QUALITY ASSURANCE PROJECT PLAN

ST. LOUIS - MIDWEST SUPERSITE

Revision 1
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1.1 Background/Introduction

The Environmental Protection Agency's "Supersites" (USEPA, 1998a) program is an innovative response to the widely recognized need for a comprehensive characterization of airborne particulate matter in major U.S. urban centers. Phase I Supersites were conducted in Atlanta, GA, and Fresno, CA. Phase II Supersites are being established in seven urban areas within the continental United States: 1) Fresno, CA; 2) Los Angeles, CA; 3) Houston, TX; 4) St. Louis, MO; 5) Pittsburgh, PA; 6) Baltimore, MD; and 7) New York, NY. These Supersites are intended to provide a more detailed physicochemical characterization of particles as compared to the particle mass compliance and speciation networks. They will operate research-grade air monitoring stations to improve understanding of measurement technologies, source contributions and control strategies, and the effects of suspended particles on health. This strategy requires the development, field evaluation, and implementation of novel particle measurement techniques.

A Supersite is best conceived as a comprehensive regional monitoring program that is integrated into the national PM monitoring network. Because it serves multiple functions that go well beyond the needs of compliance monitoring, however, a Supersite is expected to leverage other governmental and private investments, and to have analysis and evaluation built into its design. Accordingly, while different Supersites should provide a core of consistent measurements, they are not required to be identical in their designs. It is essential that Supersites be designed as "learning" rather than "measurement" programs, with an emphasis on the diffusion of new information across traditional disciplinary boundaries.

The overall goal of the St. Louis - Midwest Supersite is to provide the physical and chemical measurements needed by the health effects community, the atmospheric science community and the regulatory community to properly assess the impact of particulate matter exposure on human health and to develop control strategies to mitigate these effects. This goal will be achieved through the implementation of a comprehensive ambient particulate matter monitoring program in the Metropolitan St. Louis (IL-MO) area. The monitoring program is specifically designed to support state-of-the-art health studies, and to provide atmospheric scientists and regulatory officials with the tools to efficiently and effectively develop particulate matter control strategies.

The overall strategy of the proposed monitoring program was developed to address three overlapping particle research needs:

1. *Implementation and evaluation of highly time-resolved particle measurement techniques*. State-of-the-art continuous methods will make it possible to meet the St. Louis Supersite's quantitative data collection objectives in a cost-effective manner. The experience to be gained through the field-testing of these monitoring techniques will be shared with the scientific and instrument manufacturing communities. This will be critical in the further development and evolution of these monitors, and is intended to result in their application to large networks such as the EPA speciation network and other large air quality programs.

2. *Spatial and temporal (from minutes up to 24 hours) characterization of a large spectrum of particle physical and chemical properties in the St. Louis metropolitan area.* A number of integrated samplers will be employed and collectively, these large data sets will be used as part of future investigations to develop source/receptor models, which ultimately will be used for setting up State Implementation Plans (SIPs). Also, this information will enhance understanding of sources, formation processes, and physico-chemical properties of ambient particles.

3. *Investigation of particle health effects.* The St. Louis Supersite program will be fully integrated with three large health effects research projects. The exposure and health effects studies constitute an ambitious research portfolio that will greatly benefit from the Supersite program. The main objectives of these studies are: (i) investigate relationships between personal exposures and outdoor concentrations, and examine the health effects of chronic exposures; (ii) identify biological mechanisms responsible for particle health effects; (iii) identify susceptible populations; and (iv) investigate the relative toxicity of different particle constituents.

USEPA requires that projects performed by extramural organizations on behalf of or funded by the USEPA that involves the acquisition of environmental data, especially data generated from direct measurement activities, shall be implemented in accordance with an approved Quality Assurance Project Plan (QAPP) (USEPA, 1999). This QAPP is prepared for the St. Louis Supersite project in accordance with USEPA's specific requirements for form and content (USEPA, 1999) and general guidelines (USEPA, 1998b) in fulfillment of this requirement.

1.2 Project Organization

1.2.1 Overview of Project Organization

Figure 1-1 presents the organizational structure for the St. Louis Supersite. Table 1-1 provides the points of contact for each person identified in Figure 1-1. Dr. Jay Turner, an Associate Professor at Washington University, is the principal investigator. He is assisted by the Executive Management Team of Drs. Judith Chow (Desert Research Institute), Petros Koutrakis (Harvard School of Public Health), Peter McMurry (University of Minnesota), and Warren White (Washington University), who will share project oversight responsibility with emphasis on their areas of expertise. One-or-more members of the Executive Management Team will be consulted for all substantive decisions regarding the monitoring program scope and content.

The Internal Steering Committee consists of all co-Investigators and additional key personnel. Each investigator has assigned responsibilities; however, collectively this committee also serves as the forum for working through ideas and shaping the scope and content of the work plan. The primary mode of communication includes regularly-scheduled conference calls and the web-based information support system. The Committee will convene for at least two data analysis workshops – one following the end of the field campaign and one following completion of the chemical characterizations.

Dr. Jay Turner also serves as the Field Operations Supervisor. One-to-two full-time Field Operators (Mr. Yang Yanhui and a staff to be determined) will handle day-to-day activities at the field sites. These staff, qualified in operating and maintaining the measurement instrumentation, shall report directly to Dr. Turner and will work closely with the investigators responsible for each monitoring package (hereafter termed the "Measurement PIs"). The Field Operators are supported by Assistant Site Operators (Mr. Scott Duthie and Ms. Megan Yu). The operations staff also includes Dr. Judith Chow, who serves as the Field Operations Advisor. She works closely with the Field Operations Supervisor and the Field Operators to address field monitoring logistics. Dr. Rudolf Husar is responsible for the web-based information support system. Dr. John Watson, a Research Professor at DRI, is the Quality Assurance Manager. QA activities are an integral part of the measurement process. Dr. Watson is a continual and active participant in technical decision-making and data analysis.

A Local Government Committee has been formed to facilitate dialogue between the St. Louis Supersite team and local, state, and federal air quality officials. The objective is to provide an opportunity for input from these stakeholders during the project planning phase. A pre-study workshop was held in Summer 2000 to explore linkages between the field measurement program and state/local needs such as SIP development. A post-study workshop will be convened to disseminate the results.

1.2.2 Responsibilities of Key Individuals

- Washington University (WU), led by Drs. Jay Turner (PI), Warren White, Edward Macias and Rudolf Husar[1], is responsible for overall management of the Supersite program. Also, it oversees the field operations, data analysis/interpretation, and the infrastructure for a state-of-the-art information support system.

- Desert Research Institute (DRI) of the University and Community College System of Nevada, led by Drs. Judith Chow and John Watson, is responsible for ion analysis, quality assurance measures and data analysis.

- EPRI, led by Drs. Tina Bahadori[2] and Alan Hansen, provides experience in project management and support (such as the ARIES program in Atlanta), private sector participation, and experience in exposure and health effects studies.

- Harvard University (HSPH), led by Dr. Petros Koutrakis and Mr. George Allen, is responsible for field sampling and analysis in support of the allied exposure and health

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1. Dr. Bret Schichtel was a named investigator for this project. He has subsequently move to NPS-CIRA (Fort Collins, CO). While Dr. Schichtel is still participating in this project, day-to-day supervision of the web-based information support system has been transferred to Dr. Rudolf Husar.

2. Current Affiliation: American Chemistry Council, Washington, DC.

effects. HSPH investigators are responsible for an array of aerosol chemical characterization equipment including most of the semicontinuous monitors for aerosol composition.

- University of Maryland (UMCP), led by Dr. John Ondov, is responsible for trace element sampling and analysis, including applications to source apportionment.

- University of Minnesota (UMN), led by Dr. Peter McMurry, is responsible for aerosol physical characterization measurements.

- University of Wisconsin (UWI), led by Dr. James Schauer, is responsible for carbonaceous species characterization such as organic compound speciation and organic and elemental carbon (OC and EC) analysis, including applications of organic molecular markers to source attribution.

In addition to the project responsibilities described above, the following specific duties relevant this QAPP are defined.

Dr. Jay Turner, as Principal Investigator and Field Operations Supervisor, oversees all project tasks and has responsibility for the successful completion of Supersite measurements and interactions with other investigators that will use the measurements. Dr. Turner monitors all phases of the study and ensures that study objectives and milestones are attained. He participates in meetings with EPA’s project officer and prepares quarterly progress reports. He directly oversees the field monitoring activities, organizes and conducts meetings with internal and external collaborators, and resolves conflicts and problems as they arise. He reviews the database and ensures that Supersite data are submitted to the NARSTO Permanent Data Archive and other data archives within twelve (12) months of the end of the quarter of data collection as required by the cooperative agreement.

Dr. Judith Chow, as Co-Investigator and Field Operations Advisor, assists in project planning and oversight of field sampling, chemical analysis, data retrieval/reformatting/ processing/validation, and data analysis/modeling tasks. Dr. Chow conducts site visits and verifies instrument settings, and collaborates with other team members on quarterly to semiannual reviews, quality assurance project plan, quarterly progress reports, and final reports.

Dr. John Watson, as Quality Assurance Manager, specifies primary, calibration, performance test, and audit standards and the frequency of their application. He defines data validity flags that qualify the information based on internal and external consistency tests. He uses data from performance audits, performance tests, and validation checks to define the accuracy, precision, and validity of each data point. These measurement attributes are added to the project database. Dr. Watson also coordinates on-site and laboratory system audits for each measurement. He reviews each standard operating procedure for completeness and consistency. He analyzes performance audit results, and prepares audit reports. For the entire data set, Dr. Watson prepares data qualification statements that define the extent to which the acquired measurements attain the project's accuracy, precision, validity, and completeness objectives.

Dr. Douglas Lowenthal, as Data Base Manager, assembles the project database. His responsibilities include: 1) database design [structure of the database; tables used to hold data; and conventions such as names, units, flags, time conventions, etc.], 2) data traceability [design data processing procedures and documentation to provide traceability from the database back to the original data], 4) level 0 statistical checks [perform minimum and maximum checks, jump checks, and flatness checks], and 5) database documentation [assemble internal and external documentation describing database structures and data processing procedures].

1.3 Project Description

The St. Louis Supersite is acquiring advanced air quality measurements related to airborne particulate matter to accomplish the following objectives.

- In collaboration with allied health studies, investigate associations of excess mortality or morbidity with exposures to particles (mass, number, size, composition), and seasonal and transport-related patterns in these exposures.

- Provide high time resolution measurements for source apportionment and health effects studies. For example, diurnal patterns such as the rush-hour peaks observed for certain species carry source information.

- Observe short-lived variations in the ambient aerosol physical and/or chemical properties to improve the resolution of source apportionment methods that are limited by statistical collinearities in daily measurements.

- Provide further resolution, in space, that will make it possible to investigate the impact of local sources and to assess community exposures to ambient particles through the use of satellite sites.

- Operate state-of-the-art particle measurement techniques for an entire year, providing an evaluation of instrument performance and operability relevant to continued development and evolution of such monitors.

The measurement emphasis at the St. Louis Supersite is on in-situ, continuous, short duration measurements of: 1) $PM_{2.5}$ mass, sulfate, nitrate, carbon and aerosol light extinction; and 2) numbers of particles in discrete size ranges from 0.003 to ~10 µm. Hourly samples are collected for retrospective trace metals analysis. Substrate-based, time-integrated field sampling and laboratory analysis are applied for PM_1, $PM_{2.5}$, PM_{coarse} (PM_{10} minus $PM_{2.5}$), and PM_{10} mass; $PM_{2.5}$ and PM_{coarse} elements and carbon; $PM_{2.5}$ ions; and $PM_{2.5}$ organic speciation.

Observables common to other Supersites are: 1) daily $PM_{2.5}$ 24-hour average mass with Harvard Impactors which correlate with collocated Federal Reference Method (FRM) samplers; 2) 1-in-3 day $PM_{2.5}$ 24-hour average mass using a compliance network FRM; 3) $PM_{2.5}$ chemical speciation with Harvard Impactors and HEADS which correlate with collocated speciation network samplers; 4) coarse particle mass by dichotomous sampling and/or PM_{10} and $PM_{2.5}$ difference; and 5) high-sensitivity and time-resolved scalar and vector wind speed, wind direction, temperature, relative humidity, barometric pressure, and solar radiation.

Figures 1-2 and 1-3 show the St. Louis Supersite central monitoring location (hereafter termed the "core" site). It is located in a mixed-use (light commercial/residential), relatively low population density neighborhood in East St. Louis (IL) but is only 3 km due east of the St. Louis City (MO) Central Business District. In addition to the core site, measurements will be conducted from a movable instrument platform which will acquire data at the two "satellite" sites as well as the core site. A subset of the core site measurements will be conducted using the movable platform to provide a spatial context to the data. Figure 1-4 shows the core site and two satellite sites in relation to other fine particulate matter monitoring locations in the St. Louis area.

1.3.1 Project Tasks

The St. Louis Supersite study includes the following six tasks: 1) equipment procurement and installation; 2) network operations and data processing; 3) laboratory measurements; 4) quality assurance; 5) data validation and data analysis; and 6) management and reporting.

Under Task 1, Equipment Procurement and Installation, the equipment listed in Table 1-2 is specified, procured, acceptance-tested, installed, and calibrated. New instruments are configured and bench tested in the laboratory prior to field deployment. Instrument placement, sample presentation tubing, and wiring are documented. Arrangements are made to ensure continued sampling during the Supersite measurement period of April 15, 2001 through April 14, 2002.[3] Data logging capabilities and outputs of each instrument are specified and modifications made to the digital and analogue data acquisition systems; for many instruments, these systems provide remote access to near real time data. This communication capability can be used by health researchers to schedule clinical and toxicological measurements of test subjects.

Standard operating procedures (SOPs) relevant to St. Louis measurements are under development and will be completed (at least in draft format) prior to the start of full monitoring. Criteria gas pollutants (e.g., SO_2, CO, O_3, NO_x) are acquired at the core site by Illinois Environmental Protection Agency (IEPA) as part of the NAMS and SLAMS networks (IEPA, 2000). $PM_{2.5}$ and PM_{10} reference method sampling follows established procedures (USEPA, 1998c).

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[3] The start date is nominal, with the measurement period to be one full year following the start date.

Under Task 2, Network Operations and Data Processing, routine on-site operations and external audits are conducted. On-site activities are carried out by the Washington University staff under the direct supervision of Dr. Jay Turner, the principal investigator. On-site operations include: 1) inspection of instruments and data from the acquisition systems; 2) periodic performance tests; 3) sample receipt, changing, and storage; 4) documentation of instrument, station, and meteorological conditions; 5) preventive maintenance; 6) corrective maintenance; and 7) transmission of data, samples, and documentation.

On-site operations are supplemented with support provided by the individual Measurement PI's that includes: 1) periodic download and examination of field data; 2) review of site documentation; 3) replenishment of consumables and supplies; 4) regular contact and operations review with field staff; 5) periodic site visits to perform calibration, repair, and maintenance; and 6) coordination with other investigators and auditors. Uploaded data are integrated into a comprehensive database that is submitted to the validation checks described in Sections 2.10 and 4.0.

External audits are performed by DRI staff and include both system and performance audits as well as inter-laboratory comparison. Details are provided in Section 2.7.

Task 3, Laboratory Measurements, follows established Laboratory Measurement Guidelines and in each case are documented in laboratory SOPs. Field blanks are provided with filter packs designated for sampling. Each analysis includes daily calibration, 10% replicates, standards, blanks. Re-analyses are conducted only when performance tolerances or data validation criteria are not met. Remaining sample sections are archived under refrigeration for the duration of the project for potential re-analysis or analysis for other species. Averages and standard deviations of field blank concentrations are determined and incorporated into calculations of chemical component concentrations (Watson et al., 2001); the procedures for such calculations are specified in the SOPs. Participating laboratories are designated by institution in laboratory SOP summary of Table 2.4.

Task 4, Quality Assurance, is described in greater detail in Sections 2.5 to 2.8 and 3.1. DRI staff serve as independent QA managers for the field and laboratory measurements, conducting systems and performance audits. Data qualification statements are produced that estimate the extent to which accuracy and precision of the acquired data can be used to test hypotheses. Audit schedules, tests, and standards are also described in Sections 2.5 to 2.7. Several of the advanced measurements do not have traceable standards; their accuracy is evaluated by comparison with collocated measurements of the same or similar quantities. Several of the measurement hypotheses address these comparisons. A Quality Assurance Final Report (QAFR) will be submitted as an attachment to the final project report.

Under Task 5, Data Validation and Analysis, a research-grade database of specified accuracy, precision, validity, and completeness has been developed for the Central California Air Quality Studies (CRPAQS). Both the St. Louis and Fresno Supersites will use this database structure. Time series and scatterplots are examined to identify outliers. Validation levels described in Section 2.10 are assigned. After data validation and data management procedures are perfected, the continuous database is intended to be available to investigators within three months of the previous calendar quarter and the laboratory analysis database is intended to be available within six months after the previous calendar quarter. At project completion, St. Louis Supersite data will be compiled onto a CD-ROM with project reports and publications. The available historical database of gas, particulate, and meteorological measurements for the St. Louis Supersite are also included on the CD. These data are submitted to EPA's Supersite database and to applicable NARSTO data archives using the appropriate format developed by the Supersites Data Management Workgroup in collaboration with EPA staff and the Supersites Principal Investigators. Task 5 also uses data to examine hypotheses. Descriptions of these analyses and data analysis responsibilities are given in Section 4.

Under Task 6, Management and Reporting, the efforts of different project participants, including those associated with concurrent studies, are coordinated. The Principal Investigator attends national Supersite meetings each year and presents progress on measurements and hypothesis testing. This QAPP and the validated data set described in Section 2.10 are also project management and reporting responsibilities.

1.3.2 Project Schedule

The project schedule and milestones are shown in Figure 1-5. Measurements will begin April 15, 2001, and will continue until April 14, 2002.

1.4 Quality Objectives and Criteria for Measurement Data

Washington University and its cooperating institutions are fully committed to an effective quality assurance/quality control (QA/QC) program for the St. Louis Supersite project. Washington University and its cooperating groups will ensure that all ambient air quality and research measurement data generated for internal and external use shall meet specific data quality objectives (DQOs). In some cases, such as for monitoring of criteria pollutants (including $PM_{2.5}$), data quality objectives have been established by the EPA. These DQOs have been used to establish measurement quality objectives (MQOs) for various phases of the monitoring process. In some instances, the performance of the state-of-the-art instruments used at the St. Louis Supersite has not been reliably determined. Efforts are made to compare the same measurements on different instruments to assess the validity, reliability, and comparability of measured pollutant concentrations.

The MQOs used to characterize measurements at the St. Louis Supersite are listed below.

- **Precision:** Precision represents the reproducibility of measurements as determined by collocated sampling using the same methods or by propagation of individual measurement precisions determined by replicate analysis, blank analysis, and performance tests (Watson et al. 2001).

Precision, s_M, can thus be defined as deviations from the average response to the same measurable quantity.

$$s_m = [(\sum_{i=1}^{n} (C_m\text{-}C)^2)/(n\text{-}1)]^{1/2}$$

Precision of the continuous analyzers will be determined from replicate analyses of calibration standards, span checks, and/or precision check records.

For a direct-reading monitor, which yields a response that is linearly proportional to the ambient concentration, the calibration relationship between the true concentration, C_t, and the measured concentration, C_m, is:

$$C_m = aC_t + b$$

where: a = the proportionality constant (or span)
b = the baseline or blank level

Because C_t is assumed to be the true value, its precision is set equal to zero. Using fairly simple derived formulas for the propagating of errors, two simple rules can be used to propagate the precisions of the measured values (s_a and s_b) to estimate the precision of the derived value (s_x). This is assuming the errors are randomly distributed about the true value according to a normal distribution, and that these errors are uncorrelated with each other.

