

**The North Carolina  
Fine Particulate Matter Attainment Demonstration  
for the  
Hickory and Greensboro/Winston-Salem/High Point  
Fine Particulate Matter Nonattainment Areas  
(Catawba, Davidson, and Guilford Counties)**



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**August 21, 2009**

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## **PREFACE**

This document contains North Carolina's attainment demonstration for the Hickory and Greensboro/Winston-Salem/High Point fine particulate matter nonattainment areas, which demonstrates that both of these areas will meet the National Ambient Air Quality Standards for fine particulate matter by April 5, 2010. These areas include the entire counties of Catawba, Davidson, and Guilford.

# EXECUTIVE SUMMARY

## INTRODUCTION

Fine particulate matter, also known as fine particles and PM<sub>2.5</sub>, refers to airborne particles less than or equal to 2.5 micrometers (µm) in diameter. Fine particles are treated as though they are a single pollutant, but they come from many different sources and are composed of many different compounds. PM<sub>2.5</sub> exposure adversely affects human health, especially respiratory and cardiovascular systems. Individuals particularly sensitive to PM<sub>2.5</sub> exposure include children, people with heart and lung disease, and older adults.

A variety of meteorological and geographic factors influence the concentration levels of fine particles, including both the regional and local distribution of urbanized areas, primary and precursor emissions sources, and natural features such as oceans and forests. PM<sub>2.5</sub> concentrations can also be high and exceed the national ambient air quality standards (NAAQSs) for fine particulate matter at any time of the year. Therefore, the United States Environmental Protection Agency (USEPA) mandates the year round monitoring of PM<sub>2.5</sub> concentrations throughout the country (40 CFR 58.App. D, 4.7).

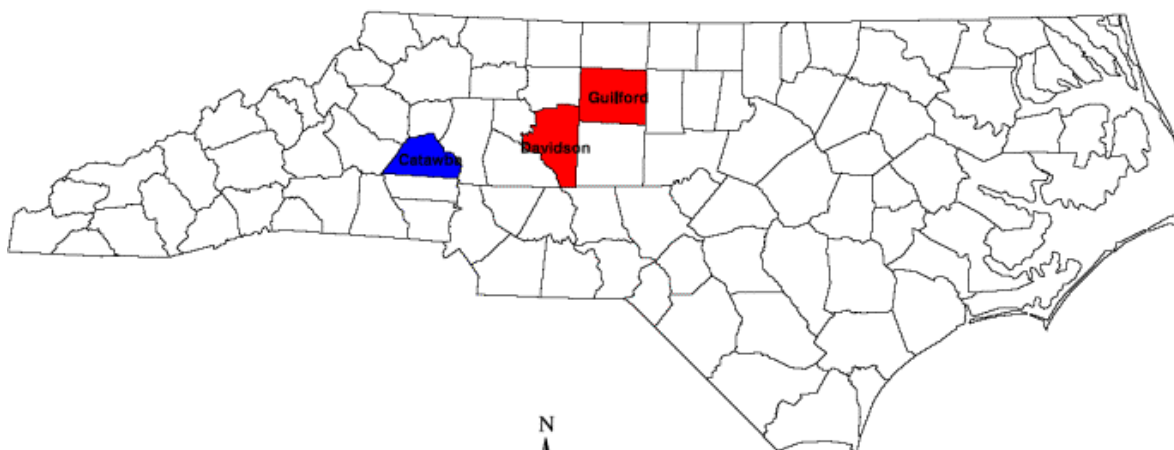
## NATIONAL AMBIENT AIR QUALITY STANDARD

In 1997, the USEPA promulgated the primary (health) and secondary (welfare) NAAQSs for PM<sub>2.5</sub> (40 CFR 50.7), setting the standard at a 15.0 micrograms per cubic meter (µg/m<sup>3</sup>) annual average and at a 65 µg/m<sup>3</sup> daily or 24-hour average. A violation of the annual PM<sub>2.5</sub> NAAQS occurs when the annual average PM<sub>2.5</sub> concentration averaged over a three consecutive year period is equal to or greater than 15.1 µg/m<sup>3</sup>. A violation of the daily PM<sub>2.5</sub> NAAQS occurs when the annual 98<sup>th</sup> percentile of daily PM<sub>2.5</sub> concentration averaged over a three consecutive year period is equal to or greater than 66 µg/m<sup>3</sup>. The annual or daily PM<sub>2.5</sub> design value for a nonattainment area is the highest design value for any monitor in that area.

The USEPA designated areas as nonattainment for the annual and daily PM<sub>2.5</sub> NAAQSs based upon air quality monitoring data measured during 2001, 2002 and 2003. The effective date of nonattainment designations was April 5, 2005.

## NATURE OF PROBLEM IN NORTH CAROLINA

In North Carolina, there were two areas designated as nonattainment for violating the annual PM<sub>2.5</sub> standard (Figure 1). All areas of North Carolina met the daily PM<sub>2.5</sub> standard. This PM<sub>2.5</sub> attainment demonstration submittal covers the Hickory PM<sub>2.5</sub> nonattainment area (Catawba County) and Greensboro/Winston-Salem/High Point PM<sub>2.5</sub> nonattainment area (referred to as the Triad area and consists of Davidson and Guilford Counties) with respect to the violations of the annual PM<sub>2.5</sub> standard.



**Figure 1. Annual PM<sub>2.5</sub> Nonattainment Boundaries for North Carolina**

When the annual PM<sub>2.5</sub> concentrations in both nonattainment areas are analyzed by the percentages of their individual component species, the organic carbon (OC) and sulfate (SO<sub>4</sub>) components each account for approximately one-third of the total PM<sub>2.5</sub> mass, the ammonium component makes up approximately ten percent of the total PM<sub>2.5</sub> mass, and the remaining nitrate (NO<sub>3</sub>), elemental carbon, crustal material, and particle bound water components each contribute approximately five percent or less of the total PM<sub>2.5</sub> mass. The percentages of species contribution fluctuate throughout the year with the most significant changes to SO<sub>4</sub> and NO<sub>3</sub>. SO<sub>4</sub> is more pronounced in the summertime or warm season months than during the wintertime. NO<sub>3</sub> fluctuates from almost undetectable in the summertime to as much as ten percent contribution of the total PM<sub>2.5</sub> mass during the coldest portion of the winter.

The speciated analysis of the PM<sub>2.5</sub> concentrations in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas demonstrates that the OC and SO<sub>4</sub> components are the most important portions of the total PM<sub>2.5</sub> mass throughout the year. OC is predominately attributed to biogenic emissions sources. SO<sub>4</sub> is associated with sulfur dioxide (SO<sub>2</sub>) emissions. When evaluated across North Carolina and also throughout both nonattainment areas and surrounding regions, the SO<sub>2</sub> is primarily from the point source sector. For this reason, SO<sub>2</sub> emissions controls from point sources are believed to be the most appropriate strategy for addressing the PM<sub>2.5</sub> nonattainment issues for Hickory and the Triad.

### CONTROLS APPLIED

Several control measures already in place or being implemented over the next few years will reduce stationary point, highway mobile, and non-road mobile sources emissions. The expected Federal and State control measures were modeled for the attainment year of 2009.

The Federal control measures that were modeled included the Tier 2 vehicle standards; the heavy-duty gasoline and diesel highway vehicle standards; low sulfur gasoline and diesel fuels, large non-road diesel engines standards; the non-road spark-ignition engines and recreational engines standard; and the Clean Air Interstate Rule (CAIR). Due to the Court challenges of

CAIR in 2008, the USEPA will be making changes to this program soon. However, the existing CAIR rules will remain in place until the USEPA promulgates changes to the program.

The State control measures that were modeled included the Clean Air Bill, in which the vehicle emissions inspection and maintenance program was expanded from 9 counties to 48; the NO<sub>x</sub> SIP Call Rule, CAIR, and the Clean Smokestacks Act, which will significantly reduce SO<sub>2</sub> emissions from the large electrical generation units with implementation beginning prior to the 2009 attainment year and well in advance of the Federal Clean Air Interstate Rule. The Clean Smokestacks Act further requires the coal-fired power plants to meet an annual SO<sub>2</sub> emissions cap without an option of emissions trading from outside of North Carolina.

### ATTAINMENT TEST RESULTS

A modeled attainment test was applied to the air quality modeling results to determine if the annual PM<sub>2.5</sub> NAAQS will be met by the attainment year 2009. The baseline period for the air quality modeling was centered on 2002 or the midpoint of the three years used for nonattainment designations.

For all FRM sites in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas, the future annual PM<sub>2.5</sub> concentrations derived from the modeled attainment test were less than 15.0 µg/m<sup>3</sup> (Table 1). Therefore, the modeling assessment indicated that both nonattainment areas will attain the annual PM<sub>2.5</sub> NAAQS by 2009.

**Table 1. Current And Future Year Predicted Annual PM<sub>2.5</sub> Concentrations**

<b>County</b>	<b>FRM Monitoring Site</b>	<b>2001-2003, Current Design Value (µg/m<sup>3</sup>)</b>	<b>2009, Future Year Predicted Design Value (µg/m<sup>3</sup>)</b>
Catawba	Hickory	15.5	13.1
Davidson	Lexington	15.8	13.4
Guilford	Mendenhall	14.0	11.5

The North Carolina Division of Air Quality (NCDAQ) provided a strong set of supplemental analyses further supporting that the Hickory and Triad PM<sub>2.5</sub> nonattainment areas will attain the annual PM<sub>2.5</sub> NAAQS by April 5, 2010. These analyses included evaluating the air quality modeling from an absolute percentage reduction perspective compared to the annual PM<sub>2.5</sub> NAAQS, investigating current air quality data trends along with the emission reductions that have recently occurred, and considering air quality modeling results from other region and national modeling exercises.

The NCDAQ believes that the modeling attainment demonstration, in conjunction with the supplemental analyses, provides the necessary evidence that the Hickory and Triad PM<sub>2.5</sub> nonattainment areas will attain the annual PM<sub>2.5</sub> NAAQS by the April 5, 2010 attainment date and furthermore continue to maintain the daily PM<sub>2.5</sub> NAAQS. In fact, both nonattainment areas have already attained the 1997 annual PM<sub>2.5</sub> standard with the 2006-2008 ambient air quality data, one year earlier than required.

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# 1.0 INTRODUCTION

## 1.1 What is fine particulate matter?

Fine particulate matter, also known as fine particles and PM<sub>2.5</sub>, refers to airborne particles less than or equal to 2.5 micrometers (µm) in diameter. Fine particles are treated as though they are a single pollutant, but they come from many different sources and are composed of many different compounds. PM<sub>2.5</sub> exposure adversely affects human health, especially respiratory and cardiovascular systems. Individuals particularly sensitive to PM<sub>2.5</sub> exposure include children, people with heart and lung disease, and older adults.

PM<sub>2.5</sub> can be liquid, solid, or can have a solid core surrounded by liquid. PM<sub>2.5</sub> can include material produced by combustion, photochemical reactions, and can contain salt from sea spray and soil-like particles. Particles are distinguished based on the method of formation. Primary particles are particles directly emitted into the atmosphere and retain the same chemical composition as when they were released. Secondary particles are those formed through chemical reactions involving atmospheric oxygen, water vapor, hydroxyl radical, nitrates, sulfur dioxide (SO<sub>2</sub>), oxides of nitrogen (NO<sub>x</sub>), and organic gases from natural and anthropogenic sources. PM<sub>2.5</sub> can therefore be composed of varying amount of different species, including:

- Sulfates
- Nitrates (usually found in the form of ammonium nitrate)
- Ammonium
- Hydrogen ion
- Particle bound water
- Elemental carbon
- Organic compounds
  - Primary organic species (from cooking and combustion)
  - Secondary organic compounds
- Crustal material (includes calcium, aluminum, silicon, magnesium, and iron)
- Sea salt (generally only found at coastal monitoring sites)
- Transitional metals
- Potassium (generally from wood burning or cooking)

The most significant sources of PM<sub>2.5</sub> and its precursors are coal-fired power plants, industrial boilers and other combustion sources. These emissions are often transported over large distances. Other sources of PM<sub>2.5</sub> emissions include mobile sources, area sources, biogenic, fires, windblown dust, and oceans.

A variety of meteorological and geographic factors influence the concentration levels of fine particles, including both the regional and local distribution of urbanized areas, primary and

precursor emissions sources, and natural features such as oceans and forests.  $PM_{2.5}$  concentrations can also be high and exceed the national ambient air quality standards (NAAQSs) for fine particulate matter at any time of the year. Therefore the United States Environmental Protection Agency (USEPA) mandates the year round monitoring of  $PM_{2.5}$  concentrations throughout the country (40 CFR 58.App. D, 4.7).

## **1.2 What is the National Ambient Air Quality Standard?**

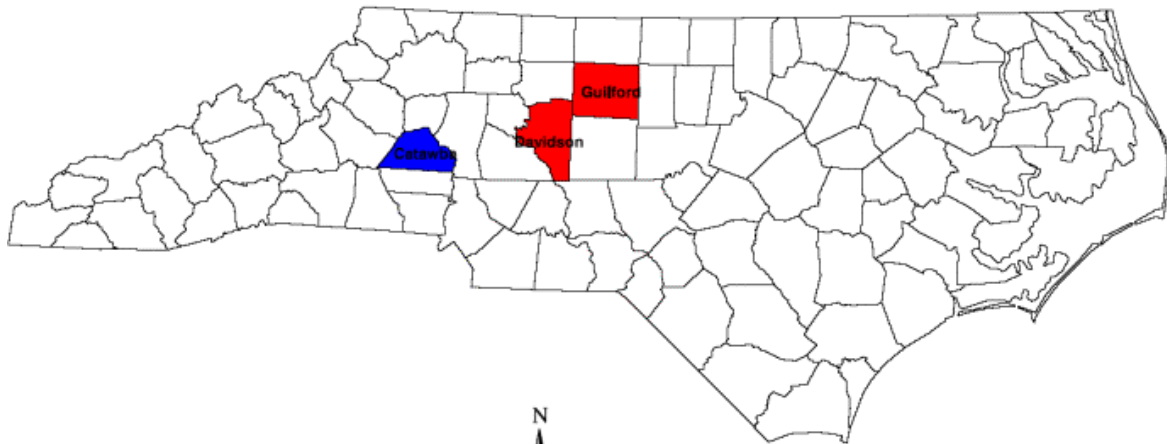
In 1997, the USEPA promulgated the primary (health) and secondary (welfare) NAAQSs for  $PM_{2.5}$  (40 CFR 50.7), setting the standard at a 15.0 micrograms per cubic meter ( $\mu\text{g}/\text{m}^3$ ) annual average and at a 65  $\mu\text{g}/\text{m}^3$  daily or 24-hour average. A violation of the annual  $PM_{2.5}$  NAAQS occurs when the annual average  $PM_{2.5}$  concentration averaged over a three consecutive year period is equal to or greater than 15.1  $\mu\text{g}/\text{m}^3$ . A violation of the daily  $PM_{2.5}$  NAAQS occurs when the annual 98<sup>th</sup> percentile of daily  $PM_{2.5}$  concentration averaged over a three consecutive year period is equal to or greater than 66  $\mu\text{g}/\text{m}^3$ . The annual or daily  $PM_{2.5}$  design value for a nonattainment area is the highest design value for any monitor in that area.

Since the 1977 amendments to the Clean Air Act (CAA), areas of the country that violated the ambient standard for a particular pollutant were formally designated as nonattainment for that pollutant. This formal designation concept was retained in the 1990 Amendments (CAAA). With the implementation of the  $PM_{2.5}$  standard, areas could be designated under Section 172 of the CAAA (subpart 1) and have five years from designation to attain the standard.

The USEPA designated areas as nonattainment for the annual and daily  $PM_{2.5}$  NAAQSs based upon air quality monitoring data measured during 2001, 2002 and 2003. The effective date of nonattainment designations was April 5, 2005.

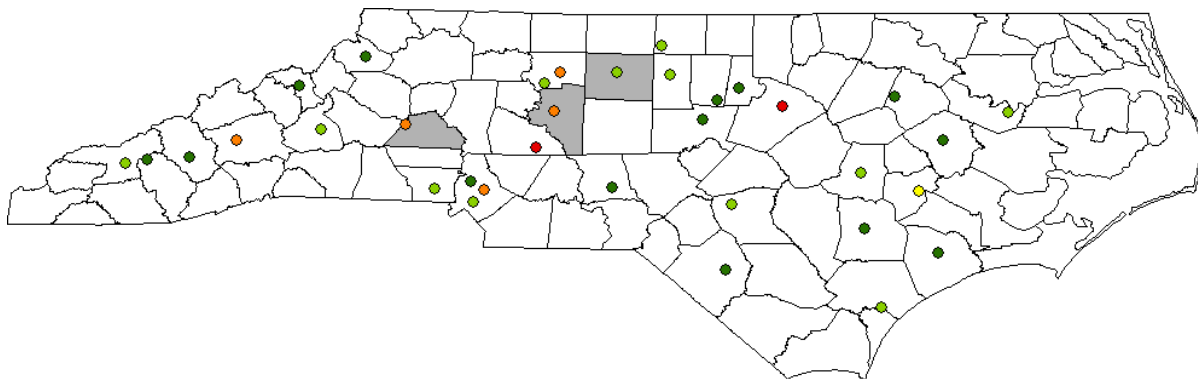
## **1.3 Nature of Problem in North Carolina**

In North Carolina, there were two areas designated as nonattainment for violating the annual  $PM_{2.5}$  standard (Figure 1.3-1). All areas of North Carolina met the daily  $PM_{2.5}$  standard. This  $PM_{2.5}$  attainment demonstration submittal covers the Hickory  $PM_{2.5}$  nonattainment area (Catawba County) and Greensboro/Winston-Salem/High Point  $PM_{2.5}$  nonattainment area (referred to as the Triad area and consists of Davidson and Guilford Counties) with respect to the violations of the annual  $PM_{2.5}$  standard.



**Figure 1.3-1. Annual PM<sub>2.5</sub> Nonattainment Boundaries for North Carolina**

Figure 1.3-2 displays the distribution of the PM<sub>2.5</sub> monitoring sites across North Carolina. A closer view of the PM<sub>2.5</sub> federal reference method (FRM) monitoring sites in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas is found in Figure 1.3-3. The Hickory monitoring site is the only FRM monitor in the Hickory PM<sub>2.5</sub> nonattainment area. There are two FRM monitoring sites, Lexington and Mendenhall, in the Triad PM<sub>2.5</sub> nonattainment area.



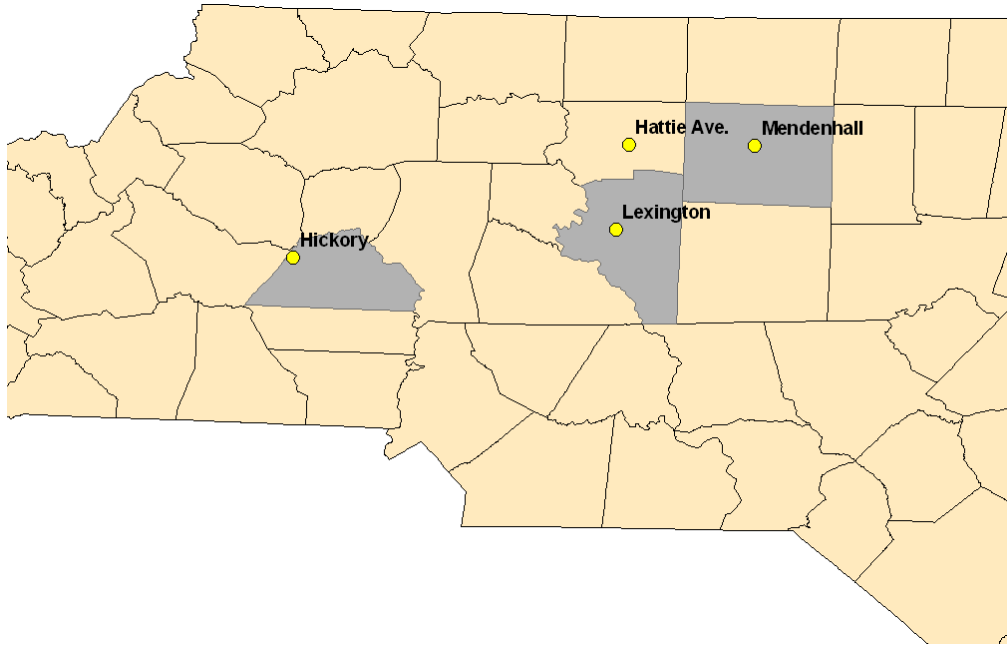
**Legend**

**PM<sub>2.5</sub> Monitoring Sites**

**Type of Monitor Present**

- Federal Reference Monitor (FRM) only
- FRM and continuous monitors
- FRM and speciated monitors
- FRM, continuous, and speciated monitors
- FRM, continuous, speciated, and continuous speciated monitors
- PM Nonattainment Areas

**Figure 1.3-2. PM<sub>2.5</sub> Monitoring Sites In North Carolina**



**Figure 1.3-3. PM<sub>2.5</sub> FRM Monitoring Sites in the Hickory and Triad Nonattainment Areas**

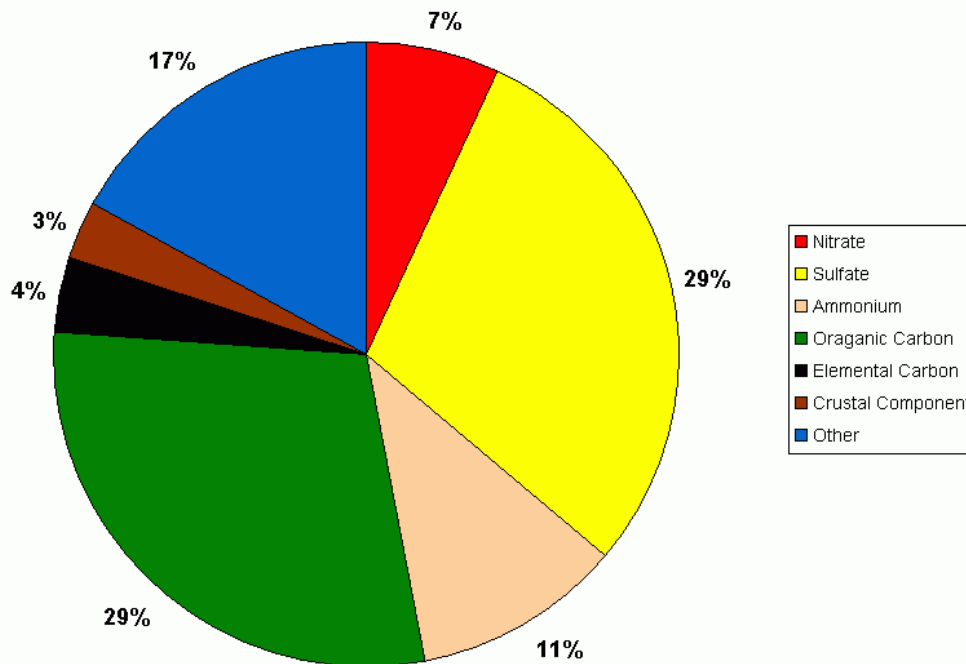
Table 1.3-1 contains the quarterly and annual average PM<sub>2.5</sub> concentrations for the FRM monitors in the PM<sub>2.5</sub> nonattainment areas for the three-year period used in the nonattainment designation determinations. Table 1.3-1 also presents the 2001-2003 PM<sub>2.5</sub> design value for the FRM monitors based on these quarterly and annual averages. The historic quarterly, yearly, and design value air quality data for the FRM monitors in both PM<sub>2.5</sub> nonattainment areas can be found in Appendix C.

