Source-Specific Best Available Retrofit Technology (BART) Modeling and Engineering Review: Edge Moor Units 4 & 5

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Contents

List of Appendices

List of Tables

List of Figures

1.0   Executive Summary

Conectiv Delmarva Generation, Inc, (Conectiv) an affiliate of Conectiv Energy, operates the Edge Moor Power Plant ("Edge Moor"), a coal and oil-fired electric generating station located in Wilmington, Delaware. Edge Moor has been identified by DNREC as a source that is eligible for consideration of BART controls for PM_{10} (CAIR serves as BART for SO_2 and NO_x). This document summarizes the procedures by which a modeling analysis and a BART engineering review have been conducted for the Edge Moor Units 4 and 5.

The Regional Haze Rule requires Best Available Retrofit Technology (BART) for any BART-eligible source that "emits any air pollutant which may reasonably be anticipated to cause or contribute to any impairment of visibility" in any mandatory Class I federal area.   The Environmental Protection Agency (EPA) has determined that implementation of the Clean Air Interstate Rule (CAIR) by electric generating unit (EGU) sources satisfies applicable BART requirements for SO_2 and NO_x emissions from those sources (see Appendix A for specific EPA BART references in this regard). The Delaware Department of Natural Resources and Environmental Control (DNREC) has indicated that the federal CAIR program is employed in Delaware as part of a Federal Implementation Plan (FIP) process under which EGU sources will meet the State's CAIR emission reduction requirements. As such, CAIR satisfies BART for SO_2 and NO_x for EGU sources in the State of Delaware. Accordingly, this report focuses solely on performing BART modeling analyses and engineering reviews for primary particulate matter (PM_{10}) emissions from Edge Moor Units 4 and 5.

The document entitled "Source-Specific Best Available Retrofit Technology (BART) Exemption and Determination Modeling Protocol: Edge Moor Units 4 and 5" was submitted to DNREC in May 2007. The modeling exercise was conducted in general accordance with the protocol following a conference call with the DNREC in which the proposed procedures were discussed and approved for use.

Even though Delaware is located within the Mid-Atlantic/Northeast Visibility Union (MANE-VU), the VISTAS modeling domain covers the entire state as well. ENSR modeled Edge Moor using the VISTAS meteorological data rather than the MANE-VU meteorological data for three reasons. First, VISTAS meteorological data covers three years (2001-2003), whereas MANE-VU meteorological data covers only one year (2002). Second, VISTAS meteorological data has a finer grid resolution of 4 km than MANE-VU's coarse grid resolution of 12 km. Third, the MANE-VU CALMET database was created in "No-Obs" mode (without a Step 2 procedure using surface and upper air station data), using MM5 data as the only source of meteorological observations. In contrast, VISTAS CALMET was run using surface and upper air station data. Therefore, the VISTAS data tests a data period three times as long as the MANE-VU data and has technical advantages in the way it was prepared. Pennsylvania, another nearby MANE-VU state with a number of BART-eligible sources, recommends the use of the VISTAS meteorological data due to these technical considerations.

The modeling procedures are consistent with those outlined in the updated final VISTAS common BART modeling protocol (Revision 3.2, dated August 31, 2006), available at http://www.vistassesarm.org/ documents/BARTModelingProtocol_rev3.2_31Aug06.pdf. This report references relevant portions of the common VISTAS report. Also, recent initiatives have been made by VISTAS to incorporate the new IMPROVE equation with CALPUFF results. Because of the inherent benefits of the new IMPROVE equation, ENSR has used that equation in its BART modeling. More discussion on this is provided in Section 4-4.

For the BART modeling analysis, ENSR compared the 98th percentile 24-hour average modeled change in light extinction from natural conditions with the threshold value of 0.5 deciviews (dv) recommended in the BART rule. It should be noted that the BART rule mentions a perception threshold of 1.0 dv, and allows a single facility to contribute up to half of this threshold and still be determined to have no perceptible impact on regional haze. We also note that in the draft MANE-VU report entitled, "Five-Factor Analysis of BART-Eligible Sources" (February 2007), MANE-VU indicates that a much lower visibility threshold, 0.1 delta-dv, can be used as a threshold for insignificant impacts (such that a formal BART determination is not warranted because the

possible reductions in visibility impacts are very small). The MANE-VU report indicates on page 14 that "…this value is below the 0.5 dv impact recommended by EPA for exemption modeling and we can be fairly certain that facilities below the 0.1 dv level have very small individual impacts on visibility at Class I areas." Mr. Gary Kleiman of NESCAUM has also verified (2006) this MANE-VU policy. For purposes of this analysis, ENSR has taken this more conservative approach because Delaware is a MANE-VU state. The 98th percentile results for total PM_{10} impacts on visibility as well as the sulfate portion (from H_2SO_4 emissions) versus the remainder of the PM_{10} are reported. The sulfate portion is specifically broken out because CAIR-related emission reductions in SO_2 also reduce the H_2SO_4 emissions, so that component of particulate emissions is already subject to CAIR-related controls.

The results of the modeling study demonstrate that visibility impacts due to primary PM_{10} emissions from Edge Moor Units 4 and 5 are clearly imperceptible, being well below the BART threshold value of 0.5 delta-dv (8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003), for all Class I areas. In addition, the visibility impacts are below the MANE-VU threshold of 0.1 delta-dv (8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003) at Shenandoah National Park. The visibility impacts for Brigantine Wilderness are just above the MANE-VU threshold of 0.1 delta-dv (a maximum value of 0.13 delta-dv, 8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003) when sulfates are included in the modeling. It should be noted that nearly all of the visibility impacts can be attributed to inorganic condensable PM emissions, which are modeled as sulfuric acid (H_2SO_4) emissions that result from the conversion of a small fraction (typically 1 percent or less) of the SO_2 in the coal-fired boiler flue gas stream into SO_3 and H_2SO_4. Conectiv anticipates that the implementation of CAIR and the Delaware Multi-Pollutant Regulation will also significantly reduce emissions of sulfates / inorganic condensable PM emissions since these emissions are directly proportional to SO_2 emissions. The modeling shows that the visibility impacts from non-sulfate PM_{10} are below 0.1 delta-dv for both Class I areas (a maximum value of 0.06 delta-dv, 8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003), and that additional BART analyses for primary particulate would likely yield no meaningful visibility improvements.

The DNREC has indicated that an engineering review of anticipated emission reductions from the BART-eligible sources should be provided even if the baseline modeling results show very low visibility impacts. Based on the discussion provided in Section 6 of this report, the anticipated reductions of SO_2 emissions from Units 4 and 5 due to the implementation of CAIR and Delaware's Multi-Pollutant Regulations are expected to result in significant reductions of primary sulfate emissions, which will likely reduce the PM_{10} visibility impacts from these units to levels of 0.1 delta-dv or lower. The emission reductions from non-BART Unit 3 will also provide beneficial visibility improvements that are in addition to those from the Edge Moor BART-eligible units.

1.1   Location of Source vs. Relevant Class I Areas

Figure 1-1 shows the location of the Edge Moor Power Plant relative to nearby Class I areas. There are two Class I areas within 300 km of the plant: (1) Brigantine Wilderness and (2) Shenandoah National Park. The nearest point of the Brigantine Wilderness is approximately 92 kilometers east of the Edge Moor Power Plant, while the nearest point of the Shenandoah National Park is approximately 248 kilometers southwest of the Edge Moor Power Plant. The BART modeling analysis has been conducted for both of these Class I areas in accordance with the referenced VISTAS common BART modeling protocol and the procedures described in the referenced source-specific BART modeling protocol.

1.2   Organization of Report Document

Section 2 of this report describes the source emissions that have been used as input to the BART modeling demonstration. Section 3 describes the input data that has been used for the modeling including the modeling domain, terrain and land use, and meteorological data. Section 4 describes the CALPUFF modeling and the air quality modeling procedures, and Section 5 discusses the CALPUFF modeling results. An engineering review of the effects of anticipated SO_2 and NO_x emission reductions is provided in Section 6. References are provided in Section 7. Appendix B describes the implementation of the new IMPROVE equation in the VISTAS states, as approved by the Federal Land Managers.

Figure 1-1 Location of Class I Areas in Relation to Edge Moor Power Plant

Class I Areas Within 300 km of the Conectiv Edge Moor, DE Power Plant
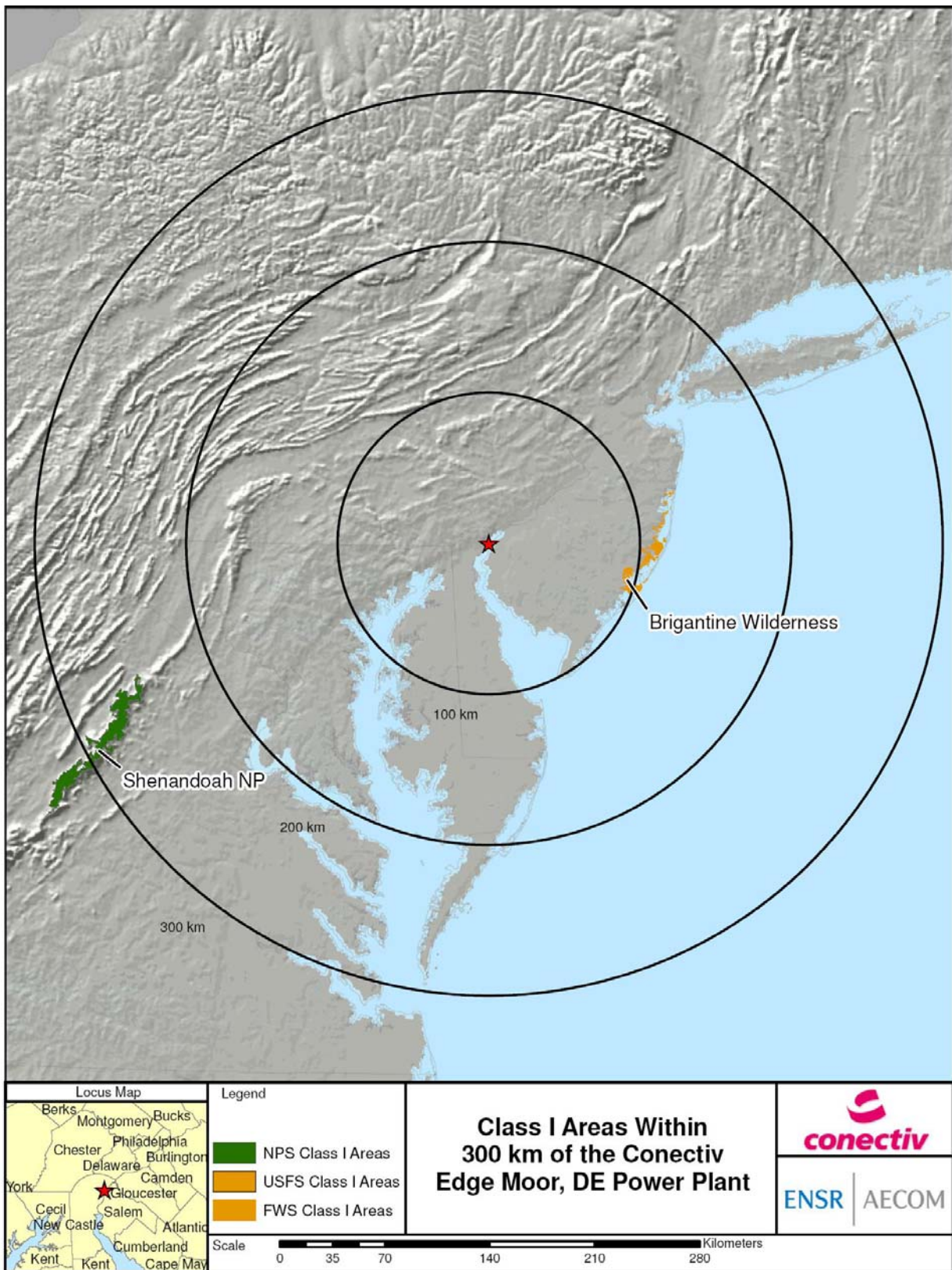
2.0 Source Description and Emissions Data

The emissions data used to assess the visibility impacts at the selected Class I areas are discussed in this section. As noted earlier, implementation of CAIR by EGUs satisfies BART requirements for SO_2 and NO_x. Therefore, this report focuses only on PM_{10}. Because the various components of PM_{10} emissions have different visibility extinction efficiencies, the PM_{10} emissions are divided, or "speciated," into several components. The EPA guidance on BART modeling encourages the use of source-specific emissions and speciation factors. Otherwise, values from EPA's AP-42 reference document can be used as the default. PM_{10} was speciated in a manner that is consistent with EPA and National Park Service guidance.

