8.0 Attainment Demonstration and Weight of Evidence

The southwestern Connecticut counties of Fairfield and Middlesex are included by the EPA in a $PM_{2.5}$ nonattainment area encompassing the New York City metropolitan area, which also comprises 10 downstate New York counties and 10 northern New Jersey counties. This multi-state area is classified by EPA as nonattainment for the 1997 annual $PM_{2.5}$ NAAQS based on measured violations in the New York and New Jersey portions of the nonattainment area. All Connecticut monitors are in compliance with the annual $PM_{2.5}$ NAAQS.

States with nonattainment areas are required to submit a SIP revision demonstrating that adopted control programs are sufficient to achieve attainment no later than April 2010. EPA modeling guidance[1] suggests the use of a photochemical grid model and appropriate weight-of-evidence (WOE) analyses to demonstrate attainment of the $PM_{2.5}$ NAAQS.

Sections 8.1 through 8.5 of this document describe the procedures, inputs and results of the regional photochemical grid modeling exercise. Section 8.6 describes various WOE analyses used as supplements to the modeling results to assess the likelihood of achieving timely attainment of the $PM_{2.5}$ NAAQS in the multi-state nonattainment area.

CTDEP's primary conclusions based on the results of the photochemical modeling and WOE analyses are:

1) There is a high level of probability that the New York-New Jersey-Connecticut area will achieve attainment of the 1997 annual $PM_{2.5}$ NAAQS by the end of the 2009; and
2) Adopted emission control programs will result in continued reductions in emissions of $PM_{2.5}$-contributing pollutants through 2012 and beyond, providing confidence that compliance with the annual NAAQS will continue once attainment is achieved.

8.1 Objective and Background of the Photochemical Modeling

The objective of the regional photochemical modeling study is to enable states to analyze the efficacy of various control strategies, and to demonstrate that the measures adopted as part of the SIP will result in attainment of the annual $PM_{2.5}$ standard by the April 2010 deadline. As described below, the modeling exercise provided estimates of the relative improvements in air quality anticipated between 2002 and 2009, based on hourly simulations of meteorology, emissions, atmospheric chemistry and transformations, while accounting for the effects of expected growth in source activity and new emission controls implemented between the two years.

The photochemical model selected for the attainment modeling demonstration was the EPA's Models-3/Community Multi-scale Air Quality (CMAQ) modeling system. The CMAQ modeling system was selected for the attainment demonstration primarily because it is a photochemical grid model capable of modeling a variety of pollutants over a range of time and space scales, i.e. a "one-atmosphere" photochemical grid model. Not only was CMAQ used to model the components (i.e., primary and secondary) that make up particles with an aerodynamic

[1] Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze. United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Analysis Division, Air Quality Modeling Group, Research Triangle Park, NC, EPA-454/B-07-002, April 2007.

diameter less than or equal to a nominal 2.5 micrometers ($PM_{2.5}$), but it also was used to model ozone formation and regional haze in the northeast states. All of the regional modeling was conducted in accordance with the EPA's modeling guidance.[2]

Under the direction of the Ozone Transport Commission's (OTC) Modeling Committee, several states and modeling centers performed the regional modeling runs and/or contributed to the preparation of technical information for the regional modeling effort. Those organizations included the:

1) New York State Department of Environmental Conservation (NYSDEC),
2) Ozone Research Center at University of Medicine & Dentistry of NJ/Rutgers University (UMDNJ/ORC),
3) University of Maryland (UMD),
4) Virginia Department of Environmental Quality,
5) Northeast States for Coordinated Air Use Management (NESCAUM)
6) Maryland Department of the Environment,
7) New Hampshire Department of Environmental Services, and
8) Mid-Atlantic Regional Air Management Agency (MARAMA).

The lead agency for coordinating the running of the CMAQ model and performing the modeling runs for the OTC was the NYSDEC. The NYSDEC ran the CMAQ model (using the protocol in Appendix 8A) for the May 1 through September 30 ozone season, which was supplemented by modeling runs performed by the UMDNJ/ORC (March and April), NESCAUM (October, November, December), and the University of Maryland (January, February) for the purposes of determining $PM_{2.5}$ attainment. The four regional modeling centers were, therefore, able to model an entire year of meteorology and emissions. The NYSDEC was responsible for post-processing the results for the NY-NJ-CT nonattainment area, including calculating the projected $PM_{2.5}$ concentrations using the relative response factor (RRF) method specified in the EPA's modeling guidance.[3]

The CMAQ modeling system was installed at all participating modeling centers and diagnostic tests were run to insure that the model was operating as designed. In addition, the CMAQ model was benchmarked against other modeling platforms to ensure similar results. The OTC modeling committee oversaw the modeling effort and reported to the OTC Oversight Committee. The CTDEP participated as a member of the various OTC committees.

8.2 Modeling Platform and Configuration

As described above, the CMAQ modeling platform was selected for use in the attainment demonstration. The CMAQ modeling system requires user specifications regarding the modeling platform, as well as meteorological, air quality and emissions input information. The CMAQ system configuration is documented in Appendix 8B, and described below. Additional documentation regarding modeling procedures are provided in Appendix 8D (TSD-2c).

[2] Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze. United States Environmental Protection Agency, Office of Air Quality Planning and Standards, Air Quality Analysis Division, Air Quality Modeling Group, Research Triangle Park, NC, EPA-454/B-07-002, April 2007.

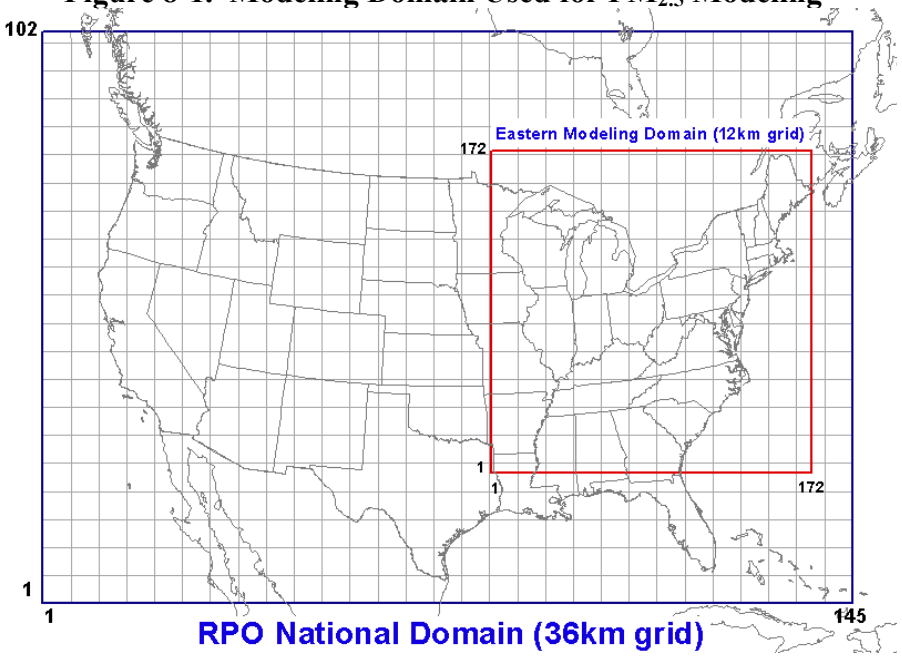
[3] Ibid.

8.2.1 Modeling Domain

When defining the modeling domain, the following parameters should all be considered: location of local urban areas; downwind extent of elevated ozone levels; location of large emission sources; availability of meteorological and air quality data; and available computer resources. In addition to the nonattainment areas of concern, the modeling domain should encompass enough of the surrounding area such that major upwind sources fall within the domain and emissions produced in the nonattainment areas remain within the domain throughout the day.

The areal extent of the OTR modeling domain (see Figure 8-1) is identical to the national grid adopted by the regional haze Regional Planning Organizations (RPOs), with a more refined "eastern modeling domain" focused on the eastern US and southeastern Canada. The placement of the eastern modeling domain was selected such that the northeastern areas of Maine are included. Based upon the existing computer resources, the southern and western boundaries of the imbedded region were limited to the area shown in Figure 8-1.

Figure 8-1. Modeling Domain Used for $PM_{2.5}$ Modeling



8.2.2 Meteorological Model Selection and Configuration

As explained in EPA's Emission Inventory Guidance,[4] 2002 was designated as the base year for 8-hour ozone SIPs, $PM_{2.5}$ SIPs, and regional haze plans; therefore, 2002 was used for baseline modeling for the $PM_{2.5}$ standard. The Pennsylvania State University/National Center for Atmospheric Research Mesoscale Meteorological Model (MM5) version 3.6 was used to generate the annual 2002 meteorology for the modeling analysis. MM5 is a non-hydrostatic,

[4] USEPA. Emissions Inventory Guidance for Implementation of Ozone and Particulate Matter National Ambient Air Quality Standards (NAAQS) and Regional Haze Regulations. United States Environmental Protection Agency, Emissions Inventory Group, Emissions, Monitoring, and Analysis Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-454/R-05-001, August 2005, updated November 2005.

prognostic meteorological model routinely used for urban-scale and regional-scale photochemical regulatory modeling studies. Based on model validation and sensitivity testing, the MM5 configurations provided in Appendix 8C were selected. Descriptions of the MM5 modeling process and the results of the model performance evaluation are provided in Appendix 8D (TSD-1).

8.2.3 Horizontal Grid Size

The basic CMAQ modeling platform utilized a two-way nested domain consisting of a coarse 36-km horizontal grid resolution for the continental United States domain and a fine 12-km grid over the eastern United States. A slightly larger domain was selected for the MM5 meteorological model simulations to provide a buffer of several grid cells around each boundary of the CMAQ 36-km domain. This was designed to minimize any errors in the meteorology from boundary effects. A 12-km inner domain was selected to better characterize air quality in the Ozone Transport Region and surrounding Regional Planning Organization regions. The horizontal grid definitions for the CMAQ and MM5 modeling domains are contained in Appendix 8E.

8.2.4 Vertical Resolution

The vertical structure of the air quality model is primarily defined by the vertical grid used in the meteorological modeling, which used a terrain-following coordinate system defined by pressure to create a total of 29 layers. The layer-averaging scheme adopted for the air quality modeling is designed to reduce the computational cost of the simulations, resulting in incorporation of 22 layers in the vertical, of which the lower 16 layers (approximately 3 km) coincide with those of the meteorological model. This ensures that the near-surface processes that affect air pollution the most are represented realistically in CMAQ, while the meteorological systems that are driven by upper level winds are allowed to develop properly in the MM5 model. Layer averaging has a relatively minor effect on the model performance metrics when compared to ambient monitoring data. Appendix 8E contains the vertical layer definitions for the meteorological and air quality modeling domains.

8.2.5 Initial and Boundary Conditions

The objective of a photochemical grid model is to estimate the air quality given a set of meteorological and emissions conditions. When initializing a modeling simulation, the exact concentration fields are unknown in every grid cell for the start time. Therefore, photochemical grid models are typically started with clean conditions within the domain and allowed to stabilize before the period of interest is simulated. In practice this is accomplished by starting the model several days prior to the period of interest; this is called ramp-up time.

The winds move pollutants into, within, and out of the domain. Although the model handles the movement of pollutants within the domain and out of the domain, estimates of the quantity of pollutants moving into the domain is needed. These are called boundary conditions. To estimate the boundary conditions for the modeling study, boundary conditions for the outer 36-km domain were derived from an annual model run performed by researchers at Harvard University using the GEOS-Chem global chemistry transport model.[5,6]

[5] Moo, N. and Byun, D. A Simple User's Guide For "geos2cmaq" Code: Linking CMAQ with GEOS-CHEM. Version 1.0. Institute for Multidimensional Air Quality Studies (IMAQS). University of Houston, 2004.

The influence of initial conditions was minimized by using a 15-day ramp-up period, which is sufficient to establish pollutant levels typically encountered in the eastern United States. Additionally, the predominant winds flow is from west to east; thus Connecticut is not influenced by nearby boundary conditions because the upwind boundary of the modeling domain is west of the Mississippi River.

8.2.6 Episode Selection

The entire 2002 base case and 2009 future case years were simulated with 2002 meteorological conditions for $PM_{2.5}$ modeling. This complete year of modeling provides a more robust analysis of the seasonal variations in $PM_{2.5}$ levels due to secondary aerosol formation, an important pathway to understanding the transport of particulate matter from out-of-state sources.

8.2.7 Emissions Inventory Development and Processing

Significant regional coordination was required to assemble the emission inventories needed to produce the emission data fields required for the modeling analysis. Recognizing the need for developing multipollutant inventories across many states to support fine-particulate, ozone and regional haze SIP modeling requirements, the Northeast and Mid-Atlantic states agreed to combine efforts under the MANE-VU RPO umbrella to compile base year and future year emission estimates for all required pollutants into a common format. MARAMA, OTC and NESCAUM joined the states in the inventory development effort.