**Table 1.3-1. PM<sub>2.5</sub> Concentrations and Design Values for the FRM monitors in the Hickory and Triad PM<sub>2.5</sub> Nonattainment Areas**

County	FRM Monitoring Site	Year	1st Quarter (Q1)	2nd Quarter (Q2)	3rd Quarter (Q3)	4th Quarter (Q4)	Annual Average	Design Value
Catawba	Hickory	2001	15.3	16.6	18.8	13.2	16.0	15.5
		2002	13.3	14.3	21.1	12.7	15.4	
		2003	12.9	16.1	19.3	11.8	15.0	
Davidson	Lexington	2001	14.8	18.6	18.8	13.6	16.5	15.8
		2002	14.9	15.0	19.3	14.3	15.9	
		2003	12.6	16.1	19.1	12.9	15.2	
Guilford	Mendenhall	2001	12.0	16.7	18.0	12.9	14.9	14.0
		2002	11.7	13.1	18.3	11.7	13.7	
		2003	11.6	13.6	16.5	11.7	13.3	



As mentioned in Section 1.1, PM<sub>2.5</sub> is composed of many species from varying sources. Figure 1.3-4 presents the North Carolina statewide averaged PM<sub>2.5</sub> speciation data from the speciation trends network (STN) monitors for the year 2004. The figure presents sulfates (SO<sub>4</sub>) and organic carbons (OC) as the main contributors to PM<sub>2.5</sub>, each with 29%; ammonium (NH<sub>4</sub>) contributes 11%; nitrates (NO<sub>3</sub>) contribute 7%; elemental carbon (EC) is approximately 4%; and crustal material is 3% of the total PM<sub>2.5</sub> mass. The “other” portion of the PM<sub>2.5</sub> that accounts for 17% of the mass can be attributed to water (H<sub>2</sub>O), sea salts, and other trace materials captured with the STN monitors.



**Figure 1.3-4. North Carolina PM<sub>2.5</sub> Speciation for 2004**

#### **1.4 Major Contributors to PM<sub>2.5</sub> in the North Carolina Nonattainment Areas**

When the annual PM<sub>2.5</sub> concentrations in both nonattainment areas are analyzed by the percentages of their individual component species, a similar distribution of components are found. The OC and SO<sub>4</sub> components each account for approximately one-third of the total PM<sub>2.5</sub> mass; NH<sub>4</sub> makes up approximately ten percent of the total PM<sub>2.5</sub> mass; and the remaining NO<sub>3</sub>, EC, crustal material, and particle bound water components each contribute approximately five percent or less of the total PM<sub>2.5</sub> mass. Individual plots of the speciated PM<sub>2.5</sub> data (similar to Figure 1.3-4) from the three PM<sub>2.5</sub> monitoring locations in the nonattainment areas can be found in Appendix C.

The percentages of species contribution fluctuate throughout the year with the most significant changes to SO<sub>4</sub> and NO<sub>3</sub>. SO<sub>4</sub> is more pronounced in the summertime or warm season months than during the wintertime. NO<sub>3</sub> fluctuates from almost undetectable in the summertime to as much as ten percent contribution of the total PM<sub>2.5</sub> mass during the coldest portion of the winter.

The speciated analysis of the PM<sub>2.5</sub> concentrations in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas demonstrates that the OC and SO<sub>4</sub> components are the most important portions of the total PM<sub>2.5</sub> mass throughout the year. OC is predominately attributed to biogenic emissions sources. SO<sub>4</sub> is associated with SO<sub>2</sub> emissions. When evaluated across North Carolina and also throughout both nonattainment areas and surrounding regions, the SO<sub>2</sub> is primarily from the point source sector. For this reason, SO<sub>2</sub> emissions controls from point sources are believed to be the most appropriate strategy for addressing the current PM<sub>2.5</sub> nonattainment issues for Hickory and the Triad.

Further details on the nature of the PM<sub>2.5</sub> problem in both PM<sub>2.5</sub> nonattainment areas are discussed in Section 2 and can also be found in the Conceptual Description of Fine Particulate Matter in North Carolina section of Appendix D.1.

### **1.5 Clean Air Act Requirements**

Section 172(c) as amended, contains the general requirements for nonattainment areas. These requirements are listed below and are discussed in more detail in Section 7.

#### Section 172(c) Nonattainment Plan Provisions

- (1) Reasonable available control measures (RACM)
- (2) Reasonable further progress (RFP)
- (3) Actual emissions inventory and periodic emissions inventory
- (4) New source review (NSR)
- (5) Permit requirements for new and modified sources
- (6) Other measures as may be necessary to provide attainment by specified attainment date
- (7) Compliance with Section 110(a)(2)
- (8) Equivalent techniques
- (9) Contingency measures

## 2.0 SIGNIFICANCE OF PM<sub>2.5</sub> PRECURSOR POLLUTANTS

As suggested in the Section 1.4, SO<sub>2</sub> emissions are believed to be the most appropriate strategy for addressing the 1997 PM<sub>2.5</sub> NAAQS for the Hickory and Triad nonattainment areas. This finding is based on several factors including:

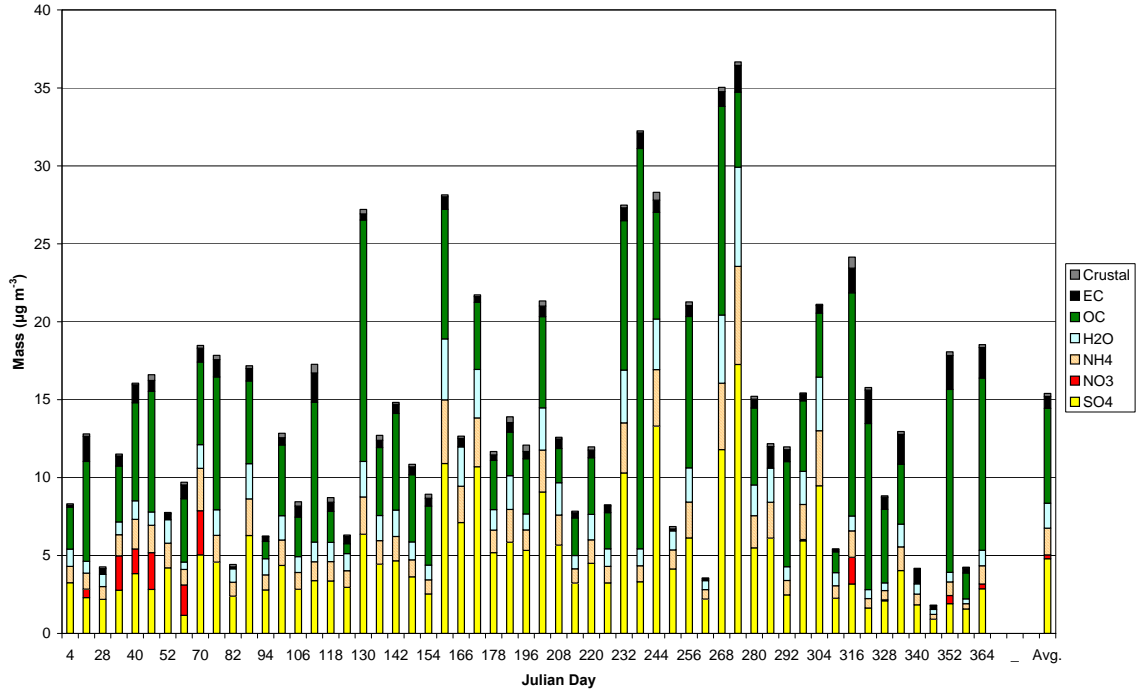
- An analysis of the percentage contribution of the PM<sub>2.5</sub> component species annually and seasonally within the nonattainment areas
- Attribution of emissions sources to these PM<sub>2.5</sub> component species
- Clean Air Fine Particulate Implementation Rule presumptions on precursor pollutants

### 2.1 PM<sub>2.5</sub> Component Species Analysis

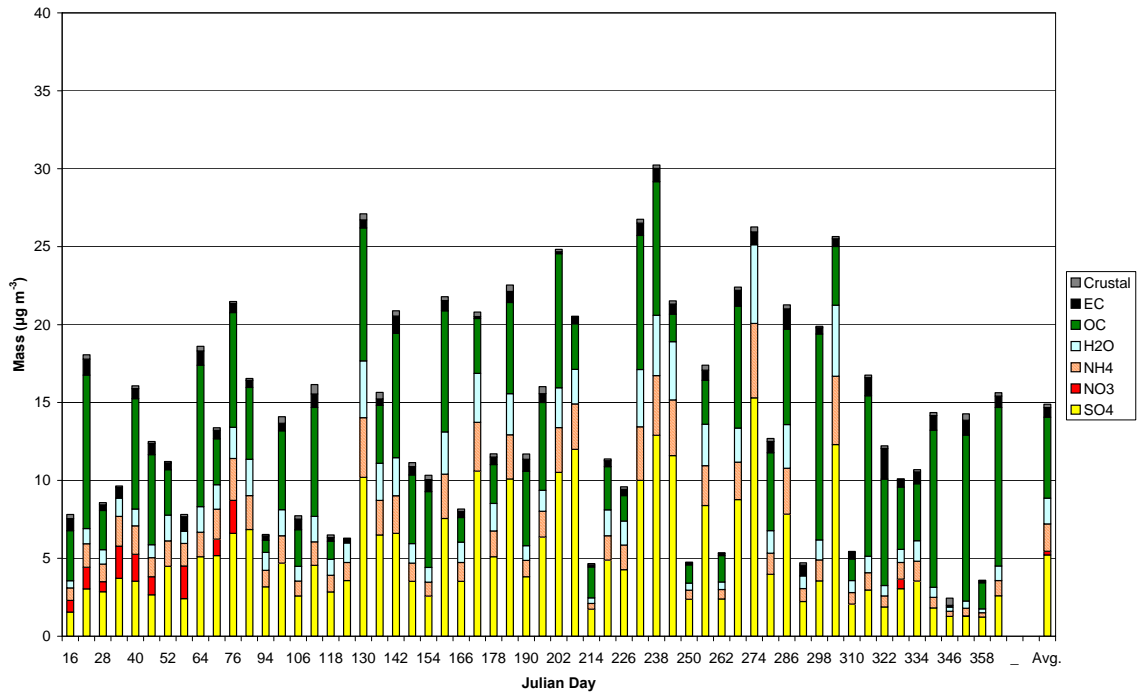
To fully understand the nature of the PM<sub>2.5</sub> nonattainment issues in the Hickory and Triad nonattainment areas, it is important to analyze the percentage contribution of the individual PM<sub>2.5</sub> component species, both from an annual perspective and seasonally throughout the year. Unfortunately, the FRM monitoring sites only provide a total mass PM<sub>2.5</sub> concentration and do not provide any information concerning the speciated breakdown of various components. A separate PM<sub>2.5</sub> monitoring network, STN, does allow for the speciation of these components, but the STN PM<sub>2.5</sub> concentration data is not directly comparable to the FRM PM<sub>2.5</sub> concentration data due to slight difference in the monitoring methodology. This creates an issue in using raw STN PM<sub>2.5</sub> data in an attainment demonstration, because it is not absolutely equivalent to the FRM PM<sub>2.5</sub> data of which the nonattainment is based and of which attainment will ultimately be evaluated.

To address this issue, Neil Frank with the USEPA developed an approach to use the raw STN PM<sub>2.5</sub> data to appropriately estimate the components of PM<sub>2.5</sub> as measured by the FRM monitors. The approach is termed the “Sulfate, Adjusted Nitrate, Derived Water, Inferred Carbonaceous material balance approach” method or SANDWICH (Frank, 2006). The SANDWICH approach is discussed in greater detail in Appendix L.

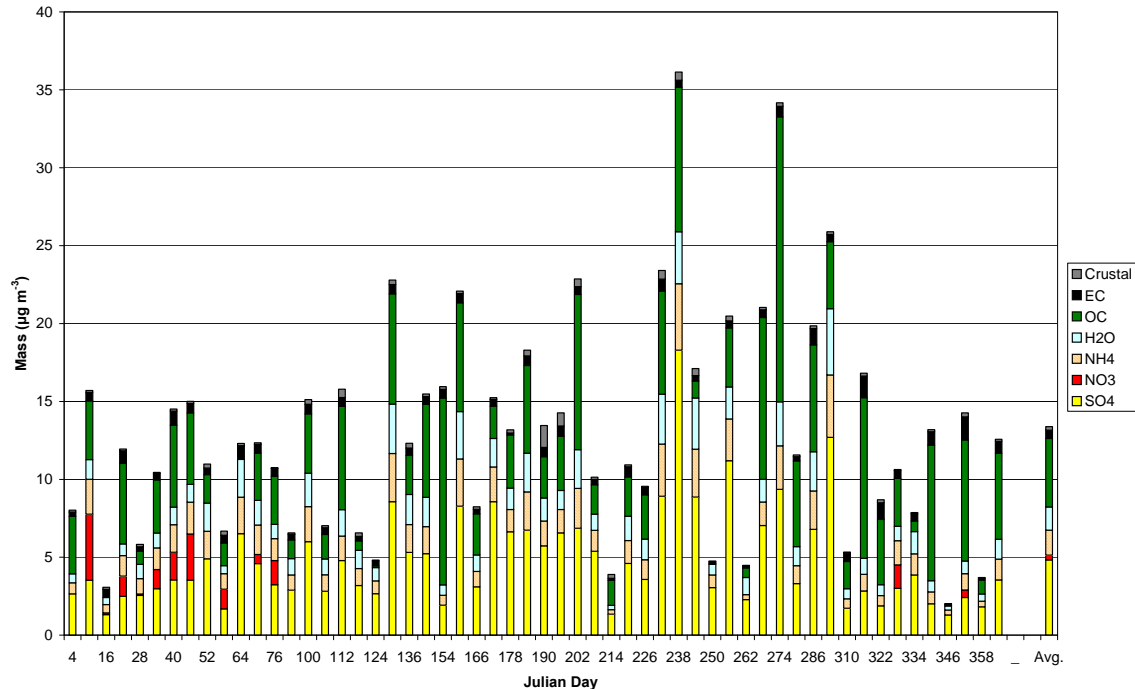
Using the SANDWICH approach, it is now possible to analyze the percentage contribution of the individual PM<sub>2.5</sub> component species relative to the total FRM PM<sub>2.5</sub> mass. Figures 2.1-1 through 2.1-3 present the speciated mass contributions of the component species at the Hickory, Lexington, and Mendenhall monitoring sites, respectively. The speciated mass contributions displayed are for the 2002 baseline year. Figures 2.1-1 through 2.1-3 illustrate daily speciated mass contributions for each day of the 2002 calendar year (expressed in Julian days) from left to right, with the farthest right bar of the charts representing the 2002 annual averaged speciated mass contributions.



**Figure 2.1-1. 2002 PM<sub>2.5</sub> Speciated Mass Contribution at Hickory Using SANDWICH**



**Figure 2.1-2. 2002 PM<sub>2.5</sub> Speciated Mass Contribution at Lexington Using SANDWICH**



**Figure 2.1-3. 2002 PM<sub>2.5</sub> Speciated Mass Contribution at Mendenhall Using SANDWICH**

From each of the three 2002 PM<sub>2.5</sub> speciated mass contribution plots, it is clear that SO<sub>4</sub> and OC are the dominant PM<sub>2.5</sub> components throughout the year. SO<sub>4</sub> is most pronounced during the summertime, but remains a reasonably important component of the total PM<sub>2.5</sub> mass in any of the seasons. NH<sub>4</sub> and H<sub>2</sub>O are less dominant than SO<sub>4</sub> and OC but are relatively consistent in each season. EC and crustal material are much less prevalent at any time of the year. Finally, NO<sub>3</sub> contributions are almost undetectable in the summertime to as much as ten percent contribution of the total PM<sub>2.5</sub> mass during the wintertime.

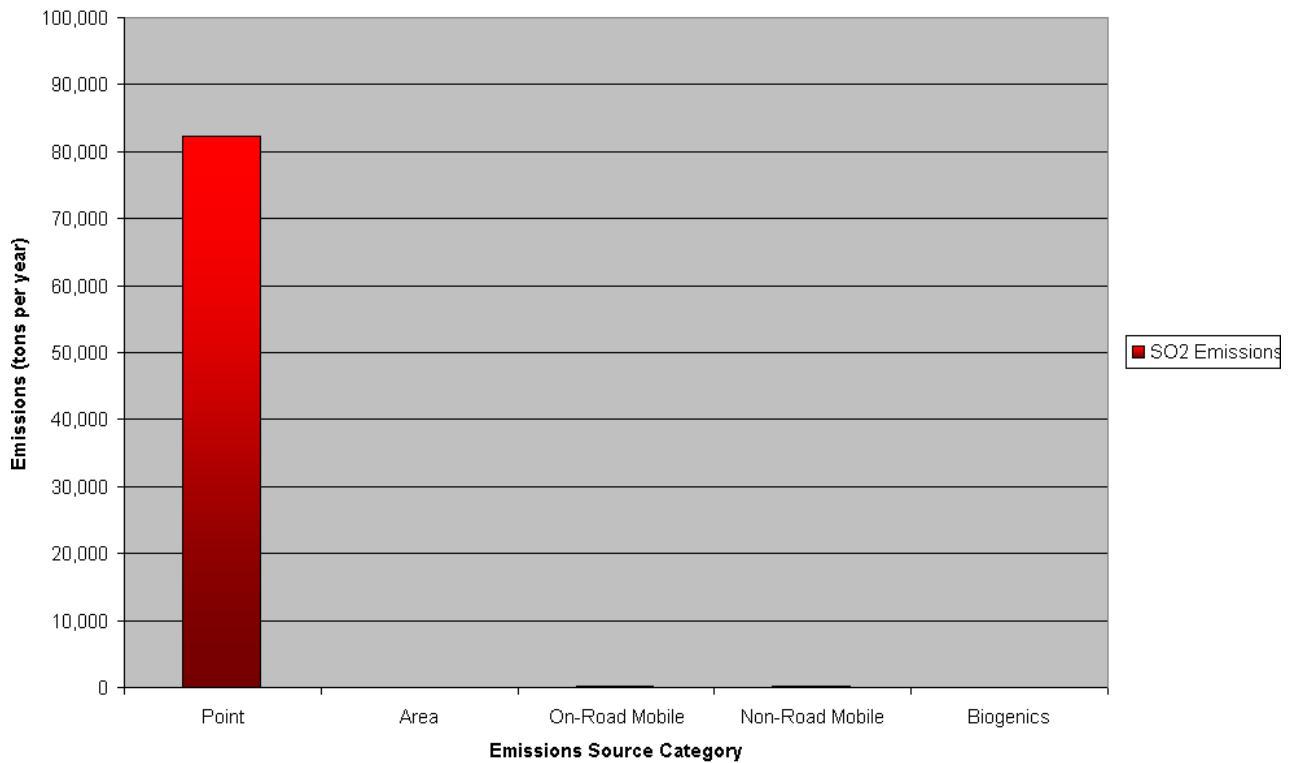
## 2.2 Attribution of Emissions Sources

Precursor pollutants to PM<sub>2.5</sub> can be emitted directly, such as in smoke from a fire, or they can form from chemical reactions of gases such as SO<sub>2</sub>, nitrogen dioxide and some organic gases. Sources of these precursor pollutants include power plants, gasoline and diesel engines, wood combustion, and high-temperature industrial processes such as smelters and steel mills. Other sources of the PM<sub>2.5</sub> precursor pollutants include mobile sources, area sources, biogenic, fires, windblown dust, and oceans.

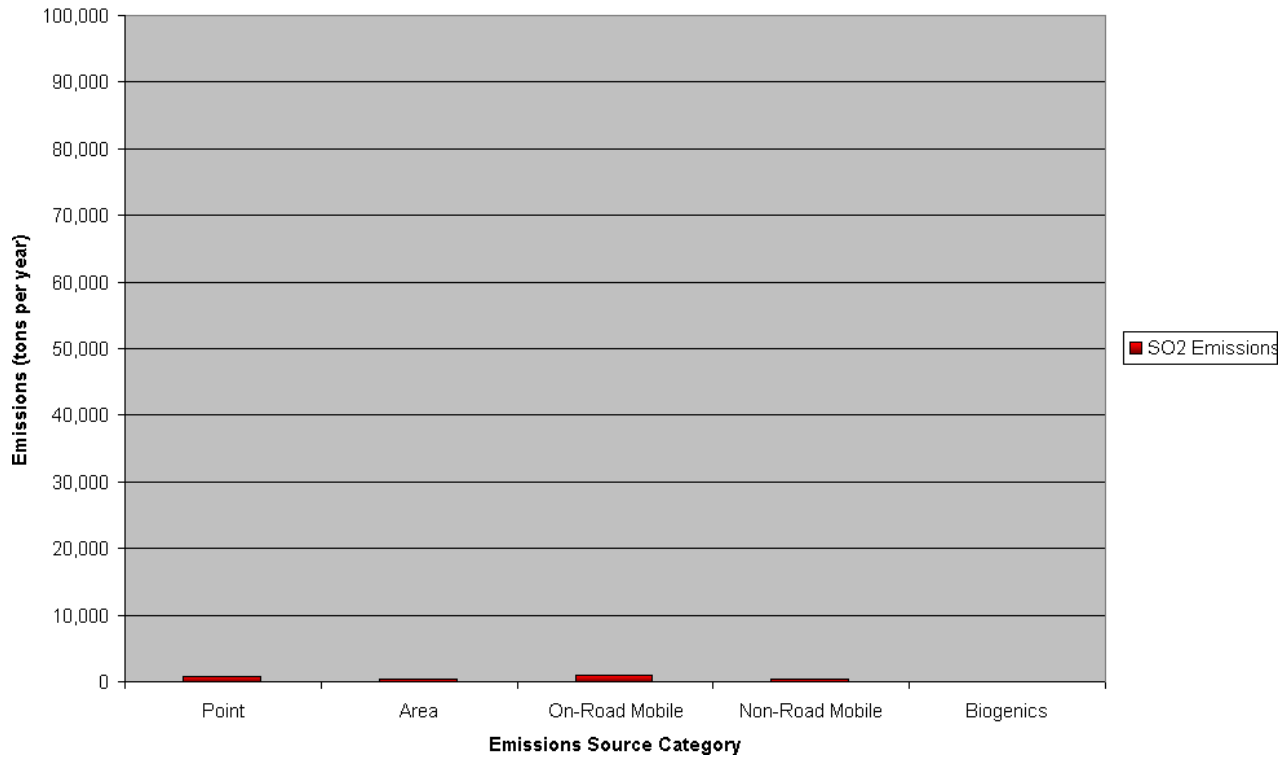
The speciated analysis of the PM<sub>2.5</sub> concentrations in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas presented above demonstrates that the OC and SO<sub>4</sub> components are the most important portions of the total PM<sub>2.5</sub> mass throughout the year at all three monitoring locations. OC is predominately attributed to biogenic volatile organic compound (VOC) emissions. SO<sub>4</sub> is associated with SO<sub>2</sub> emissions. NH<sub>4</sub> can have a variety of sources including both industrial and natural processes. What little NO<sub>3</sub> is present in the PM<sub>2.5</sub> nonattainment areas throughout the year are attributed to NO<sub>x</sub> from combustion sources. Of all these components and associated emission sources, SO<sub>4</sub> is the only dominant PM<sub>2.5</sub> component species found throughout the year

that is attributed to a set of emissions source (SO<sub>2</sub>) that are controllable through regulatory actions by the North Carolina Division of Air Quality (NCDAQ).

