APPENDIX B

Methodology

http://www.epa.gov/oar/aqtrnd98/appendb.pdf

AIRS Methodology

The ambient air quality data presented in Chapters 2 and 3 of this report are based on data retrieved from AIRS on July 14, 1999. These are direct measurements of pollutant concentrations at monitoring stations operated by state and local governments throughout the nation. The monitoring stations are generally located in larger urban areas. EPA and other federal agencies also operate some air quality monitoring sites on a temporary basis as a part of air pollution research studies. The national monitoring network conforms to uniform criteria for monitor siting, instrumentation, and quality assurance.[1,2]

In 1999, 4,369 monitoring sites reported air quality data for one or more of the six NAAQS pollutants to AIRS, as seen in Table B-1. The geographic locations of these monitoring sites are displayed in Figures B-1 to B-6. The sites are identified as National Air Monitoring Stations (NAMS), State and Local Air Monitoring Stations (SLAMS), or "other." NAMS were established to ensure a long-term national network for urban area-oriented ambient monitoring and to provide a systematic, consistent data base for air quality comparisons and trends analysis. SLAMS allow state or local governments to develop networks tailored for their immediate monitoring needs. "Other" monitors may be Special Purpose Monitors, industrial monitors, tribal monitors, etc.

Table B-1. Number of Ambient Monitors Reporting Data to AIRS

Pollutant	# of Sites Reporting Data to AIRS in 1998	# of Trend Sites 1989–1998
CO	511	363
Pb	306	189
NO_2	422	225
O_3	1,048	661
PM_{10}	1,436	934
SO_2	646	482
Total	4,369	2,854

Air quality monitoring sites are selected as national trends sites if they have complete data for at least eight of the 10 years between 1989 and 1998. The annual data completeness criteria are specific to each pollutant and measurement methodology. Table B-1 displays the number of sites meeting the 10-year trend completeness criteria. Because of the annual turnover of monitoring sites, the use of a moving 10-year window maximizes the number of sites available for trends and yields a data base that is consistent with the current monitoring network.

The air quality data are divided into two major groupings: daily (24-hour) measurements and continuous (1-hour) measurements. The daily measurements are obtained from monitoring instruments that produce one measurement per 24-hour period and typically operate on a systematic sampling schedule of once every six days, or 61 samples per year. Such instruments are used to measure PM_{10} and lead. More frequent sampling of PM_{10} (every other day or every day) is also common. Only PM_{10} weighted (for each quarter to account for seasonality) annual arithmetic means that meet the AIRS annual summary criteria are selected as valid means for trends purposes.[3] Beginning in 1998, some sites began reporting PM_{10} data based on local conditions, instead of standard, or "reference," conditions. For these sites, PM_{10} statistics were converted from local conditions to standard conditions to ensure all PM_{10} data in this report are consistent and reflect standard conditions.[4] Only lead sites with at least six samples per quarter in three of the four calendar quarters qualify as trends sites. Monthly composite lead data are used if at least two monthly samples are available for at least three of the four calendar quarters.

Monitoring instruments that operate continuously produce a measurement every hour for a possible total of 8,760 hourly measurements in a

Figure B-1. Carbon monoxide monitoring program, 1998.

Figure B-2. Lead monitoring program, 1998.

Figure B-3. Nitrogen dioxide monitoring program, 1998.

Figure B-4. Ozone program, 1998.