Modeling inventories for the MANE-VU region were prepared, with the assistance of contractors, for the 2002 base year and the projection years of 2009, 2012 and 2018. The base year inventory was compiled using 2002 inventory estimates provided by the states. Projection year inventories account for any expected changes in economic activity as well the implementation of control strategies occurring after 2002. Inventories for adjacent areas outside the MANE-VU region were obtained from the corresponding RPOs.

Section 5 provides information regarding the development of the MANE-VU inventories. Included are tables and figures summarizing annual emission estimates of $PM_{2.5}$-contributing pollutants from Connecticut sources for 2002, 2009 and 2012. Section 4 and Section 5 provide descriptions of control strategies simulated in the CMAQ modeling effort. More detailed descriptions of the inventory development process are provided in Appendices 5A through 5D, and Appendix 8D (TSD-4).

Version 2.1 of the Sparse Matrix Operator Kernel Emissions (SMOKE) Processing System was selected to convert MANE-VU annual county emission estimates for each year into CMAQ-ready modeling inputs. The SMOKE model contains routines that apply pollutant speciation profiles and allocate annual county-level emissions from the regional inventory to CMAQ model grid cells on an hourly basis. The MANE-VU inventories were processed by the NYSDEC, Virginia Department of Environmental Quality and NESCAUM. Descriptions of the SMOKE processing are included in Appendices 8D (TSD-2a and 2b), 8F and 8G.

[6] Baker, K. Model Performance for Ozone in the Upper Midwest over 3 Summers. Presentation given at the Lake Michigan Air Directors Consortium, 2005 AWMA Annual Conference, Minneapolis, MN, June 24, 2005.

8.2.8 Quality Assurance

All air quality, emissions, and meteorological data for the MANE-VU region were reviewed to ensure completeness, accuracy, and consistency before proceeding with modeling. Any errors, missing data or inconsistencies were addressed using appropriate methods that are consistent with standard practices. All modeling was benchmarked at each of the OTC modeling centers through the duplication of a set of standard modeling results.

Quality assurance activities were carried out for the various emissions, meteorological, and photochemical modeling components of the modeling study. Emissions inventories obtained from the RPOs were examined to check for errors in the emissions estimates. When such errors were discovered, the problems in the input data files were corrected.

The MM5 meteorological and CMAQ air quality model inputs and outputs were plotted and examined to ensure sufficiently accurate representation of the observed data in the model-ready fields, and temporal and spatial consistency and reasonableness. Both MM5 and CMAQ underwent operational and scientific evaluations in order to facilitate the quality assurance review of the meteorological and air quality modeling procedures.

8.3 Model Performance Evaluation[7]

An important first step in the modeling process is to verify the model's performance in terms of its ability to predict $PM_{2.5}$ and its individual components (i.e., sulfate, nitrate, ammonium, organic carbon, elemental carbon and other constituents) in the right locations and concentrations. To do this, model predictions for the base year simulation are compared to corresponding measured ambient data. This verification is accomplished through a combination of statistical and graphical evaluations. If the model appears to be producing $PM_{2.5}$ in the right locations for the right reasons, then the model can be used with greater confidence as a predictive tool to evaluate various control strategies and their effects on future $PM_{2.5}$ levels. The following subsections describe a performance evaluation conducted for the CMAQ modeling system used to project future $PM_{2.5}$ levels in the Northeast.

8.3.1 Overview

The results of a model performance evaluation were examined prior to commencing modeling in support of the attainment demonstration. EPA has included general recommendations for conducting model performance evaluations in recent modeling guidance.[8] The NYSDEC, Division of Air Resources, conducted a performance evaluation of the 2002 base case CMAQ simulation on behalf of the Ozone Transport Region member States. The performance of CMAQ was evaluated using both operational and diagnostic methods. Operational evaluation refers to the model's ability to replicate observed concentrations of particulate matter and/or its precursors (surface and aloft), whereas diagnostic evaluation assesses the model's accuracy with respect to characterizing the sensitivity of particulate formation to changes in emissions (i.e.,

[7] The following CMAQ model performance discussion is paraphrased from the draft Maryland $PM_{2.5}$ SIP, as posted at http://www.mde.state.md.us/assets/document/Air/BNAA_3-24-08/BNAA_PM_SIP.pdf (Section 9.3).

[8] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"; EPA-454/B-07-002; April 2007; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

relative response factors). Appendix 8-H provides comprehensive operational and diagnostic evaluation results. Highlights of this evaluation are provided in Section 8.3.2.

8.3.2 Diagnostic and Operational Evaluation

The issue of model performance goals for $PM_{2.5}$ is an area of ongoing research and debate. To evaluate model performance, EPA recommends that several statistical metrics be developed for air quality modeling. Performance goals refer to targets that a good performing model should achieve, whereas performance benchmarks are based on historical model performance measures for the best performing simulations. Performance goals are necessary in order to provide consistency in model applications and expectations across the country and to provide standardization in how much weight may be accorded to modeling study results in the decision-making process.

When EPA's guidance was first developed nearly four (4) years ago, an interim set of fine particulate modeling performance goals were suggested for aggregated mean normalized gross error (MNGE) and mean normalized bias (MNB) as defined in Table 8-1. The MNGE parameter provides an overall assessment of model performance and can be interpreted as precision. The MNB parameter measures a model's ability to reproduce observed spatial and temporal patterns and can be interpreted as accuracy.

Table 8-1. Interim EPA $PM_{2.5}$ Modeling Performance Goals

Pollutant	Gross Error	Normalized Bias
$PM_{2.5}$	~ +30 - +50%	~ +10%
Sulfate	~ +30 - +50%	~ -20 - -30%
Nitrate	~ +20 - +70%	~ -15 - +50%
EC	~ +15 - +60%	NA
OC	~ -40 - +50%	~ +38%

Because regional-scale $PM_{2.5}$ modeling is an evolving science, and considerable practical application and performance testing has transpired in the intervening years since these goals were postulated, they are considered as general guidelines.

It may also be possible to adopt levels of model performance goals for mean fractional bias (MFB) and mean fractional gross error (MFGE) as listed in Table 8-2 (developed by the VISTAS RPO) to help evaluate model performance.[9]

[9] For an explanation of these statistical parameters, see Section 18.4.2 of "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"; EPA-454/B-07-002; April 2007; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

Table 8-2. VISTAS RPO $PM_{2.5}$ Modeling Performance Goals

Fractional Error	Fractional Bias	Comment
≤35%	≤±15%	Ozone model performance goal for which $PM_{2.5}$ model performance would be considered good.
≤50%	≤±30%	A level of model performance that we would hope each $PM_{2.5}$ species could meet.
≤75%	≤±60%	At or above this level of performance indicates fundamental problems with the modeling system.

The above performance goals are considered to be reasonable methods for assessing model performance; therefore, they are being used to frame and put the $PM_{2.5}$ model performance into context and to facilitate model performance across episodes, species, models and sensitivity tests.

As noted in EPA's $PM_{2.5}$ modeling guidance,[10] less abundant $PM_{2.5}$ species should have less stringent performance goals. Accordingly, performance goals that are a continuous function of average observed concentrations, such as those proposed by Dr. James Boylan at the Georgia Department of Natural Resources, may be appropriate:

- Asymptotically approaching proposed performance goals or criteria when the mean of the observed concentrations are greater than 2.5 ug/m^3.
- Approaching 200% error and ±200% bias when the mean of the observed concentrations are extremely small.

The preceding goals and criteria are not regarded as a pass/fail test, but rather as a basis of inter-comparing model performance across studies, sensitivity tests and models.

The OTC model performance evaluation was initially conducted by NYSDEC using the 2002 summer ozone season data only. The Virginia Department of Environmental Quality extended the evaluation to include observations from the entire year of 2002. Four statistical parameters, two suggested by EPA (Table 8-1) and two adopted by the VISTAS RPO (Table 8-2), were computed for FRM $PM_{2.5}$ mass and for individual species of SO_4, NO_3, NH_4, EC, OM (1.8* blank-corrected OC), soil or crustal material (sum of oxides of Ca, Fe, Si, and Ti). The statistics were organized into two categories: a) by date and b) by site.

For statistics by date, the parameters were calculated on a given day for any valid pairs of observed/predicted data across all FRM and speciation monitors that fall within the OTR modeling domain plus all Virginia monitors (referred to as OTR+). Data collected from three different monitoring networks, FRM, STN, and IMPROVE, were used in the statistics. Note that predicted data used for the model performance evaluation were extracted from CMAQ outputs at the exact grid cells where monitors are located. This is in contrast to the modeled design value calculations where predictions are based on the average of the surrounding nine grid cells.

[10] Ibid.

For statistics by site, parameters were computed at a given FRM, STN, or IMPROVE monitor for any valid pairs of observed/predicted data over a period of the entire 2002 calendar year, except for the dates between July 6 and July 9 due to the exceptional event caused by the Quebec forest fires.

Figure 8-2 depicts the location of the FRM, STN and IMPROVE monitor locations used for the model evaluation across the OTR+ region.

A composite FRM time series across the OTR+ region (264 monitors) is provided in Figure 8-3. This figure indicates that there is an overall mean bias of approximately 4 $\mu g/m^3$. There is a general over-prediction during the winter months and an under-prediction during the summer months. There is excellent agreement during a mid-August poor air quality episode.

Figure 8-2. Locations Used for the Model Evaluation Across the OTR+ Region FRM (●, 264 sites), STN (■, 50 sites), AND IMPROVE (▲, 21 sites)

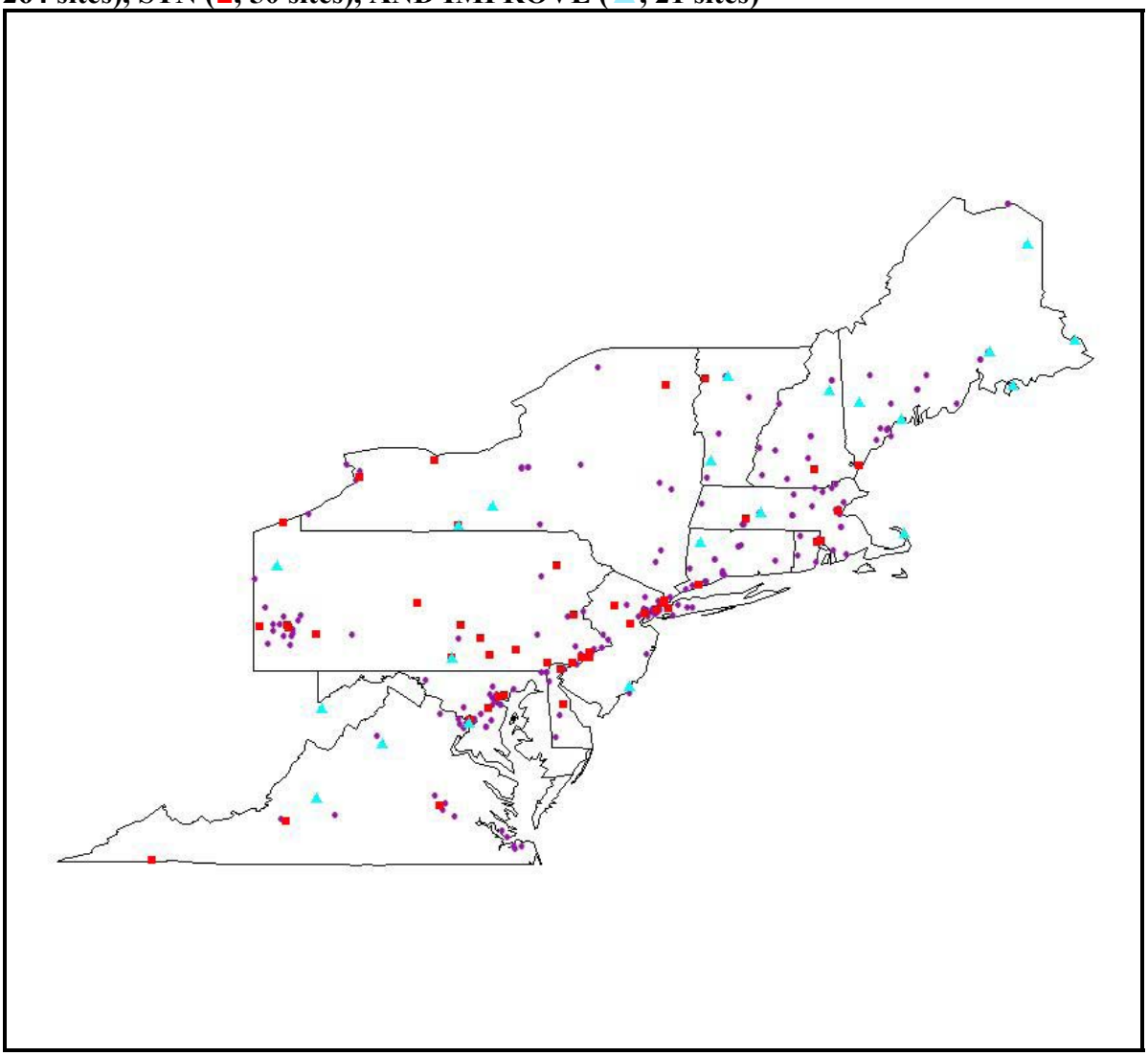


Figure 8-3. Composite FRM Time Series Across the OTR+ Region (264 Monitors)