Edge Moor Unit 4 is a nominal 175 MW dry-bottom, pulverized coal (primary fuel), tangentially-fired boiler equipped with an electrostatic precipitator (ESP) for the control of filterable particulates. Edge Moor Unit 5 is a nominal 445 MW residual oil-fired (primary fuel) boiler with a multiple cyclone (multiclone) for the control of filterable particulates.

The PM_{10} emissions and speciation approach used for the baseline modeling are described in the bullets below.

- Total PM_{10} is comprised of filterable and condensable emissions.

- Baseline filterable PM_{10} emissions (units of lb/hr) were based on the source-specific emission factors (units of lb/MMBtu) derived from stack emission tests conducted in December 1989 and the maximum daily heat input recorded by the continuous emission monitoring system (CEMS) during the period from 2001 through 2006.

- Filterable PM for Unit 4 is subdivided by size category consistent with the default approach from the AP-42 Document, Table 1.1-6. For coal-fired utility boilers equipped with an ESP, 67% of the filterable PM emissions are filterable PM_{10} and 29% of the filterable PM emissions are fine filterable PM_{10} emissions (less than 2.5 microns in size). For coal-fired utility boilers, elemental carbon is expected to be 3.7% of fine PM_{10} based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.

- Filterable PM for Unit 5 is subdivided by size category consistent with the default approach from the AP-42 Document, Table 1.3-4. For uncontrolled oil-fired utility boilers, 71% of the filterable PM emissions are filterable PM_{10} and 52% of the filterable PM emissions are fine filterable PM_{10} emissions (less than 2.5 microns in size). For oil-fired utility boilers, elemental carbon is expected to be 7.4% of fine PM_{10}, based on the best estimate for electric utility petroleum combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.

- Condensable PM_{10} consists of inorganic and organic compounds. The inorganic portion is assumed to consist of H_2SO_4; the organic portion is modeled as secondary organic aerosols.

- For Unit 4, H_2SO_4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Coal Fired Power Plants", Keith Harrison, Larry Monroe and J. Edward Cichanowicz (Southern Company Services and Southern Research Institute, Revision 3, October 2005). This procedure is consistent with the method used by Conectiv for the data provided to DNREC as part of the Company's Toxic Release Inventory (TRI) reports. Before control, H_2SO_4 is determined by the relationship 0.008 x %S/100 x 10^6/HHV x HIR x 98.06/32.07. H_2SO_4 control is 49% for an air pre-heater and 49% for a cold-side ESP.

- For Unit 5 (oil-fired), H_2SO_4 emissions are based on the AP-42 Document, Table 1.3-2, where total condensable PM_{10} is 1.5 lb/Mgal. The inorganic portion of PM_{10} is 85% of the total condensable PM_{10}, while the organic portion is 15% of the total condensable PM_{10}.

In practice, CALPUFF allows for the user to input certain components of PM_{10} as separate species and separate sizes, which will result in more accurate wet and dry deposition velocity results and also more accurate effects on light scattering from the different PM_{10} species. As noted above, the particle size distribution information is provided in the AP-42 Document, Tables 1.1-6 and Table 1.3-4, and has been used for the BART modeling analysis.

A summary of the modeling stack parameters used in the BART CALPUFF modeling is presented in Table 2-1. A summary of the modeling emission parameters, as determined by the source emission factors mentioned above, is presented in Table 2-2.

Table 2-1   Modeling Exhaust Stack Parameters

	Units	Unit 4	Unit 5
UTM-X, Zone 18, NAD83	Meters	456891.942	4398832.728
UTM-Y, Zone 18, NAD83	Meters	456891.693	4398788.334
Stack Height	Meters	67.06	83.82
Base Elevation	Meters	3.96	3.96
Stack Diameter	Meters	4.11	6.40
Gas Exit Velocity	m/s	25.91	22.86
Stack Gas Exit Temperature	Deg K	407.59	413.15

Table 2-2   Baseline Emission Rates

Estimated Maximum PM10 Emissions and Speciated PM10 Emissions																					
Conectiv Edge Moor BART Eligible Units																					
Facility	Unit	Description	Nominal Maximum Heat Input	Higher Heating Value	Higher Heating Value	Ash Content	Fuel Sulfur Content	Maximum Filterable PM Emissions			Filterable PM10					Condensible PM10			Total PM10
											total	coarse	Fine			total	SO4	organic	
													fine total	fine soil	EC				
			MMBtu/hr (a)	Btu/gal (b)	Btu/lb (b)	% wt. (c)	% wt. (c)	lb/MMBtu	lb/hr	Basis	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr	lb/hr
Edge Moor Power Plant	4	Unit 4, Coal, Nominal 175 MW, PC Tangential ,Dry Bottom, ESP	1,793	N.A.	12,567	9.12	0.75	0.0290 (d)	52.05	AP-42	35.13 (e)	19.52	15.61 (e)	15.04	0.58 (f)	22.42	6.28 (g)	16.14 (h)	57.55
Edge Moor Power Plant	5	Unit 5, #6 Oil, Nominal 445 MW, Multiple Cyclone	4,551	152,655	N.A.	0	0.62	0.0579 (i)	263.38	AP-42	187.22 (j)	50.77	136.45 (j)	126.35	10.10 (k)	44.72 (l)	38.01 (l)	6.71 (l)	231.94

(a) Nominal maximum heat input is based on information received from Conectiv on April 5, 2007.
(b) Higher heating values are based on the average values for calendar years 2001 through 2006.
(c) Ash and sulfur contents are based on the values cited in the latest complete emission statement submitted to DNREC in 2004.
(d) Total filterable PM is determined from the relationship "0.08A lb/ton" (where A is the ash content in % wt.) based on AP-42, Table 1.1-4.
(e) Total filterable PM10 is 67% of filterable PM and fine filterable PM10 is 29% of filterable PM based on AP-42, Table 1.1-6.
(f) Elemental carbon is 3.7% of fine PM based on the best estimate for electric utility coal combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(g) H2SO4 emissions are based on "Estimating Total Sulfuric Acid Emissions from Coal Fired Power Plants," Keith Harrison, Larry Monroe and J. Edward Cichanowicz, Southern Company Services and Southern Research Institute, Revision 3, October 2005. Before control, H2SO4 is determined from the relationship "0.008(%S/100)(10^6/HHV)(HIR)(98.06/32.07)" (where S is the sulfur content in % wt., HHV, the higher heating value in Btu/lb, and HIR, the heat input rate in MMBtu/hr). H2SO4 control is 49% for an air preheater and 49% for a cold- side ESP.
(h) Condensable organic PM10 is determined from the relationship, "0.20(0.1S-0.03 lb/MMBtu)" (where S is the sulfur content in % wt.) based on AP-42, Table 1.1-5.
(i) Total filterable PM is determined from the relationship "0.83(1.12S+0.37) lb/Mgal" (where S is the sulfur content in % wt.) based on AP-42, Table 1.3-4.
(j) Total filterable PM10 and fine filterable PM10 is 71% of filterable PM fine PM10 is 52% of filterable PM based on AP-42, Table 1.3-4.
(k) Elemental carbon is 7.4% of fine PM based on the best estimate for electric utility petroleum combustion in Table 6 of "Catalog of Global Emissions Inventories and Emission Inventory Tools for Black Carbon", William Battye and Kathy Boyer, EPA Contract No. 68-D-98-046, January 2002.
(l) Total condensable PM10 is 1.5 lb/Mgal based on AP-42, Table 1.3-2. Inorganic and inorganic fractions are 85% and 15% of total condensable PM10, respectively.

3.0   Input Data to the CALPUFF Model

3.1   General Modeling Procedures

Although MANE-VU has processed a single year of data for use in BART assessments, a better (3-year) database is available for Delaware (including the Edge Moor Power Station), which lies within the VISTAS modeling domain. VISTAS has developed five sub-regional 4-km CALMET meteorological databases for three years (2001-2003). The sub-regional modeling domains are strategically designed to cover all potential BART-eligible sources within VISTAS states and all PSD Class I areas within 300 km of those sources. The extents of the 4-km sub-regional domains are shown in Figure 4-4 of the VISTAS common BART modeling protocol. The BART modeling for Edge Moor has been done using the easternmost 4-km subdomain that encompasses all of Delaware, as shown in Figure 4-4 of the VISTAS BART protocol (subdomain #5).

USGS 90-meter Digital Elevation Model (DEM) files were used by VISTAS to generate the terrain data at 4-km resolution for input to the 4-km sub-regional CALMET run. Likewise, USGS 90-meter Composite Theme Grid (CTG) files were used by VISTAS to generate the land use data at 4-km resolution for input to the 4-km sub-regional CALMET run.

Three years of MM5 data (2001-2003) were used by VISTAS to generate the 4-km sub-regional meteorological datasets. See Sections 4.3.2 and 4.4.2 in the VISTAS common BART modeling protocol for more detail on these issues.

All of the modeling for the Edge Moor Power Plant used the 4-km subdomain #5. A smaller computational grid within the VISTAS subdomain #5 was designed to minimize computation time and output file size. The Edge Moor computational grid domain covers distances of 452 km W-E and 352 km N-S and is shown in Figure 3-1. This domain includes two Class I areas with a 50-km buffer, plus a nearly 100-km buffer around the source (up to the limit of the VISTAS sub-domain northern boundary).

3.2   Air Quality Database (Background Ozone and Ammonia)

Hourly measurements of ozone from all non-urban monitors, as generated by VISTAS and available on the VISTAS CALPUFF page on the TRC web site (http://www.src.com/calpuff/download/sample_files.htm), have been used as input to CALPUFF. Currently, VISTAS advises sources to use a background ammonia concentration of 0.5 ppb, which has been used for this analysis. However, since there are no NO_x emissions being considered in this application, the results are not sensitive to the ammonia concentration used.

