AECOM Environment

Submitted to:
Montana-Dakota Utilities Co.
Bismarck, North Dakota

Submitted by:
AECOM
Westford, Massachusetts
60140139.0100
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CALPUFF Visibility Modeling Protocol: MDU Heskett Unit 2 BART Analysis

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1.0 Introduction

1.1 Background

The North Dakota Department of Health (NDDH) has conducted CALPUFF modeling for emission sources for all BART-eligible facilities in North Dakota. This study updates and refines the CALPUFF modeling for one of these facilities, Heskett Unit 2, which is owned and operated by Montana-Dakota Utilities Co. (MDU). Heskett Unit 1, operational in 1954, has a capacity of 40 MW and is not BART-eligible since it was put into service before 1962. Unit 2, operational in 1963, has a capacity of 75 MW. Unit 2 was retrofitted to a fluidized-bed combustor in 1987, thus making it BART eligible.

In 2006, MDU asked ENSR (now AECOM) to review the NDDH BART analysis for Heskett Unit 2 and to provide an analysis that considered updates to the November 2005 NDDH BART modeling protocol. The 2006 updates focused on the following three areas:

- US EPA had announced a court settlement regarding BART modeling that allowed each state to use the annual average background visibility instead of the best 20% days' background visibility for BART analyses. This development occurred because the actual BART rule (published in the July 6, 2005, 70 Fed. Reg. 39104) stipulated that the annual average background visibility value should be used, while the preamble was inconsistent and mentioned that the 20% best days' background visibility should be used. As a result of the settlement, the NDDH adopted the annual average background visibility for the BART analysis.

- ENSR considered a more complete speciation of particulate emissions consistent with guidance provided by the National Park Service.

- ENSR adopted a 1-km CALPUFF grid spacing consistent with EPA guidance as provided in the CALPUFF FAQs regarding the resolution of terrain features with at least 5 grid elements. Other reasons for the adoption of the 1-km grid spacing have been provided to US EPA in recent correspondence.

The results of the BART modeling analysis indicated that the 98th percentile daily regional haze impact of the peak baseline daily emissions from Heskett Unit 2 would not reach the NDDH-adopted contribution level of 0.5 delta-deciview. Therefore, Heskett Unit 2 was determined to be exempt from further BART review as NDDH confirmed in a May 8, 2007 letter to MDU.

On May 15, 2009, EPA issued a Clarification Memo on CALPUFF that challenged a BART exemption analysis for the Big Stone plant in South Dakota. The clarification recommended that the grid spacing to be used for CALMET/CALPUFF analyses should be no less than 4 km.

In a more recent Clarification Memo issued on August 31, 2009, EPA issued further guidance for running CALMET.

In its recent review of the draft North Dakota Regional Haze Rule State Implementation Plan (SIP) (August 21, 2009), EPA Region 8 stated that any updates to the procedures stated in the November 2005 NDDH BART modeling protocol would need to adopt current CALPUFF modeling guidance, including the procedures discussed in the 2009 Clarification memos cited above.

This EPA position was further discussed in a conference call held among EPA, the Federal Land Managers, NDDH, and MDU with AECOM on November 17, 2009. As a result of that conference call, MDU is providing this modeling protocol document to guide an update to BART CALPUFF modeling for Heskett Unit 2.

For this update AECOM will conduct CALPUFF modeling to assess the visibility impact of Heskett Unit 2 emissions with four general areas of change to the modeling approach specified in the November 2005 NDDH BART modeling protocol, as described in the next section.

1.2 Elements of the Updated BART Modeling Analysis

The updates from the November 2005 NDDH BART modeling protocol that AECOM proposes to implement in the updated BART modeling analyses for Heskett Unit 2 are summarized below.

- In the CALMET modeling, we will adopt the recent EPA recommendations by increasing the grid size from 3 km to 4 km, and set other CALMET technical options to those stated in recent EPA Clarification memos. We will continue to set the extent of the modeling domain to 50 km outside the area denoted by the modeled source and the boundaries of the PSD Class I areas.
- For national consistency with other BART analyses, we will continue to use guidance from the National Park Service on the speciation of particulate matter emissions into several components that have different light scattering potential: coarse matter, inorganic fine matter, elemental carbon, sulfuric acid mist, and organic aerosol fine particulate.
- As a result of the EPA settlement regarding the definition of the natural visibility background and the NDDH position on this issue, we will continue to use the annual average background visibility as input to CALPOST for determining the change in visibility caused by emissions from Heskett Unit 2.
- We will use CALMET and CALPUFF versions 5.8, with all technical options as noted in the 2009 EPA Clarification Memos, as well as any applicable guidance from the March 16, 2006 EPA memo from Dennis Atkinson regarding the preferred CALPUFF dispersion option. In addition (and to be consistent with the CALPOST methods used by NDDH in their Regional Haze Rule SIP modeling), we will use the recommended new IMPROVE equation application, also known as Method 8, in the approved version of CALPOST (Version 6.221) for processing the visibility impacts at the North Dakota Class I areas. We will use inputs to CALPOST as provided in the proposed FLAG 2008 guidelines.

