_2 span gas; leak checks are also performed. Zero and span calibration can be manual or automated. The 5400 requires very little maintenance; however, a large amount of technical and mechanical knowledge is needed to maintain and repair the unit when required and it requires a 240V power supply to the monitoring station.

Particle-bound Polycyclic Aromatic Hydrocarbon (PAH) Monitor

The EcoChem Photoelectric Aerosol Sensor (PAS) 2000 works on the principle of photoionization of particle-bound polycyclic aromatic hydrocarbon (PAH). The aerosol flow is exposed to PAH-specific UV radiation. Electrons are emitted by PAH molecules on the aerosol surface and an electric field is applied to remove electrons. The remaining positively charged particles are collected on filter inside the electrometer where the charge is measured. The resulting electric current establishes a signal

proportional to concentration of total particle-bound PAH. A lower threshold of 3 ng/m^3 total particle-bound PAH is achieved. The time resolution of the monitor is continuous, with less than 10-second response time (adjustable). Source-specific calibration curves are available or can be generated by comparing monitor output to analytically determined PAH concentration. Compound-specific calibration is not performed.

The PAS 2000 is very easy to operate. The instrument responds to 3, 4, and 5-member ring PAHs only and provides a total PAH concentration, no differentiation between the PAH compound types is provided. The monitor is somewhat temperature sensitive and requires "shielding" from sunlight. No other significant interferences have been identified.

Hazardous Air Pollutants

Particle-bound Metals

For the Air Toxics Pilot Monitoring Program, Compendium Method IO-3, "Chemical Species Analysis of Filter- Collected Suspended Particulate Matter", and IO-3.5, "Determination of Metals in Ambient Particulate Matter Using Inductively Coupled Plasma/Mass Spectrometry, ICP/MS" is being used for measurement of arsenic, beryllium, cadmium, chromium, lead, manganese, mercury, and nickel. Particle sampling can include $PM_{2.5}$ to focus on the fine fraction of suspended particles, PM_{10} or total suspended particulate (TSP) by using a high- volume (hi-vol) sampling system to permit analysis of metals among all suspended particulate matter. Some valence-specific metals, like chromium VI (hexavalent chromium) have been identified as having high toxicity and would require separate chemical analyses. These chemicals could be collected with the same particulate matter samplers, a different filter medium and would be analyzed with more specific analytical techniques.

There are designated methods for the lead NAAQS and the procedures for lead measurements are outlined in 40 CFR, Part 50 Appendix G, "Reference method for the determination of lead in suspended particulate matter collected from ambient air". Although the procedures are very similar to the Compendium IO method, consideration must be given to the use of the reference method procedures when collecting lead data for compliance purposes. Glass fiber filters are specified for the lead reference method; however, other filter materials like quartz are used depending on the target metal analytes. Whatever filter medium is selected, a representative sample must be analyzed to determine whether background concentrations of the target metals are acceptable.

The choice between filter extraction procedures or total dissolution for metals is important. Total metals (dissolution) indicates that the particulate and its matrix, as well as the filter, are completely dissolved and results in a clear solution. This usually results in a fairly high level of solids in solution and is often more difficult to analyze. Glass and quartz fiber filters would required the use of hydrofluoric acid (HF) which means a more difficult and dangerous extraction process. "Extractables" are just the compounds of the metal that dissolve into the solution used for extraction. Different metal compounds are extracted with nitric acid than with hydrochloric acid, or combinations, and the amounts will vary depending on whether a hot plate, microwave or ultrasonic bath is used. Using different extraction methods can

complicate the interpretation of the data. Total metals determination is considered more costly, difficult to perform and subject to greater background interference. Hot acid extraction with HNO_3 / HCl to determine "extractable" metals is the procedure used for the Toxics Pilot Monitoring Program.

Volatile Organic Compounds (VOCs)

For the Air Toxics Pilot Monitoring program, Compendium Method TO-15, "Determination of Volatile Organic Compounds in Air Collected in Specially-Prepared Canisters and Analyzed by Gas Chromatography/Mass Spectrometry (GC/MS)" or TO-14A, "Determination of Volatile Organic Compounds (VOCs) in Ambient Air Using Specially Prepared Canisters with Subsequent Analysis by Gas Chromatography" are standard EPA methods used. These methods provide for collection of volatile organic compound (VOC) HAPs, including most of the 14 VOCs on the 33 Urban Air Toxics Strategy HAPs list. Compendium Method TO-15 is an extension of the Method TO-14 description in the following ways: TO-15 incorporates a multisorbent/dry purge technique for water management, thereby providing for a more extensive set of compounds (e.g., oxygenated). Compendium method TO-15 uses the GC/MS detection technique versus multiple-detectors as the only means to identify and quantify target compounds. The GC/MS approach allows for specific detection of the target analytes and reduces the chance for misidentification or the effects of coeluting compounds. The use of non-specific detectors (e.g., FID, ECD) or a combination of these detectors, used in TO-14, is determined by the required specificity and sensitivity of the application for specific target analytes. While non-specific detectors are in some cases more sensitive than specific detectors, they vary in specificity and sensitivity for a specific class of compounds. Trade-offs in sensitivity between non-selective multiple detectors and GC/MS can be somewhat mitigated by the use of ion trap technology versus full scan quadrupole MS. Detection of typical urban concentration levels generally requires that samples be passed through a preconcentration "cold-trap" to concentrate the compounds of interest and separate them from components of the sample that are not of interest (i.e., air, methane, water vapor, and carbon dioxide).

Semi-Volatile Organic Compounds (SVOCs)

The Toxic Compendium Method TO-13A, "Determination of benzo(a)pyrene and other Polynuclear Aromatic Hydrocarbons in Ambient Air Using Gas Chromatography with Mass Spectrometry" provides for the collection and analysis of PAHs. This method covers one HAP, polycyclic organic matter (POM) which is a group of compounds on the Urban Air Toxics Strategy 33 HAPs list. POM is represented by seven polynuclear aromatic hydrocarbons (PAHs), including benz(a)anthracene, chrysene, benzo(b)fluorathene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene and dibenz(a,h)anthracene.

A summary of the method and issues given below are taken from the Compendium Method TO-13A. To measure PAHs, filters and sorbent cartridges (containing PUF or XAD-2®) are cleaned in solvents and vacuum dried. The filters and sorbent cartridges are stored to protect them from. Air is drawn through the filter and sorbent cartridge using a high-volume air sampler. The filters and sorbent cartridge are extracted and then the extract is concentrated, followed by silica gel cleanup using column

chromatography to remove potential interferences. The eluent is further concentrated, then analyzed by GC/MS. A wide variety of sorbents such as Tenax®, XAD-2® and polyurethane foam (PUF) have been used to sample common PAHs. All sorbents have demonstrated high collection efficiency for Benzo (a) pyrene in particular. In general, XAD-2® resin has a higher collection efficiency for volatile PAHs than PUF, as well as a higher retention efficiency. PUF cartridges, however, are easier to handle in the field and maintain better flow characteristics during sampling. Likewise, PUF has demonstrated its capability in sampling organochlorine pesticides, polychlorinated biphenyls, and polychlorinated dibenzo-p-dioxins. PUF also has demonstrated a lower recovery efficiency and storage capability for naphthalene than XAD-2®. Consequently, while the literature cites weaknesses and strengths of using either XAD-2® or PUF, this method includes the utilization of PUF as the primary sorbent. The GC/MS method is applicable to the determination of PAHs compounds involving three member rings or higher. Naphthalene, acenaphthylene, and acenaphthene have only ~35 percent recovery when using PUF as the sorbent. Nitro-PAHs have not been fully evaluated using this procedure; therefore, they are not included in this method. (Ref - TO-13A)

The detection limits for the GC/MS method range from 1 ng to 10 pg. Particulate-phase PAHs will tend to be lost from the particle filter during sampling due to volatilization. Therefore, separate analysis of the filter will not reflect the concentrations of the PAHs originally associated with particles, nor will analysis of the sorbent provide an accurate measure of the gas phase. Consequently, this method calls for extraction of the filter and sorbent together to permit accurate measurement of total PAH air concentrations. Naphthalene, acenaphthylene, and acenaphthene possess relatively high vapor pressures and may not be efficiently trapped by this method when using PUF as the sorbent (Ref - method TO-13A)

Continuous Formaldehyde

The Alpha-Omega Power Technologies Methanalyzer is a continuous formaldehyde monitor and is based on the principles of the Hantzsch reaction. This is a fluorometric method, which involves the reaction of an amine, and aldehyde, and a $-diketone (2,4-pentanedione) to form a dihydropyridine derivative. The air sample stream is directed through the annulus formed from a single strand of Nafion® tubing and a cylindrical housing. Water is passed through the tubing as formaldehyde from the sample air stream is captured on the outside surface of the Nafion® and then diffused through the tubing and into the water stream flowing through the tube. The acid in the Nafion® tube helps to form a glycol. The glycol is then reacted with ammonium acetate and 2,4-pentanedione in a reactor at a temperature of 90/C to form a fluorescent product. The light caused by fluorescence is detected by a fluorescence detector. The instrument collects data every 10 minutes, 7 minutes over which zero air from a zero air generator is delivered to the inlet of the unit and 3 minutes over which ambient air is pulled into the instrument. Calibration is performed by mixing known flow rates of 5 ppmv of formaldehyde in nitrogen with a known flow rate of zero air from the generator to establish a span and zero level. A permeation tube device may also be used for gas calibration. The Methanalyzer is in the initial phases of field testing and evaluation by the Office of Research and Development.

The monitor uses a wet chemical technique that poses some issues with operation and maintenance. Regular maintenance includes filling the liquid reservoirs at least once per week and replacing the liquid pump tubing on a regular basis. The monitor is also susceptible to leaks and the formation of bubbles which interfere with the collection of data. Gas calibration can be done using either a gas cylinder of formaldehyde or a permeation tube. Liquid calibration can also be done using solutions of formaldehyde; however, liquid calibration does not check the inlet and formaldehyde scrubbing device and is mostly used for troubleshooting purposes.

Continuous Non-Methane Hydrocarbons (NMHC)

Thermo Environmental offers the Model 55C Direct Methane, Non-Methane Hydrocarbon Analyzer based on the principles of gas chromatography. The Model 55C provides an automated continuous measurement of methane and non-methane hydrocarbons in air. With an flame ionization detector (FID) and proprietary column design, the Model 55C can achieve detection limits of 50 ppb or less for both methane and non-methane hydrocarbons. Total analysis time is less than 70 seconds. The Model 55C incorporates a back-flushed gas chromatography system that allows for measurements of NMHCs at sub-ppm concentrations. In addition, the Model 55C can achieve complete separation of methane from the C_2 compounds, is unaffected by the oxygen content of the sample, and provides recovery of low volatility compounds.

A common problem encountered is the contamination of the analytical column, which manifests itself as both an elevated baseline and noise. This is resolved by conditioning the column at elevated temperature for several hours to remove the contaminants.

Continuous Carbon Monoxide (CO)

Carbon monoxide (CO) is one of the criteria pollutants which is also important as a precursor to ozone and a useful tracer for products of incomplete combustion from any carbonaceous fuel. Power plants and other large furnaces are usually designed and operated to provide nearly complete combustion and do not emit much CO; therefore, the major source is thought to be the transportation sector (Cooper and Alley, 1994). The additional importance of CO for purposes other than the NAAQS makes detection at levels well below the NAAQS very desirable. Although commercial CO monitors were designed to meet the performance specifications required for NAAQS, several instruments have the potential for much greater sensitivity. Modifications of commercially available non-dispersive infrared (NDIR) monitors have been made to enhance their performance (Dickerson and Delany, 1988; Parrish et al., 1994), but the manufacturers have continued to improve instruments and offer “high-sensitivity” options that could meet the requirements of monitoring non-urban air (i.e., a detection limit of about 50 ppb and resolution of 10 ppb). The principal constraints on lower detection limits of commercially available NDIR CO monitors are detector noise, water vapor interference, and background drift. (Criteria document)

There are 15 automated reference methods designated for CO compliance measurements.(ref list of designated FRMs) All of these methods incorporate the NDIR technique and include gas filter

correlation (GFC). The NDIR technique is based on the principle of absorption of infrared radiation by the CO molecule. Carbon monoxide has a characteristic infrared absorption near 4.6 nm. The absorption of infrared radiation at this wavelength can be used to measure the CO concentration in the presence of other gases. Nondispersive infrared systems have several advantages. They are not sensitive to flow rate, they require no wet chemicals, they are reasonably independent of ambient air temperature changes, they are sensitive over wide concentration ranges, and they have short response times (ref criteria document). Gas filter correlation spectroscopy analyzers are used most frequently in determining compliance with ambient air standards.

A GFC monitor (Burch et al., 1976) has the advantages of an NDIR instrument and the additional advantages of smaller size, no interference from CO_2, and very small interference from water vapor. During operation, air flows continuously through the sample cell. Radiation from the source is directed by optical transfer elements through the two main optical subsystems: (1) the rotating gas filter and (2) the optical multi-pass (sample) cell. The beam exits the sample cell through an interference filter, which limits the spectral bandpass to a few of the strongest CO absorption lines. Detection of the transmitted radiation occurs at the infrared detector. The gas correlation cell is constructed with two compartments: one is filled with 0.5 atm CO, and the second is filled with pure nitrogen. Radiation transmitted through the CO is completely attenuated at wavelengths where CO absorbs strongly. The radiation transmitted through the nitrogen is reduced by coating the exit window of the cell with a neutral attenuator so that the amounts of radiation transmitted by the two cells are made approximately equal in the bandpass that reaches the detector. In operation, radiation passes alternately through the two cells as they are rotated to establish a signal modulation frequency. If CO is present in the sample, the radiation transmitted through the CO cell is not changed, whereas that through the nitrogen cell is changed. This imbalance is linearly related to CO concentrations in ambient air. (Ref criteria document)

Water vapor produces a negative artifact such that a volume mixing ratio of 1% would reduce the apparent CO mixing ratio measurement by 50 ppb. This interference can be reduced by drying the sample air with a cold trap, desiccant, or Nafion® drying tube (Dickerson and Delany, 1988). Alternatively, the zero can be checked frequently enough so that changes in ambient humidity are unlikely to produce a significant error (Parrish et al., 1994). The greatest source of potential error in monitoring CO in the 0.1-ppm range is background drift. The stability of the instruments with respect to changes in calibration (span) is adequate, but the background (zero) drifts on time scales of minutes to hours in response to, among other factors, instrument temperature. This drift can be accounted for most easily by frequent chemical zeroing with a oxidizer that converts CO to CO_2 (criteria document).

Continuous Gas-phase Mercury

Continuous monitoring instrumentation is commercially available and somewhat expensive for both total and reactive gaseous mercury (RGM) monitoring. The Tekran® Model 2537A ambient mercury vapor analyzer provides continuous ambient monitoring of total gaseous mercury with a detection limit of about 0.1 ng/m^3. The basic principle of operation is the preconcentration by amalgamation onto patented pure gold collector cartridges, followed by thermal desorption and detection via cold vapor

atomic fluorescence spectrophotometry. The time resolution of each measurement is 2.5 minutes.

The Tekran® Model 1130 Mercury Speciation unit works in conjunction with the Model 2537A to simultaneously provide elemental and reactive gaseous mercury in ambient air. The majority of mercury present is in the elemental form; however, differentiation is important for support to modeling efforts and determination of deposition rates. The Model 1130 contains a heated, KCl-coated quartz annular denuder to capture reactive mercury while allowing the elemental mercury to pass through to the Model 2537A. During sampling (denuder absorption phase), the Model 2537A provides real-time measurements of the elemental mercury. During analysis (denuder desorption phase), the denuder is flushed with zero air and heated to desorb the captured reactive mercury in the reduced elemental form. The Model 2537A detects this eluted mercury and provides a total reactive mercury measurement. The time resolution of the Model 1130 Speciation unit is one reading per hour.

It is recommended that particulate mercury be collected in conjunction with gaseous elemental and RGM to provide a complete picture of the atmospheric behavior of mercury for modeling and emission inventories purposes. Particulate mercury can be collected by supplementing the above units with the Tekran 1135 for capture on quartz filters. An RGM artifact formation on quartz filters collected for particulate mercury has been identified which is resolved through the use of the KCl- coated annular denuder before the quartz filter (Landis).

Ozone and Particulate Matter Precursors

Ozone

Generally, there are three techniques available for the determination of ozone in ambient air. They are chemiluminescence, ultraviolet (UV) photometry and Differential Optical Absorption Spectrometry (DOAS). The chemiluminescence method is a Federal Reference Method (FRM) and the UV and DOAS are Federal Equivalent Methods (FEMs). The UV method has become very popular and used prevalently throughout the NAAQS monitoring network for ozone. The UV method has been selected most often due to simplicity of operation and cost. There are several manufacturers of monitors to provide the UV methods and only one vendor of both the chemiluminescence and DOAS systems.

Chemiluminescence

The energy releasing process of chemiluminescence produces light by the chemical reaction of ozone and ethylene. The intensity of the light produced is proportional to the concentration of ozone. The concentration of ozone is determined from a measurement of the amount of light absorbed by the sample at 254 nm. Chemiluminescence with compounds other than ethylene can be used to measure ozone (e.g., eosin-Y, Rhodamine B organic dye). The use of Rhodamine B organic dye is the only other compound considered an FEM. There is advantage to the simplicity of this approach; however, a high pressure cylinder of ethylene is required.

Commercial chemiluminescence monitors are no longer “readily available”. There are very few vendors of commercial systems. Water vapor is known to interfere with chemiluminescence monitors. Data from

interference testing with ozone and humid air suggests that the magnitude of interference is 0.0003% per ppmv water. Water vapor interference testing has yet to be done with ozone and ambient (polluted) air.

Ultraviolet (UV) Photometry

The analytical principle is based on the absorption of UV light by an ozone molecule and the subsequent use of photometry to measure reduction of the light reaching the detector at 254 nm. Frequently the UV light source is a 254-nm emission line from a mercury discharge lamp. The detection limit for ozone is 0.005 ppm. UV monitoring devices are the most popular and used throughout the ozone NAAQS monitoring network, likely due to simplicity and ease of use.

Gaseous hydrocarbons with strong absorption at the 254-nm wavelength, such as aromatic hydrocarbons (i.e., benzene and substituted benzene rings), provide an interference. The most common interferences are water vapor, aromatic hydrocarbons, and mercury. Monitoring in areas where high levels of mercury and aromatic hydrocarbons exist is not recommended. Whether there is a “true” interference with water vapor is still controversial. Issues with erratic and sometimes noisy readings and a cycling monitor baseline have been identified by a few state agencies, but the cause of these anomalies have yet to be reproduced or positively identified. Theories have revolved around the specific type of scrubbing device typically used in the zero side of the monitor. The scrubber must remove 100% of the ozone while quantitatively passing other gases that absorb at 254 nm. Some gases, however, may be partially or temporarily absorbed or adsorbed by the scrubber, such that their concentration is not equal in both measurements. An interference can occur when a gas absorbs at 254 nm or produces some other physical effect (such as water condensation on scratches in the cell window), and does not pass freely through the ozone scrubber. Hence, proper scrubber performance is critical to minimizing interferences.

A recently developed scrubber containing heated silver wool, instead of the standard manganese dioxide, has been tested to determine its improvement to the effects of certain interferences. Test were conducted using hydrogen sulfide, mercury, o-cresol, and o-nitrotoluene at varying levels of humidity (high and low). Hydrogen sulfide and o-cresol had no effect on the scrubber efficiency at the concentrations and humidity tested. Interference was found for o-nitrotoluene at low humidity and mercury at both low and high humidity. The heated silver wool scrubber solved some, but not all of the interference issues with this technique.

Differential Optical Absorption Spectrometry (DOAS)

Differential Optical Absorption Spectrometry measures the absorption through an atmospheric path length (typically 0.5 to 1.5 km) of two closely spaced wavelengths of light from an artificial source. One wavelength is chosen to match an absorption line of the compound of interest, and the other is close to but off that line, and is used to account for atmospheric effects. The term "absorption line" is used to mean the wavelength at which a given atom or molecule absorbs more than it does other wavelengths. Thus, if a compound of interest were ozone, a wavelength would be identified for which ozone in particular absorbs more than at other wavelengths. A light beam containing this particular wavelength

would be directed through a path of the atmosphere, and the amount of the wavelength absorbed would be measured. The result would indicate how much ozone was present in that path. A separate wavelength, varying slightly from the first, would be directed through the same path, and its absorption would be compared with the first wavelength results to determine absorption probably not due to ozone. This technique provides a comparison absorption level to improve accuracy in measuring the amount of radiation absorbed by the target molecule.

DOAS instruments are relatively expensive to implement for a single pollutant like ozone. Anything that interrupts the path of the laser will cause some interference (i.e., animals, cars, etc.). In open path DOAS applications, interference by miscellaneous atmospheric constituents is likely to be a problem. For example, in detecting ozone, oxygen is likely to interfere in the region below 270 nm. Sulphur dioxide has a strong absorption effect in the vicinity of 300 nm, and also presents interference, although weak, at 283 nm (Axelsson et al., 1990). Another example of species interference would be NO and NO_2 interfering with detection of nitrous acid (Vecera and Dasgupta, 1991). Heavy rain and fog, and even high humidity, have been found to interfere with the xenon lamp beam propagation, and to make absorption measurements impossible. The use of heaters on the lenses does not entirely solve this problem. However, it only becomes serious in very extreme conditions (Stevens et al., 993). In long path uses of UV light beams, atmospheric turbulence, such as that from thermal-induced effects, can distort reflections. One approach to solving this problem has been to use an extensive array of photodiode type receivers, but these arrays must all be calibrated, and can suffer from differences in surface coatings. Turbulence can be approached with other strategies, such as slotted disks, and new systems can be developed with these strategies (Edner et al., 1993).

