A.B. Brown Generating Station

Mount Vernon, Indiana

Evaluation of Compliance with the 1-hour NAAQS for SO_2

March 30, 2016

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1. Introduction

Wingra Engineering, S.C. was hired by Sierra Club to conduct an air modeling impact analysis to help the U.S. Environmental Protection Agency (USEPA), state and local air agencies identify facilities that are likely causing exceedances of the 1-hour sulfur dioxide (SO_2) national ambient air quality standard (NAAQS). This document describes the results and procedures for an evaluation conducted for the A.B. Brown Generating Station located in Mount Vernon, Indiana.

This analysis supplements the evaluation described in the September 16, 2015 report prepared on behalf of Sierra Club. It addresses comments submitted by the Indiana Department of Environmental Management (IDEM) to USEPA in its November 13, 2015 letter, *Indiana's Review of Sierra Club's Comments on Indiana's 1-Hour SO_2 Consent Decree Recommendations*. In particular, this evaluation responds to the IDEM comments by incorporating i) variable stack emissions and velocities; ii) IDEM pre-processed meteorological data; iii) building downwash; and iv) temporally varying background SO_2 concentrations developed by IDEM for this plant, among other changes from the September 2015 analysis.

To ensure the modeling analysis reflected the cumulative concentration of SO_2 emissions, it included emissions from the following additional sources of SO_2 emissions located within 50 kilometers of the A.B. Brown Generating Station:

- Warrick Power Plant - Newburgh, Indiana.
- ALCOA Inc. - Warrick Operations - Newburgh, Indiana.
- F.B. Culley Generating Station in Newburgh, Indiana.
- Green Station - Henderson, Kentucky.
- SABIC Innovative Plastics Mt. Vernon LLC - Mount Vernon, Indiana.
- Countrymark Refining and Logistics LLC – Mount Vernon, Indiana.

The dispersion modeling analysis predicted ambient air concentrations for comparison with the 1-hour SO_2 NAAQS. The modeling was performed using the most recent version of AERMOD, AERMET, and AERMINUTE, with data provided to Sierra Club by regulatory air agencies or obtained through other publicly-available sources as documented below. The analysis was conducted in adherence to all available USEPA guidance for evaluating source impacts on attainment of the 1-hour SO_2 NAAQS via aerial dispersion modeling, including the AERMOD Implementation Guide; USEPA's Applicability of Appendix W Modeling Guidance for the 1-hour SO_2 National Ambient Air Quality Standard, August 23, 2010; modeling guidance promulgated by USEPA in Appendix W to 40 CFR Part 51; USEPA's March 2011 Modeling Guidance for SO_2 NAAQS Designations;[1] and USEPA's December 2013 SO_2 NAAQS Designations Technical

[1] http://www.epa.gov/scram001/so2_modeling_guidance.htm

Assistance Document.[2]

2. Compliance with the 1-hour SO_2 NAAQS

2.1 1-hour SO_2 NAAQS

The 1-hour SO_2 NAAQS takes the form of a three-year average of the 99th-percentile of the annual distribution of daily maximum 1-hour concentrations, which cannot exceed 75 parts per billion (ppb).[3] Compliance with this standard was verified using USEPA's AERMOD air dispersion model, which produces air concentrations in units of $\mu g/m^3$. The 1-hour SO_2 NAAQS of 75 ppb equals 196.2 $\mu g/m^3$, and this is the value used for determining whether modeled impacts exceed the NAAQS.[4] The 99th-percentile of the annual distribution of daily maximum 1-hour concentrations corresponds to the fourth-highest value at each receptor for a given year.

2.2 Modeling Results

Modeling results for A.B. Brown Generating Station and the other facilities are summarized in Table 1. It was determined that based on proposed emission limitations for the A.B. Brown Generating Station and measured actual emissions for 2012-14 from other SO_2 sources in the region, that downwind SO_2 concentrations exceed the 1-hour NAAQS.

Allowable emissions from A.B. Brown Generation Station are taken from Notice and Order of the Commissioner of the Department of Environmental Management, January 11, 2016. Three emission rate scenarios were evaluated: Units 1 and 2 in operation, Unit 1 operating alone, and Unit 2 operating alone.

