**Modeling Protocol: Dispersion Modeling to Demonstrate Attainment of SO2 Primary NAAQS**

**July 25, 2011**
**Region 5 States**

Dispersion modeling is necessary to demonstrate attainment of the 1-hour ambient air quality standard for sulfur dioxide (SO2).  EPA guidance recommends use of the AERMOD, EPA's preferred near-field dispersion model, for this modeling.  The purpose of this document is to identify the procedures that will be followed by Region V States and others in conducting modeling to develop attainment plans for SO2.  Although the states may also be conducting modeling to help determine nonattainment boundaries, this document is focused on the state implementation plan (SIP) modeling analyses.

**INTRODUCTION**
On June 2, 2010, EPA revised the primary ambient air quality standard for SO2 by establishing a 1-hour standard at a level of 75 parts per billion (ppb)[1]. EPA also revoked the existing 24-hour and annual primary standards, but retained the 3-hour secondary standard.[2]  (Note, EPA is anticipating proposing a new SOx and NOx secondary standard in the near future.)  The form of the 1-hour standard is a 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour average concentrations.

Implementation of the 1-hour standard is based on monitoring and modeling data.  Specifically, areas with either monitoring or modeling data showing a violation of the standard will be designated as nonattainment, and areas with appropriate refined modeling and, where available, monitoring data showing no violations will be designated as attainment.  Monitoring data is not a requirement for attainment.  All other areas will be designated as unclassifiable.

For nonattainment areas, SIPs are due February 2014.  For attainment and unclassifiable areas, SIPs are due June 2013.  In all areas, attainment must be demonstrated as expeditiously as practicable, but no later than July 2017.

**EPA GUIDANCE**
To assist states in conducting modeling for SO2, EPA has provided several guidance documents:

- Guideline on Air Quality Models, 40 CFR Part 51, Appendix W
- Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO2 National Ambient Air Quality Standard, March 1, 2011

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[1] The standard became effective on August 23, 2010.

[2] To ensure that the anti-backsliding provisions and principles of section 172(e) are met and applied upon EPA revocation of the annual and 24-hour standards, EPA is providing that those SO2 NAAQS will remain in effect for one year following the effective date of the initial designations under section 107(d)(1) for the new SO2 NAAQS before the current NAAQS are revoked in most attainment areas. EPA is also providing that the annual and 24-hour NAAQS remain in place for any current nonattainment area, or any area for which a State has not fulfilled the requirements of a SIP call, until the affected area submits, and EPA approves, a SIP with an attainment, implementation, maintenance and enforcement SIP which fully addresses the attainment and maintenance requirements of the new SO2 NAAQS.

- Area Designations for the 2010 Revised Primary Sulfur Dioxide National Ambient Air Quality Standards, March 24, 2011

In the preamble to the final rule for the SO2 standard, EPA stated that it will provide additional guidance regarding the application of refined dispersion modeling for implementation of the 1-hour SO2 standard.  EPA further indicated that this guidance will follow Appendix W "with appropriate flexibility for use in implementation".  Consistent with these statements, this protocol document was prepared following the general procedures in Appendix W with some accommodations for the actual air quality situations in the region (e.g., more than 99% of the SO2 emissions come from sources with annual emissions of 80 TPY or more, and current monitored violations are limited to counties with major point sources, such as power plants, or urban industrial areas).  Once EPA issues its intended modeling guidance for the SO2 standard, this protocol will be reviewed and, if necessary, revised.