3.3   Natural Conditions and Monthly f(RH) at Class I Areas

There are two Class I areas (Brigantine Wilderness Area and Shenandoah National Park) that were modeled for Edge Moor. For these Class I areas, natural background conditions have been established in order to determine a change in natural conditions related to a source's emissions. For the modeling described in this document, ENSR used the natural background light extinction of 7.44 deciviews for Brigantine W and 7.41 deciviews for Shenandoah NP, modified as noted below with site-specific considerations, and corresponding to the annual average (EPA 2003, Appendix B), consistent with the July 19, 2006 EPA guidance to Region 4 on this issue ("Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations", Joseph W. Paise/ EPA OAQPS to Kay Prince/Branch Chief).

The input to CALPOST is computed by converting the deciviews to extinction using the equation:

Extinction (Mm^{-1}) = 10 exp(deciviews/10).

For example, for Brigantine, 7.44 deciviews is equivalent to an extinction of 11.04 inverse megameters (Mm^{-1}). This extinction does not include the default 10 Mm^{-1} for Rayleigh scattering. The remaining extinction of 11.04 Mm^{-1} is due to naturally occurring particles, and should be held constant for the entire year's simulation. Therefore, the data provided to CALPOST for Brigantine is the total natural background extinction minus 10 (expressed in Mm^{-1}), or 11.04 Mm^{-1}. This is most easily input as a fine soil concentration of 11.04 µg/m^3 in CALPOST, since the extinction efficiency of soil (PM-fine) is 1.0 and there is no f(RH) component. The concentration entries for all other particle constituents were set to zero, and the fine soil concentrations were kept the same for each month of the year. The monthly values for f(RH) that CALPOST used were taken from "Guidance for Tracking Progress Under the Regional Haze Rule" (EPA, 2003) Appendix A, Table A-3.

Figure 3-1   Edge Moor CALPUFF Computational Grid in Relation to the VISTAS Subdomain #5
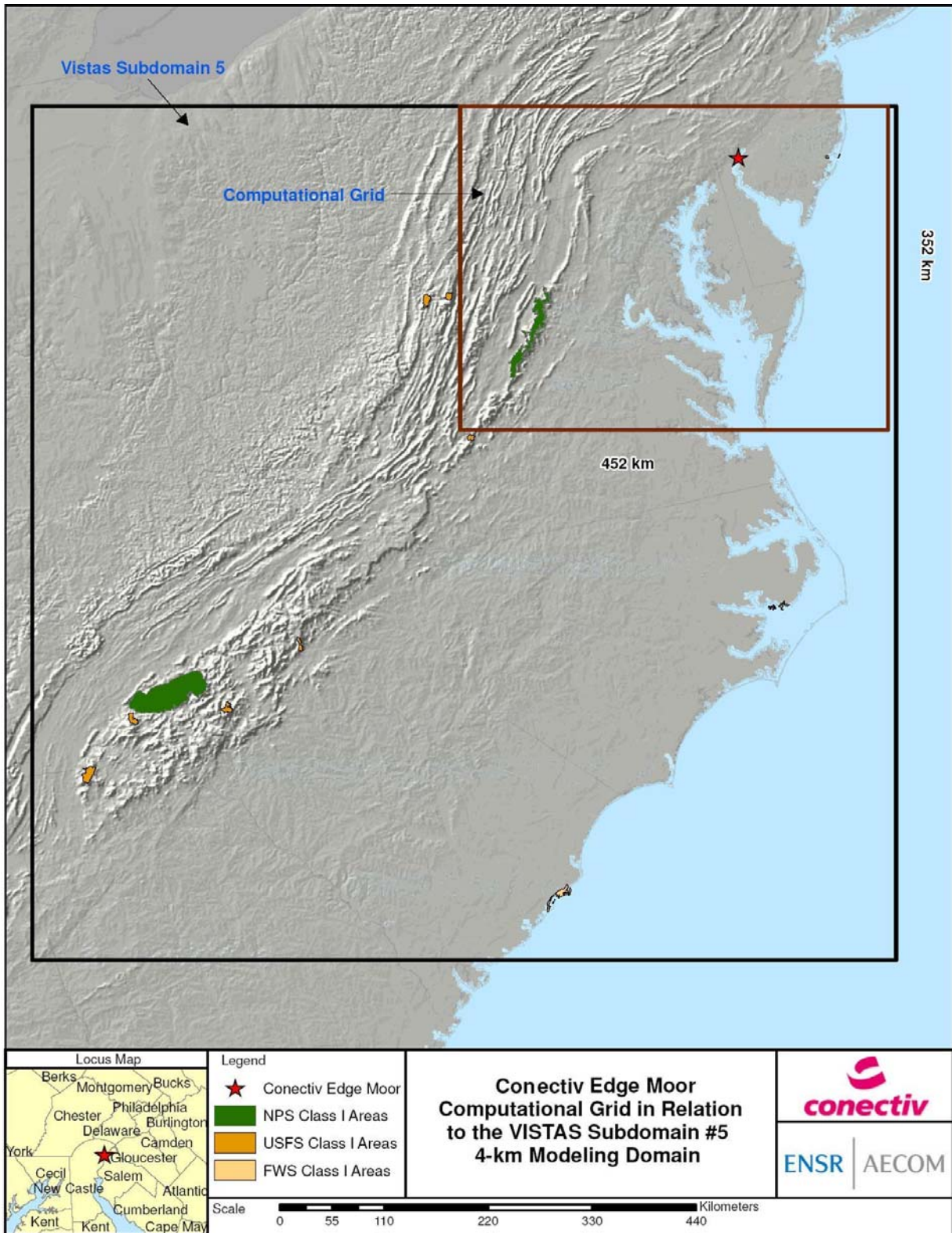
4.0   Air Quality Modeling Procedures

This section provides a summary of the modeling procedures outlined in the VISTAS protocol that have been used for the refined CALPUFF analysis conducted for the Edge Moor Power Plant.

4.1   Model Selection and Features

As noted in the VISTAS protocol, VISTAS used the BART-specific versions of CALMET and CALPUFF that have been posted at http://www.src.com/calpuff/download/download.htm#VISTAS_VERSION. These versions contain enhancements funded by the Minerals Management Service (MMS) and VISTAS. They are maintained on TRC's Atmospheric Studies Group CALPUFF website for public access.

The major features of the CALPUFF modeling system, including those of CALMET and the post processors (CALPOST and POSTUTIL) are referenced in Section 3 of the VISTAS protocol.

4.2   Modeling Domain and Receptors

The BART modeling runs for the baseline emissions used the subdomain 4-km CALMET data run in observation mode with surface stations, upper air stations, and precipitation data stations, which were supplied by VISTAS, as discussed above. This domain includes all Class I areas within 300 km of the source, plus a 50-km buffer around each source. The receptors used for each of the Class I areas are based on the National Park Service database of Class I receptors, as recommended by VISTAS.

4.3   Technical Options Used in the Modeling

CALMET modeling for the VISTAS-provided 4-km subdomains had already been conducted by the VISTAS contractor, and this modeling was reviewed and approved by the Federal Land Managers.

For CALPUFF model options, the Edge Moor Power Plant followed the VISTAS common BART modeling protocol, which states that we should use IWAQM (EPA, 1998) guidance. The VISTAS protocol also notes that building downwash effects are not required to be included, and we followed this guidance for this application as well. The Edge Moor Power Plant is several tens of kilometers from the nearest Class I area, and therefore building downwash effects can be expected to have little effect on the results of the CALPUFF modeling.

4.4   Light Extinction and Haze Impact Calculations

The CALPOST postprocessor was used as prescribed in the VISTAS protocol for the calculation of the impact of the modeled source's primary and secondary particulate matter concentrations on light extinction. The formula that is used in CALPOST is the existing IMPROVE/EPA formula, which is applied to determine a change in light extinction due to increases in the particulate matter component concentrations. Using the notation of CALPOST, the formula is the following:

$$b_{ext} = 3\ f(RH)\ [(NH_4)2SO_4] + 3\ f(RH)\ [NH_4NO_3] + 4[OC] + 1[Soil] + 0.6[Coarse\ Mass] + 10[EC] + b_{Ray}$$

The concentrations, in square brackets, are in $\mu g/m^3$ and b_{ext} is in units of Mm^{-1}. The Rayleigh scattering term (b_{Ray}) has a default value of 10 Mm^{-1}, as recommended in EPA guidance for tracking reasonable progress (EPA, 2003a).

Dr. Ivar Tombach, consultant to VISTAS, has provided a spreadsheet calculation system (see Appendix B) that incorporates the revised IMPROVE equation for determining light extinction from particulate concentration estimates. The VISTAS BART modeling protocol indicates that the unrevised IMPROVE algorithm does not incorporate the effects of naturally occurring sea salt on background visibility. The Brigantine Wilderness is significantly affected by this omission because it is off the coastline of New Jersey and surrounded by salt water. Therefore, we incorporated this effect into the present CALPUFF framework by using the guidance provided by Dr. Tombach, as presented in Appendix B. Table 4-1 lists sea salt concentrations and Rayleigh coefficients that were used in Dr. Tombach's new IMPROVE equation.

Table 4-1   Sea Salt Concentrations and Rayleigh Scattering Coefficients

	Brigantine W	**Shenandoah NP**
Sea Salt Concentration (µg/m3)	0.22	0.02
Raleigh Scattering Coefficient (Mm-1)	12	10

The assessment of visibility impacts at the Class I areas used CALPOST Method 6. Each hour's source-caused extinction was calculated by first using the hygroscopic components of the source-caused concentrations, due to ammonium sulfate and nitrate (not relevant for EGUs in CAIR states except for H_2SO_4 emissions), and monthly Class I area-specific f(RH) values. The contribution to the total source-caused extinction from ammonium sulfate and nitrate was then added to the other, non-hygroscopic components of the particulate concentration (from coarse and fine soil, secondary organic aerosols, and elemental carbon) to yield the total hourly source-caused extinction.

The EPA BART rule's recommended significance threshold for contribution to visibility impairment is 0.5 delta deciviews. As noted above, ENSR compared the PM_{10} visibility impacts to both the EPA-recommended 0.5 delta deciview threshold and the very conservative threshold of 0.1 delta deciviews for MANE-VU (98th percentile impacts), especially for the non-sulfate portion of the PM_{10} emissions. As an added check and in accordance with the EPA BART rule, the 22nd highest prediction over the three years modeled has been compared to these thresholds.

5.0 Modeling Results for Baseline PM_{10} Emissions

The BART modeling results for Units 4 and 5 at Edge Moor are provided in Table 5-1. The table lists regional haze impacts with sulfates and without sulfates modeled (sulfates result from conversion of SO_2, a pollutant for which BART is already satisfied due to regulation under CAIR). The table indicates that the 8th highest day's impacts for each year and each Class I area, even including measured sulfates, are well below 0.5 delta-dv. However, in comparing the visibility results with the very conservative MANE-VU contribution threshold of 0.1 delta-dv, Table 5-1 indicates that with sulfates included, impacts at Shenandoah National Park are below 0.1 delta-dv, but impacts at Brigantine Wilderness are slightly above that threshold, with the maximum 8th highest impact being 0.13 delta-dv.