1. For addition and subtraction of the form x = a + b or x = a – b:

$$s_x^2 = s_a^2 + s_b^2$$

2. For multiplication and division of the form x = ab or x = a/b:

$$(s_x/x)^2 = (s_a/a)^2 + (s_b/b)^2$$

Applying these equations to the measured concentration equation ($C_m = aC_t + b$), the measurement precision, s_m, is:

$$s_m^2 = (s_a^2/a^2)(C_m\text{-}b)^2 + s_b^2$$

Thus, the precision for a direct-reading measurement, s_m, is seen to be a function of the concentration, C_m, the relative standard deviation of the span (s_a/a), and the absolute standard deviation of the baseline response, s_b. Each of these (Cm, s_a/a, and s_b) must be quantified to estimate the precision of the measurement Cm. The values are determined by periodic performance testing using standard concentrations and scrubbed air. Many of the direct-reading instruments at the St. Louis Supersite automatically provide daily zero and span values that can be used in this equation. Other instruments require manual methods and estimations to obtain these values.

Precision for filter-based instruments are propagated from precisions of the volumetric measurements, the chemical composition measurements, and the field blank variability using the methods of Bevington (1969) and Watson et al. (1995). The following equations are used to calculate the precision associated with filter-based measurements:

$$C_i = (M_i - B_i)/V$$

$$V = F \times t$$

$$\overline{B_i} = \frac{1}{n}\sum_{j=1}^{n} B_{ij}$$

$$STD_{Bi} = \left[\frac{1}{n-1}\sum_{j=1}^{n}(B_{ij} - \overline{B_i})^2\right]^{1/2}$$

$$SIG_{Bi} = \left[\frac{1}{n}\sum_{j=1}^{n}(\sigma_{Bij})^2\right]^{1/2}$$

Case 1 . . . If $\overline{B_i} < SIG_{Bi}$
then $\overline{B_i} = 0$ and $\sigma_{\overline{Bi}} = 0$

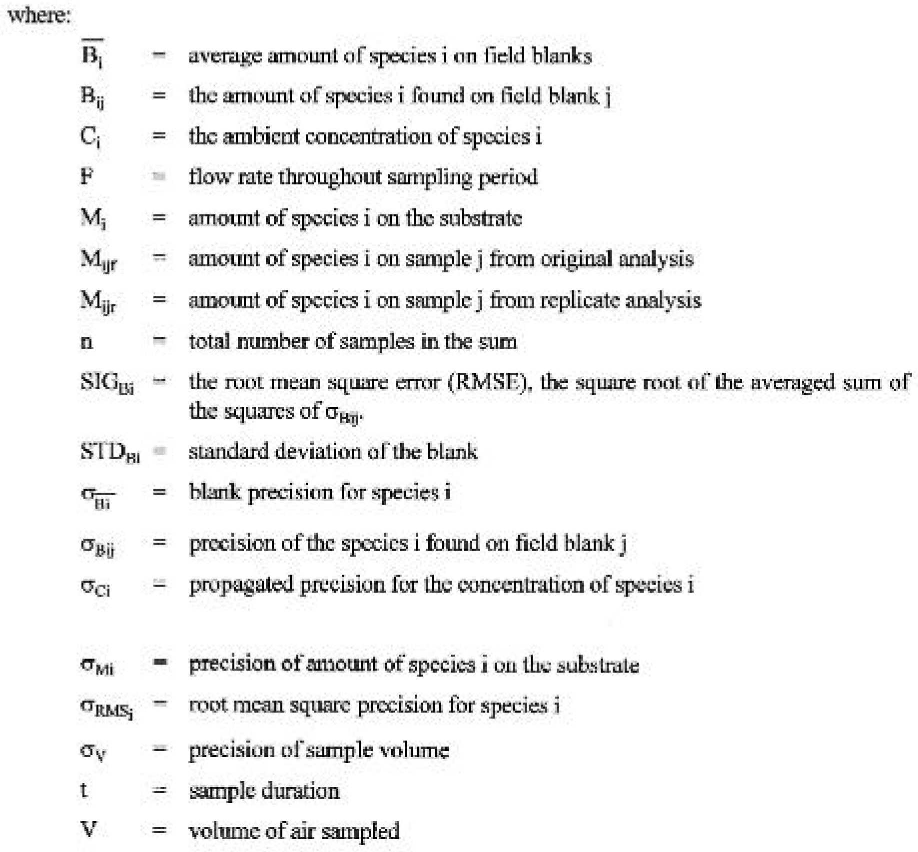
Case 2 . . . If $\overline{B_i} > SIG_{Bi}$ and $\overline{B_i} < STD_{Bi}$
then $\overline{B_i} = 0$ and $\sigma_{\overline{Bi}} = STD_{Bi}$

Case 3 . . . If $\overline{B_i} > SIG_{Bi}$ and $\overline{B_i} > STD_{Bi}$
then $\overline{B_i} = \overline{B_i}$ and $\sigma_{\overline{Bi}} = STD_{Bi}$

$$\sigma_{Ci} = \left[\frac{\sigma_{Mi}^{\,2} + \sigma_{Bi}^{\,2}}{V^2} + \frac{\sigma_V^{\,2}(M_i - B_i)^2}{V^4}\right]^{1/2}$$

$$\sigma_{RMS_i} = \left(\frac{1}{n}\sum_{j=1}^{n}\sigma_{Ci}^{\,2}\right)^{1/2}$$

$$\sigma_V/V = 0.05$$



where:

$\overline{B_i}$ = average amount of species i on field blanks
B_{ij} = the amount of species i found on field blank j
C_i = the ambient concentration of species i
F = flow rate throughout sampling period
M_i = amount of species i on the substrate
M_{ijr} = amount of species i on sample j from original analysis
M_{ijr} = amount of species i on sample j from replicate analysis
n = total number of samples in the sum
SIG_{Bi} = the root mean square error (RMSE), the square root of the averaged sum of the squares of σ_{Bij}.
STD_{Bi} = standard deviation of the blank
$\sigma_{\overline{Bi}}$ = blank precision for species i
σ_{Bij} = precision of the species i found on field blank j
σ_{Ci} = propagated precision for the concentration of species i

σ_{Mi} = precision of amount of species i on the substrate
σ_{RMS_i} = root mean square precision for species i
σ_V = precision of sample volume
t = sample duration
V = volume of air sampled

The project goal for precision is ±10%, expressed as the coefficient of variation (CV), for values that exceed ten times their lower quantifiable limits. The precision goal for gravimetric mass is ±5% CV as determined from replicate weightings.

- **Bias**: Bias is the systematic or persistent distortion of a measurement process that causes error in one direction. Bias is determined through performance audits and or by intercomparisons of the performance of similar instruments. Quantifiable biases that exceed precision intervals are corrected as part of the data validation process.

  Due to the unique nature of many of the measurements to be conducted, the situation will arise where primary standards are unavailable to determine bias. In addition, bias of the discrete methodologies can only be determined for the analytical instruments, and does include effects introduced by sample collection and transport. Bias will be calculated under three distinct situations:

    - A primary standard does not exist to determine instrumental accuracy
    - The comparison of two discrete methodologies using ambient data

  - Comparison two discrete methodologies using ambient data, one of which is a reference standard.

When a primary standard method is not available, bias will be calculated using the equation:

$$\text{Bias} = 1/n \sum_{i=1}^{n} \left[\left(X_i – S \right)/S \right] \text{ x } 100$$

where S is a non-primary standard value and X_i is the instrument results of the i^{th} measurement of the standard.

For comparison of two methodologies, neither of which is considered as a reference standard, bias will be calculated by the equation:

$$\text{Bias} = 1/n \sum_{i=1}^{n} \left[((M1_i - M2_i)/((M1_i + M2_i)/2)) \right] \text{ x } 100$$

where $M1_i$ and $M2_i$ are the i^{th} measurement of the two methodologies (M1 and M2) being subjected to comparison. The use of the average of the two methodologies in computing bias recognizes that a primary standard is not available.

If the results of a particular methodology are being compared to a primary reference standard then the following equation will apply:

$$\text{Bias} = 1/n \sum_{i=1}^{n} \left[(M2_i – M1_i)/M1_i \right] \text{ x } 100$$

Where the denominator has been replaced with the i^{th} measurement of the primary standard that will be used to determine bias.

- **Accuracy:** Accuracy is the correctness of data and refers to the degree of difference between a measured value and a known or “true” value. For particulate measurements, there are no known true values. Relative accuracy may be determined by comparing a measured value with a presumed reference, standard reference materials, or the use of two or more independent procedures to measure the same observable. Sampler accuracy will be measured by performance (flow rate) checks and audits between the sampler and a certified flow meter. The goal is ± 5% relative percent difference (RPD) or better. Since no true reference samples exist for the chemistry of airborne particulate matter, the accuracy of other speciated atmospheric components cannot be inherently determined. Analytical accuracy of the analytes will be determined by analyzing known reference materials in the laboratory.

  The accuracy of the continuous gas analyzers will be determined from performance audits conducted by the DRI. The analyzers will be challenged with standards from an independent, NIST-traceable source not used for calibration, encompassing the operational range of the instrument. A minimum of three data points, including zero will comprise the performance audit. A linear regression analysis in the following form will be used to determine the slope, intercept, and correlation coefficient:

$$y = mx + b$$

where x the audit concentration, y is the reported analyzer response, m is the slope, and b is intercept. The deviation of the slope from unity is used as the measure of accuracy. The goal for the continuous analyzers is ± 10%, or a slope within the range of 0.900 to 1.100.

For gravimetric and speciated fine particle samplers, the accuracy will be determined by flow rate checks. The estimation of accuracy for this method is:

$$\%\text{Accuracy} = [\ (Q_m - Q_a)/Q_a]\ \text{x}\ 100$$

where Q_a is the flow rate measured using a NIST traceable flow device, and Q_m is the flow rate indicated by the sampler.

- Detectability: Detectability is the low range critical value that a method-specific procedure can reliably discern. Analytical procedures and sampling equipment impose specific constraints on the determination of minimum detection limits (MDLs). For the gaseous analyzers MDLs are determined by repeatedly challenging the analyzer with zero air, and for filter-based methods the MDLs are determined by the use of field and laboratory blanks. A field blank is a filter that travels with the filters that will be utilized in sample collection and should be treated in the same manner as any other filter with the exception that it does not collect sample. A laboratory blank is a filter that is pre-weighed and processed in the same manner as all filters arriving from the field, but is kept in the laboratory. Besides providing MDL information the use of blanks provides essential field and laboratory measurement control data. The minimum detection limit (MDL) for St. Louis Supersite measurements is determined as three times the standard deviation of field blanks or three times the standard deviation of the noise of an instrument when subjected to clean air, whichever is higher.

The MDL for each continuous gas analyzer has been well characterized; this information can be found in the appropriate analyzer manual. This information can be verified through statistical evaluation of data from zero air checks, using the following:

$$\text{MDL} = t_{(n-1,1-a = 0.99)} * s$$

Where s is the standard deviation of the replicate zero analyses, t is the students t value appropriate to a 99% confidence level and a standard deviation estimate with n-1 degrees of freedom.

The determination of MDLs for discrete measurements involves a different approach. The samples are collected at a location away from analysis. Standards for the determination of detection limits for the laboratory analytical instruments are prepared in the laboratory and therefore are not subjected to the same procedures and equipment as the ambient samples. This detection limit is referred to as the instrument detection limit (IDL). The IDL is indicative of the ability of the instrument to differentiate, at a specific probability, between zero and at a specific concentration. The IDL standard does not experience the same handling procedures and therefore does not provide information relating to the detection limit at ambient.

- Completeness: Completeness is the percentage of valid data compared to the total expected data. Completeness will be determined using the following:

  $$\text{Completeness} = [(D_x - D_c)/D_c] \times 100$$

  With regard to discrete measurements, D_x is the number of samples for each species that valid results are obtained and D_c is the number of samples that scheduled to be collected and analyzed during the year. Completeness for continuous methods is the percentage of valid data obtained from the total amount possible, over a given time period.

  For this project, in which many of the instruments are prototypes or are newer technology, the completeness objective for all species and measurements is 75% of all attempted measurements. In addition to individual measurement completeness, program completeness will be measured because this dictates the robustness of the data set across the entire measurement strategy. Substitution will not take place if the completeness criteria are not met.

- **Representativeness:** Representativeness is the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environment condition. For this project, spatial and temporal data representativeness are achieved by following siting criteria for particulate monitoring sites (Watson et al., 1997). On September 12, 2000, Mr. Michael Davis (EPA Region VII) conducted an assessment of the three Supersite monitoring locations. Summary comments and photographs are presented in Appendix A. Another metric for representativeness will be comparing measurements at the core site with those from other monitoring stations in the region, including the North St. Louis City and Park Hills satellite sites. The Principal Investigator shall establish and maintain a record of characteristics of the actual sampling systems as deployed at the sites including, but not limited to: sampling height; inlet design; sample conditioning; and sampler location (including orientation relative to other monitors).

- **Comparability:** Comparability reflects the extent to which measurements of the same observable agree among different methods. Comparability may vary by method, aerosol composition, and meteorological conditions. Several of the hypotheses tested at the St. Louis Supersite include formal comparisons of measurements for different measurement configurations, aerosol compositions, and times of the year.

1.5 Project Training Requirements

The role of the principal investigator, co-investigators, measurement PIs, QA and data manager, and site operators are clearly defined. The measurement PIs ensure that project participants (e.g., site operators) are properly trained to perform individual tasks. Additional guidance about actual site operations for this project is provided to the site operators in the form of checklists, forms, SOPs, and other material forming part of this QAPP. Furthermore, the SOPs contain health and safety warnings and identify personnel qualifications including any required training.

1.6 Documentation and Records

This QAPP summarizes St. Louis Supersite measurements, defines data quality indicators, and specifies data quality objectives. Field and laboratory SOPs developed for St. Louis Supersite measurements are followed, and revised as needed, for the duration of the study. Procedures for advanced monitoring methods are being created and reviewed by the principal investigators. Revisions made to SOPs during the study period are noted and archived for traceability. Remedial actions taken as a result of field, laboratory, or data audits are also be documented. This information will be incorporated into a quality assurance final report as part of final project report delivery to EPA. Procedural summaries will also be documented in appropriate handbooks and manuals.

Field log and maintenance books will be provided by each Measurement PI. Furthermore, the field staff will keep a site log book for items not directly related to an individual measurement. After the field study is completed, the field log and maintenance books will be returned to the respective measurement PI with a photocopy retained by the project PI. The site log book(s) will be scanned with copies available for downloading by all Measurement PIs from the protected area of the St. Louis Supersite web site (http://capita.wustl.edu/StLSupersite). Raw data files will be retained by the Measurement PI unless this responsibility is explicitly transferred to the project PI.

Table 1-1. St. Louis Supersite participants.

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Table 1-2. Summary of air quality and meteorological measurements at the St. Louis Supersite.

Observable and Method	Measurement PI (by institution)	Size Range	Avg Time	Frequency	Sites	
					Core	Satellite
AEROSOL PHYSICAL PROPERTIES						
***In Situ* Measurements (Continuous or Semi-Continuous Automated Measurements)**						
Aerosol Size Distribution						
Nano-Scanning Mobility Particle Spectrometer (TSI 3085 DMA & TSI 3025A UCPC)	Minnesota	3-60 nm	5 min	daily	X	
Scanning Mobility Particle Spectrometer (TSI 3071 comparable DMA & TSI 3760 CPC)	Minnesota	20-500 nm	5 min	daily	X	
Optical Particle Counter (PMS LasAir 1002)	Minnesota	0.1-2 µm	5 min	daily	X	
Optical Particle Counter (Climet CI-500)	Minnesota	0.3-10 µm	5 min	daily	X	
Integral Moments of Aerosol Physical Properties						
Number Concentration (modified TSI 3025 Ultrafine CPC)	Minnesota	> 3 nm	5 sec	daily	X	X
“Dry” Light Scattering Coefficient (Nephelometer) (Radiance Research M903)	Minnesota	< 2.5 µm	5 sec	daily	X	X
Aerosol Electrometer (TSI 3068A)	Minnesota	< 2.5 µm	5 sec	daily	X	X
Aerosol Optical Density (Aethalometer) (Magee Scientific/AE-21)	Harvard	< 2.5 µm	5 min	daily	X	X
$PM_{2.5}$ Mass Concentration (Andersen CAMM)	Harvard	< 2.5 µm	1 hr	daily	X	X
$PM_{2.5}$ Mass Concentration (MetOne 1020 BAM)[1]	IEPA	< 2.5 µm	1 hr	daily	X	
Substrate Methods (Time-Integrated Manually-Operated Samplers)						
Particle Mass Concentration						
PM_1 mass (BGI SCC w/ Teflon filter)	Harvard	< 1.0 µm	24 hr	daily	X	X
$PM_{2.5}$ mass (Harvard Impactor w/ Teflon filter)	Harvard	< 2.5 µm	24 hr	daily	X	X
PM_{10} mass (Harvard impactor w/ Teflon filter)	Harvard	< 10 µm	24 hr	daily	X	X

Table 1-2. (continued).

Observable and Method	Measurement PI (by institution)	Size Range	Avg Time	Frequency	Sites	
					Core	**Satellite**
Aerosol Physical Properties - Substrate Methods (continued)						
Particle Mass Concentration (continued)						
Hi-Volume Dichotomous Sampler (Harvard sampler w/ Teflon filters; Andersen SA-251-I PM$_{10}$ cut; Marple Multi-Jet HVVI PM$_{2.5}$ cut)	Harvard		24 hr	2nd day	X	
- PM$_{2.5}$ mass		< 2.5 µm				
- PM$_{coarse}$ mass		2.5 - 10 µm				
NAMS/SLAMS Compliance Network[1]	IEPA					
- PM$_{2.5}$ mass (Andersen RAAS2.5-300 w/ Teflon filters)		< 2.5 µm	24 hr	3rd day	X	
- PM$_{10}$ mass (Andersen SA1200 w/ quartz filters)		< 10 µm	24 hr	6th day	X	
- TSP mass (GMW/Andersen 2310 w/ quartz filters)[2]		< ~30 µm	24 hr	12th day	X	
AEROSOL CHEMICAL PROPERTIES						
In Situ Measurements (Semi-Continuous Automated Measurements)						
PM$_{2.5}$ nitrate (HSPH continuous monitor with NO$_x$ detector)	Harvard	<2.5 µm	1 hr	daily	X	X
PM$_{2.5}$ sulfate (HSPH continuous monitor with SO$_2$ detector)	Harvard	<2.5 µm	1 hr	daily	X	X
PM$_{2.5}$ OC/EC (Sunset Laboratory)	Wisconsin	<2.5 µm	1 hr	daily	X	
Substrate Methods (Time-Integrated Manually-Operated Samplers)						
Ions: sulfate, nitrate, ammonium, potassium and sodium ions; acidity (HEADS, analysis by IC)	Harvard, DRI	<2.5 µm	24 hr	daily	X	X
OC/EC (PM$_{2.5}$ samplers w/ quartz filters, NIOSH Method 5040) (denuded & undenuded at core site; denuded only at satellite site)	Wisconsin	< 2.5 µm	24 hr	daily	X	X
Trace Metals (Harvard Impactors with Teflon filters, analytical method TBD)	Harvard	< 2.5 µm	24 hr	daily	X	X
Water Soluble Trace Metals (Harvard Impactors with Teflon filters, analytical method TBD)	Harvard	< 2.5 µm	24 hr	daily	X	X
Coarse PM OC/EC (coarse channel of Hi-volume dichotomous sampler, with quartz filters, NIOSH Method 5040)	Wisconsin	2.5-10 µm	24 hr	2nd day	X	

Table 1-2. (continued).