These modeling procedures will first be used in a reassessment of the visibility impact of the peak daily baseline emissions for the modeling period of 2000-2002 (using NDDH's RUC data). In the event Heskett Unit 2 is found to be BART-subject, the same procedures will be used to determine the visibility improvement associated with each feasible BART control option.

The BART analysis modeling updates are discussed in more detail in Section 2 below, while the references for the same are provided in Section 3.

2.0 BART Analysis Updates

Updates to the modeling procedures described in Section 1.2 will be made by AECOM to the CALMET/CALPUFF modeling for Heskett Unit 2. More details regarding this process are provided in this section.

2.1 Meteorological Processing with CALMET

One of the updates will involve the use of a 4-km grid size instead of the 3-km grid size used by NDDH. The grid size adjustment is consistent with directives in the August 31, 2009 EPA Clarification Memo and comments made by EPA and the Federal Land Managers during the November 17, 2009 conference call. The digital terrain data that will be used for this analysis will consist of 1-degree data (90-meter resolution). With this CALMET remodeling, the total grid domain will be sized to provide a 50-km buffer around this specific source as well as the PSD Class I areas. Figure 2-1 shows the proposed modeling domain.

Another update will involve changing some of the CALMET switches from the values noted in the NDDH protocol (NDDH, 2005) to those provided in the EPA Clarification Memo released on August 31, 2009. This memorandum updates the draft Interagency Workgroup on Air Quality Modeling's (IWAQM) Phase 2 summary protocol (EPA, 2009). Table 2-1 shows the changes AECOM is proposing to make to the CALMET settings consistent with the August 31, 2009 EPA Clarification Memo.

Table 2-1 Comparison of CALMET Settings Used in NDDH 2005 Protocol and in Updated Modeling

Variable	Description	NDDH 2005 Values	Updated Values
DGRIDM	Grid spacing (km)	3	4
XORIGKM	Southwest grid cell X coordinate	-380	-175
YORIGKM	Southwest grid cell Y coordinate	140	268
NX	No. of X grid cells	213	79
NY	No. of Y grid cells	153	77
NZ	No. vertical layers	12	10
ZFACE	Cell face heights (m)	0.,20.,50.,90.,140.,200., 270.,370.,500.,1000., 1700.,2500.,4200.	0.,20.,40.,80.,160.,320., 640.,1200.,2000.,3000., 4000.
BIAS	Layer-dependent biases modifying the weights of surface and upper air stations (BIAS(NZ))	-1.0, -0.9, -0.7, -0.4, 0.0, 0.3, 0.7, 1.0, 1.0, 1.0, 1.0, 1.0	0,0,0,0,0,0,0,0,0,0
TERRAD	Radius of influence of terrain features (km)	10	15
R1	Distance from a surface observation station at which the wind observation and the first guess field are equally weighted (km)	10	50
R2	Distance from an upper-air observation station at which the wind observation and the first guess field are equally weighted (km)	10	100
ZUPWND	Bottom and top of layer through which the domain scale winds are computed (m)	1., 2500.	1., 1000.
MNMDAV	Max. search distance (in grid cells) for spatial averaging of mixing ht. and temperature	7	1
ILEVZI	Layer of winds used in upwind averaging of mixing heights	3	1
ZIMAX	Maximum over land mixing height (m)	4000	3000
ZIMAXW	Maximum over water mixing height (m)	4000	3000

* Values for years 2000, 2001, 2002

2.2 CALPUFF Modeling Options

As with the CALMET modeling, AECOM will change some of the switches in CALPUFF from the values noted in the November 2005 NDDH BART modeling protocol to those provided in the Dennis Atkinson Dispersion Coefficient memorandum released on March 16, 2006. At that time, Mr. Atkinson was the Model Clearinghouse Director of the EPA Office of Air Quality Planning and Standards (OAQPS). In 2006, he released a memo detailing the settings to be used in CALPUFF modeling. AECOM will follow Mr. Atkinson's recommendations with the exception of the CDIV value, which has been updated by the model developer (TRC) to be 0.0. Table 2-2 shows the changes AECOM is planning to make to the CALPUFF settings, consistent with Mr. Atkinson's EPA directives.