However, in light of the fact that Delaware is a CAIR state, it is also important to list the non-sulfate portion of the visibility impact from the Edge Moor Power Plant, since regional CAIR controls on SO_2 will also effectively control regional emissions of sulfates (H_2SO_4). As discussed earlier, sulfates are a large contributor to visibility impacts. Table 5-1 indicates that the highest 98th percentile (8th highest) impact for the non-sulfate particulate emissions from Edge Moor Units 4 and 5 at Brigantine W is only 0.06 delta-dv. Therefore, when SO_2 controls are taken into account (see discussion in Section 6), it is very likely that Edge Moor's PM_{10} emissions will be below the MANE-VU 0.1 threshold. An engineering review of anticipated emission reductions and their effects on visibility impacts is provided in Section 6.

Based upon the modeling results, Conectiv notes that:

1) SO_2 and NO_x controls are required by, and will result from, CAIR. Future reductions in SO_2 emissions to comply with CAIR will likewise reduce the formation of sulfates (H_2SO_4) that result from inorganic condensable PM_{10} emissions.

2) Total PM_{10} impacts (even including sulfates) are well below the EPA-specified 0.5 delta-deciview regional haze contribution threshold, with the 98th percentile impact equal to only 0.13 delta-dv.

3) At least half of these impacts are due to sulfuric acid mist emissions, which the regional implementation of CAIR will effectively address.

4) After taking CAIR into account, the remaining visibility impact (from filterable and organic condensable PM_{10}) is well below MANE-VU's very conservative 0.10 delta-deciview threshold, a threshold that MANE-VU considers to be so low that a BART determination analysis is not required when that threshold is not exceeded by the modeled visibility impact.

Table 5-1   Summary of Results – Edge Moor BART Modeling

Class I Area	2001				2002				2003			
	Days > than		MAX dv ΔB_{ext}	8th Highest dv ΔB_{ext}	Days > than		MAX dv ΔB_{ext}	8th Highest dv ΔB_{ext}	Days > than		MAX dv ΔB_{ext}	8th Highest dv ΔB_{ext}
	0.1 dv ΔB_{ext}	0.5 dv ΔB_{ext}			0.1 dv ΔB_{ext}	0.5 dv ΔB_{ext}			0.1 dv ΔB_{ext}	0.5 dv ΔB_{ext}		
MVISBK=6, Annual Average Background, 4-km CALMET, New IMPROVE, Sulfates Included												
Brigantine Wilderness	17	0	0.22	0.13	8	0	0.17	0.11	9	0	0.14	0.11
Shenandoah National Park	0	0	0.05	0.02	0	0	0.05	0.04	1	0	0.11	0.05
MVISBK=6, Annual Average Background, 4-km CALMET, New IMPROVE, Without Sulfates												
Brigantine Wilderness	0	0	0.10	0.06	0	0	0.08	0.05	0	0	0.07	0.05
Shenandoah National Park	0	0	0.03	0.01	0	0	0.02	0.01	0	0	0.05	0.02

6.0   Evaluation of Air Pollution Control Technologies

EPA has determined that implementation of CAIR by EGU sources satisfies applicable BART requirements for SO_2 and NO_x emissions from those sources. The DNREC has indicated that the federal CAIR program is employed in Delaware as part of a Federal Implementation Plan (FIP) and, as such, CAIR satisfies BART for SO_2 and NO_x for EGU sources in the State of Delaware. Furthermore, the DNREC has promulgated Regulation 1146, the Electric Generating Unit Multi-Pollutant Regulation, effective December 11, 2006. This regulation establishes SO_2 and NO_x emission limits for coal and residual oil-fired EGUs with a nameplate capacity rating of 25 MW or greater. According to this regulation, NO_x emissions from coal and residual oil fired EGUs must not exceed 0.15 lb/MMBtu from May 1, 2009 through December 31, 2011, and 0.125 lb/MMBtu on or after January 1, 2012, on a 24-hour rolling average basis. For coal-fired EGUs, SO_2 emissions must not exceed 0.37 lb/MMBtu from May 1, 2009 through December 31, 2011, and 0.26 lb/MMBtu on or after January 1, 2012, also on a 24-hour rolling average basis. For residual oil-fired units, EGUs must not receive residual oil with a sulfur content in excess of 0.5% by weight on or after January 1, 2009.

Edge Moor Unit 4 is a nominal 175 MW dry-bottom, pulverized coal (primary fuel), tangentially-fired boiler equipped with low-NO_x coal burners (LNB) and overfire air (OFA) for the control of NO_x emissions and an electrostatic precipitator (ESP) for the control of filterable particulate emissions. Unit 4 is currently permitted to burn coal with a sulfur content of 1.0% wt. To comply with DNREC's Multi-Pollutant Regulation, Unit 4 is anticipated to be retrofitted with a dry-sorbent injection system using a sodium-based sorbent to further reduce SO_2 emissions. For NO_x control, Unit 4 will be undertake the addition/enhancement/optimization of low-NO_x burner (LNB), overfire air (OFA), and will implement a new selective non-catalytic reduction system (SNCR).

Edge Moor Unit 5 is a nominal 445 MW residual oil-fired (primary fuel) boiler with oil LNB and OFA for the control of NO_x emissions and a multiclone for the control of filterable particulates. Unit 5 is also currently permitted to burn oil with a sulfur content of 1.0% wt. To comply with DNREC's Multi-Pollutant Regulation, Unit 5 is anticipated to receive residual oil for use at the facility with a maximum sulfur content of no more than 0.5% by weight to reduce SO_2 emissions. NO_x additions/enhancements/optimizations anticipated to be employed will also include the addition of a new SNCR system to further control NO_x emissions.

Edge Moor Unit 3 (a coal-fired unit) is not a BART-eligible unit because it was placed into service before August 7, 1962. However, the Delaware Multi-Pollutant Regulation (and CAIR) will result in emission reductions at this unit as well.   Since the baseline period (2000-2004), Conectiv has installed enhanced LNBs and supplemental OFA on this unit.   Conectiv also plans on improving the urea injection components associated with the SNCR NOx control system as part of the Multi-Pollutant Regulation. These controls will extend the CAIR-related emission reductions at Edge Moor to the only non-BART unit at the plant.

The remainder of this section discusses the BART determination factors related to PM_{10} controls and evaluates the effectiveness of existing and proposed air pollution control technologies in reducing not only direct PM_{10} emissions, but also precursors to PM_{10} emissions, from Edge Moor Units 4 and 5.

Electrostatic Precipitator

Unit 4 is equipped with an American Air Filter, cold side ESP to control filterable particulate matter discharged from the boiler. The ESP uses electrical forces to move particles entrained within the exhaust stream onto collector plates. The entrained particles are given an electrical charge when they pass through the corona, a region where gaseous ions flow. Electrodes in the center of the gas stream are maintained at high voltage and generate the electrical field that forces the particles to the collector plates. The collector plates are periodically knocked or "rapped" by various mechanical means to dislodge the particulate, which slides downward into a

hopper where they are collected. The collection hopper is evacuated periodically, as it becomes full. The particulate is removed through a rotary valve into an ash-handling system, such as a pneumatic conveyor, and is then disposed of.

The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a "corona." The electrodes are usually given a negative polarity because a negative corona supports a higher voltage than does a positive corona before sparking occurs. The ions generated in the corona follow electric field lines from the wires to the collecting plates. Therefore, each wire establishes a charging zone through which the particles must pass. As larger particles absorb many times more ions than small particles, the electrical forces are much stronger on larger particles.

Certain design features and particle characteristics affect the control efficiency of an ESP. The rapping that dislodges the accumulated layer also releases some of the particles back into the gas stream. These re-entrained particles are then collected again in later sections, but the particles re-entrained in the last section are not collected and escape the unit. Further, part of the gas may flow around the charging zones through the clearances required for non-electrified internal components at the top of the ESP. This is called "sneakage" and places an upper limit on the collection efficiency. On Unit 4, the ESP has been designed to maintain the gas flow through at a relatively low velocity to minimize particle re-entrainment and to prevent gas flow around the charging zone to minimize sneakage.

Another major factor in the ESP's performance is the resistivity of the particles discharged from the boiler. Because the particles form a continuous layer on the ESP plates, all of the ion current must pass through the layer to reach the ground plates, creating an electric field in the layer. At high resistivities, this current can become strong enough to cause local electrical breakdown known as "back corona." At low resistivities, the particles are held on the plates so loosely that particle re-entrainment becomes much more severe. On Unit 4, ESP performance has been optimized for the relatively constant particle properties associated with the coal commonly fired in the boiler. It should also be noted that sodium based sorbent injection technology, anticipated for use by Conectiv for compliance with Delaware's Multi-pollutant Regulation is commonly used by ESP operators to reduce fly ash resistivity to improve the capture efficiency of particulate matter in such control devices,

ESPs are the most widely applied particulate control device to coal-fired utility boilers in the country. Based on performance tests conducted in December 1989, the Unit 4 ESP was demonstrated to limit filterable particulate emissions to 0.015 to 0.018 lb/MMBtu. These performance levels are much better than the MACT standard of 0.07 lb/MMBtu. As stated in the preamble to the BART Guidelines, "...unless there are new technologies subsequent to the MACT standards which would lead to cost effective increases in the level of control, States may rely on the MACT standards for purposes of BART". Because no new technologies have become available since issuance of the MACT standard, the existing ESPs may be considered representative of BART. Furthermore, the performance levels are comparable to those specified for ESPs and baghouses being applied to new coal-fired utility boilers around the country. Consequently, the existing ESP is considered BART for PM_{10} emissions from Unit 4.

Multiple Cyclone Separator

Unit 5 is equipped with a multiple cyclone separator to control filterable particulate matter discharged from the boiler. Multiple cyclone separators, also known as "multiclones", consist of a number of small-diameter cyclones, operating in parallel and having a common gas inlet and outlet. Multiclones operate on the same principle as cyclones, creating a main downward vortex and an ascending inner vortex. Multiclones are more efficient than single cyclones because they are longer and smaller in diameter. The longer length provides longer residence time, while the smaller diameter creates greater centrifugal force. These two factors result in better separation of dust particles. The pressure drop of multiclone collectors is higher than that of single-cyclone separators.

Cyclone collectors are centrifugal collectors that rely on the particle density and velocity to separate the fly ash from the flue gas. The particulate-laden flue gas enters the top or the side of the cyclone. Vanes impart a rotational velocity to the flue gas, driving the fly ash to the edge of the cylinder. The flue gas then exits the center of the cyclone out the top, leaving the fly ash to fall out the bottom. At pressures near one atmosphere and 2 to 5 inches water gauge pressure differential, multiclones have been demonstrated to be capable of achieving a 40% to 60% reduction in filterable particulate emissions.

Multiclones are a common particulate control device applied to residual oil-fired utility boilers. Based on performance tests conducted in December 1989, the Unit 5 multiclone was demonstrated to limit filterable particulate emissions to 0.020 to 0.024 lb/MMBtu. These performance levels are comparable to those specified for particulate control devices applied to new oil-fired boilers. Consequently, the existing multiclone is considered BART for PM_{10} emissions from Unit 5.