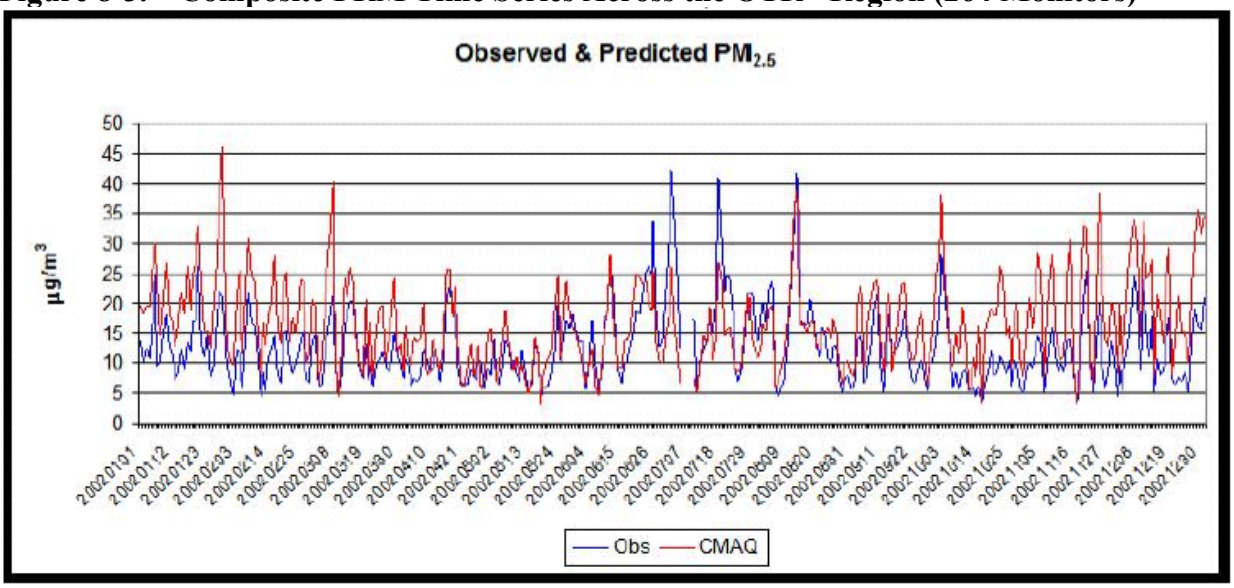
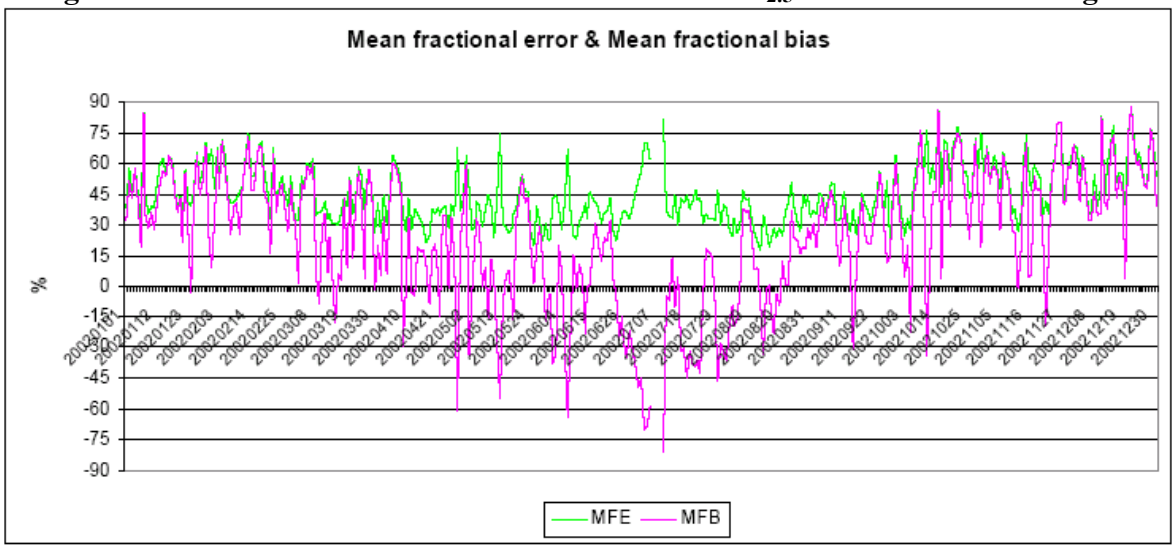


Figure 8-4 is a plot of both MFE and MFB for FRM sites across the OTR+ region. The MFE ranges from 17% to 88% with an average of approximately 45%. The MFB ranges from -82% to +88% with an average of approximately +24%. These values are generally consistent with similar studies listed in the EPA's modeling guidance.[11]

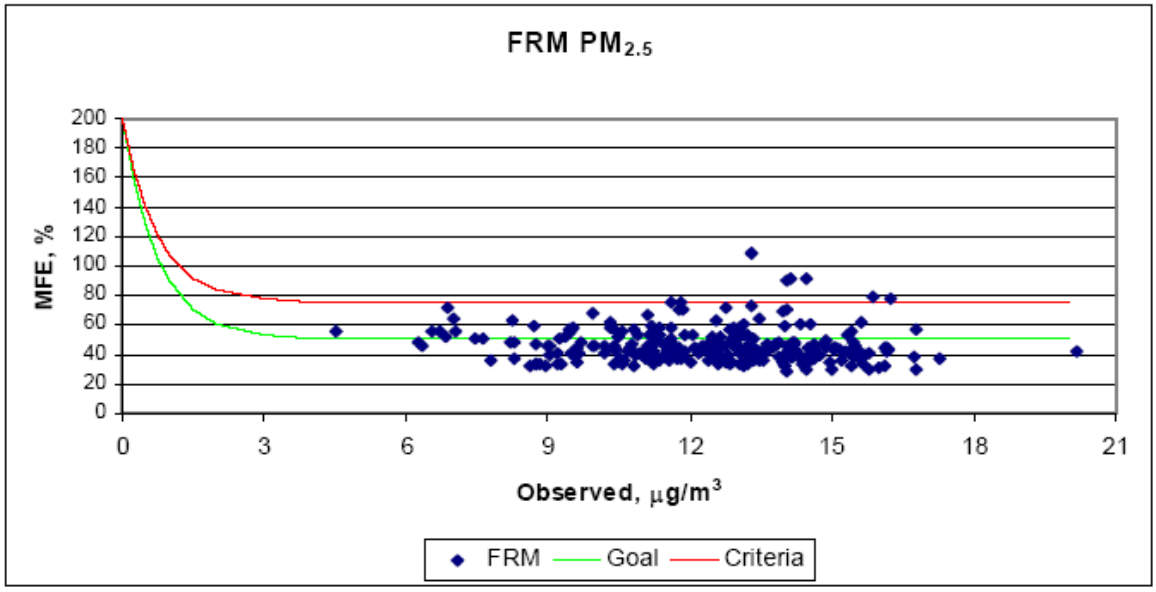
Figure 8-4. MFE and MFB Time Series for FRM $PM_{2.5}$ Across the OTR+ Region



[11] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"; EPA-454/B-07-002; April 2007; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

An MFE "bugle" plot for FRM $PM_{2.5}$ across OTR+ region is provided in Figure 8-5. "Goal" curves are the best a model can be expected to achieve while the "criteria" curves are considered acceptable for model performance. The "criteria restriction" is satisfied at 258 of 264 sites on an annual average basis.

Figure 8-5. MFE Bugle Plot for FRM $PM_{2.5}$ Across the OTR+ Region



MFE bugle plots were also generated for SO_4, NO_3, and NH_4, EC, OM, and soil/crustal across OTR+ region and are provided in Figures 8-6 through 8-11. As can be seen from the results, the performance for individual species is generally consistent with the criteria necessary for acceptable model performance.