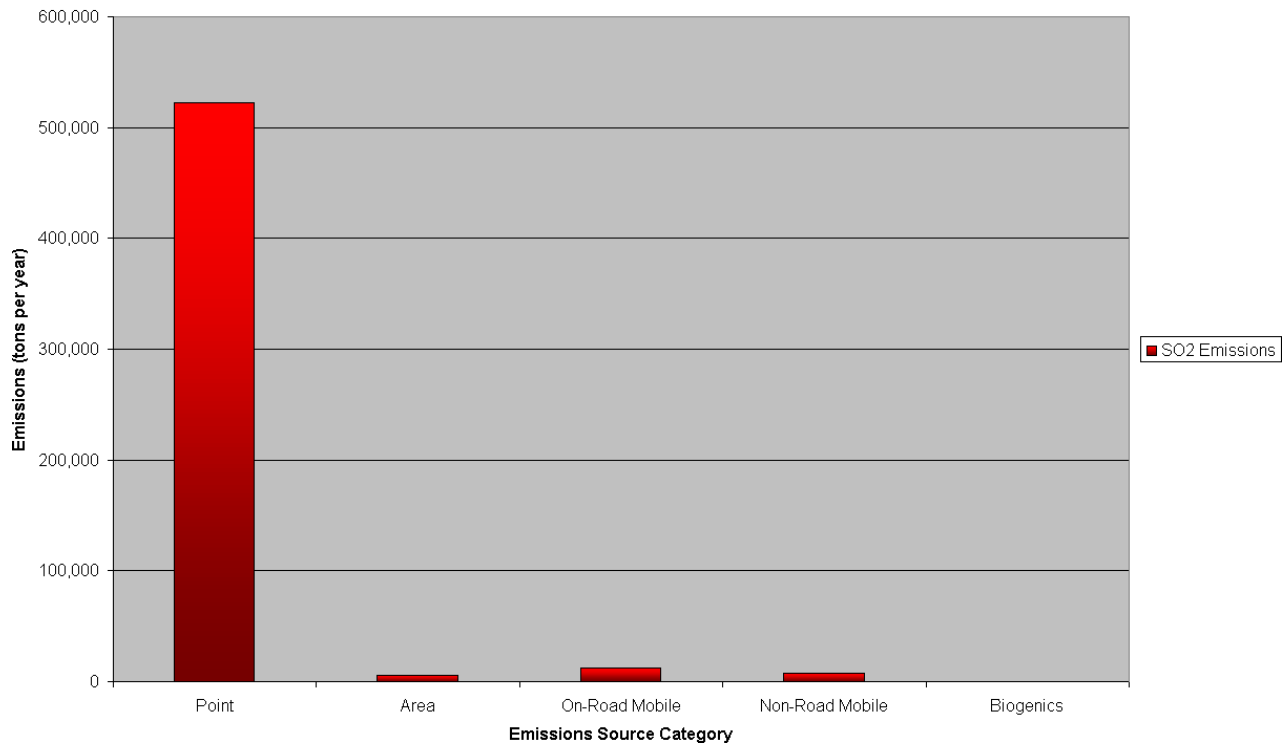
When evaluated throughout both nonattainment areas and across North Carolina, SO<sub>2</sub> is primarily from the point source sector. Figures 2.2-1 and 2.2-2 present the SO<sub>2</sub> emissions from the various source sectors in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas, respectively. Both figures are presented on same vertical axis scales to illustrate the significance of a single point source facility that is inside of the Hickory nonattainment area and immediately adjacent and upwind of the Triad nonattainment area. The magnitude of the point source sector completely masks the SO<sub>2</sub> emissions from all other source categories. When SO<sub>2</sub> emissions by source category are evaluated across North Carolina (Figure 2.2-3), the point source emissions are 6 times larger than emissions contained in either of the nonattainment area SO<sub>2</sub> emissions plots. Again, the magnitude of the point source sector completely masks the SO<sub>2</sub> emissions from all other source sectors.



**Figure 2.2-1. Hickory PM<sub>2.5</sub> Nonattainment Area SO<sub>2</sub> Emissions in 2002**



**Figure 2.2-2. Triad PM<sub>2.5</sub> Nonattainment Area SO<sub>2</sub> Emissions in 2002**



**Figure 2.2-3. North Carolina Total SO<sub>2</sub> Emissions in 2002**

### **2.3 Clean Air Fine Particulate Implementation Rule Presumptions on Precursor Pollutants**

The USEPA's Clean Air Fine Particulate Implementation Rule (72 FR 20586), commonly referred to as the PM<sub>2.5</sub> Implementation Rule, guides States as they develop state implementation plans in response to annual and/or daily PM<sub>2.5</sub> nonattainment. It establishes a hierarchy of precursor pollutants: SO<sub>2</sub> is always considered a precursor, NO<sub>x</sub> is presumptively a precursor, and VOCs and ammonia are presumed not to be precursors. The State of North Carolina is following the assertions and presumptions of significant and insignificant precursor pollutants established in the PM<sub>2.5</sub> Implementation Rule in this attainment demonstration. Further discussion on the significant or insignificance of the various precursor pollutants is discussed in Appendix O.



### 3.0 ATTAINMENT DEMONSTRATION METHODS AND INPUTS

The attainment modeling for the Hickory and Triad PM<sub>2.5</sub> nonattainment areas was performed in conjunction with the regional haze modeling being done by Southeast Regional Planning Organization (RPO), Visibility Improvement State and Tribal Association of the Southeast (VISTAS) and the PM<sub>2.5</sub> and ozone (O<sub>3</sub>) modeling being done by the Association of Southeastern Integrated Planning (ASIP). VISTAS and ASIP are managed by the ten Southeast states (Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee, Virginia and West Virginia). Since the VISTAS/ASIP regional modeling utilized annual simulations and includes modeling for the attainment year required for the Hickory and Triad PM<sub>2.5</sub> nonattainment areas, the NCDAQ decided to use this modeling for its attainment demonstration. The sections below outline the methods and inputs used by VISTAS/ASIP for the regional modeling.

#### 3.1 Analysis Method

The modeling analysis is a complex technical evaluation that begins by selection of the modeling system. VISTAS decided to use the following modeling system:

- **Meteorological Model:** The Pennsylvania State University/National Center for Atmospheric Research (PSU/NCAR) Mesoscale Meteorological Model (MM5) is a nonhydrostatic, prognostic meteorological model routinely used for urban- and regional-scale photochemical, fine particulate matter, and regional haze regulatory modeling studies.
- **Emissions Model:** The Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road mobile, area, point, fire and biogenic emission sources for photochemical grid models.
- **Air Quality Model:** The USEPA's Models-3/ Community Multiscale Air Quality (CMAQ) modeling system is a "One-Atmosphere" photochemical grid model capable of addressing O<sub>3</sub>, particulate matter, visibility and acid deposition at regional scale for periods up to one year.

Additionally, an historical year is selected to model that represents typical meteorological conditions in the Southeast when high ozone, high PM<sub>2.5</sub> and poor visibility are observed throughout the region. Once the historical year is selected, meteorological inputs are developed using the meteorological model. Emission inventories are also developed for the historical year and processed through the emissions model. These inputs are used in the air quality model to predict ozone, PM<sub>2.5</sub> and visibility, with the results compared to the historic data. The model performance is evaluated by comparing the modeled predicted data to the historic air quality data.

Once model performance is deemed adequate, typical baseline and future year emissions are processed through the emissions model. For this demonstration, the baseline year was 2002, which corresponds with the same year as the historic meteorology used in the modeling. The attainment future year the NCDAQ is using for this demonstration is 2009, since the mandatory attainment date for the Hickory and Triad PM<sub>2.5</sub> nonattainment areas is April 5, 2010. The

attainment date is set prior to the completion of the 2010 calendar year; therefore the attainment of the NAAQS would have to be met by the end of 2009. These emissions are processed through the air quality model with the meteorological inputs. The air quality modeling results are used to determine a relative reduction in future PM<sub>2.5</sub> concentrations, which is used in the attainment demonstration.

The complete modeling protocol used by the NCDAQ for this analysis can be found in Appendix D.1. For additional reference, the VISTAS/ASIP modeling protocol can be found in Appendix D.2.

### **3.2 Model Selection**

To ensure that a modeling study is defensible, care must be taken in the selection of the models to be used. The models selected must be scientifically appropriate for the intended application and be freely accessible to all stakeholders. Scientifically appropriate means that the models address important physical and chemical phenomena in sufficient detail, using peer-reviewed methods. Freely accessible means that model formulations and coding are freely available for review and that the models are available to stakeholders, and their consultants, for execution and verification at little or no cost.

The following sections outline the criteria for selecting a modeling system that is both defensible and capable of meeting the study's goals. These criteria were used in selecting the modeling system used for this modeling attainment demonstration.

#### **3.2.1 Selection of Air Quality Model**

##### **3.2.1.1 Criteria**

For an air quality model to qualify as a candidate for use in an attainment demonstration, a State needs to show that it meets several general criteria:

- The model has received a scientific peer review.
- The model can be demonstrated applicable to the problem on a theoretical basis.
- Data bases needed to perform the analysis are available and adequate.
- Available past appropriate performance evaluations have shown the model is not biased toward underestimates or overestimates.
- A protocol on methods and procedures to be followed has been established.
- The developer of the model must be willing to make the source code available to users for free or for a reasonable cost, and the model cannot otherwise be proprietary.

##### **3.2.1.2 Overview of CMAQ**

The air quality model selected for this study was CMAQ version 4.5, which was the most recent release at the point the attainment modeling exercise started. For more than a decade, the USEPA has been developing the Models-3 CMAQ modeling system with the overarching aim of producing a “One-Atmosphere” air quality modeling system capable of addressing ozone, fine

particulate matter, visibility and acid deposition within a common platform. The original justification for the Models-3 development emerged from the challenges posed by the CAAA and the USEPA's desire to develop an advanced modeling framework for "holistic" environmental modeling utilizing state-of-science representations of atmospheric processes in a high performance computing environment. The USEPA completed the initial stage of development with Models-3 and released the CMAQ model in mid 1999 as the initial operating science model under the Models-3 framework.

Another reason for choosing CMAQ as the atmospheric model is the ability to do one-atmospheric modeling. Since the NCDAQ will be using the same modeling exercise for the ozone and PM<sub>2.5</sub> attainment demonstration state implementation plans (SIPs), as well as the regional haze SIP, having a model that can handle both ozone and particulate matter is essential. A number of features in CMAQ's theoretical formulation and technical implementation make the model well suited for annual PM<sub>2.5</sub> modeling.

CMAQ contains three options for treating secondary organic aerosol (SOA), latest being the Secondary Organic Aerosol Model (SORGAM) that was updated in August 2003 to be a reversible semi-volatile scheme whereby VOC emissions can be converted to condensable gases that can then form SOA and then evaporate back into condensable gases depending on atmospheric conditions.

The CMAQ chemical-transport model processor (CTM) requires the following inputs:

- Three-dimensional hourly meteorological fields that will be generated by the CMAQ MCIP2.3 processing of the BAMS MM5 output
- Three-dimensional hourly emissions generated by SMOKE
- Initial conditions and boundary conditions
- Topographic information
- Land use categories
- Photolysis rates generated by the CMAQ JPROC processor

The configuration used for this modeling demonstration, as well as a more detailed description of the CMAQ\_SOA (CMAQ version with SOA modification) model, can be found in Appendix D.1. The resulting model performance evaluation can be found in Appendix J.

### **3.2.2 Selection of Meteorological Model**

#### **3.2.2.1 Criteria**

Meteorological models, either through objective, diagnostic, or prognostic analysis, extend available information about the state of the atmosphere to the grid upon which photochemical grid modeling is to be carried out. The criteria for selecting a meteorological model are based on both the models ability to accurately replicate important meteorological phenomena in the region of study, and the model's ability to interface with the rest of the modeling systems, particularly the air quality model. With these issues in mind, the following criteria were established for the meteorological model to be used in this study:

- Non-Hydrostatic Formulation
- Reasonably current, peer reviewed formulation
- Simulates Cloud Physics
- Publicly available at no or low cost
- Output available in I/O API format
- Supports Four Dimensional Data Assimilation
- Enhanced treatment of Planetary Boundary Layer heights for AQ modeling

### 3.2.2.2 Overview of MM5

The non-hydrostatic MM5 model is a three-dimensional, limited-area, primitive equation, prognostic model that has been used widely in regional air quality model applications. The basic model has been under continuous development, improvement, testing, and open peer-review for more than 20 years and has been used worldwide by hundreds of scientists for a variety of mesoscale studies.

MM5 uses a terrain-following non-dimensionalized pressure, or "sigma", vertical coordinate similar to that used in many operational and research models. In the non-hydrostatic MM5, the sigma levels are defined according to the initial hydrostatically balanced reference state so that the sigma levels are also time-invariant. The gridded meteorological fields produced by MM5 are directly compatible with the input requirements of "one atmosphere" air-quality models using this coordinate. MM5 fields can be easily used in other regional air quality models with different coordinate systems by performing a vertical interpolation, followed by a mass-conservation readjustment.

Distinct planetary boundary layer parameterizations are available for air-quality applications, both of which represent sub-grid-scale turbulent fluxes of heat, moisture and momentum. One scheme uses a first-order eddy diffusivity formulation for stable and neutral environments and a modified first-order scheme for unstable regimes. The other scheme uses a prognostic equation for the second-order turbulent kinetic energy, while diagnosing the other key boundary layer terms.

Initial and lateral boundary conditions are specified for real-data cases from mesoscale three-dimensional analyses performed at 12-hour intervals on the outermost grid mesh selected by the user. Surface fields are analyzed at three-hour intervals. The GEOS-CHEM global chemical transport model was run for 2002 to develop the initial and boundary conditions. More details on the GEOS-CHEM model used in this attainment demonstration can be found in Appendix P.

A Cressman-based technique is used to analyze standard surface and radiosonde observations, using the National Meteorological Center's spectral analysis, as a first guess. The lateral boundary data are introduced using a relaxation technique applied in the outermost five rows and columns of the coarsest grid domain.

Results of detailed performance evaluations of the MM5 modeling system in regulatory air quality application studies have been widely reported in the literature (e.g., Emery et al., 1999;

Tesche et al., 2000, 2003) and many have involved comparisons with other prognostic models such as the Regional Atmospheric Modeling System (RAMS) and the Systems Application International Mesoscale Model. The MM5 enjoys a far richer application history in regulatory modeling studies compared with RAMS or other models. Furthermore, in evaluations of these models in over 60 recent regional scale air quality application studies since 1995, it has generally been found that the MM5 model tends to produce somewhat better photochemical model inputs than alternative models.

The databases required for setting up, exercising, and evaluating the MM5 model for the 2002 season consist of various fixed and variable inputs.

- Topography: High resolution (e.g., 30 sec to 5 min) topographic information derived from the Geophysical Data Center global datasets from the NCAR terrain databases are available for prescribing terrain elevations throughout the 36-km and 12-km grid domain.
- Vegetation Type and Land Use: Vegetation type and land use information on the 36-km grid may be developed using the PSU/NCAR 10 min. (~18.5 km) databases while for the 12-km grids, the United States Geological Survey (USGS) data are available.
- Atmospheric Data: Initial and boundary conditions to the MM5 may be developed from operationally analyzed fields derived from the National Centers for Environmental Prediction (NCEP) Eta model (40 km resolution) following the procedures outlined by Stauffer and Seaman (1990). These 3-hour synoptic-scale initialization data include the horizontal wind components (u and v), temperature, and relative humidity at the standard pressure levels, plus sea-level pressure and ground temperature. Here, ground temperature represents surface temperature over land and sea-surface temperature over water.
- Water Temperature: Water temperatures required on both 36-km and 12-km grids can be derived from the Eta skin temperature variable. These temperatures are bi-linearly interpolated to each model domain and, where necessary, filtered to smooth out irregularities.
- Clouds and Precipitation: While the non-hydrostatic MM5 treats cloud formation and precipitation directly through explicit, resolved-scale, and parameterized sub-grid scale processes, the model does not require precipitation or cloud input. The potential for precipitation and cloud formation enters through the thermodynamic and cloud processes formulations in the model. The only precipitation-related input required is the initial mixing ratio field that is developed from the National Weather Service (NWS) and National Meteorological Center (NMC) datasets.
- Multi-Scale Four Dimensional Data Assimilation (FDDA): The standard "multi-scale" data assimilation strategy to be used on the 36-km and 12-km grids will objectively analyze three-dimensional fields produced every 3 hours from the NWS rawinsonde wind, temperature, and mixing ratio data, and similar analyses are generated every three hours from the available NWS surface data.

The configuration used for this modeling demonstration, as well as a more detailed description of the MM5 model, can be found in Appendix I as well as Section 4.6 of the Modeling Protocol (Appendix D.1).

### 3.2.3 Selection of Emissions Processing System

#### 3.2.3.1 Criteria

The principal criterion for an emissions processing system is that it accurately prepares emissions files in a format suitable for the photochemical grid model being used. The following list includes clarification of this criterion and additional desirable criteria for effective use of the system.

- File System Compatibility with the I/O API
- File Portability
- Ability to grid emissions on a Lambert Conformal projection
- Report Capability
- Graphical Analysis Capability
- MOBILE6 Mobile Source Emissions
- Biogenic Emissions Inventory System version 2 (BEIS-3)
- Ability to process emissions for the proposed domain in a reasonable amount of time.
- Ability to process control strategies
- Little or no cost for acquisition and maintenance
- Expandable to support other species and mechanisms

#### 3.2.3.2 Overview of SMOKE

The Sparse Matrix Operator Kernel Emissions (SMOKE) Modeling System was originally developed at the Micro-computing Center of North Carolina. As with most emissions models, SMOKE is principally an *emission processing system* and not a true *emissions modeling system* in which emissions estimates are simulated from “first principles”. This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting emissions inventory data into the formatted emission files required by an air quality simulation model. For mobile sources, SMOKE actually simulates emissions rates based on input mobile-source activity data, emission factors and outputs from transportation travel-demand models.

SMOKE was originally designed to allow emissions data processing methods to utilize emergent high-performance-computing as applied to sparse-matrix algorithms. Indeed, SMOKE is the fastest emissions processing tool currently available to the air quality modeling community. The sparse matrix approach utilized throughout SMOKE permits both rapid and flexible processing of emissions data. The processing is rapid because SMOKE utilizes a series of matrix calculations instead of less efficient algorithms used in previous systems. The processing is flexible because the processing steps of temporal projection, controls, chemical speciation, temporal allocation, and spatial allocation have been separated into independent operations wherever possible. The results from these steps are merged together at a final stage of processing.

SMOKE contains a number of major features that make it an attractive component of the modeling system. The model supports a variety of input formats from other emissions processing systems and models. It supports both gridded and county total land use scheme for biogenic emissions modeling. SMOKE can accommodate emissions files from up to 10 countries and any pollutant can be processed by the system.

For additional information about the SMOKE model please refer to Appendix D.1.

### 3.3 Selection of the Modeling Year

A crucial step to SIP modeling is the selection of the period of time to model to represent current air quality conditions and to project changes in air quality in response to changes in emissions. The year 2002 was selected as the base year for several reasons.

The USEPA's April 2007 *Guidance on the use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM<sub>2.5</sub>, and Regional Haze* (Attainment Modeling Guidance) identifies specific goals to consider when selecting one or more episodes for use in modeling to demonstrate the attainment of the NAAQS. The USEPA recommends that episode selection derive from three principal criteria:

- Simulate a variety of meteorological conditions
- Model time periods in which observed concentrations are close to the appropriate baseline design value
- Model periods for which extensive air quality/meteorological data bases exist
- Model a sufficient number of days so that the modeled attainment test applied at each monitor violating the NAAQS is based on multiple days

VISTAS adopted a logical, stepwise approach in implementing the Attainment Modeling Guidance in order to identify the most preferable, representative modeling year. These steps include the following:

- Representativeness of Meteorological Conditions: The VISTAS meteorological contractor (BAMS) identified important meteorological characteristics and data sets in the VISTAS region directly relevant to the evaluation of candidate annual modeling episodes. This analysis is discussed in more detail in the project report in Appendix I, Attachment 1.
- Initial Episode Typing: At the time of selection in 2003, meteorological and air quality data were available for 2002 for model inputs and model performance evaluation. VISTAS used Classification and Regression Tree (CART) analyses to evaluate the candidate modeling years (Douglas et al., 2006). The year 2002 was found to be representative of conditions in the other years. Subsequently, these analyses were repeated with the meteorological and air quality monitoring data for 2000 to 2004 to evaluate how well the 2002 modeling year represented the full 2000-2004 baseline period. This analysis confirmed that PM<sub>2.5</sub> concentrations in 2002 were representative of the five-year baseline period. The CART analysis is discussed in more detail in Appendix P.

- Data Availability: In parallel with the CART analysis, episode characterization analyses, collaborative investigations by VISTAS states (e.g., North Carolina, Georgia, and Florida) intensively studied the availability of PM<sub>2.5</sub>, meteorological, and emissions data and representativeness of alternative baseline modeling periods from a regulatory standpoint. Additionally, 2002 was the year that the USEPA was requiring states to provide emissions inventory data for the Consolidated Emissions Reporting Rule (CERR), it made sense to use 2002 as the modeling year to take advantage of the 2002 inventory.
- Years to be used by other RPOs: VISTAS also considered what years other RPO would be modeling, and several had already chosen calendar year 2002 as the modeling year.

After a lengthy process of integrated studies, the episode selection process culminated in the selection of calendar year 2002 (1 January through 31 December) as the most current, representative, and pragmatic choice for modeling. All of the USEPA criteria for model year selection were directly considered in this process together with many other considerations (e.g., timing of new emissions or aerometric data deliveries by the USEPA or the states to the modeling teams).

### **3.4 Modeling Domains**

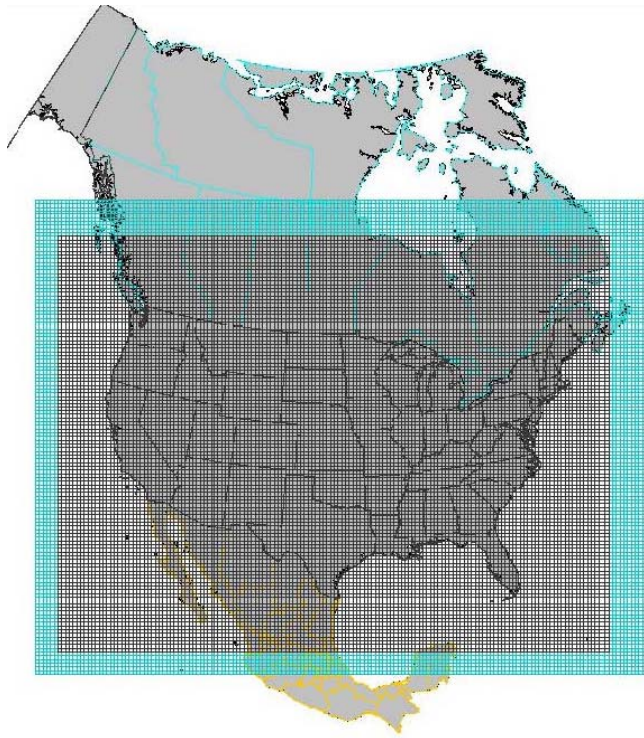
#### **3.4.1 Horizontal Modeling Domain**

The CMAQ\_SOA model was run in one-way nested grid mode. This allowed the larger outer domains to feed concentration data to the inner nested domain. One-way nesting is believed to be appropriate for the generally stagnant conditions experienced during North Carolina's poor air quality episodes. Two-way nesting was not considered due to numerical and computational uncertainty associated with the technique.

The horizontal coarse grid modeling domain boundaries were determined through a national effort to develop a common grid projection and boundary. A smaller 12-km grid, modeling domain was selected in an attempt to balance location of areas of interest, such as ozone and fine particulate matter nonattainment areas. Processing time was also a factor in choosing a smaller 12-km grid, modeling domain.

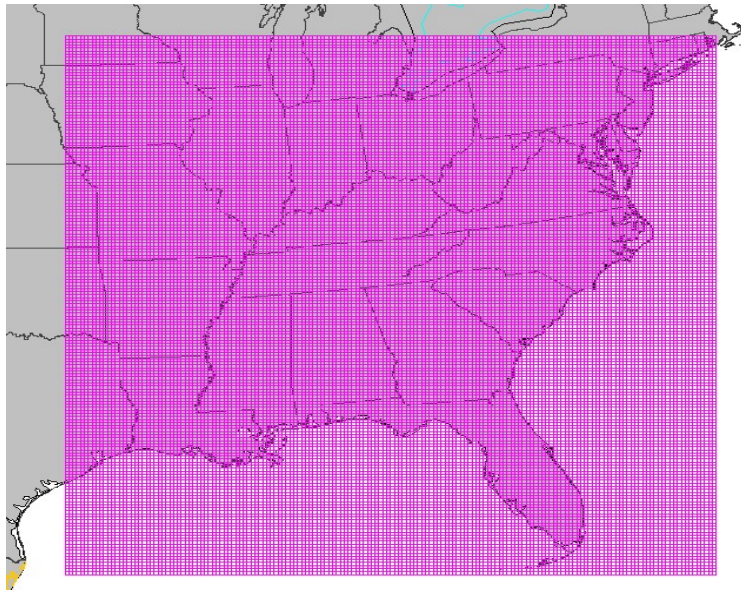
The coarse 36-km horizontal grid domain covers the continental United States. This domain was used as the outer grid domain for MM5 modeling with the CMAQ\_SOA domain nested within the MM5 domain. Figure 3.4.1-1 shows the MM5 horizontal domain as the outer most, blue grid with the CMAQ\_SOA 36-km domain nested in the MM5 domain.





**Figure 3.4.1-1. The MM5 and CMAQ\_SOA 36-km Horizontal Domains**

To achieve finer spatial resolution in the VISTAS states, a one-way nested high resolution (12-km grid resolution) was used. Figure 3.4.1-2 shows the 12-km grid, modeling domain for the VISTAS region. This is the modeling domain on which the attainment test results are based.