Dry Sorbent Injection and Fuel Oil Sulfur Content

To comply with the Multi-Pollutant Regulation, it is anticipated that dry sorbent injection (DSI) will be installed to control SO_2 emissions from Unit 4. DSI requires less capital equipment, less physical space, and less modification to existing ductwork than do spray dryer absorbers or wet scrubbers. However, reagent costs are much higher and, depending on the absorbent and amount of sorbent injected, control efficiency is lower than for a spray dryer absorber. Lime, soda ash, and sodium based sorbents (such as Trona, or sodium sesquicarbonate) are possible reagents. Lime and soda ash are the least reactive reagents, resulting in low efficiencies even at high injection rates. Trona is a very reactive reagent that can be used to achieve a range of efficiencies depending on the amount of sorbent injected.

The sorbent particles need to be ground extremely fine (milled) to maximize the surface area of the particles. The finer the particles, the faster and more complete the reaction for a given injection rate. The neutralization reaction between the SO_2 (mild acid) and the sorbent (strong base) takes place on the surface area of the sorbent particles. After finely ground sorbent is pulverized, it is blown into the hot flue gas stream using a high pressure blower. The sorbent reacts with the acid gases in the flue gas stream, and the reacted particles are removed with the ash in the particulate control device.

The chemical reaction of the acid components of the flue gas with the alkaline reagent takes place in the ductwork ahead of the particulate collection device and continues in the device itself. The main chemical reaction is as follows:

$$2(Na_3(HCO_3) \bullet (CO_3) \bullet 2H_2O) + 3SO_2 \rightarrow 3Na_2SO_3 + 5H_2O + 4CO_2$$

Plant operating conditions will ultimately affect the performance of the sodium sesquicarbonate in acid gas removal. The most important variables for high removal efficiency are injection temperature, SO_2 concentration, retention time, and fine particle size (~10 microns).

As designed, DSI will be capable of limiting SO_2 emissions from Unit 4 to the standards established in the Multi-Pollutant Regulation, that is, 0.37 lb/MMBtu by May 1, 2009 and 0.26 lb/MMBtu by January 1, 2012. In addition, DSI will remove an equivalent percentage of the SO_3 and sulfates in the gas stream, thus reducing the inorganic condensable PM_{10} from Unit 4 by a factor of about 4 (over peak, actual baseline emissions of greater than 1.0 lb/MMBtu of SO_2) by 2012. Similar reductions in visibility-affecting emissions from Unit 3, which is not a BART-eligible source, will also occur due to DSI injection for that unit.

The reduction in the fuel oil sulfur content for Unit 5 emissions will result in a reduction of directly-emitted sulfates of at least 30% relative to baseline conditions. Together, the reductions of primary sulfate emissions due to the SO_2 emission reduction measures taken for Units 4 and 5 would be expected to result in a revised 98th percentile visibility prediction of 0.1 delta-dv or lower for BART-eligible Units 4 and 5.

Selective Non-Catalytic Reduction

To comply with the Multi-Pollutant Regulation, it is presently anticipated that new selective non-catalytic reduction (SNCR) control systems will be installed to further control NO_x emissions from both Units 4 and 5. SNCR has been applied to a number of different types of combustion sources, including utility and industrial boilers fired with natural gas, oil, and coal. The SNCR process is based on a gas-phase homogeneous reaction, within a specified temperature range, between NO_x in the flue gas and injected ammonia to produce gaseous nitrogen and water vapor. The SNCR process converts NO_x to nitrogen and water by the following general reactions:

$$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$$

$$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$
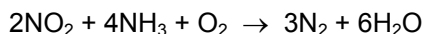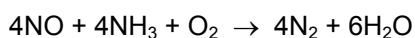
In an SNCR system, NO_x reduction does not take place in the presence of a catalyst, but rather is driven by the thermal decomposition of ammonia or urea and the subsequent reduction of NO_x. Consequently, the SNCR process operates at higher temperatures than the SCR process. Critical to the successful reduction of NO_x with SNCR is the temperature of the flue gas at the point where the reagent is injected. For the ammonia injection process, the necessary temperature range is 1,700 to 1,900 °F. The factors affecting SNCR performance are gas mixing, residence time at temperature, and ammonia slip.

Theoretically, one mole of ammonia will react with one mole of NO_x, forming elemental nitrogen and water. In reality, not all the injected reagent will react, due to imperfect mixing, uneven temperature distribution, and insufficient residence time. These physical limitations may be compensated for by injecting excess ammonia and essentially achieving low NO_x emissions at the expense of ammonia slip. Thus, for a given boiler configuration, there is a limit on the degree of NO_x reduction that can be achieved with SNCR while maintaining acceptable levels of ammonia slip.

In combination with enhanced staged combustion techniques, the SNCR will be capable of limiting NO_x emissions from Units 4 and 5 to the standards established in the Multi-Pollutant Regulation, that is, 0.15 lb/MMBtu by May 1, 2009 and 0.125 lb/MMBtu by January 1, 2012. By minimizing ammonia slip, the SNCR will not result in an appreciable change in PM_{10} emissions. This is in contrast with selective catalytic reduction (SCR), which would remove more NO_x emissions but would increase the primary emissions of H_2SO_4 by causing increased oxidation of the SO_2 emissions. During warm-weather months when NO_x emissions create very low amounts of particulate (ammonium nitrate) due to the chemistry equilibrium between ammonium nitrate and gaseous nitric acid, the operation of SCR equipment can actually lead to no visibility improvement or, in certain cases, even increased visibility impairment due to the increased H_2SO_4 emissions that result.

Staged Combustion

A number of techniques have been employed to reduce the formation of NO_x by reducing peak flame temperature and/or starving the hottest parts of the flame for oxygen. By staging the combustion process, a longer, cooler flame results, which forms less NO_x. Staged combustion techniques include low-NO_x burners (LNB), flue gas recirculation, over-fire air (OFA), and burners out of service. To further reduce NO_x emissions, Unit 4 will be retrofitted as needed with enhanced LNB and supplemental OFA. Similarly, Unit 5 will be retrofitted/enhanced with these technologies (as well as potentially flue gas recirculation) as necessary, to further reduce NOx emissions.

Conclusions on Engineering Analysis

EPA established procedures for determining BART in its Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations updated on July 24, 2005. The BART Guidelines recommend the following five steps for a case-by-case BART determination:

- Step 1– Identify all available control technologies for the unit including improvements to existing control equipment or installation of new add-on control equipment.

- Step 2– Eliminate technically infeasible options considering the commercial availability of the technology, space constraints, operating problems and reliability, and adverse side effects on the rest of the facility.

- Step 3– Evaluate the control effectiveness of the remaining technologies based on current pollutant concentrations, flue gas properties and composition, control technology performance, and other factors.

- Step 4– Evaluate the annual and incremental costs of each feasible option in accordance with approved EPA methods, as well as the associated energy and non-air quality environmental impacts.

- Step 5- Determine the visibility impairment associated with baseline emissions and the visibility improvements provided by the control technologies considered in the engineering analysis.

To minimize filterable PM_{10} emissions from Edge Moor Power Plant, Units 4 and 5 are equipped with an ESP and multiclone, respectively. These particulate collection devices have been shown to achieve performance levels comparable to those being specified as BACT for new coal- and oil-fired boilers. The existing control devices, therefore, are considered representative of BART for filterable PM_{10}. In selecting the SO_2 control technologies designed to comply with CAIR and the Multi-Pollutant Regulations, Conectiv essentially completed the first four steps in the case-by-case BART determination established by the EPA. The selected SO_2 control systems are also effective in reducing primary sulfate emissions, a constituent of condensable PM_{10}.

The fifth step in the case-by-case BART determination is satisfied in the visibility analysis documented in this report and estimates of the reductions of sulfate-caused impacts discussed in this section. The results of the visibility analysis demonstrate that visibility impacts due to primary PM_{10} emissions from Edge Moor Units 4 and 5 are clearly imperceptible, being well below the BART perceptibility threshold value of 0.5 delta-dv for all Class I areas. Furthermore, the baseline visibility impacts are below the MANE-VU threshold of 0.1 delta-dv at Shenandoah National Park. The baseline visibility impacts for Brigantine Wilderness Area are just above the MANE-VU threshold of 0.1 delta-dv when sulfates are included in the analysis. The analysis determined that more than half of the PM_{10}-caused visibility impacts can be attributed to inorganic condensable PM emissions, which result from the conversion of a small fraction of SO_2 in the gas stream into SO_3 and H_2SO_4 Consequently, it is anticipated that the implementation of CAIR and the Delaware Multi-Pollutant Regulation will not only result in a significant reduction in SO_2 emissions from Units 4 and 5 (in addition to other non-Delaware and Delaware EGU sources), but also the emissions of sulfates and other inorganic condensable PM emissions. This implementation of the additional SO_2 control systems, therefore, will result in further improvements in the visibility impacts associated with Edge Moor Units 4 and 5, such that the total PM_{10} visibility impacts are at or below the MANE-VU insignificance threshold of 0.1 delta-dv.

7.0   Conclusions

Edge Moor has been identified by DNREC as a source that is eligible for consideration of BART controls for PM_{10} (CAIR serves as BART for SO_2 and NO_x). A BART modeling and engineering analysis has been completed in accordance with an approved BART modeling protocol, and in conjunction with a conference call with the DNREC in which the proposed procedures were discussed and approved for use.

The results of the modeling study using peak daily baseline PM_{10} emissions demonstrate that visibility impacts due to primary PM_{10} emissions from Edge Moor Units 4 and 5 are clearly imperceptible, being well below the EPA-prescribed BART threshold value of 0.5 delta-dv (8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003), for both Class I areas. In addition, the visibility impacts are below the MANE-VU threshold of 0.1 delta-dv (8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003) at Shenandoah National Park. The visibility impacts for Brigantine Wilderness are just above the MANE-VU threshold of 0.1 delta-dv (a maximum value of 0.13 delta-dv, 8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003) when sulfates are included in the modeling. Conectiv anticipates that the implementation of CAIR and the Delaware Multi-Pollutant Regulation will also significantly reduce emissions of sulfates / inorganic condensable PM emissions since these emissions are directly proportional to SO_2 emissions. The modeling shows that the visibility impacts from non-sulfate PM_{10} are below 0.1 delta-dv for both Class I areas (a maximum value of 0.06 delta-dv, 8th highest or 98th percentile day in each of the three modeled years 2001, 2002 and 2003), and that additional BART analyses for primary particulate would likely yield no meaningful visibility improvements.

The DNREC has indicated that an engineering review of anticipated emission reductions from the BART-eligible sources should be provided even if the baseline modeling results show very low visibility impacts. The discussion provided in Section 6 of this report reviews the existing PM_{10} emissions control equipment and concludes that this equipment is BART. The engineering analysis also indicates that anticipated reductions of SO_2 emissions from Units 4 and 5 due to the implementation of CAIR and Multi-Pollutant Regulations are expected to result in significant reductions of primary sulfate emissions, which will likely reduce the PM_{10} visibility impacts from these units to levels of 0.1 delta-dv or lower.   The emission reductions from non-BART Unit 3 will also provide beneficial visibility improvements that are in addition to those from the Edge Moor BART-eligible units.

8.0   References

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Appendix A

Relevant Excerpts from EPA's "Additional Regional Haze Questions"

(available at http://www.tceq.state.tx.us/assets/public/implementation/air/sip/bart/EPA_QA-Haze.pdf)

Q. If the unit is already controlled (e.g., under MACT or BACT) and it is the best, the latest control technology, does the source still need to conduct a full blown BART analysis and control technology evaluation including the installed control device? Or, can the source just describe the control device on their BART-eligible source unit and make the case that it qualifies as BART, without having to evaluate other technologies?