Oxides of Nitrogen (NOx)

NO and NO_x are typically measured using chemiluminescence, which is designated as the Reference method for determining NO_2 in ambient air. Although NO is determined directly, NO_2 is estimated by difference (subtracting NO from the estimated sum of NO and NO_2 or NO_x.). Because of interferences, typical chemiluminescent monitoring systems often overestimate the actual NO_x concentration. The chemiluminescence approach is based on the gas-phase reaction of NO and O_3. This reaction produces a characteristic near-infrared luminescence which has an intensity that is proportional to the concentration of NO. To determine the concentration of NO by chemiluminescence, the sample gas flow is blended with O_3 in a reaction chamber causing photolysis to occur. The chemiluminescence that results from the reaction is monitored by an optically filtered high-sensitivity photomultiplier. The optical filter and photomultiplier respond to light in the wavelength band characteristic of the NO_2 chemiluminescence emission (i.e., longer than 600 nm wavelength). The electronic signal produced in the photomultiplier is proportional to the NO concentration in the sample air. To determine the concentration of NO_x (NO + NO_2), the sample gas is routed through a converter in which the NO_2 is converted to NO. The sample gas is then blended with O_3. The resulting chemiluminescent response is proportional to the sum of the original NO in the sample air and the NO formed from the conversion of the NO_2. Thus, NO_2 determination is not the result of direct measurement. Instead, the concentration of NO_2 is calculated as the difference between a measured

NO_x value and a corresponding measured NO value.

There are two types of NO_2-to-NO converters: the chemical reductant converter and the photolytic converter. The chemical reductant converter uses a reducing agent such as hot molybdenum metal, or carbon monoxide or hydrogen reacting on a heated gold surface, to convert NO_2 to NO. The photolytic converter uses high-energy light to perform the conversion. In the chemical reductant converter, a chemical reaction reduces NO_2 to NO; in the photolytic converter, NO_2 is decomposed by photolysis to produce NO. Nitrogen oxides monitors that use chemical reductant NO_2 converters measure NO, NO_2 and NO_x accurately as long as no other nitrogen oxide species are present in the sample air. However, numerous other compounds present in ambient air may be converted to NO by the reductant converter, resulting in a positive bias in the measurement of NO_x and consequently in NO_2.

The commercial nitrogen oxides analyzer used should have sufficient sensitivity and measurement range to encompass the ambient NO_x levels encountered in both urban and rural settings (i.e., typically from as low as 2 to over 100 ppbv). A desirable feature of a NO_x monitor is the capability for the instrument to automatically change measurement ranges as the ambient levels rapidly change. Overheating of the molybdenum converters should be avoided. Converter temperatures above 350ºC do not enhance NO_2 conversion, and may result in slight conversion of ammonia and other non-nitrogen oxide species to NO.

Total Reactive Oxides of Nitrogen (NO_Y)

Ambient NO and NO_y concentrations are determined by photometrically measuring the light intensity at wavelengths greater than 600 nanometers from the chemiluminescent reaction of NO with O_3. This principle is identical to that on which the measurement of NO and NO_x is based.

To measure NO_y, sample air is passed through a probe-mounted chemical reductant converter, and the nitrogen oxide compounds present are reduced to NO. The NO resulting from the reduction of these nitrogen oxide compounds, plus any native NO, is reacted with O_3 and the resulting chemiluminescent light is measured as the total NO_y concentration. To measure NO separately and specifically, sample air is passed around the chemical reductant converter so that no reduction of the other nitrogen oxide compounds to NO occurs. The NO (i.e., native NO only) is reacted with O_3 and the resulting chemiluminescent light intensity is proportional to the NO concentration. The primary differences between this method as implemented for NO_y monitoring and as implemented for NO_x monitoring are in the location of the converter and the calibration procedures used. The converter location is designed to convert all NO_y species to NO immediately upon entry of sample air into the sampling system. This approach minimizes loss of NO_y constituents, such as HNO_3, and assures complete capture of the total NO_y. Calibration procedures for NO_y monitoring go beyond those used for NO_x monitoring, in that a difficult-to-convert organic nitrate compound (e.g., n-propylnitrate) is needed to provide a more stringent test of converter efficiency.

Measuring NO_y is a valuable adjunct to NO and NO_x monitoring because the individual species comprising NO_y include not only NO and NO_2, but also other organic and inorganic nitrogen oxide compounds that constitute a more complete measure of nitrogen oxides emissions. Determining NO_y concentrations is useful in establishing nitrogen oxide emission patterns and temporal trends, and in assessing the photochemical "age" and reactivity of air masses. Guidance on measuring NO_y, including measurement principles, calibration procedures, and equipment descriptions, have been prepared for PAMS. The diverse nitrogen oxide compounds that comprise NO_y have not all been individually identified. NO_y includes all of the nitrogen oxide compounds that react or are formed in the lower atmosphere and contribute to the photochemical formation of O_3 and the transport and ultimate fate of nitrogen oxides. NO_y constituents that have been identified include: NO, NO_2, NO_3, PAN, nitrous acid (HONO), organic nitrates and nitrites, nitrate radical (NO_3^-), nitrogen trioxide (N_2O_3), nitrogen pentoxide, (N_2O_5), halogen-nitrogen species such as $ClONO_2$ and $BrONO_2$, and aerosol nitrates. Thus NO_y is the sum of NO_x and all other reactive nitrogen oxides. In typical urban environments, the principal NO_y compounds are NO, NO_2, HNO_3, and PAN.

It is not possible to measure individually all the compounds that comprise ambient NO_y. Even measuring several key NO_y constituents is expensive and technically difficult. However, the chemiluminescence monitoring approach for NO and NO_x described above is a practical approach to determining the total NO_y level, once the converter has been moved as close to the inlet as possible. For consistency in measurements, NO_y should be measured in a practical and standardized manner. Instruments used to measure NO_y should be sensitive enough to measure the low concentrations typically encountered during the late afternoon as well as the high concentrations encountered during the early morning hours of the day. Automatic measurement range changing will more reliably accommodate the range of NO_y concentrations experienced in a typical urban atmosphere. It is recognized that NO_y measurement is an emerging technology and as advances in the technology are made, the methods should be updated.

Volatile Organic Compounds (VOCs) - PAMS Ozone Precursors

The basic operating principle of the gas chromatography with flame ionization detection (GC/FID) methodology is used to measure ambient VOCs. Gas chromatography with FID is an established analytical technique for monitoring VOCs in ambient air. The sensitivity, stability, dynamic range, and versatility of GC/FID systems make them extremely effective in measuring very low concentrations of hydrocarbons. Detection of typical urban concentration levels
generally requires that samples be passed through a preconcentration "cold-trap" to concentrate the compounds of interest and separate them from components of the sample that are not of interest (i.e., air, methane, water vapor, and carbon dioxide). The time of elution and detection (retention time) by FID is the primary basis for the identification of each compound. The identification of sample components is determined by matching the known retention times of the components in a retention time standard with those in the sample. It is desirable to confirm GC peak identification periodically using a mass spectrometric detector, if available.

Although the peak identification and quantification expected with GC/FID systems is acceptable for meeting the objectives of PAMS, the GC/FID technique has some inherent limitations. Chromatographic systems using GC/FID rely primarily on the practical use of retention times to make compound identifications for each chromatographic peak. Commercial GC/FID systems configured for VOC analyses must be suitably designed to provide stability of system parameters to ensure consistent retention times for confident peak identification. Gas chromatographic peak misidentifications typically occur as a result of retention time shifting and interferences due to co-eluting non-target compounds. Concentration estimates for substituted hydrocarbon species such as oxygenated or halogenated hydrocarbons using FID are uncertain since these compounds do not respond to the FID solely on a per carbon basis. Generally, the identification and quantification of a targeted compound will not be significantly affected unless a substituted species, at a significant concentration, co-elutes with the target compound. Quantitative errors can be reduced by careful attention to quality control (calibration details and system blanks), frequent response checks using canister samples containing target compound mixtures of known concentration, and periodic performance audits or proficiency studies using independent reference materials.

The effects of moisture must be considered in any measurement program where sample concentration is required. Cryogenic concentration techniques are commonly used, especially for light hydrocarbons. The vast difference in boiling points of the C_2 and C_{12} hydrocarbons also may require the use of sub-ambient chromatography to adequately separate the entire range of compounds. The co-collection of moisture in the concentration trap and subsequent injection of water onto the analytical column can cause a number of problems and adversely affect the overall quality of the data generated. Moisture removal from the sample stream prior to sample concentration minimizes these problems and also allows larger sample volumes to be concentrated, thus providing greater detection sensitivity. Moisture related problems can be alleviated by various water management methods; however, some methods used to remove moisture from the sample may result in the loss of polar VOCs which affects the total non-methane organic compound (TNMOC) measurement. This effect is variable, based on drier efficiency and compound selectivity.

Carbonyls

The measurement method for carbonyls is based on U.S. EPA Compendium Method TO-11A, "Determination of Formaldehyde in Ambient Air Using Adsorbent Cartridge Followed by High Performance Liquid Chromatography", which incorporates the use of sorbent cartridges coated with 2,4-dinitrophenylhydrazine (DNPH) for sample collection.[(REF)] The analyses are performed with high performance liquid chromatography (HPLC). The two sorbents described in the compendium method are silica gel and octadecylsilane bonded silica substrate (C18). For consistency, silica gel is recommended for use in EPA programs. Currently, numerous State, federal, and private laboratories are conducting carbonyl sampling and analytical activities. However, there are concerns about the existing carbonyl database and data quality in general. The mechanical integrity of field sampling devices and the lack of field audit and sampling protocols are key issues for carbonyl measurements. One concern is the failure of aging carbonyl sampling equipment as a result of leaks, which are often

extremely difficult to detect and may go unnoticed until data quality or other quality assurance/quality control (QA/QC) results indicate a problem. Collocated sampling with duplicate equipment is one QA/QC approach to evaluate sampling abnormalities, but State agencies often do not have the necessary extra equipment to perform this check. Current performance audits for the carbonyl analysis typically employ a DNPH-silica gel cartridge spiked with selected carbonyl derivatives. National Institute of Standards and Technology (NIST) gas-phase carbonyl standards are not currently available for method calibration and bias determinations. Consequently, until these standards are available, the integrity of carbonyl sampling equipment cannot be completely tested.

Suitable QA/QC procedures are particularly important in light of discrepancies observed among nominally identical carbonyl sampling and analytical systems operating at some PAMS sites. The present carbonyl sampling methodology could benefit from the development of procedures to enhance sampling precision and accuracy. Greater standardization of sampling and analysis techniques should result in better data comparability from different sites, more consistent assessment of data quality, and better estimation of seasonal and long-term trends in air quality.

The presence of ozone in ambient air interferes with the measurement of carbonyl compounds when using Method TO-11A. The extent of interference depends upon the ambient concentration of both ozone and the carbonyl compounds, and on the duration of sampling. Carbonyl compound losses can be as high as 50 percent on days when the ambient ozone concentration reaches 120 ppbv.[ref] As a result, an ozone scrubber must be used for carbonyl sampling and it must be properly maintained. Two types of scrubbers have been developed ! the heated ozone denuder and the ozone cartridge scrubber. Both scrubbers use potassium iodide (KI) as the scrubbing agent, and their designs effectively allow for the removal of ozone at sampling flow rates up to 1 liter/minute.

Acrolein issue: It is important to note that acrolein cannot be measured using method TO-11A due to issues with poor recovery and instability. If acrolein must be measured then consideration must be given to the use of other methods.

<u>Sulfur Dioxide</u>

Sulfur oxides (SO_x) are caused by burning any material that contains sulfur or sulfur itself. The primary sulfur oxide is sulfur dioxide (SO_2) and it is one of the criteria pollutants and measured for compliance purposes. There are several automated reference methods designated for SO_2 compliance measurements.(ref list of designated FRMs). The manual FRM is based on bubbling a measured volume of ambient air through a solution of 0.04M potassium tetrachloromercurate (TCM). The SO_2 present in the air reacts with the TCM solution to form a stable mercurate complex. This complex is stable in the presence of strong oxidants such as ozone and NO_x. During subsequent analysis, the complex is reacted with acid-bleached pararosaniline dye and formaldehyde to form an intensely colored sulfonic acid. The optical density of this species is determined spectrophotometrically at 548 nm and is directly related to the amount of SO_2 collected. The lower limit of detection is 13 $\mu g/m_3$ in air sampled at 288 standard liters. Lower concentrations can be measured by sampling larger volumes of

air; however, the collection efficiency falls off rapidly at low concentrations. The effects of principal and potential interferences to this method have been minimized or eliminated. Measurements of SO_2 suffer the same issues with sensitivity in rural areas as CO. See the CO discussion for more information regarding this issue.

Nitric Acid and Ammonia

Method IO-4.2, "Determination of Reactive Acidic and Basic Gases and Strong Acidity of Atmospheric Fine Particles" can be used to determine nitric acid and ammonia in ambient air. The quantitative measurement of reactive acidic and basic gases and strong acidity of atmospheric fine particles in ambient air using annual denuder technology is described in this method. The difference between. Inorganic Compendium Methods IO-4.1 and IO-4.2 is that the latter accounts for possible interference from the dissociation of ammonium nitrate aerosol from particles collected on the filter. Consequently, an accurate and quantitative value for determining strong acidity of atmospheric fine particle is calculated. The chemical species that can be determined by this method are gaseous SO_2 , HNO_2 , nitric acid, and ammonia and particulate
$SO^{=}$, nitrate, ammonium and hydrogen ion.

The annular denuder system (ADS) consists of an inlet with an impactor or cyclone preseparator designed to remove all particles with a diameter (aerodynamic) of 2.5 :m or greater, an annular denuders to quantitate acidic and basic gases, and a filter pack for atmospheric acidity and particles. In operation, ambient air is drawn through an elutriator-accelerator jet assembly, an impactor frit and coupler assembly, and past glass denuder walls that have been etched and coated with chemicals that absorb the gaseous species of interest. The remaining air stream is then filtered through Teflon® and Nylasorb® membrane filters. Teflon® and nylon membrane filters are used to capture ammonium and nitrate aerosol and sulfate particulate matter. Nitric acid and sulfur dioxide will also be collected by the nylon filter but these measurements are treated as interference.Following each run, the ADS assembly is removed from its field housing, its ends are capped, and it is brought back to the laboratory. The annular denuders are extracted with 5 mL of deionized water. The extracted solutions are subsequently analyzed for ions corresponding to the collected gaseous species by IC. The extracts are stored in a refrigerator at 5°C until analysis.

Reactive acidic (SO_2 and HNO_3) and basic (NH_3) gases and particles are found in the atmosphere as a result of emissions from a variety of fossil fuel combustion sources, including industrial and commercial facilities, industrial processes, etc. Measurements of these chemical species are currently being used in a range of environmental studies, such as in epidemiological programs to assess the impact of acid aerosols on respiratory impairment, receptor modeling to determine the origin of particles that impact EPA's PM2.5 orPM10 air particulate standard, assessment of the impact of particulate nitrate and sulfate on visibility, and quantification of the impact of acidic and basic air pollutants on issues related to acid rain. Unique features of the annular denuder that separate it from other established monitoring methods are the elimination of sampling artifacts due to interaction between the collected gases and particles and the preservation of the samples for subsequent analysis. This preservation is accomplished

by removing NH_3 in the gas stream by the citric acid coated denuder and reducing the probability of the particulate sulfate ($SO_4^{=}$) captured by the filter pack from being neutralized to ammonium sulfate [$(NH_4)_2 SO_4$]. If NH_3 is not extracted from the gas stream prior to filtration, particulate sulfate and gaseous sulfur dioxide correction would be required for accurate measurements. These biases in its configuration and analytical methodology are addressed in this method.

Direct or "True" Nitrogen Dioxide (NO_2)

The chemiluminescence monitor currently used for NO_2 NAAQS is supplied by several commercial vendors. See discussion above on oxides of nitrogen (NO_x). This limitation of this technique is that it does not measure NO_2 directly (done by difference) and is thought to provide a surrogate measurement for NO_2 due to the non-specific conversion process. A photolytic NO_2 converter can provide improved accuracy in determining both NO_x and NO_2. Stand-alone photolytic converters to be coupled with existing monitors have not been available from commercial vendors, but a complete system, which includes the chemiluminescence detector and software to account for the converter efficiency and photolytic chemistry, is available from Eco Physics, Inc. The relatively high cost and complexity of these converters, and the need for frequent determination of the conversion efficiency and correction of all data for incomplete conversion, make them less suitable than the conventional heated molybdenum converters for routine use. At this time, the photolytic converter is not a Federal Reference or Equivalent method for NO_2 measurements.

The use of a stand-alone photolytic converter that can be used in conjunction with NO, O_3 chemiluminescence and DOAS is the most viable techniques for direct measurements of NO_2 at this time. Direct or "specific" measurement of NO_2 can be accomplished using the ECO PHYSICS CLD 780 TR, an NO analyzer designed specifically for research. The instrument works in conjunction with a photolytic converter to detect ppt level concentrations of NO and NO_2. Sensitivity of the unit is 50 ppt in 3 seconds or 10 ppt in 60 seconds with a detection limit of 3 ppt. The unit's noise at zero is less than 25 ppt in 3 seconds (response time < 200 ms). The EPA Office of Research and Development (ORD) is currently field testing and evaluating the instrument.

Diode lasers are also an alternative and are now available in photolytic converters. EPA, ORD has purchased the first converter based on this light source an is testing the performance. At the current stage of development, the stated lifetime is an order of magnitude longer than the converters mentioned above with much lower heat generation in the photolytic cell.

Diesel PM

Diesel particulate matter (DPM), is a complex aggregate of solid and liquid material. Its origin is mainly carbonaceous particles generated during incomplete combustion of diesel fuel, engine oil and other fuel components such as sulfur. The particles generated may form larger agglomerates by combining with several other organic and inorganic components of diesel exhaust. Generally, DPM is divided into solids, a soluble organic fraction (SOF), sulfates, water and ash. The solids are "dry" carbon particles, commonly known as "soot" or elemental carbon; the SOF is comprised of heavy hydrocarbons

adsorbed and condensed onto the carbon particles; and the sulfate fraction is hydrated sulfuric acid. The actual composition of DPM depends on the particular engine and its load and speed conditions. The amount of sulfates is directly related to the sulfur contents of the diesel fuel. Diesel particles are very fine. The primary carbon particles have a diameter of 0.01 - 0.08 micron, while the agglomerated particle diameters are in the 0.08 to 1 micron range. As such, diesel particulate matter is almost totally respirable and has a significant human health impact.

Elemental carbon or "soot" has been used as an indicator of DPM. Because of the large soluble organic fraction, a measure of organic $PM_{2.5}$ constituents in addition to EC, provides a better indication of DPM. Organic PM composition and formation mechanisms are poorly understood. Due to the extremely large number of organic compounds present, characterization analysis of the organic composition of $PM_{2.5}$ presents a difficult challenge. No single analytical technique can characterize the multitude of organic carbon compounds present. Identification of the ideal denuder, filter media combination, sorbents and development of routine sampling and analytical methods for semi-volatile organic aerosols is complicated due to the number and variety of semi-volatile organic aerosol compounds in the atmosphere and their varying absorptive properties. For information regarding the issues associated with Organic PM collection and analysis, see the discussion above on Organic PM --- Semi-volatile Organic Aerosols. Polycyclic aromatic compounds (PAHs) can be emitted at significant levels from diesel engines and can also be characterized by Organic PM analysis.

In addition to elemental carbon, organic PM indicators that are thought to be good for diesel include a group of hopanes and steranes (Schauer and Turpin via email) and PAHs??? Solomon, Lewtas, Lewis?? - comments and input on this.

Fostering Development of New Technology
Role of Supersites as "breeding ground" and development platform
Vendor development?
ETV? - what does it provide and how does it fit in?

Demonstration Testing and Deployment of New Technology
Role of NCORE - on going testing and 10 daily sites
How this new technology is brought into a routine monitoring network? Don't want to develop mechanism, but just to outline what types of things should be considered.
What is EPA HQ role? What about Regions, states and locals? What about ORD?

Recommendations/Future Direction

References

Section 8. Regulatory Changes and Schedule

There are three main federal regulations that are used to provide the framework for ambient air quality monitoring, 40 CFR Parts 50, 53, and 58. These regulations cover the sampling and analytical methods used, how new methods are approved, quality assurance and control procedures, and basic monitoring objectives for certain air pollutants. Our focus in this section is on the air monitoring regulations themselves and how they may be revised to fully support the national air monitoring strategy.

Federal regulations are not particularly easy to modify; however, periodic reviews and revisions are necessary in order to create an air monitoring system that is responsive to current environmental data needs. We intend to review and modify our regulations to incorporate more continuous particle techniques, revise our national air monitoring requirements, and update the data reporting requirements to reflect the development of newer databases and electronic storage capabilities. We also intend to provide ample flexibility for State, local, and tribal agencies to address their regional or local concerns.