**Figure 3.4.1-2. VISTAS 12-km Modeling Domain**

### **3.4.2 Vertical Modeling Domain**

The vertical grid used in the MM5 modeling primarily defines the CMAQ\_SOA vertical structure. The MM5 model employed a terrain following coordinate system defined by pressure, using 34 layers that extend from the surface to the 100 millibars (mb). Table 3.4.1-1 lists the layer definitions for both MM5 and for CMAQ. A layer-averaging scheme is adopted for CMAQ to reduce the computational cost of the CMAQ simulations. A layer-averaging scheme was used to generate 19 vertical layers for CMAQ\_SOA to reduce the computational cost of the CMAQ\_SOA simulations. The effects of layer averaging were evaluated in conjunction with the modeling effort and were found to have a relatively minor effect on the model performance metrics when both the 34 layer and a 19 layer CMAQ\_SOA models were compared to ambient monitoring data. Further discussion on the layer-averaging scheme can be found in Section 5 of the Modeling Protocol in Appendix D.1.

**Table 3.4.1-1: Vertical Layer Definition For MM5 and CMAQ**

MM5 Simulation					CMAQ 19 Layers				
Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)	Layer	Sigma	Pressure (mb)	Height (m)	Depth (m)
<b>34</b>	<b>0.000</b>	<b>100</b>	<b>14662</b>	<b>1841</b>	<b>19</b>	<b>0.000</b>	<b>100</b>	<b>14662</b>	<b>6536</b>
33	0.050	145	12822	1466		0.050	145		
32	0.100	190	11356	1228		0.100	190		
31	0.150	235	10127	1062		0.150	235		
30	0.200	280	9066	939		0.200	280		
<b>29</b>	<b>0.250</b>	<b>325</b>	<b>8127</b>	<b>843</b>	<b>18</b>	<b>0.250</b>	<b>325</b>	<b>8127</b>	<b>2966</b>
28	0.300	370	7284	767		0.300	370		
27	0.350	415	6517	704		0.350	415		
26	0.400	460	5812	652		0.400	460		
<b>25</b>	<b>0.450</b>	<b>505</b>	<b>5160</b>	<b>607</b>	<b>17</b>	<b>0.450</b>	<b>505</b>	<b>5160</b>	<b>1712</b>
24	0.500	550	4553	569		0.500	550		
23	0.550	595	3984	536		0.550	595		
<b>22</b>	<b>0.600</b>	<b>640</b>	<b>3448</b>	<b>506</b>	<b>16</b>	<b>0.600</b>	<b>640</b>	<b>3448</b>	<b>986</b>
21	0.650	685	2942	480		0.650	685		
<b>20</b>	<b>0.700</b>	<b>730</b>	<b>2462</b>	<b>367</b>	<b>15</b>	<b>0.700</b>	<b>730</b>	<b>2462</b>	<b>633</b>
19	0.740	766	2095	266		0.740	766		
<b>18</b>	<b>0.770</b>	<b>793</b>	<b>1828</b>	<b>259</b>	<b>14</b>	<b>0.770</b>	<b>793</b>	<b>1828</b>	<b>428</b>
17	0.800	820	1569	169		0.800	820		
<b>16</b>	<b>0.820</b>	<b>838</b>	<b>1400</b>	<b>166</b>	<b>13</b>	<b>0.820</b>	<b>838</b>	<b>1400</b>	<b>329</b>
15	0.840	856	1235	163		0.840	856		
<b>14</b>	<b>0.860</b>	<b>874</b>	<b>1071</b>	<b>160</b>	<b>12</b>	<b>0.860</b>	<b>874</b>	<b>1071</b>	<b>160</b>
13	0.880	892	911	158		0.880	892		
<b>12</b>	<b>0.900</b>	<b>910</b>	<b>753</b>	<b>78</b>	<b>10</b>	<b>0.900</b>	<b>910</b>	<b>753</b>	<b>155</b>
11	0.910	919	675	77		0.910	919		
<b>10</b>	<b>0.920</b>	<b>928</b>	<b>598</b>	<b>77</b>	<b>9</b>	<b>0.920</b>	<b>928</b>	<b>598</b>	<b>153</b>
9	0.930	937	521	76		0.930	937		
<b>8</b>	<b>0.940</b>	<b>946</b>	<b>445</b>	<b>76</b>	<b>8</b>	<b>0.940</b>	<b>946</b>	<b>445</b>	<b>76</b>
<b>7</b>	<b>0.950</b>	<b>955</b>	<b>369</b>	<b>75</b>	<b>7</b>	<b>0.950</b>	<b>955</b>	<b>369</b>	<b>75</b>
<b>6</b>	<b>0.960</b>	<b>964</b>	<b>294</b>	<b>74</b>	<b>6</b>	<b>0.960</b>	<b>964</b>	<b>294</b>	<b>74</b>
<b>5</b>	<b>0.970</b>	<b>973</b>	<b>220</b>	<b>74</b>	<b>5</b>	<b>0.970</b>	<b>973</b>	<b>220</b>	<b>74</b>
<b>4</b>	<b>0.980</b>	<b>982</b>	<b>146</b>	<b>37</b>	<b>4</b>	<b>0.980</b>	<b>982</b>	<b>146</b>	<b>37</b>
<b>3</b>	<b>0.985</b>	<b>986.5</b>	<b>109</b>	<b>37</b>	<b>3</b>	<b>0.985</b>	<b>986.5</b>	<b>109</b>	<b>37</b>
<b>2</b>	<b>0.990</b>	<b>991</b>	<b>73</b>	<b>36</b>	<b>2</b>	<b>0.990</b>	<b>991</b>	<b>73</b>	<b>36</b>
<b>1</b>	<b>0.995</b>	<b>995.5</b>	<b>36</b>	<b>36</b>	<b>1</b>	<b>0.995</b>	<b>995.5</b>	<b>36</b>	<b>36</b>
<b>0</b>	<b>1.000</b>	<b>1000</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>1.000</b>	<b>1000</b>	<b>0</b>	<b>0</b>

### 3.5 Baseline Emissions Inventory

The CAAA revised many of the provisions of the CAA related to attainment of the NAAQS and the protection of visibility in mandatory Class I Federal areas (certain national parks and wilderness areas). These revisions established new emission inventory requirements applicable to certain areas that were designated nonattainment for certain pollutants. In the case of particulate matter, the emission inventory provisions are in the general provisions under Section 172(c)(3).

There are various types of emission inventories. The first is the actual base year inventory. This inventory is the base year emissions that correspond to the meteorological data used, which for this modeling effort is data from 2002. These emissions are used for evaluating the air quality model performance.

The second type of inventory is the typical base year inventory. This inventory is similar to the actual base year inventory, except that for sources whose emissions change significantly from year to year, a more typical emission value is used. In this modeling effort, typical emissions were developed for the electric generating units (EGUs) and the wildland fire emissions. The air quality modeling runs using the typical base year inventory are used to calculate relative reduction factors used in the attainment demonstration test.

The future year base inventory is the third type of inventory and is an inventory developed for some future year for which attainment of the fine particulate matter standard is needed. For this modeling project, the future year inventory will be 2009, the last complete year for which the standard must be attained. It is the future base year inventory that control strategies and sensitivities are applied to determine what controls might be needed in order to attain and maintain the annual PM<sub>2.5</sub> standard.

Within each type of emission inventory, there are five different emission inventory source classifications: stationary point and area sources, off-road and on-road mobile sources, and biogenic sources. Stationary point sources are those sources that emit greater than a specified tonnage per year, with data provided at the facility level. Electric generating utilities and industrial sources are the major categories for stationary point sources.

Stationary area sources are those sources whose individual emissions are relatively small, but due to the large number of these sources, the collective emissions from the source category could be significant (i.e., dry cleaners, service stations, agricultural sources, fire emissions, etc.). These types of emissions are estimated on a countywide level.

Non-road (or off-road) mobile sources are equipment that can move but do not use the roadways, i.e., lawn mowers, construction equipment, railroad locomotives, aircraft, etc. The emissions from these sources, like stationary area sources, are estimated on a countywide level.

On-road mobile sources are automobiles, buses, trucks, and motorcycles that use the roadway system. The emissions from these sources are estimated by vehicle type and road type, and are summed to the countywide level.

Biogenic sources are the natural sources like trees, crops, grasses and natural decay of plants. The emissions from these sources are estimated at the grid cell level and summarized to the county level.

For each type of emission inventory and each source classification, the pollutants inventoried include VOC, NO<sub>x</sub>, PM<sub>2.5</sub>, coarse particulate (PM<sub>10</sub>), ammonia (NH<sub>3</sub>) and SO<sub>2</sub>. Table 3.5-1 presents a summary of the actual and typical 2002 annual emissions from the various source sectors for the counties in the Hickory and Triad PM<sub>2.5</sub> nonattainment areas. The full emission

summaries for all counties in North Carolina and all states in the VISTAS/ASIP region can be found in Appendix E.

**Table 3.5-1. 2002 Annual Emission Summaries**

**2002 Annual Emissions Summaries For Catawba County (Hickory Nonattainment Area)**

	Point						Non-road					
	VOC	NOx	SO2	PM-10	PM-2.5	NH3	VOC	NOx	SO2	PM-10	PM-2.5	NH3
<b>Actual</b>	4083.70	19088.60	82320.10	5016.70	4240.10	4.98	1107.30	1619.70	99.70	90.40	86.50	1.40
<b>Typical</b>	4083.70	19269.60	82371.70	5011.30	4238.90	5.00	1107.30	1619.70	99.70	90.40	86.50	1.40
	Area						Mobile					
	VOC	NOx	SO2	PM-10	PM-2.5	NH3	VOC	NOx	SO2	PM-10	PM-2.5	NH3
<b>Actual</b>	5051.90	769.60	91.30	4513.40	1189.20	477.30	6040.40	7049.90	259.80	142.00	100.10	206.40
<b>Typical</b>	5053.20	770.40	91.50	4516.20	1191.50	477.50	6040.40	7049.90	259.80	142.00	100.10	206.40

Emissions reported as tons/year.

**2002 Annual Emission Summaries For Davidson County (Triad Nonattainment Area)**

	Point						Non-road					
	VOC	NOx	SO2	PM-10	PM-2.5	NH3	VOC	NOx	SO2	PM-10	PM-2.5	NH3
<b>Actual</b>	2791.30	3240.70	408.00	457.50	391.70	6.50	809.10	1545.10	101.70	77.30	73.20	0.90
<b>Typical</b>	2791.30	3240.70	408.00	457.50	391.70	6.50	809.10	1545.10	101.70	77.30	73.20	0.90
	Area						Mobile					
	VOC	NOx	SO2	PM-10	PM-2.5	NH3	VOC	NOx	SO2	PM-10	PM-2.5	NH3
<b>Actual</b>	4804.60	655.60	97.20	4464.10	1217.90	558.80	5072.00	6456.20	229.90	128.90	92.20	175.50
<b>Typical</b>	4806.80	656.70	97.50	4468.80	1221.90	559.00	5072.00	6456.20	229.90	128.90	92.20	175.50

Emissions reported as tons/year.

**2002 Annual Emission Summaries For Guilford County (Triad Nonattainment Area)**

	Point						Non-road					
	VOC	NOx	SO2	PM-10	PM-2.5	NH3	VOC	NOx	SO2	PM-10	PM-2.5	NH3
<b>Actual</b>	3931.80	218.70	282.20	221.60	135.00	10.60	3394.10	4408.00	376.30	358.90	344.10	3.70
<b>Typical</b>	3931.80	218.70	282.20	221.60	135.00	10.60	3394.10	4408.00	376.30	358.90	344.10	3.70
	Area						Mobile					
	VOC	NOx	SO2	PM-10	PM-2.5	NH3	VOC	NOx	SO2	PM-10	PM-2.5	NH3
<b>Actual</b>	9393.70	2295.80	231.70	9006.30	2332.30	585.20	12727.20	16815.50	675.20	331.40	227.20	538.10
<b>Typical</b>	9393.60	2296.00	231.80	9006.40	2332.40	585.30	12727.20	16815.50	675.20	331.40	227.20	538.10

Emissions reported as tons/year.

In the sections that follow, a synopsis of the inventories used for each source classifications are discussed. The detail discussions of the emissions inventory development can be found in Appendix F. Further information on the emission inventory development for the entire southeast and the inventories used for other RPOs can be found in Appendix P. Discussion of other input requirements for SMOKE can also be found in Section 4.6 of the Modeling Protocol (Appendix D.1).

### **3.5.1 Stationary Point Sources**

Point source emissions are emissions from individual sources having a fixed location. Generally, these sources must have permits to operate, and their emissions are inventoried on a regular schedule. Large sources having the potential to emit at least 100 tons per year (tpy) of a criteria pollutant, 10 tpy of a single hazardous air pollutant (HAP), or 25 tpy total HAP are inventoried annually. Smaller sources have been inventoried less frequently. The point source emissions data can be grouped as EGU sources and other industrial point sources, also called non-electric generating units (non-EGUs). Appendix F.1 documents the point source modeling inventory development in more details

#### **3.5.1.1 Electric Generating Units**

The actual base year inventory for the EGU sources used 2002 continuous emissions monitoring (CEM) data reported to the USEPA's Acid Rain program or 2002 hourly emissions data provided by stakeholders. These data provide hourly emissions profiles for SO<sub>2</sub> and NO<sub>x</sub> that can be used in air quality modeling. Emissions profiles are used to estimate emissions of other pollutants based on measured emissions of SO<sub>2</sub> and NO<sub>x</sub>.

Emissions from EGU vary daily and seasonally as a function of variability in energy demand and utilization and outage schedules. Since emission from EGUs represent a significant portion of the emission inventory, a typical base year emissions inventory was developed to avoid anomalies in future year emissions due to variability in meteorology, economic and outage factors in 2002. This approach is consistent with the Attainment Modeling Guidance. To develop a typical year 2002 emissions inventory for EGU sources, each unit's average CEM heat input for 2000 through 2004 was divided by the 2002 actual heat input to generate a unit specific normalizing factor. This normalizing factor was then multiplied by the 2002 actual emissions. The heat inputs for the period 2000 through 2004 were used because the modeling current design values use monitored data from this same 5-year period. If a unit was shut down for an entire year during the 2000 through 2004 period, the average of the years the unit was operational was used. If a unit was shut down in 2002, but not permanently shutdown, the emissions and heat inputs from 2001 (or 2000) were used in the normalizing calculations. For more information about typical 2002 EGU emissions, please reference to Section 2.1.4 (EGU Analysis) of Appendix F.1 (Point Source Emissions Inventory (EI) documentation).

As part of the air quality modeling, VISTAS, in cooperation with the other eastern RPOs, contracted with ICF Resources, L.L.C., to generate future year emission inventories for the electric generating sector of the contiguous United States using the Integrated Planning Model (IPM). IPM is a dynamic linear optimization model that can be used to examine air pollution control policies for various pollutants throughout the contiguous United States for the entire electric power system. The dynamic nature of IPM enables projection of the behavior of the power system over a specified future period. Optimization logic in IPM determines the least-cost means of meeting electric generation and capacity requirements while complying with specified constraints including air pollution regulations, transmission bottlenecks, and plant-specific operational constraints. The versatility of IPM allows users to specify which constraints to exercise, and to populate IPM with their own datasets. For more discussion on how the IPM data was developed, please refer to Section 3.1.1 (Chronology of the Development of EGU

Projections) and Section 3.1.2 (VISTAS/MRPO IPM runs for EGU sources) of Appendix F.1 (Point Source EI documentation).

The IPM modeling runs took into consideration both The Clean Air Interstate Rule (CAIR) implementation and North Carolina's Clean Smokestack Act (CSA) requirements for Duke Power and Progress Energy. The VISTAS States and stakeholders also provided changes for the following:

- NO<sub>x</sub> post-combustion control on existing units
- SO<sub>2</sub> scrubbers on existing units
- SO<sub>2</sub> emission limitations
- Particulate Matter (PM) controls on existing units
- Summer net dependable capacity
- Heat rate for existing units
- SO<sub>2</sub> and NO<sub>x</sub> control plans based on State rules or enforcement settlements

For a detailed discussion about how IPM took consideration for federal, state and source-specific requirements, please also refer to Appendix F.1.

### **3.5.1.2 Other Industrial Point Sources**

For the non-EGU sources, the same inventory is used for both the actual and typical base year emissions inventories. The non-EGU category uses annual emissions as reported under the CERR for the year 2002. These emissions are temporally allocated to month, day, and hour using source category code (SCC)-based allocation factors.

The general approach for assembling future year data was to use recently updated growth and control data consistent with the USEPA's CAIR analyses. This data was supplemented with state-specific growth factors and stakeholder input on growth assumptions.

### **3.5.2 Stationary Area Sources**

Stationary area sources are sources whose individual emissions are relatively small, but due to the large number of these sources, the collective emissions could be significant (i.e., combustion of fuels for heating, structure fires, service stations, etc.). Emissions are estimated by multiplying an emission factor by some known indicator of collective activity, such as fuel usage, number of households, or population. Stationary area source emissions are estimated at the countywide level.

A portion of the area source 2002 base year inventory for North Carolina was developed by the NCDAQ and provided to the VISTAS/ASIP contractor. The VISTAS/ASIP contractor calculated the remaining portion of the area source inventory. The sources estimated by the contractor include emissions from animal husbandry, wild land fires, and particulate matter from paved and unpaved roads. For the other states within the modeling domain, either state-supplied data or data reported under CERR for 2002 was used.

The actual base year inventory will serve as the typical base year inventory for all area source categories except for wild land fires. For wild land fires, a typical year inventory was used to avoid anomalies in wildfire activity in 2002 compared to longer-term averages. Development of a typical year fire inventory provided the capability of using a comparable data set for both the base year and future years. Thus, fire emissions remain the same for air quality modeling in both the base and any future years. The VISTAS Fire Special Interest Work Group used State records to ratio the number of acres burned over a longer term period (three or more years, as available from state records) to 2002. Based on these ratios, the 2002 acreage was then scaled up or down to develop a typical year inventory.

For categories other than wildland fires, the VISTAS/ASIP contractor generated the future base year emissions inventory used in the attainment demonstration modeling. Growth factors supplied from the states or the USEPA's CAIR emission projections were applied to project the controlled emissions to the appropriate year. In some cases, the USEPA's Economic Growth and Analysis System Version 5 growth factors were used if no growth factor was available from either the states or the CAIR growth factor files. Appendix F.2 provides a detailed discussion of the area source inventory.

### **3.5.3 Off-Road Mobile Sources**

Off-road (or non-road) mobile sources are equipment that can move but do not use the roadways, such as construction equipment, aircraft, railroad locomotives, lawn and garden equipment, etc. For the majority of the non-road mobile sources, the emissions for 2002 were estimated using the USEPA's NONROAD2005c model. For the three source categories not included in the NONROAD model, i.e., aircraft engines, railroad locomotives and commercial marine, more traditional methods of estimating the emissions were used. The same inventory is used for both the actual and typical base year emissions inventories.

For the source categories estimated using the USEPA's NONROAD model, the model growth assumptions were used to create the 2009 future year inventory. The NONROAD model takes into consideration regulations affecting emissions from these source categories. For the four largest airports in North Carolina, the Federal Aviation Administration's Terminal Area Forecast was used to project growth in aircraft emissions. For the commercial marine, railroad locomotives and the remaining airport emissions, the VISTAS/ASIP contractor calculated the future growth in emissions using detailed inventory data (both before and after controls) for 1996 and 2010, obtained from the CAIR Technical Support Document. When available, state-specific growth factors were used. Appendix F.2 provides a detailed discussion of the non-road mobile source inventory

### **3.5.4 Highway Mobile Sources**

For onroad vehicles, the newest version of the MOBILE model, MOBILE6.2, was used. Key inputs for MOBILE include information on the age of vehicles on the roads, the average speeds on the roads, the mix of vehicles on the roads, any programs in place in an area to reduce emissions for motor vehicles (such as emissions inspection programs), and temperature.

The MOBILE model takes into consideration regulations that affect emissions from this source sector. The same MOBILE run is used to represent the actual and typical year emissions for



onroad vehicles using input data reflective of 2002. The MOBILE model is then run for the 2009 inventory using input data reflective of that year. The 2002 vehicle miles traveled (VMT), speeds, vehicle age and vehicle mix data were obtained from the North Carolina Department of Transportation (NCDOT). For urban areas in North Carolina that run travel demand models (TDMs), the VMT and speed data from TDMs were used. For a detailed discussion about the highway mobile source inventory development used in the attainment demonstration modeling, please refer to Appendix F.3.

### **3.5.5 Biogenic Emission Sources**

Biogenic emissions were prepared with the SMOKE-BEIS3 (Biogenic Emission Inventory System 3 version 0.9) preprocessor. SMOKE-BEIS3 is a modified version of the Urban Airshed Model (UAM)-BEIS3 model. Modifications include use of MM5 data, gridded land use data, and improved emissions characterization. The emission factors that are used in SMOKE-BEIS3 are the same as the emission factors as in UAM-BEIS3. The basis for the gridded land use data used by BEIS3 is the county land use data in the Biogenic Emissions Landcover Database version 3 (BELD3) provided by the USEPA. A separate land classification scheme, based upon satellite (AVHRR, 1 km spatial resolution) and census information aided in defining the forest, agriculture, and urban portions of each county.

The base year biogenic emissions are used for the typical and future year modeling. This is a common practice in air quality modeling since the same meteorology is used for all the modeling years and the biogenic emissions are very dependent on the meteorology. Variation in these emissions could impact the control strategies needed to demonstrate attainment. Therefore, these emissions are kept constant.

## 4.0 MODEL PERFORMANCE EVALUATION

There are many aspects of model performance. This section will focus primarily on the methods and techniques recommended by the USEPA for evaluating the performance of the air quality model. Before the air quality model can be fully evaluated, an understanding of the meteorological modeling performance is needed to understand potential biases and errors that may be passed from the meteorological model directly into the air quality model. The meteorological modeling evaluation is fully documented in Appendix I and is briefly summarized in Section 4.1. The air quality modeling evaluation is fully documented in Appendix J and is briefly summarized in Section 4.2.

### 4.1 Meteorological Model Performance

Generally speaking, the meteorological modeling performance was quite good at both the 36-km and 12-km grid resolutions. Synoptic features were routinely accurately predicted and the meteorological model showed considerable skill in replicating the state variables (e.g. temperature, mixing ratio, relative humidity, wind speed and direction, cloud cover, and precipitation). The meteorological modeling performance statistics fell within expected and acceptable ranges of error during the majority of the 2002 modeled year.

The meteorological modeling performance for North Carolina was very similar to the performance for the VISTAS/ASIP region for the 12-km modeling domain. Again, large-scale meteorological patterns were accurately predicted. The meteorological model demonstrated substantial skill throughout the entire year and was especially skillful during the summertime season from May through September.

For the North Carolina portion of the 12km modeling domain, the temperature bias was negative for the entire year. The months of April through September had an average bias closer to zero (- 0.1 Kelvin) than the fall and winter months. Overall, the diurnal pattern was captured very well, with only a slight cool bias in the daytime, and a slight warm bias overnight.

Modeled mixing ratio followed observed trends fairly well. There was a slight low bias in the morning through the early afternoon, and a high bias in the late afternoon and at overnight. The bias values were generally near zero for most of the year (within  $\pm 0.25$  g/kg). Another atmospheric moisture parameter, relative humidity, also showed a high bias in the daytime with a low bias at night. Relative humidity biases tracked with temperature biases (higher in fall and winter, lower in spring and summer), as it is a function of temperature. Precipitation has a negative bias in the late fall (October through December) and a positive bias in the spring to summer period. Though the model has a tendency to overestimate the amount of spring and summertime precipitation, the spatial coverage of measurable precipitation is estimate fairly well.

Wind speed had approximately 0.5 m/s (meters per second) high bias during the daytime hours, and approximately 1 m/s high bias at overnight. This high bias is in part due to the inability of the model to produce calm, or no wind condition. The models always have some level of winds present. This is further aggravated by the fact that observation networks have a “starting thresholds” for their wind speed instrumentation. The instruments need winds in excess of

1.34 m/s in order to register. As a result, wind speeds less than 1.34 m/s are reported as “calm”. When omitting calm observations, the positive bias improves to between 0.2 to 0.6 m/s.

The meteorological model performance could have impact on the air quality model performance. For example, the low temp bias in winter could impact the nitrate chemistry and allow for more nitrate formation during this period. Moisture biases may impact secondary aerosol formation, though it is questionable to what extent this may happen. Additionally, the under prediction of precipitation in the late fall (October through December) may lead to over prediction of PM<sub>2.5</sub>. Conversely the over prediction precipitation amounts in the April to September time frame may lead to under prediction of total PM<sub>2.5</sub> concentrations. Also, the slightly higher modeled wind speeds could lead to additional dispersion of pollutants and ultimately to an under-prediction of PM<sub>2.5</sub> in the modeling results.