A. If the unit has "best, latest…", then the source can just describe the control device on their BART-eligible source unit and make the case that it qualifies as BART, without having to evaluate other technologies. The streamlining of BART analyses in this situation is addressed in Section IV.C of the BART Guidelines, "How does a BART review relate to [MACT] Standards under CAA section 112, or to other emission limitations required under the CAA?

Q. How does the CAIR substitute for BART?

A. States subject to and participating in the CAIR cap and trade program for SO_2 and NO_x may treat the CAIR requirements for EGUs as a substitute for the application of BART controls for these pollutants. States do not need to require BART-eligible EGUs subject to the CAIR to install, maintain, and operate BART per 40 CFR 51.308(e)(4).

Q. If a CAIR facility is found to be exempt from BART for SO_2 and NO_x, and the State does exemption modeling on PM_{10} and concludes there is no impact on a Class I area, can the State totally exempt the utility from BART?

A. States subject to and participating in the CAIR cap and trade program for SO_2 and NO_x are allowed to treat the CAIR requirements for EGUs as a substitute for the application of BART controls per 40 CFR 51.308(e)(4). This does not mean EGUs are exempt for SO_2 and NO_x, only that CAIR satisfies the BART requirement for those pollutants. The remaining visibility pollutants to consider for determining BART-eligible sources are PM, and, using judgment, VOCs, and ammonia. For PM, the July 6, 2005, final BART rule at 70 FR 39160 notes PM_{10} may be used an indicator for PM in this step of the determination and thus, PM_{10} can be used for the exemption modeling.

Appendix B

**Re-Calculating CALPOST Visibility Outputs
with the New IMPROVE Algorithm**

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Recalculating CALPOST Visibility Outputs with the New IMPROVE Algorithm

15 August 2006

Introduction

CALPOST processes outputs from CALPUFF modeling of a source's emissions to calculate the incremental visibility impairments caused by the modeled source. Those increments are presented in two tables, both labeled "Ranked Daily Visibility Change", in the CALPOST output (.LST) file. The table of interest to us has the subtitle "Modeled Extinction by Species" and lists the dates and locations of such incremental impacts in light extinction (b_{ext}) in ranked order, starting with the one that represents the largest percentage change in light extinction.[1]

Visibility effects are calculated in CALPOST from CALPUFF-modeled particulate matter component concentrations using effectively the "traditional" IMPROVE algorithm. CALPOST allows for choice of the humidity scattering enhancement function (f(RH)) to be used with the IMPROVE algorithm; for modeling in connection with the US EPA's Regional Haze Regulations (RHR), the appropriate form of f(RH) is the one described and tabulated in the EPA's 2003 guidance for tracking progress under the RHR.

Recently, the IMPROVE Steering Committee developed a new algorithm for estimating light extinction from particulate matter component concentrations. This algorithm (the "new IMPROVE algorithm") provides a better correspondence between the measured visibility and that calculated from particulate matter component concentrations. The new algorithm differs in several substantive ways from the traditional one:

- The extinction efficiencies of sulfates, nitrates, and organics have been changed and are now functions of their concentrations. The extinction efficiencies of

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[1] The other table in the CALPOST output file, with the subtitle "% of Modeled Extinction by Species", provides equivalent results in terms of changes in the haze index, in deciviews. The two tables represent the same results, with identical ranking of events, while just using different (but mathematically related) metrics.

sulfate and nitrate are no longer identical, although the new hygroscopic scattering enhancement factors applied to them are the same.

- The concentration of particulate organic matter (POM; variously also labeled OCM or OMC, and sometimes just called "organics") is now taken to be 1.8 times that of the measured organic carbon (OC) concentration. (Confusingly, CALPOST labels the organics concentration as OC.)

- The contribution of fine sea salt to light extinction has been added, and is accompanied by its own hygroscopic scattering enhancement factor, $f_{ss}(RH)$.

- The light scattering by air itself (Rayleigh scattering) now varies with site elevation and mean temperature. It is to be rounded off to the nearest one Mm^{-1} when used with the new algorithm.

- The light absorption by NO_2 gas has been added.

The new IMPROVE algorithm is represented by the following formula:[2]

$$
\begin{aligned}
b_{ext} = \ & 2.2 \cdot f_S(RH) \cdot [small\ sulfate] + 4.8 \cdot f_L(RH) \cdot [large\ sulfate] \\
& + 2.4 \cdot f_S(RH) \cdot [small\ nitrate] + 5.1 \cdot f_L(RH) \cdot [large\ nitrate] \\
& + 2.8 \cdot [small\ organics] + 6.1 \cdot [large\ organics] \\
& + 10 \cdot [elemental\ carbon] \\
& + 1 \cdot [fine\ soil] \\
& + 1.7 \cdot f_{SS}(RH) \cdot [sea\ salt] \\
& + 0.6 \cdot [coarse\ matter] \\
& + Rayleigh\ scattering\ (site\ specific) \\
& + 0.33 \cdot [NO_2(ppb)]
\end{aligned}
\qquad \text{(Eq. 1)}
$$

The concentrations of "large" and "small" sulfate particles are calculated as follows:

$$[large\ sulfate] = \{[total\ sulfate]/20\} \cdot [total\ sulfate]\ if\ [total\ sulfate] < 20\ \mu g^3$$

$$[large\ sulfate] = [total\ sulfate]\ if\ [total\ sulfate] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. 2)}$$

$$[small\ sulfate] = [total\ sulfate] - [large\ sulfate].$$

Identical formulas, with changes in component names, are used for nitrate and organics. In effect, these formulas conclude that low concentrations of these components are mainly in the form of "small" particles with their own extinction efficiency and $f_S(RH)$, while high concentrations (approaching 20 $\mu g/m^3$) are mainly in the form of "large" particles with a different extinction efficiency and $f_L(RH)$. The scaling factor [total sulfate]/20 sets the fraction of total sulfate that is small.

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[2] Square brackets denote concentrations.

2

The sea salt concentration is taken to be 1.7•[Cl⁻] or, if chloride ion measurements are not available, the chlorine concentration can be used in its place. Site specific Rayleigh scattering values have been calculated for all IMPROVE sites.[3] Nitrogen dioxide concentrations are not measured at IMPROVE sites and the concentrations are sufficiently low that the NO_2 term is very small and can typically be ignored in rural areas.

In order for CALPOST to calculate CALPUFF-modeled source impacts on visibility using the new IMPROVE algorithm, CALPOST would have to be extensively reprogrammed. As an alternative, such a calculation could be done "off line" by adding another layer of post processing after CALPOST. To this end, I have developed a processor, in the form of an Excel workbook, that takes the CALPOST "Ranked Daily Visibility Change: Modeled Extinction by Species" output table based on default annual average natural conditions concentrations and creates an equivalent table of results based on the new algorithm.

The following describes the science behind the processor (which we'll call the CALPOST-IMPROVE Processor) and provides instructions for using it.

Concepts

In addition to the mechanical changes imposed by all the new terms in the new IMPROVE formula, applying the new algorithm also requires some conceptual changes. The biggest of these is that the extinction efficiencies of sulfates, nitrates, and organics now depend on the concentrations of those species. The practical implication of this is that extinction is no longer linearly additive. You cannot take a background level of extinction and add to it CALPOST's calculation of extinction caused by the particulate matter coming from a source, because when the two aerosols mix in the atmosphere their combined mass concentration results in increases in the extinction efficiencies of both the background and the source contribution. This means that combining background particulate matter with the particulate matter from a source gives an extinction result that is greater than the sum of the two separated extinctions.

With the nonlinear behavior resulting from applying the new IMPROVE algorithm, the extinction impact of the source (i.e., the increase in extinction resulting from introducing source emissions into the atmosphere) is the sum of three parts:

> (Part A) The source impact calculated by the new IMPROVE algorithm using the CALPOST outputs for a plume in isolation;

> (Part B) An increase in that source impact because the extinction efficiency increases when the source's aerosol combines with the background aerosol; and correspondingly,

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[3] *Revised IMPROVE Algorithm for estimating Light Extinction from Particle Speciation Data.* Report to IMPROVE Steering Committee, November 2005.

3

(Part C) An increase in the extinction of the background aerosol because of that same mixing.

The total new extinction is the sum of the above three components plus the original background extinction. The original background extinction is just that calculated by the new IMPROVE algorithm from background concentrations of the various components, without any consideration of the effects of the plume.

For example, assume that the sulfate concentration attributed to a source is $[S_S]$ and the sulfate in the natural background is $[S_N]$, for a total ambient sulfate concentration of $[S_T]$. According to Equations 1 and 2, the total extinction due to sulfate for this combination is

$$b_{ext}(sulfate) = 2.2 \cdot f_S(RH) \cdot [small\ sulfate] + 4.8 \cdot f_L(RH) \cdot [large\ sulfate], \qquad \text{(Eq. 3)}$$

where

$$[large\ sulfate_T] = \{[S_T]/20\} \cdot [S_T]\ if\ [S_T] < 20\ \mu g^3$$

$$[large\ sulfate_T] = [S_T]\ if\ [S_T] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. 4)}$$

$$[small\ sulfate_T] = [S_T] - [large\ sulfate_T],$$

and the subscript T denotes total sulfate

For the portion of the extinction due directly to the source emissions (Parts A and B, above), we have, however

$$[large\ sulfate_S] = \{[S_T]/20\} \cdot [S_S]\ if\ [S_T] < 20\ \mu g^3$$

$$[large\ sulfate_S] = [S_S]\ if\ [S_T] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. 5)}$$

$$[small\ sulfate_S] = [S_S] - [large\ sulfate_S],$$

because we are now partitioning $[S_S]$ into large and small sulfate, where the size of the fraction depends on the concentration of all of the sulfate, $[S_T]$.

Similarly, for the portion of the extinction due to the background (the original background S_N plus the enhancement described under Part C, above), we have

$$[large\ sulfate_N] = \{[S_T]/20\} \cdot [S_N]\ if\ [S_T] < 20\ \mu g^3$$

$$[large\ sulfate_N] = [S_N]\ if\ [S_T] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. 6)}$$

$$[small\ sulfate_N] = [S_N] - [large\ sulfate_N],$$

4

As a check, we see that adding the corresponding formulas in Equations 5 and 6 gives the results in Equations 4.

Finally, for the original background, where there is no source impact, the corresponding formulas are

$$[large\ sulfate_N] = \{[S_N]/20\} \cdot [S_N]\ if\ [S_N] < 20\ \mu g^3$$

$$[large\ sulfate_N] = [S_N]\ if\ [S_N] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. 7)}$$

$$[small\ sulfate_N] = [S_N] - [large\ sulfate_N],$$

As usual, the fractional change in extinction is then calculated as

$$(b_{ext,T} - b_{ext,N})/b_{ext,N}, \qquad \text{(Eq. 8)}$$

which can also be expressed in deciviews.

These formulas are used in the CALPOST-IMPROVE Processor. Similar formulas apply for nitrates and organics. There is no nonlinearity in the remaining terms in Equation 1.