For other regional power plants including Warrick Power Plant and F.B. Culley Generating Station in Indiana and Green Station in Kentucky, "Actual" represents the emissions which occurred during the period from 2012-14. Actual emission measurements were taken from the USEPA Emissions Modeling Clearinghouse State-Level Hourly Sulfur Dioxide (SO_2) Data. [5]

To more accurately predict the dispersion of emissions, hourly exit velocities were used for Warrick Power Plant and F.B. Culley Generating Station in Indiana and Green Station in Kentucky. Continuous emissions monitor measurements were not publicly available for this analysis, so exit

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[2] http://www.epa.gov/oaqps001/sulfurdioxide/pdfs/SO2ModelingTAD.pdf
[3] USEPA, Applicability of Appendix W Modeling Guidance for the 1-hour SO_2 National Ambient Air Quality Standard, August 23, 2010.
[4] The ppb to $\mu g/m^3$ conversion is found in the source code to AERMOD v. 14134, subroutine Modules. The conversion calculation is 75/0.3823 = 196.2 $\mu g/m^3$.
[5] https://www3.epa.gov/ttn/chief/emch/so2naaqs/index.html

velocities were derived from the hourly flow rates provided in the USEPA Clearinghouse database.

The background concentrations were based on a temporally varying approach, using a separate value for each season for each of the 24 hours in a day. This was the same file developed by IDEM and described in the USEPA technical support document for the A.B. Brown Generating Station.[6] It was based on the Buena Vista monitoring site in Evansville (Site Number 18-163-0005), excluding data from the general direction of A.B. Brown Generating Station (southwest).

Table 1 - SO_2 Modeling Results with Actual Hourly Emissions and Exit Velocities

Scenario	99^{th} Percentile 1-hour Daily Maximum ($\mu g/m^3$)			Complies with NAAQS?
	AB Brown	All Facilities	NAAQS	
A.B. Brown Unit 1 Alone	187.0	1,197.0	196.2	No
A.B. Brown Unit 2 Alone	162.0	1,197.0	196.2	No
A.B. Brown Units 1 & 2	191.3	1,197.0	196.2	No

Figure 1 shows the geographic extent of NAAQS exceedances in the region.

2.3 Conservative Modeling Assumptions

A dispersion modeling analysis requires the selection of numerous parameters which affect the predicted concentrations. For the enclosed analysis, several parameters were selected which under-predict facility impacts.

Assumptions used in this modeling analysis which likely under-estimate concentrations include the following:

- For A.B. Brown Generating Station, no consideration of facility operation at less than 100% load was applied. Stack parameters such as exit flow rate and temperature are typically lower at less than full load, reducing pollutant dispersion and increasing predicted air quality impacts.
- Other than A.B. Brown Generating Station, no consideration of building or structure downwash was incorporated. These downwash effects typically increase predicted concentrations near the facility.

[6] USEPA, Technical Support Document, Indiana, Area Designations for the 2010 SO_2 Primary National Ambient Air Quality Standard, Table 3, February 2016. https://www3.epa.gov/so2designations/round2/05_IN_tsd.pdf