Observable and Method	Measurement PI (by institution)	Size Range	Avg Time	Frequency	Sites	
					Core	Satellite
Substrate Methods (Time-Integrated Manually-Operated Samplers) (continued)						
Coarse PM Trace Metals (Harvard Impactors PM_{10} - $PM_{2.5}$, and coarse channel of Hi-volume dichotomous sampler, with Teflon filters, analytical method TBD)	Harvard	2.5-10 µm	24 hr	Daily / 2nd day	X	
Selected Elements (12+ elements from As, Cu, Mn, Ni, Cr, Cd, Se, Ag, Pb, Al, Fe, Zn, Ca, V, Ti, Be, Ba) (HFASS-GRAZZ, chemistry on ~1200 samples retrospectively selected)	Maryland	< 1.2 µm	1 hr	daily	X	
Organic Compound Speciation (hi-volume sampler with quartz filters, analysis by GC-MS, chemistry on ~110 samples retrospectively selected)	Wisconsin	< 2.5 µm	24 hr	daily	X	
Toxicological Sampling (two Harvard high-volume slit impactors with PUF substrates, chemistry on samples retrospectively selected)	Washington	< 0.1 µm, 0.1-2.5 µm, 2.5-10 µm	1 week	weekly	X	
GASES						
Nitrogen oxides (NO/NO_x) (API 200A)[1]	IEPA	Gas	5-min	daily	X	
Sulfur Dioxide (SO_2) (Dasibi 4108)[1]	IEPA	Gas	5-min	daily	X	
Ozone (Dasibi 1008 RS)[1]	IEPA	Gas	5-min	daily	X	
Carbon monoxide (TECO48)[1]	IEPA	Gas	5-min	daily	X	
Ammonia, Nitric/Nitrous Acid, Sulfur Dioxide (HEADS denuders)	Harvard	Gas	24-hour	daily	X	X
VOC gases (XonTech 911 sampler with SUMMA canisters, analysis by GC-MS, ozone precursors and USEPA TO-15 toxics analyte lists)[3]	EPA RVII	Gas	24-hour	3rd day	X	
METEOROLOGY						
Wind speed/direction (Climatronics 102083-G0-H0 high-sensitivity wind vane and anemometer)[4]	Washington	NA	5-min	daily	X	
Temperature (Climatronics 100093 temperature sensor with motor aspirated shied, 2 & 10 m)[4]	Washington	NA	5-min	daily	X	
Relative humidity (Climatronics 102425)[4]	Washington	NA	5-min	daily	X	
Solar radiation (Climatronics CM3 pyranometer)[4]	Washington	NA	5-min	daily	X	

Table 1-2. (continued).

Observable and Method	**Measurement PI (by institution)**	**Size Range**	**Avg Time**	**Frequency**	**Sites**	
					Core	**Satellite**
METEOROLOGY (continued)						
Atmospheric pressure (Climatronics 102270-G3) [4]	Washington	NA	1-hr	daily	X	
Precipitation (Climatronics 100097-1-G0)	Washington	NA	15-min	daily	X	

(1) Operated by Illinois Environmental Protection Agency at the East St. Louis SLAMS compliance monitoring site. For the SO_2, O_3, and NO_x monitors, averaging times are one hour for the data reported to AIRS, while this data will be reported at higher time resolution for the Supersite study period.

(2) TSP filters are extracted and analyzed for Lead, Arsenic, Beryllium, Cadmium, Chromium, Iron, Manganese, Nickel, Selenium, and Vanadium, Sulfate, and Nitrate.

(3) A separate QAPP has been prepared by EPA Region VII for the VOC sampling.

(4) Meteorological sensors are mounted on a 10 meter tower.

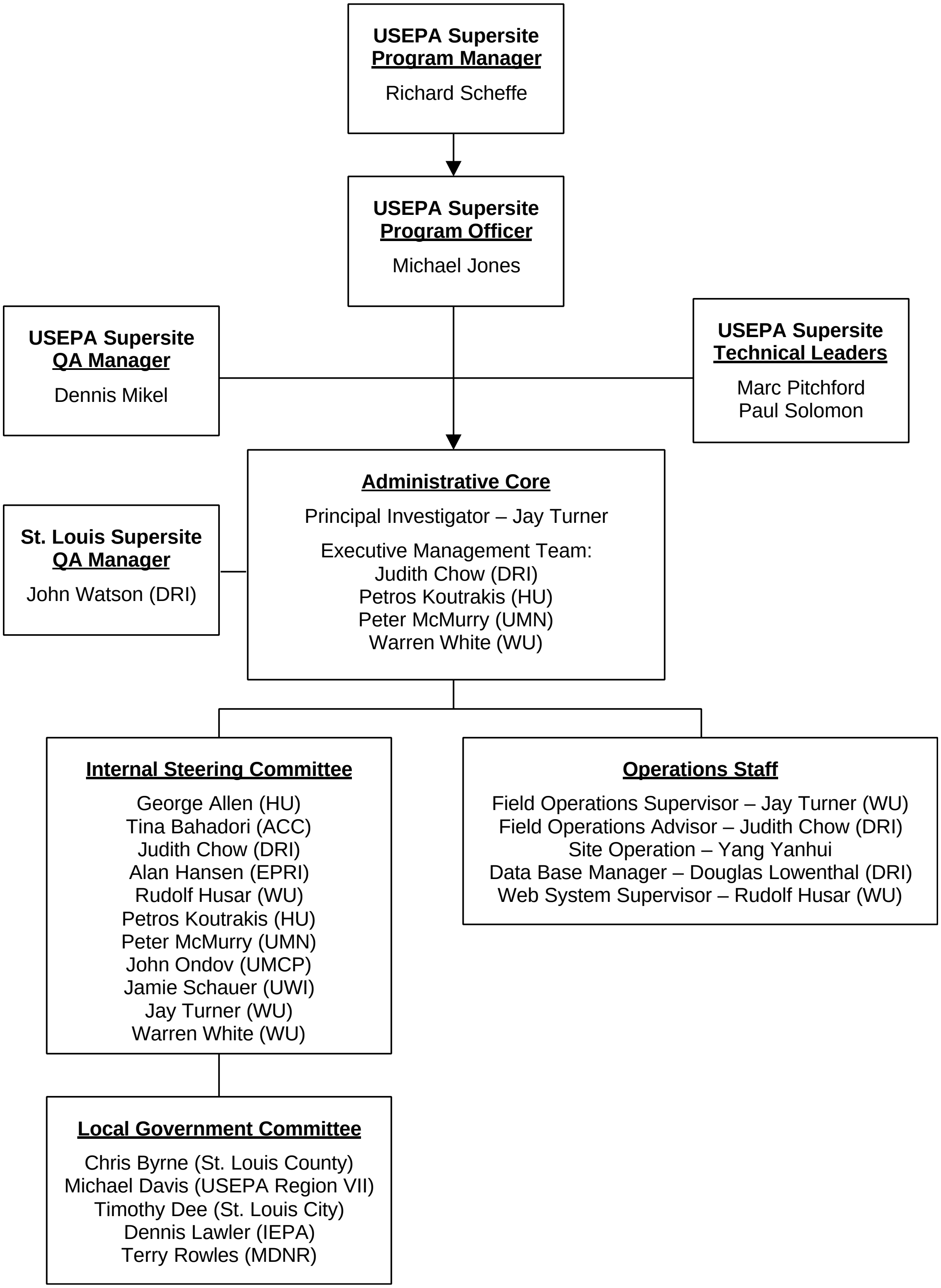


Figure 1-1. Organizational chart of the St. Louis Supersite management structure.

Figure 1-2. St. Louis Supersite core monitoring location, 13th and Tudor Streets, East St. Louis (IL).

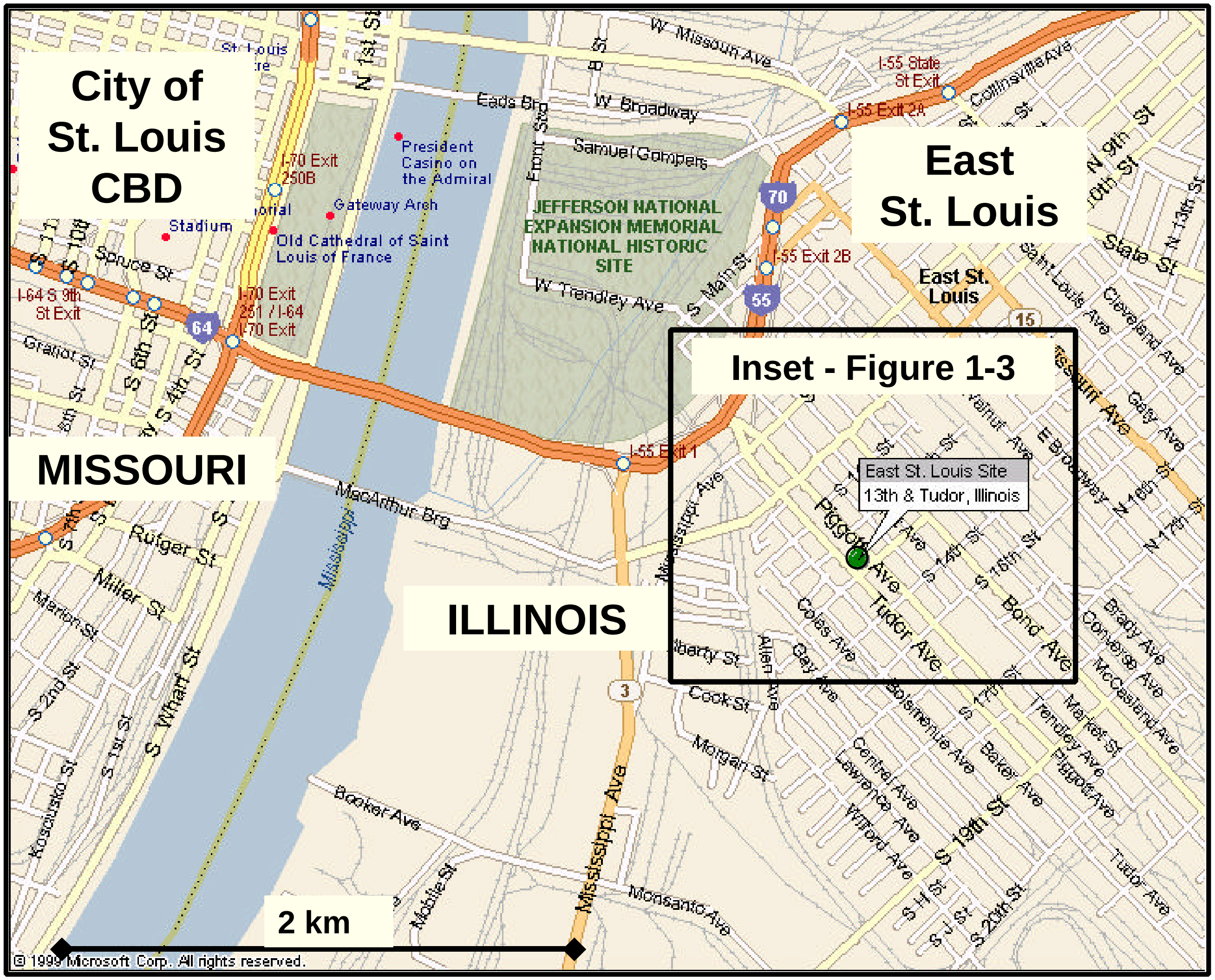
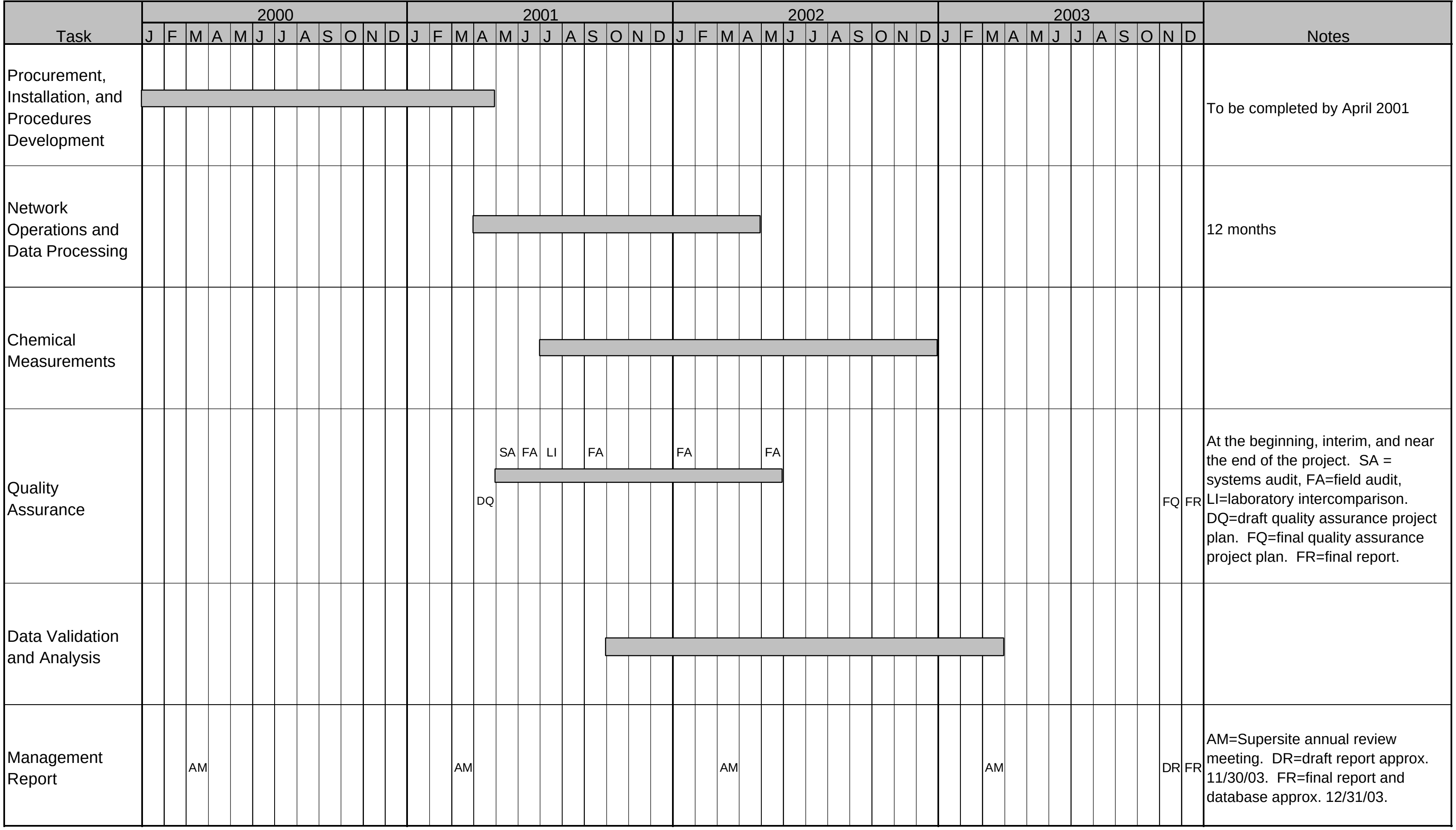


Figure 1-3. St. Louis Supersite core monitoring location, 13th and Tudor Streets, East St. Louis (IL). Inset from Figure 1-2.

Figure 1-4. $PM_{2.5}$ monitoring locations in the greater St. Louis region. Supersite: East St. Louis, IL (core site); north St. Louis City, MO (satellite site); and Park Hills, MO (satellite site). Other $PM_{2.5}$ monitoring locations include mass compliance monitors and/or speciation monitors.

Figure 1-5. Project milestones for St. Louis Supersite.



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2. MEASUREMENT/DATA ACQUISITION

2.1 Sampling Design

St. Louis was chosen for the Supersite measurements owing to: 1) its historical role in particulate matter health effects studies (e.g., Harvard Six Cities Study) and air pollution characterization studies (e.g., RAPS, MISST); 2) its geographic characteristics as an urban island, isolated by relatively large distances from other urban centers yet periodically influenced by regional scale phenomena; 3) an aerosol composition with substantial seasonal variation, including elevated summertime sulfate and wintertime nitrate; 4) a long time record of $PM_{2.5}$ data, extending (with gaps) back to the late 1970s; and 5) meteorological and emissions characteristics broadly representative of several Midwest urban centers. The East St. Louis (IL) core monitoring location, as shown in Figure 1-3, is centrally located to represent the urban population; satellite sites in North St. Louis City (MO) and Park Hills (MO) represent an urban residential area of relatively high population density and a rural background area, respectively. The $PM_{2.5}$ compliance and speciation networks are also relatively dense for an area of St. Louis' size, which provides additional information for assessing a representativeness of the Supersite measurements.

A twelve-month sampling program (April 15, 2001-April 14, 2002) will be conducted at one core sampling site (East St. Louis, IL) and two satellite sites (City of St. Louis, MO, and Park Hills, MO). This network for the St. Louis - Midwest Supersite is complemented by the state/local compliance monitoring network and the St. Louis Community Air Project (CAP) Study monitoring site. The locations of these sites are shown in Figure 2-1 and summarized in Table 2-1.

2.1.1 Site Selection

St. Louis was proposed as a Supersite for its favorable geographic location, and for the opportunities it offers for integration with past and present air pollution and health studies. Metropolitan St. Louis is a major population center well isolated from other urban centers of even moderate size, and is impacted by both distant and local sources. Local industry includes food and beverage manufacturing, refining, chemical plants, incinerators, and power generators. St. Louis is climatologically representative of the country's eastern interior, affected by a wide range of synoptic weather patterns and free of localized influences from the Great Lakes, Ocean, Gulf, and mountains. It accordingly provides an ideal environment for studying the sources, transport, and properties of ambient particles. Furthermore, these advantages have long been evident to field-study planners, resulting in a unique legacy of historical data.

More than 2.5 million people live in the St. Louis (IL-MO) Metropolitan Statistical Area (MSA), which includes twelve counties covering 16,320 square kilometers; it is the 18th largest metropolitan area in the United States. It is an ethnically diverse region with ~81%

White, ~17% African American, and ~2% Other. The median and average income for 1989 was estimated at $28,500 and $33,500, respectively. Figures 2-2 and 2-3 show the population density of the Metropolitan St. Louis area and the Supersite and state/local compliance $PM_{2.5}$ monitoring sites. The core site is located in a relatively low density population area but is approximately 3 km east of the City of St. Louis Central Business District (CBD). One satellite site - north St. Louis City - is located 9 km northwest of the core site in an urban residential neighborhood of relatively high population density. The other satellite site - Park Hills (not shown) - is located 90 km south/southwest of the core site and features relatively low population density in a predominantly rural setting.

Meteorological and aerosol $PM_{2.5}$ climatology have recently been assessed by conducting a clustering analysis on three-day back trajectories generated using HYSPLIT. (NOAA-ARL, 1997). Back trajectories for St. Louis were generated over the period CY 1999-2000 for arrival times of noon local time and arrival heights of 25 meters and 500 meters. Retaining only those cases for which there were a full 72 hours of back trajectory and a valid 24-hour integrated $PM_{2.5}$ value at the Margaretta station (the North St. Louis City satellite monitoring location for the Supersite project), there were 481 days of valid data. After filtering this data set to remove days where the 25 m and 500 m trajectories exhibited grossly different features[4] and trajectory patterns which rarely occur,[5] the resulting data set included 365 days (50% of the maximum possible data set size). Following a modified approach to the method of Doerling et al. (1992), six clusters were defined based entirely on the back trajectory patterns. Figure 2-4 shows the mean trajectories for each cluster, while Figure 2-5 shows the $PM_{2.5}$ distributions by cluster.[6] The numbers in parenthesis along the top of Figure 2-5 represent the number of trajectories in each cluster. Among the several trends evident from these figures: air masses arrive in St. Louis from a range of geographic regions; and $PM_{2.5}$ values are relatively high for Ohio River Valley and Stagnant air masses, and relatively low for fast-moving air masses from the Northwest.

St. Louis is impacted by both distant and local sources. The region's main industries include aviation, biotechnology, chemicals, electrical utilities, food and beverage manufacturing, refining, research, telecommunications and transportation. Local emission source categories include:

- Point sources such as manufacturing, refining, chemical plants, incinerators, and power generation.

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[4] Examples include days for which the 25 m and 500 m three-day back trajectories originated from grossly different regions. This is typically indicative of meteorological transitions periods for which the 24-hour $PM_{2.5}$ value is difficult to assign to a given air mass type.