Figure 8-6. MFE Bugle Plot for SO_4 Across the OTR+ Region

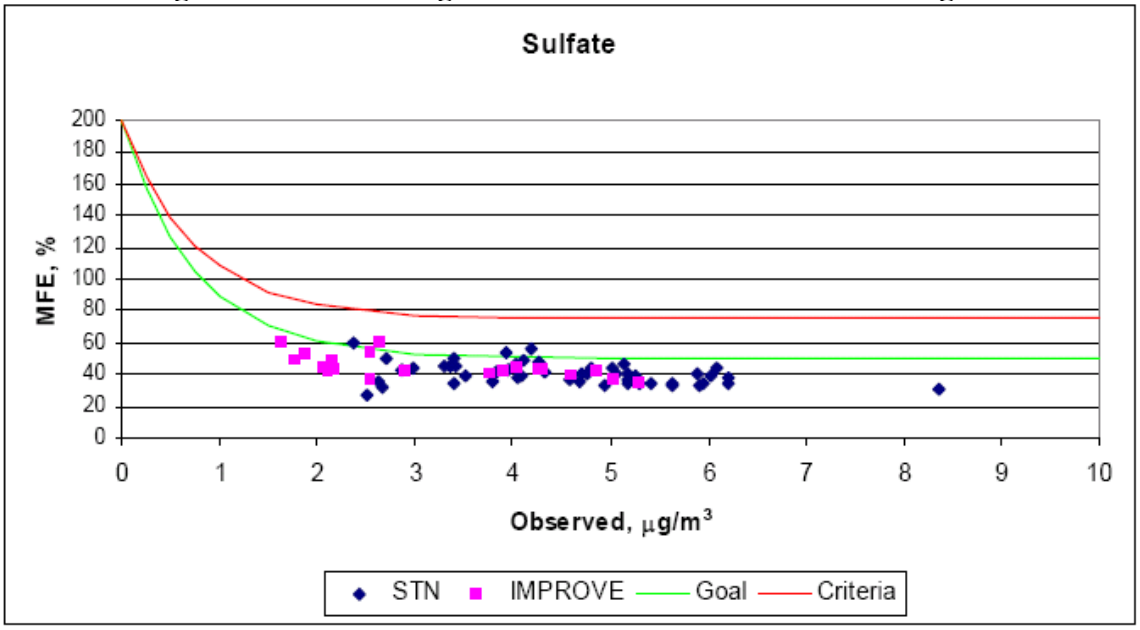


Figure 8-7. MFE Bugle Plot for NO_3 Across the OTR+ Region

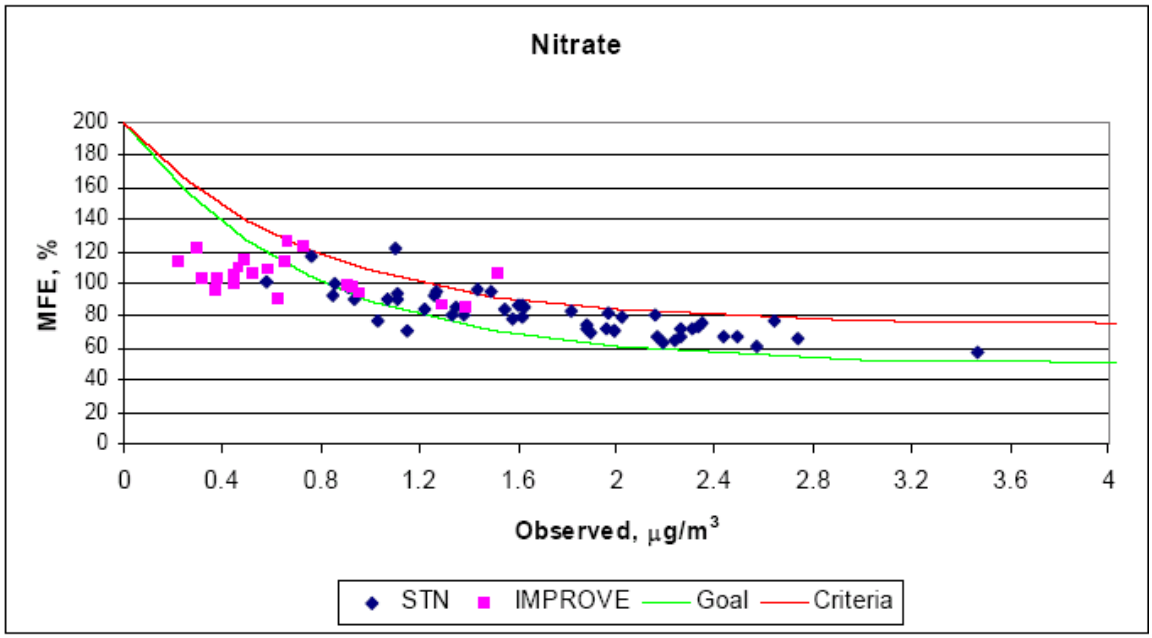


Figure 8-8. MFE Bugle Plot for NH_4 Across the OTR+ Region

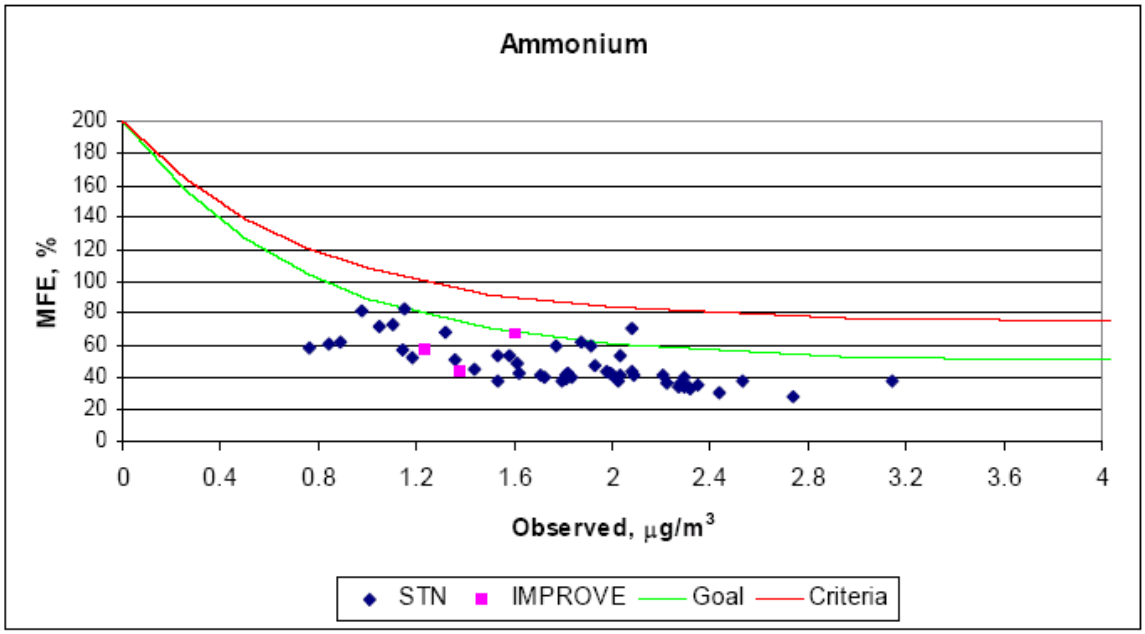


Figure 8-9. MFE Bugle Plot for EC Across the OTR+ Region

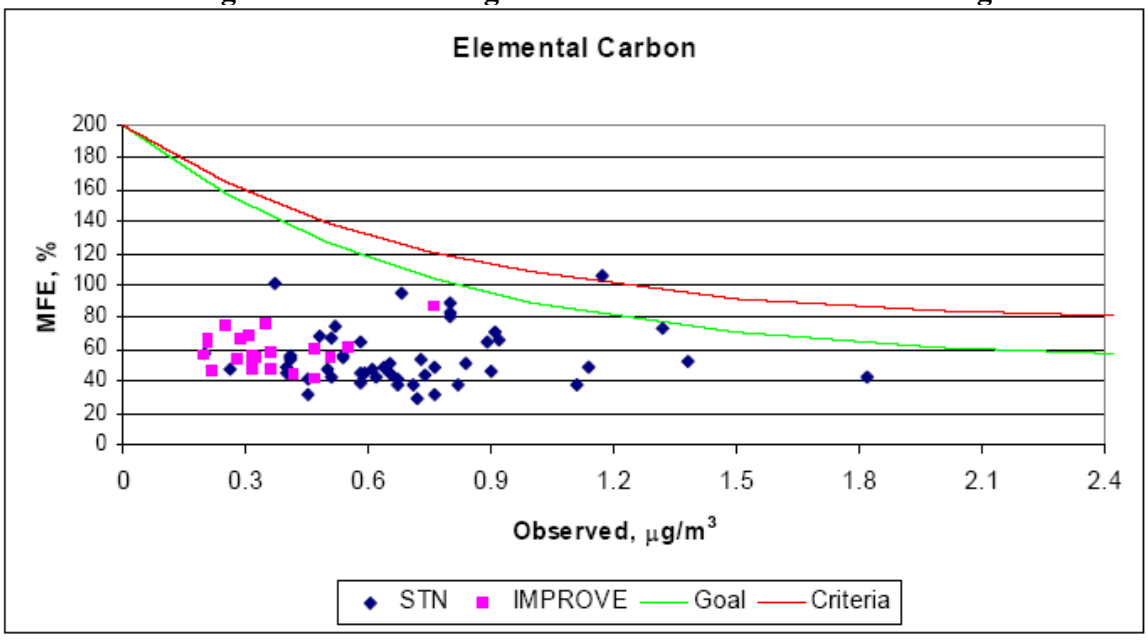


Figure 8-10. MFE Bugle Plot for OM Across the OTR+ Region

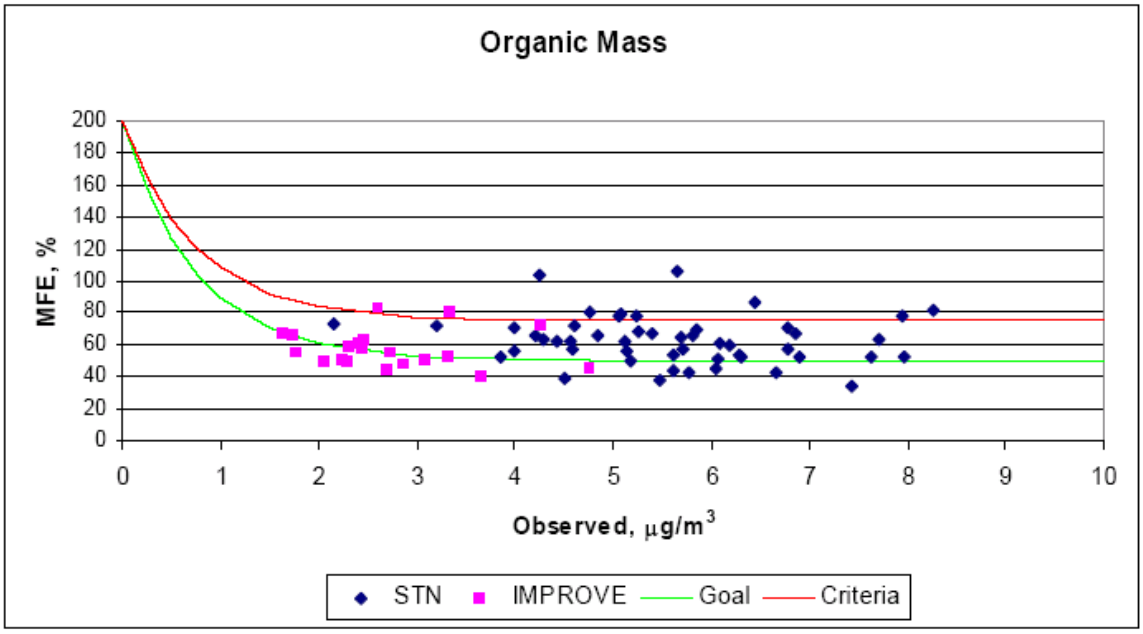
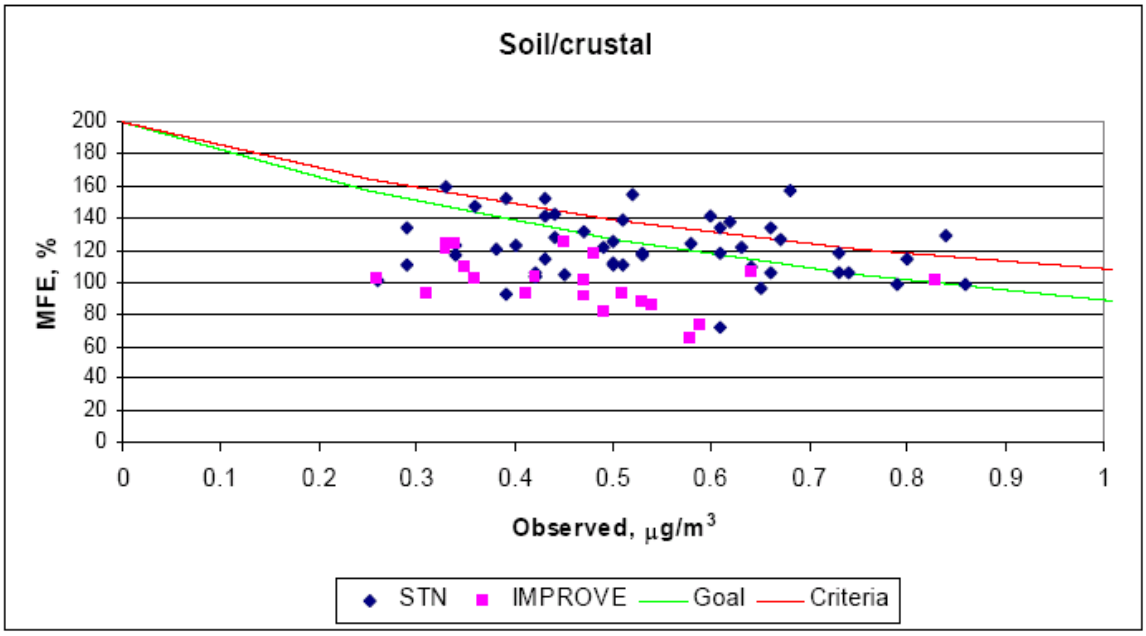


Figure 8-11. MFE Bugle Plot for Soil/Crustal Across the OTR+ Region



The plots show that concentration-dependent performance goals for sulfate, ammonium, and elemental carbon are easily met. Concentration-dependent performance criteria for nitrate, organic mass, and soil/crustal material are met at nearly all IMPROVE sites and most STN sites.

8.3.3 Summary of Model Performance

CMAQ was employed to simulate $PM_{2.5}$ for the calendar year 2002. A review of $PM_{2.5}$ and its individual species was conducted for the study domain.

The CMAQ model performance for surface $PM_{2.5}$ is good with acceptable bias and error. Several observations can be made with respect to model performance, including the following:

1. Organic matter (OM) is comprised of primary and secondary components. Approximately 80-90% of CMAQ calculated OM consists of primary OM. Observed OM has a distinct maximum during the summer when secondary formation is highest; CMAQ exhibits substantial under-prediction of secondary organic aerosol (SOA) formation.
2. CMAQ captures seasonal variation in SO_4 well.
3. CMAQ appears to overestimate primary $PM_{2.5}$ components (EC, soil, primary OM), especially during colder months.
4. CMAQ appears to underestimate secondary OM during the summer.

Seasonal biases in the CMAQ calculated $PM_{2.5}$ component concentrations are not of great regulatory concern since attainment tests are based on the application of relative response factors to observed concentrations. As described in Section 8.4, the largest overall changes in any $PM_{2.5}$ species between 2002 and 2009 are projected to occur in sulfate, the species for which CMAQ performs at its best. Most other species show relatively more modest improvements in fine particle concentrations between 2002 and 2009. CMAQ's performance is poorest for soil/crustal material and organic matter. The poor performance for soil/crustal material is only a minor concern since soil/crustal material comprises on the order of 5% of total $PM_{2.5}$ mass measured in the Northeast region.

The underestimation of summertime organic matter concentrations by CMAQ is of more concern since organic matter is an important part of the $PM_{2.5}$ budget at some Northeast locations. Much of the bias is likely due to an underestimation of secondary organic aerosols, most of which have a biogenic source. Since changes in biogenic emissions are expected to be small over the next decade, CMAQ-calculated relative response factors for organic matter are not crucial. In addition, following EPA guidance, the impact of this bias is minimized by normalizing model predicted changes in organic matter by observed $PM_{2.5}$ partitioning.

While there are some differences between the spatial data between sub-regions, there is nothing to suggest a tendency for the model to respond in a systematically different manner between regions. Examination of the statistical metrics by sub-region confirms the absence of significant performance problems arising in one area but not in another, building confidence that the CMAQ modeling system is operating consistently across the full OTC domain.

In summary, CMAQ's $PM_{2.5}$ model performance is determined to be acceptable for this modeling demonstration. Biases in CMAQ and the inventories used in the model are such that the calculated future design values are likely to be somewhat higher than they would be in reality, providing additional confidence in conclusions of the attainment demonstration.