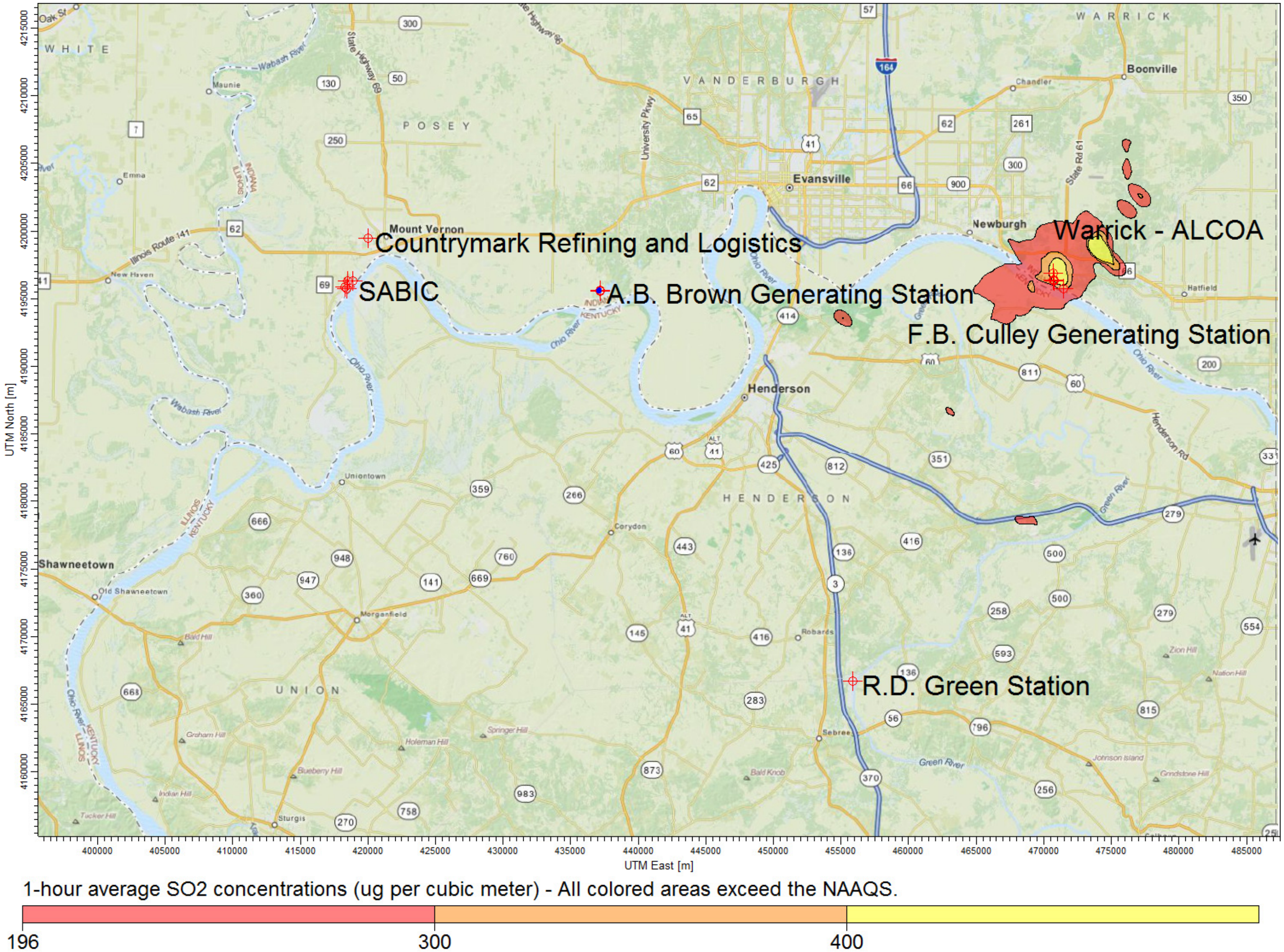

Figure 1 - View of Regional Impacts for the 2012-14 Period

3. Modeling Methodology

3.1 Air Dispersion Model

The modeling analysis used USEPA's AERMOD program, v. 15181. AERMOD, as available from the Support Center for Regulatory Atmospheric Modeling (SCRAM) website, was used in conjunction with a third-party modeling software program, *AERMOD View*, sold by Lakes Environmental Software.

3.2 Control Options

The AERMOD model was run with the following control options:

- 1-hour average air concentrations
- Regulatory defaults
- Flagpole receptors

To reflect a representative inhalation level, a flagpole height of 1.5 meters was used for all modeled receptors. This parameter was added to the receptor file when running AERMAP, as described in Section 4.4.

An evaluation was conducted to determine if the modeled facility was located in a rural or urban setting using USEPA's methodology outlined in Section 7.2.3 of the Guideline on Air Quality Models.[7] For urban sources, the URBANOPT option is used in conjunction with the urban population from an appropriate nearby city and a default surface roughness of 1.0 meter. Methods described in Section 4.1 were used to determine whether rural or urban dispersion coefficients were appropriate for the modeling analysis.

3.3 Output Options

The AERMOD analysis was based on three years of recent meteorological data. The modeling analyses used one run with three years of sequential meteorological data from 2012-2014. Consistent with USEPA's Modeling Guidance for SO_2 NAAQS Designations, AERMOD provided a table of fourth-highest 1-hour SO_2 impacts concentrations consistent with the form of the 1-hour SO_2 NAAQS.[8]

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[7] USEPA, Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions, Appendix W to 40 CFR Part 51, November 9, 2005.

[8] USEPA, Area Designations for the 2010 Revised Primary Sulfur Dioxide National Ambient Air Quality Standards, Attachment 3, March 24, 2011, pp. 24-26.

Please refer to Table 1 for the modeling results.

