FINAL

AERMOD VALIDATION REPORT

Montgomery County Resource Recovery Facility

Prepared for:
Recycling and Resource Management Division
Department of Environmental Protection

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AERMOD VALIDATION REPORT

Introduction

This report has been prepared by Trinity Consultants (Trinity) under engagement by Maryland Environmental Service (MES) to validate air dispersion model predictions in comparison to the sulfur dioxide (SO_2) monitoring data collected at the Montgomery County Resource Recovery Facility (MCRRF).

Executive Summary

Background

The Montgomery County Resource Recovery Facility (MCRRF) currently employs three water wall furnaces fueled by non-recycled waste to generate steam that powers a turbine to generate electricity. The GenOn Dickerson Generating Station (GenOn) is located adjacent to the MCRRF. Ambient air concentrations associated with MCRRF emissions were analyzed using the USEPA-approved AERMOD dispersion model, Version 12345. AERMOD modeling results indicated that contributions attributable to MCRRF emissions were a small fraction of the concentrations measured during the 2014 (metals) and 2015 (PCDDs/PCDFs) sampling events. This observation indicated that neither of the monitoring sites were being measurably impacted by MCRRF emissions. The assessment results are available here: https://www.montgomerycountymd.gov/SWS/Resources/Files/rrf/hra2014-full-report.pdf.

Model Validation

To validate the AERMOD analysis, Montgomery County (County) initiated a 12-month dispersion model evaluation study using SO_2 as a tracer gas.[1] The County installed SO_2 monitors at 3 stations sited near the MCRRF. Hourly data collection combined with hourly weather data from the County weather station near the MCRRF began in May 2018. Data collection ended on April 30, 2019.

The goal of the SO_2 and meteorological data collection is to create a site-specific data set to be used to establish the validity of the AERMOD results from the "Fourth Operational Phase Ambient Air Monitoring Program", completed in 2015.

Data collection was performed according to the "Quality Assurance Project Plan for Ambient SO_2 Monitoring at the Montgomery County Resource and Recovery Facility". Statistical data validation was performed prior to inputting the hourly stack emissions data from GenOn and MCRRF along with meteorological data from the County's weather station into the AERMOD model, Version 12345, in order to predict SO_2 concentrations at the locations of the three nearby monitoring stations.

An exclusion technique was applied for determining the appropriate background SO_2 concentrations in cases where the wind is coming from a direction that might intersect MCRRF and GenOn prior to reaching the monitor. The appropriate background SO_2 concentration was added to the SO_2 concentrations predicted by AERMOD.

To determine the accuracy of the AERMOD predicted concentrations, the 25 highest AERMOD SO_2 concentrations and the 25 highest hourly ambient concentrations for each monitoring station were ranked from highest-to-lowest. The highest values from AERMOD and the highest ambient values were then compared. This comparison showed the 25 highest ambient and modeled SO_2 concentrations matched within a factor of two. According to US EPA methodology, results within a factor of two between measured and ambient concentrations validate AERMOD predictions.

[1] *AERMOD: Latest Features and Evaluation Results,* EPA-454/B-19-027, EPA-454/R-03-003, U. S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions Monitoring and Analysis Division, Research Triangle Park, NC, June 2003.

Conclusion

Based on this evaluation study, the AERMOD model provides an accurate concentration prediction for the area surrounding the MCRRF.

Modeling Approach

Air pollution models predict pollutant concentrations by simulating the evolution of the pollutant plume over time and space given data inputs including the magnitude of emissions, stack exhaust parameters (e.g. height, air flowrate, and temperature), and meteorological data. AERMOD is a refined, steady-state, multiple source dispersion model that was promulgated in December 2005 as the EPA-preferred model to use for industrial sources in this type of air dispersion modeling analysis.[2]

Previous analyses of ambient air concentrations associated with MCRRF emissions were conducted using the AERMOD dispersion model, Version 12345. To maintain consistency with previous studies, the same version was used in this study. Modeling was performed for the 1-hour averaging period in order to match the hourly collected data for the ambient SO_2 concentrations.

Trinity executed dispersion modeling analyses using AERMOD and the facility data provided by the County, which included the following:[3]

- Building parameters (i.e., locations, length, width, and height);
- Physical stack locations and exhaust parameters for each emissions source of interest (e.g., stack height, stack exit inner diameter);
- Hourly stack emissions, exhaust flow and temperature data;[4]
- Ambient SO_2 monitoring data at three locations near MCRRF and GenOn; and
- Hourly meteorological data/observations (both surface and upper air data).

[2] *User's Guide for the AMS/EPA Regulatory Model (AERMOD),* EPA-454/B-19-027, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 2019.
[3] Data provided by Montgomery County via email on 5/1/2020.
[4] MCRRF exhaust flowrate and temperature data received from Montgomery County via email on 6/4/2020.

Figure 1 shows the locations of the MCRRF and GenOn relative to the weather (Met) and monitoring stations (Stations 1 through 3) in Montgomery County, Maryland. SO_2 emissions from MCRRF and GenOn are released from single stacks at each facility. Hourly meteorological data during the period beginning on May 1, 2018 through April 30, 2019 were collected at a 10-meter tower that was installed just 0.35 miles to the east-northeast of MCRRF.