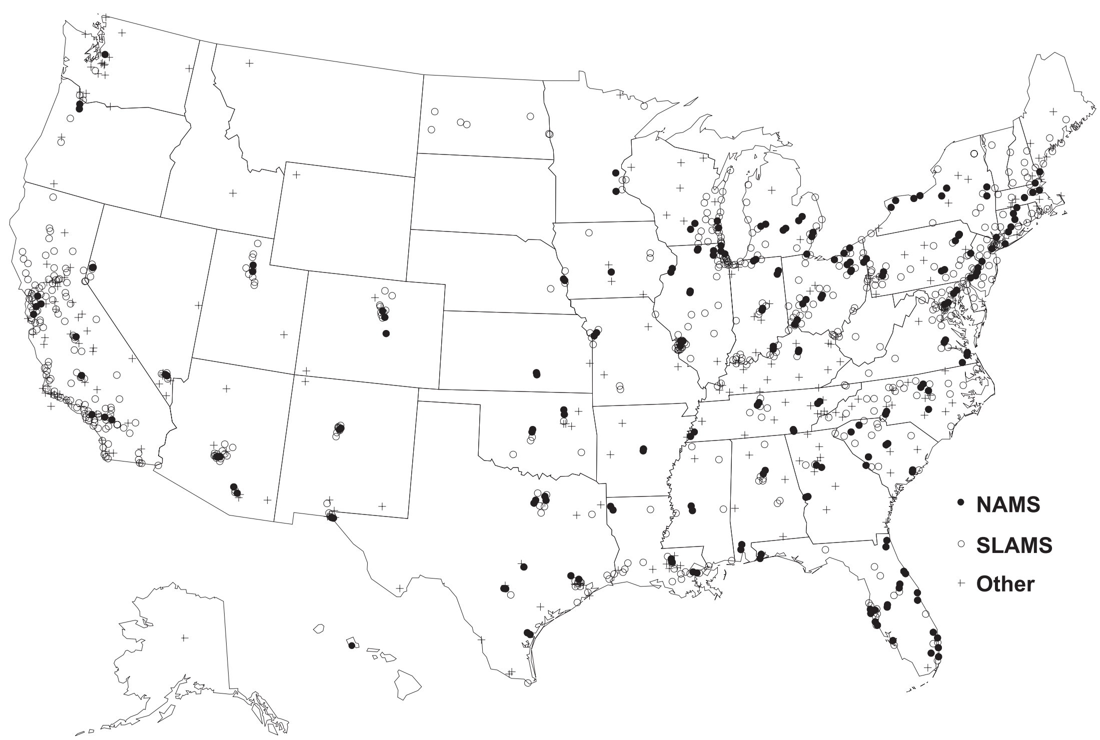

Figure B-5. PM_{10} monitoring program, 1998.

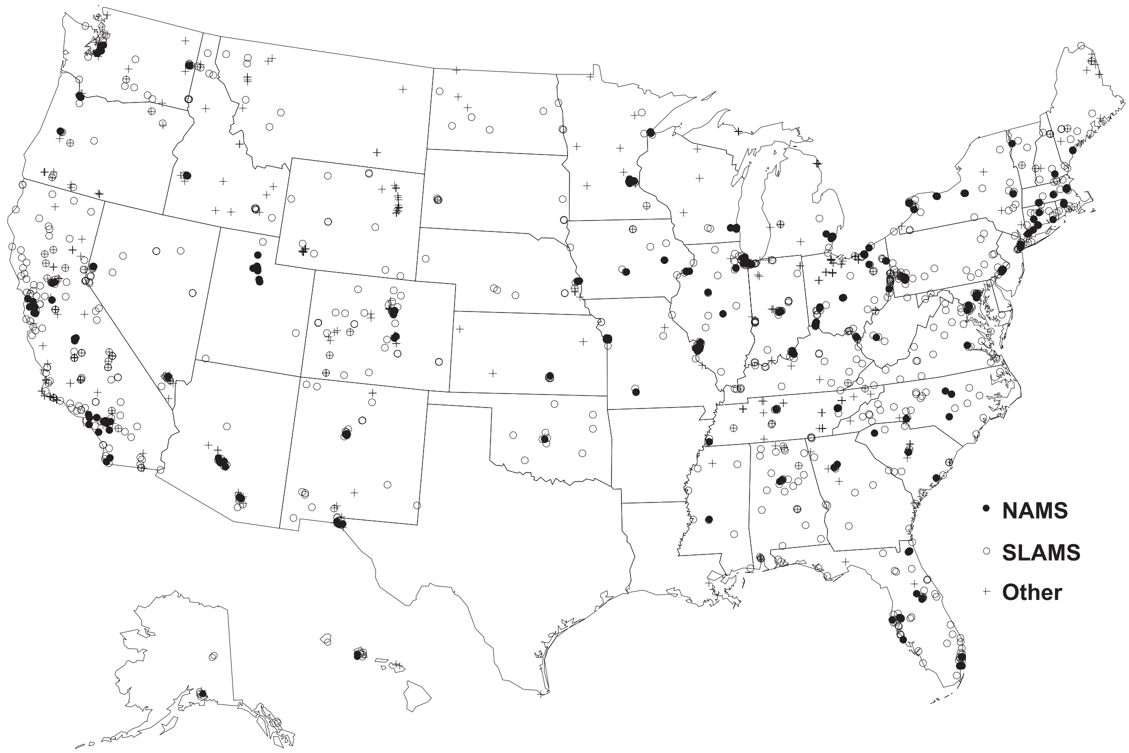

Figure B-6. Sulfur dioxide monitoring program, 1998.