Specific Regulations to be Reviewed:

There are three main regulatory "Parts" of the Code of Federal Regulations (CFR) that we will investigate in our work to modify the monitoring regulations. These regulations are all part of CFR Title 40 which deals with the environment. Specifically:

40 CFR 50[1] Appendices: National Primary and Secondary Ambient Air Quality Standards (NAAQS), Appendix L. This regulation provides us with the NAAQS and the federal reference methods for measuring each air pollutant with an established standard. We are NOT going to modify the national ambient air quality standards with this regulatory review. Reviews and, if needed, revisions of the NAAQS occur in separate formal processes. We do want to review a portion of the minor requirements in the Appendix L portion of this regulation which describes the reference method for measuring PM2.5. The overall reference method will not be modified; however, we do want to reduce some of the requirements for reporting supplementary data on the samplers' performance. We have successfully completed two annual quality assurance reports on the PM2.5 FRM network operation, and we believe that we can reduce the amount of supplementary data being reported to EPA, specifically in Table L-1. This is a small textural change; however, it should provide some burden relief to State, local, tribal, and other monitoring agencies' data managers.

40 CFR 53 Ambient Air Monitoring Reference and Equivalent Methods. This regulation provides air quality monitoring instrument manufacturers with the application and testing requirements for reference and equivalent methods that must be followed in order to

[1]Regulations are cited in documents using the format "Title# CFR Part#".

have their sampler/analyzer approved for regulatory use. The EPA's Office of Research and Development (ORD) is currently responsible for these approvals. This regulation describes the complexities of how new criteria pollutant methods can be formally introduced into the ambient air monitoring network. EPA is a strong proponent of this formal process given the policy and financial impact that decisions using data from federal reference and equivalent methods can carry. We will review this regulation; however, changes to it may or may not be possible in this package. We do intend to provide for regionally-equivalent continuous particle sampler approvals, their testing and applicability requirements; however, this may need to take place with the ongoing particulate matter NAAQS review package.

40 CFR 58 Ambient Air Quality Surveillance. This regulation is the primary focus of our efforts in the national monitoring strategy. Nearly all data collection and reporting requirements, all the quality assurance requirements, the NAAQS pollutant network design criteria, the air quality index reporting, and annual data certification requirements are included within this regulation. This regulation describes how the Clean Air Act air monitoring authority has been interpreted and implemented by the EPA and our State and local agency partners for air pollutants with established NAAQS. Tribal agencies are not regulated under this provision; however, the technical requirements within should be familiar to any tribal agency that plans to conduct monitoring.

Participants in the Regulatory Review

We are soliciting input from a variety of parties for this regulatory review process. The National Monitoring Strategy Committee (NMSC) is providing broad recommendations for the national air monitoring program that will require regulatory change. These are likely to include core, multi-pollutant monitoring approaches and to promote mapping and public data reporting. To manage this work, we created three separate work groups, one each for the subjects of regulatory review, quality assurance, and technology.

The quality assurance group will provide recommendations for changes to the quality assurance provisions of the monitoring regulations as well as all existing quality assurance practices; and the technology work group will make recommendations for use in the methods sections of the regulations and in technical guidance used by monitoring agencies. The regulatory review work group must take information from all of these parties, in addition to the NMSC, and review the 40 CFR 58 requirements to develop an appropriate regulatory package.

The NMSC and the three work groups include representatives from the EPA OAQPS, the ten EPA Regional Offices, State agencies, local agencies, and tribal governments. All regulatory changes will undergo public review and comment inherent within the regulatory modification process. EPA will also work through existing mechanisms such as the STAPPA/ALAPCO Monitoring Committee and the Standing Air Monitoring Work Group (SAMWG) to communicate with stakeholders on these

regulatory changes.

Expected Regulatory Changes

EPA expects to see regulatory change in several areas. Most of these changes are still being discussed and finalized by the various workgroups in place; however, we do have some expectation on what may be eventually incorporated. The final rule should include:

- Network design changes, including changes to the minimum number of air quality monitoring networks based upon the current air quality program needs.
- Changes to the information reporting requirements, including network design review reports, network assessments, data certification, and data reporting requirements. This might also include emphasizing near real-time reporting and mapping objectives, and more timely certification. The existing regulations were prepared using 1970s and 80s information and data collection technologies, which have significantly improved since that time.
- Simplifying, consolidating and clarifying the language used in the regulations. This would probably include defining more clearly what is actually "required" versus what should be better included within technical guidance. We also hope to reduce the shear size of the regulation by combining various requirements, reducing repetitive language.
- Define a graded approach for quality assurance activities; more specifically, tailoring the quality system and quality assurance project plan development to the data collection objectives.
- Define an approach for using more continuous monitors in place of some of the manually-operated monitors. It is likely that a regional equivalency criteria will be investigated and incorporated into the regulatory package for the current PM NAAQS review, as opposed to this monitoring strategy regulation; however, it is important to mention here given the overall implications.

Schedule

Regulatory changes typically take a minimum of 18 to 24 months to complete, including the original proposal package preparation, publication and comment periods, reviewing and responding to comments, and finalizing a package for publication. Cost estimates are generally prepared for a rule-making action such as the one. A complete funding review of air monitoring grant funds will also be needed as part of the overall monitoring strategy implementation.

Key Milestones (later milestones are subject to change):
October - NMSC recommendations on the national network.
October 23-25 - Monitoring Strategy Workshop
December 1 - Draft rule-making language prepared for work group review.
March-September - External scientific review of monitoring strategy
October 2002 - Proposal in the Federal Register

October-January 2003 - 60 or 90-day Public comment period
January-March 2002 - Review public comments, prepare responses
April 2003 - Final regulatory package published in Federal Register

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United States
Environmental Protection Agency
Office of Air Quality Planning
& Standards

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National Air Monitoring Strategy
Outlook for the Future

January 14, 2002

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Emissions, Monitoring & Analysis Division
Monitoring & Quality Assurance Group
Research Triangle Park, North Carolina

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EPA, along with State, local, and tribal officials, is evaluating the nation's air monitoring networks to assess their future ability to meet clean air objectives set forth by the Congress and the Clean Air Act.

The overarching objective of the strategy is to manage the nation's air monitoring networks such that changing priorities and needs, both national and local, can be accommodated within a scientifically sound and resource optimized framework.

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Why Do We Need Monitoring Networks?

EPA administers two grant programs to assist States in collecting and evaluating ambient air data from the nation's air monitoring networks. These grant programs, authorized in the Clean Air Act §105 and §103, address a variety of air quality program data collection needs that include:

1. **Compliance:** Comparing air quality data to National Ambient Air Quality Standards (NAAQS) or other benchmarks which drive regulatory actions.

2. **Population exposure/public awareness**: Data to support the Air Quality Index (AQI) and other means to indicate levels of pollution to which populations may be potentially exposed.

3. **Accountability for progress in emissions control programs**: Data to capture measurable ambient impacts associated with emissions control programs.

4. **Emission control program development**: Data to support construction of emission reduction programs.

5. **Environmental welfare assessments**: Data to support assessments such as visibility impairment, and watershed degradation.

6. **Research**: Data to assist research programs (e.g., develop associations between measurements and adverse health indicators, describe physical and chemical atmospheric processes).

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What are the Network Priorities?

Responding effectively to changing priorities, which are largely established by Congressional, scientific, and EPA leadership, is clearly an important goal of the monitoring strategy. Current national monitoring program priorities include developing a complete $PM_{2.5}$ monitoring program, and answering attainment questions on ozone, nonattainment areas. Toxic air pollutants are emerging as a national program priority and represent one of several challenges facing the monitoring community. Other priorities of a more localized nature include responding to public concerns, other criteria pollutant concerns (e.g., CO, SO_2), and specific air quality modeling needs. The monitoring strategy focus will be to produce a system capable of responding to an evolution of changing program priorities. After developing a concise list of monitoring objectives, priorities will be assigned through consensus among a Monitoring Strategy Steering Committee (NMSC) composed of EPA, state and tribal officials. In addition, public outreach efforts are an important component and can help strengthen public acceptance. While the NMSC will guide the outreach effort, state and local agencies can solicit public comment and input throughout the entire process.

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Why does EPA Believe Change is Needed?

Several indicators are pointing to a need for a revamped network. In the following graph[1], the trends data is shown for the last 20 years for each major pollutant tracked. Reductions in ambient concentrations range from 20 percent for ozone and PM_{10} to 98 percent for lead. This is great news: the Clean Air Act is working, and the hard work that air regulators have done to reduce air pollution is paying off. To maintain progress, however, we still need air

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[1]Percentages reflect annual means for sulfur dioxide, PM10, nitrogen dioxide, and annual maximums for lead, ozone, and carbon monoxide.

quality monitors. Duplicate monitors, monitors in areas with excessively low ambient concentrations of pollutants, or monitors within close proximity of each other that show the same concentration levels, are examples of possible inefficient use of resources.

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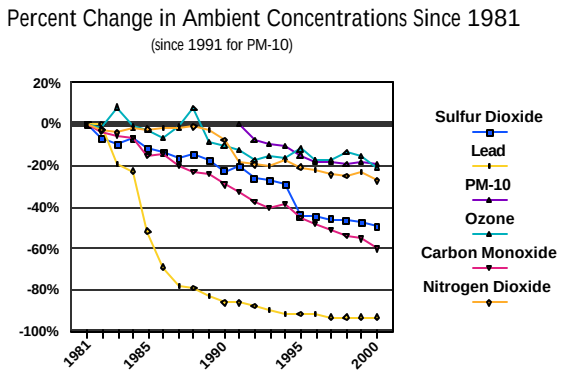
Will Our Region or State Lose Monitoring Grant Funds?

No. The NMSC members and other state and local representatives seek to assess the present network and align it with the needs of the future network. Reducing monitors that provide little information on air quality will free resources to build new monitors needed for



assessing other issues, such as toxic air pollutants. In addition, new technologies which will yield more accurate information and become less costly in the long term can be implemented in place of older and less effective monitors. And, local monitoring personnel will benefit as well, with a switch to continuous monitoring technology that takes fewer hours of hands-on operation. Site operators can be redirected from operating obsolete monitoring equipment to more continuous technologies that can provide real time information to the public.

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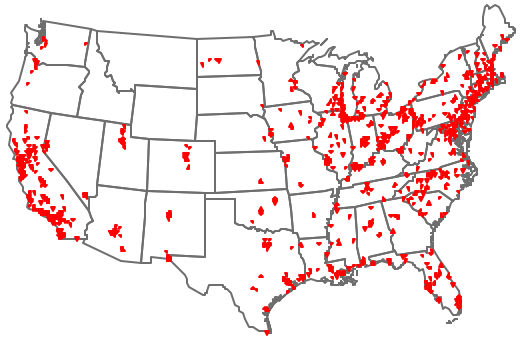
The map below displays the current distribution of ozone air monitoring sites in the continental United States. You can see how certain monitoring networks have become densely sited in some geographic



locations. The combination of national and regional network assessment work will help us to identify those monitors that are statistically measuring the same concentrations within a local area that could be omitted or better located.

Distribution of Current Ozone and PM Monitoring Sites

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What are the Local Resource Implications for Changing Monitors?

Funding for ambient air monitoring programs is expected to remain level for the foreseeable future. However, to enable network changes, EPA will modify regulations and technical guidance to reflect technological advances including continuous particle methods, satellite reporting to database systems, and monitor placement geared toward pollutants that are posing the greatest risk (such as toxic air pollutants in some areas) and co-location of multi-pollutant monitors.. Each State and local agency will have the opportunity to gear their networks to their local needs and also maintain a minimum, Federal core network as mandated by regulation. EPA expects the minimum core network to be smaller than the current network. The savings from reducing the size of the present network would offset the costs encountered by building new, localized networks.

To learn more about the monitoring strategy, visit EPA's website at:

http://www.epa.gov/ttn/amtic/monitor.html

This website also has detailed maps that represent the present monitoring configuration. Go to the following link and scroll to the last file:

http://www.epa.gov/ttn/amtic/netamap.html

OAQPS
Office of Air Quality Planning and Standards
United States Environmental Protection Agency

Regulatory Review Work Group Draft -

I began with the draft from our October 23-25, 2001 Workshop, and I have amended it based upon our discussions up through January 14, 2002. Let me know if you see problems with my notes!!! Items to still discuss include:

-Network design reporting & data certification reporting.
-Concentration ranges for PM2.5 and Ozone: should we have a low-medium-high-superhigh table, or a low-near the NAAQS-superhigh table? That is, use low as <80% of the NAAQS, near the NAAQS as ±20% of NAAQS (80-120% as a range), and super-high of >120%.
-One more reason to use MSA/CMSA criteria rather than urbanized areas - the Census Bureau no longer fully supports the urbanized area statistic beginning with the 2000 Census. They are using metropolitan areas (MSA, PMSA, CMSA).
-Someone has asked that we discuss requiring meteorological measurements at some monitoring sites. We need to discuss this issue.
-Requirement for public reporting/mapping, specifically for ozone and PM. Let's talk about this.

1. **Ncore -** We discussed the Ncore concept at the workshop; however, we did not reach a broad consensus. The National Monitoring Strategy Committee (NMSC) is going to discuss Ncore more thoroughly prior to bringing this up again for our regulatory review work group to address. The NMSC is scheduled to reach some resolution on this in March 2002. We will need to revisit.

2. **NAMS -** NAMS were originally intended to be the nationally required trends sites. They were created during a time when the various air quality monitoring agencies were measuring with a variety of approaches and consistent trends analyses were not possible. EPA continues to need long-term sites for trends purposes; however, we use all available NAMS/SLAMS data to do this. There are very few technical differences between a long-term SLAMS and NAMS. We did agree on the idea of having minimum requirements for monitoring various NAAQS-related (criteria) pollutants; however, they do not necessarily have to be called NAMS.

3. **Sulfur Dioxide (SO_2):**
   -Current NAMS requirement uses concentration ranges and population statistics to determine the number of required NAMS. There is no requirement for the number of SLAMS in 40 CFR 58.
   -**<u>Our current proposal for minimum requirements:</u>** 1 SO_2 NAMS per Metropolitan Statistical Area (MSA) or Consolidated Metropolitan Statistical Area (CMSA) with a population of 1,000,000 or more. This will result in 50 sites, using the 2000 census statistics, as opposed to the range of ~200-1,100 in the existing regulations. There are about 592 sites

operating as of 12/2001. (See spreadsheet for a complete listing for this pollutant and all other criteria pollutants.)

-**Our SLAMS proposal:** Add language to the SLAMS criteria in Appendix D that provides for a "backstop"—meaning, if emissions increase, additional monitoring should be considered. Also, modify the focus onto stationary sources. Our workgroup members are going to check with their respective agencies to see if they would recommend a target emissions level or other criteria to initiate this backstop measure. (Note: there is a tons per year level in the lead SLAMS network criteria.)

4. **Carbon monoxide (CO):**

-Current NAMS requirement is for 2 sites in any urbanized area with a population of 500,000 or more, and it results in ~130 required sites. There is no requirement for the number of SLAMS in 40 CFR 58.

-**Our current proposal for minimum requirements:** 1 CO NAMS per Metropolitan Statistical Area (MSA) or Consolidated Metropolitan Statistical Area (CMSA) with a population of 1,000,000 or more. This will result in 50 sites, using the 2000 census statistics, as opposed to ~130 in the existing regulation (there are 498 sites operating as of 12/2001). We also discussed the idea of whether this site should be a population oriented site or a street canyon site–our current proposal is that this would be a population oriented site.

-Our SLAMS proposal: Street canyon sites would become SLAMS. We would add language that focuses the SLAMS on microscale siting, with some flexibility for middle scale since it is increasingly difficult to get street canyon sites in some cities. We discussed the idea of adding language to the SLAMS criteria in Appendix D that provides for a "backstop"—meaning, if emissions increase, additional monitoring should be considered, but we did not decide how to do this.

5. Ozone (O_3):

-Current NAMS requirement is for 2 sites in any urbanized area with a population of 200,000 or more, resulting in about 300 NAMS. There is no requirement for the number of SLAMS in 40 CFR 58.

-Our NAMS proposal emphasizes continued interest in maintaining a strong O_3 monitoring program. We may add language on regional scale sites as being peak concentration sites. We developed a draft design criteria that incorporates concentration and population as follows:

MSA or CMSA population	Super-High Concentration (>125% of 8-hour or 1-hour NAAQS)	High Concentration (>8-hour or 1-hour NAAQS)	Medium Concentration (>80% of 8-hour or 1-hour NAAQS, but <NAAQS)	Low Concentration (<80% of the 8-hour or 1-hour NAAQS)
>10 million	5	10	5	2-3
4-10 million	3	6	3	1-2
1-4 million	2	4	2	1
350,000-1 million	1-2	2-3	1-2	0-1
200,000-350,000	1	1-2	1	0

A complete breakdown by MSA/CMSA is provided in the spreadsheet. This results in about 424 required sites (1,167 sites are operating as of 12/2001). We agreed on a "super-high" category of 125% of the NAAQS, but this number is rather subjective. We agreed to watch for a classification system decision on the 8-hour NAAQS that might provide a better basis for the "super-high" category. This information is not available at this time, but I will continue to check with our ozone policy group as they proceed with 8-hour designation-related work. We can always propose a percentage range, and solicit comment with the idea of using a designation classification system percentage once it is available.

6. **Nitrogen Dioxide (NO_2):**
-Current NAMS requirement is 2 sites in each "area" with a population of 1,000,000 or more. There is no requirement for the number of SLAMS in 40 CFR 58.
-Our current proposal for minimum requirements: 1 NO_2 NAMS per Metropolitan Statistical Area (MSA) or Consolidated Metropolitan Statistical Area (CMSA) with a population of 1,000,000 or more. This will result in 50 sites, using the 2000 census statistics, as opposed to ~100 in the existing regulations. There are 437 sites operating as of 12/2001. (See spreadsheet for a complete listing for this pollutant and all other criteria pollutants.)
-There is one maintenance area for the NO_2 NAAQS, specifically, in the Los Angeles CMSA. CARB expressed some concern about maintaining a maximum concentration site in this area.
-We discussed the idea of using non-FRM methods, for example high resolution NO_x/NO_y boxes to provide data for use in ozone air quality data analyses.

7. **Lead:** No changes were recommended. This regulation was modified in 1999, and there are 10 required NAMS nationally, and several source oriented sites where violations persist. There are 247 sites operating as of 12/2001.

8. **Particulate Matter (PM_{10}):**

-Current NAMS requirement uses concentration ranges and population statistics to determine the number of required NAMS. There is no requirement for the number of SLAMS in 40 CFR 58.

-**Our current proposal for minimum requirements**: The PM_{10} and $PM_{2.5}$ NAAQS are currently under review, and it is likely that we will have a new coarse ($PM_{10-2.5}$) NAAQS. This will undoubtedly involve some additional changes to the monitoring regulations beyond this particular regulatory review. Given that, we decided to keep some of the basic criteria for PM_{10} NAMS, with reductions for areas that measure lower concentrations. We also proposed a minimum sampling frequency requirement of 1 in 6 days (there still is a need for more frequent sampling in high concentration areas due to the expected exceedance calculations in the 40 CFR 50). The proposed PM_{10} network size is 119-399 sites versus the existing requirement for ~235-735 PM_{10} sites. There are about 1,200 sites operating as of 12/2001. More specifically, our proposed revision to the minimum requirements are:

MSA or CMSA population	High Concentration (>24-hour or annual NAAQS)	Medium Concentration (>80% of 24-hour or annual NAAQS, but <NAAQS)	Low Concentration (<80% of 24-hour or annual NAAQS)
>1 million	6-10	3-6	1
500,000 - 1 million	4-8	2-3	0
250,000- 500,000	3-4	1-2	0
100,000-250,000	1-2	0-1	0

9. **Particulate Matter ($PM_{2.5}$):**

-The NAMS criteria in the existing regulation are presented as goals. The SLAMS requirements are based upon population statistics, and total ~850 sites (which includes 100 background/transport sites). There are a number of complicated requirements for those who want to use spatial averaging in comparisons to the NAAQS.

We now have a substantial amount of $PM_{2.5}$ data, and a better understanding of the concentration ranges. We restructured the $PM_{2.5}$ criteria to resemble the other criteria pollutants, and simplified where possible. Here is a summary table for the network:

MSA or PMSA population (note: we suggest PMSA rather than CMSA)	Superhigh Concentration (>120% of the 24-hour or annual NAAQS)	High Concentration (>24-hour or annual NAAQS)	Medium Concentration (>80% of 24-hour or annual NAAQS, but <NAAQS)	Low Concentration (<80% of 24-hour or annual NAAQS)
>4 million	2-6	4-8	2-6	2*
1-4 million	2-4	3-6	2-4	2*
500,000 - 1 million	1-2	2-3	1-2	1*
350,000- 500,000	1	1-2	1	0
200,000-350,000	1	1	0-1	0
non-MSA's (other)	1	1	0-1	0

A complete breakdown by MSA/CMSA is provided in the spreadsheet.
*Indicates that alternative samplers (e.g., continuous) could be used in these cases, with a trigger level for action to replace the sampler with an FRM.

-We discussed reducing the sampling frequency minimum requirement to 1 in 6 with additional language on collecting more frequent samples in areas near the NAAQS.
-We propose to put the spatial averaging text into a separate section, to allow for those not using the averaging approach to use a simpler network design criteria.
-We discussed removing the acronym "core"–no one really knows that this is an acronym for community-oriented, and it loses its meaning.
-We propose for the SLAMS: add network design language to reduce the network size in "super high" and "super low" areas; maintaining sites in areas near the NAAQS; and require sites in areas with populations <200,000.
-We had some debate on the usefulness of collocating $PM_{2.5}$ measurements at PAMS sites.