**DATA ANALYSIS**

EPA guidance (i.e., Appendix W, and other documents, such as "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM2.5, and Regional Haze") recommend that air quality measurements be used in a complementary manner to dispersion models, with due regard for the strengths and weaknesses of both analysis techniques.  In particular, analysis of air quality measurements can provide a "conceptual understanding" of the area's air quality situation.  A conceptual description is useful for helping a state identify priorities and allocate resources in performing a modeled attainment demonstration.  Data analyses of most value are those which help define source-receptor relationships.  These include air quality and emissions trends analyses, and wind direction analyses, such as simple pollution roses and more sophisticated inverse nonparametric analyses.  The data analyses can also be used, along with the dispersion modeling, to support the attainment demonstration as part of a "weight of evidence" determination

**MODEL**

EPA guidance (i.e., Appendix W) states that:

> For a wide range of regulatory applications in all types of terrain, the recommended model is AERMOD. This recommendation is based on extensive developmental and performance evaluation… Differentiation of simple versus complex terrain is unnecessary with AERMOD. In complex terrain, AERMOD employs the well-known dividing-streamline concept in a simplified simulation of the effects of plume-terrain interactions.

> If aerodynamic building downwash is important for the modeling analysis… then the recommended model is AERMOD. The state-of-the-science for modeling atmospheric deposition is evolving and the best techniques are currently being assessed and their results are being compared with observations. Consequently, while deposition treatment is available in AERMOD, the approach taken for any purpose should be coordinated with the appropriate reviewing authority. Line sources can be simulated with AERMOD if point or volume sources are appropriately combined.

EPA recently released a new version of AERMOD (Version 11103) which includes a number of enhancements to more fully support the form of the new 1-hour SO2 standard, as well as new versions of AERMAP (Version 11103) and AERMET (Version 11059).

According to Appendix W, AERMOD is appropriate for the following applications:
- Point, volume, and area sources
- Surface, near-surface, and elevated releases

- Stacks less than good engineering practice height (i.e., those subject to building downwash)
- Primary pollutants (and continuous releases of toxic and hazardous pollutants)
- Rural or urban areas
- Simple or complex terrain
- Transport distances up to 50 km

For regulatory applications, the regulatory default option should be set which requires the use of terrain elevation data and stack-tip downwash, and assumes a 4-hour half-life for SO2 in urban areas. A conservative alternative is AERSCREEN (Version 11076), which is a screening-level model based on AERMOD. AERSCREEN could be used to screen out sources from refined modeling. The model produces estimates of "worst-case" 1-hour concentrations for a single source, without the need for hourly meteorological data, and includes conversion factors to estimate "worst-case" 3-hour, 8-hour, 24-hour, and annual concentrations. AERSCREEN is intended to produce concentration estimates that are equal to or greater than the estimates produced by AERMOD with a fully developed set of meteorological and terrain data, but the degree of conservatism will vary depending on the application.

EPA guidance (i.e., Appendix W) also provide for the use of alternative models and, in certain situations, use of measured data in lieu of model estimates. This protocol provides this same flexibility. Use of an alternative model will be allowed if a demonstration is made that the alternative model performs better than AERMOD based on an adequate network of SO2 monitors. Such an approach was used in supporting the use of the Rough Terrain Dispersion Model (in conjunction with the Industrial Source Complex model, which was the predecessor of AERMOD) for the Hamilton County, Ohio SO2 SIP (August 23, 1994, Federal Register). Use of measured data alone (including ground-based ambient monitoring and fluid modeling) should only be considered in rare situations where there are unique local complexities (e.g., terrain or building downwash) which may be difficult to address with AERMOD.

**EMISSIONS**
*Use of actual v. allowable emissions:* Appendix W recommends the use of short-term allowable emissions - i.e., maximum allowable emission limit and actual or design capacity (whichever is greater) for stationary point sources, including the main facility(ies) of interest and other nearby facilities.

As discussed further below, this protocol recommends a 2-step process in which actual emissions are used to identify which sources should be modeled and allowable emissions are used in the modeling for those sources. Using actual emissions as an initial screen will ensure that the modeling is focused on those sources with significant SO2 emissions, and using allowable emissions in the modeling will ensure that the resulting SIP emissions for those sources are protective of public health.

*Selecting the source(s) at the center of the modeling analysis and other (nearby) sources to be included in the analysis:* EPA's March 24, 2011, memo suggests that the modeling should initially focus on the most significant sources of SO2 emissions, e.g., sources emitting greater than 100 tons/year. Furthermore, the memo states that sources less than 100 tons/year can be potential contributors to a NAAQS violation, especially sources with short stacks and/or located in complex terrain (i.e., where receptor elevations are above stack height).