[5] Such trajectories should not be forced into a given cluster but occur too rarely to warrant identifying a unique cluster for their representation.

[6] The Ohio River Valley (OVR) trajectory was identified after evaluating the $PM_{2.5}$ distributions which revealed a coherent set of "outliers" whose trajectories nominally followed the Ohio River Valley. Subsequently, all trajectories were reassigned to the clusters with the OVR cluster included.

- Area sources such as cooking and residential fuel combustion.
- Mobile sources such as cars, trucks, off-road heavy equipment, barges, trains, and aircraft. St. Louis is home to one international airport, many smaller scale airports, and high-traffic train routes.
- Agricultural activities including fertilizer and herbicides application, tilling and livestock.
- Biogenic sources including emissions of oxides of nitrogen from biological activity in soils, and hydrocarbon emissions from plants. In the latter case, however, the emissions are primary isoprene which does not significantly contribute to particle formation via secondary processes.

Agriculture is the main industry surrounding the Metropolitan St. Louis area with corn, grain sorghum and soybean being the major crops. There are several significant point sources (e.g., power generation, cement kilns, lead smelters, charcoal kilns) located in the outstate Missouri.

2.1.1.1 Historical Data

A rich historical data set will be used to place the Supersite measurements in context. This section merely highlights the data sets available; data synthesis and interpretation will be covered in a separate document.

- Regional Air Pollution Study (RAPS) (Trijonis and Eldon, 1980). A comprehensive USEPA program in 1975 and 1976 utilized a network of 25 air monitoring stations distributed throughout the area. Ten of these stations included high-volume samplers collecting total suspended particles, and dichotomous samplers collecting inhalable (~PM_{20}) and fine (~$PM_{2.4}$) particles. All dichotomous sampler collection substrates were beta-gauged for mass and analyzed by X-ray fluorescence (XRF) for sulfur, major crustal elements, and selected trace metals.

- Harvard Six Cities Study (Dockery et al., 1993). An air pollution health study conducted from September 1979 to January 1987 collected 24-hour integrated samples in the Carondolet neighborhood of St. Louis. Depending on the year, particle mass was determined using gravimetric analysis or beta attenuation; in addition, filter samples were analyzed using XRF or ion chromatography.

- Granite City $PM_{2.5}$ and PM_{10} Receptor Model Study (Glover et al. (1991). Twelve distinct source profiles were developed from dust collected between 1986 and 1987 in Granite City, IL. The identified regional sources were generally consistent the RAPS study, but emission profiles were observed to have changed over the ten year period between these studies.

- Long-term $PM_{2.5}$ and PM_{coarse} measurements were acquired by dichotomous samplers from 1988 to 1997 at several sites in St. Louis County as part of a PM_{10} compliance monitoring program. Annual average $PM_{2.5}$ mass concentrations for the Clayton site, which is a suburban area located about 15 km west of downtown St. Louis City, have remained steady at approximately 15 $\mu g/m^3$ for the last ten years.

- Midwest Aerosol Characterization Study (MARCH-MW). A forty-day field study during August and September 1999 acquired daily samples for $PM_{2.5}$ and PM_{10} mass, $PM_{2.5}$ chemical speciation, and associated gaseous precursors (e.g., ammonia, sulfur dioxide, and nitric acid). Sampling was simultaneously conducted in six Midwest cities: Athens (OH), Charleston (WV), Cincinnati (OH), Chicago (IL), Detroit (MI), and St. Louis (MO). The St. Louis monitoring site for MARCH-MW was the same location as the Margaretta Street (N. St. Louis City) satellite site for the St. Louis Supersite program.

- A $PM_{2.5}$ saturation monitoring study from March to October 1999 in St. Louis collected $PM_{2.5}$ samples using Airmetrics battery-powered mini-volume samplers at seventeen locations in the City of St. Louis and the near suburbs of St. Louis County. The results indicate that there is an urban-scale gradient in $PM_{2.5}$ mass radiating outward from a maximum concentration in the urban core region. Additionally, $PM_{2.5}$ mass tended to correlate with air mass history.

2.1.1.2 $PM_{2.5}$ Compliance and Speciation Networks

There are currently fourteen $PM_{2.5}$ mass monitor sites operating in the St. Louis Metropolitan Statistical Area (MSA) as part of the compliance monitoring network for the $PM_{2.5}$ NAAQS (see Table 2-1 and Figure 2-1). Background monitors to the southeast (Houston, Randolph County, IL) and southwest (Bonne Terre, St. Francois County, MO) are about 60 and 85 km from St. Louis City, respectively.

At least three chemical speciation sites are programmed for the St. Louis area. One site - the Blair Street (St. Louis City, MO) location - is a “Mini-Trends” site which has been operating on a 1-in-3 day schedule since February 2000. The second speciation monitor is operating at the Arnold (MO) site. An effort is underway to operate a third speciation monitor at the Alton (IL) site during the Supersite monitoring period. In addition, the St. Louis Community Air Project (CAP) will operate a speciation monitor in south St. Louis City on a 1-in-6 day schedule coincident with the Supersite monitoring period.

2.1.1.3 Supersite Core Monitoring Site

The St. Louis Supersite core monitoring location is collocated with the Illinois EPA “East St. Louis RAPS Site” (38.6122N,-90.16028W) at 13th and Tudor Streets, East St. Louis (IL). IEPA has been operating compliance monitors at this site since the 1970s. Current SLAMS measurements include: SO_2, O_3, NO/NO_2, CO, TSP/Pb, PM_{10} and $PM_{2.5}$. Figure 2-6 shows an aerial view of the site prior to installation of the Supersite infrastructure. It is located 2 km east of the Mississippi River which separates East St. Louis (IL) from the

City of St. Louis (MO), and is 3 km east of the City of St. Louis' Central Business District (CBD). Interstate 55/64/70 lies approximately 1 km to the west; this highway leads to the Poplar Street Bridge, one of the major routes across the Mississippi River in the St. Louis area. At the microscale level, the site is straddled by freeway on/off ramps with relatively little traffic (nominally <10 cars/min during rush hour). The immediate neighborhood is mixed use (light manufacturing and residential) with relatively low population density.

PM compliance monitoring at the East St. Louis site has a long history. As previously mentioned, TSP, PM_{10}, and $PM_{2.5}$ mass are currently measured. From 1985 though the 3rd quarter of 2000, the annual average number of runs reported to AIRS was 55 for TSP (nominal every sixth day) and 98 for PM_{10} (nominal every third day).

2.1.1.4 Supersite Satellite Monitoring Sites

The movable platform will be operated at two satellite sites as well as the core site. Seasonal measurements will be conducted at each site during the yearlong sampling program. In light of the objectives presented previously, satellite sites are being established: 1) at a community-oriented urban residential site with predicted maximum $PM_{2.5}$ exposures (North St. Louis City Site), and 2) upwind of the metropolitan area to characterize material transported into the area (Park Hills, MO). We anticipate 25-30 consecutive days of sampling during each of the four visits to a satellite site. Table 1-2 indicates the measurements taken at the satellite sites and their sampling frequencies. Prior to deployment to each satellite site, the movable platform will be collocated with the core site for comparison of continuous measurements. Following the second such visit, the Internal Steering Committee will determine whether collocated measurements are warranted between every change in location of the movable platform (nominally every month). In no case, however, shall the frequency of collocated core site / movable platform measurements be less than quarterly.

The North St. Louis City[7] satellite site (38.67222N, 90.23889W) is collocated with the City of St. Louis' Margaretta Avenue compliance monitoring station at Taylor Avenue and Margaretta Avenue. The site is located in a high-density, low-to-middle income urban residential area approximately 6 km northwest of the City of St. Louis' CBD and is designated as a Category "B" community-oriented (CORE) SLAMS site. Current measurements conducted by City of St. Louis' Division of Air Pollution Control include daily $PM_{2.5}$ monitoring as well as ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide, and PM_{10}.

The Park Hills satellite site (37.84778N, 90.49194W) is located in an open area on the Mineral Area College Campus in St Francois County, MO approximately 60 miles south of St. Louis City. This relatively rural satellite site has no significant local emission sources and according to prevailing meteorology will be upwind or downwind of the St. Louis area on numerous days.

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[7] Approval for operating at the Margaretta site is still pending, hence the satellite site could be moved to a similar location in North St. Louis City.

Figures 1-4 and 2-1 show the St. Louis Supersite locations in relation to other particulate matter monitors in the St. Louis Area.

2.1.2 Measurements and Sampling Frequency

Measurements and samples to be acquired at the St. Louis Supersite are given in Table 1-2, along with the respective lead institution, averaging times, and sampling frequencies.

2.2 Sampling Method Requirements

Sampling methods and procedures are specified in Standard Operating Procedures (SOPs) that include checklists and calibration forms for each monitoring instrument and sampler. SOPs describe monitoring or sampling requirements, acceptance testing procedures, preparation, installation, sample collection, handling and preservation, data acquisition, routine maintenance, routine service checks, calibrations, QC checks, and audit procedures.

A two-tiered approach will be implemented for organizing the sampling protocols. Each Measurement PI is responsible for developing an SOP for each instrument. Furthermore, a Field Operations checklist is being developed to organize the various tasks, incorporating the instrument-specific SOPs by reference.

Table 2-2 lists the SOPs applicable to Supersite measurements and their current status. In several cases the measurements are relatively new and SOPs are still in preparation; all SOPs will be in at least draft format prior to starting field measurements and are available from the QA Manager. An effort is being made to assemble measurements in the standardized Supersite format shown in Table 2-3; the respective Measurement PIs are given the latitude to use an alternate format, however, as long as the elements in Table 2-2 are addressed. Analytical laboratory-related SOPs (Table 2-4) are also assembled in a standardized SOP format (Table 2-5) where practicable; again, discretion is given to the respective laboratories to use SOPs in alternative formats that capture the content of Table 2-2.

Table 1-2 includes many measurements not covered by this QAPP because they fall under programs outside the formal Supersite cooperative agreement. These measurements include: compliance monitoring at the East St. Louis site by IEPA; and VOC sampling at the East St. Louis site conducted by Washington University on behalf of EPA Region VII. Separate QAPPs have been prepared for these measurements.

2.2.1 Sample Preparation, Setup, and Recovery Procedures

Sample preparation, setup, and recovery procedures for field related measurements and activities are described in the SOPs given in Table 2-2. General sample handling and sample chain-of-custody procedures are discussed in Section 2.3. Similar procedures for laboratory related activities and operations are described in Section 2.4. Detailed information is contained in the SOPs.

2.2.2 Sampling and Measurement System Corrective Actions

Problems that arise in the field or the laboratory during the course of the project are resolved expeditiously to ensure that the project's overall data quality objectives are achieved. Detailed instructions for trouble shooting and corrective actions for each instrument are given in the SOPs. Table 2-6 provides corrective actions in response to anticipated sampling and measurement problems. Additional corrective actions are discussed in Section 2.5 on QC requirements.

2.3 Sample Handling and Custody

Sample handling, chain-of-custody, and archiving are specifically discussed in SOPs. Many of the measurements specified in Table 1-2 are *in situ*, with instruments located in an environmentally controlled room. To minimize sampling losses or changes and to ensure comparability among the measurements, sample inlet lines are: 1) kept as short as possible by locating instruments close to the shelter ceiling, 2) located at a common height above rooftop level (~1.5 m), equivalent to the height of FRM inlets, 3) made of conducting material with straight or gently curving entries to instruments to minimize particle losses, and 4) with diameters as small as possible to minimize residence time that might causes changes in temperature and humidity.

Filter packs, denuders, and absorbents from integrated aerosol samplers are prepared in clean laboratories and shipped to and from the staging location (Washington University) by overnight transport using controls (e.g., cooled containers, temperature indicators) set forth in the respective SOPs. Samples are stored in freezers at the staging location after sampling until analysis. Shipments are coordinated between the field and laboratory. Sample identifiers are clearly marked - and in many cases bar-coded - to indicate sample type, analysis type, and sampling time and location. These identifiers are entered into field and laboratory data acquisition systems to track sample status at any time during the study.

2.4 Analytical Methods Requirements

Table 1-2 identifies the sampling and analysis methods. Several common quality control activities take place for all analyses: 1) acceptance testing for contamination of substrates, reagents, extraction vials prior to use; 2) field and laboratory blank designation and analysis to determine blank levels and variability; 3) periodic performance tests of zero and span values for field and laboratory instruments to determine reproducibility and calibration drift; 4) periodic multi-point calibrations in the range of ambient concentrations to determine linearity and concentration relationships; and 5) data validation flags for field and laboratory operations that indicate deviations from procedures. Results from these common quality control activities are compiled into a separate database and used to develop the data qualifications statement.

Detailed requirements for analytical methods are specific to the type of sampling instrument, flow rate, sampling period, and analysis method. Laboratory-related SOPs, summarized in Table 2-4, contain detailed information for filter and substrate preparation, filter pack assembly/disassembly, shipping/receiving, chemical analysis, and QA/QC.

2.5 Quality Control Requirements

Table 2-7 summarizes calibration standards and frequency, performance test standards and frequency, performance tolerances, and audit standards and frequency to be implemented for the St. Louis Supersite. Detailed QA/QC procedures are specified in each listed SOP.

2.6 Instrument/Equipment Testing, Inspection, and Maintenance Requirements

Prior to deployment in the field, each instrument is bench-tested and inspected in the laboratory. Maintenance frequency varies depending on instrument. Instrument and equipment testing, inspection, and maintenance requirements are discussed in detail in the SOPs.

2.7 Instrument Calibration and Frequency

Several types of standards are needed for calibration, auditing, and performance tests. Primary standards are well characterized and protected, with stable concentrations to which all other standards are traceable. Transfer standards are often more easily produced or commonly available and are traceable to primary standards; these are used for calibration, performance testing, and auditing. The same standards can be used for calibration and performance testing, but audit standards should be independently traceable to primary standards. Performance tests may measure instrument response rather than response to a specific value of an observable when transfer standards for the primary observable are lacking.

Table 2-7 identifies the intended primary and transfer standards and the intended frequency of application for calibration, performance testing, and auditing. The particular method for delivering these standards to the instrument depends on the instrument audited.

Calibration, performance testing, and auditing methods for laboratory operations are largely based on the preparation of standard solutions from mineral salts. NIST does not provide these types of standards. Standard solutions in a large range of concentrations are available commercially for inorganic monoatomic and polyatomic ions.

Gas and meteorological monitors are often used in compliance networks, as common procedures and standards have been developed for their calibration and auditing. Independent state/local air agency or USEPA regional staff perform these audits each year, along with audits of other air quality and meteorological monitors in the state. Some of the novel measurements in Table 1-2 will be evaluated by comparison with other measurements that have traceable standards and audit trails.

The QA Manager conducts a field and laboratory systems audits, a laboratory performance audit and/or interlaboratory comparisons, and four field performance audits. Systems audits examine all phases of measurement and data processing to determine that the SOPs are followed and that operational staff is properly trained. The systems audit is intended to be a cooperative assessment resulting in improved data, rather than a judgmental activity. Performance audits establish the extent to which data specifications are being achieved in practice and evaluate measurement accuracy against independent standards. The field systems audit is conducted at the beginning of the project after all equipment is installed and operating. It will be followed by the first field performance audit. These audits will identify deficiencies and implement remedial actions. Subsequent field performance audit results will be used to define accuracy of field measurements.

Laboratory audits present standards with known concentrations to each laboratory process. These standards are analyzed according to normal procedures and the results will be compared with the standard values. As shown in Table 2-7, reliable transfer standards can be obtained for mass, elements, ions, and total carbon. In some cases, however, NIST standards are not available (e.g., elemental carbon, organic carbon). In such cases, interlaboratory comparisons are an effective audit tool. Audit strategies, issues, and procedures are described in detail in respective SOPs.

Interlaboratory comparisons will operate on the exchange of portions of the same filters or sample extract. Mass, elemental, ion, and carbon analysis can all be performed on portions of the same filter.

The audit team is led by the QA Manager (John Watson), who will oversee the following audit team members responsible for conducting the tests: Mr. Dale Crow, Mr. Matt Gonzi, and Mr. Steve Schmidt. The audit team may consult the project PI or the Measurements PIs during field audits to reconcile any questions regarding implementation of the audit tests; the audit authority, however, resides with the QA Manager.

In the case of a failure of a performance or technical systems audit, written notification including the details of the recommended corrective action will be sent from the audit team to the project PI and to the QA Manager. The PI - in collaboration with the QA Manager - will determine the party responsible for taking corrective action and will verify any work completed.

All audits will be reported in the Quality Assurance Final Report, which will be submitted as an attachment to the Project Final Report.

2.8 Inspection/Acceptance Requirements for Supplies and Consumables

Field/laboratory supplies, consumables, quantities, cost, frequency of replacement, catalog number, and vendor information are listed in detail in each SOP. Measurement PIs are responsible for checking/replenishing supplies on a quarterly basis.

2.9 Data Acquisition Requirements (Non-direct Measurements)

Data from the compliance and speciation networks will be integrated into the St. Louis Supersite data base for future data analysis. No specific data acquisition is needed for this collaborative effort.

2.10 Data Management

2.10.1 Overview

The St. Louis Supersite database is based on the system developed for the California Regional $PM_{2.5}$/PM_{10} Air Quality Study (CRPAQS) and will support data collection, distribution, and archiving requirements for the project. Data from the St. Louis Supersite that passes Level 1 data validation (see below) will be sent to the St. Louis Supersite database maintained by DRI for further processing and validation. Microsoft Access 2000 is used to organize and validate Supersite data prior to submission to the data base. Figure 2-7 shows the generalized data flow from generation to archival.

The following specifications are maintained by the St. Louis Supersite Data Manager and will be available in electronic format to all project participants. The four most important reference tables for the data providers are the Sites, Parameters, Instruments, and Methods tables. These tables are required for reference to properly format data files for submittal.

- Monitoring Sites: Each site location is identified with a unique alphanumeric site ID accompanied by its name, address, coordinates, elevation, etc. To verify the coordinates and elevations for each site, the field managers use a Global Positioning System (GPS), pressure-based altimeter, and topographical maps. Coordinates are determined with GPS using map basis NAD-83 (Federal Aviation Administration convention). The GPS time stamp is recorded to correct coordinate deviations. Immediate surroundings are recorded with a digital camera of the area around the site are to be displayed on St. Louis Supersite web site.

- Parameters: Each observed parameter is assigned a unique code that is accompanied by its definition, units, averaging time, applicable temperature and pressure adjustments, and data reporting format.

- Methods: The characteristics of the method used to make the observation measurement. This is essentially how an instrument, under what conditions, an observation value (Obs_Value) was obtained. Sampling frequency and duration, parameter, instrument, units, along with other method related information is available in this lookup table.

- Data Validation Flags: A table of validation flags (Study_Valid_Flags) is being developed as part of the CRPAQS database.

- Air Obs (observation data files): Basic air observation data are constructed into normalized table formats that have the same structure for different types of data, meteorology, or air quality. Each record contains the site code, sample date, sample time, variable code, measurement value, measurement precision, validity code, and validation level. Separate tables are produced for different averaging times and for non-uniform data sets. These files are transparent to most users and can be easily manipulated into convenient data analysis forms.

The QA Manager audits the integrity of the database by randomly selecting data sets and tracing them through the data management system to their final values in the finished database. Unit conversion, sample times, site and variable codes, and data validation flags are applied manually, and the results are compared with data extracted from the internet-based data set.

St. Louis Supersite data will be submitted to the NARSTO center at Oak Ridge National Laboratory for archiving and distribution through EPA and NARSTO centralized databases. The St. Louis Supersite data will adhere to the consistent metadata requirements and data formats for NARSTO technical programs data, including the USEPA PM Supersites program.