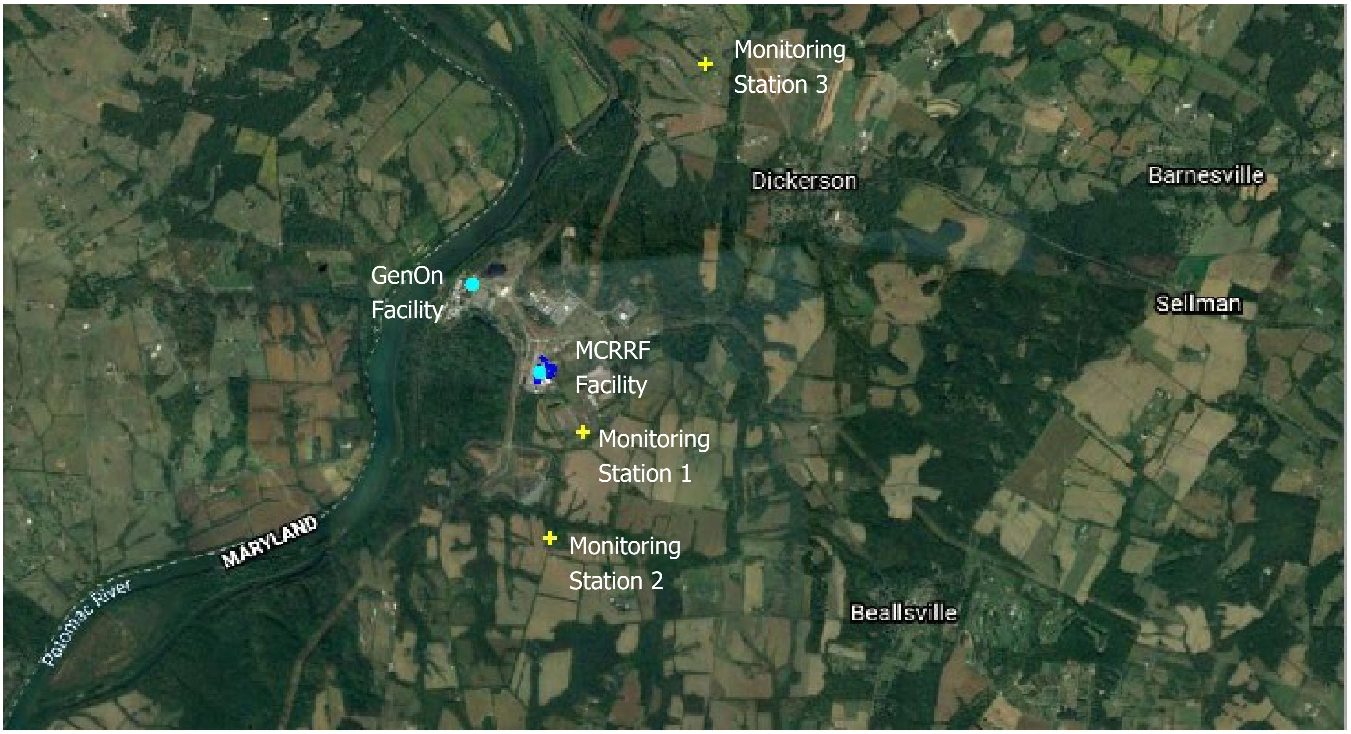
Figure 1. Location of MCRRF and GenOn Relative to Weather and Monitoring Stations

The model evaluation consisted of comparing concentrations predicted by the model to that measured by the monitors. Receptors in AERMOD were positioned at the precise locations of the ambient SO_2 monitors, presented as yellow crosses in Figure 2. Receptors are the locations at which concentrations are computed in the model.

MCRRF and GenOn are the only significant emission sources in the area and as such can be considered representative of the emission sources that contribute to ambient SO_2 concentrations at the locations of the monitors. Therefore, stack emissions data from each source during the monitoring period (5/1/2018 –

4/30/2019) were entered into AERMOD. These sources are vertical, unobstructed stacks and were thus modeled as point sources, presented as blue circles in Figure 2.

Figure 2. Receptors Positioned at Locations of Ambient SO_2 Monitors



Hourly readings of SO_2 emissions, stack temperatures and flowrates were made at both MCRRF and GenOn, and those hourly values were incorporated into AERMOD.

Building structures can obstruct wind flow near emission points and potentially cause higher pollutant concentrations than if the buildings were absent. For this reason, detailed building dimensions for the MCRFF were provided by MES to Trinity and those structures were included in the AERMOD model setup.[5] Since the GenOn facility is considered a more distant inventory source with a very tall stack, no building information was included for that site.

Figure 3 shows the overall site layout of MCRRF used in the dispersion analysis where:

- Blue outlines represent buildings; and
- Light blue circle represents the point source.

[5] Provided by Montgomery County via email on 5/1/2020.

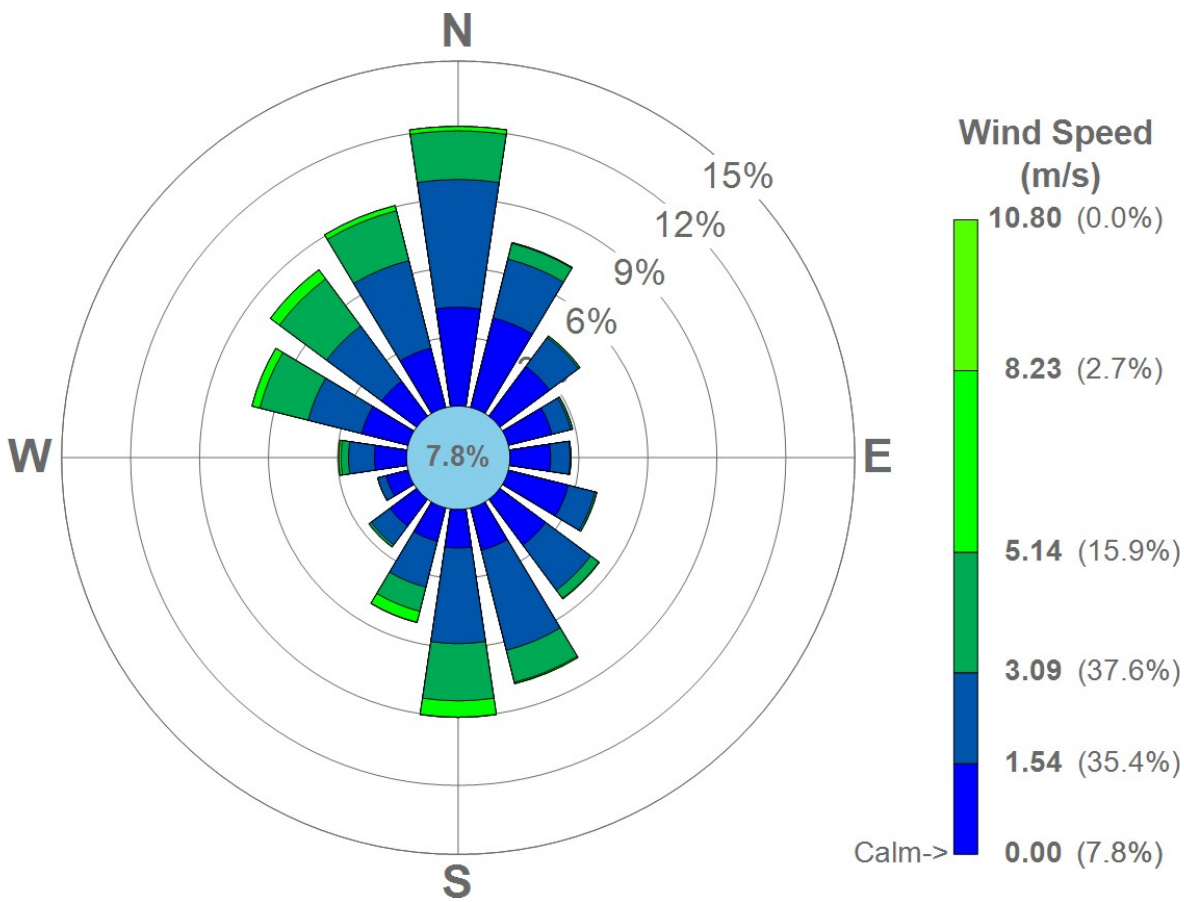
Figure 3. Modeled Buildings and Source at MCRRF