EPA's March 1, 2011, memo, recognizes that the routine inclusion of all sources within 50 km is likely to produce an overly conservative concentration estimate. A thorough discussion is provided in the memo of which nearby sources to include in the modeling, and notes that while there is no definitive distance

recommendation, the analysis should focus on the area within about 10 kilometers of the project location in most cases.

EPA's guidance effectively requires some analysis with AERMOD or AERSCREEN for all sources. Current Region 5 state inventories show a very large number of facilities with non-zero SO2 emissions (see Figure 1) – e.g., there are more than 1,100 facilities with actual emissions of at least 1 ton/year. Having to model this number of sources and incorporate them all in the SIP could be a problem for some states. An analysis of the SO2 emissions inventory for Region 5 shows that sources emitting 80 tons/year or more make-up 99.6% of total SO2 point source emissions in the region. To provide for a more manageable process, the following approach is recommended.

Step 1:  Use actual annual average emissions to identify sources to be modeled.  Specifically, assume that any source (total facility) with actual annual average emissions (highest year for the period 2008-2010) of 80 TPY or more will be included in the modeling.

Step 2: Use allowable emissions or federally enforceable permit limits for those sources to be modeled.[3] In the absence of allowable emissions or federally enforceable permit limits, then assume potential to emit emissions (i.e., design capacity).   Because EPA has already stated that the modeling may rely on SO2 reductions expected to result from federal rules, including those affecting EGUs (i.e., Clean Air Transport Rule) and industrial boilers (i.e., technology-based standards under CAA section 112(d)), EPA assistance is needed to determine the appropriate emission reduction credits and allowable emission levels for these sources.

A modeling domain should be established centered on the dominant source(s) in a given county or area and extend out to no more than 50 km (from the dominant source(s)).

EPA has indicated that the attainment demonstration modeling must result in federally enforceable emission limits being established for all modeled sources.  This may necessitate a SIP revision for some sources.  To ensure that the real air quality problems are addressed, states should give priority to SIP revisions for sources located in nonattainment areas and for other sources with the highest (actual) SO2 emissions.

Given the proximity of large SO2 sources to state boundaries, interstate cooperation and coordination will be necessary.  As shown in Figure 1, there are several "large" SO2 sources located within 50 km of another state.  For cases involving just a few large sources, the states in question will discuss who will take the lead on the modeling, and will agree to share emissions data and modeling results.  For cases involving many large sources, both states may need to be involved in the modeling.