Description of Processor

The CALPOST-IMPROVE Processor is a Microsoft Excel workbook that consists of four worksheets:

1. Input/Output – The output table from CALPOST is imported to here and user entries are made for the Rayleigh scattering coefficient and, if desired, for a sea salt concentration at the Class I area of interest. A revised table, with extinction based on the new IMPROVE algorithm is then presented on the same page. This is the only page on which user input takes place, and the results of the calculations appear on this page.

2. Calculations -- The calculations themselves are all done on this worksheet. There is no user input to this page. The variables are explained on the worksheet itself, so the user can find intermediate values if so inclined. Since NO_2 concentrations are not measured at IMPROVE sites and the NO_2 absorption in rural areas is expected to be small, NO_2 has been omitted from these calculations.

3. F(RH) – This worksheet tabulates the traditional IMPROVE f(RH) against RH, and then also lists values for the three new humidity growth functions, $f_S(RH)$, $f_L(RH)$, and $f_{SS}(RH)$. It serves as a lookup table for the "Calculations" worksheet .

4. Rayleigh & Sea Salt – This page tabulates the IMPROVE-recommended Rayleigh scattering coefficients for all VISTAS Class I areas and for Class I areas in adjacent states. It also lists the average sea salt concentrations for the same

5

locations, based on chloride or chlorine measurements by IMPROVE monitors between 2000 and 2004. This sheet just provides information for the user; it is not linked to the rest of the workbook. The user can obtain Rayleigh and sea salt numbers for the Class I area of interest from this table and then manually enter them in the designated spaces in worksheet 1.

Instructions for Using the CALPOST-IMPROVE Processor

Step 1. Begin by opening the output (.LST) file from CALPOST in a text editor or word processing program.[4] In the second half of the file, locate the table "Ranked Daily Visibility Change" with the subheading "Modeled Extinction by Species".[5]

Step 2. Copy this table and paste it onto a new page. Save it as a text (.txt) file, not as a formatted (e.g., MS Word .doc or .rtf) file. The final table should contain only the column headings and the data. Delete all other captions, any additional data summaries at the end, and blank lines before or after the table. The processor can handle a maximum of 22 lines of data (i.e., the highest rank in the last, unlabeled, column should be 22) plus a row of column captions. Delete any data that exceed this limit. The result should look like the example in Figure 1.

Step 3. Open the CALPOST-IMPROVE Processor with Microsoft Excel. Save the open file under a new name so that the original empty processor will remain available for future use. The front worksheet, labeled "Input/Output" looks like Figure 2. There is a large empty box, surrounded by double lines, into which the table created above will be imported, as described below.[6] Two smaller boxes provide for user input of the Rayleigh scattering coefficient and, optionally, sea salt concentration for the Class I area, as described below. Results of the new IMPROVE algorithm calculations appear in blue in the lower half of the worksheet and some additional results, that are also useful for quality control, appear in green to the right of the large box. At the moment, many results cells will display nonsensical numbers and error messages, such as shown in Figure 2.

Step 4. Select the upper left cell (A7) in the large box. On the Excel menu bar, go to *Data>Get External Data* and click on *Import Text File*. (If the large box is not empty, click on *Edit Text Import* instead.) Select the file that contains the table created in Step 2 and click on the *Get Data* button. Go through the Text Import Wizard steps, checking that all values appear correctly in separate columns. (The label "COORDINATES (km)" will be split over two columns; this is OK.) When everything appears in order, click *Finish*.

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[4] The background concentrations that were entered into CALPOST must be the EPA-prescribed default annual average natural conditions concentrations for the East. The processor will not give correct answers if other concentrations were used in CALPOST.

[5] For future reference, this may also be a good time to locate the table with the same title but with the subtitle "% of Modeled Extinction by Species", which appears later in the output file.

[6] If the workbook has already been used, the boxes may not be empty. This does not matter.

6

```
YEAR DAY HR   RECEPTOR     COORDINATES (km)  TYPE BEXT(Model) BEXT(BKG)
BEXT(Total) %CHANGE  F(RH)  bxSO4  bxNO3     bxOC     bxEC  bxPMC  bxPMF
2002 175  0   1027         1479.069    24.683    D       5.495     21.650     27.145
25.38   3.500  5.401  0.045  0.042    0.002   0.001   0.004      1
2002 172  0   1021         1479.244    23.778    D       4.923     21.650     26.573
22.74   3.500  4.475  0.404  0.038    0.001   0.001   0.004      2
2002 284  0   1045         1484.348    27.580    D       3.150     21.470     24.620
14.67   3.300  2.684  0.428  0.033    0.001   0.001   0.003      3
2002 353  0   1026         1482.762    24.457    D       2.594     21.290     23.884
12.18   3.100  2.017  0.557  0.018    0.001   0.000   0.002      4
2002 283  0   1026         1482.762    24.457    D       2.502     21.470     23.972
11.65   3.300  2.269  0.201  0.028    0.001   0.001   0.003      5
2002 195  0   1045         1484.348    27.580    D       2.011     21.830     23.841
9.21    3.700  1.963  0.031  0.015    0.001   0.000   0.001      6
2002  20  0   1117         1486.636    34.592    D       1.872     21.200     23.072
8.83    3.000  1.542  0.320  0.009    0.000   0.000   0.001      7
2002 173  0   1128         1479.259    35.042    D       1.649     21.650     23.299
7.62    3.500  1.625  0.012  0.010    0.000   0.000   0.001      8
2002 234  0   1021         1479.244    23.778    D       1.524     22.190     23.714
6.87    4.100  1.482  0.029  0.011    0.000   0.000   0.001      9
2002 298  0   1021         1479.244    23.778    D       1.459     21.470     22.929
6.80    3.300  1.284  0.160  0.014    0.001   0.000   0.001     10
2002 299  0   1021         1479.244    23.778    D       1.436     21.470     22.906
6.69    3.300  1.281  0.140  0.013    0.000   0.000   0.001     11
2002 275  0   1026         1482.762    24.457    D       1.270     21.470     22.740
5.92    3.300  1.202  0.058  0.009    0.000   0.000   0.001     12
2002 263  0   1045         1484.348    27.580    D       1.237     22.100     23.337
5.60    4.000  1.223  0.008  0.005    0.000   0.000   0.001     13
2002 252  0   1026         1482.762    24.457    D       1.189     22.100     23.289
5.38    4.000  1.166  0.013  0.009    0.000   0.000   0.001     14
2002 285  0   1021         1479.244    23.778    D       0.992     21.470     22.462
4.62    3.300  0.813  0.179  0.001    0.000   0.000   0.000     15
2002 161  0   1026         1482.762    24.457    D       0.873     21.650     22.523
4.03    3.500  0.842  0.020  0.009    0.000   0.000   0.001     16
2002 150  0   1026         1482.762    24.457    D       0.857     21.380     22.237
4.01    3.200  0.822  0.026  0.007    0.000   0.000   0.001     17
2002 340  0   1140         1481.017    37.258    D       0.817     21.290     22.107
3.84    3.100  0.663  0.153  0.001    0.000   0.000   0.000     18
2002 151  0   1117         1486.636    34.592    D       0.745     21.380     22.125
3.49    3.200  0.704  0.033  0.007    0.000   0.000   0.001     19
2002 160  0   1021         1479.244    23.778    D       0.735     21.650     22.385
3.40    3.500  0.710  0.014  0.010    0.000   0.000   0.001     20
2002 346  0   1021         1479.244    23.778    D       0.703     21.290     21.993
3.30    3.100  0.620  0.080  0.002    0.000   0.000   0.000     21
2002 247  0   1021         1479.244    23.778    D       0.661     22.100     22.761
2.99    4.000  0.654  0.004  0.002    0.000   0.000   0.000     22
```

Figure 1. Example of CALPOST Output Table, in Proper Format for Importing into the CALPOST-IMPROVE Processor.

Step 5.[7] The "Import Data" window will appear, with cell A7 indicated as the location at which data will be entered. Click on the *Properties* button. In the window that appears, select "Overwrite existing cells with new data, clear unused cells" and uncheck "Adjust column width", then click on *OK*. Now click on the *OK* button in the "Import Data" window.

Step 6. Assuming that your Excel application is set up to automatically recalculate whenever any entries are changed, you should now have filled the cells in the large box

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[7] If the processor already had data in it and *Edit Text Import* was clicked in Step 4, then the "Import Data" window will not appear and Step 5 can be skipped.

7

Figure 2. Example of Appearance of Input/Output Worksheet before Data Entry.

on the first worksheet, numbers should have appeared in the green columns to the right, and some numbers will have appeared in the output table in blue on the lower half of the worksheet. If the data import worked properly, none of the imported data should have spilled out of the large box. Check that all the column captions in bold outside the large box are now duplicated on the first line in the box. (There won't be a caption for Rank.)

Step 7. As a further check on whether everything is correct so far, the dv information in the three columns to the right of the large box should be the same as that in the second CALPOST table "Ranked Daily Visibility Change: % of Modeled Extinction by Species", which was mentioned in Footnote 1.

Step 8. Fill in the small box after red instruction 3 with the Rayleigh scattering coefficient for the Class I area of interest. Also, if you wish, fill in the other small box, the one after red instruction 4, with the annual average sea salt concentration. (The sea salt box may be left blank, but the Rayleigh scattering coefficient box must be filled in.) To help with filling in these two boxes, the fourth worksheet, "Rayleigh & Sea Salt", provides IMPROVE-calculated values of the Rayleigh coefficients for Class I areas in the VISTAS region and in adjacent states. Also, average sea salt concentrations for 2000-2004, calculated in accordance with the new IMPROVE procedures, can be found there. At this point the "Input/Output" worksheet should look something like Figure 3, with all columns filled with meaningful data.

Step 9. The new IMPROVE algorithm output table at the bottom of the page can be compared with the original CALPOST table at the top of the page. All of the columns in both tables show exactly the same variables, except that the F(RH) column in the top table is replaced by just the RH in the lower table (since the new procedure has three different f(RH) functions). Although the events are in the same order in both tables, note that their rankings may have changed, as in New Ranks 12 vs. 13 and 19 vs. 20 in Figure 3.

For those who are interested in more detail, values of the three f(RH) functions appear in columns L through N on the second, "Calculations" spreadsheet. The extinction impact of the source, including enhancement of the extinction efficiencies for sulfates, nitrates, and organics due to the Part B that was described above, appears in columns U through AA. Extinction due to the annual average natural background appears in Columns AH through AL; natural background extinctions for those components that are enhanced by greater total mass concentrations (Part C) appear in columns AS through AV.