8.4 Attainment Demonstration Modeling

The CMAQ regional photochemical modeling system was used to develop projections of $PM_{2.5}$ design values for 2009, the last full calendar year before the required April 2010 attainment deadline. The EPA recommends[12] using regional photochemical model estimates in a "relative" rather than "absolute" sense, with a goal of minimizing uncertainties and biases in the modeling system. This was accomplished by running CMAQ for baseline year (i.e., 2002) and future year (i.e., 2009) emission scenarios, both using 2002 meteorology data. The "absolute" modeled results from each of these runs were then used to develop ratios, or "relative response factors" (RRF), for each monitor location, representing the "relative" improvement expected near[13] each monitor between 2002 and 2009 due to implemented control programs. Finally, the RRF's developed for each monitor were multiplied by representative baseline period design values to calculate projected 2009 $PM_{2.5}$ design values for comparison to the NAAQS.[14] These steps are described in more detail below.

8.4.1 Baseline $PM_{2.5}$ Design Values

In accordance with EPA's guidance,[15] the baseline design values used in the modeling application were calculated differently than the measured design values used for NAAQS designation purposes, although both are based on monitored quarterly averages of ambient air quality data. Design values used for $PM_{2.5}$ NAAQS designations were calculated using the average of the three annual average $PM_{2.5}$ values recorded over the 2002 through 2004 period at each monitor. For modeling purposes, the baseline design value is calculated by averaging three, three-year annual average design values, centered on the baseline inventory year of 2002. In other words, the modeling baseline design value for each monitor was calculated using the average of the 2000-2002, 2001-2003, and 2002-2004 annual average design values. Therefore, the baseline design value used in the modeling is actually a five-year weighted average, with the greatest weight given to the baseline inventory year of 2002.

Table 8-3 lists the baseline design values used for the modeling, developed from quarterly averages at each FRM site across the NY-NJ-CT annual $PM_{2.5}$ nonattainment.[16] Baseline values exceeded the annual PM $_{2.5}$ NAAQS at seven sites in the nonattainment area, five in New York and two in New Jersey. Baseline values for all Connecticut monitors comply with the annual $PM_{2.5}$ NAAQS. Further explanation of how these values were calculated is provided in Appendix 8D (TSD-5).

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[12] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"; EPA-454/B-07-002; April 2007; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

[13] "Near" was determined by using an average of the concentration predicted within a 3x3 array of grid cells surrounding each monitor, as recommended by the USEPA for 12-km grid resolution modeling.

[14] Note that this process was actually carried out separately for each $PM_{2.5}$ species, then summed to determine total $PM_{2.5}$ mass. See the remainder of Section 8.4 for details.

[15] See footnote 12, above.

[16] Note that one monitor – PS 59 (360610056) in Manhattan – recorded an anomalously high average concentration of 25.2 $\mu g/m^3$ during the third quarter of 2003. Examination of the data by the NYSDEC revealed that there were only five valid data points recorded at the beginning of the quarter, with the monitor subsequently shut down because of construction activity at the site. Because the limited data are not representative of air quality over the entire quarter, data for the 3rd quarter of 2003 was treated as missing when calculating the baseline design value for this site in Table 8-3. Appendix 8D (see Attachment 1 of TSD-5) provides a more detailed analysis of this particular issue.

Table 8-3. NY-NJ-CT Nonattainment Area Baseline Annual $PM_{2.5}$ Design Values Used for Modeling Purposes and the Nearest STN Monitor to Each FRM Monitor

FRM Site ID	FRM Monitoring Site Name	State	Baseline Design Value (DV_B) ($\mu g/m^3$)	Nearest STN Monitor
90010010	Bridgeport - Roosevelt School	CT	13.1	090019003
90010113	Bridgeport - Congress Street	CT	12.6	090019003
90011123	Danbury	CT	12.8	090019003
90012124	Stamford	CT	12.9	090019003
90013005	Norwalk	CT	12.9	090019003
90019003	Westport	CT	11.8	090019003
90091123	New Haven- 715 State St	CT	13.7	090091123
90092123	Waterbury	CT	13.1	090091123
90099005	Hamden	CT	11.6	090091123
340030003	Fort Lee Library	NJ	13.7	360050110
340171003	Jersey City Primary	NJ	14.9	360610062
340172002	Union City	NJ	**16.0**	360610062
340210008	Trenton	NJ	13.9	340230006
340218001	Washington Crossing	NJ	11.9	340230006
340230006	New Brunswick	NJ	12.5	340230006
340270004	Morristown	NJ	12.4	340273001
340273001	Chester	NJ	11.1	340273001
340310005	Paterson	NJ	13.2	360050083
340390004	Elizabeth	NJ	**15.7**	340390004
340390006	Elizabeth Downtown	NJ	13.5	340390004
340392003	Rahway	NJ	13.1	340390004
360050080	Morrisania Center -Gerard Ave.	NY	**15.8**	360050110
360050083	Botanical Gardens	NY	13.8	360050083
360050110	IS 52 East 156 Street	NY	14.7	360050110
360470052	PS 314-60th St and GawanusExp.	NY	**15.1**	360610062
360470076	PS 321- 180 7th Ave.	NY	14.2	360610062
360470122	JHS 126 424 Leonard St	NY	14.8	360610062
360590008	Hempstead, Nassau County	NY	12.2	360810124
360610056	PS 59, 288 E. 57th St., Manhattan	NY	**16.9**	360610062
360610062	Post Office, 350 Canal St.	NY	**16.3**	360610062
360610079	School IS 45, 2351 1st Ave.	NY	14.7	360050110
360610128	PS 19, 185 1st Avenue	NY	**15.9**	360610062
360710002	NYC- 55 Broadway	NY	11.5	090019003
360810124	NYC- 14439 Gravett Road	NY	13.3	360810124
360850055	Post Office, 364 Port Richmond	NY	14.0	340390004
360850067	Susan Wagner	NY	12.1	340390004
361030001	East Farmingdale Water Plant	NY	12.1	360810124
361191002	5th Avenue & Madison, Thruway Exit 9	NY	12.3	360050083

Note: Baseline values greater than the annual average NAAQS of 15.0 $\mu g/m^3$ are in **bold**.

8.4.2 Baseline Species Concentrations

The next step in the modeled attainment test is to determine the baseline species composition at each FRM monitor, based on measured species data. The $PM_{2.5}$ species composition is highly complex, but if the goal of air quality management decisions is to reduce $PM_{2.5}$, it is necessary to know the dominant chemical species. Nine of the FRM monitor sites in the NY-NJ-CT nonattainment area are collocated with Speciation Trends Network (STN) monitors that collect major ions, including sulfate (SO_4), nitrate (NO_3), and ammonium (NH_4); carbon species, including elemental carbon (EC) and organic carbon (OC); and about 50 trace elements. Four of the STN sites are located in the New York portion of the nonattainment area, three in the New Jersey portion and two in the Connecticut portion.

At sites where both STN and FRM data are available, total FRM mass can be directly related to the mass of individual species, as measured at the corresponding STN site. At those FRM sites that do not have a collocated STN monitor, it can reasonably be assumed that the speciation data from the nearest STN monitor is sufficient to characterize the FRM site. Table 8-3 lists the nearest STN site that was associated with the FTM site for computing baseline species concentrations.

It is known that FRM monitor filters do not retain semi-volatile species such as ammonium nitrate and some organics with high efficiency, especially during the warmer months. Hence, one cannot simply add up the major species from the STN monitor and expect to relate this identically to the total mass from the FRM monitor. It is necessary to adjust some of the STN data to estimate the species composition of mass measured by the FRM monitor. According to the modeling guidance[17] the mass from the FRM monitor can be expressed as:

$PM_{2.5}$ = "retained nitrate mass" + "ammoniated sulfate mass" + "ammonium associated with sulfate and retained nitrate" + "particle-bound water" + "other primary $PM_{2.5}$" + "blank mass" + "carbonaceous mass" [Eq. 1]

where $PM_{2.5}$ refers to the total mass measured at each FRM site; "retained nitrate mass" and "ammonium associated with sulfate and retained nitrate" refer only to the fractions of NO_3 and NH_4, respectively, that are not volatilized; "ammoniated sulfate mass" refers to the SO_4 that is measured by the STN; "particle-bound water" refers to water that is associated with the hygroscopic ammonium sulfate and nitrate, and can be estimated as a polynomial function of retained ammonium, sulfate, and nitrate; "other primary $PM_{2.5}$" refers to unspeciated, inert $PM_{2.5}$ such as soil/crustal elements (here assumed to be the sum of major crustal oxides – Si, Ca, Fe, and Ti); "blank mass" refers to passively collected contamination, assumed to be 0.5 $\mu g/m^3$; and "carbonaceous mass" refers to elemental carbon (EC) and an estimate of retained organic carbon (OC). Because of uncertainties in the measured OC, the modeling guidance suggests that organic mass be computed as the difference between the measured FRM mass and the sum of the other species listed above.

[17] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"; EPA-454/B-07-002; April 2007; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

NYSDEC used EPA's official Air Quality System (AQS) database of STN data to compute the baseline species concentrations at each FRM site in the NY-NJ-CT nonattainment area for the period 2002-2004. This database also includes the adjusted speciation data needed to compute the various retained species. A separate calculation of the quantity of the component species was performed for each of the $PM_{2.5}$ components listed in Equation #1 (except blank mass) for each FRM monitoring site. This calculation applied the same ratio of each species collected from the "nearest" STN site, to the total $PM_{2.5}$ mass measured at the FRM site. Each of these site-specific ratios is called a "component-specific design value". EPA modeling guidance procedures[18] were used to carry out the calculations, including procedures for estimating retained NH_4, particle-bound water and other primary $PM_{2.5}$.

8.4.3 Relative Response Factors

As stated in the introduction to Section 8.4, EPA recommends that air quality modeling results be used in a relative sense to compute future $PM_{2.5}$ design values. This is accomplished by applying what EPA's guidance calls the "speciated modeled attainment test" (SMAT), as described below.

For each species *i*, the future concentration of each species (DV_{Fi}) was calculated as the product of the baseline concentration (DV_{Bi}) and the corresponding RRF_i:

$$DV_{Fi} = DV_{Bi} \times RRF_i \qquad \text{[Eq. 2]}$$

For each quarter and species, the quarterly average concentration for the base and future year simulations was computed. The RRF is the ratio of the quarterly average future-to-base year modeled values for the species of interest. For each FRM site, the concentrations of the nine grid cells surrounding the FRM site were averaged.

RRF values were based on the application of the CMAQ model for 2002 and 2009. Future $PM_{2.5}$ design values were estimated at each existing FRM monitoring site by multiplying the component-specific modeled RRF "near" each monitor times the observed component-specific design value. EPA procedures[19] were used for calculations, including the assumption that the blank concentration of 0.5 $\mu g/m^3$ remains constant in the future year. Future total $PM_{2.5}$ design values at a site were then estimated by summing the future year design values of the seven $PM_{2.5}$ components.

8.4.4 Future $PM_{2.5}$ Design Values

Table 8-4 summarizes the results of applying the SMAT at each FRM site in the NY-NJ-CT nonattainment area, listing both the measured baseline and modeled future (i.e., 2009) design values for each FRM site. Figure 8-12 shows a mapped representation of the 2009 modeled design values.

[18] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze"; EPA-454/B-07-002; April 2007; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.
[19] Ibid.