Meteorological Data

The County's weather station data for May 2018 through April 2019 was prepared for AERMOD using the U.S. EPA's AERMET meteorological processing utility (Version 12345). That version of AERMET was used to maintain consistency with previously conducted evaluation studies. A more detailed discussion of how meteorological data was input into the model is available in the appendix.

Figure 4 presents a wind rose of the modeled meteorological data. A wind rose illustrates the distribution of wind speed and direction for a given data site.

Figure 4. Wind Rose for May 2018 – April 2019 Meteorological Data



Monitoring Data Validation

The monitoring data provided has been captured in accordance to the methodology described in the "Quality Assurance Project Plan for Ambient SO_2 Monitoring at the Montgomery County Resource and Recovery Facility". The data met all U.S. EPA data capture requirements as described further in the appendix to this report.

SO_2 Background Concentration Determination

In order to make a fair comparison of the modeled emission impacts and the actual concentrations measured by the monitors, ambient SO_2 background (from sources other than MCRFF and GenOn) must be included. The three ambient SO_2 concentration monitors that were positioned near MCRRF could be used as a source of background SO_2 concentrations, however that runs the risk of double counting SO_2 emission impacts from both MCRRF and GenOn if the wind direction is such that the plume emitted from the sources travels towards the monitors.

No ambient SO_2 monitor is located at an appropriate position relative to MCRRF that would always provide a representative ambient background concentration. As such, an exclusion technique was applied for determining background SO_2 concentrations in cases where the wind is coming from a direction that might intersect MCRRF and GenOn prior to reaching the monitor.

The exclusion zone was determined based on the direction of the monitors relative to the sources. The exclusion zone defines the range of wind directions (defined by a 90 degree sector) for which a given monitor is downstream of the sources.[6] Therefore, if the wind direction is within the exclusion zone, it is expected that emissions from the sources will impact the SO_2 concentrations measured at the monitoring locations.

The exclusion zone was defined as shown in Table 1 for each monitoring station according to their position relative to MCRRF and GenOn. An example of the exclusion zone for monitoring station 2 can be seen in Figure 5.

Table 1. Exclusion Zones

Monitoring Station	Wind Direction (degrees)
Station 1	280° - 10°
Station 2	300° - 30°
Station 3	165° - 255°

In order to estimate the background SO_2 concentration to be added to the modeled concentrations for a given monitor during hours when the wind direction is within the exclusion zone, the background is assumed to be the measured SO_2 concentration during the same hour for a monitor that is located outside of the exclusion zone (where available). In this case, when the wind direction is in the exclusion zone for Station 1 or 2, it is outside the exclusion zone for Station 3.

Table 2 provides a list of monitoring stations used as background when wind direction is in the exclusion zone of the monitoring station undergoing analysis. Removing the potential for double-counting modeled source emissions in the background in this manner is a reasonable approach for determining the total model impacts that are to be compared to the monitor observations.

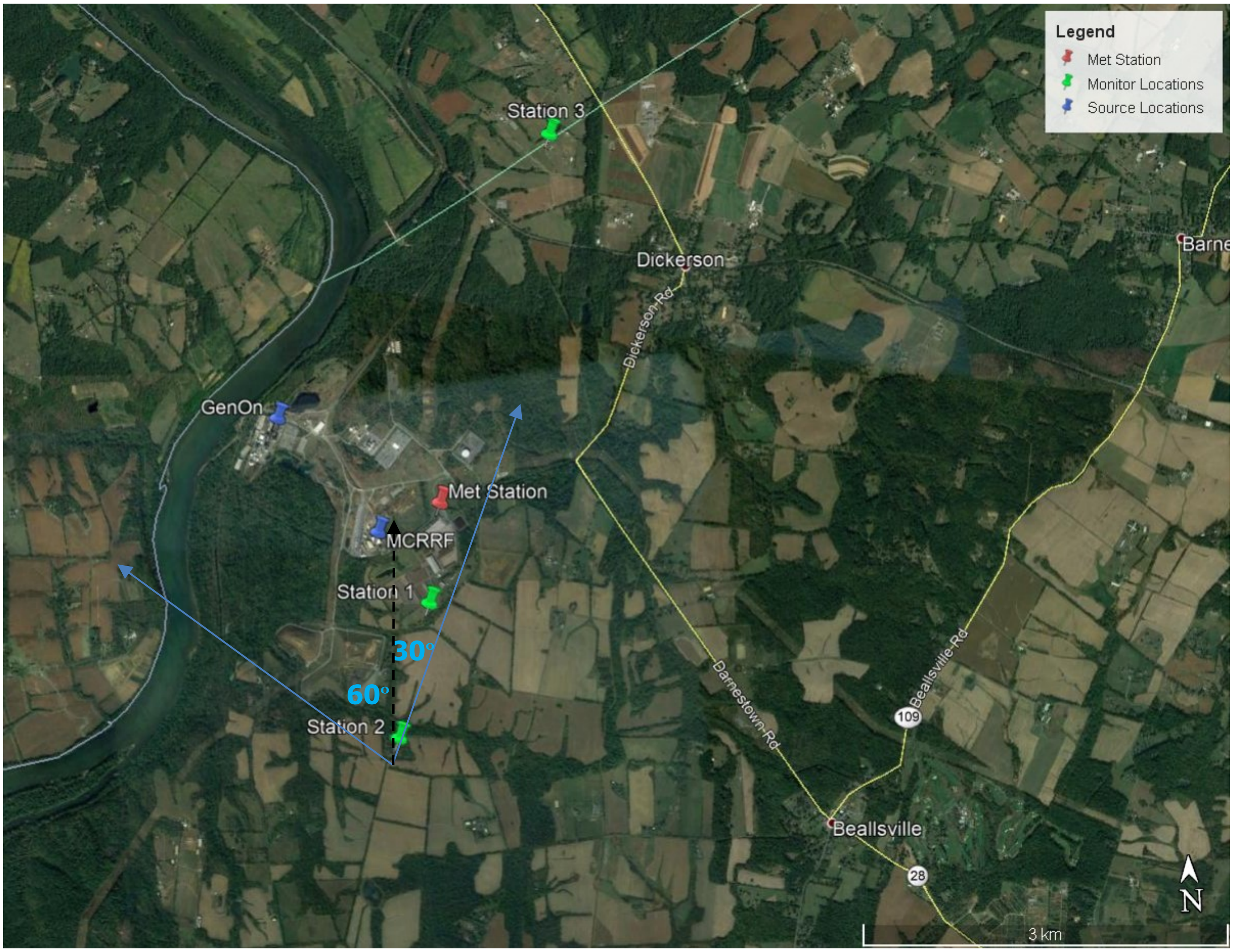
Table 2. Exclusion Zone Background Determination