2.10.2 Data Validation Levels

Mueller (1980), Mueller et al., (1983), and Watson et al. (2001) define a four-level data validation process for an environmental measurement study. Data records are designated as having passed these levels by entries in the column of each data file. These levels, and the validation codes that designate them, are defined as follows:

- Level 0: These data are obtained directly from the data loggers that acquire the data in the field. Averaging times represent the minimum intervals recorded by the data logger, which do not necessarily correspond to the averaging periods specified for the database files. Level 0 data have not been edited for instrument downtime, nor have procedural adjustments for baseline and span changes been applied. Level 0 data are not contained in the St. Louis Supersite database; although they are consulted on a regular basis to ascertain instrument functionality and to identify potential episodes prior to receipt of Level 1 data.

- Level 1: These data have passed several validation tests applied by the measurement investigator prior to data submission. Level 1 criteria are currently under development for many of the new instruments. The general features of Level 1 are: 1) removal of values when monitoring instruments fail specified validation criteria; 2) flagging measurements when significant deviations from measurement assumptions have occurred; 3) verifying computer file entries against data sheets, where appropriate; 4) replacement of data from a backup data acquisition system in the event of failure of the primary system; 5) adjustment of measurement values for quantifiable baseline and span or interference biases; and 6) identification, investigation, and flagging of data that are beyond reasonable bounds or that are unrepresentative of the variable being measured (e.g., high light scattering associated with adverse weather).

- Level 2: Level 2 data validation takes place after data from various measurement methods have been assembled in the master database. Level 2 validation is the first step in data analysis. Level 2 tests involve the testing of measurement assumptions (e.g., internal nephelometer temperatures do not significantly exceed ambient temperatures), comparisons of collocated measurements (e.g., filter nitrate and in-situ continuous nitrate), and internal consistency tests (e.g., the sum of measured aerosol species does not exceed measured mass concentrations). Level 2 tests also involve the testing of measurement assumptions, comparisons of collocated measurements, and internal consistency tests.
- Level 3: Level 3 is applied during the model reconciliation process, when the results from different modeling and data analysis approaches are compared with each other and with measurements. The first assumption upon finding a measurement, which is inconsistent with physical expectations, is that the unusual value is due to a measurement error. If, upon tracing the path of the measurement, nothing unusual is found, the value can be assumed to be a valid result of an environmental cause. The Level 3 designation is applied only to those variables that have undergone this reexamination after the completion of data analysis and modeling. Level 3 validations continue for as long as the database is maintained.

A higher validation level assigned to a data record indicates that those data have gone through, and passed a greater level of scrutiny than data at a lower level. All data supplied to the St. Louis Supersite database will have undergone data validation through Level 1. Data will achieve Level 1 status prior to use in data analysis and modeling. The validation tests passed by Level 1 data are stringent by the standards of most air quality and meteorological networks, and few changes are made in elevating the status of a data record from Level 1 to Level 2. Since some analyses are applied to episodes rather than to all samples, some data records in a file will achieve Level 2 designation while the remaining records will remain at Level 1. Only a few data records will be designated as Level 3 to identify that they have undergone additional investigation. Data designated as Levels 2 or 3 validations are not necessarily “better” than data designated at Level 1. The level signifies that they have undergone additional scrutiny as a result of the tests described above.

2.10.3 Data Transmittal

For the duration of the St. Louis Supersite project, Washington University and the respective Measurement PIs will collect, validate, and submit data to the St. Louis Supersite Data Manager for inclusion in the database system. The Data Manager interacts with numerous data source providers to make data available as early as possible. Data transmittal file formats and transmittal file naming conventions have been established to make the job of collecting and processing data into the database more efficient and accurate. Data are submitted in electronic form using file transfer protocol (FTP) after being validated to Level 1 by Washington University's Air Quality Laboratory and its collaborators.

The Data Manager shall conduct spot checking and cross-referencing exercises to ensure the documents and data being submitted to the database are indeed the correct files. For example, contents of files provided by the Measurement PIs shall be verified by the Data Manager prior to upload to the database. The Data Manager shall keep a record - either electronically or in a hardcopy log - of all files submitted by the Measurement PIs for upload to the database. Original datasets are stored under a password protected area on the DRI network, which is backed-up on a nightly basis. Working copies are made and stored at several different locations.

Table 2-1. State/local agency PM monitoring during the St. Louis - Midwest Supersite period.

State	Map Locator	City	Site Address	Agency	$PM_{2.5}$ FRM	$PM_{2.5}$ Continuous Mass	$PM_{2.5}$ Speciation	PM_{10}	Meteorology [f]
IL	C [a]	East St. Louis	13th & Tudor Streets	IEPA	1/3 [d]	X		1/6	X
	1	Granite City	2040 Washington	IEPA	1/3			1/6	
	2	Granite City	23rd & Madison	IEPA	1/3				
	3	Granite City	15th & Madison	IEPA				1/6	
	4	Wood River	Water Treatment Plant	IEPA	1/3			1/6	
	5	Alton	SIUE Dental School	IEPA	1/3		1/3 (pending)		
MO	S [b]	St. Louis	Margaretta Street	City of St. Louis APCP	daily			1/6	
	6	St. Louis	Blair Street	City of St. Louis APCP	daily		1/3		X
	7	St. Louis	Mound & 2nd Streets	City of St. Louis APCP	daily				
	8	St. Louis	South Broadway & Hurck	City of St. Louis APCP	daily			1/6	
	9	St. Louis	Hall & Carrie Streets	City of St. Louis APCP				1/6	
	10 [c]	St. Louis	Grant School	City of St. Louis APCP			1/6 [e]		
	11	Arnold	Tenbrook	MDNR	1/3		1/3		
	12	Clayton	Hunter Avenue	St. Louis County DOH	1/3				X
	13	Florissant	Pershall Road	St. Louis County DOH	1/3				X
	14	West Alton	Highway 94	St. Louis County DOH	1/3				

[a] Collocated with Supersite core monitoring location.
[b] Collocated with Supersite satellite monitoring location.
[c] St. Louis CAP Study monitoring location.
[d] Every-third-day sampling schedule.
[e] Every-sixth-day sampling schedule.
[f] Meteorology includes 10-meter towers only.

Table 2-2. Summary of SOPs applied to St. Louis Supersite field measurements.

SOP No.	Measurement(s)	Instrument	SOP Title	Date of Last Revision	Primary Source(s)	Status
I. Filter Mass and Chemistry						
STLFLT01	PM_{10}, $PM_{2.5}$ and PM_1 mass and elements	Harvard Impactors	Harvard Impactor Field Protocol	11/05/96	Harvard	draft
STLFLT02	$PM_{2.5}$ sulfate, nitrate, chloride, and ammonium; gaseous nitous acid, nitric acid and ammonia	Harvard/EPA Annular Denuder System (HEADS)	Field Protocol for simple HEADS, PM_{10} and $PM_{2.5}$ with Harvard Impactor (all at 10 LPM with Gast pumps)	09/28/93	Harvard Revision 0	draft
STLFLT03	$PM_{2.5}$ organic and elemental carbon; samples for speciated organics analysis	Wisconsin Organics PM Sampler	Carbonaceous $PM_{2.5}$ Sampling for the St. Louis Supersite	NA	Wisconsin	draft
STLFLT04	PM fine and PM coarse mass and OC/EC	Harvard High-Volume Dichotomous Sampler	Hi-Vol Dichotomous Sampler for PM Mass and Carbon Analysis	NA	Harvard	draft
STLFLT05	PM mass collection for toxicity testing	Harvard High-Volume Trichot Toxicological Sampler	PM Sampling for Toxicological Analysis	NA	Harvard	draft
II. Continuous Particle Mass and Chemistry						
STLCH01	$PM_{2.5}$ mass	Andersen Continuous Ambient Mass Monitoring System (CAMM)	CAMM Continuous $PM_{2.5}$ Field Site Operating Protocol for EPA-ETV Program	08/01/00	Harvard	draft

SOP No.	Measurement(s)	Instrument	SOP Title	Date of Last Revision	Primary Source(s)	Status
II. Continuous Particle Mass and Chemistry (continued)						
STLCH02	$PM_{2.5}$ nitrate	Harvard Nitrate Monitor	Semicontinuous PM Nitrate By HSPH Method	NA	Harvard	draft
STLCH03	$PM_{2.5}$ sulfate	Harvard Sulfate Monitor	Semicontinuous PM Sulfate BY HSPH Method	NA	Harvard	draft
STLCH04	$PM_{2.5}$ organic and elemental carbon	Sunset Labs ECOC	Semi-Real Time Analysis of ECOC	NA	Wisconsin	draft
STLCH05	$PM_{2.5}$ selected elements (retrospectively)	University of Maryland High-Frequency Aerosol Slurry Sampler	Measurement and Analysis of the Chemical Composition of the Ambient Aerosol Using SEAS	11/20/00	Maryland (Version 2)	draft
III. Continuous Light Scattering						
STLSCA01	Seven-wavelength light absorption	Andersen AE30S seven-color aethalometer	Routine Operation of Andersen Instruments Aethalometers for Measurement of Black Carbon Concentrations	03/07/00	STI/DRI	draft
IV. Particle Sizes						
STLSD01	Particle Size Distributions	Aerosol Size Distributions Package	University of Minnesota Aerosol Measurement System	07/18/98	Minnesota	draft
STLSD01	Aerosol Integral Moments	Aerosol Integral Moments Package	University of Minnesota Aerosol Integral Moment System	NA	Minnesota	draft

SOP No.	Measurement(s)	Instrument	SOP Title	Date of Last Revision	Primary Source(s)	Status
V. Meteorology						
STLM001	Wind speed and direction	Climatronics 102083-G0-H0	Meteorological Parameter Procedures for Wind Speed and Wind Direction Sensors	07/28/95; 09/30/95	ARB SOP #T.1, T.2, & T.3; #V.1, V.2 & V.3	draft
STLM002	Temperature	Climatronics 100093	Meteorological Parameter Procedures for Inside/Outside Temperature Sensors	06/01/95	ARB SOP #AA.1, AA.2, & AA.3;	draft
STLM003	Relative humidity	Climatronics 102425	Meteorological Parameter Procedures for Percent Relative Humidity Sensors	10/01/97	ARB SOP #U.1 & U.2	draft
STLM004	Solar radiation	Climatronics 102318	Meteorological Parameter Procedures for Solar Radiation Sensors	06/30/00	DRI	draft
STLM005	Atmospheric pressure	Climatronics 102270-G3	Meteorological Parameter Procedures for Atmospheric Pressure Sensors	06/30/00	DRI	draft
STLM006	Precipitation	Climatronics 100097-1-G0	Meteorological Parameter Procedures for Precipitation Sensors	NA	DRI	draft
VI. Data Base Management						
STLD001	Meteorological and continuous gaseous data processing	NA	Meteorological and Continuous Gaseous Data Processing and Validation	12/31/94	DRI SOP #3-109.2	draft
STLD002	Data processing and validation	NA	Data Processing and Validation	12/31/94	DRI SOP #3-003.4	draft

Table 2-3. Format for St. Louis Supersite project field operation SOPs.

Section	Contents
1.0	General Information
1.1	Principles and Applicability
1.2	Summary of Method (including range, sensitivity, precision, and accuracy)
1.3	Definitions
1.4	Health and Safety Warnings
1.5	Cautions (activities that could result in equipment damage or sample degradation or voiding)
1.6	Interferences
1.7	Personnel Qualifications (specify required training if necessary)
2.0	Installation/Collection Procedures
2.1	Apparatus and Materials
2.1.1	Description of Apparatus/Material
2.1.2	Reagents and Gases
2.1.3	Initial Startup
2.2	Installation/Sampling
2.2.1	Power and Space
2.2.2	Probe Assembly
2.2.3	Sample Collection
2.2.4	Handling and Preservation
2.2.5	Sample Preparation and Analysis
2.2.6	Data Acquisition System
2.2.7	Troubleshooting
2.3	Instrument or Method Calibration
2.3.1	Standards
2.3.2	Calibration
2.3.3	Calculations
3.0	Quality Control and Quality Assurance
3.1	Routine Service Checks
3.1.1	General Information
3.1.2	Frequency of QC Checks (e.g., daily, weekly, monthly, annually)
3.2	Detailed Maintenance Procedures
3.3	Acceptance Testing Procedures
3.3.1	General Information
3.3.2	Physical Inspection
3.3.3	Operational Tests
3.3.4	Final Review
3.4	Quality Assurance
3.4.1	Performance Audit Procedures/Schedule
3.4.2	Systems Audit Procedure/Schedule
3.4.3	Data Validation Procedure Summary
3.5	Checklist
4.0	References

Table 2-4. Summary of laboratory-related SOPs (St. Louis Supersite measurements only; state/local compliance monitoring not included).

SOP No.	Observable/Method	SOP Title	Date of Last Revision
HU1-1	PM mass	• Laboratory Procedures for Gravimetric Sample Preparation and Balance Room Conditions • Laboratory Procedures for Using the Mettler MT-5 Microbalance with 123R5 Spreadsheet Data • Laboratory Procedures for Daily Calibration of the Mettler MT-5 Microbalance	02/21/99 (Rev. 0) 02/19/98 (Rev. 1.01) 02/19/98 (Rev. 1.01)
HU1-2	HEADS filter pack and denuder processing	Laboratory Procedures for Assembly and Disassembly of HEADS Samplers	08/30/94 (Rev. 1)
HU1-3	Toxicological Sampler PUF pretreatment	Protocol for the Toxicological Sampler	11/03/00 Rev-Draft
DRI 2-109.4	Ionic species filter extraction	Extraction of Ionic Species from Filter Samples	8/8/96
DRI 2-203.4	Water-Soluble Chloride (Cl^-), Nitrate (NO_3^-), and Sulfate ($SO_4^=$)	Analysis of Filter Extracts and Precipitation Samples by Ion Chromatography	4th qtr 94
DRI 2-205.2	40 elements from Na to U	X-ray Fluorescence (XRF) Analysis of Aerosol Filter Samples	9/22/90
DRI 2-206.4	Water-Soluble Sodium (Na^+) and Potassium (K^+)	Analysis of Filter Extracts and Precipitation Samples by Atomic Absorption Spectroscopy	4th qtr 94
DRI 2-207.5	Water-Soluble Ammonium (NH_4^+) or Gaseous Ammonia (NH_3 as NH_4^+)	Analysis of Filter Extracts and Precipitation Samples by Automated Colorimetric Analysis	11/20/98
Maryland INAA	Elements by Inelastic Neutron Activation Analysis	Standard Operating Procedure for INAA - Ondov	draft
Maryland GFAAZ	Elements by Graphite Furnace Atomic Absorption Spectroscopy	Standard Operating Procedure for GFAAZ - Ondov	3/15/01 (Version 2)
Wisconsin SS-LA-2	Filter preparation for carbon sampling and analysis	Preparation of Quartz Fiber Filters for Collection of Carbonaceous PM	draft
Wisconsin SS-LA-3	EC-OC by NIOSH Method 5040	ECOC Measurement of PM on Quartz Fiber Filters	draft
Wisconsin SS-LA-4	Organic compound speciation by GC-MS	GC/MS Analysis of Organic Compounds in PM and PUF Samples	draft
Wisconsin SS-LA-4	Elements by Inductively Coupled Plasma - Mass Spectrometry	• Digestion of Aerosol Samples for ICPMS Analysis • Analysis of Trace Metals in Aerosol Samples	draft

Table 2-5. Format for St. Louis Supersite laboratory operation SOPs.

Section	**Contents**
1.0	General Discussion
1.1	Purpose of Procedure
1.2	Measurement Principle
1.3	Measurement Interferences and Their Minimization
1.4	Ranges and Typical Values of Measurements Obtained by This Procedure
1.5	Typical Lower Quantifiable Limits, Precision, and Accuracy
1.6	Responsibilities of Personnel for Carrying Out Portions of This Procedure
1.7	Definitions
1.8	Related Procedures
2.0	Apparatus, Instrumentation, Reagents, and Forms
2.1	Apparatus and Instrumentation
2.1.1	Description (including manufacturer and model numbers and number of items to be kept on hand)
2.1.2	Characterization (typical stability response time, idiosyncrasies)
2.1.3	Maintenance (routine maintenance, troubleshooting, references to operating manual)
2.1.4	Spare Parts List
2.2	Reagents (purity grade, supplier, storage, when to reorder)
2.3	Forms (copies of all paperwork, description of each entry, when to reorder)
3.0	Calibration Standards
3.1	Preparation of Working Standards (ranges of standard values, traceability to primary standards)
3.2	Use (what is compared to standards)
3.3	Typical accuracy of Calibration Standards
4.0	Procedures
4.1	General Flow Diagram
4.2	Start-Up
4.3	Routine Operation
4.4	Shut-Down
4.5	Checklists
5.0	Quantification
5.1	Calibration Procedures
5.2	Calculations (background subtraction, interference corrections, precision calculations)
6.0	Quality Control
6.1	Performance Testing (frequency of blanks and standards)
6.2	Reproducibility Testing (frequency of replicates)
6.3	Control Charts, Tolerances, and Actions to be Taken
6.4	Flags for Non-Standard Procedures
6.5	Data validation Feedback
7.0	Quality Assurance
7.1	Performance Audit Schedule
7.2	Systems Audit Schedule
7.3	Data Validation Procedure Summary
8.0	References

Table 2-6. Typical corrective actions for anticipated sampling and measurement problems.

Item	Potential Problem	Corrective Actions	Notification or Documentation
Filter conditioning	Environmental chamber temperature and/or relative humidity out of specification	Check control system and reset, if necessary. If these actions do not correct the problem, check with the laboratory supervisor and/or building maintenance. Wait at least 24 hours after problem has been resolved before conducting a weighing session.	Document problem in laboratory logbook and notify laboratory supervisor.
Filter inspection (pre-weigh)	One or more filter defects detailed in SOP observed.	Discard filter and replace it with an acceptable one.	Document problem in logbook and notify laboratory supervisor if problem persists.
Filter inspection (pre-weigh)	Filter dropped or contaminated by technician.	Discard filter and replace it with an acceptable one.	None
Filter loading (pre-sampling)	Filter defect noted, filter dropped, or filter contaminated.	Discard filter and replace it with a spare filter or use a field blank.	Document problem on field data sheet and notify field coordinator.
Filter unloading (post-sampling)	Filter defect noted, filter dropped, or filter contaminated.	Examine filter and flag or invalidate filter results.	Document problem on field data sheet and have field coordinator approve.
Denuder handling	Denuder breaks	Carefully wrap denuder in aluminum foil, label the foil, and set the unit aside. Ship the broken denuder to the laboratory.	Document potential sample losses on field data sheet. Notify field/lab coordinator to arrange for the denuder's repair or replacement.
Container shipment	Shipment is delayed or lost	Contact sender and obtain the shipment's tracking number. Track and locate the shipment. Use spare or field blank samples for sampling, if necessary. If shipment is subsequently never located, file claim with carrier.	Document any filter pack replacements or losses of certain sampling periods in logbook and notify field coordinator.
Container shipment	Shipment is damaged	Assess damage to internal components. Repair or replace if necessary and file claim with carrier.	Document problem in logbook and notify field coordinator.
Sampler ambient temperature and pressure measurement	Out of acceptable tolerance	Inspect electrical connections and fittings. Recalibrate sensor. Contact sampler manufacturer if problem is not resolved.	Document problem on field data sheet and notify field coordinator.
Initial filter pack flow rate	Out of ±10% acceptable flow range	Verify connectors and fittings. Perform leak check and total flow checks. Use spare filter pack if necessary.	Notify field coordinator and request additional filter packs.

Item	**Potential Problem**	**Corrective Actions**	**Notification or Documentation**
Elapsed sample time	Sampler did not run or failed to shut down as intended.	Check sampler time clock and event programming. Contact sampler manufacturer if problem is not resolved.	Document problem on field data sheet and notify field coordinator.
Site power	Power interruption	Check circuit breaker and reset. Check line voltages.	Document problem on field data sheet and notify field coordinator. Record any sample time loss or changes in sampling duration.
Test results	Poor precision among collocated samplers or instrument	Check test results. Identify samplers or instruments that appear to produce unexpected tests results. Troubleshoot sampling or measurement subsystems most likely to cause imprecision (flow leaks, flow control problems, temperature sensor inaccuracy, pressure sensor inaccuracy, sample programming faults, etc). Contact instrument manufacturer if problem is not resolved.	Notify site operator, field coordinator, and principal investigators. Notify instrument manufacturer if problem is determined to be one of design, construction, or faulty component(s).