Table 2-2 Comparison of CALPUFF Settings Used in NDDH 2005 Protocol and in Updated Modeling

Variable	Description	NDDH 2005 Values	Updated Values
NSPEC	Number of chemical species	7	9
NSE	Number of chemical species emitted	4	7
MSPLIT	Allow puff splitting (1=yes)	1	0
MDISP	Method used to compute dispersion coefficients	2	3
MPDF	PDF used for dispersion under convective conditions (1=yes)	1	0
NX	No. of X grid cells	213	79
NY	No. of Y grid cells	153	77
NZ	No. vertical layers	12	10
DGRIDM	Grid spacing (km)	3	4
ZFACE	Cell face heights (m)	0.,20.,50.,90.,140.,200., 270.,370.,500.,1000.,1700., 2500.,4200.	0.,20.,40.,80.,160.,320., 640.,1200., 2000.,3000., 4000.
XORIGKM	Southwest grid cell X coordinate	-380	-175
YORIGKM	Southwest grid cell Y coordinate	140	268
IBCOMP	Southwest X-index of computational grid	20	2
JBCOMP	Southwest Y-index of computational grid	6	2
IECOMP	Northeast X-index of computational grid	213	78
JECOMP	Northeast Y-index of	153	76

Variable	Description	NDDH 2005 Values	Updated Values
	computational grid		
Dry Part. Dep.	Chemical parameters of particulate deposition species	Model defaults for which mean diameter = 6.25 m and standard deviation = 0.0 m for PMC	Model defaults for all but PMC for which mean diameter = 6.0 m and standard deviation = 2.0 m
XMAXZI	Maximum mixing height	4000	3000
IRESPLIT	Hours when puff is eligible for vertical split	Hours 0-4 and 19-23	Hour 17
ROLDMAX	Vertical puff split allowed only when the ratio of last hour's mixing height to max. mixing height experienced by the puff is smaller than this value	0.33	0.25
MDISP2	Backup method used to compute dispersion coefficients	1	3
MREG	Test options specified to see if they conform to regulatory values (1=yes)	0	1
CSPEC	Species modeled	SO2,SO4,NOX,HNO3,NO3, PMC,PMF	SO2,SO4,NOX,HNO3, NO3, EC,PMC,PMF,SOA
CDIV	Divergence criterion for dw/dz across puff used to initiate adjustment for horizontal convergence (1/s)	0.01, 0.01	0,0

2.3 Characterization of Baseline Emissions

The National Park Service has issued guidance on how to speciate particulate matter emissions into different constituents that have different light scattering EPA potential: coarse matter, inorganic fine matter, elemental carbon, sulfuric acid mist, and organic aerosol fine particulate. The guidance is located at http://www.vistas-sesarm.org/BART/calpuff.asp on the VISTAS regional planning organization web site. While NDDH did not include this guidance in its BART screening protocol, AECOM believes it should be included in this updated analysis.

Engineers from MDU have reviewed the speciation profiles and selected the data for a dry bottom PC with FGD and ESP controls spreadsheet as the most representative of the emissions from Heskett Unit 2. A series of Method 8 stack tests conducted August 24 – 26, 2000 found an average H_2SO_4 rate of 9.0 lb/hr (2.9 ppm) at full load. The resulting emissions that will be used in the CALPUFF regional haze modeling are listed in Table 2-3 (these values have not changed from the ENSR 2006 BART modeling). To simplify the modeling, the coarse and fine inorganic matter will be combined as fine matter, which has a slightly higher visibility extinction efficiency than coarse matter.

Table 2-3 Heskett Unit 2 emissions data for updated BART modeling

Component	Emission Rate (lb/hr)
SO_2	1475.5
NO_2	302.8
Coarse matter (PMC)	8.2
Inorganic fine matter (PMF)	6.3
Elemental carbon (EC)	0.2
H_2SO_4	9.0
Organic aerosols (SOA)	2.0

2.4 Natural Background Determination

Following the settlement of a court case involving how to determine natural background visibility for BART analyses, EPA determined that each state can select either the annual average or 20% best days' background. NDDH has adopted the annual average background visibility approach. The concentrations to be used in the CALPOST input for the particulate species that contribute to visibility impairment are listed in Table 2-4. In the post-processing, the various elements of the Theodore Roosevelt National Park will be considered as a single Class I area, departing from the treatment in the November 2005 NDDH BART modeling protocol. The bases for this change are reflected in EPA's comments 23, 39 and 53 pertaining to the August 21, 2009 draft NDDH Regional Haze SIP and comments provided by EPA and the Federal Land Managers during the November 17, 2009 conference call.