9

CALPOST Recalculation with New IMPROVE Algorithm

-------------------------- INPUT from CALPOST (based on old IMPROVE algorithm) --------------------

1. At cell A7, import "Ranked Daily Visibility Change" (bext) table, including column headings, from CALPOST (22 days, max)

2. Check calculated values below against CALPOST's "Ranked Daily Visibility Change" (dv) table

YEAR	DAY	HR	RECEPTOR	COORDINA	TES (km)	TYPE	BEXT(Model)	BEXT(BKG)	BEXT(Total)	%CHANGE	F(RH)	bxSO4	bxNO3	bxOC	bxEC	bxPMC	bxPMF	Rank	dv(total)	dv(bkg)	Δdv
2002	175	0	1027	1479.069	24.683	D	5.495	21.65	27.145	25.38	3.5	5.401	0.045	0.042	0.002	0.001	0.004	1	9.99	7.72	2.26
2002	172	0	1021	1479.244	23.778	D	4.923	21.65	26.573	22.74	3.5	4.475	0.404	0.038	0.001	0.001	0.004	2	9.77	7.72	2.05
2002	284	0	1045	1484.348	27.58	D	3.15	21.47	24.62	14.67	3.3	2.684	0.428	0.033	0.001	0.001	0.003	3	9.01	7.64	1.37
2002	353	0	1026	1482.762	24.457	D	2.594	21.29	23.884	12.18	3.1	2.017	0.557	0.018	0.001	0	0.002	4	8.71	7.56	1.15
2002	283	0	1026	1482.762	24.457	D	2.502	21.47	23.972	11.65	3.3	2.269	0.201	0.028	0.001	0.001	0.003	5	8.74	7.64	1.10
2002	195	0	1045	1484.348	27.58	D	2.011	21.83	23.841	9.21	3.7	1.963	0.031	0.015	0.001	0	0.001	6	8.69	7.81	0.88
2002	20	0	1117	1486.636	34.592	D	1.872	21.2	23.072	8.83	3	1.542	0.32	0.009	0	0	0.001	7	8.36	7.51	0.85
2002	173	0	1128	1479.259	35.042	D	1.649	21.65	23.299	7.62	3.5	1.625	0.012	0.01	0	0	0.001	8	8.46	7.72	0.73
2002	234	0	1021	1479.244	23.778	D	1.524	22.19	23.714	6.87	4.1	1.482	0.029	0.011	0	0	0.001	9	8.63	7.97	0.66
2002	298	0	1021	1479.244	23.778	D	1.459	21.47	22.929	6.8	3.3	1.284	0.16	0.014	0.001	0	0.001	10	8.30	7.64	0.66
2002	299	0	1021	1479.244	23.778	D	1.436	21.47	22.906	6.69	3.3	1.281	0.14	0.013	0	0	0.001	11	8.29	7.64	0.65
2002	275	0	1026	1482.762	24.457	D	1.27	21.47	22.74	5.92	3.3	1.202	0.058	0.009	0	0	0.001	12	8.22	7.64	0.57
2002	263	0	1045	1484.348	27.58	D	1.237	22.1	23.337	5.6	4	1.223	0.008	0.005	0	0	0.001	13	8.47	7.93	0.54
2002	252	0	1026	1482.762	24.457	D	1.189	22.1	23.289	5.38	4	1.166	0.013	0.009	0	0	0.001	14	8.45	7.93	0.52
2002	285	0	1021	1479.244	23.778	D	0.992	21.47	22.462	4.62	3.3	0.813	0.179	0.001	0	0	0	15	8.09	7.64	0.45
2002	161	0	1026	1482.762	24.457	D	0.873	21.65	22.523	4.03	3.5	0.842	0.02	0.009	0	0	0.001	16	8.12	7.72	0.40
2002	150	0	1026	1482.762	24.457	D	0.857	21.38	22.237	4.01	3.2	0.822	0.026	0.007	0	0	0.001	17	7.99	7.60	0.39
2002	340	0	1140	1481.017	37.258	D	0.817	21.29	22.107	3.84	3.1	0.663	0.153	0.001	0	0	0	18	7.93	7.56	0.38
2002	151	0	1117	1486.636	34.592	D	0.745	21.38	22.125	3.49	3.2	0.704	0.033	0.007	0	0	0.001	19	7.94	7.60	0.34
2002	160	0	1021	1479.244	23.778	D	0.735	21.65	22.385	3.4	3.5	0.71	0.014	0.01	0	0	0.001	20	8.06	7.72	0.33
2002	346	0	1021	1479.244	23.778	D	0.703	21.29	21.993	3.3	3.1	0.62	0.08	0.002	0	0	0	21	7.88	7.56	0.32
2002	247	0	1021	1479.244	23.778	D	0.661	22.1	22.761	2.99	4	0.654	0.004	0.002	0	0	0	22	8.22	7.93	0.29

3. Enter value of site-specific Rayleigh scattering coefficient, from "Rayleigh & Sea Salt" worksheet — 11

4. (Optional) Insert annual average sea salt concentration, from "Rayleigh & Sea Salt" worksheet. Leave blank if not used. — 0.02

------------------------------ OUTPUT (based on new IMPROVE algorithm) ------------------------------

YEAR	DAY	HR	RECEPTOR	COORDINATES	(km)	TYPE	BEXT(Source)	BEXT(BKG)	BEXT(Total)	%CHANGE	RH(%)	bsSO4	bsNO3	bsOC	bsEC	bsPMC	bsPMF	New Rank	dv(total)	dv(bkg)	Δdv
2002	175	0	1027	1479.069	24.683	D	4.441	22.04	26.521	20.32	86	4.363	0.039	0.033	0.002	0.001	0.004	1	9.75	7.90	1.85
2002	172	0	1021	1479.244	23.778	D	3.989	22.04	26.063	18.24	86	3.604	0.349	0.029	0.001	0.001	0.004	2	9.58	7.90	1.68
2002	284	0	1045	1484.348	27.58	D	2.464	21.78	24.264	11.40	84	2.076	0.357	0.026	0.001	0.001	0.003	3	8.86	7.78	1.08
2002	353	0	1026	1482.762	24.457	D	2.000	21.57	23.586	9.35	82	1.528	0.455	0.014	0.001	0	0.002	4	8.58	7.69	0.89
2002	283	0	1026	1482.762	24.457	D	1.947	21.78	23.744	9.02	84	1.753	0.167	0.022	0.001	0.001	0.003	5	8.65	7.78	0.86
2002	195	0	1045	1484.348	27.58	D	1.609	22.21	23.837	7.30	87	1.569	0.027	0.012	0.001	0	0.001	6	8.69	7.98	0.70
2002	20	0	1117	1486.636	34.592	D	1.427	21.48	22.916	6.70	81	1.16	0.26	0.007	0	0	0.001	7	8.29	7.64	0.65
2002	173	0	1128	1479.259	35.042	D	1.316	22.04	23.370	6.02	86	1.297	0.01	0.008	0	0	0.001	8	8.49	7.90	0.58
2002	234	0	1021	1479.244	23.778	D	1.249	22.64	23.896	5.56	89	1.213	0.026	0.009	0	0	0.001	9	8.71	8.17	0.54
2002	298	0	1021	1479.244	23.778	D	1.134	21.78	22.924	5.25	84	0.988	0.133	0.011	0.001	0	0.001	10	8.30	7.78	0.51
2002	299	0	1021	1479.244	23.778	D	1.114	21.78	22.903	5.16	84	0.986	0.117	0.01	0	0	0.001	11	8.29	7.78	0.50
2002	275	0	1026	1482.762	24.457	D	0.981	21.78	22.770	4.54	84	0.925	0.048	0.007	0	0	0.001	13	8.23	7.78	0.44
2002	263	0	1045	1484.348	27.58	D	1.038	22.64	23.684	4.62	89	1.026	0.007	0.004	0	0	0.001	12	8.62	8.17	0.45
2002	252	0	1026	1482.762	24.457	D	0.998	22.64	23.643	4.44	89	0.978	0.012	0.007	0	0	0.001	14	8.60	8.17	0.43
2002	285	0	1021	1479.244	23.778	D	0.775	21.78	22.561	3.58	84	0.625	0.149	8E-04	0	0	0	15	8.14	7.78	0.35
2002	161	0	1026	1482.762	24.457	D	0.696	22.04	22.744	3.18	86	0.67	0.017	0.007	0	0	0.001	16	8.22	7.90	0.31
2002	150	0	1026	1482.762	24.457	D	0.651	21.67	22.322	3.03	83	0.623	0.021	0.005	0	0	0.001	17	8.03	7.73	0.30
2002	340	0	1140	1481.017	37.258	D	0.625	21.57	22.200	2.92	82	0.5	0.125	8E-04	0	0	0	18	7.98	7.69	0.29
2002	151	0	1117	1486.636	34.592	D	0.567	21.67	22.237	2.64	83	0.533	0.027	0.005	0	0	0.001	20	7.99	7.73	0.26
2002	160	0	1021	1479.244	23.778	D	0.586	22.04	22.634	2.68	86	0.565	0.012	0.008	0	0	0.001	19	8.17	7.90	0.26
2002	346	0	1021	1479.244	23.778	D	0.534	21.57	22.109	2.50	82	0.467	0.065	0.002	0	0	0	21	7.93	7.69	0.25
2002	247	0	1021	1479.244	23.778	D	0.553	22.64	23.195	2.46	89	0.548	0.004	0.002	0	0	0	22	8.41	8.17	0.24

Figure 3. Example of Appearance of Finished Input/Output Worksheet.

10

Appendix
Details of Calculation Approach

As an example of the calculation steps, assume that the sulfate concentration resulting from emissions from a source is $[S_E]$ and the sulfate in the undisturbed natural background is $[S_N]$, for a total ambient sulfate concentration of $[S_T]$. According to Equations 1 and 2 in the main body of this document, the total extinction due to sulfate for this combination is

$$b_{ext}(sulfate) = 2.2 \cdot f_S(RH) \cdot [small\ sulfate] + 4.8 \cdot f_L(RH) \cdot [large\ sulfate], \qquad \text{(Eq. A-1)}$$

where

$$[large\ sulfate_T] = \{[S_T]/20\} \cdot [S_T]\ if\ [S_T] < 20\ \mu g^3$$

$$[large\ sulfate_T] = [S_T]\ if\ [S_T] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. A-2)}$$

$$[small\ sulfate_T] = [S_T] - [large\ sulfate_T],$$

and the subscript T denotes total sulfate

For the original background, where there is no source impact, the corresponding formulas for the terms in Equations A-2 are

$$[large\ sulfate_N] = \{[S_N]/20\} \cdot [S_N]\ if\ [S_N] < 20\ \mu g^3$$

$$[large\ sulfate_N] = [S_N]\ if\ [S_N] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. A-3)}$$

$$[small\ sulfate_N] = [S_N] - [large\ sulfate_N],$$

where the subscript N denotes natural sulfate.

Similar calculations need to be carried out for nitrates. Contributions of the other particulate components are linear and can just be calculated according to Equation 1.

If the impact due to NO_2 is also to be considered, then the source impact due to this component is, according to Equation 1,

$$b_{ext}(NO_2) = 0.33 \cdot [NO_2], \qquad \text{(Eq. A-4)}$$

where $[NO_2]$ is in ppb. It is reasonable to assume that the ambient NO_2 concentrations under natural conditions would be so small as to cause negligible light absorption, so the corresponding term is not needed in the natural conditions calculation.

The contributions due to the various components are summed together as in Equation 1 to obtain the total extinction $b_{ext,T}$ and the natural background extinction $b_{ext,N}$. The

11

fractional change in extinction is then calculated as the difference, normalized by the natural background extinction

$$(b_{ext,T} - b_{ext,N})/b_{ext,N},$$ (Eq. A-5)

a result that can also be expressed in deciviews.

These formulas are used in the CALPOST-IMPROVE Processor. Similar formulas apply for nitrates and organics. There is no nonlinearity in the remaining terms in Equation 1.

12

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