10. **Data Management, Reporting, Certification, and AIRS:**
We formed a smaller workgroup to focus on the required AIRS data and site fields, data submittals (90 days after the end of the quarter), and the July 1 certification process. This group will report back to us with some recommendations. Group members include: Richard Guillot (lead), Doug Jager, Dennis Mikel, David Lutz, Wayne Cornelius, someone from NE, CARB, TX, maybe NJ.

11. **Network Assessments and Reviews:**
We discussed this area, but more work is needed. We would like to have an annual update of site movements/relocations. Full assessments would take place on a less frequent basis, such as

once in every 5 years. We would also like to use the network review/assessment process to "declare victory" in clean areas, and discontinue/reduce monitoring where possible.

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
5602	1	New York--Northern New Jersey--Long Island, NY--NJ--CT--PA CMSA	21,199,865	19,549,649	1,650,216	8.4%	10,536					Low		1	1	Superhigh	# SITES MAX	5	5	1		1	Moderate	1
	PMSA	Bergen--Passaic, NJ PMSA	1,373,167	1,278,440	94,727	7.4%		426	Medium	2	4													
	PMSA	Bridgeport, CT PMSA	459,479	443,722	15,757	3.6%		262	Medium	1	1													
	PMSA	Danbury, CT PMSA	217,980	193,597	24,383	12.6%		381	Medium	0	1													
	PMSA	Dutchess County, NY PMSA	280,150	259,462	20,688	8.0%		814	Low	0	0						(Moderate)							
	PMSA	Jersey City, NJ PMSA	608,975	553,099	55,876	10.1%		47	High	2	3													
	PMSA	Middlesex--Somerset--Hunterdon, NJ PMSA	1,169,641	1,019,835	149,806	14.7%		1,053	Medium	2	4													
	PMSA	Monmouth--Ocean, NJ PMSA	1,126,217	986,327	139,890	14.2%		1,118	Low	2	2													
	PMSA	Nassau--Suffolk, NY PMSA	2,753,913	2,609,212	144,701	5.5%		1,218	Medium	2	4													
	PMSA	New Haven--Meriden, CT PMSA	542,149	530,180	11,969	2.3%		430	High	2	3		1											
	PMSA	New York, NY PMSA	9,314,235	8,546,846	767,389	9.0%		1,151	Superhigh	2	6													
	PMSA	Newark, NJ PMSA	2,032,989	1,915,928	117,061	6.1%		1,590	High	3	6										1			
	PMSA	Newburgh, NY--PA PMSA	387,669	335,613	52,056	15.5%		1,375	Low	0	0													
	PMSA	Stamford--Norwalk, CT PMSA	353,556	329,935	23,621	7.2%		210	Medium	1	1													
	PMSA	Trenton, NJ PMSA	350,761	325,824	24,937	7.7%		228	Medium	1	1													
	PMSA	Waterbury, CT PMSA	228,984	221,629	7,355	3.3%		234	Medium	0	1													
4472	2	Los Angeles--Riverside--Orange County, CA CMSA	16,373,645	14,531,529	1,842,116	12.7%	34,009					High	1	6	10	Superhigh	Extreme	5	5	1		1	Serious	1
	PMSA	Los Angeles--Long Beach, CA PMSA	9,519,338	8,863,164	656,174	7.4%		4,069	Superhigh	2	6		1				(Extreme)							(LA is the only
	PMSA	Orange County, CA PMSA	2,846,289	2,410,556	435,733	18.1%		782	Superhigh	2	4		1				(Extreme)							maintenance area.)
	PMSA	Riverside--San Bernardino, CA PMSA	3,254,821	2,588,793	666,028	25.7%		27,295	Superhigh	2	4	(High)	2				(Extreme)							
	PMSA	Ventura, CA PMSA	753,197	669,016	84,181	12.6%		1,863	Medium	1	2						(Severe)							
1602	3	Chicago--Gary--Kenosha, IL--IN--WI CMSA	9,157,540	8,239,820	917,720	11.1%	6,995					Medium		3	6	High	Severe	6	6	1		1		1
	PMSA	Chicago, IL PMSA	8,272,768	7,410,858	861,910	11.6%		5,107	Superhigh	2	6		2											
	PMSA	Gary, IN PMSA	631,362	604,526	26,836	4.4%		938	High	2	3		1								1			
	PMSA	Kankakee, IL PMSA	103,833	96,255	7,578	7.9%		678		0	0													
	PMSA	Kenosha, WI PMSA	149,577	128,181	21,396	16.7%		272		0	0													
8872	4	Washington--Baltimore, DC--MD--VA--WV CMSA	7,608,070	6,727,050	881,020	13.1%	9,634					Low		1	1	Superhigh		3	3	1		1		1
	PMSA	Baltimore, MD PMSA	2,552,994	2,382,172	170,822	7.2%		2,636	Superhigh	2	4						Severe							
	PMSA	Hagerstown, MD PMSA	131,923	121,393	10,530	8.7%		459	High	0	0													
	PMSA	Washington, DC--MD--VA PMSA	4,923,153	4,223,485	699,668	16.6%		6,539	High	4	8						(Serious)							
7362	5	San Francisco--Oakland--San Jose, CA CMSA	7,039,362	6,253,311	786,051	12.6%	7,435					Low		1	1	High	Moderate	6	6	1		1		1
	PMSA	Oakland, CA PMSA	2,392,557	2,082,914	309,643	14.9%		1,466	Medium	2	4													
	PMSA	San Francisco, CA PMSA	1,731,183	1,603,678	127,505	8.0%		1,012	Medium	2	4													
	PMSA	San Jose, CA PMSA	1,682,585	1,497,577	185,008	12.4%		1,300	Medium	2	4													
	PMSA	Santa Cruz--Watsonville, CA PMSA	255,602	229,734	25,868	11.3%		440	Low	0	0													
	PMSA	Santa Rosa, CA PMSA	458,614	388,222	70,392	18.1%		1,604	Medium	1	1													
	PMSA	Vallejo--Fairfield--Napa, CA PMSA	518,821	451,186	67,635	15.0%		1,613	Medium	1	2													
6162	6	Philadelphia--Wilmington--Atlantic City, PA--NJ--DE--MD CMSA	6,188,463	5,892,937	295,526	5.0%	6,012					Medium		3	6	High	Severe 05	6	6	1		1		1
	PMSA	Atlantic--Cape May, NJ PMSA	354,878	319,416	35,462	11.1%		836		0	2						(Moderate)							
	PMSA	Philadelphia, PA--NJ PMSA	5,100,931	4,922,175	178,756	3.6%		3,918	Medium	2	6													
	PMSA	Vineland--Millville--Bridgeton, NJ PMSA	146,438	138,053	8,385	6.1%		500		0	0													
	PMSA	Wilmington--Newark, DE--MD PMSA	586,216	513,293	72,923	14.2%		758	High	2	3													
1122	7	Boston--Worcester--Lawrence, MA--NH--ME--CT CMSA	5,819,100	5,455,403	363,697	6.7%	5,635					Low		1	1	High	Serious	6	6	1		1		1
	PMSA	Boston, MA--NH PMSA	3,406,829	3,227,707	179,122	5.5%		2,030.0	Medium	2	4												Not Cla.	
	PMSA	Brockton, MA PMSA	255,459	236,409	19,050	8.1%		297.3	Low	0	0													
	PMSA	Fitchburg-Leominster, MA PMSA	142,284	138,165	4,119	3.0%		278.6	Low	0	0													
	PMSA	Lawrence, MA--NH PMSA	396,230	353,232	42,998	12.2%		437.8	Low	0	0													
	PMSA	Lowell, MA--NH PMSA	301,686	280,578	21,108	7.5%		249.7	Low	0	0													
	PMSA	Manchester, NH PMSA	198,378	173,783	24,595	14.2%		315.6	Incomplete	0	0						(Marginal)							
	PMSA	Nashua, NH PMSA	190,949	168,233	22,716	13.5%		324.1		0	0													
	PMSA	New Bedford, MA PMSA	175,198	175,641	(443)	-0.3%		214.1	Medium	0	0													
	PMSA	Portsmouth--Rochester, NH--ME PMSA	240,698	223,271	17,427	7.8%		627.6	Low	0	0													
	PMSA	Worcester, MA--CT PMSA	511,389	478,384	33,005	6.9%		860.4	Medium	1	2													
2162	8	Detroit--Ann Arbor--Flint, MI CMSA	5,456,428	5,187,171	269,257	5.2%	6,568					Medium		3	6	High	Maint. area	6	6	1		1		1
	PMSA	Ann Arbor, MI PMSA	578,736	490,058	88,678	18.1%		2,036	Medium	1	2													
	PMSA	Detroit, MI PMSA	4,441,551	4,266,654	174,897	4.1%		3,890	Medium	4	8													
	PMSA	Flint, MI PMSA	436,141	430,459	5,682	1.3%		642	Medium	1	1													
1922	9	Dallas--Fort Worth, TX CMSA	5,221,801	4,037,282	1,184,519	29.3%	9,314					Low		1	1	High	Serious	6	6	1		1		1
	PMSA	Dallas, TX PMSA	3,519,176	2,676,248	842,928	31.5%		6,377	High	3	6													
	PMSA	Fort Worth-Arlington, TX PMSA	1,702,625	1,361,034	341,591	25.1%		2,937	Medium	2	4													

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
3362	10	Houston--Galveston--Brazoria, TX CMSA	4,669,571	3,731,131	938,440	25.2%	7,810					Medium		3	6	Superhigh	Severe	3	3	1		1		1
	PMSA	Brazoria, TX PMSA	241,767	191,707	50,060	26.1%		1,423	Low	0	0													
	PMSA	Galveston--Texas City, TX PMSA	250,158	217,399	32,759	15.1%		399	Low	0	0													
	PMSA	Houston, TX PMSA	4,177,646	3,322,025	855,621	25.8%		5,988	Medium	2	6													
0520	11	Atlanta, GA MSA	4,112,198	2,959,950	1,152,248	38.9%		6,135	Superhigh	2	6	Low		1	1	Superhigh	Serious	3	3	1		1		1
4992	12	Miami--Fort Lauderdale, FL CMSA	3,876,380	3,192,582	683,798	21.4%	3,261					Low		1	1	Medium	Maint. Area	2	2	1		1		1
	PMSA	Fort Lauderdale, FL PMSA	1,623,018	1,255,488	367,530	29.3%		1,219	Low	2	2													
	PMSA	Miami, FL PMSA	2,253,362	1,937,094	316,268	16.3%		2,042	Low	2	2													
7602	13	Seattle--Tacoma--Bremerton, WA CMSA	3,554,760	2,970,328	584,432	19.7%	7,224					Low		1	1	Medium	Maint. Area	2	2	1		1		1
	PMSA	Bremerton, WA PMSA	231,969	189,731	42,238	22.3%		393		0	1													
	PMSA	Olympia, WA PMSA	207,355	161,238	46,117	28.6%		714	Low	0	0													
	PMSA	Seattle--Bellevue--Everett, WA PMSA	2,414,616	2,033,156	381,460	18.8%		4,441	Medium	2	4													
	PMSA	Tacoma, WA PMSA	700,820	586,203	114,617	19.6%		1,676	Medium	1	2													
6200	14	Phoenix--Mesa, AZ MSA	3,251,876	2,238,480	1,013,396	45.3%		14,624	Low	2	2	High	2	6	10	High	Serious	4	4	1	2	1	Serious	1
5120	15	Minneapolis--St. Paul, MN--WI MSA	2,968,806	2,538,834	429,972	16.9%		6,106	Medium	2	4	Low	1	1	1	Medium		2	2	1		1		1
1692	16	Cleveland--Akron, OH CMSA	2,945,831	2,859,644	86,187	3.0%	3,619					Medium		3	6	High	Maint. Area	4	4	1		1		1
	PMSA	Akron, OH PMSA	694,960	657,575	37,385	5.7%		905	High	2	3													
	PMSA	Cleveland-Lorain-Elyria, OH PMSA	2,250,871	2,202,069	48,802	2.2%		2,714	Superhigh	2	4										1			
7320	17	San Diego, CA MSA	2,813,833	2,498,016	315,817	12.6%		4,262	High	3	6	Medium		3	6	High	Serious	4	4	1		1		1
7040	18	St. Louis, MO--IL MSA	2,603,607	2,492,525	111,082	4.5%		6,427	Superhigh	2	4	Medium		3	6	High	Moderate	4	4	1		1		1
2082	19	Denver--Boulder--Greeley, CO CMSA	2,581,506	1,980,140	601,366	30.4%	8,506					Low		1	1	High		4	4	1		1		1
	PMSA	Boulder--Longmont, CO PMSA	291,288	225,339	65,949	29.3%		748	Low	0	0													
	PMSA	Denver, CO PMSA	2,109,282	1,622,980	486,302	30.0%		3,756	Low	2	2		1										Serious	
	PMSA	Greeley, CO PMSA	180,936	131,821	49,115	37.3%		4,002	Low	0	0													
7442	20	San Juan--Caguas--Arecibo, PR CMSA	2,450,292	2,270,808	179,484	7.9%	1,409					Medium		3	6	Low		1	1	1		1		1
	PMSA	Arecibo, PR PMSA	174,300	155,055	19,295	12.4%		216		0	0													
	PMSA	Caguas, PR PMSA	308,365	279,501	28,864	10.3%		228		0	1		1											
	PMSA	San Juan--Bayamon, PR PMSA	1,967,627	1,836,302	131,325	7.2%		965	Low	2	2													
8280	21	Tampa--St. Petersburg--Clearwater, FL MSA	2,395,997	2,067,959	328,038	15.9%		2,529	Medium	2	4	Low		1	1	High	Maint. Area	4	4	1		1		1
6280	22	Pittsburgh, PA MSA	2,358,695	2,394,811	(36,116)	-1.5%		4,645	Superhigh	2	4	Medium	1	3	6	High	Moderate	4	4	1	1	1		1
6442	23	Portland--Salem, OR--WA CMSA	2,265,223	1,793,476	471,747	26.3%	6,903					Low		1	1	Medium	Maint. Area	2	2	1		1		1
	PMSA	Portland--Vancouver, OR--WA PMSA	1,918,009	1,515,452	402,557	26.6%		5,001	Medium	2	4													
	PMSA	Salem, OR PMSA	347,214	278,024	69,190	24.9%		1,902	Low	0	0													
1642	24	Cincinnati--Hamilton, OH--KY--IN CMSA	1,979,202	1,817,571	161,631	8.9%	3,825					Low		1	1	High	Maint. Area	4	4	1		1		1
	PMSA	Cincinnati, OH--KY PMSA	1,646,395	1,526,092	120,303	7.9%		3,354	Superhigh	2	4													
	PMSA	Hamilton-Middletown, OH PMSA	332,807	291,479	41,328	14.2%		471	High	1	1													
6922	25	Sacramento--Yolo, CA CMSA	1,796,857	1,481,102	315,755	21.3%	5,162					Low		1	1	Superhigh	Severe	2	2	1		1		1
	PMSA	Sacramento, CA PMSA	1,628,197	1,340,010	288,187	21.5%		4,134	High	3	6		Unclass											
	PMSA	Yolo, CA PMSA	168,660	141,092	27,568	19.5%		1,028	Medium	0	0													
3760	26	Kansas City, MO--KS MSA	1,776,062	1,582,875	193,187	12.2%		5,451	Medium	2	4	Low		1	1	High	Maint. Area	4	4	1		1		1
5082	27	Milwaukee--Racine, WI CMSA	1,689,572	1,607,183	82,389	5.1%	1,794					Low		1	1	High	Severe	4	4	1		1		1
	PMSA	Milwaukee--Waukesha, WI PMSA	1,500,741	1,432,149	68,592	4.8%		1,457	Medium	2	4													
	PMSA	Racine, WI PMSA	188,831	175,034	13,797	7.9%		337		0	0													
5960	28	Orlando, FL MSA	1,644,561	1,224,852	419,709	34.3%		3,486	Low	2	2	Low		1	1	Medium		2	2	1		1		1
3480	29	Indianapolis, IN MSA	1,607,486	1,380,491	226,995	16.4%		3,533	Superhigh	2	4	Low		1	1	High	Maint. Area	4	4	1		1		1
7240	30	San Antonio, TX MSA	1,592,383	1,324,749	267,634	20.2%		9,317	Low	2	2	Low		1	1	High		4	4	1		1		1
5720	31	Norfolk--Virginia Beach--Newport News, VA--NC MSA	1,569,541	1,443,244	126,297	8.8%		2,407	Medium	2	4	Low		1	1	High	Maint. Area	4	4	1		1		1
4120	32	Las Vegas, NV--AZ MSA	1,563,282	852,737	710,545	83.3%		39,165	Low	2	2	High	2	6	10	High		4	4	1		1	Serious	1
1840	33	Columbus, OH MSA	1,540,157	1,345,450	194,707	14.5%		3,150	Superhigh	2	4	Low		1	1	High	Maint. Area	4	4	1		1		1
1520	34	Charlotte--Gastonia--Rock Hill, NC--SC MSA	1,499,293	1,162,093	337,200	29.0%		3,412	High	3	6	Low		1	1	High	Maint. Area	4	4	1		1		1
5560	35	New Orleans, LA MSA	1,337,726	1,285,270	52,456	4.1%		3,796	Medium	2	4	Low		1	1	High		4	4	1		1		1
7160	36	Salt Lake City--Ogden, UT MSA	1,333,914	1,072,227	261,687	24.4%		1,642	Medium	2	4	Medium	2	3	6	Medium	Maint. Area	2	2	1	1	1		1
3120	37	Greensboro--Winston-Salem--High Point, NC MSA	1,251,509	1,050,304	201,205	19.2%		3,914	High	3	6	Low		1	1	High	Maint. Area	4	4	1		1		1
0640	38	Austin--San Marcos, TX MSA	1,249,763	846,227	403,536	47.7%		4,242	Low	2	2	Low		1	1	High		4	4	1		1		1
5360	39	Nashville, TN MSA	1,231,311	985,026	246,285	25.0%		4,118	High	3	6	Low		1	1	High	Maint. Area	4	4	1		1		1
6480	40	Providence--Fall River--Warwick, RI--MA MSA	1,188,613	1,134,350	54,263	4.8%		1,141	Medium	2	4	Low		1	1	High	Serious	4	4	1		1		1
6640	41	Raleigh--Durham--Chapel Hill, NC MSA	1,187,941	855,545	332,396	38.9%		3,557	High	3	6	Low		1	1	High	Maint. Area	4	4	1		1		1
3280	42	Hartford, CT MSA	1,183,110	1,157,585	25,525	2.2%		1,678	Low	2	2	Low		1	1	High	Serious	4	4	1		1		1
1280	43	Buffalo--Niagara Falls, NY MSA	1,170,111	1,189,288	(19,177)	-1.6%		1,590	High	3	6	Low		1	1	High	Marginal	4	4	1		1		1
4920	44	Memphis, TN--AR--MS MSA	1,135,614	1,007,306	128,308	12.7%		3,002	High	3	6	Low		1	1	High	Maint. Area	4	4	1		1		1