Ambient SO_2 Monitor	Monitoring Station Used as Background
Station 1	Station 3
Station 2	Station 3
Station 3	Station 2

[6] https://www.tceq.texas.gov/assets/public/permitting/air/Modeling/guidance/airquality-mod-guidelines6232.pdf

Figure 5 below presents an example of an exclusion zone for monitoring station 2. If the wind direction is such that the monitor is upstream of the sources, then the SO_2 concentrations measured by the ambient monitor can be considered representative of the background and can be added directly to the modeled concentration at that particular hour.

Figure 5. Representation of Monitoring Station 2 Exclusion Zone



Predicted and Actual SO_2 Concentrations Comparison Results

In order to validate the model performance for each of the three SO_2 monitors, the highest 25 monitor and modeled concentrations were compared. The robust 25 highest concentration comparison is a typical methodology prescribed by EPA to evaluate model performance in relation to actual monitored concentrations.[7] The 25 highest modeled concentrations were determined by ranking the AERMOD output from highest to lowest at each of the monitor locations. The hourly values from each monitor were also ranked from highest-to-lowest. The highest values from AERMOD and the highest monitor values were then compared to determine how well the model predicted the actual concentrations. The highest 25 modeled and monitored concentrations raw data are available in the appendix.

To illustrate the relationship between the concentrations predicted by the model and the actual concentrations measured by the monitors, the highest 25 modeled and monitor concentrations were plotted for each monitoring station as can be seen in Figures 6 to 8 below. The solid line in each figure is a 1:1 line, representing an exact match between modeled and monitored concentrations. The dashed lines above and below the solid line represent the factor of two (2) for comparison.

[7] U.S. Environmental Protection Agency. 1992. "Protocol for Determining the Best Performing Model". EPA-454/R-92-025, September 1992).