Figure B-7. Class I Areas in the IMPROVE Network meeting data completeness criteria.

year. For hourly data, only annual averages based on at least 4,380 hourly observations are considered as trends statistics. The SO_2 standard-related daily statistics require at least 183 daily values to be included in the analysis. Ozone sites meet the annual trends data completeness requirement if they have at least 50 percent of the daily data available for the ozone season, which varies by state, but typically runs from May through September.[5]

Air Quality Trend Statistics

The air quality statistics presented in this report relate to the pollutant-specific NAAQS and comply with the recommendations of the Intra-Agency Task Force on Air Quality Indicators.[6] A composite average of each trend statistic is used in the graphical presentations throughout this report. All sites were weighted equally in calculating the composite average trend statistic. Missing annual summary statistics for the second through ninth years for a site are estimated by linear interpolation from the surrounding years. Missing end points are replaced with the nearest valid year of data. The resulting data sets are statistically balanced, allowing simple statistical procedures and graphics to be easily applied. This procedure is conservative since end-point rates of change are dampened by the interpolated estimates.

IMPROVE Methodology

Data collected from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network is summarized in Chapters 2 ($PM_{2.5}$ section) and 6 of this report. The completeness criteria and averaging method used to summarize the IMPROVE data are slightly different from those used for the criteria pollutants. (Data handling guidance is currently being developed for the IMPROVE network. Future summaries will be based on this guidance.)

The source data sets are available on the public FTP site. The $PM_{2.5}$ data were obtained from Dr. James Sisler of Colorado State University. The visibility data were obtained from **ftp://alta_vista.cira.colostate.edu/DATA/IMPROVE/Trends 88-98/10-50-90/TREND98.LIS**.

The annual average statistics in these files were used to assess trends in this report. The IMPROVE data are not reported in terms of a calendar year. The IMPROVE year runs from March to February of the following year. It follows that the four seasons are: March to May (spring), June to August (summer), September to November (autumn), and December to the following February (winter). The network samplers monitor on Wednesdays and Saturdays throughout the year, yielding 104 samples per year and 26 samples per season. Sites were required to have data at least 50 percent of the scheduled samples (13 days) for every calendar quarter.

IMPROVE monitoring sites are selected as trends sites if they have complete data for at least eight of the 10 years between 1989 and 1998 or (six of seven years for those who began monitoring in 1992). A year is valid only if there are at least 13 samples (50 percent complete) per season for both measured and reconstructed $PM_{2.5}$. The same linear interpolation applied to the criteria pollutants is applied here. In all, 34 IMPROVE sites met the data completeness criteria. They are denoted in Figure B-7 with a square or a square with an X.

For consistency, the same sites are used in both the $PM_{2.5}$ section and the Visibility chapter. The exception is Washington D.C., which is not included in the visibility trends analysis because it is an urban site.

Air Toxics Methodology

Data Base

The 1989–1998 ambient air quality data presented in Chapter 5 of this report are based on air toxics data retrieved from AIRS in August, 1999, data retrieved from the IMPROVE network **ftp://alta_vista.cira.colostate.edu/DATA/IMPROVE/** in June, 1999, and data voluntarily submitted to EPA by state and local monitoring agencies and received by June 30, 1999.[7] All statistical summaries are based on annual average concentrations. Measurements for hazardous air pollutants (HAPs) are frequently reported as non-detectable concentrations. To calculate annual average concentrations, one-half of the actual or plausible detection limit is used to substitute values for non-detects (or if the reported value is zero). The plausible detection limit, used for cases where the minimum detectable level (MDL) is missing, is the lowest measured concentration for the given monitor and HAP.

Separate summaries are presented for sites in an MSA/PMSA, excluding the (primarily rural) sites from the IMPROVE network, and for other sites. Areas (one or more counties) are either assigned to a MSA, to a CMSA (consolidated MSA) consisting of two or more PMSAs (primary MSAs), or are just assigned to a county. Each non-IMPROVE site in an MSA or CMSA was assigned either to its MSA or PMSA. Some analyses allocated MSA/PMSAs to states. If the MSA/PMSA crosses state boundaries, the state containing the largest portion of that MSA/PMSA was used.