4. Model Inputs

4.1 Geographical Inputs

The "ground floor" of all air dispersion modeling analyses is establishing a coordinate system for identifying the geographical location of emission sources and receptors. These geographical locations are used to determine local characteristics (such as land use and elevation), and also to ascertain source-to-receptor distances and relationships.

The Universal Transverse Mercator (UTM) NAD83 coordinate system was used for identifying the easting (x) and northing (y) coordinates of the modeled sources and receptors. Stack locations were obtained from facility permits and prior modeling files provided by the state regulatory agency. The stack locations were then verified using aerial photographs.

The facility was evaluated to determine if it should be modeled using the rural or urban dispersion coefficient option in AERMOD. A Geographic Information System (GIS) was used to determine whether rural or urban dispersion coefficients would apply to a site. Land use within a three-kilometer-radius circle surrounding the facility was considered. USEPA guidance states that urban dispersion coefficients are used if more than 50% of the area within 3 kilometers has urban land uses. Otherwise, rural dispersion coefficients are appropriate.[9]

USEPA's AERSURFACE v. 13016 was used to develop the meteorological data for the modeling analysis. This model was also used to evaluate surrounding land use within 3 kilometers. Based on the output from the AERSURFACE, approximately 1.9% of surrounding land use around the modeled facility was of urban land use types including Type 21 – Low Intensity Residential, Type 22 – High Intensity Residential and Type 23 – Commercial / Industrial / Transportation.

This is less than the 50% value considered appropriate for the use of urban dispersion coefficients. Based on the AERSURFACE analysis, it was concluded that the rural option would be used for the modeling summarized in this report. Please refer to Section 4.5.3 for a discussion of the AERSURFACE analysis.

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[9] USEPA, Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions, Appendix W to 40 CFR Part 51, November 9, 2005, Section 7.2.3.

4.2 Emission Rates and Source Parameters

The modeling analysis considered SO_2 emissions from the A.B. Brown Generating Station, as well as three other power plants and three industrial sources located in the region. Other off-site sources were not considered. Stack parameters and emissions used for the modeling analysis are summarized in Table 2.

The above stack parameters and emissions were obtained from regulatory agency documents and databases identified in Section 2.2. For A.B. Brown Generating Station, the analysis was conducted based on 100% operating load using maximum exhaust flow rates and temperatures. Operation at less than full capacity loads was not considered. This assumption tends to under-predict impacts since stack parameters such as exit flow rate and temperature are typically lower at less than full load, reducing pollutant dispersion and increasing predicted air quality impacts. Stack location, height and diameter were verified using aerial photographs, and flue gas flow rate and temperature were verified using combustion calculations.

4.3 Building Dimensions

For A.B. Brown Generating Station, building dimensions and a prior downwash analysis were obtained from IDEM supporting files from their modeling analysis. For other facilities, no building dimensions or prior downwash evaluations were available. Therefore this modeling analysis did not address the effects of downwash and this may under-predict impacts for these other facilities.

4.4 Receptors

For A.B. Brown Generating Station, three receptor grids were employed:

1. A 100-meter Cartesian receptor grid centered on A.B. Brown Generating Station and extending out 5 kilometers.
2. A 500-meter Cartesian receptor grid centered on A.B. Brown Generating Station and extending out 10 kilometers.
3. A 1,000-meter Cartesian receptor grid centered on A.B. Brown Generating Station and extending out 50 kilometers. 50 kilometers is the maximum distance accepted by USEPA for the use of the AERMOD dispersion model.[10]

A flagpole height of 1.5 meters was used for all these receptors.

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[10] USEPA, Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions, Appendix W to 40 CFR Part 51, Section A.1.(1), November 9, 2005.

Table 4 – Facility Stack Parameters and Emissions [11]

Facility	A.B. Brown Generating Station		Warrick Power Plant			
Stack	B01	B02	W01	W02	W03	W04
Description	Unit 1	Unit 2	Unit 1	Unit 2	Unit 3	Unit 4
X Coord. [m]	437153	437153	470747	470746.25	470742.15	470708
Y Coord. [m]	4195630	4195630	4196346	4196351.22	4196348.98	4196369
Base Elevation [m]	127.1	127.1	121.3	121.3	121.3	120.42
Release Height [m]	133.97	133.97	116.13	116.13	116.13	152.4
Inside Diameter [m]	4.267	4.267	7.132	7.132	7.132	5.944
Gas Exit Temperature [°K]	327.59	327.59	328.706	328.706	328.706	328.706
Gas Exit Velocity [m/s]	27.509	27.509	Variable	Variable	Variable	Variable
Scenario 1 - Emission Rate [g/s]	271.3	0	Variable	Variable	Variable	Variable
Scenario 2 - Emission Rate [g/s]	0	220	Variable	Variable	Variable	Variable
Scenario 3 - Emission Rate [g/s]	135.2	135.8	Variable	Variable	Variable	Variable