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[3] In some situations, use of max hourly actual emissions may be more appropriate given current operations at a facility (based on current fuels and control equipment).  While SIP actions may be needed for these facilities (to reconcile current actual and SIP allowable emissions), this is expected to be largely a paper exercise and, as such, should be conducted on a different (longer) timeframe.
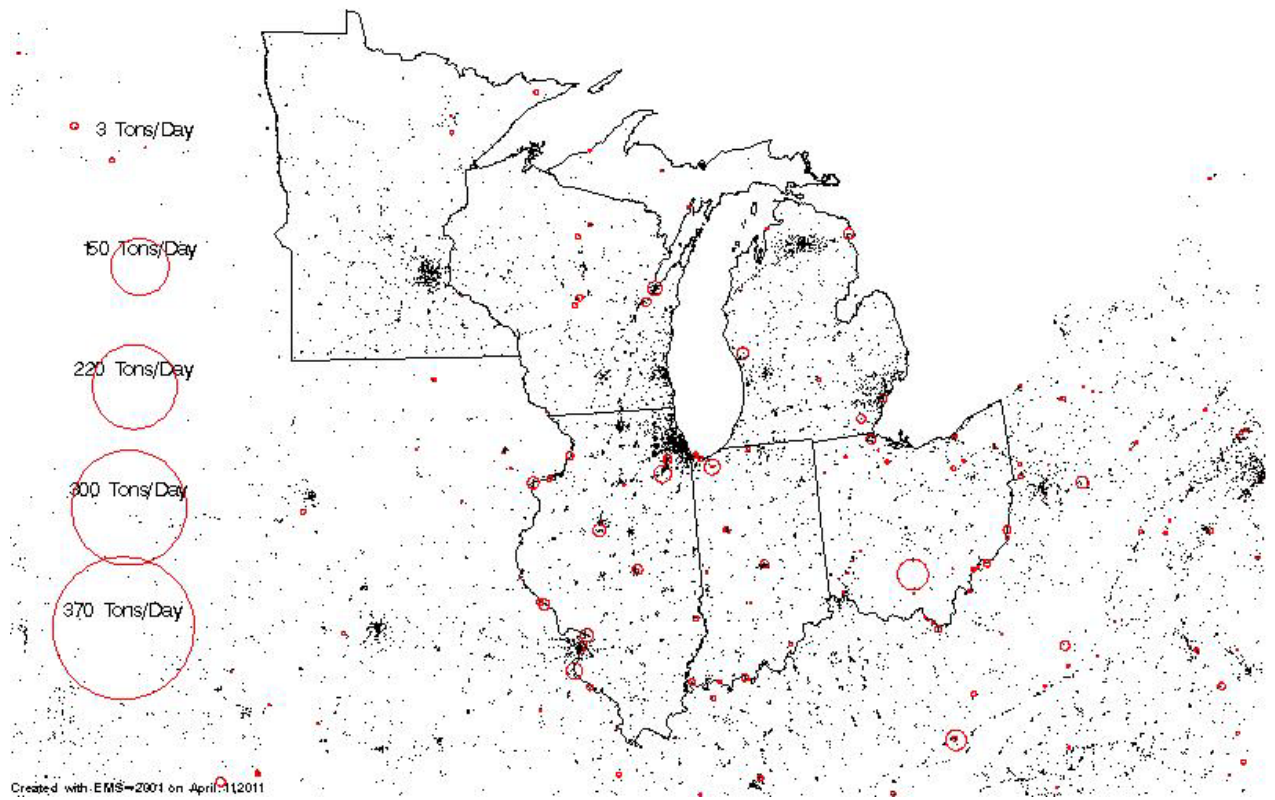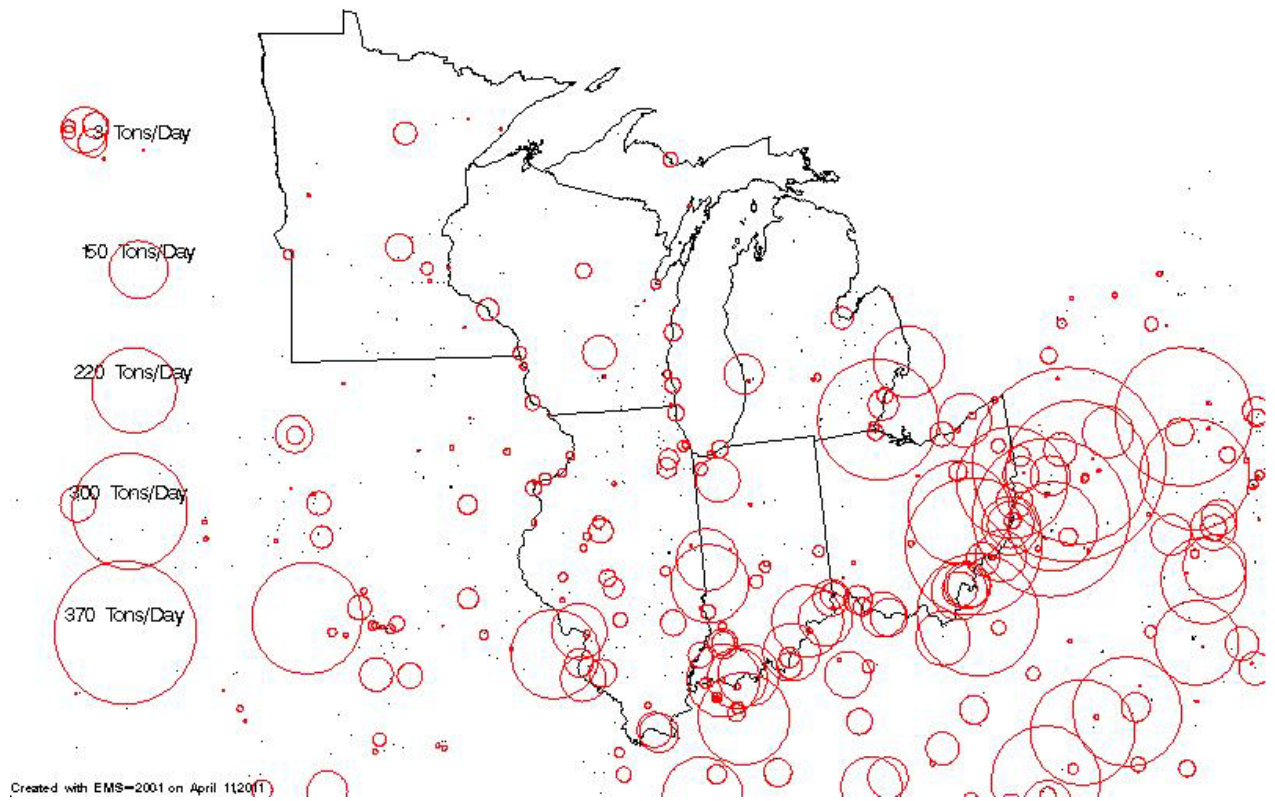
Figure 1. SO2 Emission Sources in the upper Midwest (2007 emissions)–EGUs (top),nonEGUs (bottom)