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
8960	45	West Palm Beach--Boca Raton, FL MSA	1,131,184	863,518	267,666	31.0%		2,023	Low	2	2	Low		1	1	Medium		2	2	1		1		1
3600	46	Jacksonville, FL MSA	1,100,491	906,727	193,764	21.4%		2,614	Medium	2	4	Low		1	1	Medium		2	2	1		1		1
6840	47	Rochester, NY MSA	1,098,201	1,062,470	35,731	3.4%		3,467	Medium	2	4			1	10	Medium		2	2	1		1		1
3000	48	Grand Rapids--Muskegon--Holland, MI MSA	1,088,514	937,891	150,623	16.1%		2,747	Medium	2	4	Low		1	1	High	Maint. Areas	4	4	1		1		1
5880	49	Oklahoma City, OK MSA	1,083,346	958,839	124,507	13.0%		4,261	Low	2	2	Low		1	1	Medium		2	2	1		1		1
4520	50	Louisville, KY--IN MSA	1,025,598	948,829	76,769	8.1%		2,064	High	3	6	Low		1	1	High	Moderate	4	4	1		1		1
6760	51	Richmond--Petersburg, VA MSA	996,512	865,640	130,872	15.1%		2,978	High	2	3	Low		0	0	High	Maint. Area	2	3	0		0		0
3160	52	Greenville--Spartanburg--Anderson, SC MSA	962,441	830,563	131,878	15.9%		3,294	High	2	3	Low		0	0	High	Maint. Area	2	3	0		0		0
2000	53	Dayton--Springfield, OH MSA	950,558	951,270	(712)	-0.1%		1,683	High	2	3	Low		0	0	High	Maint. Area	2	3	0		0		0
2840	54	Fresno, CA MSA	922,516	755,580	166,936	22.1%		8,113	Superhigh	1	2	Medium	1	2	3	Superhigh	Serious	1	2	0		0		0
1000	55	Birmingham, AL MSA	921,106	840,140	80,966	9.6%		3,194	Superhigh	1	2	Medium		2	3	High	Marginal	2	3	0		0		0
3320	56	Honolulu, HI MSA	876,156	836,231	39,925	4.8%		598	Low	1	1	Low		0	0	Low		0	1	0		0		0
0160	57	Albany--Schenectady--Troy, NY MSA	875,583	861,424	14,159	1.6%		3,251	Medium	1	2			0	8	Medium	Marginal	1	2	0		0		0
8520	58	Tucson, AZ MSA	843,746	666,880	176,866	26.5%		9,240	Low	1	1	Medium	2	2	3	Medium		1	2	0	1	0		0
8560	59	Tulsa, OK MSA	803,235	708,954	94,281	13.3%		5,056	Medium	1	2	Low		0	0	High		2	3	0		0		0
8160	60	Syracuse, NY MSA	732,117	742,177	(10,060)	-1.4%		3,070	Medium	1	2			0	8	Medium		1	2	0		0		0
5920	61	Omaha, NE--IA MSA	716,998	639,580	77,418	12.1%		2,480	Low	1	1	Medium		2	3	Medium		1	2	0		0		0
0200	62	Albuquerque, NM MSA	712,738	589,131	123,607	21.0%		10,539	Low	1	1	High		4	8	Medium		1	2	0		0		0
3840	63	Knoxville, TN MSA	687,249	585,960	101,289	17.3%		2,465	Superhigh	1	2	High		4	8	High	Maint. Area	2	3	0		0		0
2320	64	El Paso, TX MSA	679,622	591,610	88,012	14.9%		1,058	Medium	1	2	Medium	1	2	3	Medium	Serious	1	2	0		0	Moderate	0
0680	65	Bakersfield, CA MSA	661,645	543,477	118,168	21.7%		8,152	Superhigh	1	2	High	2	4	8	Superhigh	Severe	1	2	0		0		0
0240	66	Allentown--Bethlehem--Easton, PA MSA	637,958	595,081	42,877	7.2%		1,129	Medium	1	2	Low		0	0	High	Marginal	2	3	0		0		0
3240	67	Harrisburg--Lebanon--Carlisle, PA MSA	629,401	587,986	41,415	7.0%		1,987	High	2	3	Low		0	0	High	Marginal	2	3	0		0		0
7560	68	Scranton--Wilkes-Barre--Hazleton, PA MSA	624,776	638,466	(13,690)	-2.1%		2,224	Medium	1	2	Low		0	0	High	Marginal	2	3	0		0		0
8400	69	Toledo, OH MSA	618,203	614,128	4,075	0.7%		1,369	High	2	3	Low		0	0	Medium	Maint. Area	1	2	0	1	0		0
0760	70	Baton Rouge, LA MSA	602,894	528,264	74,630	14.1%		1,617	High	2	3	Low		0	0	High	Serious	2	3	0		0		0
9320	71	Youngstown--Warren, OH MSA	594,746	600,895	(6,149)	-1.0%		1,564	High	2	3	Medium		2	3	High	Marginal	2	3	0		0		0
8000	72	Springfield, MA MSA	591,932	587,884	4,048	0.7%		736	Medium	1	2	Low		0	0	High	Serious	2	3	0		0		0
7510	73	Sarasota--Bradenton, FL MSA	589,959	489,483	100,476	20.5%		1,326	Low	1	1			0	8	High		2	3	0		0		0
4400	74	Little Rock--North Little Rock, AR MSA	583,845	513,117	70,728	13.8%		2,926	High	2	3	Low		0	0	High		2	3	0		0		0
4880	75	McAllen--Edinburg--Mission, TX MSA	569,463	383,545	185,918	48.5%		1,543	Low	1	1	Low		0	0	Medium		1	2	0		0		0
8120	76	Stockton--Lodi, CA MSA	563,598	480,628	82,970	17.3%		1,415	High	2	3	Low	1	0	0	High	Serious	2	3	0		0		0
1440	77	Charleston--North Charleston, SC MSA	549,033	506,875	42,158	8.3%		2,618	Medium	1	2	Low		0	0	Medium		1	2	0		0		0
9040	78	Wichita, KS MSA	545,220	485,270	59,950	12.4%		2,989	Medium	1	2	Low		0	0	Medium		1	2	0		0		0
5160	79	Mobile, AL MSA	540,258	476,923	63,335	13.3%		2,818	High	2	3	Medium		2	3	High		2	3	0		0		0
1760	80	Columbia, SC MSA	536,691	453,331	83,360	18.4%		1,465	High	2	3	High		4	8	High		2	3	0		0		0
1720	81	Colorado Springs, CO MSA	516,929	397,014	119,915	30.2%		2,157	Low	1	1	Low		0	0	Medium		1	2	0		0		0
2760	82	Fort Wayne, IN MSA	502,141	456,281	45,860	10.1%		2,495	Medium	1	2	Low		0	0	High		2	3	0		0		0
2020	83	Daytona Beach, FL MSA	493,175	399,413	93,762	23.5%		1,549	Low	0	0	Low		0	0	Medium		1	2	0		0		0
3980	84	Lakeland--Winter Haven, FL MSA	483,924	405,382	78,542	19.4%		1,861	Low	0	0	Low		0	0	Medium		1	2	0		0		0
3660	85	Johnson City--Kingsport--Bristol, TN--VA MSA	480,091	436,047	44,044	10.1%		2,880	High	1	2			0	4	High		2	3	0		0		0
4280	86	Lexington, KY MSA	479,198	405,936	73,262	18.0%		1,939	High	1	2	Low		0	0	High	Maint. Area	2	3	0		0		0
0600	87	Augusta--Aiken, GA--SC MSA	477,441	415,184	62,257	15.0%		2,447	Superhigh	1	1	Low		0	0	High		2	3	0		0		0
4900	88	Melbourne--Titusville--Palm Bay, FL MSA	476,230	398,978	77,252	19.4%		1,011	Low	0	0	Low		0	0	Medium		1	2	0		0		0
4000	89	Lancaster, PA MSA	470,658	422,822	47,836	11.3%		946	High	1	2	Low		0	0	High	Marginal	2	3	0		0		0
1560	90	Chattanooga, TN--GA MSA	465,161	424,347	40,814	9.6%		1,836	Superhigh	1	1	Low		0	0	High		2	3	0		0		0
2120	91	Des Moines, IA MSA	456,022	392,928	63,094	16.1%		1,763	Low	0	0	Low		0	0	Medium		1	2	0		0		0
3720	92	Kalamazoo--Battle Creek, MI MSA	452,851	429,453	23,398	5.4%		1,874	High	1	2			0	4	Medium		1	2	0		0		0
4040	93	Lansing--East Lansing, MI MSA	447,728	432,674	15,054	3.5%		1,702	Medium	1	1			0	4	Medium		1	2	0		0		0
5170	94	Modesto, CA MSA	446,997	370,522	76,475	20.6%		1,511	Superhigh	1	1	Low	1	0	0	High	Serious	2	3	0		0		0
2700	95	Fort Myers--Cape Coral, FL MSA	440,888	335,113	105,775	31.6%		785	Low	0	0	Low		0	0	Medium		1	2	0		0		0
3560	96	Jackson, MS MSA	440,801	395,396	45,405	11.5%		2,427	High	1	2	Low		0	0	Medium		1	2	0		0		0
1080	97	Boise City, ID MSA	432,345	295,851	136,494	46.1%		1,621	Low	0	0	Low		0	0				?	0		0		0
4720	98	Madison, WI MSA	426,526	367,085	59,441	16.2%		1,199	Medium	1	1	Low		0	0	Medium		1	2	0		0		0
7840	99	Spokane, WA MSA	417,939	361,364	56,575	15.7%		1,758	Low	0	0	Low	1	0	0	Medium		1	2	0		0	Serious	0
6080	100	Pensacola, FL MSA	412,153	344,406	67,747	19.7%		1,697	Medium	1	1	Low		0	0	High		2	3	0		0		0
1320	101	Canton--Massillon, OH MSA	406,934	394,106	12,828	3.3%		966	Superhigh	1	1	Low		0	0	High	Maint. Area	2	3	0		0		0
6960	102	Saginaw--Bay City--Midland, MI MSA	403,070	399,320	3,750	0.9%		1,781	Low	0	0			0	4				?	0		0		0
7120	103	Salinas, CA MSA	401,762	355,660	46,102	13.0%		3,324	Low	0	0	Low		0	0	Medium	Maint. Area	1	2	0		0		0
7480	104	Santa Barbara--Santa Maria--Lompoc, CA MSA	399,347	369,608	29,739	8.0%		2,738	Low	0	0	Low		0	0	Medium	Serious	1	2	0		0		0

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
7680	105	Shreveport--Bossier City, LA MSA	392,302	376,330	15,972	4.2%		2,363	Medium	1	1	Low		0	0	High		2	3	0		0		0
3880	106	Lafayette, LA MSA	385,647	344,953	40,694	11.8%		2,618	Medium	1	1			0	4	High		2	3	0		0		0
0840	107	Beaumont--Port Arthur, TX MSA	385,090	361,226	23,864	6.6%		2,207	Medium	1	1			0	4	High	Moderate	2	3	0		0		0
9280	108	York, PA MSA	381,751	339,574	42,177	12.4%		909	High	1	2	Low		0	0	High	Marginal	2	3	0		0		0
1880	109	Corpus Christi, TX MSA	380,783	349,894	30,889	8.8%		1,531	Low	0	0	Low		0	0	Medium		1	2	0		0		0
6680	110	Reading, PA MSA	373,638	336,523	37,115	11.0%		862	High	1	1	Low		0	0	High	Maint. Area	2	3	0		0		0
6880	111	Rockford, IL MSA	371,236	329,676	41,560	12.6%		1,560	High	1	1			0	4	Medium		1	2	0		0		0
6520	112	Provo--Orem, UT MSA	368,536	263,590	104,946	39.8%		2,014	Low	0	0	Low	1	0	0	Medium		1	2	0		0	Moderate	0
8780	113	Visalia--Tulare--Porterville, CA MSA	368,021	311,921	56,100	18.0%		4,844	Superhigh	1	1	Medium	1	1	2	High	Serious	2	3	0		0		0
0920	114	Biloxi--Gulfport--Pascagoula, MS MSA	363,988	312,368	51,620	16.5%		1,803	Medium	1	1	Low		0	0	High		2	3	0		0		0
6360	115	Ponce, PR MSA	361,094	342,660	18,434	5.4%		371	Low	0	0	Medium		1	2				?	0		0		0
1960	116	Davenport--Moline--Rock Island, IA--IL MSA	359,062	350,861	8,201	2.3%		1,704	Medium	1	1	Medium		1	2	Medium		1	2	0		0		0
0460	117	Appleton--Oshkosh--Neenah, WI MSA	358,365	315,121	43,244	13.7%		1,404	Low	0	0			0	4	Medium		1	2	0		0		0
6120	118	Peoria--Pekin, IL MSA	347,387	339,172	8,215	2.4%		1,803	High	1	1	Low		0	0	Medium		1	1	0		0		0
3440	119	Huntsville, AL MSA	342,376	293,047	49,329	16.8%		1,348	High	1	1	Low		0	0	High		1	2	0		0		0
3290	120	Hickory--Morganton--Lenoir, NC MSA	341,851	292,409	49,442	16.9%		1,643	High	1	1	Low		0	0	High		1	2	0		0		0
6720	121	Reno, NV MSA	339,486	254,667	84,819	33.3%		6,375	Low	0	0	Medium	1	1	2	Medium	Marginal	1	1	0		0	Moderate	0
1240	122	Brownsville--Harlingen--San Benito, TX MSA	335,227	260,120	75,107	28.9%		896	Low	0	0	Low		0	0	Medium		1	1	0		0		0
5240	123	Montgomery, AL MSA	333,055	292,517	40,538	13.9%		2,013	High	1	1	Low		0	0	High		1	2	0		0		0
7920	124	Springfield, MO MSA	325,721	264,346	61,375	23.2%		1,834	Medium	0	1	Low		0	0	Medium		1	1	0		0		0
2400	125	Eugene--Springfield, OR MSA	322,959	282,912	40,047	14.2%		4,562	Low	0	0	Low	2	0	0	Medium		1	1	0		0		0
4680	126	Macon, GA MSA	322,549	290,909	31,640	10.9%		1,551	Superhigh	1	1	Low		0	0	High		1	2	0		0		0
2710	127	Fort Pierce--Port St. Lucie, FL MSA	319,426	251,071	68,355	27.2%		1,140	Low	0	0	Low		0	0	Medium		1	1	0		0		0
3400	128	Huntington--Ashland, WV--KY--OH MSA	315,538	312,529	3,009	1.0%		2,161	Superhigh	1	1	Low		0	0	High	Maint. Area	1	2	0	1	0		0
3810	129	Killeen--Temple, TX MSA	312,952	255,301	57,651	22.6%		2,109		0	1			0	4				?	0		0		0
2580	130	Fayetteville--Springdale--Rogers, AR MSA	311,121	210,908	100,213	47.5%		1,848	Medium	0	1			0	4				?	0		0		0
2560	131	Fayetteville, NC MSA	302,963	274,566	28,397	10.3%		661	High	1	1	Low		0	0	High		1	2	0		0		0
8680	132	Utica--Rome, NY MSA	299,896	316,633	(16,737)	-5.3%		2,659	Medium	0	1	Low		0	0	Medium		1	1	0		0		0
2440	133	Evansville--Henderson, IN--KY MSA	296,195	278,990	17,205	6.2%		1,477	High	1	1	Low		0	0	High	Maint. Area	1	2	0		0		0
5520	134	New London--Norwich, CT--RI MSA	293,566	290,734	2,832	1.0%		662	Low	0	0	Low		0	0	High	Serious	1	2	0		0		0
7520	135	Savannah, GA MSA	293,000	258,060	34,940	13.5%		1,368	High	1	1	Low		0	0	Medium		1	1	0		0		0
8240	136	Tallahassee, FL MSA	284,539	233,598	50,941	21.8%		1,182	Medium	0	1	Low		0	0	Medium		1	1	0		0		0
2360	137	Erie, PA MSA	280,843	275,572	5,271	1.9%		813	Medium	0	1	Low		0	0	High	Marginal	1	2	0		0		0
1800	138	Columbus, GA--AL MSA	274,624	260,860	13,764	5.3%		1,577	Superhigh	1	1	Low		0	0	High		1	2	0		0		0
7800	139	South Bend, IN MSA	265,559	247,052	18,507	7.5%		466	High	1	1	Low		0	0	High	Maint. Area	1	2	0		0		0
0380	140	Anchorage, AK MSA	260,283	226,338	33,945	15.0%		1,732	Low	0	0	Low	1	0	0				?	0		0	Serious	0
5790	141	Ocala, FL MSA	258,916	194,833	64,083	32.9%		1,599	Low	0	0			0	4	Medium		1	1	0		0		0
4840	142	Mayaguez, PR MSA	253,347	237,143	16,204	6.8%		290	Low	0	0			0	4				?	0		0		0
0960	143	Binghamton, NY MSA	252,320	264,497	(12,177)	-4.6%		1,238	Low	0	0			0	4				?	0		0		0
1480	144	Charleston, WV MSA	251,662	250,454	1,208	0.5%		1,255	Superhigh	1	1	Low		0	0	High	Maint. Area	1	2	0		0		0
2670	145	Fort Collins--Loveland, CO MSA	251,494	186,136	65,358	35.1%		2,611	Low	0	0	Low		0	0	Medium		1	1	0		0	Moderate	0
5345	146	Naples, FL MSA	251,377	152,099	99,278	65.3%		2,006		0	1	Low		0	0				?	0		0		0
4360	147	Lincoln, NE MSA	250,291	213,641	36,650	17.2%		2,522	Low	0	0			0	4	Low		0	0	0		0		0
7460	148	San Luis Obispo--Atascadero--Paso Robles, CA MSA	246,681	217,162	29,519	13.6%		3,184	Low	0	0	Low		0	0	Medium		1	1	0		0		0
2240	149	Duluth--Superior, MN--WI MSA	243,815	239,971	3,844	1.6%		7,405	Low	0	0	Low		0	0	Medium		1	1	0		0		0
6400	150	Portland, ME MSA	243,537	221,095	22,442	10.2%		626	Low	0	0	Low		0	0	Medium	Moderate	1	1	0		0		0
4600	151	Lubbock, TX MSA	242,628	222,636	19,992	9.0%		893	Low	0	0	Low		0	0				?	0		0		0
5800	152	Odessa--Midland, TX MSA	237,132	225,545	11,587	5.1%		1,846	Low	0	0			0	2				?	0		0		0
6800	153	Roanoke, VA MSA	235,932	224,477	11,455	5.1%		905	High	1	1	Low		0	0	High		1	2	0		0		0
9200	154	Wilmington, NC MSA	233,450	171,269	62,181	36.3%		1,067	Medium	0	1	Low		0	0	Medium		1	1	0		0		0
3680	155	Johnstown, PA MSA	232,621	241,247	(8,626)	-3.6%		1,780	High	1	1	Low		0	0	High	Marginal	1	2	0		0		0
3080	156	Green Bay, WI MSA	226,778	194,594	32,184	16.5%		524	Low	0	0			0	2	Medium		1	1	0		0		0
0480	157	Asheville, NC MSA	225,965	191,774	34,191	17.8%		1,101	High	1	1	Low		0	0	High		1	2	0		0		0
9260	158	Yakima, WA MSA	222,581	188,823	33,758	17.9%		4,271	Medium	0	1	Low	1	0	0				?	0		0		0
2900	159	Gainesville, FL MSA	217,955	181,596	36,359	20.0%		916	Low	0	0	Low		0	0	Medium		1	1	0		0		0
0320	160	Amarillo, TX MSA	217,858	187,547	30,311	16.2%		1,812	Low	0	0			0	2				?	0		0		0
4640	161	Lynchburg, VA MSA	214,911	193,928	20,983	10.8%		2,557	Medium	0	1			0	2				?	0		0		0
8800	162	Waco, TX MSA	213,517	189,123	24,394	12.9%		1,030	Low	0	0			0	2				?	0		0		0
4940	163	Merced, CA MSA	210,554	178,403	32,151	18.0%		1,981	Superhigh	1	1	Medium		0	1	High	Serious	1	2	0		0		0
4420	164	Longview--Marshall, TX MSA	208,780	193,801	14,979	7.7%		1,760	Medium	0	1			0	2	High		1	2	0		0		0