Table 2-7. Quality assurance activities at the St. Louis Supersite.

	Observable (Method)	*Percent Tolerance*	*Instrument*	*Primary Standard*	*Calibration Standard*	*Calibration Frequency*	*Performance Test Standard*	*Performance Test Frequency*	*Performance Audit Standard*	*Performance Audit Frequency*	*Audit by* [a]
Flow Rates											
	1-25 l min^{-1} flows	±5%	various	NIST certified bubble meter	Mass flow meter Bubble meter (Gillibrator)	6 months & when out of spec	Calibrated rotameter Bubble meter (Gillibratror)	1 month	Mass flow meter	4 months	DRI
	25-200 l min^{-1} flows	±5%	various	NIST certified Vol-u-met	Dry test meter	6 months & when out of spec	Calibrated rotameter Dry test meter	1 month	Dry test meter	4 months	DRI
	>1000 l min^{-1} flows	±5%	various	Spirometer	Calibrated Orifice/ Roots Meter	6 months & when out of spec	Calibrated Orifice	1 month	Calibrated Orifice/Roots Meter	4 months	DRI
Number by Particle Size											
	3-60 nm SMPS	±15%	TSI 3085 DMA & TSI 3025A UCPC	UMN Differential Mobility Analyzer	UMN Differential Mobility Analyzer	1 year	Small particle mist	3 months	Small particle mist	4 months	DRI
	20-500 nm SMPS	±15%	TSI 3071 comparable DMA & TSI 3760 CPC	UMN Differential Mobility Analyzer	UMN Differential Mobility Analyzer	1 year	Small particle mist	3 months	Small particle mist	4 months	DRI
	0.2-2 µm OPC	±15%	PMS LasAir 1002	UMN Vibrating Orifice Aerosol Generator	UMN Vibrating Orifice Aerosol Generator	1 year	Polystyrene latex suspension	3 months	Polystyrene latex suspension	4 months	DRI
	0.3-10 µm OPC	±15%	Climet CI-500	UMN Vibrating Orifice Aerosol Generator	UMN Vibrating Orifice Aerosol Generator	1 year	Polystyrene latex suspension	3 months	Polystyrene latex suspension	4 months	DRI
Integrated Particle Properties											

	Observable (Method)	*Percent Tolerance*	*Instrument*	*Primary Standard*	*Calibration Standard*	*Calibration Frequency*	*Performance Test Standard*	*Performance Test Frequency*	*Performance Audit Standard*	*Performance Audit Frequency*	*Audit by* [a]
	Number of condensation particles CPC	±20%	modified TSI 3025 Ultrafine CPC	UMN Differential Mobility Analyzer	UMN Differential Mobility Analyzer	1 year	Small particle mist	3 months	Small particle mist	4 months	DRI
	Particle light scattering Nephelometer	±10%	Radiance Research M903	Filtered air for 0 SUVA-134 for span	Filtered air for 0 SUVA-134 for span at station T and P	3 months & when out of spec	Filtered air for 0 SUVA-134 for span at station T and P	1 month	Filtered air for 0 SUVA-134 for span at station T and P	4 months	DRI
	Electrical Charge Integral	±15%	TSI 3068A	Comparison with collocated samples	Comparison with collocated filter samples	1 year	Voltage tests	1 month	Voltage tests	4 months	DRI
	Light Transmission Aethalometer	±5%	Magee Scientific AE-21	Neutral density filters	Neutral density filters	3 months & when out of spec	Neutral density filter	1 month	Neutral density filters	4 months	DRI
	$PM_{2.5}$ Mass CAMMS	±10%	Andersen CAMMS	Comparison with collocated filter samples	Comparison with collocated filter samples	1 year	Pressure measurement	1 month	Pressure measurement	4 months	DRI
***In Situ* Monitors**											
	Semicontinuous Sulfate	±15%	Harvard Prototype	NIST SO_2 mixture	Certified SO_2 mixture and dynamic dilution	3 months & when out of spec	Span with certified SO_2 & zero with scrubbed air	2 weeks	Certified SO_2 mixture and dynamic dilution	4 months 4 months	DRI
	Semicontinuous Nitrate (to be deployed Fall 2001)	±15%	Harvard Prototype	Mineral salt solutions	Salt solution	3 months & when out of spec	Mixed salt solution and distilled water	1 month	Mixed salt solution	4 months	DRI
	EC-OC TOT	±15%	Sunset Lab	NIST pthalate solutions	Sucrose solution	3 months & when out of spec	Sucrose solutions Methane gas incjetions	1 week 1 week	Pthalate and sucrose solutions	4 months	DRI
Laboratory Chemical Analysis											

	Observable (Method)	Percent Tolerance	Instrument	Primary Standard	Calibration Standard	Calibration Frequency	Performance Test Standard	Performance Test Frequency	Performance Audit Standard	Performance Audit Frequency	Audit by [a]
	Mass Electrobalance	±10 µg	Mettler MT-5	Class M weights	Class M weights	50 filters	Class M weight	10 samples	Class M weights	1 year	DRI
	Soluble Elements ICPMS	±5 to 15%	VG PlasmaQuad II+	Mineral salt solutions	Salt solution	3 months & when out of spec	Mixed salt solution	10 samples	Mixed salt solution	1 year	DRI
	Total Elements (XRF)	±5%	Kevex 700/800	EPA polymer films, NIST impregnated glass	Micromatter film deposits	6 months & when out of spec	Multi-element immpregnated glass	15 samples	Micromatter film deposits	1 year	DRI
	Total elements GFAAZ	±5 to 15%	Perkin Elmer SIMMA 6000	NIST standards	Salt solution	3 months & when out of spec	NIST standards	10 samples	NIST standards	1 year	DRI
	Total elements INAA	±5 to 15%	Gamma ray spectrometer	NIST standards	Salt solution	3 months & when out of spec	NIST standards	10 samples	NIST standards	1 year	DRI
	Total elements ICPMS	±0.005 to ±0.05 µg/mL	VG PlasmaQuad II+	Mineral salt solutions	Salt solution	3 months & when out of spec	NIST standards and Mixed Salt Solution	10 samples	NIST standards and Mixed Salt Solution	1 year	DRI
	Toxic Metals by GRAAZ	±15%	Perkin Elmer SIMMA 6000	Mineral salt solutions	Salt solution	3 months & when out of spec	Mixed salt solution	10 samples	Mixed salt solution	1 year	DRI
	Anions and cations IC	±0.05 µg/mL	Dionex 500DX	Mineral salt solutions	Salt solution	100 samples	Mixed salt solution and distilled water	10 samples	Mixed salt solution	1 year	DRI
	EC-OC TOT	±0.2 µg/cm^2	Sunset Lab	NIST pthalate solution	Sucrose solution	3 months & when out of spec	Sucrose solution	1 day	Pthalate and sucrose solutions on filters CO_2 and CH_4	1 year	DRI
	Organic compounds Extraction-Derivitization-GCMS	±5 to 30%	Hewlett Packard 5973	Multi species solutions	Multi species solutions	3 months & when out of spec	Multi species solutions Internal standard	20 samples Every sample	Multi species solutions	1 year	DRI

	Observable (Method)	*Percent Tolerance*	*Instrument*	*Primary Standard*	*Calibration Standard*	*Calibration Frequency*	*Performance Test Standard*	*Performance Test Frequency*	*Performance Audit Standard*	*Performance Audit Frequency*	*Audit by* [a]
Gases											
	NO/NO_x Chemiluminescence	±10%	API 2000A	NIST NO mixture	Certified NO mixture and dynamic dilution	3 months & when out of spec	Span with certified NO & zero with scrubbed air	1 day	Certified NO mixture and dynamic dilution	4 months	IEPA/ USEPA
	CO Correlation Non-Dispersive Infrared Absorption	±10%	TECO 48	NIST CO mixture	Certified CO mixture and dynamic dilution	3 months & when out of spec	Span with certified CO & zero with scrubbed air	1 day	Certified CO mixture and dynamic dilution	4 months	IEPA/ USEPA
	SO_2 Pulsed Fluorescence	±10%	Dasibi 4108	NIST SO_2 mixture	Certified SO_2 mixture and dynamic dilution	3 months & when out of spec	Span with certified SO_2 & zero with scrubbed air	1 day	Certified SO_2 mixture and dynamic dilution	4 months	IEPA/ USEPA
	O_3 Ultraviolet Absorption	±10%	Dasibi 1008 RS	ARB Primary UV Photometer	Dasibi 1003H UV photometer	3 months & when out of spec	Span with internal ozone generator & zero with scrubbed air	1 day	Dasibi 1008 with temperature pressure adjustments	4 months	IEPA/ USEPA

Meteorology											
	Wind speed (anemometer)	±0.5 m/s	Climatronics 102083-G0-H0	Certified wind tunnel	Certified wind tunnel Synchronized motor	At purchase	Visual inspection Synchronized motor when out of spec	1 week	Synchronized motor	4 months	DRI
	Wind direction (wind vane)	±10°	Climatronics 102083-G0-H0	Surveyor compass Solar azimuth	Surveyor compass Solar azimuth	1 year	Visual inspection Re-alignment when out of spec	1 week	Surveyor compass Solar azimuth	4 months	DRI
	Temperature (thermocouple)	±1° C	Climatronics 100093	NIST thermometer and water bath	NIST thermometer and water bath	1 year	On-site psychrometer	1 month	NIST thermometer and water bath	4 months	DRI
	Relative humidity (Lithium Chloride)	±2%	Climatronics 102425	NIST thermometer and dew cups	NIST thermometer and psychrometer	1 year	On-site psychrometer	1 month	Collocated chilled mirror sensor	4 months	DRI
	Solar radiation (pyranometer)	±20 W/m^2 24 hour average	Climatronics CM3 102318	NIST standard luminence	NIST standard luminance	At purchase	Visual inspection of max and min	1 week	Collocated pyranometer	4 months	DRI
	Atmospheric pressure (barometer)	±3 mm Hg	Climatronics 102270-G3	Mercury barometer	Mercury barometer	At purchase	Visual inspection of max and min	1 week	Mercury barometer	4 months	DRI
	Precipitation (tipping bucket)	±5%	Climatronics 100097-1-G0	Volumetric pipette	Volumetric pipette	At purchase	Visual inspection	1 month	Rain gauge calibrator	4 months	Met Associates

Figure 2-1. The St. Louis Supersite locations in the Metropolitan St. Louis area. The $PM_{2.5}$ compliance monitoring network and speciation network is also shown; all compliance monitors are SLAMS, except 2nd & Mound which is a Special Purpose Monitor (SPMS).

Figure 2-2. Population density by census tract (number/square mile, 1990 Census) for the Metropolitan St. Louis area. Blue markers are the metro area Supersite monitoring locations; white markers are $PM_{2.5}$ compliance sites and/or speciation monitor sites.

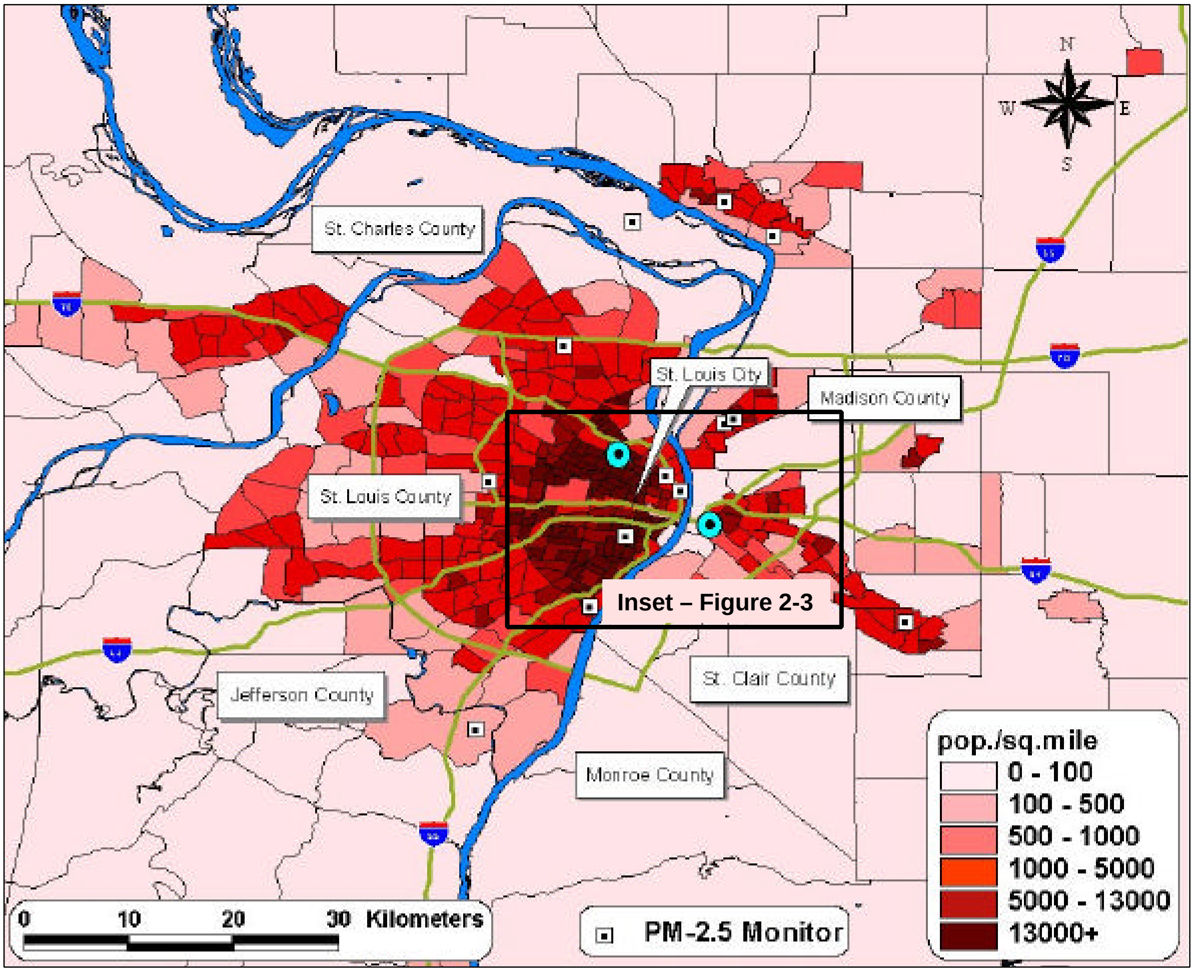


Figure 2-3. Population density by census tract (number/square mile, 1990 Census) for the City of St. Louis and neighboring ring suburbs (inset from Figure 2-2). Blue markers are the metro area Supersite monitoring locations; white markers are $PM_{2.5}$ compliance sites and/or speciation monitor sites.

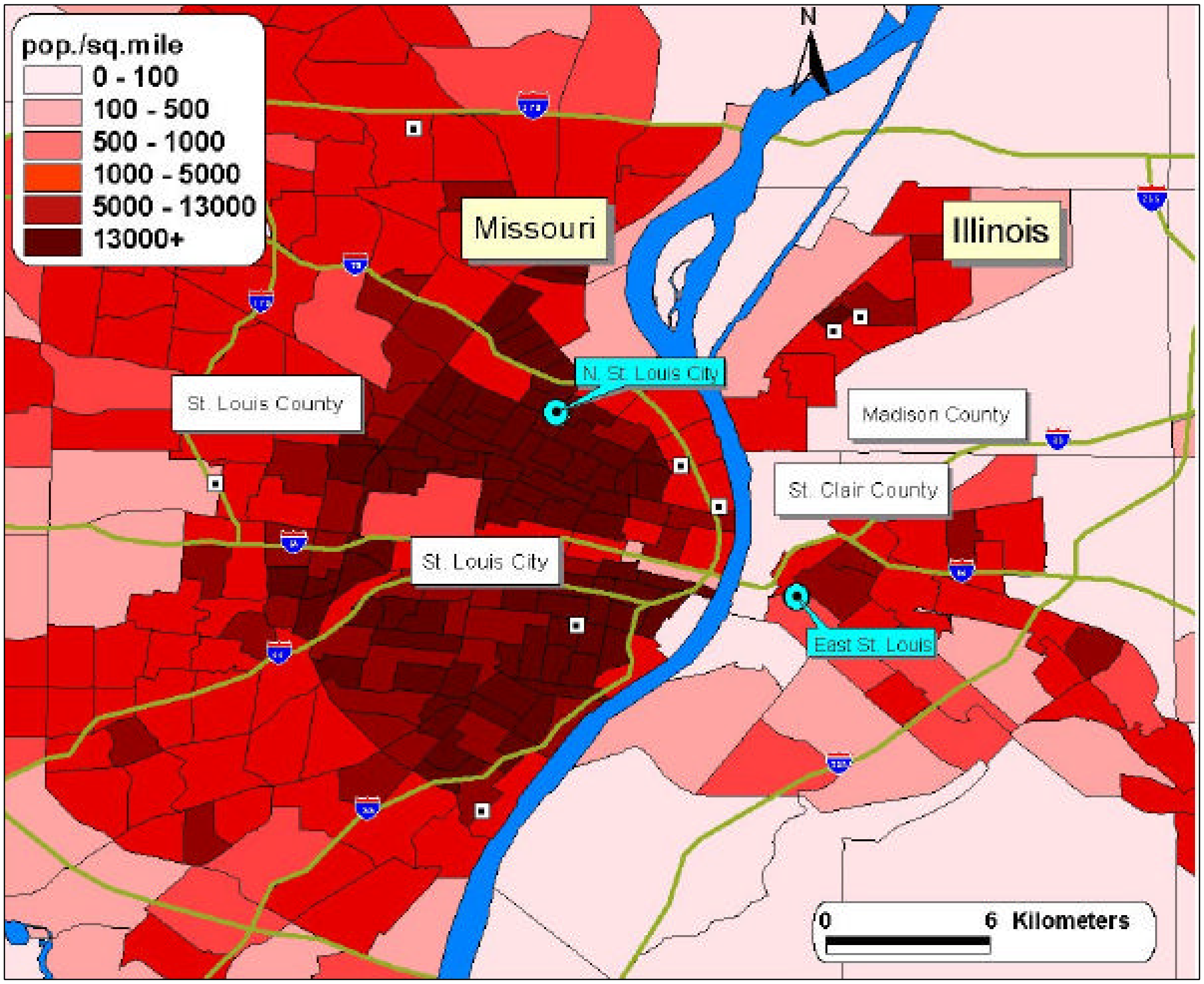


Figure 2-4. Mean trajectories for air mass clusters constructed for three-day back trajectories arriving in St. Louis, CY 1999-2000. The clustering method was a modified version of Doerling et al. (1992).