Overall, the NCDAQ believes that the meteorological model performance is adequate for this modeling exercise and should produce credible inputs for the air quality modeling for the attainment demonstration for the Hickory and Triad PM<sub>2.5</sub> nonattainment areas.

## **4.2 Air Quality Model Performance**

Model performance analysis was completed with the final emissions inventory for the entire VISTAS/ASIP 36km domain. For the full model performance evaluation for the 36-km domain, please see the ASIP Technical support Document in Appendix P.

The remainder of the discussion of model performance presented here focuses on the comparison of observational data from the FRM and STN monitoring sites and model output data from the 2002 actual annual air quality modeling. The evaluation primarily focuses on the air quality model’s performance with respect to individual components of PM<sub>2.5</sub>, as good model performance of the component species dictates good model performance of total or reconstituted fine particulate matter. Model performance of the total fine particulate matter will also be provided as a means to discuss the overall model performance for this Implementation Plan.

The air quality model evaluation focused on both the FRM and STN monitors across the state. Designations were based on FRM monitors, and calculations of future design values are based on current design value information from these sites. Since future attainment demonstrations hinge on the model representing the FRM sites well, it follows that model performance for these sites should be evaluated. STN data was also evaluated as this data is used to speciate the FRM data so component based relative response factors can be calculated for each FRM monitoring site. More detailed information on the attainment test process is described in Appendix L.

Only a brief summary of the model performance evaluation for the 12-km grid domain will be discussed in the subsections to follow. For the full model performance evaluation for the 12-km grid domain, please refer to Appendix J. A full model performance, including an analysis of model statistics, scatter plots, time series, and stacked bar charts for the 12-km VISTAS/ASIP domain, all North Carolina monitoring sites collectively, and individually for the monitoring sites within the nonattainment area, please refer to Appendix J.

#### 4.2.1 Modeling Performance Goals, and Criteria

In 2004, VISTAS/ASIP established model performance goals and criteria for components of fine particle mass (Table 4.2.1-1) based on previous model performance for ozone and fine particles. The Attainment Modeling Guidance for fine particulate matter at the time noted that PM models might not be able to achieve the same level of performance as ozone models. VISTAS’s evaluation considered several statistical performance measures and displays. Fractional bias and mean fractional error were selected as the most appropriate metrics to summarize model performance; other metrics were also calculated and are included for FRM and STN monitors in the full model performance evaluation found in Appendix J.

**Table 4.2.1-1. Established Model Performance Goals and Criteria for the PM<sub>2.5</sub> Component Species**

<b>Fractional Bias</b>	<b>Mean Fractional Error</b>	<b>Comment</b>
≤15 percent	≤35 percent	Goal for PM <sub>2.5</sub> model performance based on ozone model performance, considered excellent performance
≤30 percent	≤50 percent	Goal for PM <sub>2.5</sub> model performance, considered good performance
≤60 percent	≤75 percent	Criteria for PM <sub>2.5</sub> model performance, considered average performance. Exceeding this level of performance indicates fundamental concerns with the modeling system and triggers diagnostic evaluation.

An additional way to evaluate model performance statistics is to visualize performance based on these fractional bias and mean fractional error goals via “soccer plots” and “bugle plots”. The soccer plot is so named because the dotted lines resemble a soccer goal. The soccer plot is useful as both bias and error are shown on a single plot. As bias and error approach zero, the points are plotted closer to or within the “goal”, represented here by the dashed boxes.

The bugle plot, named for the shape formed by the criteria and goal lines. The bugle plots are shaped as such because the goal and criteria lines are adjusted based on the average concentration of the observed species. As the average concentration becomes smaller, the criteria and goal lines become larger to adjust for the model’s poor ability to predict at low concentrations.

The analysis of bugle plots demonstrated that greater emphasis should be placed on performance of those components with the greatest contribution to PM<sub>2.5</sub> mass (e.g. SO<sub>4</sub> and OC) and that greater bias and error could be accepted for components with smaller contributions to total PM<sub>2.5</sub> mass (e.g. EC, NO<sub>3</sub>, and soil). The soccer plots and bugle plots have been included as suggested model performance evaluation displays in the Attainment Modeling Guidance.

## 4.2.2 Domain-Wide Model Performance

As a summary of model performance, soccer and bugle plots for the all of the VISTAS STN and FRM monitors are included here. Plots have been developed for the average monthly modeled concentrations and the performance statistics for all of the PM<sub>2.5</sub> component species (SO<sub>4</sub>, NO<sub>3</sub>, NH<sub>4</sub>, OC, and EC) and reconstructed PM<sub>2.5</sub> total mass from the STN monitoring sites (Figures 4.2.2-1 and 4.2.2-2), as well as the total PM<sub>2.5</sub> mass from the FRM monitoring sites (Figures 4.2.2-3 and 4.2.2-4).

The soccer plots for monthly average component performance for all the VISTAS/ASIP STN sites shows generally good model performance for most species of PM<sub>2.5</sub> and total PM<sub>2.5</sub>. The exception is the prediction of NO<sub>3</sub> values, which most values fall outside the criteria goal (Figure 4.2.2-1). There are a few months that fall on the criteria level goal, which is better seen in the zoomed view presented in the image on the right in Figure 4.2.2-1. However, when the very low concentration of NO<sub>3</sub> is taken into consideration, as presented in the bugle plots (Figures 4.2.2-2), NO<sub>3</sub> performance largely falls within the criteria and goal model performance lines. One can still note a general tendency for under prediction in NO<sub>3</sub>, and other species in right hand image in Figure 4.2.2-2, which leads to a slight under prediction in total reconstructed PM<sub>2.5</sub>.

Monthly total PM<sub>2.5</sub> concentration performance at all the VISTAS/ASIP FRM monitors largely falls within goal level thresholds, with only three months falling just outside goal level performance (Figure 4.2.2-3). Figure 4.2.2-4 suggests a slight negative bias in PM<sub>2.5</sub> prediction for most of the year, with mean fractional error values remaining within goal levels across the year.

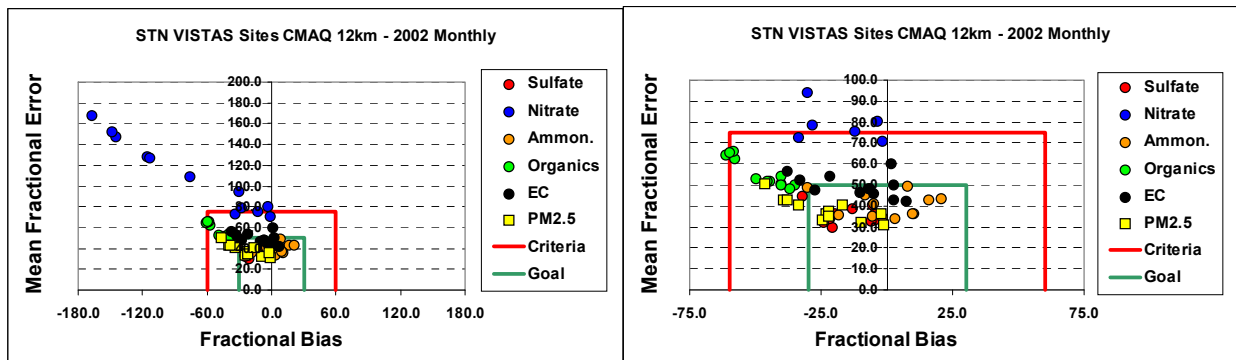


Figure 4.2.2-1. VISTAS STN Soccer Plots

The image on the left is a soccer plot depicting both the mean fractional error and fractional bias for component concentration for all VISTAS STN monitoring sites. The image on the right is a zoomed view of the soccer plot on the left to better depict the area inside the criteria/goal lines. Each point represents a monthly value as compared to the model performance criteria (red box) and modeling performance goals (green box).

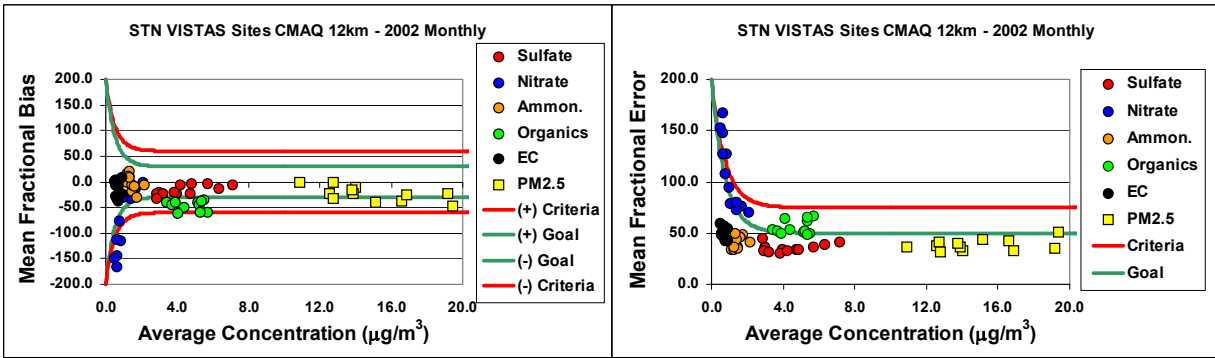


Figure 4.2.2-2. VISTAS STN Bugle Plots

The image on the left is a bugle plot of the mean fraction bias for particulate matter and its component concentrations for all VISTAS STN monitoring sites. The image on the right is a bugle plot of mean fraction error for particulate matter and its component species for all VISTAS STN monitoring sites. Each point represents a monthly mean fraction bias value as compared to the model performance criteria (red lines) and modeling performance goals (green lines).

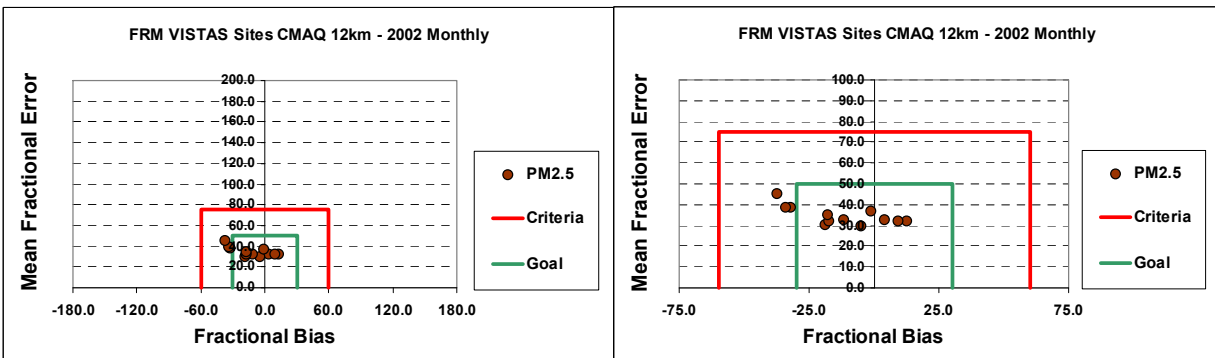
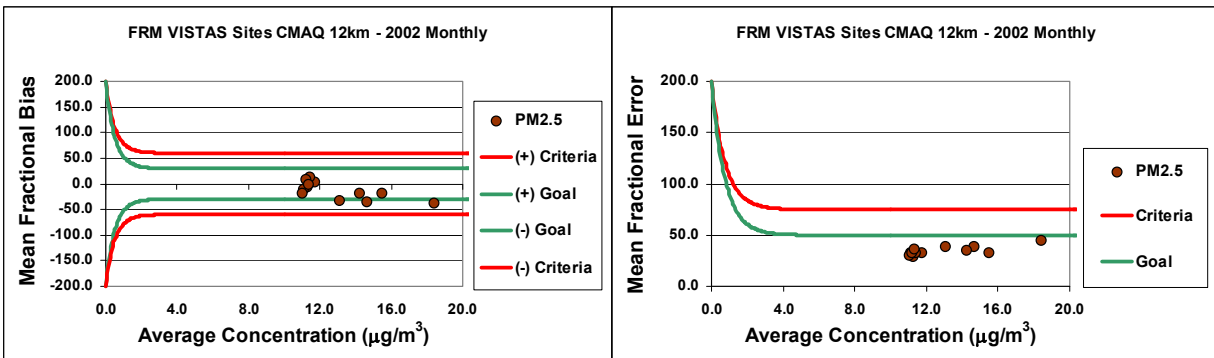


Figure 4.2.2-3. VISTAS FRM Soccer Plots

Soccer plots depicting both the mean fractional error and fractional bias for component concentration for all the VISTAS FRM Monitoring sites. The image on the right is a zoomed view of the soccer plot on the left to better depict the area inside the criteria/goal lines. Each point represents a monthly value as compared to the model performance criteria (red box) and modeling performance goals (green box).



**Figure 4.2.2-4. VISTAS FRM Bugle Plots**

The image on the left is a bugle plot of the mean fraction bias for particulate matter and its component species concentrations for all the VISTAS FRM Monitoring sites. The image on the right is a bugle plot of mean fraction error for particulate matter and its component species for all the VISTAS FRM Monitoring sites. Each point represents a monthly mean fraction bias value as compared to the model performance criteria (red lines) and modeling performance goals (green lines).

Overall, the general tendency is for the model to have some difficulty in predicting  $\text{NO}_3$ , as the monthly average values tend to fall outside the criteria goals for performance in the soccer plots. Part of this under prediction lies in the fact that  $\text{NO}_3$  are generally found in low concentration across the southeast, and the model generally has difficulties representing any compound with low atmospheric concentrations. The bugle plots are more encouraging with  $\text{NO}_3$  performance, as these plot take into consideration the concentration of the component when evaluating performance. The bugle plots show all components and total  $\text{PM}_{2.5}$  falling within criteria level, or better, of model performance goals. The weaker performance of  $\text{NO}_3$  accounts for the slight negative bias in the both the total reconstructed  $\text{PM}_{2.5}$  mass from STN sites as well as FRM total  $\text{PM}_{2.5}$  data.

#### 4.2.3 Nonattainment Area Model Performance

The statistical metrics were calculated for the Hickory (Catawba County) and Hattie Avenue (Forsyth County) STN monitors to demonstrate model performance for the components of  $\text{PM}_{2.5}$  in and near the  $\text{PM}_{2.5}$  nonattainment areas. Model performance statistics for the STN sites were calculated on a component and total  $\text{PM}_{2.5}$  basis for the entire base year.

Model performance statistics were also calculated collectively for the FRM monitors within the VISTAS 12-km domain, as well as individually for the 3 FRM monitors in the nonattainment areas (Hickory, Lexington, and Mendenhall) to demonstrate the model's ability to replicate total  $\text{PM}_{2.5}$  mass at these sites. Summaries and statistical tables for the STN monitoring sites and FRM monitoring sites can be found in Appendix J.

As a summary of model performance at the nonattainment area level, the soccer and bugle plots for the Hickory STN (Figure 4.2.3-1 and 4.2.3-2) and FRM monitor (Figure 4.2.3-3 and 4.2.4-4) follow. Plots have been developed for the average monthly concentrations of  $\text{PM}_{2.5}$  and its component species at the STN sites, and for total  $\text{PM}_{2.5}$  from FRM monitors for all North Carolina STN sites collectively and other the monitoring sites within the  $\text{PM}_{2.5}$  nonattainment areas are included in Appendix J.

Monthly average component concentration performance at the Hickory STN site is similar to overall 12-km VISTAS domain and North Carolina statewide model performance. Nitrate generally falls outside of suggested criteria model performance goals. Some under prediction of organic carbon values is present, but this is in line with the overall model performance seen across North Carolina. Overall, the PM<sub>2.5</sub> model performance was within criteria level, if not within the goal level thresholds.

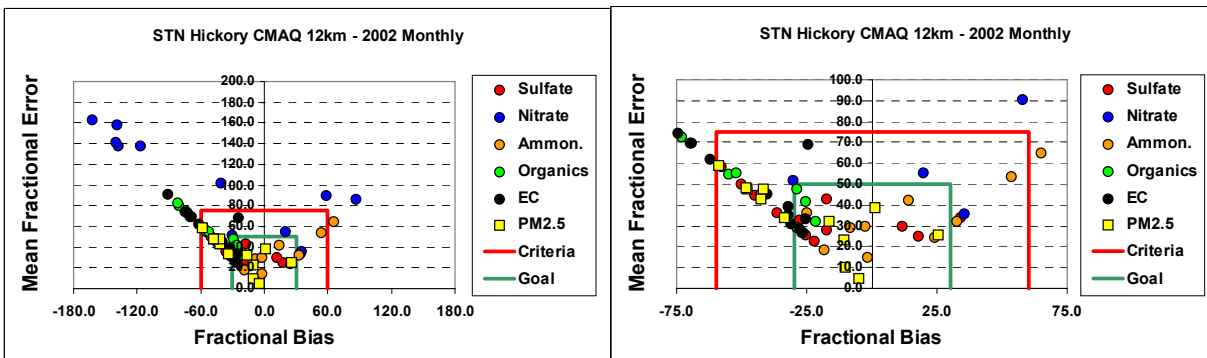


Figure 4.2.3-1. Hickory STN Soccer Plots

The image on the left is the soccer plot depicting both the mean fractional error and fractional bias for component concentration for the Hickory (37-035-0004) STN monitoring site. The image on the right is a zoomed view of the soccer plot on the left to better depict the area inside the criteria/goal lines. Each point represents a monthly value as compared to the model performance criteria (red box) and modeling performance goals (green box).

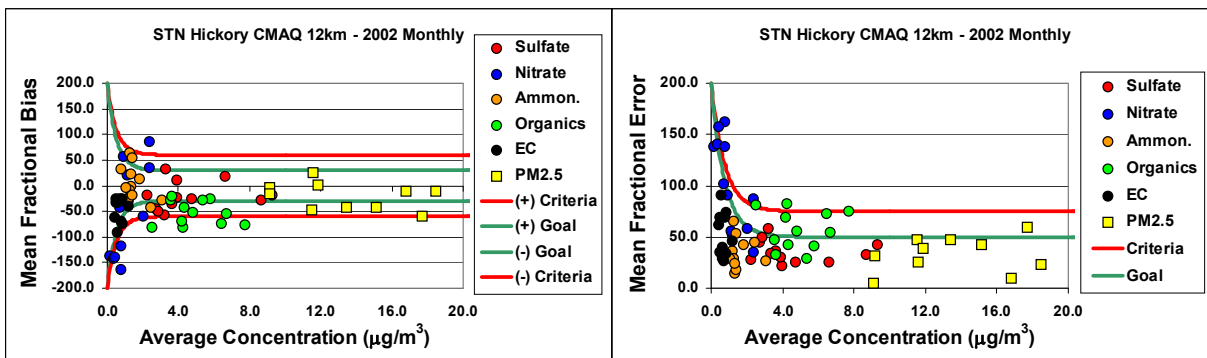
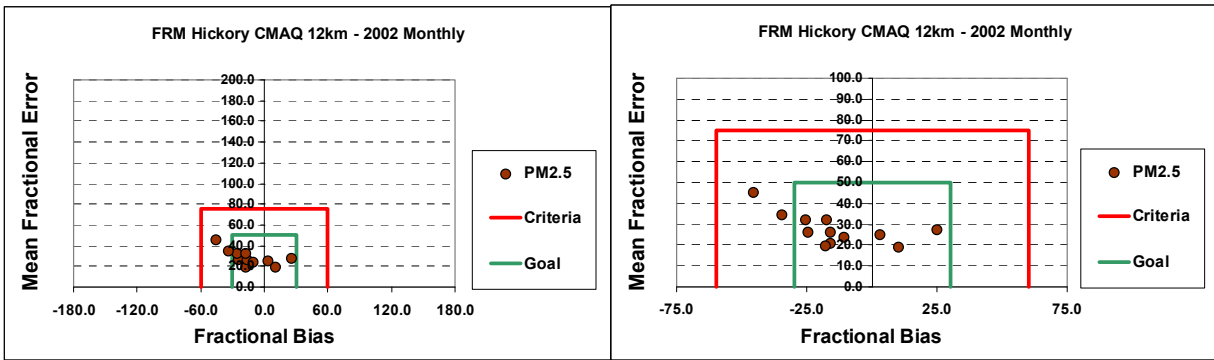


Figure 4.2.3-2. Hickory STN Bugle Plots

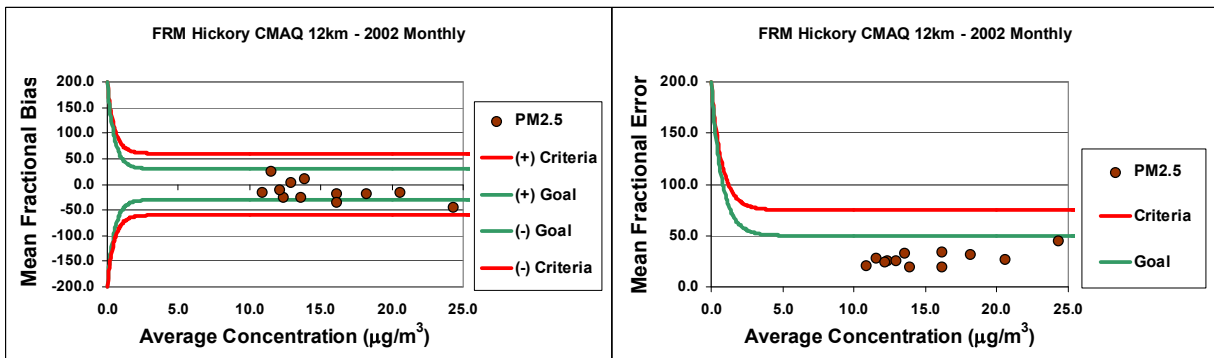
The image on the left is the bugle plot of the mean fraction bias for particulate matter and its component species concentrations for the Hickory (37-035-0004) STN monitoring site. The image on the right is the bugle plot of mean fraction error for particulate matter and its component species for the Hickory STN site. Each point represents a monthly mean fraction bias value as compared to the model performance criteria (red lines) and modeling performance goals (green lines).





**Figure 4.2.3-3. Hickory FRM Soccer Plots**

The image on the left is the soccer plot depicting both error and bias for the light extinction due to particulate matter and its component species for the Hickory FRM monitoring site (37-035-0004). The image on the right is a zoomed view of the soccer plot on the left to better depict the area inside the criteria/goal lines. Each point represents a monthly mean fraction bias value as compared to the model performance criteria (red box) and modeling performance goals (green box).



**Figure 4.2.3-4. Hickory FRM Bugle Plots**

Bugle plot depicting the mean fractional bias for the light extinction due to particulate matter and its component species for the Hickory FRM monitoring site (37-035-0004). The image on the right is the bugle plot depicting the mean fraction error for the light extinction due to particulate matter and its component species for the Hickory FRM monitoring site. Each point represents a monthly mean fraction bias value as compared to the model performance criteria (red lines) and modeling performance goals (green lines).

#### 4.2.4 Air Quality Model Performance Summary

Overall, the model performance for North Carolina through the 2002 baseline modeling year is reasonable good. For the most part, mean normalized bias and mean normalized gross error are within the recommended limits for good model performance for most of component species as well as total PM<sub>2.5</sub> mass. Overall performance was good for sulfate and organic carbon, which are the largest constituents of PM<sub>2.5</sub> for North Carolina. Nitrate performance was less than ideal, especially during the summer months. This is likely due to the generally low atmospheric concentrations seen in North Carolina. When the performance is weighted by the concentration, as in the bugle plots, the performance metrics indicate better model performance. The model also does a good job capturing PM<sub>2.5</sub> component and total concentrations through various

episode-clean out cycles (see Section 5, Appendix J). Overall, the NCDAQ believes that the model performance is well within the limits of acceptable performance established in the Attainment Modeling Guidance.

## **5.0 CONTROLS APPLIED**

Several control measures already in place or being implemented over the next few years will reduce stationary point, highway mobile, and non-road mobile sources emissions. The Federal and State control measures that have impacts on air quality in North Carolina were modeled for the attainment year and are discussed in the sections below. Although all the control listed below may not directly reduce PM<sub>2.5</sub> concentrations in North Carolina, the modeling assessment in this submittal was based on one atmosphere modeling completed for ozone and fine particulate matter attainment demonstrations and regional haze plans.