***Operating Load and Stack Parameters:*** EPA guidance recommends that, at a minimum, a source be modeled using design capacity (100 percent load).  Where the source operates at substantially less than design capacity and the changes in the stack parameters associated with the operating conditions lead to higher ground-level concentrations, the guidance recommends that the source also be modeled at loads such as 50 and 75 percent of capacity.

In addition, for sources considering installing $SO_2$ control devices, changes in stack exit parameters (e.g., velocity and temperature) should be taken into account.  Therefore, not only should the modeling analysis consider several operating loads, the affected source may need to be involved with the determination of representative post-control stack parameters.

**METEOROLOGY**
Meteorological data to be used in AERMOD should be prepared in accordance with "Regional Meteorological Data Processing Protocol, EPA Region 5 and States", December 15, 2010.  (Note, this document is currently being revised to reflect current tools and methods.) The document highlights several aspects of meteorological data processing including:  choice of surface met data, choice of upper air met data, approach for processing surface characteristics, and guidelines for determining representativeness.  The recently released met processing tools, AERMINUTE and AERMET, should be used for processing 1-minute wind data.  The 1-minute wind data address many of the issues with excess calm and missing data hours.   The 1-minute data should be processed for use in regulatory modeling.

In accordance with Appendix W, either 5 years of National Weather Service or at least 1 year of on-site meteorological data should be used in the modeling.

**BACKGROUND CONCENTRATIONS**
EPA's March 1, 2011, memo notes that ambient air quality data should generally be used to account for background concentrations.  The memo identifies the following hierarchy for developing background concentrations:

> Tier Ia - highest measured 1-hour concentration

> Tier Ib – 1-hour design value for latest 3-year period

> Tier II - multi-year average of 2nd high measured 1-hour concentrations for each season and hour-of-day combination, or the 4th high measured 1-hour concentration for hour-of-day only.

> Tier III - no background concentration needs to be included, if a comprehensive emissions inventory

A weight-of-evidence approach using available monitoring and modeling data were used to establish a reasonable regional background concentration.  Specifically, three analyses of monitoring data and three modeling analyses were considered.