Figure 6. Monitoring Station 1 to Modeled Concentrations Hourly Comparison

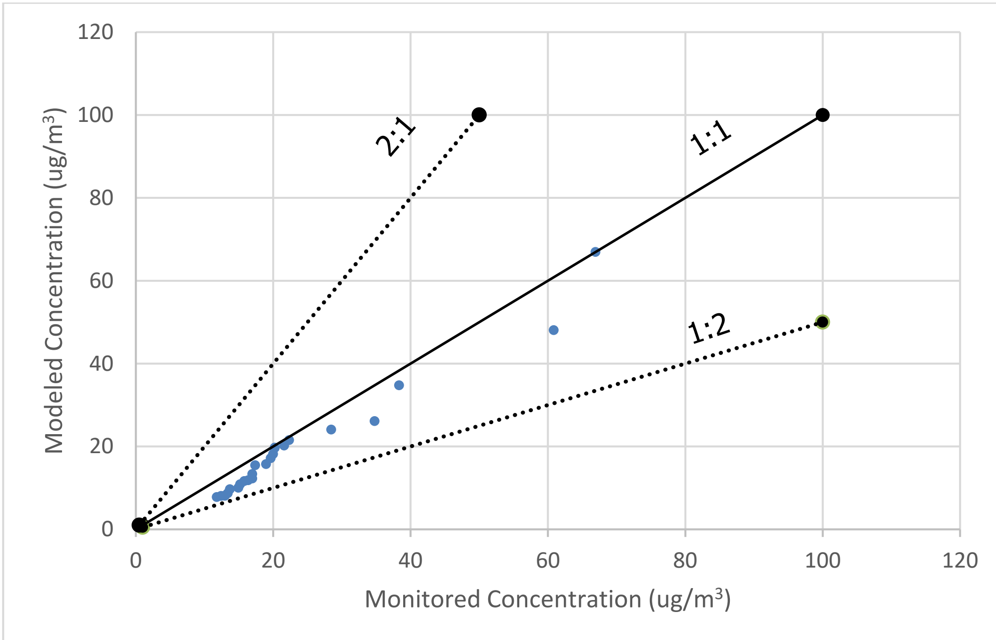


Figure 7. Monitoring Station 2 to Modeled Concentrations Hourly Comparison

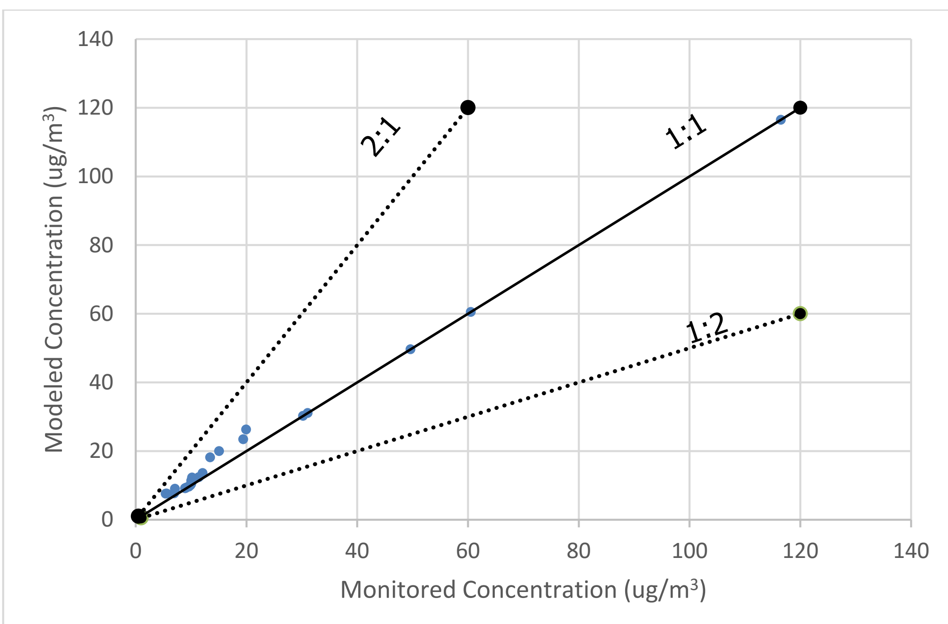
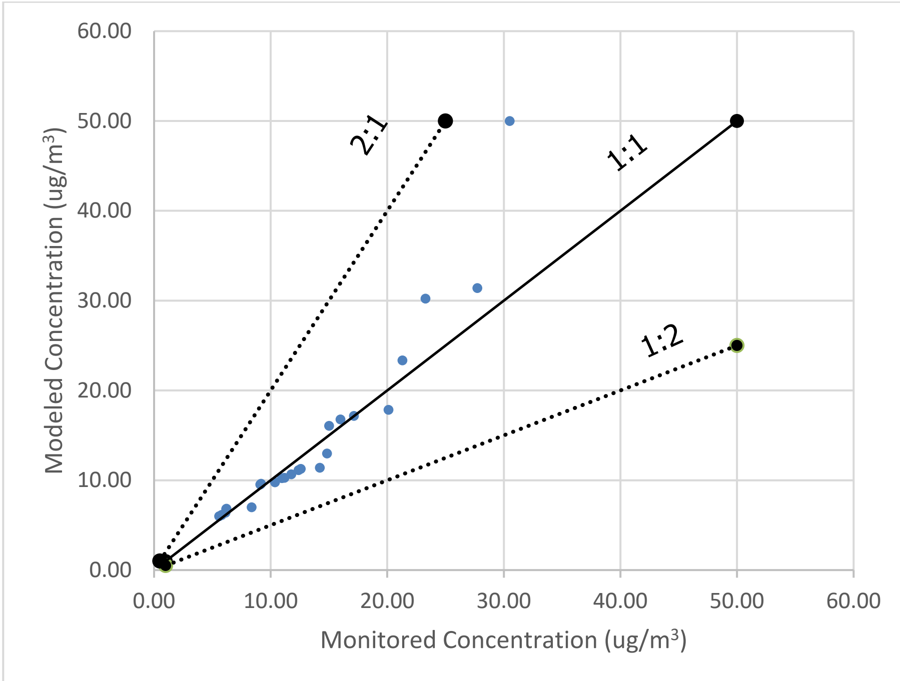


Figure 8. Monitoring Station 3 to Modeled Concentrations Hourly Comparison



A data point above the 1:1 line indicates where the model has over-predicted the concentration and a point below the line indicates where AERMOD has underpredicted. Model performance is generally deemed acceptable if modeled concentrations are within a factor of 2 of monitored concentrations.[8]

Conclusion

In summary, hourly stack emissions data and County's weather station data were input into the AERMOD model in order to predict SO_2 concentrations at the locations of three nearby monitoring stations. Those predictions were then added to an appropriate background concentration prior to comparing the total model impacts to the monitored values.

As shown in Figures 6 through 8 above, the datapoints fall within the area between the 1:2 and 2:1 lines, indicating a strong correlation between the 25 highest monitored and modeled concentrations, and thus validating the modeling data.

The data from Station 3 (as shown in Figure 8) have the most variability which is expected given the larger distance between the sources and that monitor. The highest values at station 3 are also the farthest above the 1:1 (perfect prediction) line so AERMOD tends to conservatively overestimate impacts at that location.

Therefore, as shown in the figures and detailed statistical analysis included in the appendix the AERMOD model has been shown to predict accurate concentrations in the area surrounding the MCRRF.

[8] Ibid

APPENDIX A. AERMOD VALIDATION TECHNICAL SUPPORT DOCUMENT

1. FACILITY LOCATIONS

Table 1-1. Location of MCRRF and GenOn Relative to Weather and Monitoring Stations

	Distance & Direction of Stations Relative to Sources	
	MCRRF	**GenOn (Dickerson Station)**
Monitoring Station 1	0.71 km, SE	1.96 km, SE
Monitoring Station 2	1.69 km, S	2.8 km, SE
Monitoring Station 3	3.55 km, NE	3.22 km, NE

2. MODELING METHODOLOGY

2.1 Model Selection

The AERMOD modeling was performed using regulatory default options in accordance with the procedures outlined in the *Guidelines of Air Quality* Models, except as otherwise noted in this report.

Modeling was performed for the 1-hour averaging period in order to match the monitored observations. The pollutant identification was set to "SO_2" in AERMOD, which allowed additional internal model options to be available and used, thus enabling the output options to be configured properly. Other model options, supporting AERMOD pre-processors, data sets, outputs, and source characterizations are discussed in the following subsections.

2.2 Building Downwash Analysis

Building structures that obstruct wind flow near emission points may cause stack discharges to become caught in the turbulent wakes of these structures leading to downwash of the plumes. Wind blowing around a building creates zones of turbulence that are greater than if the building were absent. These effects generally cause higher pollutant concentrations since building downwash inhibits dispersion from elevated stack discharges. For this reason, building downwash algorithms are considered an integral component of the selected air dispersion model. MES provided Trinity with detailed building dimensions for the MCRFF and those structures were included in the AERMOD model setup.[9] Since the GenOn facility is considered a more distant inventory source with a very tall stack, no building information was included for that site.

The AERMOD model has the Plume Rise Modeling Enhancements (PRIME) incorporated in the regulatory version, so the direction-specific building downwash dimensions used as input were determined by the Building Profile Input Program, PRIME version (BPIP PRIME), version 04272.[10] BPIP PRIME is designed to incorporate the concepts and procedures expressed in the Good Engineering Practice (GEP) Technical Support document, the Building Downwash Guidance document, and other related documents,[11] while incorporating the PRIME enhancements to improve prediction of ambient impacts in building cavities and wake regions.

2.3 Meteorological Data

The County's weather station data for May 2018 through April 2019 was prepared for AERMOD using the U.S. EPA's AERMET meteorological processing utility (Version 12345). That version of AERMET was used to maintain consistency with previously conducted evaluation studies. Standard U.S. EPA meteorological data processing guidance was used as outlined in a recent memorandum[12] and other documentation.