### **5.1 Federal Control Measures**

#### **5.1.1 Tier 2 Vehicle Standards**

Federal Tier 2 vehicle standards will require all passenger vehicles in a manufacturer's fleet, including light-duty trucks and Sport Utility Vehicles (SUVs), to meet an average standard of 0.07 grams of NO<sub>x</sub> per mile. Implementation began in 2004, with full compliance required 2007. The Tier 2 standards will also cover passenger vehicles over 8,500 pounds gross vehicle weight rating (the larger pickup trucks and SUVs), which are not covered by the current Tier 1 regulations. For these vehicles, the standards will be phased in beginning in 2008, with full compliance required by 2009. The new standards require vehicles to be 77% to 95% cleaner than those on the road today. The Tier 2 rule also reduced the sulfur content of gasoline to 30 parts per million (ppm) starting in January of 2006. Most gasoline sold in North Carolina prior to January 2006 had a sulfur content of about 300 ppm. Sulfur occurs naturally in gasoline, and interferes with the operation of catalytic converters on vehicles, which results in higher NO<sub>x</sub> emissions. Lower-sulfur gasoline is necessary to achieve the Tier 2 vehicle emission standards.

#### **5.1.2 Heavy-Duty Gasoline and Diesel Highway Vehicles Standards**

New USEPA standards designed to reduce NO<sub>x</sub> and VOC emissions from heavy-duty gasoline and diesel highway vehicles began to take effect in 2004. The second phase of the standards and testing procedures, which began in 2007, will reduce particulate matter from heavy-duty highway engines, and will also reduce highway diesel fuel sulfur content to 15 ppm since the sulfur damages emission control devices. The total program is expected to achieve a 90% reduction in PM emissions and a 95% reduction in NO<sub>x</sub> emissions for these new engines using low sulfur diesel, compared to existing engines using higher-content sulfur diesel.

#### **5.1.3 Large Non-road Diesel Engines Rule**

In May 2004, the USEPA promulgated new rules for large non-road diesel engines, such as those used in construction, agricultural, and industrial equipment, to be phased in between 2008 and 2014. The non-road diesel rules also reduce the allowable sulfur in non-road diesel fuel by over 99%. Non-road diesel fuel currently averages about 3,400 ppm sulfur. The rule limits non-road diesel sulfur content to 500 ppm by 2006 and 15 ppm by 2010. The combined engine and fuel rules would reduce NO<sub>x</sub> and PM emissions from large non-road diesel engines by over 90%, compared to current non-road engines using higher-content sulfur diesel.

#### **5.1.4 Non-road Spark-Ignition Engines and Recreational Engines Standard**

The new standard, effective in July 2003, regulates NO<sub>x</sub>, hydrocarbons (HC) and carbon monoxide (CO) for groups of previously unregulated non-road engines. The new standard applies to all new engines sold in the United States and imported after these standards begins and applies to large spark-ignition engines (forklifts and airport ground service equipment), recreational vehicles (off-highway motorcycles and all-terrain-vehicles), and recreational marine diesel engines. The regulation varies based upon the type of engine or vehicle.

The large spark-ignition engines contribute to ozone formation and ambient CO and PM levels in urban areas. Tier 1 of this standard was implemented in 2004 and Tier 2 started in 2007. Like the large spark-ignition, recreational vehicles contribute to ozone formation and ambient CO and PM levels. For the off-highway motorcycles and all-terrain-vehicles, the new exhaust emissions standard was phased-in. Fifty percent of model year 2006 engines had to meet the standard, and for model year 2007 and later, all of the engines have to meet the standard. Recreational marine diesel engines over 37 kilowatts are used in yachts, cruisers, and other types of pleasure craft. Recreational marine engines contribute to ozone formation and PM levels, especially in marinas. Depending on the size of the engine, the standard began phasing-in in 2006.

When all of the non-road spark-ignition and recreational engine standards are fully implemented, an overall 72% reduction in HC, 80% reduction in NO<sub>x</sub>, and 56% reduction in CO emissions are expected by 2020. These controls will help reduce ambient concentrations of ozone, CO, and fine PM.

#### **5.1.5 NO<sub>x</sub> SIP Call in Surrounding States**

In October 1998, the USEPA made a finding of significant contribution of NO<sub>x</sub> emissions from certain states and published a rule that set ozone season NO<sub>x</sub> budgets for the purpose of reducing regional transport of ozone (63 FR 57356). This rule, referred to as the NO<sub>x</sub> SIP Call, required ozone season controls to be put on utility and industrial boilers, as well as internal combustion engines, in 22 states in the Eastern United States. A NO<sub>x</sub> emissions budget was set for each state and the states were required to develop rules that would assure that each state met its budget. A NO<sub>x</sub> trading program was established, allowing sources to buy credits to meet their NO<sub>x</sub> budget as opposed to actually installing controls. The emission budgets were to be met by the beginning of 2004. Even with the trading program, the amount of ozone season NO<sub>x</sub> emissions has decreased significantly in and around North Carolina.

#### **5.1.6 Clean Air Interstate Rule**

On May 12, 2005, the USEPA promulgated the “Rule To Reduce Interstate Transport of Fine Particulate Matter and Ozone (Clean Air Interstate Rule); Revisions to Acid Rain Program; Revisions to the NO<sub>x</sub> SIP Call”, referred to as CAIR. This rule established the requirement for States to adopt rules limiting the emissions of NO<sub>x</sub> and sulfur dioxide (SO<sub>2</sub>) and a model rule for the states to use in developing their rules. The purpose of the CAIR is to reduce interstate transport of precursors of fine particulate and ozone.

The CAIR applies to (1) any stationary, fossil-fuel-fired boiler or stationary, fossil-fuel-fired combustion turbine serving at any time, since the start-up of a unit’s combustion chamber, a

generator with nameplate capacity of more than 25 Megawatt hours (MW) producing electricity for sale and (2) for a unit that qualifies as a cogeneration unit during the 12-month period starting on the date that the unit first produces electricity and continues to qualify as a cogeneration unit, a cogeneration unit serving at any time a generator with nameplate capacity of more than 25 MW and supplying in any calendar year more than one-third of the unit's potential electric output capacity or 219,000 MW, whichever is greater, to any utility power distribution system for sale.

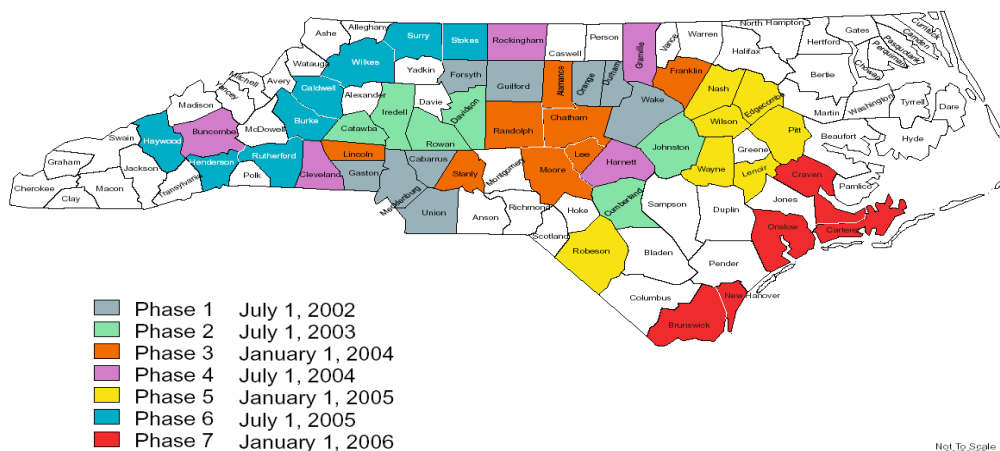
This rule provides annual state caps for NO<sub>x</sub> and SO<sub>2</sub> in two phases, with the Phase I caps for NO<sub>x</sub> and SO<sub>2</sub> starting in 2009 and 2010, respectively. Phase II caps become effective in 2015. The USEPA is allowing the caps to be met through a cap and trade program if a state chooses to participate in the program. When fully implemented, the CAIR will reduce SO<sub>2</sub> emissions in the eastern United States by over 70 percent and NO<sub>x</sub> emissions by over 60 percent from 2003 levels. Due to Court challenges of CAIR in 2008, the USEPA will be making changes to this program by 2011. However, the existing CAIR rules will remain in place until the USEPA promulgates changes to the program.

## 5.2 State Control Measures

North Carolina has adopted a number of regulations and legislation to address pollution issues across the State. These include the Clean Air Bill, the NO<sub>x</sub> SIP Call Rule, the CSA, the Open Burning Rule, and the CAIR. All of these regulations were modeled in the attainment demonstration. These regulations are summarized below and the actual regulations and legislation can be viewed in Appendix M.

### 5.2.1 Clean Air Bill

The 1999 Clean Air Bill expanded the vehicle emissions inspection and maintenance program in North Carolina from 9 counties to 48 counties between July 1, 2002 and January 1, 2006 (Figure 7.2.1-1). Vehicles are tested using the onboard diagnostic system (OBDII) test, an improved method of testing for pollutant emissions.



**Figure 5.2.1-1. North Carolina's OBDII Test Phase-in Map**

The effective dates for the counties in the Hickory and Triad PM<sub>2.5</sub> nonattainment area are listed in Table 5.2.1-1 below.

**Table 5.2.1-1 OBDII Phase-in Effective Dates**

County	Date
Catawba	July 1, 2003
Davidson	July 1, 2003
Guildford	July 1, 2002

### **5.2.2 NO<sub>x</sub> SIP Call Rule**

In response to the USEPA's NO<sub>x</sub> SIP call, North Carolina adopted rules to control the emissions of NO<sub>x</sub> from large stationary combustion sources. These rules cover (1) fossil fuel-fired stationary boilers, combustion turbines, and combined cycle systems serving a generator with a nameplate capacity greater than 25 MW and selling any amount of electricity, (2) fossil fuel-fired stationary boilers, combustion turbines, and combined cycle systems having a maximum design heat input greater than 250 million British thermal units per hour, and (3) reciprocating stationary internal combustion engines rated at equal or greater than 2400 brake horsepower (3000 brake horsepower for diesel engines and 4400 brake horsepower for dual fuel engines). As part of the NO<sub>x</sub> SIP call, the USEPA rules established a NO<sub>x</sub> budget for sources in North Carolina and other states.

Besides amending existing NO<sub>x</sub> rules and adopting new NO<sub>x</sub> rules specifically to address the USEPA NO<sub>x</sub> SIP call, the North Carolina rules also require new sources to control emissions of NO<sub>x</sub>. The objective of this requirement is (1) to aid in meeting the NO<sub>x</sub> budget for North Carolina for minor sources and (2) to aid in attaining and maintaining the ambient air quality standard for ozone in North Carolina.

North Carolina's NO<sub>x</sub> SIP Call rule was predicted to reduce summertime NO<sub>x</sub> emissions from power plants and other industries by 68% by 2006. In October 2000, the North Carolina Environmental Management Commission (EMC) adopted rules requiring the reductions. In 2009, the North Carolina NO<sub>x</sub> SIP Call program was replaced with the North Carolina's CAIR rule, which is discussed below in Section 5.2.5.

### **5.2.3 Clean Smokestacks Act**

In June 2002, the North Carolina General Assembly enacted the CSA, which requires coal-fired power plants in North Carolina to reduce annual NO<sub>x</sub> emissions by 77% by 2009. These power plants must also reduce annual sulfur dioxide emissions by 49% by 2009 and by 73% by 2013. It is significant to note that this law sets a cap of NO<sub>x</sub> and SO<sub>2</sub> emissions for the State, which the public utilities cannot meet by purchasing emissions credits. The CSA reduces NO<sub>x</sub> emissions beyond the requirements of the NO<sub>x</sub> SIP Call Rule. One of the first state laws of its kind in the nation, this legislation provides a model for other states in controlling multiple air pollutants from older coal-fired power plants.

## 5.2.4 Open Burning Bans

The rule adopted by the EMC in June 2004 is aimed at reducing emissions that contribute to ozone and particle pollution when the air quality is expected to be poor. The ban is triggered on "air quality action days," when the NCDAQ or local air programs forecast Code Orange, Red or worse ozone conditions for a particular metro area. The following counties in the Hickory area are subject to this rule: Alexander, Catawba, Southeastern Burke and Southeastern Caldwell counties. The following counties in the Triad area are subject to this rule: Alamance, Caswell, Davidson, Davie, Forsyth, Guilford, Randolph, Rockingham and Stokes counties.

## 5.2.5 Clean Air Interstate Rule

In response to the USEPA's CAIR, the NCDAQ developed a state CAIR. Under the USEPA's rule, North Carolina has caps as follows:

- Annual NO<sub>x</sub>: 62,183 tons for 2009-2014 and  
51,819 tons for 2015 and each year thereafter;
- Ozone season NO<sub>x</sub>: 28,392 tons for 2009-2014 and  
23,660 tons for 2015 and each year thereafter;
- Annual SO<sub>2</sub>: 137,342 tons for 2010-2014 and  
96,139 tons for 2015 and each year thereafter.

The State's NO<sub>x</sub> allocations have been distributed among the covered facilities. The USEPA will determine the SO<sub>2</sub> allocations, which are based on the acid rain program. For the most part the proposed rules incorporate the USEPA's model rule. The USEPA's model rule for definitions; permitting; monitoring, reporting, and record keeping; trading and banking; designated representative; opt-in provision, and new source growth are incorporated by reference.

The rule requires the EMC to periodically review the allocations in 2010 and every five years thereafter and to decide whether to reallocate. This rule does not preclude the EMC from adopting additional emission reduction requirements for covered sources if necessary to attain or maintain an ambient air quality standard.

The EMC adopted North Carolina's CAIR on March 9, 2006 and the rule became effective July 1, 2006. Due to the Court challenges of CAIR in 2008, the USEPA will be making changes to this program soon. However, the existing CAIR rules will remain in place until the USEPA promulgates changes to the program.

## 6.0 ATTAINMENT DEMONSTRATION

An attainment demonstration consists of (a) analyses that estimate whether selected emissions reductions will result in ambient concentrations that meet the NAAQS, and (b) an identified set of control measures which will result in the required emissions reductions. The necessary emission reductions for both of these attainment demonstration components may be determined by relying on results obtained with air quality models.

Section 3.0 of the Attainment Modeling Guidance recommends applying both a modeled attainment test and a subsequent screening test (or unmonitored area analysis) to the air quality modeling results to determine if the annual PM<sub>2.5</sub> NAAQS will be met. Additional technical or corroboratory analyses may also be used as part of a “supplemental analysis” or a more stringent “weight of evidence” determination to supplement the modeled attainment test and to further support a demonstration of attainment of the annual PM<sub>2.5</sub> NAAQS.

This section does not present a modeled attainment test or a subsequent screening test with respect to the daily PM<sub>2.5</sub> NAAQS, because all portions of North Carolina were initially designated as attaining the daily PM<sub>2.5</sub> standard. Continued attainment of the daily PM<sub>2.5</sub> NAAQS is projected and assumed due to the widespread reductions in SO<sub>2</sub> and NO<sub>x</sub> emissions already discussed in Section 5 and the modeling projections discussed later in this Section that demonstrate significant decreases in PM<sub>2.5</sub> concentrations into the future.

### 6.1 Attainment Test Introduction

The purpose of a modeling assessment is to determine if control strategies currently being implemented (“on the books”) and proposed control strategies will lead to attainment of the NAAQS for PM<sub>2.5</sub> by the attainment year of 2009. The modeling is applied in a relative sense, similar to the 8-hour ozone attainment test. However, the PM<sub>2.5</sub> attainment test is more complicated and reflects the fact that PM<sub>2.5</sub> has many components. In the test, ambient PM<sub>2.5</sub> is divided into major components, with a separate relative response factor (RRF) and future design value (DVF) calculated for each of the PM<sub>2.5</sub> components. Since the attainment test is calculated on a per species basis, the attainment test for PM<sub>2.5</sub> is referred to as the Speciated Modeled Attainment Test (SMAT). In its entirety, SMAT consists of four basic steps.

First, the observed quarterly mean PM<sub>2.5</sub> and quarterly mean composition for each monitor is calculated. This is achieved by multiplying the monitored quarterly mean concentration of PM<sub>2.5</sub> from FRM monitors by the monitored fractional composition of PM<sub>2.5</sub> species for each quarter (e.g., (20% sulfate) x (15.0 µg/m<sup>3</sup> PM<sub>2.5</sub> mass) = 3.0 µg/m<sup>3</sup> sulfate mass).

The monitored quarterly mean concentration of PM<sub>2.5</sub> from FRM monitors are the 5 year baseline design values (DVB) that are the result of averaging the 3 current design values (DVC) that straddle the modeling base year. The fractional composition of PM<sub>2.5</sub> species is derived from STN monitoring site data that has been processed by the “sulfate, adjusted nitrate, derived water, inferred carbonaceous material balance approach”, or SANDWICH method, so STN and FRM masses are equivalent. The mean composition derived from the SANDWICH method includes the percent of PM<sub>2.5</sub> that can be attributed to SO<sub>4</sub>, NO<sub>3</sub>, OC, EC, other primary inorganic particulates (or crustal materials), NH<sub>4</sub>, and particle bound water (PBW).



The second step is to use model results to derive component specific RRF for each monitor for each quarter. The RRF is basically the ratio of the model's future projections to the baseline current projections. For each component, the future year modeled quarterly mean concentration predicted near the monitoring site divided by the base year modeled quarterly mean concentration predicted near the monitoring site.

For the third step, the component specific RRFs are applied to the observed air quality concentrations to project quarterly species estimates. For each quarter, the current quarterly mean component concentration (step 1) are multiplied by the component-specific RRF obtained in step 2. This leads to an estimated future quarterly mean concentration for each component.

The fourth step sums the quarterly components to get a quarterly mean PM<sub>2.5</sub> value. These quarterly mean values are then averaged to produce a future year annual average PM<sub>2.5</sub> estimate, or future design value (DVF), for each FRM monitoring site. This final value is then compared to the NAAQS (15.0 µg/m<sup>3</sup>) to determine if attainment is reached. For a more detailed discussion of SMAT and the data at each step for the monitors in the nonattainment areas, see Appendix L.

## 6.2 Attainment Test Results

The goal of the SMAT process is to sum the quarterly mean PM<sub>2.5</sub> components to get annual mean PM<sub>2.5</sub> values. Table 6.2-1 displays the quarterly mean concentration and annual mean future design values (DVF) estimates for 2009 for the FRM sites in the North Carolina PM<sub>2.5</sub> nonattainment areas.

**Table 6.2-1. Quarterly Mean and Annual Mean PM<sub>2.5</sub> Mass Estimates for 2009**

AIRS ID	County	Site Name	Quarter 1 Concentration	Quarter 2 Concentration	Quarter 3 Concentration	Quarter 4 Concentration	2009 Annual DVF
37-035-0004	Catawba	Hickory	12.4	13.3	15.2	11.4	13.1
37-057-0002	Davidson	Lexington	12.7	14.0	14.5	12.2	13.4
37-081-0013	Guilford	Mendenhall	10.2	11.7	13.9	10.2	11.5

These 2009 annual DVFs are the final product of the SMAT process and are then compared to the NAAQS (15.0 µg/m<sup>3</sup>) to determine if attainment goals will be reached. Since the values at the FRM site in both the nonattainment areas are less than 15.0 µg/m<sup>3</sup>, all areas have passed the attainment test portion of the attainment demonstration.

## 6.3 Supplemental Analyses

The Attainment Modeling Guidance asserts that all attainment demonstrations should be accompanied by supplemental analysis that further supports the modeling conclusions. This supplemental analysis can include additional analyses of air quality, emissions and meteorological data, and consider modeling outputs other than the results of the attainment test. If the attainment test results fall short of the standard, the results of corroboratory analyses may be used in a weight of evidence determination (WOE) to show that attainment is likely despite modeled results, which may be inconclusive.

The Attainment Modeling Guidance defines the guidelines for supplemental analysis/WOE for the annual PM<sub>2.5</sub> standard as follows:

- Site with a DVF less than 14.5 µg/m<sup>3</sup> should submit basic supplemental analysis to confirm the outcome of the model attainment test.
- Sites with a DVF between 14.5 and 15.5 µg/m<sup>3</sup> should submit a weight of evidence demonstration to aggregate supplemental analysis to support the model attainment demonstration.
- Sites with a DVF greater than or equal to 15.5 µg/m<sup>3</sup> should consider additional control measure to ensure attainment, as more qualitative analysis is unlikely to attainment.

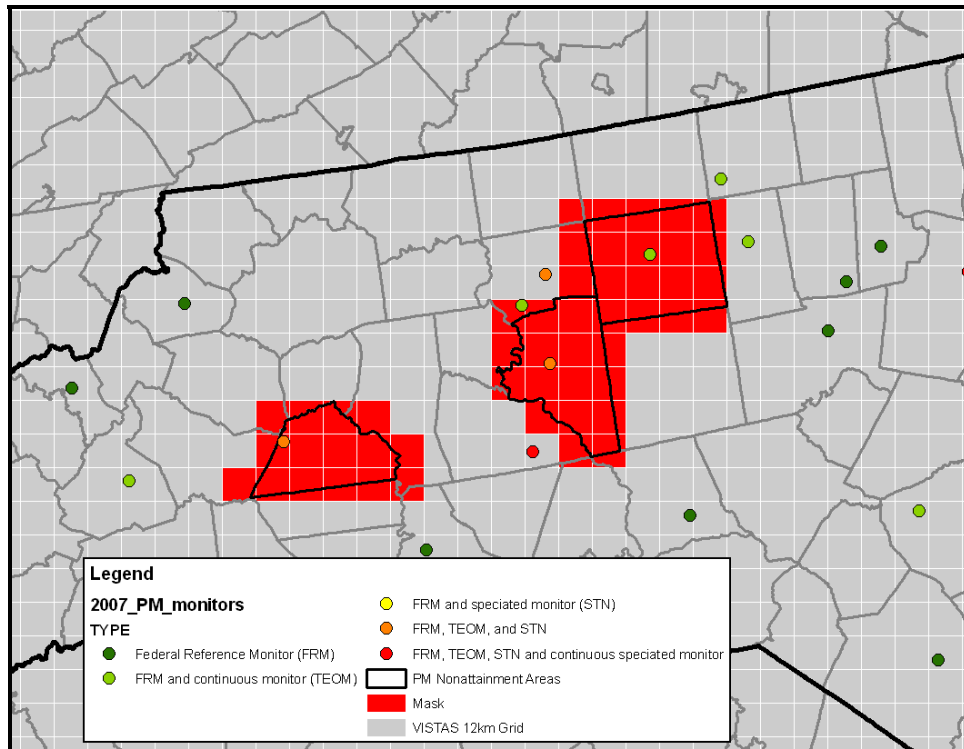
All North Carolina PM<sub>2.5</sub> nonattainment areas have DVFs lower than 14.5µg/m<sup>3</sup>, making the following section an examination of supplemental analysis to corroborate modeling results, rather than a WOE analysis to show attainment.

### 6.3.1 Air Quality Modeling Metrics

Section 7.1 of the Attainment Modeling Guidance suggests several additional modeling exercises that can be performed as part of supplemental analysis. One of the metrics that can be considered as part of this type of additional analysis is the calculation of the percent change in number of grid cells greater than or equal to 15 µg/m<sup>3</sup> within the nonattainment area.

For the Hickory and Triad nonattainment areas, the cell counts of modeling data were tallied from both the 2002 baseline and the 2009 attainment year modeling run for a subset of the highest days from the base year. This was done in order to quantify the reduction of PM<sub>2.5</sub> on our highest days through out the year, and not just based on a single annual average from the modeling. This subset of days included all days with a 24-hour PM<sub>2.5</sub> concentration greater than 30 µg/m<sup>3</sup> at any of the monitoring sites in either nonattainment area, as well as the four days with the highest average daily values from each quarter. This selection process identified 28 days for presentation and coincides with the days used in the model performance evaluation (Appendix J) and in the model results section (Appendix K). A full listing of the days and the observed 24-hour PM<sub>2.5</sub> concentrations from the monitors in the nonattainment areas can be found in either Appendix J or Appendix K.