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
2720	165	Fort Smith, AR--OK MSA	207,290	175,911	31,379	17.8%		1,819	Medium	0	1			0	2				?	0		0		0
1660	166	Clarksville--Hopkinsville, TN--KY MSA	207,033	169,439	37,594	22.2%		1,264	High	1	1	Low		0	0	High		1	2	0		0		0
1620	167	Chico--Paradise, CA MSA	203,171	182,120	21,051	11.6%		1,668	High	1	1	Low		0	0	High		1	2	0		0		0
7880	168	Springfield, IL MSA	201,437	189,550	11,887	6.3%		1,191	Medium	0	1			0	2	Medium		1	1	0		0		0
5330	169	Myrtle Beach, SC MSA	196,629	144,053	52,576	36.5%		1,154	Low	0	0			0	2			0	0	0		0		0
3350	170	Houma, LA MSA	194,477	182,842	11,635	6.4%		2,509	Low	0	0			0	2	High		1	1	0		0		0
4080	171	Laredo, TX MSA	193,117	133,239	59,878	44.9%		3,306	Low	0	0	Low		0	0	Medium		0	1	0		0		0
6740	172	Richland--Kennewick--Pasco, WA MSA	191,822	150,033	41,789	27.9%		2,982	Low	0	0	Low		0	0			0	0	0		0		0
1360	173	Cedar Rapids, IA MSA	191,701	168,767	22,934	13.6%		717	Low	0	0	Low		0	0	Medium		0	1	0		0		0
3960	174	Lake Charles, LA MSA	183,577	168,134	15,443	9.2%		1,105	Medium	0	1			0	2	High	Maint. Area	1	1	0		0		0
3920	175	Lafayette, IN MSA	182,821	161,572	21,249	13.2%		907	High	1	1			0	2			0	0	0		0		0
2330	176	Elkhart--Goshen, IN MSA	182,791	156,198	26,593	17.0%		468	High	1	1			0	2	Medium		0	1	0		0		0
4890	177	Medford--Ashland, OR MSA	181,269	146,389	34,880	23.8%		2,812	Medium	0	1	Low	1	0	0	Medium		0	1	0		0	Moderate	0
1400	178	Champaign--Urbana, IL MSA	179,669	173,025	6,644	3.8%		1,000	Medium	0	1			0	2	Medium		0	1	0		0		0
4800	179	Mansfield, OH MSA	175,818	174,007	1,811	1.0%		900		0	0			0	2			0	0	0		0		0
8640	180	Tyler, TX MSA	174,706	151,309	23,397	15.5%		934		0	0			0	2	High		1	1	0		0		0
4100	181	Las Cruces, NM MSA	174,682	135,510	39,172	28.9%		3,804	Low	0	0	Low	1	0	0	Medium	Marginal	0	1	0		0		0
2520	182	Fargo--Moorhead, ND--MN MSA	174,367	153,296	21,071	13.7%		2,794	Low	0	0			0	2	Low		0	0	0		0		0
7760	183	Sioux Falls, SD MSA	172,412	139,236	33,176	23.8%		1,389	Low	0	0	Low		0	0	Low		0	0	0		0		0
2750	184	Fort Walton Beach, FL MSA	170,498	143,776	26,722	18.6%		944		0	0			0	2			0	0	0		0		0
8440	185	Topeka, KS MSA	169,871	160,976	8,895	5.5%		548	Low	0	0	Low		0	0			0	0	0		0		0
1305	186	Burlington, VT MSA	169,391	151,506	17,885	11.8%		562	Low	0	0	Low		0	0			0	0	0		0		0
6980	187	St. Cloud, MN MSA	167,392	148,976	18,416	12.4%		1,744	Low	0	0			0	2			0	0	0		0		0
0860	188	Bellingham, WA MSA	166,814	127,780	39,034	30.5%		2,126	Low	0	0	Low		0	0	Low		0	0	0		0		0
8600	189	Tuscaloosa, AL MSA	164,875	150,522	14,353	9.5%		1,338	Superhigh	1	1	Low		0	0			0	0	0		0		0
6690	190	Redding, CA MSA	163,256	147,036	16,220	11.0%		3,793	Medium	0	1	Low		0	0	High		1	1	0		0		0
0740	191	Barnstable--Yarmouth, MA MSA	162,582	134,954	27,628	20.5%		260	Incomplete	0	0			0	2			0	0	0		0		0
0870	192	Benton Harbor, MI MSA	162,453	161,378	1,075	0.7%		580	Medium	0	1			0	2	High		1	1	0		0		0
9360	193	Yuma, AZ MSA	160,026	106,895	53,131	49.7%		9,991		0	0	Low	1	0	0	Medium		0	1	0		0		0
1540	194	Charlottesville, VA MSA	159,576	131,107	28,469	21.7%		1,184		0	0	Low		0	0			0	0	0		0		0
3520	195	Jackson, MI MSA	158,422	149,756	8,666	5.8%		698		0	0			0	2			0	0	0		0		0
3710	196	Joplin, MO MSA	157,322	134,910	22,412	16.6%		1,271	Medium	0	1	Medium		0	1			0	0	0		0		0
4320	197	Lima, OH MSA	155,084	154,340	744	0.5%		810		0	0	Low		0	0	High		1	1	0		0		0
0500	198	Athens, GA MSA	153,444	126,262	27,182	21.5%		592	Superhigh	1	1			0	2			0	0	0		0		0
9000	199	Wheeling, WV--OH MSA	153,172	159,301	(6,129)	-3.8%		944	Superhigh	1	1	Low		0	0	Medium		0	1	0		0		0
1260	200	Bryan--College Station, TX MSA	152,415	121,862	30,553	25.1%		586		0	0			0	2			0	0	0		0		0
3620	201	Janesville--Beloit, WI MSA	152,307	139,510	12,797	9.2%		721		0	0			0	2	High		1	1	0		0		0
6020	202	Parkersburg--Marietta, WV--OH MSA	151,237	149,169	2,068	1.4%		1,009	High	1	1	Low		0	0	High	Maint. Area	1	1	0		0		0
1040	203	Bloomington--Normal, IL MSA	150,433	129,180	21,253	16.5%		1,173	High	1	1			0	2			0	0	0		0		0
3605	204	Jacksonville, NC MSA	150,355	149,838	517	0.3%		756	Medium	0	1	Low		0	0			0	0	0		0		0
8320	205	Terre Haute, IN MSA	149,192	147,585	1,607	1.1%		1,042	High	1	1	Low		0	0	Medium		0	1	0		0		0
2290	206	Eau Claire, WI MSA	148,337	137,543	10,794	7.8%		1,665		0	0			0	2			0	0	0		0		0
6015	207	Panama City, FL MSA	148,217	126,994	21,223	16.7%		747		0	0	Low		0	0	High		1	1	0		0		0
7490	208	Santa Fe, NM MSA	147,635	117,043	30,592	26.1%		2,013	Low	0	0	Low		0	0			0	0	0		0		0
5200	209	Monroe, LA MSA	147,250	142,191	5,059	3.6%		638	Medium	0	1			0	2	Medium		0	1	0		0		0
0060	210	Aguadilla, PR MSA	146,424	128,172	18,252	14.2%		118		0	0			0	2			0	0	0		0		0
2030	211	Decatur, AL MSA	145,867	131,556	14,311	10.9%		1,255	Incomplete	0	0	Low		0	0	High		1	1	0		0		0
6895	212	Rocky Mount, NC MSA	143,026	133,235	9,791	7.3%		1,063	Medium	0	1	Low		0	0	High		1	1	0		0		0
2650	213	Florence, AL MSA	142,950	131,327	11,623	8.9%		1,258	High	1	1			0	2			0	0	0		0		0
6580	214	Punta Gorda, FL MSA	141,627	110,975	30,652	27.6%		703		0	0			0	2			0	0	0		0		0
6560	215	Pueblo, CO MSA	141,472	123,051	18,421	15.0%		2,405	Low	0	0			0	2			0	0	0		0		0
9080	216	Wichita Falls, TX MSA	140,518	130,351	10,167	7.8%		1,524		0	0			0	2			0	0	0		0		0
3610	217	Jamestown, NY MSA	139,750	141,895	(2,145)	-1.5%		1,081	Low	0	0	Low		0	0	High		1	1	0		0		0
9340	218	Yuba City, CA MSA	139,149	122,643	16,506	13.5%		1,243	Medium	0	1	Low		0	0	High		1	1	0		0		0
2180	219	Dothan, AL MSA	137,916	130,964	6,952	5.3%		1,136	High	1	1	Low		0	0			0	0	0		0		0
8050	220	State College, PA MSA	135,758	123,786	11,972	9.7%		1,115	Low	0	0			0	2	Medium		0	1	0		0		0
1740	221	Columbia, MO MSA	135,454	112,379	23,075	20.5%		685		0	0			0	2			0	0	0		0		0
3150	222	Greenville, NC MSA	133,798	107,924	25,874	24.0%		656	Medium	0	1	Low		0	0	High		1	1	0		0		0
8080	223	Steubenville--Weirton, OH--WV MSA	132,008	142,523	(10,515)	-7.4%		582	Superhigh	1	1	Low	2	0	0	Medium		0	1	0	2	0		0
8360	224	Texarkana, TX--Texarkana, AR MSA	129,749	120,132	9,617	8.0%		1,514	Medium	0	1			0	2			0	0	0		0		0

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
0880	225	Billings, MT MSA	129,352	113,419	15,933	14.0%		2,642	Low	0	0	Low		0	0			0	0	0	1	0		0
0280	226	Altoona, PA MSA	129,144	130,542	(1,398)	-1.1%		521		0	0	Low		0	0	High	Marginal	1	1	0		0		0
8920	227	Waterloo--Cedar Falls, IA MSA	128,012	123,798	4,214	3.4%		568	Low	0	0	Low		0	0			0	0	0		0		0
3870	228	La Crosse, WI--MN MSA	126,838	116,401	10,437	9.0%		1,006		0	0			0	2			0	0	0		0		0
2190	229	Dover, DE MSA	126,697	110,993	15,704	14.1%		595	Medium	0	1			0	2	High		1	1	0		0		0
0040	230	Abilene, TX MSA	126,555	119,655	6,900	5.8%		913		0	0			0	2			0	0	0		0		0
0220	231	Alexandria, LA MSA	126,337	131,556	(5,219)	-4.0%		1,318	Medium	0	1			0	2			0	0	0		0		0
8940	232	Wausau, WI MSA	125,834	115,400	10,434	9.0%		1,586		0	0			0	2	Medium		0	1	0	1	0		0
2655	233	Florence, SC MSA	125,761	114,344	11,417	10.0%		805	Medium	0	1			0	2			0	0	0		0		0
2975	234	Glens Falls, NY MSA	124,345	118,539	5,806	4.9%		1,723		0	0			0	2			0	0	0		0		0
6820	235	Rochester, MN MSA	124,277	106,470	17,807	16.7%		656	Medium	0	1			0	2			0	0	0		0		0
7720	236	Sioux City, IA--NE MSA	124,130	115,018	9,112	7.9%		1,126	Low	0	0	Low		0	0			0	0	0		0		0
2620	237	Flagstaff, AZ--UT MSA	122,366	101,760	20,606	20.2%		22,578	Low	0	0	Low		0	0	Medium		0	1	0		0		0
0120	238	Albany, GA MSA	120,822	112,561	8,261	7.3%		679	High	1	1	Low		0	0			0	0	0		0		0
1020	239	Bloomington, IN MSA	120,563	108,978	11,585	10.6%		410		0	0			0	2			0	0	0		0		0
7610	240	Sharon, PA MSA	120,293	121,003	(710)	-0.6%		681	Medium	0	1			0	2	High		1	1	0		0		0
9140	241	Williamsport, PA MSA	120,044	118,710	1,334	1.1%		1,216		0	0	Low		0	0	Medium		0	1	0		0		0
5280	242	Muncie, IN MSA	118,769	119,659	(890)	-0.7%		398	High	1	1			0	2			0	0	0		0		0
2995	243	Grand Junction, CO MSA	116,255	93,145	23,110	24.8%		3,303	Low	0	0	Low		0	0			0	0	0		0		0
0580	244	Auburn--Opelika, AL MSA	115,092	87,146	27,946	32.1%		612		0	0			0	2			0	0	0		0		0
4200	245	Lawton, OK MSA	114,996	111,486	3,510	3.1%		1,087	Low	0	0			0	2	Medium		0	1	0		0		0
2040	246	Decatur, IL MSA	114,706	117,206	(2,500)	-2.1%		578	High	1	1			0	2	Medium		0	1	0		0		0
2980	247	Goldsboro, NC MSA	113,329	104,666	8,663	8.3%		555	High	1	1	Low		0	0			0	0	0		0		0
7620	248	Sheboygan, WI MSA	112,646	103,877	8,769	8.4%		505		0	0			0	2	High	Maint. Area	1	1	0		0		0
0450	249	Anniston, AL MSA	112,249	116,034	(3,785)	-3.3%		611		0	0			0	2			0	0	0		0		0
3285	250	Hattiesburg, MS MSA	111,674	98,738	12,936	13.1%		968	Medium	0	1			0	2			0	0	0		0		0
3500	251	Iowa City, IA MSA	111,006	96,119	14,887	15.5%		619	Low	0	0			0	2			0	0	0		0		0
7640	252	Sherman--Denison, TX MSA	110,595	95,021	15,574	16.4%		940		0	0			0	2			0	0	0		0		0
1950	253	Danville, VA MSA	110,156	108,711	1,445	1.3%		1,029		0	0			0	2			0	0	0		0		0
3580	254	Jackson, TN MSA	107,377	90,801	16,576	18.3%		845	High	1	1	Low		0	0			0	0	0		0		0
8140	255	Sumter, SC MSA	104,646	102,637	2,009	2.0%		672		0	0			0	2			0	0	0		0		0
7200	256	San Angelo, TX MSA	104,010	98,458	5,552	5.6%		1,535		0	0			0	2			0	0	0		0		0
2880	257	Gadsden, AL MSA	103,459	99,840	3,619	3.6%		555	Superhigh	1	1	Low		0	0			0	0	0		0		0
7000	258	St. Joseph, MO MSA	102,490	97,715	4,775	4.9%		840	Medium	0	1	Low		0	0			0	0	0		0		0
1900	259	Cumberland, MD--WV MSA	102,008	101,643	365	0.4%		758		0	0			0	2			0	0	0		0		0
3850	260	Kokomo, IN MSA	101,541	96,946	4,595	4.7%		554	High	1	1			0	2			0	0	0		0		0
4150	261	Lawrence, KS MSA	99,962	81,798	18,164	22.2%		471		0	0			0	0			0	0	0		0		0
2985	262	Grand Forks, ND--MN MSA	97,478	103,181	(5,703)	-5.5%		3,451	Low	0	0			0	0			0	0	0		0		0
5140	263	Missoula, MT MSA	95,802	78,687	17,115	21.8%		2,612		0	0		1	0	0			0	0	0		0	Moderate	0
1010	264	Bismarck, ND MSA	94,719	83,831	10,888	13.0%		2,667	Low	0	0	Low		0	0			0	0	0		0		0
5990	265	Owensboro, KY MSA	91,545	87,189	4,356	5.0%		462	High	1	1	Low		0	0	Medium	Maint. Area	0	1	0		0		0
2335	266	Elmira, NY MSA	91,070	95,195	(4,125)	-4.3%		415		0	0			0	0	Medium		0	1	0		0		0
0730	267	Bangor, ME MSA	90,864	91,629	(765)	-0.8%		397	Low	0	0	Low		0	0	Medium		0	1	0		0		0
4240	268	Lewiston--Auburn, ME MSA	90,830	93,679	(2,849)	-3.0%		305	Low	0	0	Low		0	0		Moderate	0	0	0		0		0
2200	269	Dubuque, IA MSA	89,143	86,403	2,740	3.2%		612		0	0			0	0			0	0	0		0		0
6660	270	Rapid City, SD MSA	88,565	81,343	7,222	8.9%		2,779	Low	0	0	Low		0	0	Low		0	0	0		0		0
6320	271	Pittsfield, MA MSA	84,699	88,695	(3,996)	-4.5%		252	Medium	0	1			0	0	Medium		0	1	0		0		0
6240	272	Pine Bluff, AR MSA	84,278	85,487	(1,209)	-1.4%		873	Incomplete	0	0			0	0			0	0	0		0		0
8750	273	Victoria, TX MSA	84,088	74,361	9,727	13.1%		852		0	0			0	0	Medium		0	1	0		0		0
3700	274	Jonesboro, AR MSA	82,148	68,956	13,192	19.1%		716	Medium	0	1			0	0			0	0	0		0		0
1580	275	Cheyenne, WY MSA	81,607	73,142	8,465	11.6%		2,703	Low	0	0	Low		0	0			0	0	0		0		0
3040	276	Great Falls, MT MSA	80,357	77,691	2,666	3.4%		2,661	Low	0	0			0	0			0	0	0		0		0
1890	277	Corvallis, OR MSA	78,153	70,811	7,342	10.4%		668		0	0			0	0			0	0	0		0		0
6340	278	Pocatello, ID MSA	75,565	66,026	9,539	14.4%		1,122	High	1	1	Medium	2	0	0			0	0	0		0		0
1350	279	Casper, WY MSA	66,533	61,226	5,307	8.7%		5,342		0	0	Low		0	0			0	0	0		0		0
2340	280	Enid, OK MSA	57,813	56,735	1,078	1.9%		1,054	Low	0	0			0	0			0	0	0		0		0
Source: U.S. Census Bureau, Census 2000 Redistricting Data (P.L. 94-171) Summary File and 1990 Census.			**229,192,836**	**201,381,763**	**27,811,073**	**13.8%**		**613,142**	**TOTALS**	**262**	**468**		**43**	**119**	**399**		**90**	**337**	**442**	**50**	**13**	**50**	**14**	**50**
		Counties outside MSA's:																						
AK		Fairbanks, AK (partial NA area)	82,840						Medium	0	1		0	0	0			0	0	0	0	0	Serious	0
AK		Juneau, AK (partial NA area)	30,711										1	0	0			0	0	0		0		0

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
	AL	Clay County	14,254						High	1	1			0	0	High		1	1	0		0		0
	AL	DeKalb County	64,452						Superhigh	1	1			0	0			0	0	0		0		0
	AL	Escambia County	38,440						High	1	1			0	0			0	0	0		0		0
	AL	Sumter County	14,798						High	1	1			0	0	Medium		0	1	0		0		0
	AL	Talladega County	80,321						Superhigh	1	1			0	0			0	0	0		0		0
	AL	Walker County	70,713						Superhigh	1	1			0	0			0	0	0		0		0
	AR	Ashley County	24,209						Superhigh	1	1			0	0			0	0	0		0		0
	AR	Garland County	88,068						Medium	0	1			0	0			0	0	0		0		0
	AR	Mississippi County	51,979						High	1	1			0	0			0	0	0		0		0
	AR	Phillips County	26,445						Medium	0	1			0	0			0	0	0		0		0
	AR	Polk County	20,229						Medium	0	1			0	0			0	0	0		0		0
	AR	Pope County	54,469						Medium	0	1			0	0			0	0	0		0		0
	AR	White County	67,165						Medium	0	1			0	0			0	0	0		0		0
	AZ	Cochise County, AZ (Douglas NA area)	117,755										2	0	0	Medium		0	1	0	1	0		0
	AZ	Gila County, AZ (Miami NA area)	51,335										2	0	0			0	0	0	1	0		0
	AZ	Greenlee County, AZ (Morenci NA area)	8,547										0	0	0			0	0	0	1	0		0
	AZ	Santa Cruz County, AZ (Nogales NA area)	38,381						Medium	0	1	Medium	1	0	0			0	0	0		0		0
	CA	Imperial County, CA (Imperial Valley NA area)	142,361						High	1	1	High	1	0	0	High		1	1	0		0		0
	CA	Inyo County, CA (Owens Valley & Searles Valley NA areas)	17,945						Medium	0	1	High	2	0	0	Medium		0	1	0		0		0
	CA	Kings County, CA (part of San Joaquin Valley planning area)	129,461						Superhigh	1	1	Medium	1	0	0	High		1	1	0		0		0
	CA	Mono County, CA (Mono Basin NA area)	12,853						Superhigh	1	1	High	1	0	0	Medium		0	1	0		0		0
	CA	Plumas County, CA	20,124						Medium	0	0	Medium		0	0	Medium		0	1	0		0		0
	CO	Archuleta County, CO (Pagosa Springs NA area)	9,898										1	0	0			0	0	0		0		0
	CO	Pitkin County, CO (Aspen NA area)	14,872										1	0	0			0	0	0		0		0
	CO	Prowers County, CO (Lamar NA area)	14,483									Medium	1	0	0			0	0	0		0		0
	CO	Routt County, CO (Steamboat Springs NA area)	19,690										1	0	0			0	0	0		0		0
	CO	San Miguel County, CO (Telluride NA area)	6,594										1	0	0			0	0	0		0		0
	DE	Sussex County, DE	156,638						Medium	0	1			0	0	High	Marginal	1	1	0		0		0
	GA	Floyd County	90,565						Superhigh	1	1			0	0			0	0	0		0		0
	GA	Glynn County	67,568						Medium	0	1			0	0	Medium		0	1	0		0		0
	GA	Hall County	139,277						Superhigh	1	1			0	0			0	0	0		0		0
	GA	Lowndes County	92,115						High	1	1			0	0			0	0	0		0		0
	GA	Washington County	21,176						High	1	1			0	0			0	0	0		0		0
	GA	Wilkinson County	10,220						High	1	1			0	0			0	0	0		0		0
	Guam	Guam (Piti and Tanguisson NA areas)	0										0	0	0			0	0	0	2	0		0
	IA	Clinton County	50,149						Medium	0	1			0	0			0	0	0		0		0
	ID	Bonner County, ID (Sandpoint NA area)	36,835										1	0	0			0	0	0		0		0
	ID	Power County, ID (Fort Hall Reservation & Portneuf Valley NA areas)	7,538									High	2	0	0			0	0	0		0		0
	ID	Shoshone County, ID (Pinehurst & Shoshone Co NA areas)	13,771						Medium	0	1		2	0	0			0	0	0		0		0
	IL	Adams County	68,277						Medium	0	1			0	0	Medium		0	1	0		0		0
	IL	La Salle County	111,509						High	1	1	Medium		0	0			0	0	0		0		0
	IL	Randolph County	33,893						Medium	0	1			0	0	Medium		0	1	0		0		0
	IN	Dubois County	39,674						High	1	1			0	0			0	0	0		0		0
	IN	Henry County	48,508						Medium	0	1			0	0			0	0	0		0		0
	IN	Knox County	39,256						Medium	0	1			0	0			0	0	0		0		0
	IN	La Porte County	110,106						Medium	0	1			0	0	High		1	1	0		0		0
	IN	Spencer County	20,391						High	1	1			0	0			0	0	0		0		0
	KY	Bell County	30,060						High	1	1			0	0	High		1	1	0		0		0
	KY	Edmonson County, KY	11,644											0	0	High	Maint. Area	1	1	0		0		0
	KY	Franklin County	47,687						Medium	0	1			0	0			0	0	0		0		0
	KY	Hardin County	94,174						High	1	1			0	0	Medium		0	1	0		0		0
	KY	McCracken County	65,514						High	1	1			0	0	High	Maint. Area	1	1	0		0		0
	KY	Perry County	29,390						Superhigh	1	1			0	0	Medium		0	1	0		0		0
	KY	Pike County	68,736						High	1	1			0	0	Medium		0	1	0		0		0
	KY	Warren County	92,522						High	1	1			0	0	High		1	1	0		0		0
	LA	Concordia Parish	20,247						Medium	0	1			0	0			0	0	0		0		0
	LA	Iberville Parish	33,320						Medium	0	1			0	0	High		1	1	0		0		0
	LA	Pointe Coupee Parish, LA	22,763											0	0	Medium	Maint. Area	0	1	0		0		0
	LA	Tangipahoa Parish	100,588						Medium	0	1			0	0			0	0	0		0		0
	MD	Kent & Queen Anne's Counties, MD (near DC)	52,000											0	0		Marginal	0	0	0		0		0