Table 2-4 Annual Average Natural Levels of Aerosol Components (μg/m³)

Component	Lostwood Wilderness(1)	Theodore Roosevelt NP(1)
Ammonium sulfate	0.12	0.12
Ammonium nitrate	0.10	0.10
Organic carbon mass	0.60	0.60
Elemental carbon	0.02	0.02
Soil	0.50	0.50
Coarse mass	3.00	3.00

(1) From "Federal Land Managers' Air Quality Related Values Workgroup" (FLAG, 2008), Appendix V-1, Table V.1-2.

2.5 Light Extinction and Haze Impact Calculations

The FLAG 2008 document (dated June 26, 2008) provides guidance on the recommended new IMPROVE equation application. CALPOST Version 6.221 defines this application as Method 8, Mode 5. The assessment of visibility impacts at the Class I areas will use CALPOST Method 8.

The CALPOST postprocessor will be used for the calculation of the impact of the modeled source's primary and secondary particulate matter concentrations on light extinction. In the new IMPROVE equation, the total sulfate, nitrate, and organic carbon compound concentrations are each split into two fractions, representing small and large size distributions of those components. New terms, such as sea salt (important for coastal locations), absorption by NO_2 (only used where NO_2 data are available), and site-specific Rayleigh scattering have been added to the equation. The new IMPROVE equation for calculating light extinction is shown below.

$$
\begin{aligned}
b_{ext} = \; & 2.2 \times f_S(RH) \times [\text{Small Sulfate}] + 4.8 \times f_L(RH) \times [\text{Large Sulfate}] \\
& + 2.4 \times f_S(RH) \times [\text{Small Nitrate}] + 5.1 \times f_L(RH) \times [\text{Large Nitrate}] \\
& + 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}] \\
& + 10 \times [\text{Elemental Carbon}] \\
& + 1 \times [\text{Fine Soil}] \\
& + 0.6 \times [\text{Coarse Mass}] \\
& + 1.7 \times f_{SS}(RH) \times [\text{Sea Salt}] \\
& + \text{Rayleigh Scattering (Site Specific)} \\
& + 0.33 \times [NO_2 \text{ (ppb)}] \quad \{\text{or as: } 0.1755 \times [NO_2 \; (\mu g/m^3)]\}
\end{aligned}
$$

Where:

[ ] indicates concentrations in $\mu g/m^3$

$f_S(RH)$ = Relative humidity adjustment factor for small sulfate and nitrate

$f_L(RH)$ = Relative humidity adjustment factor for large sulfate and nitrate

$f_{SS}(RH)$ = Relative humidity adjustment factor for sea salt

For Total Sulfate $< 20 \; \mu g/m^3$:

$$[\text{Large Sulfate}] = ([\text{Total Sulfate}] / 20 \; \mu g/m^3) \times [\text{Total Sulfate}]$$

For Total Sulfate $\geq 20 \; \mu g/m^3$:

$$[\text{Large Sulfate}] = [\text{Total Sulfate}]$$

And:

$$[\text{Small Sulfate}] = [\text{Total Sulfate}] - [\text{Large Sulfate}]$$

To calculate large and small nitrate and organic mass, substitute ({Large, Small, Total} {Nitrate, Organic Mass}) for Sulfate.