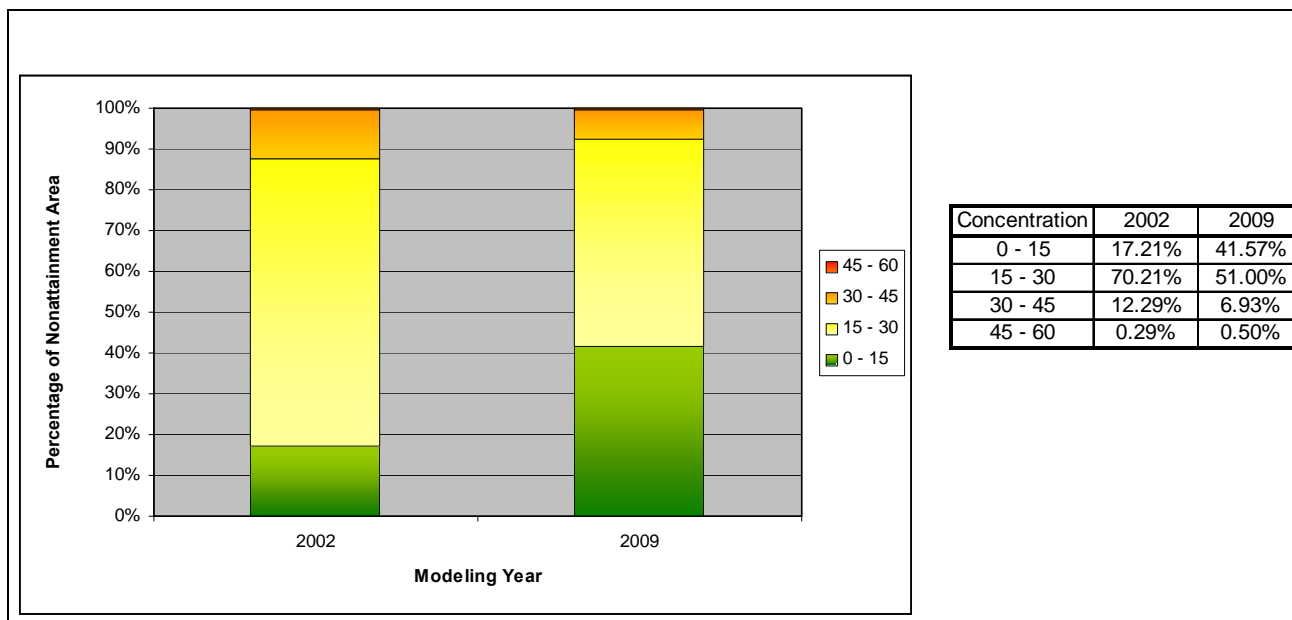
Data was extracted for only the grid cells that contained portions of either of the PM<sub>2.5</sub> nonattainment areas. Figure 6.3.1-1 highlights the 50 cells that encompass the North Carolina PM<sub>2.5</sub> nonattainment areas.



**Figure 6.3.1-1. Area for which the Air Quality Metrics were Applied**

The cell counts were binned based on concentration ranges of  $15 \mu\text{g}/\text{m}^3$  intervals to help illuminate the change in severity on the days in North Carolina with the highest  $\text{PM}_{2.5}$  concentrations. Figure 6.3.1-2 presents the cell count results both graphically and in tabular form. The graph clearly shows a striking increase in the number of days below  $15 \mu\text{g}/\text{m}^3$ . By 2009, 41.57% of cells fall in the  $0 - 15 \mu\text{g}/\text{m}^3$  range, a substantial increase from the 17.21% in 2002. Raw cell counts show a total of 341 cells shifted to the  $0 - 15 \mu\text{g}/\text{m}^3$  range between 2002 and 2009 (Table 6.3.1-1).

Figure 6.3.1-2 also shows a decrease in the number of cells in the  $15 - 30 \mu\text{g}/\text{m}^3$  bin (269 cell decrease) and the  $30 - 45 \mu\text{g}/\text{m}^3$  bin (75 cell decrease). The number of cells in the  $45 - 60$  range remain relatively constant from 2002 to 2009. A closer examination of the daily cell counts shows that all of the cells in the highest concentration category occur on the same day in both the 2002 and 2009 modeling and are likely associated with a fire. Overall, the results from the air quality modeling metric are encouraging. The metric shows a substantial increase in the number of cells below  $15 \mu\text{g}/\text{m}^3$ , and an increase in cells below  $30 \mu\text{g}/\text{m}^3$ .



**Figure 6.3.1-2. Percentage of Cell in PM<sub>2.5</sub> Nonattainment Areas within Concentration Categories for 2002 and 2009. Table of Actual Values is Presented on the Right.**

**Table 6.3.1-1. Number of Cells within Concentration Bins. Increases (decreases) in the Number of Cells within the Bins are Noted by Red (Blue) Coloration in the Last Column.**

Concentration	2002	2009	Difference
0 - 15	241	582	<b>341</b>
15 - 30	983	714	<b>-269</b>
30 - 45	172	97	<b>-75</b>
45 - 60	4	7	<b>3</b>

### 6.3.2 Other Modeling Results

One way to acquire modeling sensitivity runs is to examine the modeling results from other RPOs or from USEPA modeling studies. Other modeling studies may use different physical and chemical modeling options for their meteorological and air quality modeling runs, which would provide a comparison or sensitivity based on these different options.

An air quality modeling exercise that contained results for North Carolina PM<sub>2.5</sub> nonattainment areas is the USEPA's modeling for the CAIR. The Technical Support Document for the final CAIR, March 2005, provided modeling results with and without the implementation for the CAIR. Differences between the USEPA's modeling and the attainment demonstration are: 1) the meteorology was for 2001, 2) the DVB was the weighted design values for the 1999-2003 period and 3) the modeling results were for 2010. The DVF was calculated using the CAIR SMAT tool, so methodologies between the CAIR DVF and the values presented in Section 6.4 are the same. These modeling results are listed in Table 6.3.2-1 below.

**Table 6.3.2-1. USEPA’s CAIR Modeling Results**

Future Year	Catawba County	Davidson County
2010	14.07	14.36
2015	13.45	13.61

The USEPA’s results were for the highest monitor in a county where more than one monitor is located. The USEPA’s modeling results predicts that both the North Carolina nonattainment areas should be below the annual PM<sub>2.5</sub> standard by 2010. Although this is one year later than the attainment year for these areas, the USEPA’s 2010 CAIR DVFs are 1 µg/m<sup>3</sup> higher than what the NCDAQ is showing in the attainment demonstration, but still support that both the North Carolina nonattainment areas will attain the annual PM<sub>2.5</sub> standard by the attainment year of 2009.

**6.3.3 Air Quality Trends and Additional Reductions in Emissions**

Since the annual PM<sub>2.5</sub> designation in 2002, annual average concentrations of PM<sub>2.5</sub> have decreased. PM<sub>2.5</sub> concentrations hovered near the standard at the two nonattaining monitors through the middle portion of the decade, while the Mendenhall monitor has maintained values lower than the NAAQS since 2001. In 2007, the PM<sub>2.5</sub> concentrations fell below the NAAQS at all monitoring sites in both nonattainment areas. Table 6.3.3-1 provides the annual average data, with Figure 6.3.3-1 providing a graphical representation of the data.

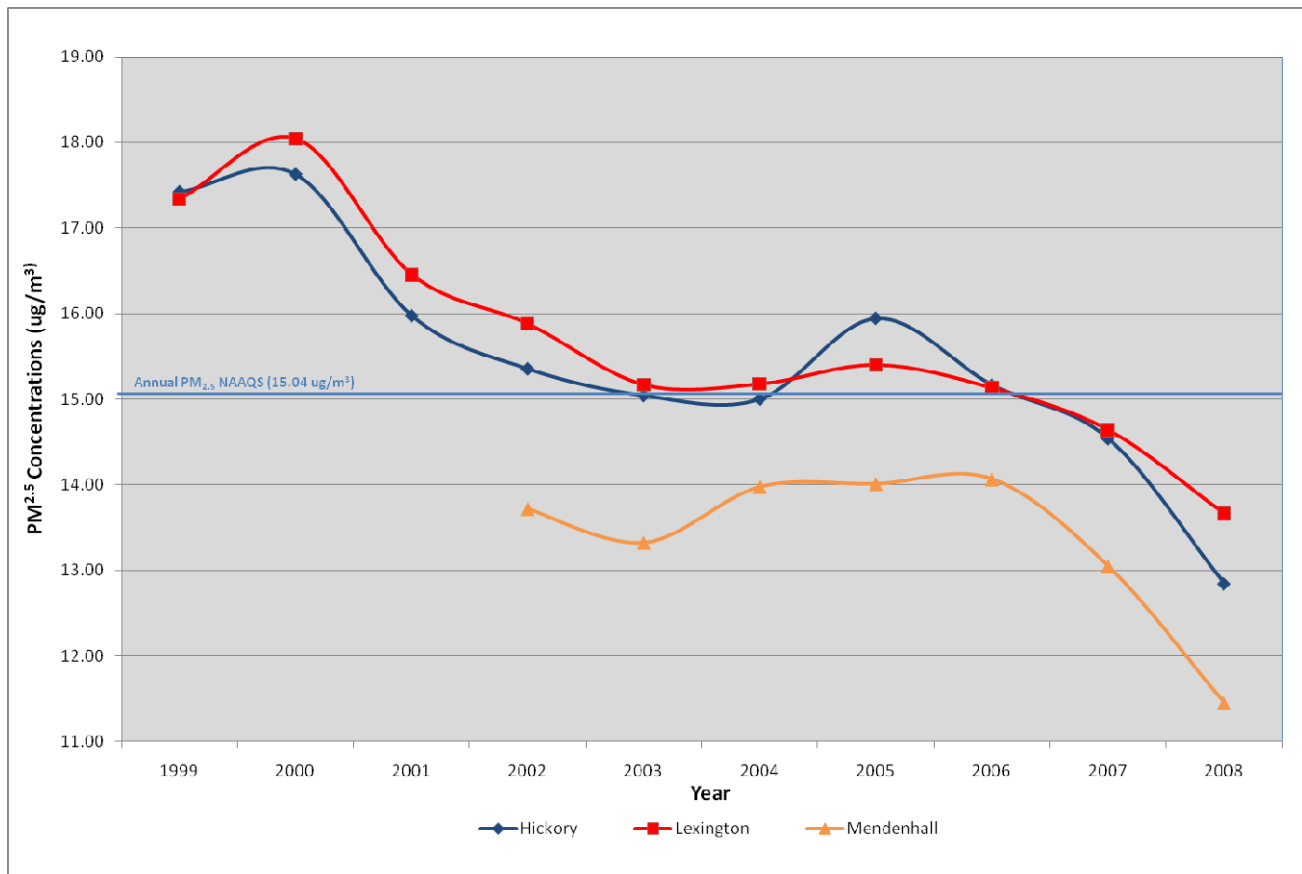
**Table 6.3.3-1. Annual Average PM<sub>2.5</sub> Concentrations for the Past 10 Years**

Monitoring Site	County	AIRS ID	Annual Averages									
			1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Hickory	Catawba	3703500041	17.4	17.6	16.0	15.4	15.0	15.0	15.9	15.2	14.5	12.8
Lexington	Davidson	3705700021	17.3	18.0	16.5	15.9	15.2	15.2	15.4	15.1	14.6	13.7
Mendenhall	Guilford	3708100131				13.7	13.3	14.0	14.0	14.1	13.0	11.4

Average of 1st-4th Quarter For Each Year. Values in colored orange are in excess of the Annual PM<sub>2.5</sub> NAAQS.

**Note: Mendenhall was not in operation from 1999 to 2001**

**Note: There was an extended loss of monitoring data at the Mendenhall site during the 4<sup>th</sup> quarter of 2006. The NCDAQ has performed an extensive data imputation study to estimate a 4<sup>th</sup> quarter average concentration such that an appropriate annual average concentration and design value could be calculated. This study, titled “Mendenhall PM<sub>2.5</sub> Data Imputation for 4Q2006” can be found in Appendix C.3**



**Figure 6.3.3-1. Annual PM<sub>2.5</sub> Average Concentrations for the FRM Monitors in the Hickory and Triad Nonattainment Areas**

With the improvement in annual average PM<sub>2.5</sub> values, there has also been an improvement in PM<sub>2.5</sub> design values. When one takes into account the period of record, PM<sub>2.5</sub> design values have improved significantly over the last 10 years. Like with the annual averages, the three-year design values also began to hover near the level of the standard for both the Hickory and Lexington monitors during the middle portion of the decade. With the most recent design value period, 2006-2008, the PM<sub>2.5</sub> design values have achieved attainment of the NAAQS at all three monitoring sites in the two nonattainment areas (See Table 6.3.3-2).

**Table 6.3.3-2. Three Year Design Values for the FRM Monitors in the Hickory and Triad PM<sub>2.5</sub> Nonattainment Areas**

Monitoring Site	County	AIRS ID	Design Values							
			1999-2001	2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008
Hickory	Catawba	3703500041	17.0	16.3	15.5	15.1	15.3	15.4	15.2	14.2
Lexington	Davidson	3705700021	17.2	16.8	15.8	15.4	15.2	15.2	15.1	14.5
Mendenhall	Guilford	3708100131				13.7	13.8	14.0	13.7	12.9

Average Over 12 Quarters. Negative & Underlined Indicate Altered Calculation

**Note:** Both of the footnotes that apply to Table 6.3.3-1 are also applicable with this table.

The very recent attainment of the annual PM<sub>2.5</sub> NAAQS at all of the monitoring sites can be directly attributed to the dramatic reduction of SO<sub>2</sub> emissions throughout North Carolina due to coal-fired power plants compliance with the CSA Phase 1 SO<sub>2</sub> emissions cap. From a peak in 2005, the SO<sub>2</sub> emissions from the EGUs within North Carolina have fallen by approximately 55% or 275,282 tons per year (See Figure 6.3.3-2). Following the discussion found in Section 2, the assertion in this attainment demonstration that reductions in SO<sub>2</sub> emissions within and surrounding both nonattainment areas would have the biggest impact on improving PM<sub>2.5</sub> concentrations and associated design values has proven accurate.

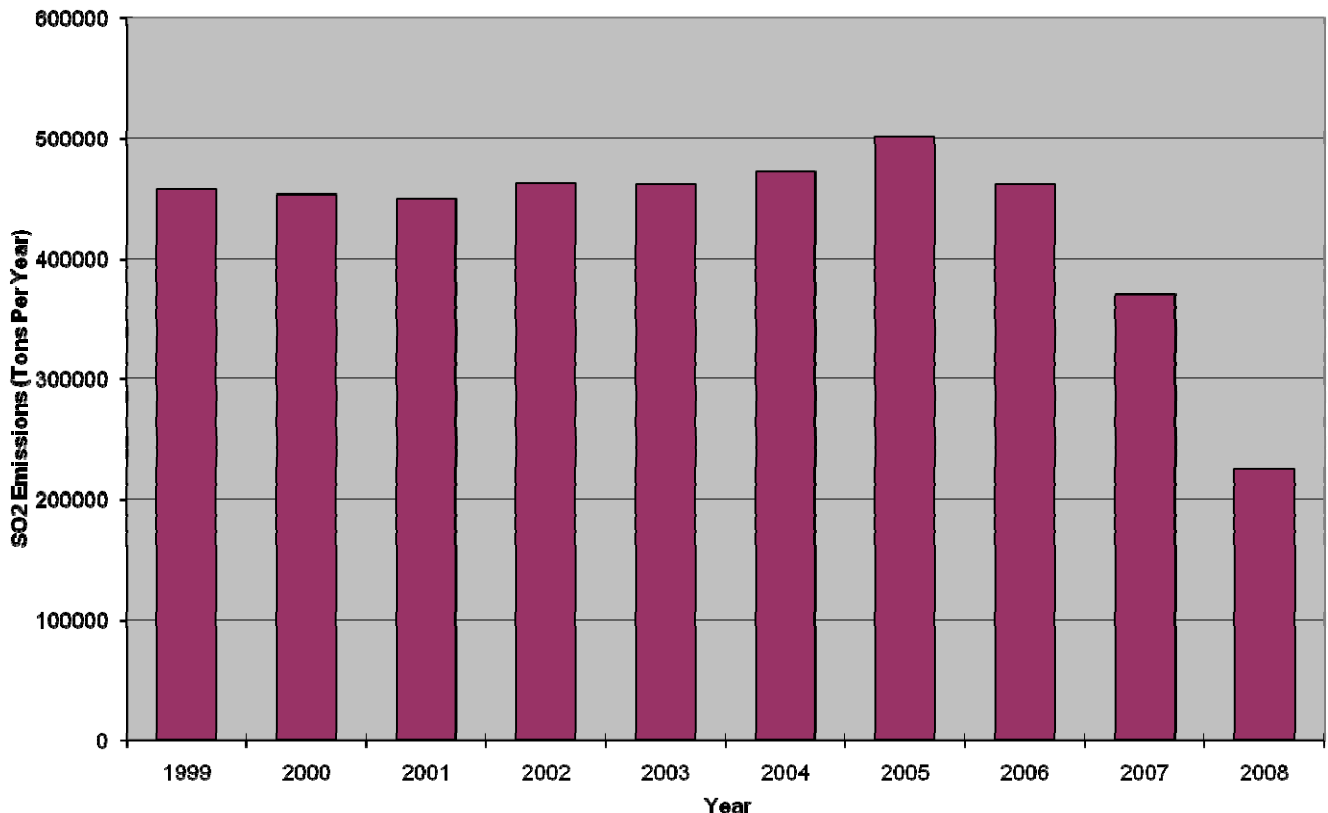


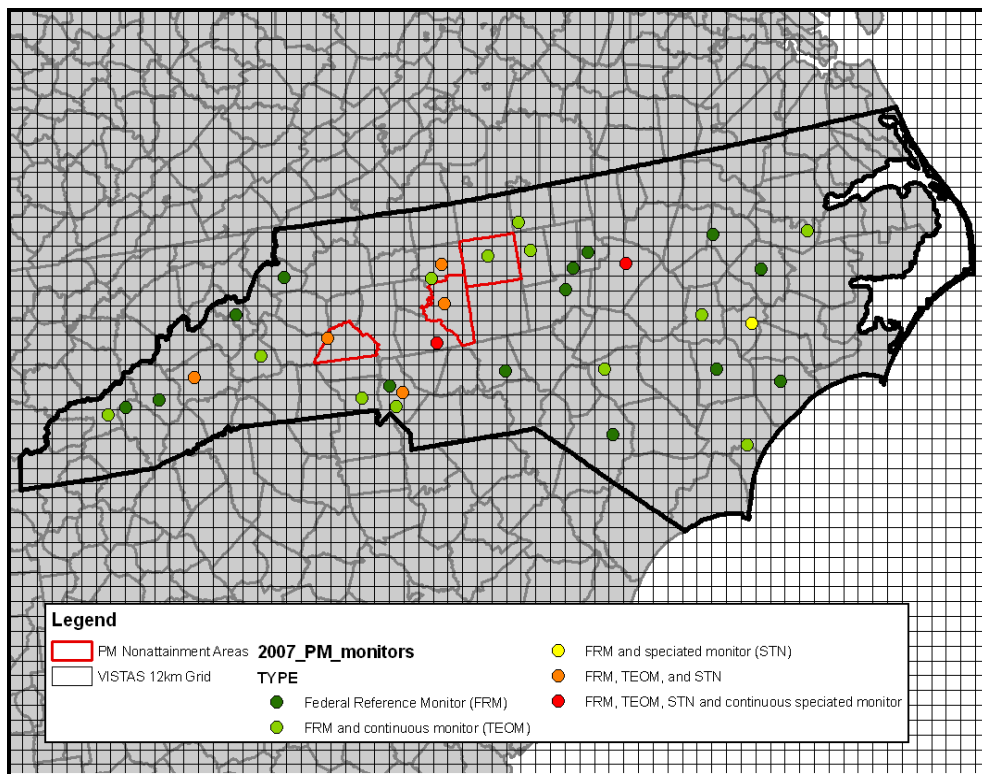
Figure 6.3.3-2. Annual SO<sub>2</sub> Emissions From EGUs In NC

#### 6.4 Unmonitored Area Analysis

The modeled attainment test does not address future air quality at locations where there is not a PM<sub>2.5</sub> monitor nearby. To guard against the possibility that air quality levels could exceed the standard in areas with limited monitoring, Section 3.4 of the Attainment Modeling Guidance suggests that additional review is necessary, particularly in nonattainment areas where the PM<sub>2.5</sub> monitoring network just meets or minimally exceeds the size of the network required. This review is intended to ensure that a control strategy leads to reductions in PM<sub>2.5</sub> and its constituent pollutants at other locations that could have baseline (and future) design values exceeding the NAAQS, were a monitor deployed there. The test is called an “unmonitored area analysis”. The purpose of the analysis is to use a combination of model output and ambient data to identify areas that might exceed the NAAQS if monitors were located there.

The NCDAQ, along with Local and Tribal Programs, currently operates a network of 34 PM<sub>2.5</sub> monitors. Twenty-nine of these monitors were established as State and Local Air Monitoring Stations (SLAMS). These SLAMS monitors were selected based on specific monitoring objectives (background concentration, area of highest concentration, high population, source impact, transport, and rural impact) as required by the USEPA and siting scales (micro, middle, neighborhood, urban, and regional) established by the USEPA. Of the remaining 8 monitors, 7 are categorized as “Other” or “Special Purpose Monitors” that were established by NCDAQ to evaluate models, study PM<sub>2.5</sub> formation and transport, and obtain a better understanding of PM<sub>2.5</sub> in North Carolina. The remaining monitor is a Tribal monitor operated by the Eastern Band of Cherokee Nation.

The NCDAQ believes that the density of its monitoring network more than adequately captures the full extent of the PM<sub>2.5</sub> air quality concerns in North Carolina. With an average of one monitor per 3711 km<sup>2</sup>, this is one of the densest statewide PM<sub>2.5</sub> monitoring networks in the southeast. A map of each PM<sub>2.5</sub> monitor and its position relative to the NCDAQ/ASIP 12-km modeling grid is provided in Figure 6.4-1. As can be seen by the figure, the spatial coverage of the monitors, and their resulting “nearby” 3x3 arrays, covers the majority of the urban areas where PM<sub>2.5</sub> tends to be higher.

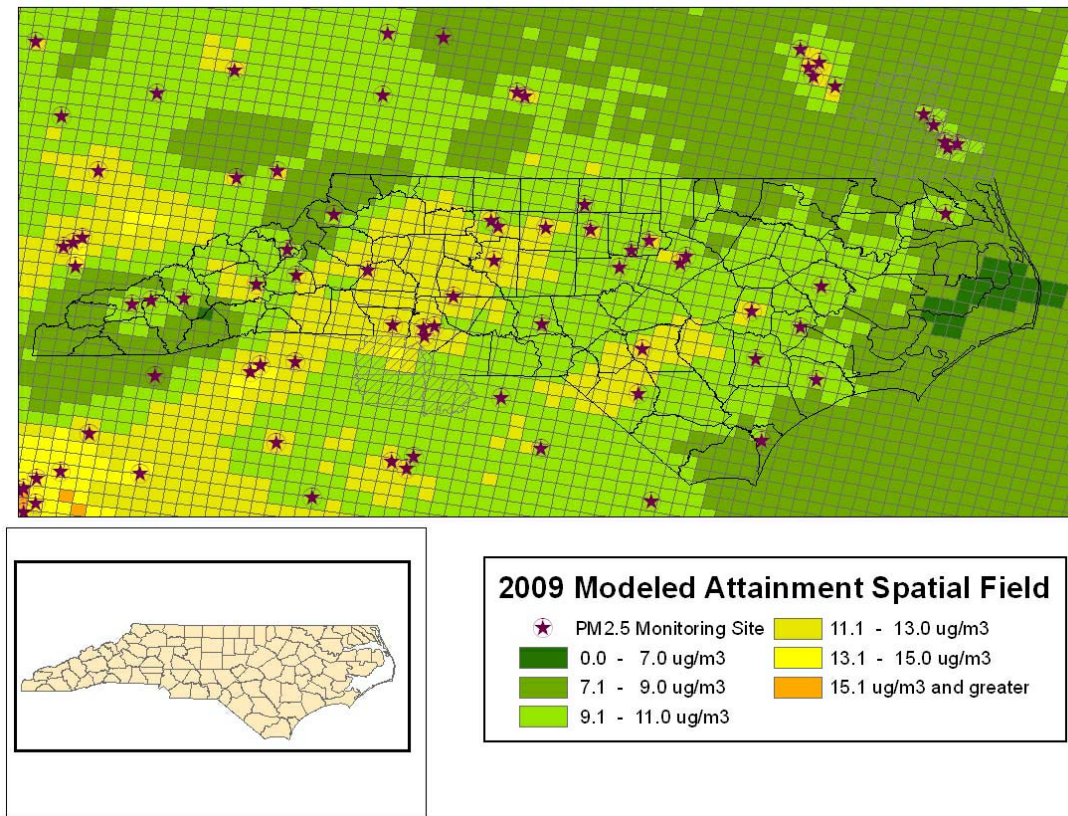


**Figure 6.4-1. PM<sub>2.5</sub> Monitors and Nonattainment Areas with Respect to the VISTAS 12km Grid Domain**

The adequacy of the NCDAQ PM<sub>2.5</sub> monitoring network is further demonstrated when plotted against a projected spatial field of annual PM<sub>2.5</sub> design values. Figure 6.4-2 presents the 2009 future year PM<sub>2.5</sub> design value modeling output from this attainment demonstration and the location of each PM<sub>2.5</sub> monitor in and around North Carolina. This 2009 PM<sub>2.5</sub> design value



spatial field was created by the USEPA's Modeled Attainment Test Software (MATS). It is clear from the MATS analysis that all of the regions of higher, yet attaining, PM<sub>2.5</sub> design values have numerous representative PM<sub>2.5</sub> monitors. There are not any identified PM<sub>2.5</sub> hotspots that would require any additional monitoring considerations in North Carolina.