***Monitoring Data***: The first analysis consisted of identifying the 1-hour design value (i.e., Tier Ib) for the two state-operated rural SO2 monitors in the region: one in northern Wisconsin (Forest County) and one in southeastern Iowa (Lake Seguma).  The 2007-2009 1-hour design values at these sites (i.e., Method !b) are 8 and 5 ppb, respectively.

The second analysis considered the SO2 data collected by EPA at rural CASTNET monitoring sites in the region. Due to differences in sampling methodology (use of filter pack analysis) and averaging times (weekly averages), these data are not directly comparable to the continuous reference monitoring conducted by states. Nevertheless, the average of the maximum weekly values from the five CASTNET sites in the region, which is on the order of 4 ppb, is useful.

The third analysis consisted of a wind direction analysis conducted by Wisconsin DNR for monitoring data from two sites in the northern part of the state: Rhinelander and Green Bay (see "Modeling Protocol : Dispersion Modeling to Demonstrate Attainment of SO2 Primary NAAQS, Comment on Emissions and Background", May 2, 2011). Removing all 1-hour values associated with winds coming from the direction of the nearby significant SO2 sources resulted in an adjusted design value of about 17 ppb for Rhinelander and about 21 ppb for Green Bay. However, some hours included in the adjusted design value calculation still showed high concentrations. Examination of these hours showed considerable variability in SO2 concentrations within the hour with indications of impacts from nearby sources. This variability demonstrates a limitation of this analysis.

***Modeling Analyses:*** The first analysis consisted of modeling by Illinois EPA. Recognizing the limited number (coverage) of SO2 monitors in the state for determining background concentrations, the Illinois EPA investigated discrete modeling of non-point background sources (area, on-road mobile, offroad mobile), in conjunction with background point sources, as a possible alternative to monitored values. Two pilot studies were conducted which evaluated monitored vs. modeled impacts at Wabash County and Tazewell County monitors. Two of the three monitoring sites were in violation of the 1-hour standard based upon 2007-2009 monitoring data. Background emissions for the county containing the monitor and for a 50 kilometer "buffer" around the county were modeled. Thus, for Wabash County, background emissions included area, on-road, and nonroad emissions from Wabash County and adjoining Illinois and Indiana counties. Somewhat analogous to emissions processing for CAMx chemical transport modeling, the AERMOD modeling used county-level base year emissions (2008 NEI SCC-based emissions) which were allocated to census tracts (from the 2000 Census) using surrogates (population, households, land use/land cover, etc.) for the apportionment. The boundaries of the census tracts became the borders of the AERMOD "AREAPOLY" constructs; the borders defined by vertices assigned through use of Census/third-party spatial information and a geographic information system.

Modeling was conducted for all point and non-point emission sources, however, when modeling was performed using only area, on-oad, and nonroad emissions, the following results were obtained:

> Wabash County
> Mt. Carmel (violating monitor): 6.09 ug/m3 (2.3 ppb), 4th high averaged over 5 years met data; 7.50 ug/m3 (2.8 ppb), peak 2008 concentration
> Rural Wabash County (non-violating monitor): 5.60 ug/m3 (2.1 ppb), 4th high averaged over 5 years met data; 7.15 ug/m3 (2.7 ppb), peak 2008 concentration

> Tazewell County
> Pekin (violating monitor): 14.76 ug/m3 (5.6 ppb), 4th high averaged over 5 years met data; 19.99 ug/m3 (7.6 ppb), peak 2008 concentration