2.3.1 Surface Data

Raw hourly surface meteorological for May 2018 through April 2019 was obtained from a nearby weather station (39.202650, -77.448947) with the following AERMET-relevant parameters:

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[9] Provided by Montgomery County via email on 5/1/2020.

[10] Earth Tech, Inc., *Addendum to the ISC3 User's Guide, The PRIME Plume Rise and Building Downwash Model*, Concord, MA.

[11] U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, *Guidelines for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations) (Revised)*, Research Triangle Park, North Carolina, EPA 450/4-80-023R, June 1985.

[12] Fox, Tyler, U.S. Environmental Protection Agency. 2013. "Use of ASOS Meteorological Data in AERMOD Dispersion Modeling." Available Online: http://www.epa.gov/ttn/scram/guidance/clarification/20130308_Met_Data_Clarification.pdf

- Wind speed and direction (at 10 meters);
- Temperature (at 2 meters and 10 meters);
- Vertical temperature difference (2 and 10 meters);
- Dew point (assume to be at 2 meters);
- Relative humidity (assume to be at 10 meters);
- Solar radiation; and
- Rainfall.

The measure of data completeness for all parameters was determined as 99.4%.

2.3.2 Upper Air Data

In addition to surface meteorological data, AERMET requires the use of data from a near-sunrise-time upper air sounding to estimate daytime mixing heights. Upper air data from the nearest U.S. National Weather Service (NWS) radiosonde station, located in Sterling, VA (IAD), was obtained from the National Oceanic and Atmospheric Administration (NOAA) in FSL format.

2.3.3 Land Use Analysis

Parameters derived from analysis of land use data (surface roughness, Bowen ratio, and albedo) are also required by AERMET. In accordance with U.S. EPA guidance, these values were determined using the U.S. EPA AERSURFACE tool (Version 13016).[13] The AERSUFACE settings used for processing are summarized in Table 2-1, below. NLCD 1992 (CONUS) Land Cover data used in AERSURFACE processing was obtained from the Multi-Resolution Land Use Consortium (MRLC).

U.S. EPA guidance dictates that on at least an annual basis, precipitation at a surface site should be classified as wet, dry, or average in comparison to the 30-year climatological record at the site. This determination is used to adjust the Bowen ratio estimated by AERSURFACE. To make the determination, annual precipitation in the modeled year (May 2018 – April 2019)[14] was compared to the 1981-2010 climatological record for Dulles International Airport (KIAD), which is a nearby National Weather Service (NWS) station.[15] The 30th and 70th percentile values of the annual precipitation distribution from 1989-2018 were calculated. Per U.S. EPA guidance, the modeled year was classified for AERSUFACE processing as "wet" if its annual precipitation was higher than the 70th percentile value, "dry" if its annual precipitation was lower than the 30th percentile value, and "average" if it was between the 30th and 70th percentile values. The values used in this case are included in Table 2-1.

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[13] U.S. Environmental Protection Agency. 2013. "AERSURFACE User's Guide." EPA-454/B-08-001, Revised 01/16/2013. Available Online: http://www.epa.gov/scram001/7thconf/aermod/aersurface_userguide.pdf

[14] NOAA. Climate Data Online Search, Global Summary of the Month Dataset, station KIAD for May 2018 to April 2019. Available Online: https://www.ncdc.noaa.gov/cdo-web/search

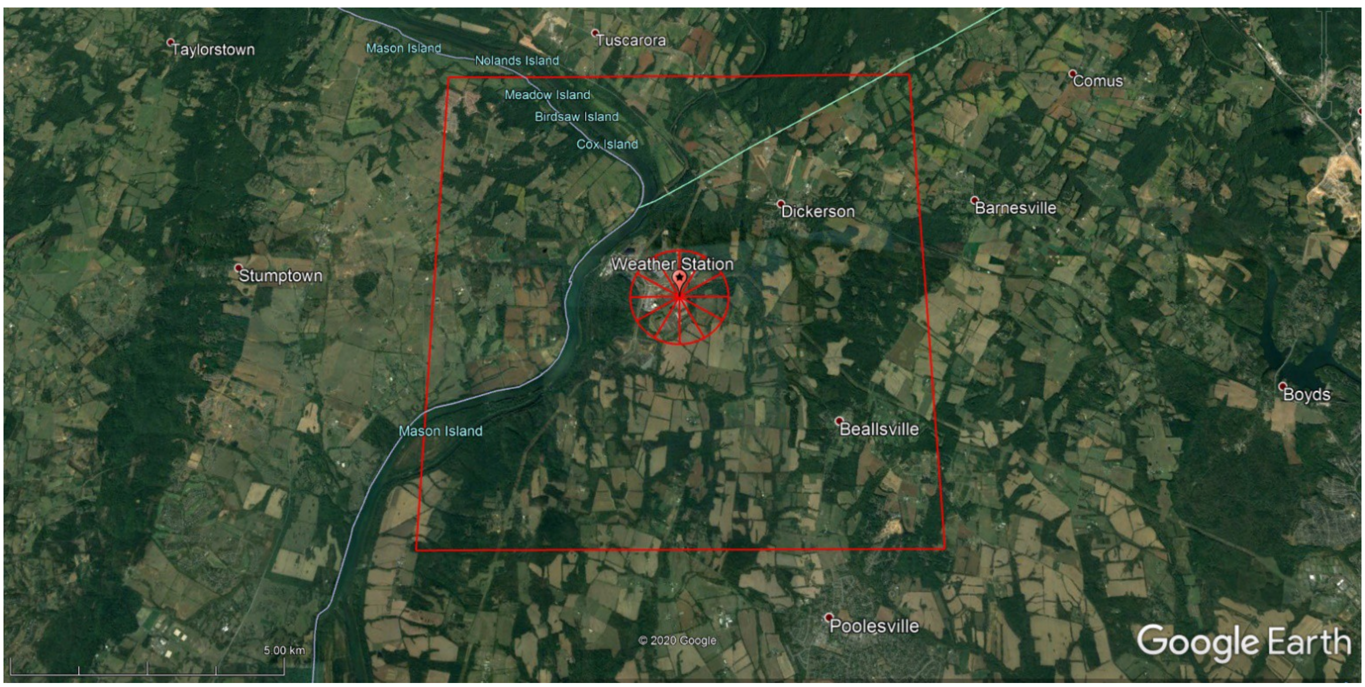
[15] Anthony Arguez, Imke Durre, Scott Applequist, Mike Squires, Russell Vose, Xungang Yin, and Rocky Bilotta. 2010. NOAA's U.S. Climate Normals (1981-2010). [KIAD]. NOAA National Centers for Environmental Information. DOI:10.7289/V5PN93JP