Completeness

All calculations are based on the average of calculated or measured 24-hour values. For each HAP, a series of completeness rules are applied sequentially starting with using the raw hourly data to determine daily completeness. A day is complete if the total number of hours monitored for that day is 18 or more (i.e., 75 percent of 24 hours). For example, 18 hourly averages, three six-hour averages or three eight-hour averages will satisfy the daily completeness criteria. Once daily completeness is satisfied, quarterly completeness is determined. Calendar quarters are 1. (Late winter) Jan–March, 2. (Early summer) April–June, 3. (Late summer) July–Sept, 4. (Early winter) Oct–Dec. A calendar quarter is complete if it has 75 percent or more complete days out of the expected number of daily samples for that quarter, and if there are at least five complete days in the quarter. To determine the expected number of daily samples, the most frequently occurring sampling interval (days from one sample to the next sample) was used; in cases of ties, the minimum sampling interval was applied. A calendar year is complete if both the summer and winter six month seasons have at least one complete quarter, i.e., if a) quarter 1 or quarter 4 or both quarters 1 and 4 are complete, and b) quarter 2 or quarter 3 or both quarters 2 and 3 are complete.

National Analyses

Based on the available years of monitoring data across the nation, the national analyses were restricted to the six year period 1993–1998. A site was included for a particular HAP if and only if there were four or more complete years for that period.

California Analyses

A similar, but longer term trend analysis was performed on sites located only in California using 1989 to 1998 data. A site was included for a given HAP if there was at least one period of five years or longer such that a) at least 75 percent of those years are complete, and b) the period ends in 1995 or later. The most recent, longest such period was used.

Trend Analysis

Annual averages for years with four complete quarters were computed by averaging the four quarterly averages. If a year had one or more missing or incomplete quarters, then the missing quarterly averages were filled in (if possible) using the General Linear Model (GLM) fill in methodology described below and the annual average was computed by first averaging the quarterly averages (actual or filled-in) for a season and then averaging across the two seasons.[8] Quarterly averages were used for all quarters with one or more complete days, even if the quarter was incomplete. Sometimes, the filled in quarterly average can be negative and occasionally this leads to a negative annual average. To deal with this case, negative or zero filled-in quarterly averages were used to compute the annual average (this avoids biasing the results), but any resulting negative annual averages were reset to zero.

The overall slope (trend) was estimated non-parametrically as the arithmetic mean of the ratios of the difference in the annual average to the difference in calendar year, for all pairs of calendar years. The significance level of the trend was computed using the associated non-parametric Theil test, based on the number of pairs of years where the annual averages increased. The p-values are calculated for a two-sided test for whether or not the annual averages have a trend (which may be increasing or decreasing). The trend is reported as “Significant Up Trend” or “Significant Down Trend” if the corresponding one-sided test is significant at the five percent significance level; otherwise the result is reported as “Non-significant Up Trend,” “no trend,” or “Non-significant Down Trend.”

For the tables showing annual averages by monitor, the GLM fill-in method was not used. Instead, those annual averages were computed by averaging all complete daily averages for each quarter (whether from incomplete or complete quarters), then averaging across the two quarters in each season, and then, finally, averaging over the two seasons. All other analyses used the filled-in quarterly averages as described above.

GLM Fill-In Methodology

The general linear model (GLM) fill-in methodology and software used to fill in missing quarterly averages was based on the report by Cohen and Pollack (1990),[9] which can be consulted for more details. The only major change was modifying the method to apply to a sequence of at most 24 quarterly values (a six-year period) instead of five annual means. Initially, each site is allocated to a region, which for these analyses was the MSA/PMSA for sites within an MSA or PMSA, or else was the county. If for every quarter there is at least one site in the region with complete data for that quarter, then the missing quarterly averages for all sites in that region are computed by fitting a general linear model such that the expected value for a given site and quarter q is the sum of the site average and a quarterly adjustment term (this is the fixed effect of the q’th quarter, 1 <= q <= 24, assumed to be the same value for all sites in the region). If a region has one or more quarters that are incomplete for every site, then the region is expanded to become a larger, augmented region with some site data for every quarter, and the GLM approach is applied to the augmented region. Candidates for the augmented region are selected by finding the nearest site(s) that have complete data for the missing quarter(s). The selected augmented region is the region giving the lowest mean square error for the GLM model. For the California only analyses, the GLM fill-in approach was applied to the 10-year sequence of 40 quarterly averages, but augmented regions could only include sites in California.