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

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MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
	ME	Hancock & Waldo Counties, ME (now in tip of Bangor MSA)	88,071											0	0	High	Maint. Area	1	1	0		0		0
	ME	Knox & Lincoln Counties, ME	73,234											0	0	Medium	Moderate	0	1	0		0		0
	MN	Crow Wing County	55,099						Medium	0	1			0	0			0	0	0		0		0
	MN	Itasca County, MN	43,992						Medium	0	1			0	0			0	0	0		0		0
	MO	St. Genevieve County	17,842						Medium	0	1			0	0	High		1	1	0		0		0
	MS	Adams County	34,340						Medium	0	1			0	0	High		1	1	0		0		0
	MS	Bolivar County	40,633						Medium	0	1			0	0	High		1	1	0		0		0
	MS	Jones County	64,958						High	1	1			0	0			0	0	0		0		0
	MS	Lauderdale County	78,161						Medium	0	1			0	0	Medium		0	1	0		0		0
	MS	Lee County	75,755						Medium	0	1			0	0	High		1	1	0		0		0
	MS	Lowndes County	61,586						Medium	0	1			0	0			0	0	0		0		0
	MS	Pearl River County	48,621						Medium	0	1			0	0			0	0	0		0		0
	MS	Scott County	28,423						Medium	0	1			0	0			0	0	0		0		0
	MS	Warren County	49,644						Medium	0	1			0	0	Medium		0	1	0		0		0
	MT	Flathead County, MT (Columbia Falls, Whitefish and vicinity, Kalispell NA areas)	74,471										3	0	0	Low		0	0	0		0		0
	MT	Lake County, MT (Polson and Ronan NA areas)	26,507						Medium	0	1		2	0	0			0	0	0		0		0
	MT	Lewis & Clark County, MT (East Helena NA area)	55,716										0	0	0			0	0	0	1	0		0
	MT	Lincoln County, MT (Libby NA area)	18,837						High	1	1		1	0	0			0	0	0		0		0
	MT	Missoula County	95,802						Medium	0	1			0	0			0	0	0		0		0
	MT	Ravalli County	36,070						High	1	1			0	0			0	0	0		0		0
	MT	Rosebud County, MT (Lame Deer NA area)	9,383										1	0	0			0	0	0		0		0
	MT	Sanders County, MT (Thompson Falls & vicinity NA area)	10,227										1	0	0			0	0	0		0		0
	MT	Silver Bow County, MT (Butte NA area)	34,606										1	0	0			0	0	0		0		0
	NC	Caswell County	23,501						Medium	0	1			0	0			0	0	0		0		0
	NC	Duplin County	49,063						Medium	0	1			0	0			0	0	0		0		0
	NC	Haywood County	54,033						High	1	1			0	0			0	0	0		0		0
	NC	Jackson County	33,121						Medium	0	1			0	0			0	0	0		0		0
	NC	Lenoir County	59,648						Medium	0	1			0	0			0	0	0		0		0
	NC	McDowell County	42,151						High	1	1			0	0			0	0	0		0		0
	NC	Mitchell County	15,687						High	1	1			0	0			0	0	0		0		0
	NC	Montgomery County	26,822						Medium	0	1			0	0			0	0	0		0		0
	NC	Pasquotank Count	34,897						Medium	0	1			0	0			0	0	0		0		0
	NC	Robeson County	123,339						High	1	1			0	0			0	0	0		0		0
	NC	Swain County	12,968						Medium	0	1			0	0			0	0	0		0		0
	NH	Cheshire County	73,825						Medium	0	1			0	0	Medium		0	1	0		0		0
	NM	Grant County, NM	31,002										0	0	0			0	0	0	1	0		0
	NV	White Pine County, NV (Central Steptoe Valley NA area)	9,181										0	0	0			0	0	0	1	0		0
	NY	Jefferson County, NY	111,738											0	0	Medium	Marginal	0	1	0		0		0
	NY	Essex County, NY	38,851											0	0	Medium	Marginal	0	1	0		0		0
	OH	Athens County	62,223						Medium	0	1			0	0			0	0	0		0		0
	OH	Preble County	42,337						Medium	0	1			0	0	Medium		0	1	0		0		0
	OH	Scioto County	79,195						Superhigh	1	1			0	0			0	0	0		0		0
	OK	Cherokee County	42,521						Medium	0	1			0	0	High		1	1	0		0		0
	OK	Mayes County	38,369						Medium	0	1			0	0			0	0	0		0		0
	OK	Muskogee County	69,451						Medium	0	1			0	0			0	0	0		0		0
	OK	Ottawa County	33,194						Medium	0	1			0	0			0	0	0		0		0
	OR	Josephine County, OR (Grants Pass NA area)	75,726										1	0	0			0	0	0		0		0
	OR	Klamath County, OR (Klamath Falls NA area)	63,775						Medium	0	1		1	0	0			0	0	0		0		0
	OR	Lake County, OR (Lakeview NA area)	7,422										1	0	0			0	0	0		0		0
	OR	Union County, OR (LaGrande NA area)	24,530										1	0	0			0	0	0		0		0
	PA	Adams County	91,292						Medium	0	1			0	0			0	0	0		0		0
	PA	Armstrong County, PA	72,392										0	0	0	High		1	1	0	1	0		0
	PA	Warren County, PA (Conewango Township & other NA areas)	43,863										0	0	0			0	0	0	2	0		0
	SC	Beaufort County	120,937						Medium	0	1			0	0			0	0	0		0		0
	SC	Chesterfield County	42,768						Medium	0	1			0	0			0	0	0		0		0
	SC	Colleton County	38,264						Medium	0	1			0	0	Medium		0	1	0		0		0
	SC	Georgetown County	55,797						Medium	0	1			0	0			0	0	0		0		0
	SC	Greenwood County	66,271						High	1	1			0	0			0	0	0		0		0
	SC	Oconee County	66,215						Medium	0	1			0	0	High		1	1	0		0		0
	TN	Dyer County	37,279						Medium	0	1			0	0			0	0	0		0		0

Metropolitan Areas Ranked by Population: 2000 ------ Monitoring Requirements with 4 Ozone & PM2.5 Categories = Super-high, High, Medium, Low

Source: U.S. Census Bureau for Population, AIRS for AQ data, Monitoring Strategy Regulatory Review WorkGroup for network site numbers.

MSA/ CMSA Code	Rank	Area Name	Census Population		Change, 1990 to 2000		Area Size		PM2.5 REQUIREMENTS			PM10 REQUIREMENTS				O3 REQUIREMENTS				SO2 REQUIREMENTS		CO REQUIREMENTS		NO2 REQUIREMENTS
			April 1, 2000	April 1, 1990	Number	Percent	sq. Miles	sq. Miles	CONC RANGE	# SITES MIN	# SITES MAX	CONC RANGE	NA Areas?	# SITES MIN	# SITES MAX	CONC RANGE	1-hr NA Areas?	# SITES MIN	# SITES MAX	NAMS	N/A Areas?	NAMS	N/A Areas?	NAMS
	TN	Lawrence County	39,926						Medium	0	1			0	0	High		1	1	0		0		0
	TN	Maury County	69,498						High	1	1			0	0			0	0	0		0		0
	TN	McMinn County	49,015						High	1	1			0	0			0	0	0		0		0
	TN	Putnam County	62,315						Medium	0	1			0	0	High		1	1	0		0		0
	TN	Roane County	51,910						High	1	1	Low		0	0			0	0	0		0		0
	UT	Tooele County, UT	40,735										0	0	0			0	0	0	1	0		0
	VA	Page County	23,177						Medium	0	1			0	0	Medium		0	1	0		0		0
	VA	Smyth County, VA (White Top Mountain NA area)	33,081											0	0		Marginal	0	0	0		0		0
	WA	Walla Walla County, WA (Wallula NA area)	55,180									Medium	1	0	0			0	0	0		0		0
	WI	Dodge County, WI	85,897						Medium	0	1			0	0	Medium		0	1	0		0		0
	WI	Door County, WI	27,961											0	0	High	Marginal	1	1	0		0		0
	WI	Grant County, WI	49,597						Medium	0	1			0	0			0	0	0		0		0
	WI	Jefferson County, WI	74,021						Medium	0	1			0	0	High		1	1	0		0		0
	WI	Kewaunee County, WI	20,187											0	0	High	Maint. Area	1	1	0		0		0
	WI	Manitowoc County, WI	82,887											0	0	High	Moderate	1	1	0		0		0
	WI	Walworth County, WI (at IL-WI border)	93,759											0	0	Medium	Maint. Area	0	1	0		0		0
	WV	Greenbrier County, WV	34,453											0	0		Maint. Area	0	0	0		0		0
	WV	Harrison County	68,652						High	1	1			0	0			0	0	0		0		0
	WV	Marion County	56,598						High	1	1			0	0			0	0	0		0		0
	WV	Mercer County	62,980						Medium	0	1			0	0			0	0	0		0		0
	WV	Monongalia County, WV	81,866						High	1	1			0	0			0	0	0		0		0
	WV	Raleigh County, WV	79,220						Medium	0	1			0	0			0	0	0		0		0
	WY	Sheridan County, WY (Sheridan, Trona Industrial area NA areas)	26,560										1	0	0			0	0	0		0		0
		SUBTOTALS	**7,464,604**							**40**	**104**		**36**	**0**	**0**			**24**	**47**	**0**	**12**	**0**	**1**	**0**
									PM2.5:	Minimum	Maximum	PM10:	NA areas	Minimum	Maximum		Ozone:	Minimum	Maximum	SO2	NA Areas	CO	NA Areas	NO2
		TOTALS - Metropolitan Areas + Add'l Counties:	**236,657,440**							**302**	**572**		**79**	**119**	**399**			**361**	**489**	**50**	**25**	**50**	**15**	**50**

§ 58.40 PAMS network establishment and Appendix PAMS language

REVISION February 14, 2002

(a) In addition to the plan revision, the State shall submit a photochemical assessment monitoring network description including a schedule for implementation to the Administrator within 6 months after;

(1) Date of redesignation or reclassification of any existing l-hr O_3 nonattainment area to serious, severe, or extreme; or

(2) The designation of a new area and classification to serious, severe, or extreme O_3 nonattainment.

The network description will apply to all serious, severe, and extreme, 1-hour O_3 nonattainment areas within the State. Some O_3 nonattainment areas may extend beyond State or Regional boundaries. For areas that are under the 8-hour nonattainment designations only, PAMS monitoring is encouraged but not required. In instances where PAMS network design criteria as defined in appendix D to this part require monitoring stations located in different States and/or Regions, the network description and implementation schedule should be submitted jointly by the States involved. When appropriate, such cooperation and joint network design submittals are preferred. Network descriptions shall be submitted through the appropriate Regional Office(s). Alternative networks, including different monitoring schedules, periods, or methods, may be submitted, but they must include a demonstration that they satisfy the monitoring data uses and fulfill the PAMS monitoring objectives described in sections 4.1 and 4.2 of appendix D to this part.

(b) For purposes of plan development and approval, the stations established or designated as PAMS must be stations from the SLAMS network or become part of the SLAMS network required by § 58.20. (Reg review group- please note -do we need to change network name ?)

(c) The requirements of appendix D to this part applicable to PAMS must be met when designing the PAMS network.

§ 58.41 PAMS network description.

The PAMS network description required by § 58.40 must contain the following:

(a) Identification of the monitoring area represented.

(b) The AIRS site identification number for existing stations.

(c) The proposed location for scheduled stations.

(d) Identification of the site type and location within the PAMS network design for each station as defined in appendix D to this part except that during any year, a State may choose to submit detailed information for the site scheduled to begin operation during that year's PAMS monitoring season, and defer submittal of detailed information on the remaining sites until succeeding years. Such deferred network design phases should be submitted to EPA for approval no later than January 1 of the first year of scheduled operation. As a minimum, general information on each deferred site should be submitted each year until final approval of the complete network is obtained from the Administrator.

(e) The sampling and analysis method for each of the measurements.

(f) The operating schedule for each of the measurements.

(g) An O_3 event forecasting scheme, if appropriate.

(h) A schedule for implementation. This schedule should include the following:

(1) A timetable for locating and submitting the Aerometric Information System, Air Quality Subsystem (AQS) site identification form for each scheduled PAMS that is not located at the time of submittal of the network description;

2 A timetable for phasing-in operation of the required number and type of sites as defined in appendix D to this part; and

3 A schedule for implementing the quality assurance procedures of appendix A to this part for each PAMS.

[58 FR 8468, Feb. 12, 1993, as amended at 64 FR 3035, Jan. 20, 1999]

§ 58.42 PAMS approval.

The PAMS network required by § 58.40 is subject to the approval of the Administrator. Such approval will be contingent upon completion of each phase of the network description as outlined in § 58.41 and upon conformance to the PAMS network design criteria contained in appendix D to this part.

§ 58.43 PAMS methodology.

PAMS monitors must meet the monitoring methodology requirements of appendix C to this part applicable to PAMS.

§ 58.44 PAMS network completion.

(a) The complete, operational PAMS network will be phased in as described in Appendix D to this part over a period of 3 years after;

(1) Date of redesignation or reclassification of any existing O_3 nonattainment area to serious, severe, or extreme; or

2 The designation of a new area and classification to serious, severe, or extreme O_3 nonattainment.

(b) The quality assurance criteria of appendix A to this part must be implemented for all PAMS.

§ 58.45 PAMS data submittal.

(a) The requirements of this section apply only to those stations designated as PAMS by the network description required by § 58.40.

(b) All data shall be submitted to the Administrator in accordance with the format, reporting periods, reporting deadlines, and other requirements as specified for NAMS in § 58.35.

(c) The State shall report oxides of nitrogen and meteorological data consistent with the requirements of § 58.35 for criteria pollutants.

(d) Lee et al - this needs to be in alignment with what you decide- will it be a regional assessment or state assessment, and who approves - The Regional Administrator or the actual Administrator? - placeholder for now:

States shall prepare a regional assessment of their PAMS network and submit to the Regional Administrator. Guidelines for this assessment shall be specified by the US EPA. This report shall include, in part, a summary of the data and data collection activities pertaining to all precursor, carbon monoxide and surface and upper-air meteorological monitoring activities.

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§ 58.46 System modification.

(a) Any proposed changes to the PAMS network description will be evaluated during the annual SLAMS Network Review specified in § 58.20. Changes proposed by the State must be approved by the Administrator. The State will be allowed 1 year (until the next annual evaluation) to implement the appropriate changes to the PAMS network.

(b) PAMS network requirements are mandatory only for serious, severe, and extreme 1-hr O_3 nonattainment areas. When any such area is redesignated to attainment, the State may continue its PAMS monitoring program subject to available funding and approval by the Regional Administrator.

APPENDIX:

4. Network Design for Photochemical Assessment Monitoring Stations (PAMS)

In order to obtain more comprehensive and representative data on O_3 air pollution, the 1990 Clean Air Act Amendments require enhanced monitoring for ozone (O_3), oxides of nitrogen, and monitoring for VOC in O_3 nonattainment areas classified as serious, severe, or extreme. This will be accomplished through the establishment of a network of Photochemical Assessment Monitoring Stations (PAMS).

4.1 PAMS Data Uses. Data from the PAMS are intended to satisfy several coincident needs related to attainment of the National Ambient Air Quality Standards (NAAQS), SIP control strategy development and evaluation, corroboration of emissions tracking, preparation of trends appraisals, and exposure assessment.

(a) NAAQS attainment and control strategy development. Like SLAMS and NAMS data, PAMS data will be used for monitoring O_3 exceedances and providing input for attainment/nonattainment decisions. In addition, PAMS data will help resolve the roles of transported and locally emitted O_3 precursors in producing an observed exceedance and may be

utilized to identify specific sources emitting excessive concentrations of O_3 precursors and potentially contributing to observed exceedances of the O_3 NAAQS. The PAMS data will enhance the characterization of O_3 concentrations and provide critical information on the precursors which cause O_3, therefore extending the database available for future attainment demonstrations. These demonstrations will be based on photochemical grid modeling and other approved analytical methods and will provide a basis for prospective mid-course control strategy corrections. PAMS data will provide information concerning (1) which areas and episodes to model to develop appropriate control strategies; (2) boundary conditions required by the models to produce quantifiable estimates of needed emissions reductions; and (3) the evaluation of the predictive capability of the models used.

(b) SIP control strategy evaluation. The PAMS will provide data for SIP control strategy evaluation. Long-term PAMS data will be used to evaluate the effectiveness of these control strategies. Data may be used to evaluate the impact of VOC and NO_x emission reductions on air quality levels for O_3 if data is reviewed following the time period during which control measures were implemented. Speciation of measured VOC data will allow determination of which organic species are most affected by the emissions reductions and assist in developing cost-effective, selective VOC reductions and control strategies. A State or local air pollution control agency can therefore ensure that strategies which are implemented in their particular nonattainment area are those which are best suited for that area and achieve the most effective emissions reductions (and therefore largest impact) at the least cost.

(c) Emissions tracking. PAMS data will be used to corroborate the quality of VOC and NO_x

emission inventories. Although a perfect mathematical relationship between emission inventories and ambient measurements does not yet exist, a qualitative assessment of the relative contributions of various compounds to the ambient air can be roughly compared to current emission inventory estimates to evaluate the accuracy of the emission inventories. While the regulatory assessments of progress will be made in terms of emission inventory estimates, the ambient data can provide independent trends analyses and corroboration of these assessments which either verify or highlight possible errors in emissions trends indicated by inventories. The ambient assessments, using speciated data, can gauge the accuracy of estimated changes in emissions. The speciated data can also be used to assess the quality of the VOC speciated and NO_x emission inventories for input during photochemical grid modeling exercises and identify potential urban air toxic pollutant problems which deserve closer scrutiny.

The speciated VOC data will be used to determine changes in the species profile, resulting from the emission control program, particularly those resulting from the reformulation of fuels.

(d) Trends.. Long-term PAMS data will be used to establish speciated VOC, nitrogen compounds, and CO trends and to supplement the O_3 and air toxics trends databases. Multiple statistical indicators will be tracked, including O_3 and its precursors during the events encompassing the days during each year with the highest O_3 concentrations.

As the spatial distribution and number of O_3 and O_3 precursor monitors improves, trends analyses will be less influenced by instrument or site location anomalies. The requirement that surface meteorological monitoring be established at each PAMS will help maximize the utility of these trends analyses by comparisons with meteorological trends, and transport influences. The meteorological data can also help interpret the ambient air pollution trends by taking meteorological factors into account.

4.2 PAMS Monitoring Objectives. Unlike the SLAMS and NAMS design criteria which are pollutant specific, PAMS design criteria are site specific. Concurrent measurements of O_3, oxides of nitrogen, speciated VOC, CO, and meteorology are obtained at PAMS sites. Design criteria for the PAMS network are based on selection of an array of site locations relative to O_3 precursor source areas and predominant wind directions associated with high O_3 events. Specific monitoring objectives are associated with each location. The overall design should enable characterization of precursor emission sources within the area, transport of O_3 and its precursors, and the photochemical processes related to O_3 nonattainment. Specific objectives that must be addressed include assessing ambient trends in O_3, oxides of nitrogen, VOC species, and determining spatial and diurnal variability of O_3, oxides of nitrogen, and VOC species. Specific monitoring objectives associated with each of these sites may result in four distinct site types. Note that detailed guidance for the locating of these sites may be found in reference 19) Check on reference number changes.

Type 1 sites are established to characterize upwind background and transported O_3 and its precursor concentrations entering the area and will identify those areas which are subjected to overwhelming transport. Type 1 sites are located in the predominant morning upwind direction from the local area of maximum precursor emissions during the O_3 season and at a distance sufficient to obtain urban scale measurements as defined in section 1 of this appendix. Typically, Type 1 sites will be located near the edge of the photochemical grid model domain in the predominant morning upwind direction from the city limits or fringe of the urbanized area. Depending on the boundaries and size of the nonattainment area and the orientation of the grid, this site may be located outside of the nonattainment

area. The appropriate predominant morning wind direction should be determined from historical wind data occurring during the period 7 a.m. to 10 a.m. on high O_3 days or on those days which exhibit the potential for producing high O_3 levels, i.e., O_3-conducive days as described in reference 25. Alternate schemes for specifying this morning wind direction may be submitted as a part of the network description required by Secs. 58.40 and 58.41.

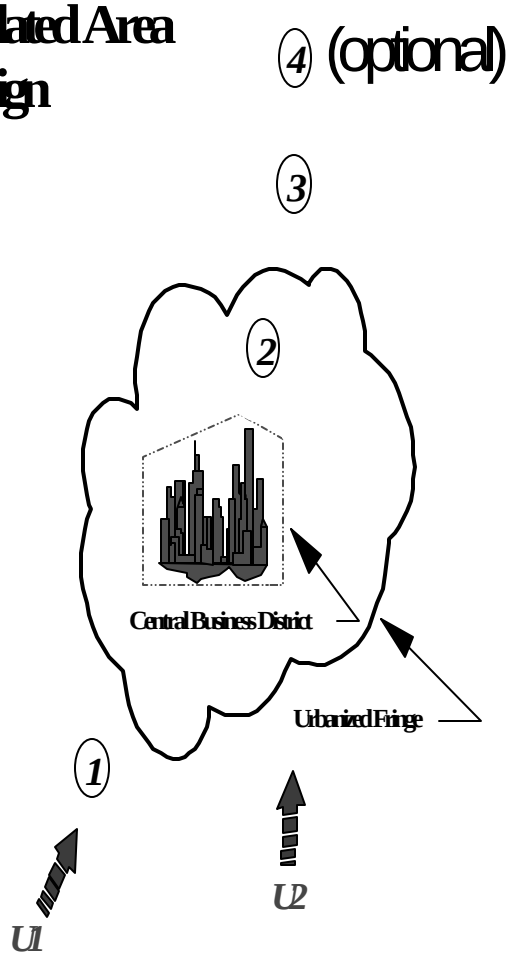
Type 2 sites are established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions are expected to impact and are suited for the monitoring of urban air toxic pollutants. Type 2 sites are located immediately downwind of the area of maximum precursor emissions and are typically placed near the downwind boundary of the central business district to obtain neighborhood scale measurements. The appropriate downwind direction should be obtained similarly to that for type 1 sites. Additionally, a second Type 2 site may be desirable depending on the size of the area.