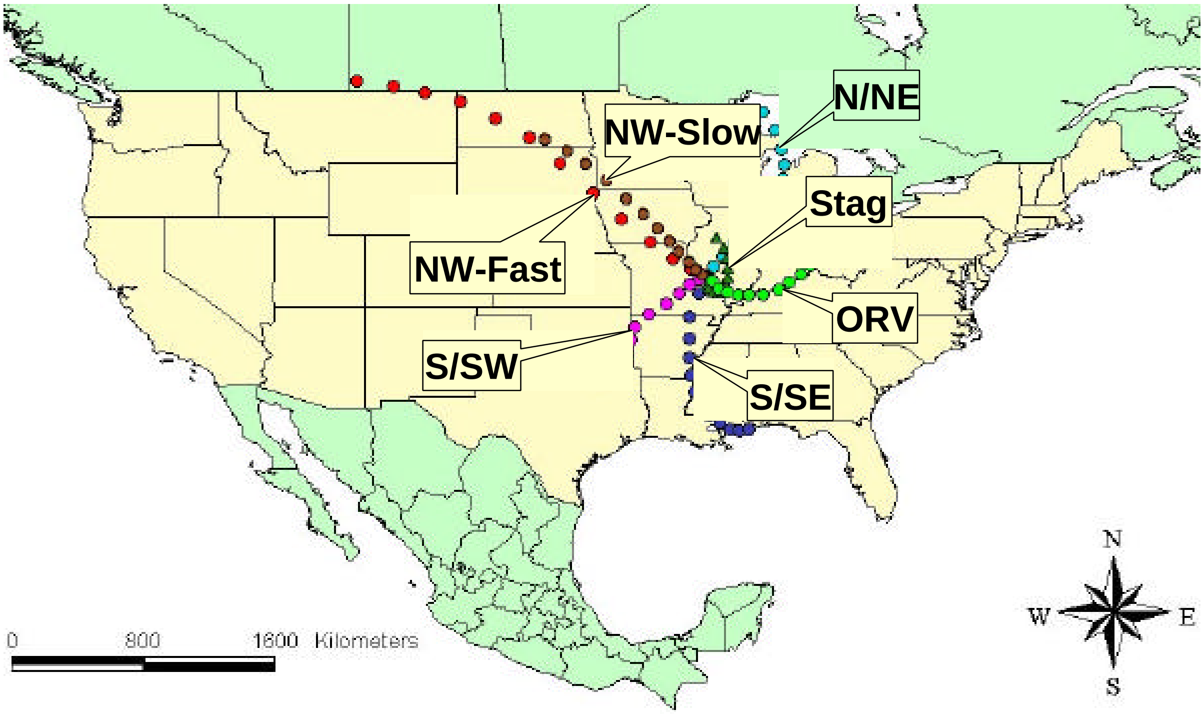


Figure 2-5. $PM_{2.5}$ mass distributions for the clusters represented by the mean trajectories in Figure 2-4, CY 1999-2000. The Ohio River Valley cluster is relatively infrequent but corresponds to high $PM_{2.5}$mass concentrations; fast-moving Northwest trajectories feature low $PM_{2.5}$ mass concentrations. The number is parenthesis along the top axis correspond to the number of trajectories in each cluster.

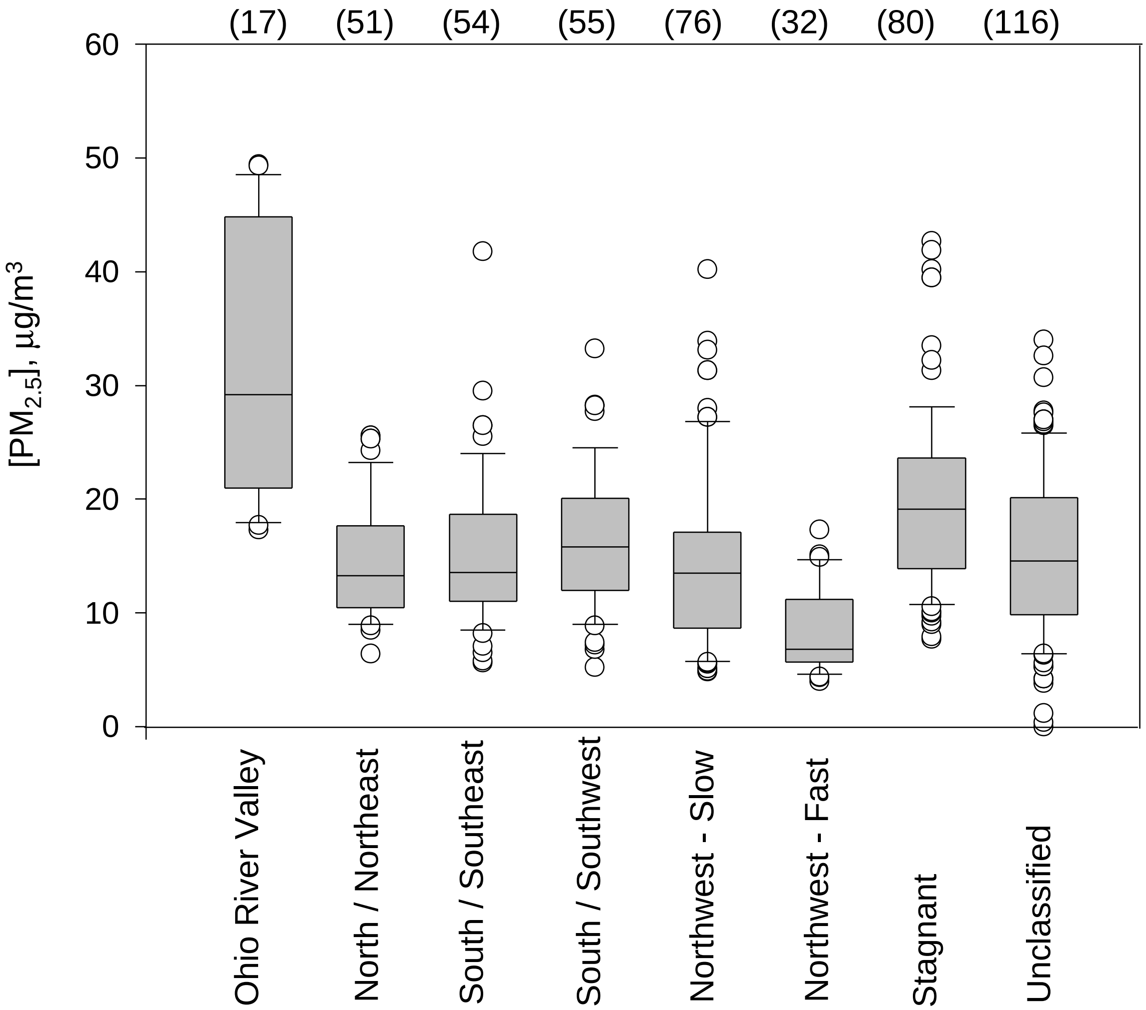
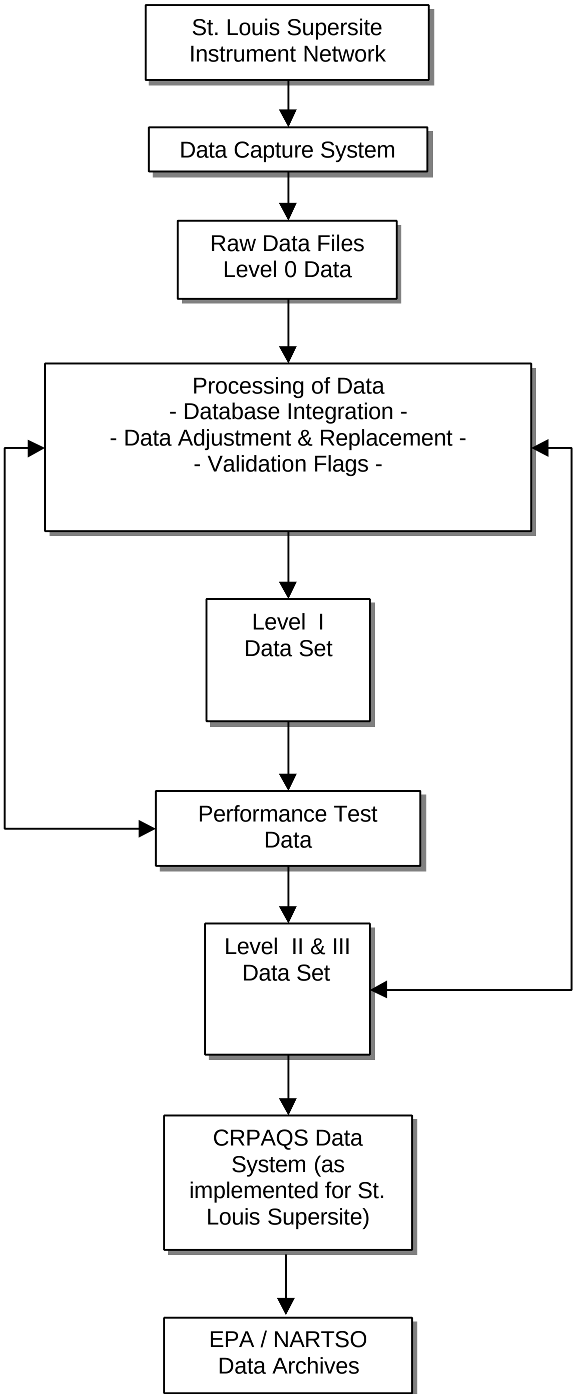


Figure 2-6. Aerial view of the St. Louis Supersite core monitoring location (red rectangle). This view faces to the west, with the IEPA monitoring shelter immediately north of the Supersite footprint. Interstates 55/64/70 run west of the site; the Mississippi River and northern edge of the City of St. Louis' Central Business District are in the background. The highway ramps near the site feature relatively little traffic, with at most 10 vehicles per minute during rush hour periods.

Figure 2-7. Flow diagram of the data management system for the St. Louis Supersite.



3. ASSESSMENT AND OVERSIGHT

3.1 Assessment and Response Actions

Success of the project will be evaluated in terms of: 1) accuracy, precision, validity, and completeness of acquired data; 2) extent to which data can be used to test stated questions (e.g., hypotheses and issues warranting investigation); 3) confidence of conclusions regarding investigations; 4) consistency of St. Louis Supersite measurements with those from other local measurements (e.g., speciation monitors) and other Supersites; 5) integration with other monitoring networks and research studies; 6) leveraging of Supersite resources with those from other agencies; and 7) relevance of study conclusions to Supersite program objectives. Periodic publications and a final report by the Principal Investigator will discuss accomplishments with respect to each of these areas.

Referring to the above list, the first metric sets forth the data qualification. Assessment tools include systems audits, performance audits, database integrity audits, interlaboratory comparisons, comparisons with results from other Supersites,[8] external review by a peer review panel, and peer review as part of the publication process. Table 2-7 lists the types and frequencies of the performance evaluations. For St. Louis Supersite measurements, the QA Manager will conduct a field and laboratory systems audit, a laboratory performance audit and/or interlaboratory comparison, and four field performance audits.

The second metric will be assessed by the data analysts as they use the acquired measurements to test the issues articulated in Table 3-1.[9] Part of the success in using the data will be the ratio of data manipulation vs. data analysis time, which should be reduced by using the database structure described in Section 2.10.

The third metric - confidence in study conclusions - will be evaluated according to the following criteria: 1) high confidence: low uncertainty in the data or data analysis approach, or more than one independent analysis approach, each of which has moderate uncertainties; 2) medium confidence: moderate uncertainty in the data or data analysis approach without independent analysis methods; and 3) low confidence: large uncertainty in the data or data analysis approach and independent analysis methods were not available or provided contradictory findings. These ratings were applied by each investigator and modified under scrutiny by all investigators in the Northern Front Range Air Quality Study (Watson et al., 1998). Decision-makers found it useful for scientists to express their own levels of be in the conclusions.

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8 . Comparison of St. Louis data to the other Supersites will presumably be conducted by outside investigators under the Supersite Phase III program. Results from this analysis will be discussed in the QAFR to the extent it is available.

9 . Table 3-1 is not intended to be an exhaustive list of measurement questions and issues. The intent is to present a relevant subset of such questions/issues to support the data quality objectives for this study.

The fourth and fifth metrics - concerning consistency with other local studies - will generally rely on the data qualifications discussed for the first metric. In this case, comparable data qualification must be available for the non-Supersite measurements to support a meaningful comparison.

Concerning the fifth and sixth metrics, measurements from the St. Louis Supersite will be closely coordinated with concurrent epidemiological, clinical, exposure, and toxicological studies. Dr. Petros Koutrakis serves as the liaison between the St. Louis Supersite and the collaborating heath scientists. Scientific papers will be submitted to external peer review, and the resulting comments will be addressed in finally published papers. The principal investigators and/or selected task leaders will report on progress and results at annual meetings of Supersite investigators. These presentations will be structured to obtain feedback and experience from similar projects taking place in other U.S. cities.

Finally, the seventh metric - relevance of the study conclusions to the Supersites program objectives - will be addressed in the Project Final Report by revisiting the objectives set forth in the Request for Assistance and creating a matrix to demonstrate how the study conclusions address the individual objectives.

3.2 Reports to Management

Figure 1-5 shows the schedule for project deliverables and reports to management. These deliverables and reports include: 1) the Quality Assurance Project Plan and its revisions; 2) quarterly progress reports; 3) a draft final report (11/30/03); and 4) a final report and data base (12/31/03). Presentations and technical meetings and publications in peer-reviewed journals will be produced throughout the project. In addition to these written documents, there will be annual review meetings to discuss the progress of the project and quality of the data.

Table 3-1. St. Louis Supersite questions/issues and testing methods.

Questions/Issues	Background	Data Analysis, Methods, and Data Used
1. What is the temporal variability of aerosol chemical and physical properties?	Measurements integrated over many hours represent a smoothed signal with attendant loss of information concerning shorter-term fluctuations. Such variability might be an important factor concerning adverse health effects. Short-term fluctuations also contain useful information for source apportionment and research into aerosol chemistry/physics.	Measure several key aerosol chemical and physical properties at high time resolution (from seconds to one hour). Sustain these measurements for one full year to investigate temporal variability at several scales of resolution (e.g., transient, diurnal, weekly, seasonal). Analyze time series in light of the measurement uncertainties (calculated from performance tests and obtained from collocated measurements for most instruments). Applies to: $PM_{2.5}$ mass, sulfate, nitrate, aethalometer black carbon, and OC/EC; selected PM elements analyzed retrospectively; and aerosol size distributions (discrete and integral moments).
2. What is the spatial variability of aerosol chemical and physical properties?	An array of substrate-based speciation monitors can be used to assess spatial variability on the scale of several hours to a day. However, many important phenomena occur on shorter time scales (see #1 above).	Measure several key aerosol chemical and physical properties at high time resolution (from seconds to one hour) at both the core and satellite locations. To support analysis at different spatial scales and environments, one satellite site is a high density urban residential location 9 km from the core site, while the other site is a relatively rural background location approximately 90 km from the core site. Quantify spatial correlations for the high-time resolution data for measurements sustained over several weeks during each season to evaluate diurnal and seasonal variability. Compare site-to-site differences with measurement uncertainties obtained from collocated measurements at the core site. Applies to: $PM_{2.5}$ mass, sulfate, nitrate, and aethalometer black carbon; and aerosol integral moments.
3. To what extent can features of the aerosol size distribution can be reconstructed from measurements of aerosol integral moments?	Detailed ambient aerosol size distribution measurements require complex instrumentation and expertise. A more attractive approach for routine analysis is to measure selected moments of size aerosol size distribution and apply reconstruction techniques to estimate key parameters relevant to aerosol dynamics and health studies (e.g., aerosol surface area).	Measure the detailed aerosol size distribution using two SMPS units and two OPC units. Also measure the ultrafine (<0.1 µm), accumulation (0.1 to 2.5 µm), and coarse (2.5 to 10 µm) integral moments of the size distribution. Compare key parameters (e.g., aerosol surface area) by direct construction from the detailed size distributions and by using the integral moment data to fit a lognormal size distribution.

Table 3-1. St. Louis Supersite questions/issues and testing methods.

Questions/Issues	Background	Data Analysis, Methods, and Data Used
4. To what extent can detailed organic compound speciation be used to identify and quantify sources of organic PM?	The carbon-containing component of ambient aerosol is often a large fraction of the total aerosol mass. Chemical speciation of the organic fraction provides an opportunity to identify, and in some cases quantify, the sources contributing to the organic PM burden.	Collect 24-hour integrated $PM_{2.5}$ samples for analysis by GC/MS for more than two hundred compounds. Retrospectively analyze at least 110 of the samples, spanning a range of environmental conditions (e.g., low-, moderate- and high-PM episodes; range of meteorological conditions). Compare to published source profiles to identify, and in some cases quantify, the sources contributing to the PM burden.
5. To what extent can elemental analysis at high time resolution improve PM source apportionment?	Given that meteorological conditions and source emission strengths can exhibit significant diurnal and directional variability, analysis of samples collected at higher time resolution may provide more specificity on the proximity and direction of elemental contributors than time-integrated samples.	Collect hourly-integrated PM samples using the High Frequency Aerosol Slurry Sampler (HFASS). Retrospectively analyze at least 1200 of the samples, spanning a range of environmental conditions (e.g., low-, moderate- and high-PM episodes; range of meteorological conditions). Investigate diurnal profiles in PM elemental composition. Compare to published source profiles to identify, and in some cases quantify, the sources contributing to the PM burden.
6. How equivalent, comparable, or predictable are continuous measurements to filter-based measurements?	Both semicontinuous and integrated measurements are susceptible to a variety of measurement issues ranging from sensitivity to sampling artifacts. It is important to compare data collected using both methods to determine the extent to which they can be used as the same observables.	Collect data for several aerosol physical and chemical properties using both semicontinuous and time-integrated (24-hour) samplers. Time-average the semicontinuous data for direct comparison to the time-integrated data. Applies to: $PM_{2.5}$ mass, sulfate, nitrate, OC/EC, ions, and selected metals.
7. What is the contribution of carbon to the coarse aerosol fraction?	Most analyses of coarse PM have focused on elemental composition, with emphasis on geologic components. However, there can be significant levels of carbon-containing components in the aerosol coarse fraction which to date have been ill-characterized.	Collect 24-hour integrated coarse PM (alternate day sampling schedule) on quartz fiber filters using a hi-volume dichotomous sampler. Analyze for OC/EC composition. Collect several collocated samples to determine the measurement precision.

Table 3-1. St. Louis Supersite questions/issues and testing methods.

Questions/Issues	Background	Data Analysis, Methods, and Data Used
8. What are the most accurate and precise methods for determining coarse PM mass and elemental composition?	Coarse PM mass and elemental composition can be estimated by near-direct measurement using the coarse channel of a dichotomous sampler, or from the difference between analyzed PM_{10} and $PM_{2.5}$ samples. There are trade-offs to these methods; the dichot coarse filter sample is prone to particle losses during handling and transport, while the difference method may suffer from a relatively high propagated uncertainty.	Collected 24-hour integrated samples using a hi-volume dichotomous sampler (alternate day sampling schedule), and $PM_{2.5}$ and PM_{10} Harvard Impactors (daily schedule). Analyze for gravimetric mass and elemental composition. Collect several collocated samples to determine the measurement precision. Compare the differences with measurement uncertainties.

4. DATA VALIDATION AND USABILITY

4.1 Data Review, Validation, and Verification Requirements

Continuous data are uploaded and examined daily by the individual investigators and/or AQL's laboratory to ensure data are acquired within the specified range. Corrective action is taken when errors or anomalies are found. Detailed information on data processing and data validation is given in the specific SOPs. Additional information on data management and validation procedures are given in the SOPs listed in Table 2-2.

Specific data validation procedures discussed in Section 2.10 are applied to all data acquired from the St. Louis Supersite. Field and laboratory validation flags applied at each level of the data validation process will be part of the final data base to verify the validity of each measurement.

4.2 Reconciliation with User Requirements

Table 3-1 summarizes selected questions to be investigated at the St. Louis Supersite. This list is not intended to be comprehensive, as there are a myriad of questions which could be addressed by a study of this nature. Rather, the intent is to provide a list which provides adequate foundation for defining the data quality objectives.

Measurement methods evaluation issues are based on evidence that there is climatology for the validity and comparability of measurements acquired by the same instruments. Meteorological conditions, source contributions, and aerosol chemical composition in the Midwest are known to change substantially over a year and even between different parts of the day. Long-term measurements – for a year or more – are needed to evaluate the feasibility, practicality, and equivalence of different measurement techniques. Evaluation of these measurements will determine where and when less complex, more convenient, or more widely available measurements can be used in place of the advanced methods implemented at the Supersite.