## Annual Max SO2 4th High 2007

The second analysis consisted of regional CAMx modeling by LADCO using 2007 emissions and meteorology to estimate 4th high 1-hour SO2 concentrations across the region. This modeling showed a spatial gradient with higher values across the southern tier of states and lower values across the northern tier of states (see Figure 2). Overall, a ballpark background value of 5-15 ppb is suggested.
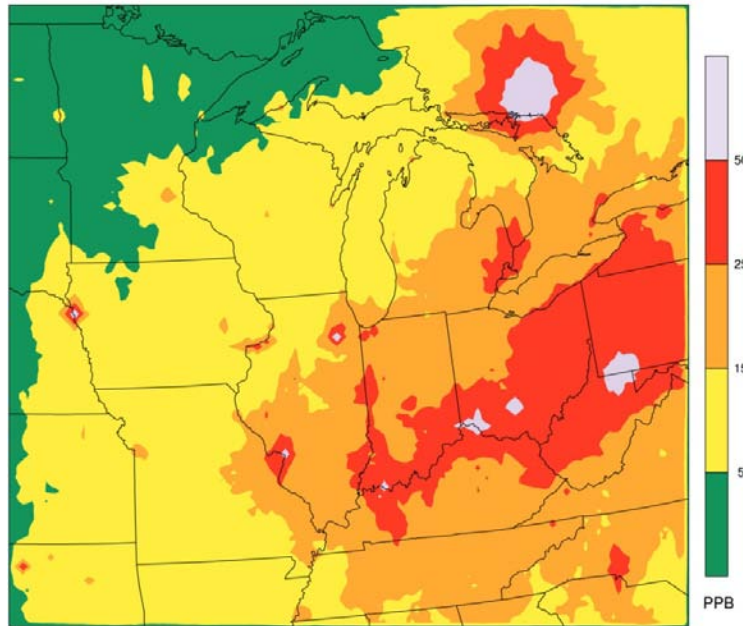


**Figure 2. LADCO CAMx modeling results (12 km grid spacing)**

The third analysis consisted of CAMx modeling by Wisconsin DNR to estimate the maximum hourly impact from five large SO2 sources in the state. This modeling showed an impact of about 5 ppb, comparable to the design value at the Forest County monitoring site in the State.

In summary, a weight-of-evidence approach based on available monitoring and modeling data was used to determine a regional background concentration for the Midwest. The monitoring data analyses suggest a concentration in the range of 4 – 8 ppb, while the modeling analyses suggest a concentration in the range of 5 – 15 ppb. Based on this information, a default regional background value of 8 ppb is recommended. Use of local data or refined analyses may be used to develop more site-specific values. The background value will be used to account for regional SO2 concentrations and smaller, non-modeled sources, assuming that the approach above will be followed for selecting the sources to be modeled and for establishing the emissions to be used for those sources.

**RECEPTOR SPACING**

According to Appendix W, modeled receptors should be "utilized in sufficient detail to estimate the highest concentrations and possible violations of a NAAQS....  In designing a receptor network, the emphasis should be placed on receptor resolution and location, not total number of receptors.  The selection of receptor sites should be a case-by-case determination taking into consideration the topography, the climatology, monitor sites, and the results of the initial screening procedure."

As discussed in the March 24 guidance memo, receptors should be placed:

- in areas considered ambient air
- of sufficient density to detect significant concentration gradients -- close together near the source in question to detect local gradients (e.g., 50-100 m) and farther apart away from the source (e.g., 500 m); and
- at key locations, such as around facility fence lines, and at monitor locations

In keeping with the limitation of AERMOD, receptor placement should not extend beyond 50 km of a given source.

As necessary, receptor placement may extend beyond the boundaries of the county in question. For situations involving "large" SO2 sources located within 50 km of another state, the states in question should agree on the receptor grid.

**ATTAINMENT DATE**
SIPs for attainment/unclassified areas are due by June 2013 and for nonattainment areas by February 2014. In all areas, attainment is required as expeditiously as practicable, but no later than July 2017. Thus, the modeling for all areas should reflect emission reductions expected to be in place by July 2017.


**REFERENCES**
USEPA, 2005, Appendix W to Part 51 - Guideline on Air Quality Models, November 9, 2005

US EPA, 2010, Guidance Concerning the Implementation of the 1-hour SO2 NAAQS for the Prevention of Significant Deterioration Program, August 23, 2010

US EPA 2011, Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO2 National Ambient Air Quality Standard, March 1, 2011

USEPA, 2011, Area Designations for the 2010 Revised Primary Sulfur Dioxide National Ambient Air Quality Standards, March 24, 2011