Table 8-4. Baseline and Modeled Future (2009) Annual $PM_{2.5}$ Design Values for the NY-NJ-CT Nonattainment Area

FRM Site ID	FRM Monitoring Site Name	State	Baseline Design Value (DV_B) ($\mu g/m^3$)	2009 Modeled Design Value (DV_F) ($\mu g/m^3$)
90010010	Bridgeport - Roosevelt School	CT	13.1	11.5
90010113	Bridgeport - Congress Street	CT	12.6	11.2
90011123	Danbury	CT	12.8	11.2
90012124	Stamford	CT	12.9	11.4
90013005	Norwalk	CT	12.9	11.3
90019003	Westport	CT	11.8	10.4
90091123	New Haven- 715 State St	CT	13.7	11.7
90092123	Waterbury	CT	13.1	11.2
90099005	Hamden	CT	11.6	9.9
340030003	Fort Lee Library	NJ	13.7	12.1
340171003	Jersey City Primary	NJ	14.9	13.3
340172002	Union City	NJ	**16.0**	14.3
340210008	Trenton	NJ	13.9	11.8
340218001	Washington Crossing	NJ	11.9	10.1
340230006	New Brunswick	NJ	12.5	10.4
340270004	Morristown	NJ	12.4	10.4
340273001	Chester	NJ	11.1	9.3
340310005	Paterson	NJ	13.2	11.4
340390004	Elizabeth	NJ	**15.7**	13.5
340390006	Elizabeth Downtown	NJ	13.5	11.8
340392003	Rahway	NJ	13.1	11.4
360050080	Morrisania Center -Gerard Ave.	NY	**15.8**	14.2
360050083	Botanical Gardens	NY	13.8	12.4
360050110	IS 52 East 156 Street	NY	14.7	13.3
360470052	PS 314-60th St and GawanusExp.	NY	**15.1**	13.6
360470076	PS 321- 180 7th Ave.	NY	14.2	12.8
360470122	JHS 126 424 Leonard St	NY	14.8	13.3
360590008	Hempstead, Nassau County	NY	12.2	11.0
360610056	PS 59, 288 E. 57th St., Manhattan	NY	**16.9**	**15.3**
360610062	Post Office, 350 Canal St.	NY	**16.3**	14.4
360610079	School IS 45, 2351 1st Ave.	NY	14.7	13.3
360610128	PS 19, 185 1st Avenue	NY	**15.9**	14.3
360710002	NYC- 55 Broadway	NY	11.5	10.3
360810124	NYC- 14439 Gravett Road	NY	13.3	12.1
360850055	Post Office, 364 Port Richmond	NY	14.0	12.3
360850067	Susan Wagner	NY	12.1	10.6
361030001	East Farmingdale Water Plant	NY	12.1	10.7
361191002	5th Avenue & Madison, Thruway Exit 9	NY	12.3	10.9

Note: Values greater than the annual average NAAQS of 15.0 $\mu g/m^3$ are in **bold**.

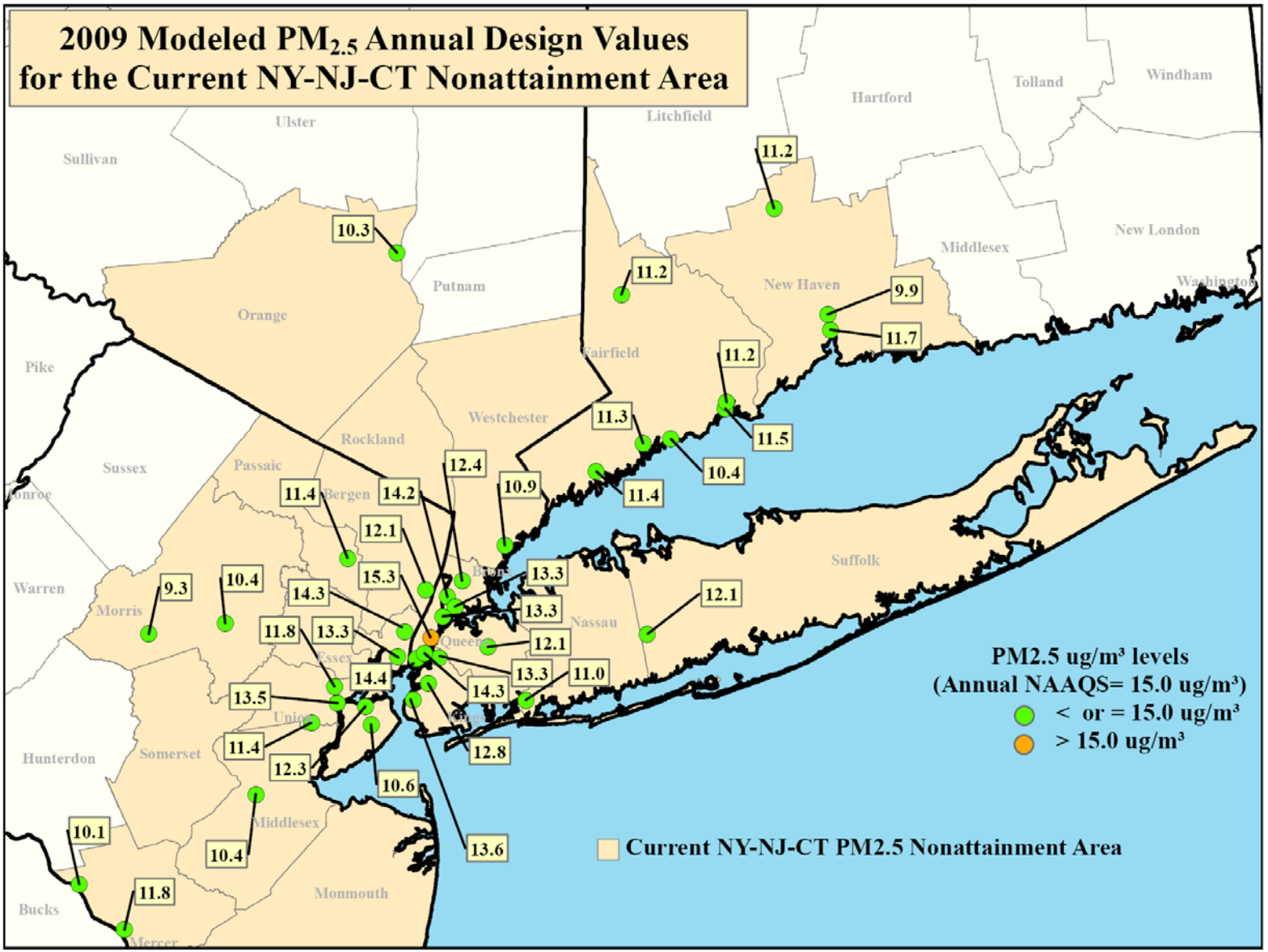


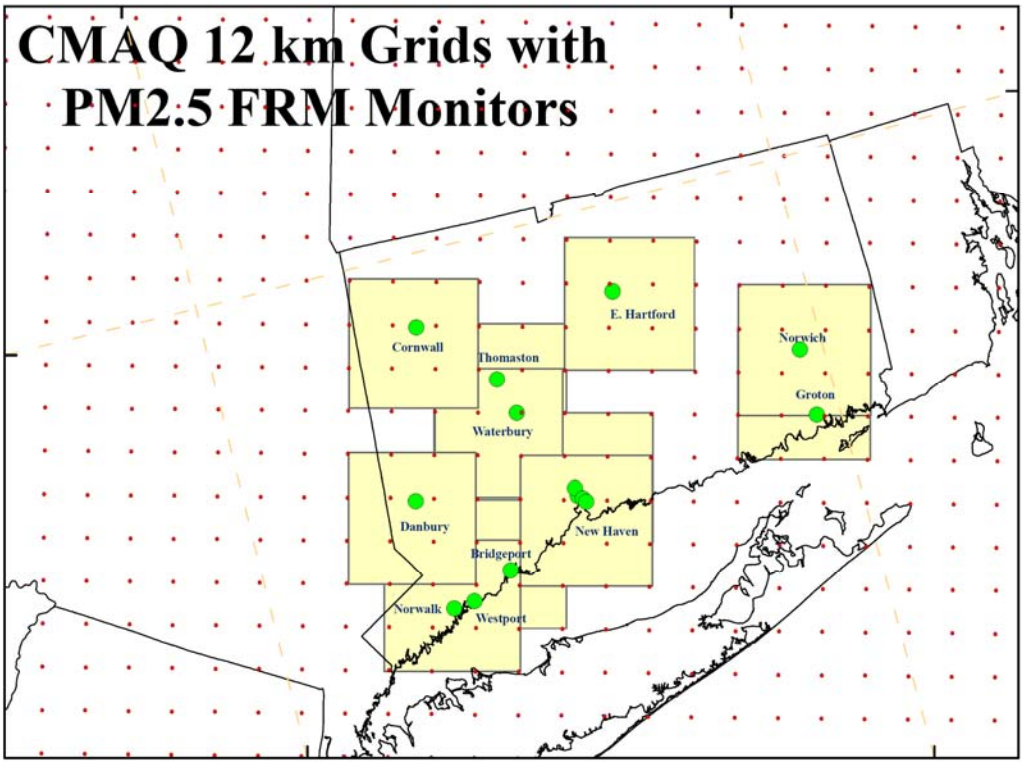
Figure 8-12. Modeled 2009 $PM_{2.5}$ Design Values for the New York- New Jersey- Connecticut Nonattainment Area

As can be seen in the table and figure, the only site with a projected 2009 future design value greater than the annual $PM_{2.5}$ NAAQS of 15.0 ug/m^3 is the PS 59 site located in Manhattan, New York City. The projected 2009 value for the PS 59 site is 15.3 ug/m^3, which is within the weight-of-evidence (WOE) range of 14.5 ug/m^3 to 15.5 ug/m^3, as defined in EPA's $PM_{2.5}$ modeling guidance.[20] All other sites are projected to be in compliance with the NAAQS and below the WOE range of values. As a result, corroboratory WOE analyses are needed to demonstrate attainment at the PS 59 monitor. These WOE analyses, which are provided in Section 8.6**,** support the conclusion that the entire NY-NJ-CT nonattainment area will attain the annual $PM_{2.5}$ NAAQS by the April 2010 deadline.

8.5 Unmonitored Area Analysis

The EPA modeling guidance requires an evaluation to ensure that the modeling effort provides adequate areal coverage such that areas of maximum concentrations are identified. The CTDEP's monitoring network, laid over the 12 kilometer CMAQ modeling grid, is depicted in Figure 8-13. This network of monitors covers the majority of the State when the nine CMAQ modeling grid squares encompassing each of the monitors are considered. More importantly, the densest portion of the network covers virtually all of southwest Connecticut, which is included in the NY-NJ-CT nonattainment area. Thus, the existing monitoring network is adequate to detect high $PM_{2.5}$ levels and further analysis of unmonitored areas is unnecessary.

Figure 8-13. CMAQ Grid Cells Associated With Connecticut's $PM_{2.5}$ Monitors



[20] "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze"; EPA-454/B-07-002; April 2007; Page 17; http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

8.6 Weight-of-Evidence Analyses

By definition, models are simplistic approximations of complex phenomena. It is generally recognized that there is significant uncertainty associated with the results of photochemical grid modeling. In addition to the uncertainties associated with the dispersion and chemical response mechanisms built into the air quality model, the required meteorological, baseline and projected emissions, and air quality input data sets also contain their own levels of uncertainty that can affect the performance of the modeling system. These uncertain aspects of the modeling analyses can sometimes prevent definitive assessments of future attainment status, especially when projected pollutant levels are at levels close to air quality standards.

Due to these uncertainties, modeling results should not be used in a strictly deterministic fashion to determine "bright-line" compliance by comparing projected air quality levels directly with the ozone NAAQS. Modeling is more appropriately used as a probabilistic tool, along with other available assessment techniques, to assess the likelihood of complying with the NAAQS by a certain deadline. Of course, a properly performing model which projects air quality in an area to be well above, or well below, the level of the NAAQS may warrant greater consideration among the mix of available other assessments when determining the likelihood of compliance.

EPA addresses the modeling uncertainty issue in its modeling guidance,[21] recommending that weight-of-evidence (WOE) analyses be performed to better determine the likelihood of NAAQS compliance when the model attainment test results are "inconclusive". For annual $PM_{2.5}$ modeling results, EPA's guidance defines an uncertainty range of 14.5 $\mu g/m^3$ to 15.5 $\mu g/m^3$, with WOE analyses required for any location where future year model projections fall within that range.

As described in Section 8.4 (see Table 8-4), CMAQ modeling projects that all monitors in the NY-NJ-CT nonattainment area, except the PS 59 monitor in New York County (Manhattan), will have annual 2009 $PM_{2.5}$ design values below the modeling uncertainty range; therefore not requiring WOE analysis. For the PS 59 monitor, CMAQ modeling projects a 2009 annual average design value of 15.3 $\mu g/m^3$, which is within the uncertainty range requiring WOE analysis. The remainder of this section presents WOE analyses of monitoring data and describes additional control programs not included in the CMAQ modeling to provide further evidence that the NY-NJ-CT area will achieve attainment of the annual $PM_{2.5}$ NAAQS by the April 2010 deadline. Additional discussions of monitored $PM_{2.5}$ data and trends are provided in Appendix 8D (TSD-3a, TSD-3b and TSD-5).

[21] Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze; EPA OAQPS; EPA-454/B-07-002; April 2007; See page 98 of: http://www.epa.gov/scram001/guidance/guide/final-03-pm-rh-guidance.pdf.

8.6.1 Monitoring Data Show General Downward Trend Towards Timely Attainment

Monitors throughout the NY-NJ-CT nonattainment area have recorded gradual improvements in annual average $PM_{2.5}$ levels over the last several years. Figure 8-14 displays annual $PM_{2.5}$ levels for monitors located in the Connecticut portion of the nonattainment area during the period from 2000 through 2007. $PM_{2.5}$ levels at all relevant sites have consistently been less than the 15.0 $\mu g/m^3$ annual NAAQS, with a general downward trend during the period.