Several empirical and statistical measures are applied to evaluate predictability and equivalence (Mathai et al., 1990). Ordinary, unweighted linear regression is most commonly used and is the requirement for federal equivalent method (FEM) relationships with FRMs. Unweighted regression statistics are dominated by the highest concentrations. The effective variance weighting (Watson et al., 1984) includes the precisions of both variables in the calculation and bases the standard errors on them. When the slope equals unity within three standard errors, when the intercept does not significantly differ from zero within three standard errors, and when the correlation coefficient also exceeds 0.9, the measurements are considered comparable. When the correlation coefficient exceeds 0.9 but the slope and intercept criteria are not met, the dependent variable is predictable from the independent variable.

Other comparison measures include average ratios and standard deviations, ratios of averages, and the distribution of differences (X minus Y) for $<1\sigma$, 1σ to 2σ, 2σ to 3σ, and $>3\sigma$ precision intervals. These measures indicate the extent to which long-term averages are more or less equivalent than individual values and whether or not the majority of differences are within stated uncertainty intervals.

Mauderly et al. (1998) identify several indicators for adverse health effects: 1) PM mass; 2) PM surface area; 3) PM number (i.e., ultrafine concentration); 4) transition metals (especially the soluble fraction); 5) acids (especially sulfuric acid); 6) organic compounds; 7) bioaerosols; 8) sulfate and nitrate compounds (typically neutralized in whole or in part by ammonia or sodium); 9) peroxides and other free radicals that accompany and help to form PM; 10) soot (elemental carbon and associated PAH); and 11) correlated co-factors (other pollutants and variation in meteorology). Long-term data records of these variables are needed to examine relationships to health end-points and to determine the range of concentrations to which humans might be exposed. Owing to the complexity and expense of measurement technology, such long-term records are lacking.

Measurements at the St. Louis Supersite can be acquired to support health studies related to all but categories 7 and 9. PM surface area (category 2), while not directly measured, can be reconstructed from the detailed size distributions and integral moment measurements. Furthermore, all of these parameters will be measured at relatively high time resolution except sulfuric acid (category 5) and the detailed organic species characterization (category 6) which will be 24-hour integrated values.

For QA purposes, substantial comparisons among measurements will be made to determine their predictability, comparability, and equivalence. To evaluate equivalence, comparability (or lack thereof), and/or predictability among different measurements, the following definitions are used:

- **Equivalence:** For PM$_{2.5}$ mass concentration, U.S. EPA (1997) requires Federal Equivalent Methods (FEM) to meet the following requirements when collocated with an FRM: 1) collocated precision of 2 μg/m^3 or 5% (whichever is larger), 2) linear regression slope of 1 ± 0.05, 3) linear regression intercept of 0 ± 1 μg/ m^3, and 4) linear regression correlation coefficient (r) of ^{3}0.97 (U.S. EPA, 1997). Although these criteria are specific to PM$_{2.5}$ mass equivalence, they can be used as criteria for other measurements.

- **Comparability:** Comparable monitors should provide readings in units which are consistent, be equipped with a standardized size-selective inlet, and yield measurements that are the same as collocated sampler measurements. Within stated precision intervals, the criteria for comparability are met when: 1) the slope (by either ordinary least squares or effective variance weighting) equals unity within three standard errors, or average ratios (Y/X) equal unity within one standard deviation, 2) the intercept does not significantly differ from zero within three standard errors, and 3) the correlation coefficient exceeds 0.9 (Berkson, 1950; Kendall, 1951; Madansky, 1959). This is a less demanding definition than equivalence because it considers the reported precisions of the two measurements being compared.

· **Predictability:** Some measurements may be correlated even though they measure different observables in other units. The criterion for predictability between two measurements is met when the correlation coefficient exceeds 0.9, although the slope may substantially deviate from unity and the intercept from zero.

· **Non-related**: Measurements are deemed non-related when the correlation coefficient is less than 0.9 and there is no consistent or linear relationship between them.

Although the different observables measured are quite diverse, it is possible that they may be highly correlated owing to their quantification of related particle properties or to large fluctuations caused by emissions and meteorology. Relationships between variables will depend on the composition of the aerosol as well as meteorological conditions. Measures of predictability, comparability, and equivalence are applied to data sets stratified by aerosol composition and season. Predictability requires a consistent and reliable relationship between measurements, even if they are of different quantities. Light scattering or light absorption measurements are examples of continuously measured particle properties from which $PM_{2.5}$ concentrations might be predicted. Comparability can be established between monitors that ostensibly measure the same observable, but with different principles. $PM_{2.5}$ mass acquired from the CAMM, FRM, dichotomous sampler, and Harvard impactors are expected to be comparable, and if they are shown to be so, they can be used interchangeably in data analysis. Equivalence is a regulatory term that allows a method to be designated as a Federal Equivalent Method (FEM) applicable to compliance monitoring. Equivalence is more demanding than predictability or comparability in that it requires demonstration of comparability within high tolerances over a wide range of concentration loadings and measurement environments.

5. REFERENCES

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APPENDIX A.

EVALUATION OF CONFORMANCE WITH MONITOR SITING CRITERIA

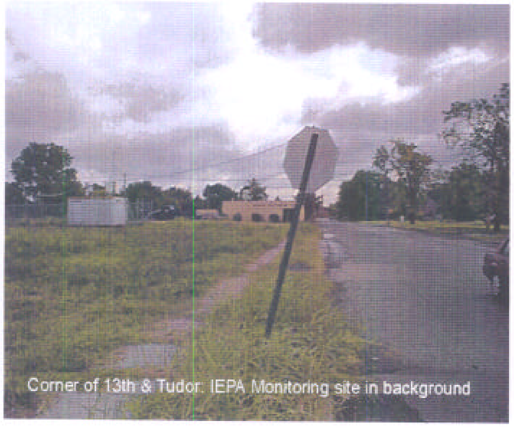
SECTION III - EVALUATION OF CONFORMANCE WITH APPENDIX E REQUIREMENTS

IIIE - $PM_{2.5}$ NAMS/SLAMS SITE EVALUATION

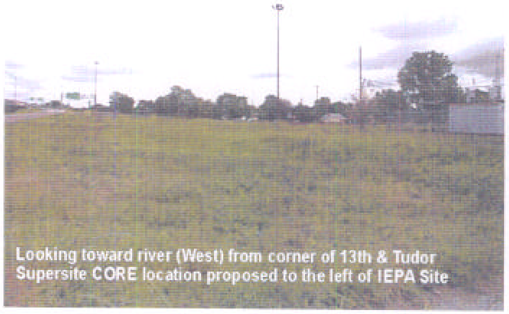
Agency Name : St. Louis Supersite Research Consortium
Site Address : 13th & Tudor Raps Site
City & State : East St. Louis, Illinois
AIRS Site ID : 171630010-1
Date : September 12, 2000
Observed by : Michael F. Davis, EPA Region VII

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET	
			Yes	No
Vertical Probe Placement (Par. 8.1)	2-7m above ground for microscale	Site not yet Established- No observed obstructions	X	
	2-15m above ground for other scales			
Obstructions on Roof	2m from walls, parapets, penthouses, etc.	No potential obstructions	X	
Spacing from Trees (Par. 8.2)	Should be ≥20m from dripline of trees	No trees	N/A	
	Must be ≥10m from dripline if trees are an obstruction**	No trees	X	
Obstacle Distance (Par.8.2)	2 x height differential (street canyon sites exempt)	No obstacles	X	
Unrestricted Airflow (Par. 8.2)	At least 270° including the predominant wind direction	Unrestricted Airflow	X	
Furnace or Incinerator Flues (Par.8.2)	**Recommended** that none are in the vicinity	None	N/A	
Distance between Co-located Monitors (Appendix A, Par. 3.5.2)	1 to 4m	Site not yet established		
Spacing from Station to Road (Par. 8.3)	See Par. 8.3 and/or Figure 2 of Appendix E	Nearest roadway- 68'	X	
Paving (Par. 8.4)	Area **should** be paved or have vegetative ground cover.	Grass covered	N/A	
Comments	See associated photos			

** A tree is considered an obstruction if the distance between the tree(s) and the sampler is less than the height that the tree protrudes above the sampler.

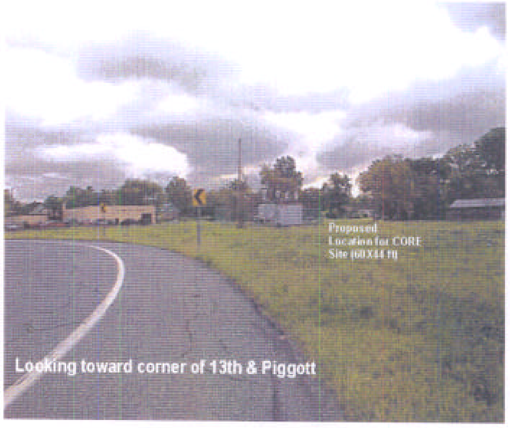


Corner of 13th & Tudor. IEPA Monitoring site in background



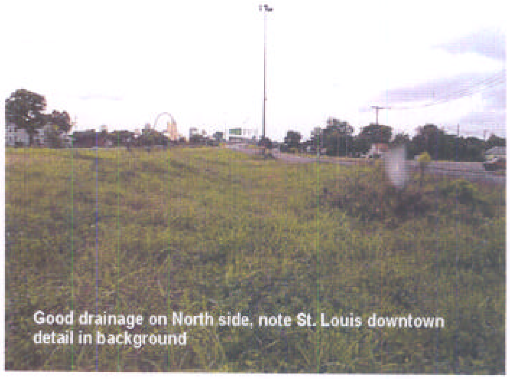
Looking toward river (West) from corner of 13th & Tudor
Supersite CORE location proposed to the left of IEPA Site

Detail view of highway off ramp area leading into intersection of 13th & Tudor. Traffic stops at sign. Area is predominantly residential with light traffic flow.

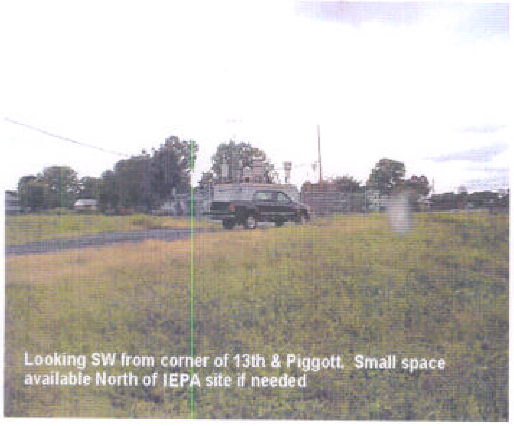


Looking toward corner of 13th & Piggott

Northern boundary of site, looking East toward 13th, note drainage on all sides of site. Distanct to 13th, 222 ft.



Good drainage on North side, note St. Louis downtown detail in background



Looking SW from corner of 13th & Piggott. Small space available North of IEPA site if needed

Looking West down 13th from Piggott

SECTION III - EVALUATION OF CONFORMANCE WITH APPENDIX E REQUIREMENTS

IIIE - PM$_{2.5}$ NAMS/SLAMS SITE EVALUATION

Agency Name : St. Louis Supersite Research Consortium
Site Address : Engine House 54 - Margaretta Street
City & State : St. Louis, Missouri 631151
AIRS Site ID : 29-510-0086
Date : September 12, 2000
Observed by : Michael F. Davis, EPA Region VII

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET	
			Yes	No
Vertical Probe Placement (Par. 8.1)	2-7m above ground for microscale	Site not yet Established- No observed obstructions	X	
	2-15m above ground for other scales			
Obstructions on Roof	2m from walls, parapets, penthouses, etc.	No potential obstructions	X	
Spacing from Trees (Par. 8.2)	Should be ≥20m from dripline of trees	Trees < 20m	N/A	
	Must be ≥10m from dripline if trees are an obstruction**	Trees do not obstruct flow	X	
Obstacle Distance (Par.8.2)	2 x height differential (street canyon sites exempt)	No obstacles	X	
Unrestricted Airflow (Par. 8.2)	At least 270° including the predominant wind direction	Unrestricted Airflow	X	
Furnace or Incinerator Flues (Par.8.2)	**Recommended** that none are in the vicinity	None	N/A	
Distance between Co-located Monitors (Appendix A, Par. 3.5.2)	1 to 4m	Site not yet established		
Spacing from Station to Road (Par. 8.3)	See Par. 8.3 and/or Figure 2 of Appendix E	54.8 meters ADT <10,000	X	
Paving (Par. 8.4)	Area **should** be paved or have vegetative ground cover.	Paved	N/A	
Comments	See associated photos			

** A tree is considered an obstruction if the distance between the tree(s) and the sampler is less than the height that the tree protrudes above the sampler.

East

Southeast

South

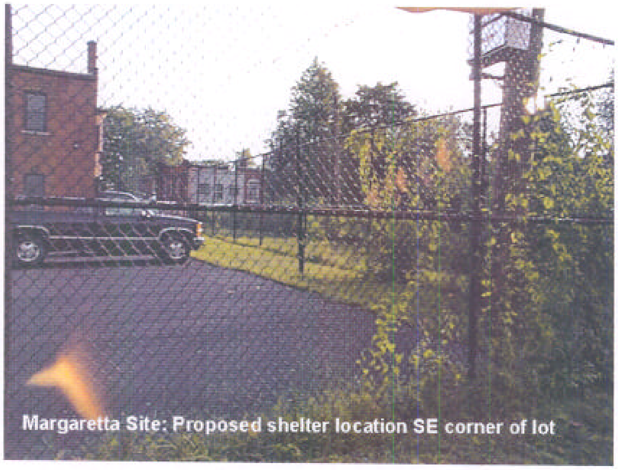
Southwest

North- Tree in background is approx. 40' tall, 35' from dripline to PM2.5 inle and 45" to glass manifold inlet. Margaretta Street in background - 180°

Northeast View

West

Northwest



Margaretta Site: Proposed shelter location SE corner of lot

Margaretta Site: Proposed shelter location, looking SW

Margaretta Site looking NW, note power and proximity to St. Louis City monitoring location (white trailer & platform)

SECTION III - EVALUATION OF CONFORMANCE WITH APPENDIX E REQUIREMENTS

IIIE - $PM_{2.5}$ NAMS/SLAMS SITE EVALUATION

Agency Name : St. Louis Supersite Research Consortium

Site Address : Mineral Area College

City & State : Park Hills, Missouri

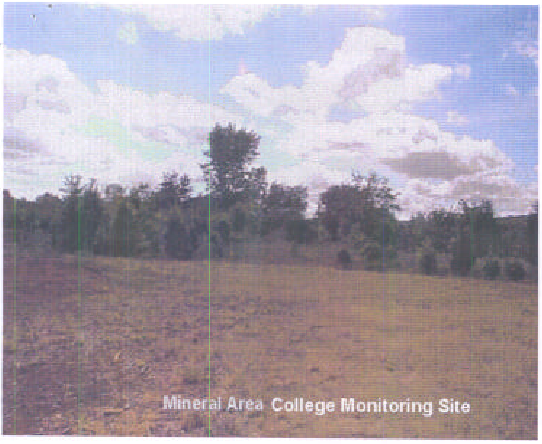
AIRS Site ID : N/A

Date : September 12, 2000

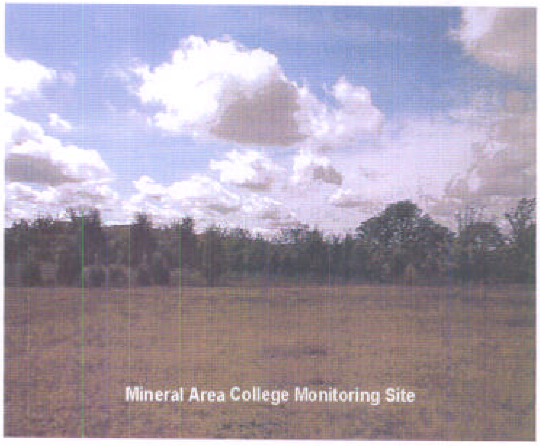
Observed by : Michael F. Davis, EPA Region VII

CRITERIA	REQUIREMENTS	OBSERVED	CRITERIA MET	
			Yes	No
Vertical Probe Placement (Par. 8.1)	2-7m above ground for microscale	Site not yet Established- No observed obstructions	X	
	2-15m above ground for other scales			
Obstructions on Roof	2m from walls, parapets, penthouses, etc.	No potential obstructions	X	
Spacing from Trees (Par. 8.2)	Should be ≥20m from dripline of trees	Trees >20m	N/A	
	Must be ≥10m from dripline if trees are an obstruction**	Trees do not obstruct flow	X	
Obstacle Distance (Par.8.2)	2 x height differential (street canyon sites exempt)	No obstacles	X	
Unrestricted Airflow (Par. 8.2)	At least 270° including the predominant wind direction	Unrestricted Airflow	X	
Furnace or Incinerator Flues (Par.8.2)	**Recommended** that none are in the vicinity	None	N/A	
Distance between Co-located Monitors (Appendix A, Par. 3.5.2)	1 to 4m	Site not yet established		
Spacing from Station to Road (Par. 8.3)	See Par. 8.3 and/or Figure 2 of Appendix E	Nearest road-way >200'	X	
Paving (Par. 8.4)	Area **should** be paved or have vegetative ground cover.	Grass covered	N/A	
Comments	See associated photos			

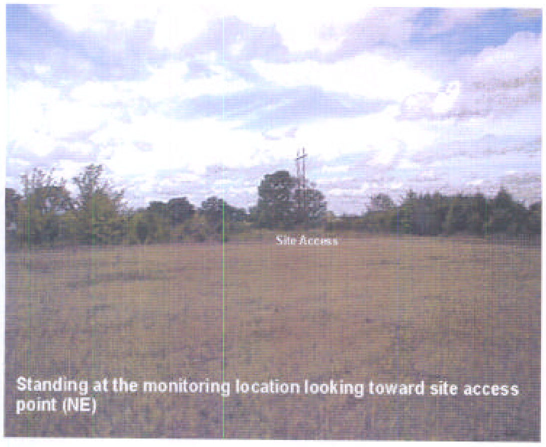
** A tree is considered an obstruction if the distance between the tree(s) and the sampler is less than the height that the tree protrudes above the sampler.



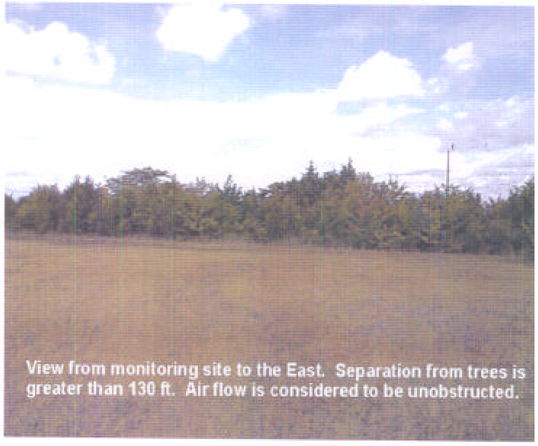
Mineral Area College Monitoring Site



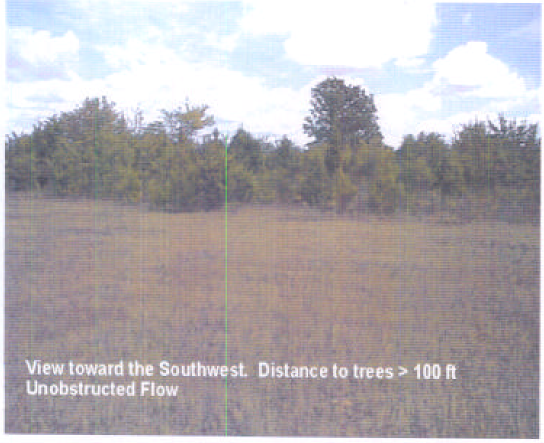
Mineral Area College Monitoring Site



Standing at the monitoring location looking toward site access point (NE)



View from monitoring site to the East. Separation from trees is greater than 130 ft. Air flow is considered to be unobstructed.



View toward the Southwest. Distance to trees > 100 ft
Unobstructed Flow

View toward proposed monitoring site from site access point