**Figure 6.4-2. PM<sub>2.5</sub> Monitors and 2009 Modeled Attainment Spatial Field**

### 6.5 Data Access

The modeling input and output files are very large and it would not be reasonable to submit all of these files with the SIP attainment demonstration. These include all files used to process the emissions, meteorology and air quality models and any other files used to develop the modeling. To request access to these files please contact the Division of Air Quality, Attainment Planning Branch Supervisor at 919.733.3340.

## 7.0 CLEAN AIR ACT SECTION 172(c) REQUIREMENTS

Section 172(c) of the CAA, as amended, contains the general requirements for nonattainment areas. These requirements are listed below and are discussed in more detail in the following chapter.

### Section 172(c) Nonattainment Plan Provisions

- (1) Reasonable available control measures
- (2) Reasonable further progress
- (3) Actual emissions inventory and periodic emissions inventory
- (4) New source review
- (5) Permit requirements for new and modified sources
- (6) Other measures as may be necessary to provide attainment by specified attainment date
- (7) Compliance with Section 110(a)(2)
- (8) Equivalent techniques
- (9) Contingency measures

### 7.1 Reasonable Available Control Measures

Section 172(c)(1) of the CAA requires SIPs to provide for the implementation of all RACM to demonstrate attainment as expeditiously as practicable. A subset of RACM is reasonably available control technology (RACT), which relates specifically to stationary point sources.

In April 2007, the USEPA promulgated the PM<sub>2.5</sub> Implementation Rule. In this rule the USEPA established what would be required for RACM and RACT for PM<sub>2.5</sub> nonattainment areas. The USEPA stated that if a state projects that an area will attain the standard within 5 years of designation as a result of existing measures (i.e. projected to have a design value of 14.5 or lower), then the State may conduct a limited RACT and RACM analysis that does not involve additional air quality modeling. Additionally, if a state could not achieve significant emissions reductions during 2008 due to time needed to implement the potential measures or other relevant factors, then the state could conclude that there are no further RACM for the nonattainment area that would advance the attainment date by one year or more.

The predicted design values for the Hickory and Triad nonattainment areas are 13.1 µg/m<sup>3</sup> and 13.4 µg/m<sup>3</sup>, respectively, well below the annual PM<sub>2.5</sub> standard; therefore, the NCDAQ may conduct a limited RACT and RACM analysis. A couple of RACM type measures have already been implemented by the NCDAQ. First is the CSA that was passed in 2002 by the North Carolina General Assembly. This legislation capped SO<sub>2</sub> emissions from coal-fired power plants, with implementation beginning as early as 2006. Another is the NCDAQ open burning rule. With the adoption of the revisions to the open burning rule in 2004, open burning during code Orange or higher air quality action days was prohibited. The prohibition of open burning will reduce fine particulate matter on days that are forecasted to have elevated PM<sub>2.5</sub> concentrations. Copies of these measures are included in Appendix M.

Additional RACM measures could not be implemented during 2008. It would take at least two years to complete rule making and another eighteen months to two years for implementation of control measures. There are no other RACM available to advance the attainment date.

## **7.2 Reasonable Further Progress**

In the PM<sub>2.5</sub> Implementation Rule, the USEPA maintained that an area that demonstrates attainment by 2010 would be considered to have satisfied the RFP requirement and need not submit any additional material to satisfy this requirement. The USEPA will view the attainment demonstration as demonstrating that the area is making reasonable further progress toward attainment.

## **7.3 Actual Emissions Inventory**

Section 172(c)(3) requires the development of a comprehensive, accurate current inventory of actual emissions from all sources in the nonattainment area. Such inventory is due two years after the effective date of the PM<sub>2.5</sub> nonattainment designations, i.e., April 5, 2007. The NCDAQ met this requirement through the submittal of the 2002 emission inventories under the CERR for the North Carolina counties in this nonattainment area.

The NCDAQ submitted statewide emissions for area, non-road mobile and highway mobile sources. For stationary point sources, The NCDAQ submitted inventories for those counties without a local program. The final 2002 emission inventories used in the attainment demonstration went through the public hearing process with the full attainment demonstration, which included any updates or revisions that were necessary since the CERR submittal.

## **7.4 Periodic Emissions Inventory**

Section 172(c)(3) requires periodic inventory submittals. The NCDAQ plans to meet this requirement through the CERR and the recently promulgated Air Emissions Reporting Requirements (AERR) submittals. As such, the NCDAQ submitted the 2005 emissions inventory June 1, 2007 and will submit the 2008 emissions inventory on or before June 1, 2010. Similar to the 2002 CERR submittal, the CERR and AERR submittals will include point sources for all but those counties with local programs, and statewide area, non-road mobile and highway mobile sources.

## **7.5 Permit Program Requirements**

Sections 172(c)(5) requires a permit program consistent with the requirements of Section 173. On November 30, 2005, the NCDAQ submitted amendments to the nonattainment new source review (NNSR) rules contained in 15A NCAC 2D .0531 to the USEPA for review and approval. These rules adopted the new offset requirement. Further, on March 16, 2007, the NCDAQ submitted amendments to 15A NCAC 2D .0530 Prevention of Significant Deterioration (PSD) permitting rules to the USEPA. The NCDAQ believes that the adoption and submittal of the NNSR and the PSD rules meet the “prevention of significant deterioration” requirement of Section 110(a)(2)(D)(i) since major sources in North Carolina are subject to PSD and NNSR programs. Finally, the NCDAQ adopted an Emissions Banking Rule, 15A NCAC 2D .2300 to

establish a bank where sources could place their shutdown credits, as well as credits achieved through installing controls that go above and beyond what is required. The NCDAQ believes it has met the permit program requirements for a PM<sub>2.5</sub> nonattainment area.

## **7.6 Other Measures**

Section 172(c)(6) requires the nonattainment SIPs to include enforceable limitation and other control measures, along with schedules for compliance as needed to demonstrate attainment. Section 5.0 of this document discusses in detail the Federal and State measures that were modeled to show attainment. Appendix M contains the rules and compliance schedules.

## **7.7 Compliance with Section 110(a)(2)**

Section 172(c)(7) requires nonattainment SIPs to meet the applicable provisions of Section 110(a)(2). On October 2, 2007, the USEPA provided guidance on SIP elements required under Section 110(a)(1) and (2) for the 8-hour ozone and PM<sub>2.5</sub> NAAQSs. Regarding the 1997 PM<sub>2.5</sub> NAAQSs, all SIP elements are adequately covered.

## **7.8 Equivalent Techniques**

The NCDAQ believes that the procedures for modeling, emissions inventory and planning follow the USEPA guidance and is not requesting approval for equivalent techniques, as envisioned under Section 172(c)(8).

## **7.9 Contingency Measures**

Section 172(c)(9) requires that the nonattainment SIP contain specific measures that would take effect upon a State's failure to attain the PM<sub>2.5</sub> standard in a given area. These contingency measures must be fully adopted rules or control measures that are ready to be implemented quickly upon failure to meet the standard by the attainment date.

In the PM<sub>2.5</sub> Implementation Rule, the USEPA stated that the measures should provide for emission reductions equivalent to about one year of reductions needed for RFP. However, since North Carolina is able to model attainment of the PM<sub>2.5</sub> NAAQS within five years of designation, RFP is not required. The USEPA's guidance to the NCDAQ was to have contingency measures that amounted to one-seventh of the emission reductions that occurred between the base year 2002 and the attainment year 2009, or approximately one year's worth of emission reductions. Another suggestion was to do sensitivity modeling to determine approximately the level of emission reductions needed to model 15.0 µg/m<sup>3</sup> and use one-seventh of this emission reduction level to determine the amount of contingency measures needed.

The NCDAQ's attainment demonstration includes expected emission reductions due to the CSA legislation. These emission reductions went well beyond what was needed to attain the annual PM<sub>2.5</sub> NAAQS of 15.0 µg/m<sup>3</sup>, evident by the predicted future design values being greater than 1.5 µg/m<sup>3</sup> below the standard. Therefore, the NCDAQ thought it was unreasonable to require contingency measures of one-seventh of the SO<sub>2</sub> emission reduction modeled when the State had already reduced a significant amount of the precursor pollutants throughout the State.

Additionally, the NCDAQ did not believe it was a wise use of State resources to perform further modeling to determine the approximate level of emissions needed to just attain the standard when both nonattainment areas have already attained the annual PM<sub>2.5</sub> NAAQS.

Therefore, the NCDAQ has documented the expected 2009 utility emissions, based on the latest CSA compliance plans, which go beyond what was modeled in the attainment demonstration, as well as the estimated emission reductions expected between 2009 and 2010. All of these emission reductions will take place without further action from the State. Since the purpose of the contingency measures is to provide for the implementation of measures in the event an area fails to attain the NAAQS and the areas have already attained the standard, the NCDAQ believes it has met the spirit of this requirement.

Since the most significant man-made emissions contributor to PM<sub>2.5</sub> formation in North Carolina is the precursor pollutant SO<sub>2</sub>, the NCDAQ has elected to have only SO<sub>2</sub> contingency measures. The USEPA has stated in the Implementation Rule that the reductions from SO<sub>2</sub> emissions could be from not only the nonattainment area but also emissions within a distance that may be up to 200 kilometers (km) from the nonattainment area. The NCDAQ elected to go outside the nonattainment area for contingency measures. The exact regions of influence that were used are discussed in detail in Appendix N.

The contingency plan relies on the already adopted CSA. As stated earlier, this legislation will require SO<sub>2</sub> emission reductions from coal-fired power plants. For several coal-fired electric generating units subject to the CSA, the SO<sub>2</sub> controls came on-line either during 2009 or 2010. Full implementation of these units was not modeled in the attainment demonstration, therefore they are reductions above what was needed to show attainment and would be implemented without further action from the State or the USEPA. Additionally, when the attainment demonstration modeling project started, the latest compliance plan for CSA was the 2006 plan. The utilities companies now have a better understanding of what the SO<sub>2</sub> emissions will be in 2009 and are reflected in the 2009 CSA compliance plan. The difference between the emissions modeled and the current expectations for the 2009 emissions are further emission reductions that are expected to occur that were not modeled as part of the attainment demonstration.

The 2002 baseline emissions for the two nonattainment areas' regions of influence were 215,080 and 401,290 tons of SO<sub>2</sub> per year for the Hickory and Triad areas, respectively. The NCDAQ has determined that SO<sub>2</sub> emissions will be reduced beyond what was modeled by an additional 46,000 tons per year in the Hickory area and 43,000 tons per year in the Triad area. This results in a twenty-two percent and eleven percent reduction from the 2002 baseline SO<sub>2</sub> emissions in the Hickory and Triad areas, respectively. The analysis of the emission reductions is included in Appendix N.

Based on the significant reductions that are expected between what was modeled for the attainment demonstration and what is expected to occur between 2009 and 2010, the NCDAQ believes that the existing control measures required by the CSA is sufficient to satisfy the contingency measures requirement.

## **8.0 MOTOR VEHICLE EMISSIONS BUDGETS**

### **8.1 Transportation Conformity**

The purpose of transportation conformity is to ensure that Federal transportation actions occurring in a nonattainment area do not hinder the area from attaining and/or maintaining the annual PM<sub>2.5</sub> standard. This means that the level of emissions estimated by the NCDOT or the metropolitan planning organizations for the Transportation Implementation Plan and Long Range Transportation Plan must not exceed the motor vehicle emission budgets (MVEBs) as defined in this attainment demonstration SIP.

The NCDAQ consults with the transportation partners as one of the requirements in developing the attainment demonstration SIP and setting MVEBs. The NCDAQ sent out a request for comments on setting the geographic extent of the MVEBs to all of the transportation partners. In the letter, NCDAQ expressed its preference for setting county level budgets and some of the reasons why NCDAQ believed county level budgets were appropriate. Additionally, the NCDAQ consulted the partners for the data used in the development of the MVEBs, as well as the data used in the attainment demonstration modeling. These correspondences and the responses received from the transportation partners can be found in Appendix B.

### **8.2 Pollutants to be Considered**

40 CFR 93.119(f)(7) through (10) identifies the pollutants for PM<sub>2.5</sub> for which regional emissions analysis needs to be performed for transportation conformity purposes. Only primary, or direct, PM<sub>2.5</sub> tailpipe emissions must be considered for transportation conformity regional emissions analysis. The precursor pollutants NO<sub>x</sub>, VOC, SO<sub>2</sub> and ammonia, as well as reentrained road dust only need to be considered if the NCDAQ and/or the USEPA has deemed the pollutant as a significant contributor to the overall PM<sub>2.5</sub> nonattainment problem.

The PM<sub>2.5</sub> precursor NO<sub>x</sub> is presumed to be a significant contributor to the PM<sub>2.5</sub> nonattainment problem by the USEPA. The NCDAQ has determined that NO<sub>x</sub> is a relatively minor contributor to the PM<sub>2.5</sub> concentrations in North Carolina. However, the NCDAQ is not asserting that NO<sub>x</sub> is an insignificant precursor for the 1997 PM<sub>2.5</sub> standard. Therefore, the NCDAQ will establish county level MVEBs for NO<sub>x</sub> for all three PM<sub>2.5</sub> nonattainment counties.

For the purpose of this attainment demonstration, VOC and ammonia are presumed to be insignificant contributors to the PM<sub>2.5</sub> nonattainment problem by the USEPA. The NCDAQ agrees with the USEPA that both VOC and ammonia are insignificant contributors to the PM<sub>2.5</sub> nonattainment problem in North Carolina. The discussion of the insignificance of these precursors is presented in Section 2.0 and in Appendix O. Additionally, the NCDAQ has determined that reentrained road dust is not a significant contributor to the overall PM<sub>2.5</sub> nonattainment problem. This is discussed further in Appendix F.3.

The PM<sub>2.5</sub> precursor SO<sub>2</sub> could not be deemed insignificant to the overall PM<sub>2.5</sub> nonattainment problem since sulfate is such a large fraction of the PM<sub>2.5</sub> composition. However, the NCDAQ has determined that SO<sub>2</sub> emitted by the mobile source sector is insignificant. The USEPA in its Federal Register notice for PM<sub>2.5</sub> does not address the mobile sector in its listing of significant

sources of SO<sub>2</sub> emissions. North Carolina agrees with the following statements addressing SO<sub>2</sub> from on-road mobile emissions as published in the May 6, 2005 Federal Register, 70 FR 24283:

*While speciated air quality data show that sulfate is a relatively significant component (e.g., ranging from nine to 40 percent) of PM<sub>2.5</sub> mass in all regions of the country, emissions inventory data and projections show that on-road emissions of SO<sub>x</sub> constitute a “de minimis” (i.e., extremely small) portion of total SO<sub>x</sub> emissions. Emissions inventory data for 1999 for the 372 potential PM<sub>2.5</sub> nonattainment counties for PM<sub>2.5</sub> (based on 1999–2001 air quality data) show that on-road sources were responsible for only two percent of total SO<sub>x</sub> emissions.*

*Furthermore, EPA has already adopted two regulations that will greatly reduce emissions of SO<sub>x</sub> from on-road sources by the time such regulations are both in full effect in 2009. .... This regulation will reduce the sulfur content of diesel fuel by approximately 97 percent nationally when fully effective.*

Although sulfate is a significant component to the PM<sub>2.5</sub> nonattainment problem in North Carolina, the majority of the SO<sub>2</sub> emissions in 2009 come from the stationary point source sector with the mobile source sector only contributing one half of one percent (0.05 %). This is consistent with what the USEPA stated above. The discussion about the significance of mobile source SO<sub>2</sub> emissions can be found in Appendix F.3. For the reasons discussed, the NCDAQ has determined that mobile source SO<sub>2</sub> emissions are insignificant to the PM<sub>2.5</sub> nonattainment problem.

To summarize so far, the NCDAQ has determined that the precursor pollutants VOC, ammonia and mobile source SO<sub>2</sub>, as well as reentrained road dust are insignificant contributors to the overall PM<sub>2.5</sub> nonattainment problem in North Carolina. Therefore, the NCDAQ is not establishing MVEBs for these pollutants.

An affirmative insignificance finding from the USEPA only relieves the transportation partners from a regional emissions analysis for these pollutant emissions for these areas and does not relieve them of the other transportation conformity requirements. The transportation partners will need to note the insignificance finding for these pollutants (if found adequate and approved by the USEPA) in future conformity determinations.

The only mobile source pollutant left to be addressed for transportation conformity purposes is direct PM<sub>2.5</sub> emissions.

### **8.3 Highway Mobile Source Direct PM<sub>2.5</sub> Emissions**

40 CFR 93.109(k) in the Transportation Conformity Rule Amendments for the new 8-hour ozone and fine particulate matter NAAQSs addresses areas with insignificant motor vehicle emissions as follows,

*Notwithstanding the other paragraphs in this section, an area is not required to satisfy a regional emissions analysis for §93.118 and/or §93.119 for a given pollutant/precursor and NAAQS, if EPA finds through the adequacy or approval process that a SIP*

*demonstrates that regional motor vehicle emissions are an insignificant contributor to the air quality problem for that pollutant/precursor and NAAQS. The SIP would have to demonstrate that it would be unreasonable to expect that such an area would experience enough motor vehicle emissions growth in that pollutant/precursor for a NAAQS violation to occur.*

The rule suggests that such a finding would be based on a number of factors, including the percentage of motor vehicle emissions in the context of the total SIP inventory, the current state of air quality as determined by monitoring data for that NAAQS, the absence of SIP motor vehicle control measures, and historical trends and future projections of the growth of motor vehicle emissions.

The NCDAQ believes strongly that the primary PM<sub>2.5</sub> emissions from mobile sources do not contribute significantly to the PM<sub>2.5</sub> nonattainment problem. However, the USEPA has indicated they will not approve a SIP that does not set MVEBs for primary PM<sub>2.5</sub> for the Triad. Therefore, the NCDAQ will establish county level MVEBs for primary PM<sub>2.5</sub> for the Triad PM<sub>2.5</sub> nonattainment counties. The sections that follow discuss the insignificance of PM<sub>2.5</sub> emissions

### **Mobile Source PM<sub>2.5</sub> Emissions Insignificant**

The NCDAQ has examined the sources of PM<sub>2.5</sub> emissions and their contribution to PM<sub>2.5</sub> formation in the nonattainment counties. This was accomplished using the 2009 emissions inventories developed for the attainment demonstration modeling. The percent contribution of primary PM<sub>2.5</sub> from mobile sources is 1.6 % and 4.8 % for the Hickory and Triad nonattainment areas, respectively.

Additionally, the NCDAQ performed sensitivity modeling in order to address the language of Section 93.109(k) in the Transportation Conformity Rule Amendments; *“The SIP would have to demonstrate that it would be unreasonable to expect enough motor vehicle emissions growth in that pollutant/precursor for a NAAQS violation to occur”*. The primary PM<sub>2.5</sub> emissions from on-road mobile sources were doubled in the nonattainment areas, therefore, simulating a doubling of the VMT. The results of the emissions sensitivities showed such similar results that looking at just the difference between two air quality model simulations, one with base case emissions and another with reduced emissions inputs, showed no change. In both nonattainment areas, the modeling future design value increased by less than 0.1 µg/m<sup>3</sup>.

Based on the analysis discussed in detail in Appendix F.3, the NCDAQ steadfastly believes that the on-road mobile PM<sub>2.5</sub> emissions are insignificant contributors to the PM<sub>2.5</sub> nonattainment problem. The NCDAQ considers it unreasonable to expect that the PM<sub>2.5</sub> nonattainment areas will experience enough motor vehicle PM<sub>2.5</sub> emissions growth for a future PM<sub>2.5</sub> violation to occur due to mobile source direct PM<sub>2.5</sub> emissions.

Due to above analysis and agreement from the USEPA, budgets for direct PM<sub>2.5</sub> will not be set for the Hickory non-attainment area. An affirmative insignificance finding from the USEPA only relieves the transportation partners from a regional emissions analysis for PM<sub>2.5</sub> emissions for this area and does not relieve them of the other transportation conformity requirements. The



transportation partners will need to note the PM<sub>2.5</sub> insignificance finding (if found adequate and approved by the USEPA) in future conformity determinations.

#### 8.4 Establishing PM<sub>2.5</sub> and NO<sub>x</sub> Motor Vehicle Emission Budgets

As part of the consultation process on setting MVEBs, the NCDAQ sent out a request for comment on setting the geographic extent of the MVEBs to all of the transportation partners. In the letter, the NCDAQ expressed its preference for setting county level budgets and some of the reasons why the NCDAQ believed county level budgets were appropriate. With respect to the PM<sub>2.5</sub> nonattainment areas, the comments received were in agreement with the NCDAQ. Additionally, the NCDAQ consulted the partners for the data used in the development of the MVEBs, as well as the data used in the attainment demonstration modeling. These correspondences and the responses received from the transportation partners can be found in Appendix B.

MVEBs will be set for the attainment year 2009. By the time the MVEBs are found adequate or approved by the USEPA, the next transportation conformity regional emissions analysis should be for years 2009 and beyond. Therefore, MVEBs will not be set for the baseline year 2002.

Although the emissions are usually expressed in terms of tons, the MVEBs will be set in terms of kilograms (kg). The reason for this assertion is because the MOBILE model generates the emissions factors in grams per mile. In past conformity exercises, there have been some issues with conversion to tons, as well as concerns with how the MVEBs were rounded. Setting MVEBs in kilograms will avoid these issues in future conformity determinations.

Tables 8.4-1 and 8.4-2 below display the Triad highway mobile PM<sub>2.5</sub> and the Triad and Hickory highway mobile NO<sub>x</sub> emissions expressed in tons per year and the corresponding kilograms per year values for 2009. These two tables are for reference purposes only and are not the tables presenting the 2009 MVEBs, which is discussed next.

**Table 8.4-1. County Level PM<sub>2.5</sub> Highway Mobile Emissions for 2009**

County	MVEB (Tons/year)	MVEB (Kilograms/year)
Davidson	78.4	71,152
Guilford	181.1	164,286

**Table 8.4-2. County Level NO<sub>x</sub> Highway Mobile Emissions for 2009**

County	MVEB (Tons/year)	MVEB (Kilograms/year)
Catawba	3183.4	2,887,955
Davidson	4780.2	4,336,567
Guilford	11,034.9	10,010,856

The NCDAQ will set MVEBs, for transportation conformity purposes, as county budgets for 2009. Tables 8.4-3 and 8.4-4 below present the Triad PM<sub>2.5</sub> and the Triad and Hickory NO<sub>x</sub> MVEBs in kilograms per year, by county. Upon the USEPA's affirmative adequacy finding for these county level sub-area MVEBs, these MVEBs will become the applicable MVEBs for each county. Please see Appendix F.3, Section 4 for a detailed discussion on the planning assumptions and methodology used to develop these budgets.

**Table 8.4-3. County Level PM<sub>2.5</sub> MVEBs for 2009**

County	MVEB (Kilograms/year)
Davidson	71,152
Guilford	164,286

**Table 8.4-4. County Level NO<sub>x</sub> MVEBs for 2009**

County	MVEB (Kilograms/year)
Catawba	2,887,955
Davidson	4,336,567
Guilford	10,010,856

## 9.0 REFERENCES

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