Similar downward trends were recorded at monitoring sites in the New York portion of the nonattainment area over the 2000 to 2007 period, as displayed in Figure 8-15. Five of eight sites recorded $PM_{2.5}$ levels above the annual NAAQS in 2000, with four of twelve sites exceeding the standard in 2007. When simple linear extrapolation of trend lines are applied to the data (see the dashed lines in Figure 8-14), each of the four exceeding monitors are projected to achieve annual average $PM_{2.5}$ levels below the NAAQS by 2008, prior to the required April 2010 attainment date. Note that the PS 59 monitor in Manhattan is one of these sites.

Downward trends in annual average $PM_{2.5}$ levels have also been measured in the New Jersey portion of the nonattainment area over the 2000 to 2007 period, as shown in Figure 8-16. In 2000, five of thirteen monitors recorded annual levels exceeding the $PM_{2.5}$ NAAQS. By 2007, twelve monitors recorded annual values less than the NAAQS, with the other monitor (Union City) recording a value equal to the annual NAAQS of 15.0 $\mu g/m^3$. Linear extrapolation of the Union City trend line (the dashed line in Figure 8-15) projects continued improvement in $PM_{2.5}$ concentrations at that site[22] to levels below the NAAQS.

A continuation of the overall downward trend in annual $PM_{2.5}$ concentration levels is supported by emission projections. As was discussed earlier in Sections 5.3 and 5.4, significant additional reductions in $PM_{2.5}$ and precursor emissions are expected to occur in the nonattainment area through at least 2012. These results reinforce the conclusion that the NY-NJ-CT area will achieve attainment of the annual $PM_{2.5}$ NAAQS by the April 2010 deadline.

8.6.2 NYDEC's WOE Demonstration Suggests Timely Attainment at the PS 59 Site

As described in Section 8.4, the CMAQ modeling results project one monitor in the NY-NJ-CT nonattainment area to exceed the annual $PM_{2.5}$ NAAQS of 15.0 $\mu g/m^3$ in 2009. The PS 59 monitor, located in Manhattan, is projected to have an annual design value of 15.3 $\mu g/m^3$, within the weight-of-evidence range specified by EPA.

The NYDEC has prepared a WOE demonstration[23] for the PS 59 monitor describing factors to be considered when determining whether the site will attain the annual $PM_{2.5}$ NAAQS by the April 2010 deadline. NYDEC's full WOE demonstration is included in Appendix 8D (see Attachments 1 and 2 of TSD-5). A summary of key findings is provided as follows:

[22] Note that the Union City monitor was not in full operation during 2003 and 2004, so the extrapolated trend line in Figure 8-15 is based on the remaining annual average values recorded during the 2000-2007 time period.
[23] The NYDEC WOE demonstration described here is in draft form, subject to change prior to submission by NYDEC to EPA.

Figure 8-14. Trends in Annual $PM_{2.5}$ Levels in the Connecticut Portion of the NY-NJ-CT Nonattainment Area

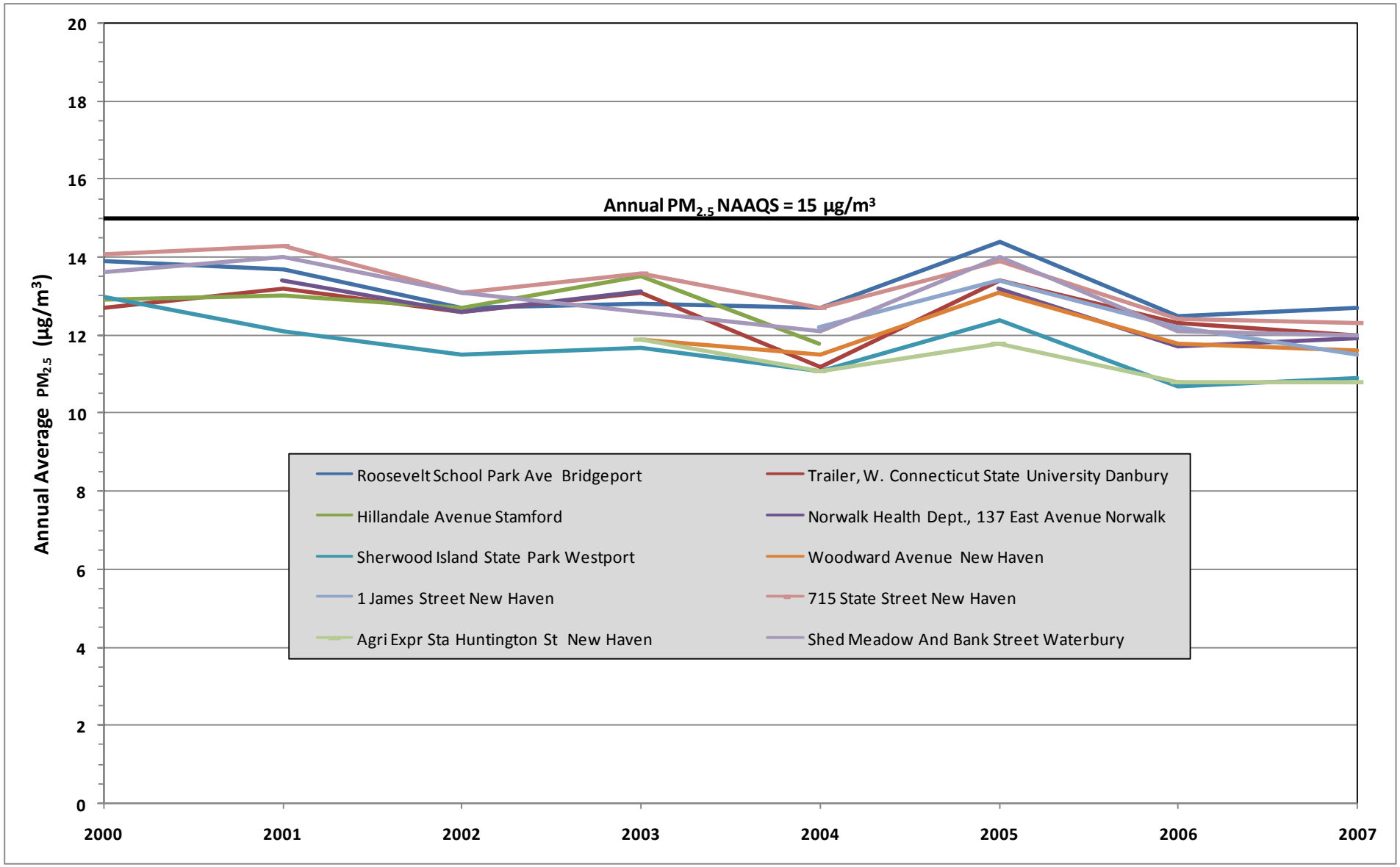


Figure 8-15. Trends in Annual $PM_{2.5}$ Levels in the New York Portion of the NY-NJ-CT Nonattainment Area

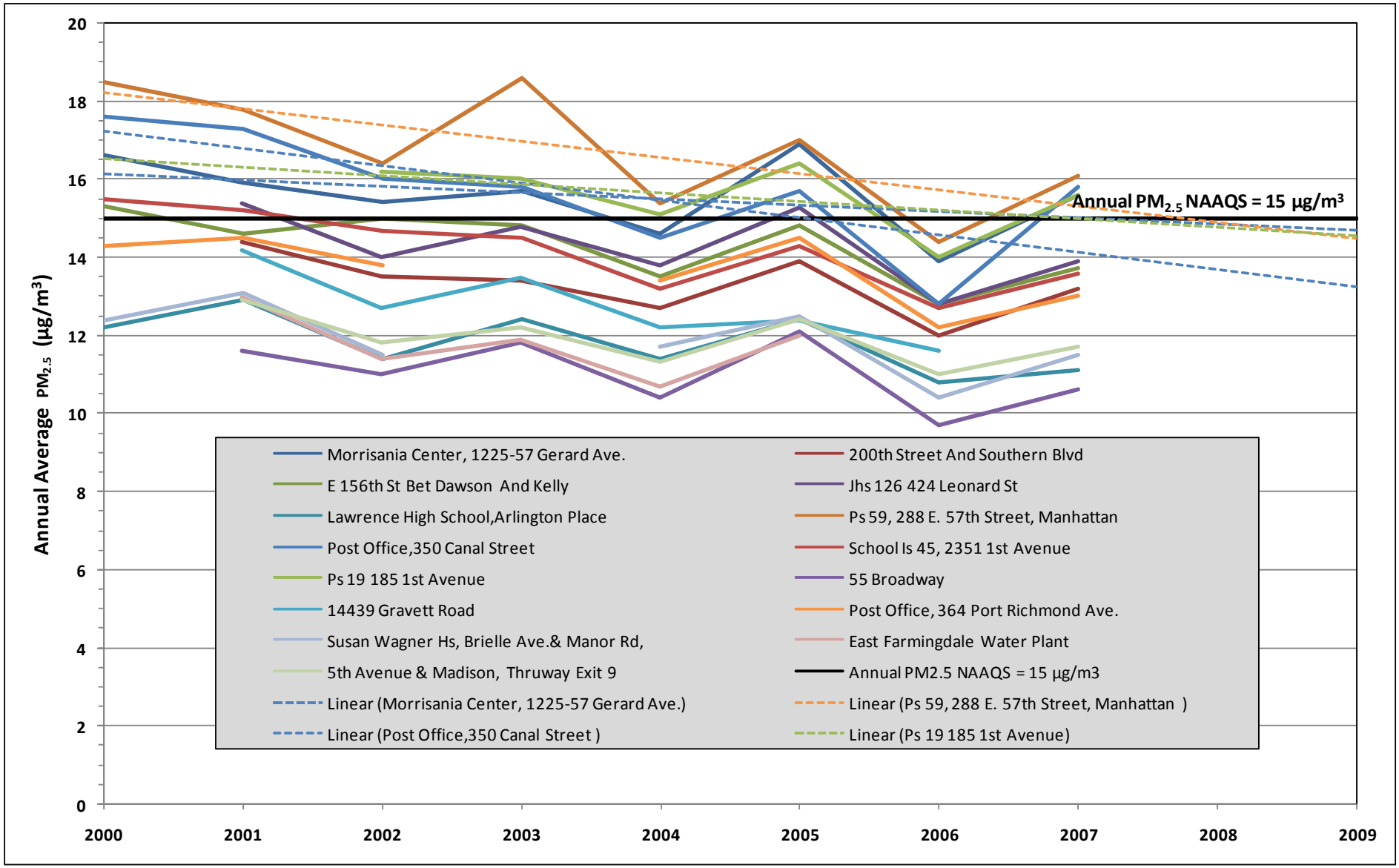
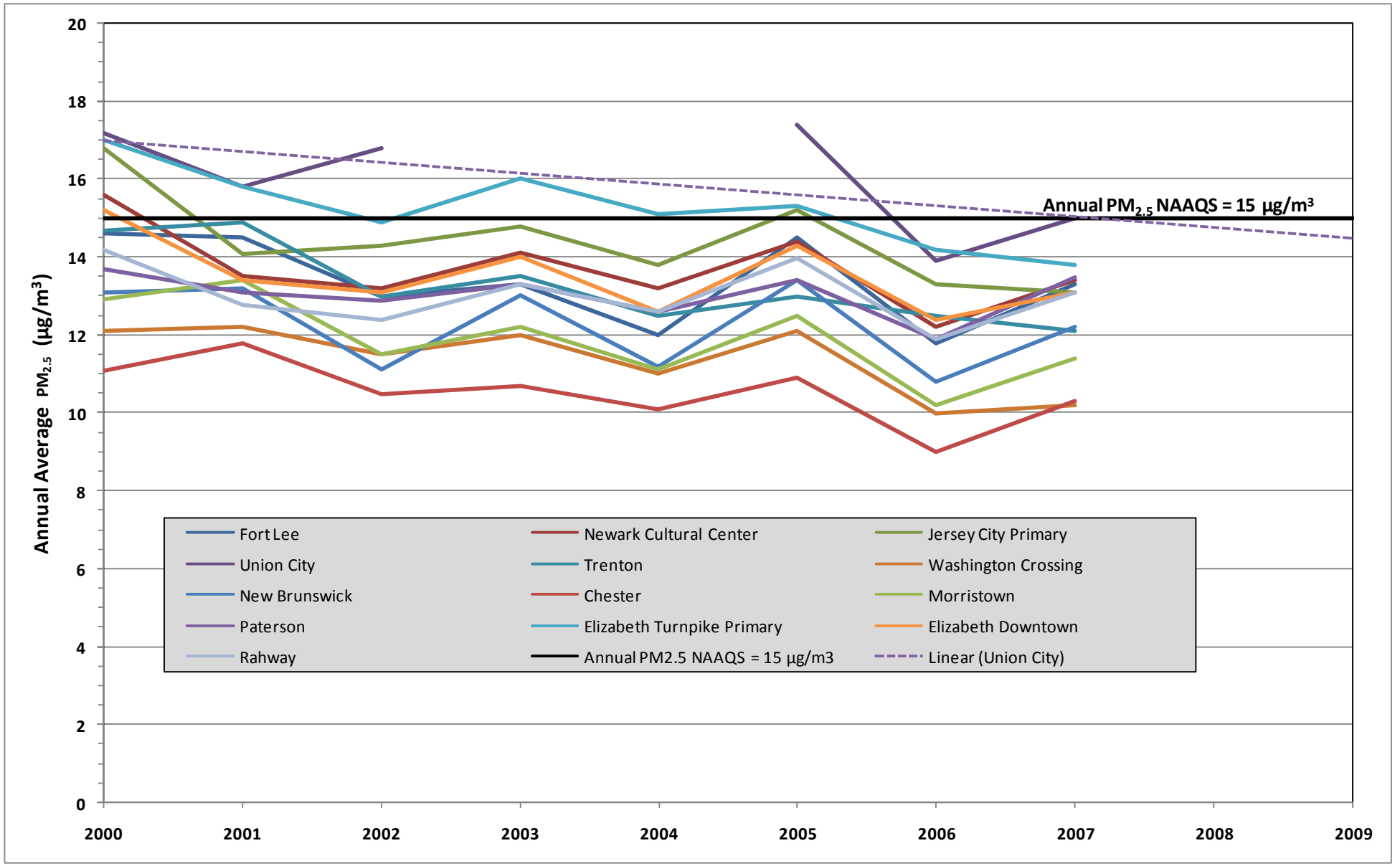