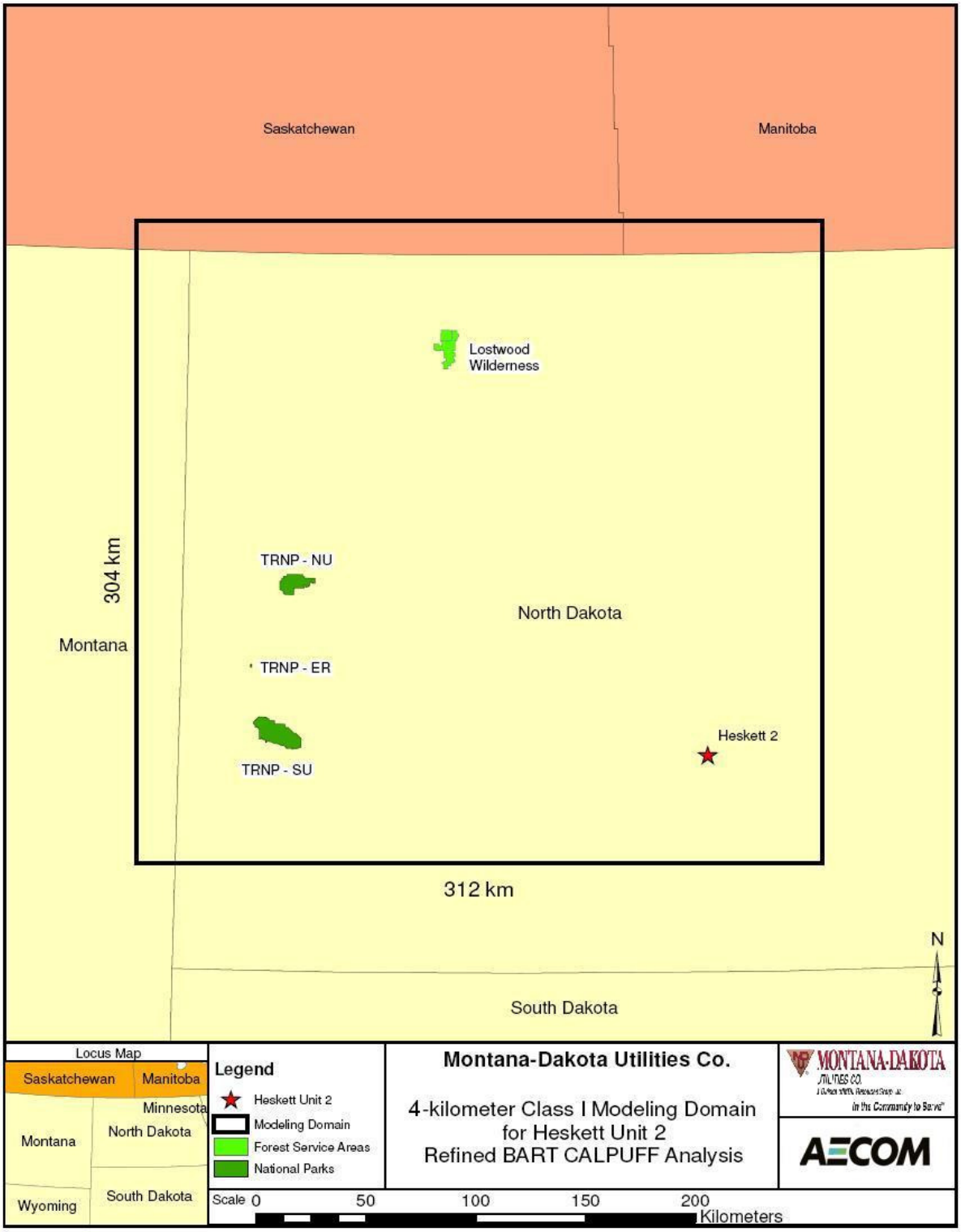
The FLAG 2008 document provides inputs to the new IMPROVE equation for the annual average natural conditions. Inputs to the CALPOST Method 8 calculations for each Class I area are listed in Table 2-5.

Table 2-5 New IMPROVE Equation CALPOST Inputs

Component	Lostwood Wilderness(1)	Theodore Roosevelt NP(1)
Sea salt concentration ($\mu g/m^3$)	0.03	0.01
Raleigh scattering (Mm^{-1})	11	11
Monthly f_L (RH)	2.51, 2.45, 2.54, 2.06, 2.03, 2.21, 2.23, 2.05, 2.02, 2.13, 2.69, 2.67	2.47, 2.42, 2.45, 2.12, 2.14, 2.21, 2.14, 1.99, 1.99, 2.10, 2.58, 2.57
Monthly f_S (RH)	3.21, 3.15, 3.36, 2.60, 2.54, 2.86, 2.89, 2.60, 2.53, 2.72, 3.60, 3.52	3.17, 3.11, 3.22, 2.71, 2.74, 2.85, 2.73, 2.49, 2.48, 2.66, 3.42, 3.37
Monthly f_{SS} (RH)	3.77, 3.66, 3.67, 2.86, 2.79, 3.07, 3.11, 2.82, 2.80, 2.99, 3.93, 3.95	3.67, 3.56, 3.51, 2.93, 2.97, 3.09, 2.96, 2.72, 2.72, 2.93, 3.75, 3.78

(1) From "Federal Land Managers' Air Quality Related Values Workgroup" (FLAG, 2008), Appendix V-1, Tables V.1-2 to V.1-5.

Figure 2-1 Modeling domain for 4 kilometer grid



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