Table 2-1. AERSURFACE Input Parameters

AERSURFACE Parameter	Value
Met Station Latitude	39.202650
Met Station Longitude	-77.448947
Datum	NAD 1983
Radius for surface roughness (km)	1.0
Vary by Sector?	Yes
Number of Sectors	12
Temporal Resolution	Seasonal
Continuous Winter Snow Cover?	No
Station Located at Airport?	No
Arid Region?	No
Surface Moisture Classification	Wet (May 2018 – April 2019)

U.S. EPA recommendations were used to specify the area used for the AERSURFACE analysis. Surface roughness was estimated based on land use within a 1 km radius of the meteorological station, with directional variation in roughness accounted for by using the default of twelve (12), thirty-degree sectors. The albedo and Bowen ratio were estimated based on a 10x10 km box centered on the meteorological station. Figure 2-1 shows the areas used for the land use analysis.

Figure 2-1. Areas Used for AERSURFACE Land Use Analysis



2.3.4 AERMET Processing Options

Standard AERMET processing options were used in this project.[16] The options elected include:

- MODIFY keyword for upper air data
- ONSITE THRESHOLD 0.5 keyword to provide a lower bound of 0.5 m/s for onsite wind data
- AUDIT keywords to provide additional QA/QC and diagnostic information
- METHOD STABLEBL BULKRN keyword to allow use of Bulk Richardson stable layer processing

2.4 Data validation

A review of meteorological data and concentrations measured by the three ambient SO_2 monitoring stations was completed prior to comparing it with the concentrations predicted by the model. Data validation is the process designed to ensure that reported values meet the quality goals of the project. The quality of the data and success of the program to meet data quality objectives largely depends upon adherence to the procedures delineated in a Quality Assurance Project Plan (QAPP) developed for this program. The monitoring data provided has been captured in accordance with the methodology described in the "Quality Assurance Project Plan for Ambient SO_2 Monitoring at the Montgomery County Resource and Recovery Facility".

U.S. EPA data capture requires 80% or better for a monitoring year. U.S. EPA defines a systematic approach to be used for data validation. For this project, all level 0 and level 1 validation steps as defined in a QAPP have already been performed; therefore, only a level 2 data validation for the SO_2 and meteorological data was performed.

Level 2 data validation takes place after data from various measurement methods have been assembled in a database. Level 2 data validation involves comparisons with other independent data sets and includes intercomparing collocated measurements or making comparison with other measurement systems or analyses.

The guidelines outlined in Table 2-2 were followed for validating 1-hour monitoring SO_2 concentrations.

[16] U.S. Environmental Protection Agency. 2014. "User's Guide for the AERMOD Meteorological Preprocessor (AERMET)". EPA-454/B-03-002, November 2004).

Table 2-2. Data Treatment Protocols

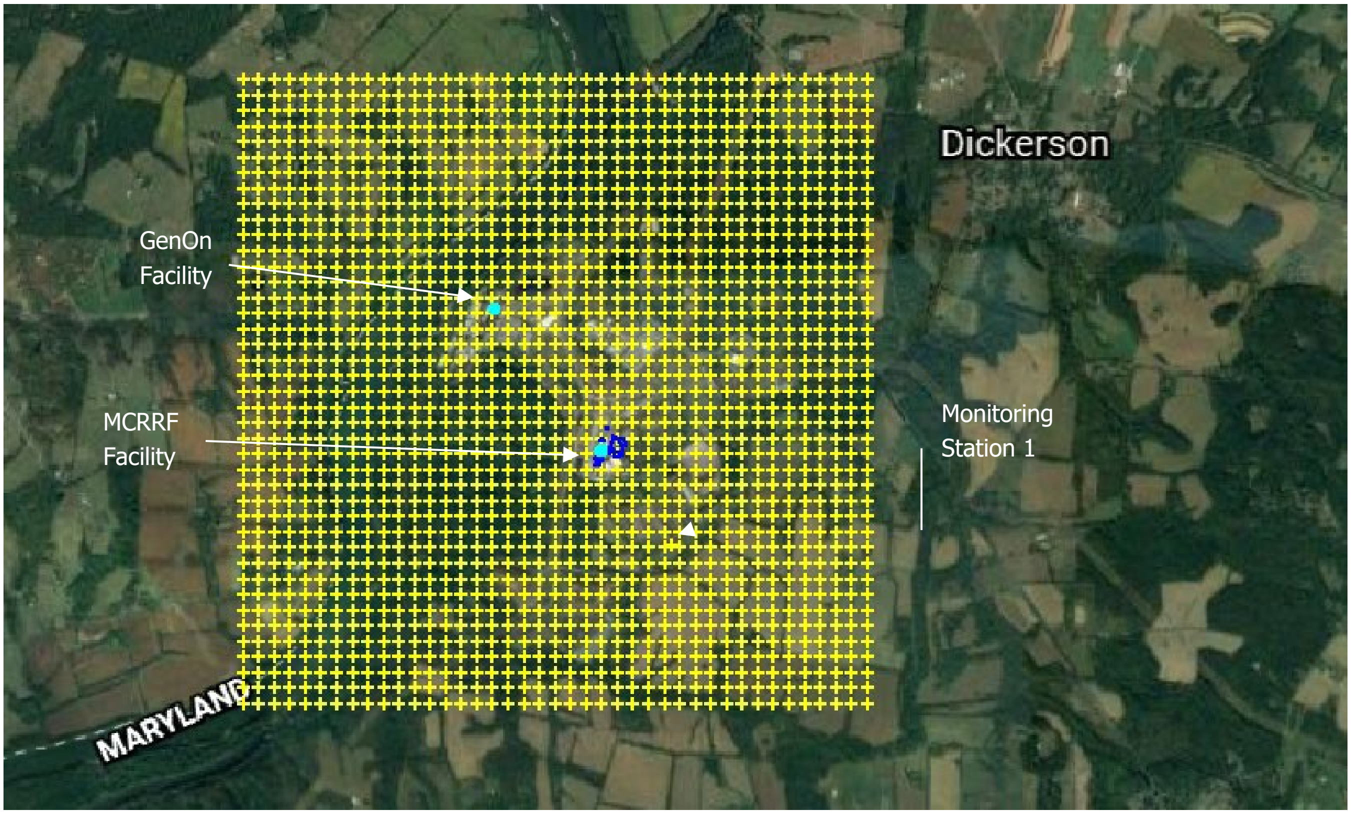
Protocol	Issue	Description	Treatment	Examples
A.	Calibration Spikes	Status of hourly data not showing "Ok"	Removed	Site 1, 9/14/2018, 15:00
B.	Aberrant Data	Big abrupt spikes in hourly data	Removed	Site 2, 10/12/2018, 4:00
C.	Continual Negative Data	Negative concentrations deviated from zero checks	Adjust based on zero check response	Site 1, 8/16/2018 to 8/31/2018
D.	Continual Positive Data	Positive concentrations deviated from zero checks	Adjust based on zero check response	Site 3, 11/20/2018 to 1/2/2019
E.	Initial Tuning	Initial tuning for instrument setup or right after a power outage	Removed	Site 2, 5/1/2018, 12:00