This methodology can lead to occasional anomalous results. If a quarter is incomplete for all sites in a region, then the augmented region containing the nearest sites with available data for that quarter may include sites a long distance away, possibly in other states. The adjustment for that quarter will then be highly influenced by the very few sites with complete data for that quarter. Alternative data completeness rules and fill-in methodologies are currently under investigation; such methods ideally need to retain the advantages of balancing the impacts of the different missing value patterns at each site, while avoiding such anomalous results.

Emissions Estimates Methodology

Trends are presented for annual nationwide emissions of CO, lead, NO_x, VOCs, PM_{10}, and SO_2. These trends are estimates of the amount and kinds of pollution being emitted by automobiles, factories, and other sources based upon best available engineering calculations. Because of recent changes in the methodology used to obtain these emissions estimates, the estimates have been recomputed for each year. Thus, comparisons of the estimates for a given year in this report to the same year in previous reports may not be appropriate.

The emissions estimates presented in this report reflect several major changes in methodologies that were instituted mainly in 1996. First, state-derived emissions estimates were included primarily for nonutility point and area sources. Also, 1985–1994 NO_x emission rates derived from test data from the Acid Rain Division, U.S. EPA, were utilized. The MOBILE5b model was run instead of MOBILE5a for the years 1995 through 1998. The Office of Mobile Sources, U.S. EPA, provided new estimates from the beta version of the non-road model for most non-road diesel equipment categories. Finally, additional improvements were made to the particulate matter fugitive dust categories.

In addition to the changes in methodology affecting most source categories and pollutants, other changes were made to the emissions for specific pollutants, source categories, and/or individual sources. Activity data and correction parameters for agricultural crops, construction, and paved roads were included.

State-supplied MOBILE model inputs for 1990, 1995, and 1996 were used, as well as state-supplied VMT data for 1990. Rule effectiveness from pre-1990 chemical and allied product emissions was removed. Lead content of unleaded and leaded gasoline for the on-road and non-road engine lead emission estimates was revised, and Alaska and Hawaii nonutility point and area source emissions from several sources were added. Also, this report incorporates data from CEMs collected between 1994 and 1998 for NO_x and SO_2 emissions at major electric utilities.

All of these changes are part of a broad effort to update and improve emissions estimates. Additional emissions estimates and a more detailed description of the estimation methodology are available in two companion reports, the *National Air Pollutant Emission Trends, 1900–1998* and the *National Air Pollutant Emission Trends Procedures Document, 1900–1998*.[10,11]

References

1. Clean Air Act Amendments of 1990, U.S. Code, volume 42, section 7403 (c)(2), 1990.

2. Ambient Air Quality Surveillance, 44 CFR 27558, May 10, 1979.

3. Aerometric Information Retrieval System (AIRS), Volume 2, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October, 1993.

4. Falke, S. and Husar, R. (1998) Correction of Particulate Matter Concentrations to Reference Temperature and Pressure Conditions, Paper Number 98-A920, Air & Waste Management Association Annual Meeting, San Diego, CA, June 1998.

5. Ambient Air Quality Surveillance, 51 FR 9597, March 19, 1986.

6. U.S. Environmental Protection Agency Intra-Agency Task Force Report on Air Quality Indicators, EPA-450/4-81-015, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, February 1981.

7. Rosenbaum, A. S., Stiefer, M. P., and Iwamiya, R. K. November, 1999. *Air Toxics Data Archive and AIRS Combined Dataset: Contents Summary Report*. SYSAPP-99/26d. Systems Applications International, San Rafael, CA.

8. In most cases, four non-missing quarterly means are available after applying the GLM method, so that the resulting annual mean is the arithmetic mean of the four quarterly averages. In some cases, a quarter was incomplete for all the sites in the database so that no filled-in quarterly mean would be available for that quarter. Seasonal averaging was thus employed to deal with this situation in a reasonable manner.

9. Cohen, J.P. and A. K. Pollack. 1990. *General Linear Models Approach to Estimating National Air Quality Trends Assuming Different Regional Trends.* SYSAPP-90/102. Systems Applications International, San Rafael, CA.

10. National Air Pollutant Emission Trends, 1900-1998, EPA-454/R-00-002, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, February 2000.

11. National Air Pollutant Emission Trends Procedures Document, 1900-1998, EPA-454/R-00-001, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, February 2000.