Type 3 sites are intended to monitor maximum O_3 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, Type 3 sites will be located 10 to 30 miles downwind from the fringe of the urban area. The downwind direction should also be determined from historical wind data, but should be identified as those afternoon winds occurring during the period 1 p.m. to 4 p.m. on high O_3 days or on those days which exhibit the potential for producing high O_3 levels. Alternate schemes for specifying this afternoon wind direction may also be submitted as a part of the network description required by Secs. 58.40 and 58.41.

Type 4 sites are important for some, but not all O_3 nonattainment areas. These sites are established to characterize the extreme downwind transported O_3 and its precursor concentrations exiting the area and will identify those areas which are potentially contributing to overwhelming transport in other areas. Type 4 sites are located in the predominant afternoon downwind direction, as determined for the type 3 site, from the local area of maximum precursor emissions during the O_3 season and at a distance sufficient to obtain urban scale measurements as defined elsewhere in this appendix. Typically, Type 4 sites will be located near the downwind edge of the photochemical grid model domain. Alternate schemes for specifying the location of this site may be submitted as a part of the network description required by Secs. 58.40 and 58.41.

Alternative PAMS network designs should, on a site-by-site basis, provide those data necessary to enhance the attainment/nonattainment database for criteria pollutants and explain the origins of overwhelming O_3 transport. The alternative PAMS data should be usable for the corroboration and verification of O3 precursor emissions inventories and should comprise a qualitative (if not quantitative) measure of the accuracy of mid course correction calculations (refer to Reference #__, Mid Course Correction Guidance.)

Figure 5 - Isolated Area Network Design



Legend:

1 - A circle denotes a PAMS Site. The number inside describes the Site number.

U1 - High ozone day predominant morning wind direction

U2 - High ozone day predominant afternoon wind direction

The data should be sufficient to evaluate the effectiveness of the implemented O_3 control strategies and should provide data necessary to establish photochemical grid modeling boundary conditions and necessary inputs including appropriate meteorological parameters, and provide measurements which can serve as model evaluation tools. Further, utilizing its PAMS database (alternative or not), a State should be able to draw conclusions regarding population exposure and conduct trends analyses for both criteria and non-criteria pollutants. Overall, the PAMS network should serve as one of several complementary means, together with modeling and analysis of other data bases (e.g., inventories) and availability of control technology, etc., for States to justify the modification of existing control programs, design new programs, and evaluate future courses of actions for O_3 control.

4.3 Monitoring Period. PAMS precursor monitoring will be conducted annually throughout the months of June, July and August (as a minimum) when peak O_3 values are expected in each area. Alternate precursor monitoring periods may be submitted for approval to the Regional Administrator Note reg review group - need to make this authority consistent with the NAMS authority! as a part of the PAMS network description required by §58.40. Changes to the PAMS monitoring period must be identified during the annual SLAMS Network Review specified in §58.20. PAMS O_3 monitors must adhere to the O_3 monitoring season specified in section 2.5 of appendix.

4.4 Minimum Monitoring Network Requirements. A Type 2 Site is required for each area. Overall, only two sites are required, providing all chemical measurements are made. For example, if a design includes two, Type 2 sites, then a third site will be necessary to capture the NOy measurement. The minimum required number and type of monitoring sites and sampling requirements are attached as Table 2. Any alternative plans may be put in place in lieu of these requirements, pending approval by the Assistant Administrator (Reg review? Regional or main Administrator?)

Table 2. MINIMUM REQUIRED PAMS MONITORING LOCATIONS AND FREQUENCIES

Measurement	Where Required	Sampling Frequency (All daily except for upper air meteorology)[1]
Speciated VOC[2]	Two sites per area, one of which must be a Type 2 Site.	During the PAMS monitoring period: 1) Hourly auto GC, or 2) Eight 3-hour canisters, or 3) 1 morning and 1 afternoon canister with a 3-hour or less averaging time plus Continuous Total Non-methane Hydrocarbon measurement.
NOx	All Type 2 Sites	Hourly during the ozone season[3]
NOy	One site per area at the Type 3 or Type 1 Site	Hourly during the ozone season
CO (ppb level)	One site per area at a Type 2 Site	Hourly during the ozone season
Ozone	All sites	Hourly during the ozone season
Surface Met	All sites	Hourly during the ozone season
Upper Air Meteorology	One representative location within PAMS area	Sampling frequency must be approved as part of the PAMS Network Description described in 40 CFR 58.41.

[1]Daily or with an approved alternative plan.
[2]Speciated VOC is defined in the Technical Guidance Document Reference __, Target Compounds.
[3]Approved ozone season as stipulated in 40CFR58, Reference --.

Note also that O_3 event (peak day) monitoring will require the development of a scheme for forecasting such high O_3 days or will necessitate the stipulation of what meteorological conditions constitute a potential high O_3 day; monitoring could then be triggered only via meteorological projections. The O_3 event forecasting and monitoring scheme should be submitted as a part of the network description required by Secs. 58.40 and 58.41 and should be reviewed during each annual

Section 9- Communications
DRAFT

Monitoring data are a critical part of the nation's air program infrastructure. The nation's ambient air monitoring networks inform the public of air quality levels and exposure, establish the compliance status of cities and other areas, track air quality trends and evaluate progress of emission control programs, and support development of emission control and air quality research programs . Monitoring programs, which are operated largely by State and local agencies and Tribal nations, are subject to continual changes in local, state, tribal, federal and academic priorities. New and revised national ambient air quality standards (NAAQS) and other regulatory needs, changing air quality (e.g., general trend toward reduced concentrations of criteria pollutants), and an influx of scientific findings and technological advancements challenge the response capability of the nation's networks. The single-pollutant measuring approach commonly administered in networks is not an optimal design for recent integrated air quality management trends such as the linkages across ozone, fine particulate matter, regional haze, air toxics, and multi-media interactions (e.g., atmospheric deposition). Indeed, the current design of the nation's networks still is based largely on the existing monitoring regulations (Code of Federal Regulations, parts 53 and 58) that were developed in the late 1970's.

The United States spends well over $200 million annually on routine ambient air monitoring programs. The incentives for growth in ambient monitoring activities generally are clear and compelling. and based on scientific findings that lead to revision of air quality standards or identification of important measurement gaps. Less clear is the justification or incentive for divesting in existing monitoring programs. Monitoring programs appear to suffer from inertia once established, and conscious downsizing efforts occur with far less frequency than recent program enhancements (e.g., PAMS, $PM_{2.5}$, air toxics). Stability in networks is a positive attribute, as considerable time spans (decadal length) often are required to detect and interpret important air quality trends. This strategy seeks to achieve an appropriate balance between needed stability and a desired improvement in response capability to scientific finding and emerging priorities. Assuming limited, at best, resource growth in monitoring programs, serious efforts must be devoted to optimizing resources to meet evolving monitoring challenges. The aggregation of so many technical, institutional, and resource issues form the backdrop for an ambient air monitoring strategy.

The goal of the strategy is to manage the nation's air monitoring networks such that critical stable network elements as well as changing priorities can be accommodated within a scientifically sound and resource optimized framework that addresses national and local interests. This framework requires progress on various aspects that shape the monitoring networks, including:

- Establishing an assessment program that supports decision-making steps related to network divestments and investments;
- Developing a communications strategy to explain to all stakeholders the rationale behind network changes and the associated benefits;

- Integrating across programs and organizations to optimize monitoring programs and the utilization of monitoring data;
- Incorporating emerging technological and scientific advances in measurement techniques;

To achieve this objective, states, locals, tribes and US EPA representatives need to work together. The following discusses the advantages of implementing these changes.

1) What are the benefits to state and local agencies in implementing the National Monitoring Strategy?

Increased data to the public: The Monitoring Strategy seeks to incorporate new, continuous technologies into the national network. Incorporation of these new technologies will lead to more efficient, electronic reporting of real-time data (such as the ozone network reporting system). Moving from filter-based methods and periodic reporting, to continuous methods and subsequent satellite-GIS type reporting via internet networks will provide the public with real-time, current information.

Conservation of Resources. By dis-investing in monitors for pollutants in attainment areas and redundant locations, a state agency can save resources to fund more immediate monitoring priorities (e.g., toxic air pollutants.) This dis-investment does not mean omitting monitors in crucial areas: it simply means using the local regional assessment to ascertain which monitors are providing redundant measurements.

Integrated NCORE Monitoring. Since NCORE sites will measure multiple types of pollutants, a local area will be able to determine health effects from pollutant-mixture and pollutant interaction data. Also, a local area will have a basis for comparing their local measurements with national data, since each NCORE site will be designed for national uniformity to FRM methods and laboratory techniques. Trend assessments will also be performed at the NCORE site, which will yield more valuable information about the local area's air quality in relation to the nation.

More Resources for Local Issues. As these NCORE sites are funded, they will be providing much of the data needed to meet national requirements. Utilizing the concept of splitting federal funds between national NCORE sites and local sites allows local areas to monitor for pollutants which are of most importance to local communities. This then benefits the public, since the local objectives of providing better spatial representation and population exposure assessments are met with federal funds and not delegated to a lower priority depending on state budgets. The local area will thus have a large amount of their monitor funding available for purely local needs. These needs would cover hot-spot monitoring, local source characterization, environmental justice issues, and any other need the local authority deems necessary. The other advantage to an NCORE site is that continuous and advanced technologies will be operated together with well established methods to enable the local area the ability to incorporate these proven technologies into their local networks without having spent local resources. As both the NCORE and local monitoring is performed, information will be provided that could lead to new air quality standards, which would be more protective of public health.

Differences in monitoring objectives among state and local agencies. Federal requirements will be changed to enable a greater degree of local monitoring flexibility while maintaining a minimum core national network to meet national needs. These requirements are being changed in concert with state and local monitoring staff across the nation. For example, both federal regulators and state representatives widely support the notion of annual network assessments. Network assessments will help the local authority review their monitoring needs for the coming year, as well as provide information for adjustments as local priorities change.

Public Involvement. Working with EPA, state and local agencies would need to establish a public education and outreach program. This program would communicate the purposes of air monitoring networks and specific air monitors, with the understanding that monitors are not established for perpetuity. Needs for air monitoring change over time, and networks need to change to meet new priorities using limited resources. The public should be made aware that loss of a monitor or a monitoring station within a community does not connote loss of information. Resources saved by dis-investments in redundant monitors can be better used locally for more pressing monitoring needs.

State and local agencies should establish one or more public workshops to discuss potential monitoring network changes. Engagement of the public early in the process will help state and local agencies with additional outreach mechanisms, and provide important input for agencies to address citizen concerns.

2) What are the benefits to the research and academic community when implementation of the Monitoring Strategy occurs?

The networks operated by State and local agencies provide an enormous resource of "routine" data that complement the more advanced measurements conducted by research organizations in attempting to uncover the specific causes of adverse health effects related to air pollution, or to test air quality simulation models that try to replicate the complex physical and chemical behavior of the atmosphere.

The NCORE network will be designed to ensure that long term research interests will benefit fromm the routine monitoring conducted by S/L/Ts. This strategy recognizes the leveraging value of a spectrum of other air monitoring efforts, including intensive research oriented studies (NARSTO, PM2.5 Supersites, CRPAQS, PM health centers), deposition monitoring (CASTNET, IADN, NADP) and numerous other smaller research projects.

3) How will the Tribal Community Benefit from implementation of the Monitoring Strategy?
[Laura McKelvey to add]

There are several representatives on the Monitoring Strategy Steering Committee from national tribes, and they have been very active in shaping the Strategy. The tribal representation on the Committee is crucial, since ambient monitoring is a relatively new area for tribal communities. The Strategy will benefit these communities by fostering development of the latest technologies for ambient monitoring and public reporting. Thus, all lessons learned over the last 20 years of ambient monitoring can be

relayed to the tribal community, thereby saving the tribal technical staff from using outdated technical and reporting methods.

As with the state public involvement discussed above, tribal environmental and technical communities will need to develop their own outreach programs to their communities, in the form of public meetings and written announcements.

4. What is the Schedule for Implementation of a New National Network? We are nearing the completion of the planning stage for network revision. The following table outlines future work:

Strategy Committee Oversight	January -June 2002
CASAC Review	March-December 2002
Initial Assessment Guidance	February 2002
National Tribal Forum	January 2002
CASAC comments, revisions are made	June 2002
Draft Strategy Document	March 2002
Draft Regulation Package Release	October 2002
Regional Assessments/ Recommendations	November 2002
Implementation of New Sites	TBD

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United States
Environmental Protection Agency
Office of Air Quality Planning
& Standards

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National Air Monitoring Strategy
Outlook for the Future

January 14, 2002

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Emissions, Monitoring & Analysis Division
Monitoring & Quality Assurance Group
Research Triangle Park, North Carolina

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EPA, along with State, local, and tribal officials, is evaluating the nation's air monitoring networks to assess their future ability to meet clean air objectives set forth by the Congress and the Clean Air Act.

The overarching objective of the strategy is to manage the nation's air monitoring networks such that changing priorities and needs, both national and local, can be accommodated within a scientifically sound and resource optimized framework.

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Why Do We Need Monitoring Networks?

EPA administers two grant programs to assist States in collecting and evaluating ambient air data from the nation's air monitoring networks. These grant programs, authorized in the Clean Air Act §105 and §103, address a variety of air quality program data collection needs that include:

1. **Compliance:** Comparing air quality data to National Ambient Air Quality Standards (NAAQS) or other benchmarks which drive regulatory actions.

2. **Population exposure/public awareness**: Data to support the Air Quality Index (AQI) and other means to indicate levels of pollution to which populations may be potentially exposed.

3. **Accountability for progress in emissions control programs**: Data to capture measurable ambient impacts associated with emissions control programs.

4. **Emission control program development**: Data to support construction of emission reduction programs.

5. **Environmental welfare assessments**: Data to support assessments such as visibility impairment, and watershed degradation.

6. **Research**: Data to assist research programs (e.g., develop associations between measurements and adverse health indicators, describe physical and chemical atmospheric processes).

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What are the Network Priorities?

Responding effectively to changing priorities, which are largely established by Congressional, scientific, and EPA leadership, is clearly an important goal of the monitoring strategy. Current national monitoring program priorities include developing a complete $PM_{2.5}$ monitoring program, and answering attainment questions on ozone, nonattainment areas. Toxic air pollutants are emerging as a national program priority and represent one of several challenges facing the monitoring community. Other priorities of a more localized nature include responding to public concerns, other criteria pollutant concerns (e.g., CO, SO_2), and specific air quality modeling needs. The monitoring strategy focus will be to produce a system capable of responding to an evolution of changing program priorities. After developing a concise list of monitoring objectives, priorities will be assigned through consensus among a Monitoring Strategy Steering Committee (NMSC) composed of EPA, state and tribal officials. In addition, public outreach efforts are an important component and can help strengthen public acceptance. While the NMSC will guide the outreach effort, state and local agencies can solicit public comment and input throughout the entire process.

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Why does EPA Believe Change is Needed?

Several indicators are pointing to a need for a revamped network. In the following graph[1], the trends data is shown for the last 20 years for each major pollutant tracked. Reductions in ambient concentrations range from 20 percent for ozone and PM_{10} to 98 percent for lead. This is great news: the Clean Air Act is working, and the hard work that air regulators have done to reduce air pollution is paying off. To maintain progress, however, we still need air

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[1]Percentages reflect annual means for sulfur dioxide, PM10, nitrogen dioxide, and annual maximums for lead, ozone, and carbon monoxide.

quality monitors. Duplicate monitors, monitors in areas with excessively low ambient concentrations of pollutants, or monitors within close proximity of each other that show the same concentration levels, are examples of possible inefficient use of resources.

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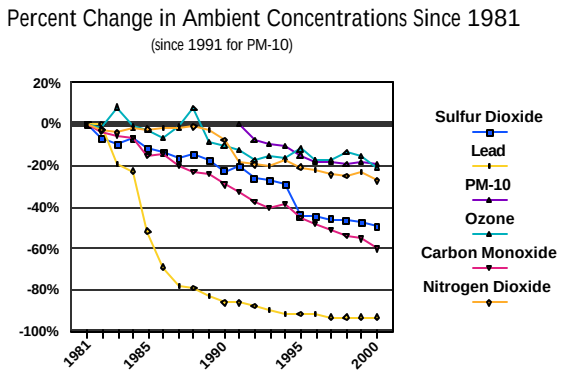
Will Our Region or State Lose Monitoring Grant Funds?

No. The NMSC members and other state and local representatives seek to assess the present network and align it with the needs of the future network. Reducing monitors that provide little information on air quality will free resources to build new monitors needed for



assessing other issues, such as toxic air pollutants. In addition, new technologies which will yield more accurate information and become less costly in the long term can be implemented in place of older and less effective monitors. And, local monitoring personnel will benefit as well, with a switch to continuous monitoring technology that takes fewer hours of hands-on operation. Site operators can be redirected from operating obsolete monitoring equipment to more continuous technologies that can provide real time information to the public.

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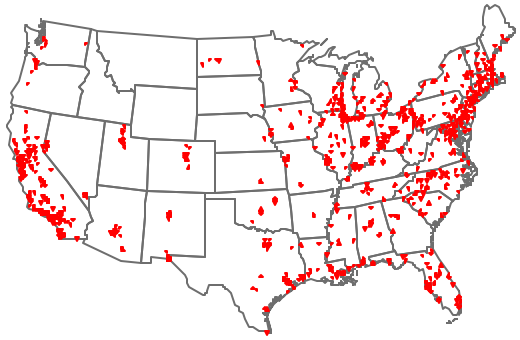
The map below displays the current distribution of ozone air monitoring sites in the continental United States. You can see how certain monitoring networks have become densely sited in some geographic



locations. The combination of national and regional network assessment work will help us to identify those monitors that are statistically measuring the same concentrations within a local area that could be omitted or better located.

Distribution of Current Ozone and PM Monitoring Sites

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What are the Local Resource Implications for Changing Monitors?

Funding for ambient air monitoring programs is expected to remain level for the foreseeable future. However, to enable network changes, EPA will modify regulations and technical guidance to reflect technological advances including continuous particle methods, satellite reporting to database systems, and monitor placement geared toward pollutants that are posing the greatest risk (such as toxic air pollutants in some areas) and co-location of multi-pollutant monitors.. Each State and local agency will have the opportunity to gear their networks to their local needs and also maintain a minimum, Federal core network as mandated by regulation. EPA expects the minimum core network to be smaller than the current network. The savings from reducing the size of the present network would offset the costs encountered by building new, localized networks.

To learn more about the monitoring strategy, visit EPA's website at:

http://www.epa.gov/ttn/amtic/monitor.html

This website also has detailed maps that represent the present monitoring configuration. Go to the following link and scroll to the last file:

http://www.epa.gov/ttn/amtic/netamap.html

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United States Environmental Protection Agency

Section 10. Monitoring Program Funding Strategy

There are a number of resource issues within the air monitoring program that must be addressed to realize any success with the national air monitoring strategy. The national air monitoring strategy will result in changes to our air monitoring regulations, our data management and reporting structure, technical aspects of air pollution monitoring, and our overall program assessment and management. EPA will initiate a work group to review the current program funding and the new demands placed upon it in the national air monitoring strategy, and develop a plan for how EPA, States, local agencies, and tribal governments will manage our existing funding. Undoubtedly, there will also be a number of initiatives that may not have adequate funding. This funding work group will need to identify where these gaps exist so that appropriate levels of management can begin to broach the subject of securing funding.

Known Resource Issues

The National Air Monitoring Strategy Committee and the technology, quality assurance and regulatory work groups will address the technical merits of our existing programs and what improvements or changes must occur. Each group will also need to provide a cost estimate of the actual costs of operating a revised ambient air monitoring program. These cost figures will be used as input information for the funding work group.

The air monitoring community is aware of a number of existing resource issues that should be evaluated by this work group. A listing of these would include *at a minimum*:

- Transitioning from the existing 103 authority to a 105 authority for the particulate matter grants. The 103 grant for particulate matter monitoring will need to address the new coarse particulate standard, if it is to be adopted. Given that complexity, when should this grant transition take place and over what time period?
- Ensuring adequate QA resources, including movement of NPEP into STAG programs.
- Evaluation of existing Photochemical Assessment Monitoring Station (PAMS) program funding in response to proposed changes. How can any available funds be intelligently applied toward other air toxics or priority monitoring areas?
- Allocation of any increase to the air toxics monitoring grants, either increases due to existing funding being made available or new grant monies.
- How to provide adequate funding for the continuous particulate matter monitoring program initiatives that are identified?
- Meeting the NCcore and IT related fundings needs.
- Ensuring stable funding.

EPA recommends that this funding work group be established in FY2003, after many of the technical recommendations on the national air monitoring strategy are generally agreed upon by the air monitoring community. This work group should consist of EPA staff who are conversant in air monitoring, grants, and the budgeting process, along with representatives from air pollution control agencies from the State, local and tribal agencies.