[11] Stack parameters for A.B. Brown, SABIC and Countrymark were obtained from the supporting AERMOD files for the IDEM modeling analysis, AB_Brown__IDEM_rec_flex_consultant_revision1_RevisedRates.dta. Stack height, diameter, elevation for Warrick, Green and Culley plants were obtained from the USEPA Emissions Modeling Clearinghouse State-Level Hourly Sulfur Dioxide (SO_2) Data. Stack temperatures for Warrick, Green and Culley plants were obtained from U.S. Energy Information Administration, Form EIA-923 Detailed Data, Schedule 6, Stack & Flue Data, http://www.eia.gov/electricity/data/eia923/. ALCOA production operation actual emissions for 2014 and stack parameters provided by “Email, J. Koch – Indiana DEM to S. Klafka - Wingra Engineering, S.C., Subject: Request for Detailed Emissions Summary Reports, August 13, 2015.”

Facility	ALCOA Inc. – Warrick Operations						F.B Culley
Stack	A102	A161	A162	A163	A164	A165	CS023
Description	Ring Furnace	POTLINE 2	POTLINE 3	POTLINE 4	POTLINE 5	POTLINE 6	Units 2 and 3
X Coord. [m]	470710	470710	470710	470710	470710	470710	471456
Y Coord. [m]	4196858	4196858	4196858	4196858	4196858	4196858	4195765
Base Elevation [m]	119.17	119.17	119.17	119.17	119.17	119.17	120.7
Release Height [m]	28.96	14.94	60.66	60.66	14.94	14.94	152.1
Inside Diameter [m]	1.173	0.61	6.096	6.096	0.61	0.61	7.315
Gas Exit Temperature [°K]	351.333	355.222	343	343	350.222	370.222	326.483
Gas Exit Velocity [m/s]	43.855	49.655	31.653	31.653	69.519	81.266	Variable
Actual Emission Rate [g/s]	2.814	19.2	20.43	20.52	20.62	17.1	Variable

Facility	SABIC				Countrymark	R.D. Green Station	
Stack	SAB_E&L	SAB_COS	SABBW1_BW2	SABH530A_B	COUNTRY_1	G01	G02
Description	-	-	-	-	-	Unit 1	Unit 2
X Coord. [m]	418315.69	418408	418846.34	418486	420000	455837	455890
Y Coord. [m]	4195863.81	4195760	4196308.43	4196344	4199500	4166727	4166719
Base Elevation [m]	122.88	121.91	120.11	121.43	125.39	125.88	125.88
Release Height [m]	76.2	48.77	77.11	36.12	30.18	106.68	106.68
Inside Diameter [m]	2.286	1.57	2.286	1.515	1.951	4.572	4.572
Gas Exit Temperature [°K]	431.48	962.04	430.37	562.32	449.82	327.594	327.594
Gas Exit Velocity [m/s]	21.014	6.187	24.36	16.685	10.835	Variable	Variable
Actual Emission Rate [g/s]	0.01151	20.42	134.5	0.5926	13.72	Variable	Variable

Elevations from stacks and receptors were obtained from National Elevation Dataset (NED) GeoTiff data. GeoTiff is a binary file that includes data descriptors and geo-referencing information necessary for extracting terrain elevations. These elevations were extracted from 1 arc-second (30 meter) resolution NED files. The USEPA software program AERMAP v. 11103 is used for these tasks.

4.5 Meteorological Data

To improve the accuracy of the modeling analysis and to address comments on the September 15, 2015 modeling analysis, pre-processed meteorological data for the period 2012-2014were obtained from IDEM. These data were used for their modeling analysis of the A.B. Brown Generating Station.