Figure 8-16. Trends in Annual $PM_{2.5}$ Levels in the New Jersey Portion of the NY-NJ-CT Nonattainment Area



1. The PS 59 data set lacks complete information for the third quarter of 2003. Construction work occurring at the site location during that quarter likely influenced a number of samples, biasing the collected fine particulate levels on the high side. NYDEC applied substitution procedures using contemporaneous data from PS 59 and other nearby sites to appropriately adjust the data set.
2. The lack of a collocated speciation monitor at the PS 59 site required the use of speciation data from the nearest neighborhood monitor. Analysis suggests that differences between the sites may have contributed to overestimates of 2009 modeled $PM_{2.5}$ levels at the PS 59 site. Calculations based on the only other site with similar $PM_{2.5}$ concentration levels suggest PS 59 would achieve attainment by 2009.
3. A significant portion of $PM_{2.5}$ mass in New York City has been attributed to secondary species from upwind emission sources. Analysis of $PM_{2.5}$ and precursor data reveals a downward trend at the PS 59 site. Additional upwind reductions expected from CAIR, mobile source and other programs should continue the downward trend, increasing the potential for timely attainment of the annual $PM_{2.5}$ NAAQS.

8.6.3 Other Data Analysis Conducted for New York City Indicate Timely Attainment

A recent study[24] suggests that the sum of sulfate and nitrate comprise about 40% or more of the $PM_{2.5}$ mass in the New York City metropolitan area, and that 70% or more of the measured $PM_{2.5}$ results from transport into the region. Based on results from source apportionment modeling using Positive Matrix Factorization (PMF), the authors determined that the largest single source factor affecting NYC is "secondary sulfate" associated with SO_2 emissions from upwind regions. It is clear that emission reductions in upwind states will be needed to further reduce $PM_{2.5}$ in the NY-NJ-CT nonattainment area.

As previously shown in Figures 8-13 through 8-15, $PM_{2.5}$ levels are generally improving across the NY-NJ-CT nonattainment area. Although the data records for $PM_{2.5}$ are somewhat short, $PM_{2.5}$ mass appears to be decreasing by about 0.1-0.5 $\mu g/m^3$ per year, depending on the monitoring location. At the PS 59 site, annual $PM_{2.5}$ levels improved, based on the linear trend line, by more than 0.4 $\mu g/m^3$ per year during the 2000-2007 period. In addition to $PM_{2.5}$ mass, several criteria pollutants are also measured at the PS 59 site. Examination by NYDEC of the trends in SO_2 and NO_2 from 1993 to 2006 using the seasonal Kendall test revealed that ambient levels are declining at rates of 3.4% per year and 1.7% per year, respectively. This strengthens the argument that this area will achieve timely attainment of the NAAQS, given that there are various measures scheduled to be implemented aimed at decreasing the emissions of these $PM_{2.5}$ precursors (e.g., the CAIR program).

8.6.4 New York City's PlaNYC Will Provide Additional Local Emission Reductions

In December of 2006, New York City announced the intent to develop a strategy to deal with growth, infrastructure, sustainability and the need for environmental improvement. The resulting plan, known as PlaNYC, contains measures that New York City has, or plans to, institute or promote to address these issues between now and 2030. Many of these will become effective in the near term.

[24] Qin, Y., Kim., E., Hopke, P. K., 2006. The concentrations and sources of $PM_{2.5}$ in metropolitan New York City. Atmospheric Environment 40, S312-S332.

The portion of PlaNYC that concerns air quality encompasses a comprehensive program for addressing pollution that originates from residential units, motor vehicles, buses, truck and other diesel equipment, as well as utility operations throughout New York City. Many of these program elements will result in a reduction of particulate matter and its precursors. Table 8-5 provides a conceptual description of these air quality related elements, which were not included in the CMAQ modeling exercise. Details on PlaNYC, and the progress achieved towards implementing its goals, are provided in Appendices 8H and 8I.

Table 8-5. Air Quality Goals of New York City's PlaNYC

Reduce road vehicle emissions
1. Capture the air quality benefits of the NYC transportation plan 2. Improve fuel efficiency of private cars 3. Reduce emissions from taxis, black cars, and for-hire vehicles 4. Replace, retrofit, and refuel diesel trucks 5. Reduce school bus emissions
Reduce other transportation emissions
6. Retrofit ferries, promote use of cleaner fuels, and engine replacements 7. Work with Port Authority to reduce emissions from vehicles, vessels and facilities 8. Reduce emissions from construction vehicles
Reduce emissions from buildings and power plants
9. Capture the air quality benefits of the NYC energy plan 10. Promote the use of cleaner burning heating fuels
Pursue natural solutions to improve air quality
11. Capture the benefits of the NYC open space plan 12. Reforest targeted areas of the City's parkland 13. Reduce heating effect of asphalt parking lots with increased tree plantings
Understand the scope of the challenge
14. Launch collaborative local air quality study to track local pollution

New York City's efforts to implement these PlaNYC measures have not been considered in the attainment modeling and are not considered to be a SIP commitment. Nevertheless, PlaNYC and other non-SIP measures being pursued in New York (see Appendix 8H) should provide improvements in $PM_{2.5}$ levels beyond those predicted by the modeling, helping to ensure compliance with the annual standard by 2010 and continued maintenance of the NAAQS in subsequent years. In addition, emission reductions resulting from PlaNYC will be crucial to achieving compliance with the revised 24-hour $PM_{2.5}$ NAAQS, which was promulgated by EPA in 2006.

8.6.5 Early SO_2 Emission Reductions are Anticipated from the CAIR Program

Phase 1 SO_2 reductions mandated by EPA's CAIR program are not required until 2010. As a result, the CMAQ modeling projections for 2009 included in this attainment demonstration do not reflect any SO_2-related reductions from the CAIR program. However, EPA anticipates[25] that CAIR incentives will lead to early reductions in SO_2 emissions prior to the April 2010 attainment deadline. Therefore, any early SO_2 reductions from upwind CAIR sources should provide pre-2010 improvements in measured $PM_{2.5}$ concentrations that are not reflected in the 2009 CAIR modeling results. In addition, CAIR program emission reductions will serve as a starting point for securing emission reductions from electricity generating units that will be necessary to reach attainment of the 2006 24-hour $PM_{2.5}$ NAAQS.

8.6.6 Additional Connecticut Non-SIP Control Measures Provide Further Reductions

Connecticut is pursuing implementation of a number of non-SIP initiatives in the stationary and mobile source sectors that should provide emission reductions beyond those accounted for in the 2009 MANE-VU emission inventory and SIP modeling. These initiatives will also play an important role in achieving attainment of the 2006 24-hour $PM_{2.5}$ NAAQS. These initiatives are described in detail in Section 4.4.1. Such Connecticut programs, by reducing electricity demand and use; reducing vehicle emissions; or by reducing vehicle miles travelled, create directionally correct reductions in $PM_{2.5}$ and precursor emissions.

None of the programs described in Section 4.4.1 produce emissions reductions that are quantified or are not quantifiable in a manner typical of attainment planning efforts. However, in the case of the energy efficiency (EE) programs administered by the Energy Conservation and Management Board, there are estimates of NOx and SOx emissions reductions in 2007 associated with projects funded through the ECMB (*see* Table 8-6). These estimates, combined with the legislated growth in Connecticut's energy efficiency and conservation efforts in future years, convey a compelling argument that Connecticut's EE programs are doing much to limit the growth of electricity demand and the otherwise high NOx and SOx emissions associated with such growth. The efforts Connecticut has made to reduce peak demand and encourage EE (through ECMB programs, product efficiency standards exceeding federal requirements, the OneThing campaign and integrated planning) provide further weight-of-evidence that Connecticut will continue to reduce emissions of $PM_{2.5}$ precursors through 2010 and beyond.

[25] For a discussion regarding early CAIR emission reductions, see Section XIII of EPA's "Corrected Response to Significant Public Comments on the Proposed Clean Air Interstate Rule"; Corrected April 2005; See: http://epa.gov/oar/interstateairquality/pdfs/cair-rtc.pdf.

Table 8-6. Pollutant Reductions from Conservation and Load Management Program Activities (Tons)[26]

	2007 Annual Actual	2007 Lifetime Actual	2008 Annual Plan	2008 Lifetime Plan
SOx	336	4,076	236	2,801
NOx	104	1,258	73	864

Section 4.4.1 also identifies several Connecticut mobile source programs that produce directionally correct emissions reductions. While the emissions reductions are not easily quantified, such as in the case of the legislated school bus anti-idling program, CTDEP has provided emissions estimates associated with the TCMs implemented in 2002 through 2007. Although the estimated emission reductions from the TCMs are relatively small, many are focused on urban areas where ambient $PM_{2.5}$ levels are typically highest.

8.6.7 Additional Federal Non-Road Engine Control Measures Result in Continued Emission Reductions

The federal locomotive and marine diesel engine and spark-ignition rules described in Section 4.4.2 will have a positive, albeit minimal, impact on complying with the April 2010 attainment date because they only begin to take effect in 2008. Emission reductions from these measures are not accounted for in this SIP. However, the new regulations will help to ensure that emissions continue to decrease through 2012 and beyond

8.7 Attainment Demonstration Conclusions

Monitored air quality data demonstrate that Connecticut monitors remain in attainment of the annual $PM_{2.5}$ NAAQS. CMAQ modeled results for 2009 verify continued attainment at all Connecticut monitors, with design values at all sites projected to be less than the EPA-defined lower threshold of model uncertainty (i.e.,14.5 ug/m^3). Furthermore, the CMAQ modeling projects that all but one monitor in the NY-NJ-CT nonattainment areas will be in compliance with the annual $PM_{2.5}$ NAAQS by 2009 and below the model uncertainty threshold, thus not requiring WOE analyses.

The only site with a projected 2009 design value greater than the annual NAAQS is the PS 59 site located in Manhattan, New York City. The 2009 CMAQ projection for that site is 15.3 ug/m^3, slightly above the $PM_{2.5}$ NAAQS of 15.0 ug/m^3, but within the range of values (i.e., 14.5 ug/m^3 – 15.5 ug/m^3) for which EPA recommends that supplemental WOE analyses be used to demonstrate attainment.[27]

Two types of WOE analyses support the conclusion that the PS 59 monitor, and all of the NY-NJ-CT area, will come into compliance with the annual $PM_{2.5}$ NAAQS by the April 2010 attainment date. Analysis of $PM_{2.5}$ and precursor emission and monitored data trends indicate

[26] Benefits are calculated for the lifetime of funded measures. From *Report of the Energy Conservation and Management Board Year 2007 Programs and Operation*s. Available at: http://www.ctsavesenergy.org/files/ECMB%202007%20FINAL%2002.20.08.pdf.

[27] Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze, USEPA, EPA-454/B-07-002, April, 2007, p. 105.

that timely attainment is likely to be achieved. In addition, numerous control programs that were not included in the CMAQ modeling exercise will provide supplemental emission reductions through 2009 and beyond, increasing the level of confidence that attainment of the annual $PM_{2.5}$ NAAQS will occur by April 2010, and be maintained into the future.

The continued downward trend in emissions also serves as the initial step towards reaching attainment of the recently revised 2006 24-hour $PM_{2.5}$ NAAQS. However, significant additional emission controls will be needed on a national, regional and local level to ensure timely attainment of that NAAQS.