The meteorological data were prepared using the USEPA's program AERMET which creates the model-ready surface and profile data files required by AERMOD. Required data inputs to AERMET included surface meteorological measurements, twice-daily soundings of upper air measurements, and the micrometeorological parameters surface roughness, albedo, and Bowen ratio. One-minute ASOS data were available so USEPA methods were used to reduce calm and missing hours.[12] The USEPA software program AERMINUTE v. 15272 is used for these tasks.

4.5.1 Surface Meteorology

Surface meteorology was obtained for Evansville Regional Airport located near the A.B. Brown Generating Station. Integrated Surface Hourly (ISH) data for the period 2012-2014 were obtained from the National Climatic Data Center (NCDC). The ISH surface data was processed through AERMET Stage 1, which performs data extraction and quality control checks.

4.5.2 Upper Air Data

Upper-air data are collected by a "weather balloon" that is released twice per day at selected locations. As the balloon is released, it rises through the atmosphere and sends the data to the surface via radio. The measuring and transmitting device is known as either a radiosonde or rawindsonde. Data collected and radioed back include: air pressure, height, temperature, dew point, wind speed, and wind direction. The upper air data were processed through AERMET Stage 1, which performs data extraction and quality control checks.

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[12] USEPA, Area Designations for the 2010 Revised Primary Sulfur Dioxide National Ambient Air Quality Standards, Attachment 3, March 24, 2011, p. 19.

For A.B. Brown Generating Station, the concurrent 2012-2014 upper air data from twice-daily radiosonde measurements obtained at the most representative location were used. This location was the Lincoln, Illinois measurement station. These data are in Forecast Systems Laboratory (FSL) format and were downloaded in ASCII text format from NOAA's FSL website.[13] All reporting levels were downloaded and processed with AERMET.

4.5.3 AERSURFACE

AERSURFACE is a program that extracts surface roughness, albedo, and daytime Bowen ratio for an area surrounding a given location. AERSURFACE v. 13016 was used to develop surface roughness, albedo, and daytime Bowen ratio values in a region surrounding the meteorological data collection site. AERSURFACE was used to develop surface roughness in a one kilometer radius surrounding the data collection site. Bowen ratio and albedo was developed for a 10 kilometer by 10 kilometer area centered on the meteorological data collection site.

These micrometeorological data were processed for monthly periods using 30-degree sectors. The Bowen ratio was adjusted based on soil moisture and precipitation, and snow cover, as recommended by IDEM and ask described in USEPA guidance.[14]

4.5.4 Data Review

Missing meteorological data were not filled as the data file met USEPA's 90% data completeness requirement.[15] The AERMOD output file shows there were 0.81% missing data.

Pre-processed meteorological data for the period 2012-2014 were obtained from IDEM. These data were used for their modeling analysis of the A.B. Brown Generating Station. The surface and upper air stations are recommended by the IDEM for modeling facilities located in Posey County.[16]

5. Background SO_2 Concentrations

Background concentrations were determined consistent with USEPA's Modeling Guidance for SO_2 NAAQS Designations.[17, 18] The background concentrations for both 3-year periods were based on a

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[13] Available at: http://esrl.noaa.gov/raobs/
[14] USEPA, Regional Meteorological Data Processing Protocol, U.S. EPA Region 5 and States, Draft, May 6, 2011. https://www.pca.state.mn.us/sites/default/files/aq2-50.pdf
[15] USEPA, Meteorological Monitoring Guidance for Regulatory Modeling Applications, EPA-454/R-99-05, February 2000, Section 5.3.2, pp. 5-4 to 5-5.
[16] Indiana DEM, Air Dispersion Meteorological Data, http://www.in.gov/idem/airquality/2376.htm
[17] USEPA, Area Designations for the 2010 Revised Primary Sulfur Dioxide National Ambient Air Quality Standards, Attachment 3, March 24, 2011, pp. 20-23.
[18] USEPA, SO_2 NAAQS Designations Modeling Technical Assistance Document, Dec. 2013, section 8.1, pp 27-28.

temporally varying approach, using a separate value for each season for each of the 24 hours in a day. This was the same file developed by IDEM and described in the USEPA technical support document for the A.B. Brown Generating Station. It was based on the Buena Vista monitoring site in Evansville (Site Number 18-163-0005), excluding data from the general direction of A.B. Brown Generating Station (southwest).

6. Reporting

All files from the programs used for this modeling analysis are available to regulatory agencies. These include analyses prepared with AERSURFACE, AERMET, AERMAP, and AERMOD.