2.5 Receptor Locations

The modeled receptors were positioned at the precise locations of the ambient SO_2 monitors.

Since dispersion models are inherently less accurate at predicting concentrations at a specific time and place, Trinity also evaluated model predictions over a uniform receptor grid. This helped ensure that the model predictions were of similar magnitude to monitored predictions and observations. A 100 meter-spaced receptor grid centered on the modeled sources, extending over a range of 4 km was included in this evaluation as can be seen in Figure 2-2.

Figure 2-2. Full-Grid Analysis of SO_2 Concentrations Near Monitoring Station 1



Trinity compared the results from the full-grid analysis to those from the specific station 1 location and deemed the differences to be inconsequential on the whole, since the percent difference between the maximum modeled hourly SO2 concentrations was only 8%. Therefore, the model-to-data comparison for each monitor was performed with single receptors at the precise locations of the monitors.

2.6 Treatment of Terrain

The terrain elevation for each receptor, building, and emission source were determined using USGS 1/3 arc-second National Elevation Data (NED). The NED, obtained from the USGS,[17] has terrain elevations at 10-meter intervals. Using the AERMOD terrain processor, AERMAP, the terrain height for each source, receptor, and building included in the model were determined by assigning the interpolated height from the digital terrain elevations surrounding each source. These were used directly in the AERMOD model.

In addition to determining terrain elevations, AERMAP also computes the hill height scales associated with each receptor location. This computation enables the model to determine the effect that terrain will have on plumes from the sources. AERMAP searches all nearby elevation points for the terrain height and location that has the greatest influence on each receptor to determine the hill height scale for that receptor. AERMOD then uses the hill height scale in order to select the point where a plume may divide between going around a terrain feature and lofting over the feature.

[17] http://www.mrlc.gov/viewerjs/

2.7 Good Engineering Practice (GEP) Stack Height Analysis

Stack height regulations restrict the use of stack heights in excess of GEP in air dispersion modeling analyses. Under these regulations, that portion of a stack in excess of the GEP is generally not creditable when modeling to determine source impacts. The GEP Stack Height Analysis essentially prevents the use of excessively tall stacks to reduce ground-level pollutant concentrations. The minimum stack height not subject to the effects of downwash, called the GEP stack height, is defined by the following formula:

H_{GEP} = H + 1.5L, where:

H_{GEP} = minimum GEP stack height,
H = structure height, and
L = lesser dimension of the structure (height or projected width).

The wind direction-specific downwash dimensions and the dominant downwash structures used in this analysis are determined using BPIP PRIME. In general, the lowest GEP stack height for any source is 65 meters by default.[18] A source may construct a stack that exceeds GEP, but is limited to the GEP stack height in the air quality analysis demonstration. In the case of this analysis, which is a model validation study, actual stack heights are more appropriately used than a regulatory limit on stack height, as the emissions actually occur from the stack's true height above ground. That said, the MCRRF stack height is below the GEP height determined by the above formula.

2.8 Representation of Emission Sources

2.8.1 Stack Emissions Data

MCRRF and GenOn are the primary sources of SO_2 in the area, and thus are representative of the emission sources that contribute to ambient SO_2 concentrations at the locations of the monitors. Stack emissions data from each source during the monitoring period (5/1/2018 – 4/30/2019), was inputted into AERMOD. In the case of MCRRF, hourly emission rates, exhaust flowrates, and temperature measurements were provided for each of the three flue gas streams emitted from the water wall furnaces. Since plumes from adjacent stack flues tend to mix and behave as a single plume, parameters from each of the flue gas streams were combined to represent the gas stream exiting the stack. The following methodology was applied to combine the gas streams:

1. Hourly emission rates from each unit were added.
2. Weighted temperature averages were calculated according to magnitude of exhaust flowrates.
3. Exhaust flowrate measurements from each unit were added. Exhaust flowrates provided at standard conditions were converted to actual conditions by relying on Charles's law for an ideal gas, as shown in formula below:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Where V_1 is the volume at temperature T_1 and V_2 is the volume at temperature T_2. This equation can similarly be applied for flowrates instead of volume.

[18] 40 CFR §51.100(ii)

In order to test the validity of the methodology followed for combining the parameters of the flue gas streams from the water wall furnaces at MCRRF, the dispersion modeling was performed while inputting hourly emission data individually for the flue gas streams. The resulting difference in the maximum hourly SO_2 concentration in the case of monitoring station 1 was less than 5%. Therefore, combining parameters for the flue gas streams from MCRRF was determined to not compromise the validity of the results.

2.8.2 Coordinate System

In all modeling analysis data files, the location of emission sources, structures, and receptors, are represented in the Universal Transverse Mercator (UTM) coordinate system. The UTM grid divides the world into coordinates that are expressed in north meters (measured from the equator) and east meters (measured from the central meridian of a particular zone, which is arbitrarily set at 500 km). The datum for this modeling analysis is based on North American Datum 1983 (NAD 83). UTM coordinates for this analysis all reside within UTM Zone 18.

2.8.3 Source Types

The AERMOD dispersion model allows for emission units to be represented as point, area, or volume sources. The modeled sources are vertical, unobstructed stacks and were thus modeled as point sources.

For point sources with unobstructed vertical releases, it is appropriate to use actual stack parameters (i.e., height, diameter, exhaust gas temperature, and gas exit velocity) in the modeling analyses. The stack heights and diameters utilized in the modeling analyses were based on provided design values.

2.8.4 Source Parameters

The source parameters utilized in this analysis are included in Table 2-3.

Table 2-3. Modeled Source Locations and Parameters

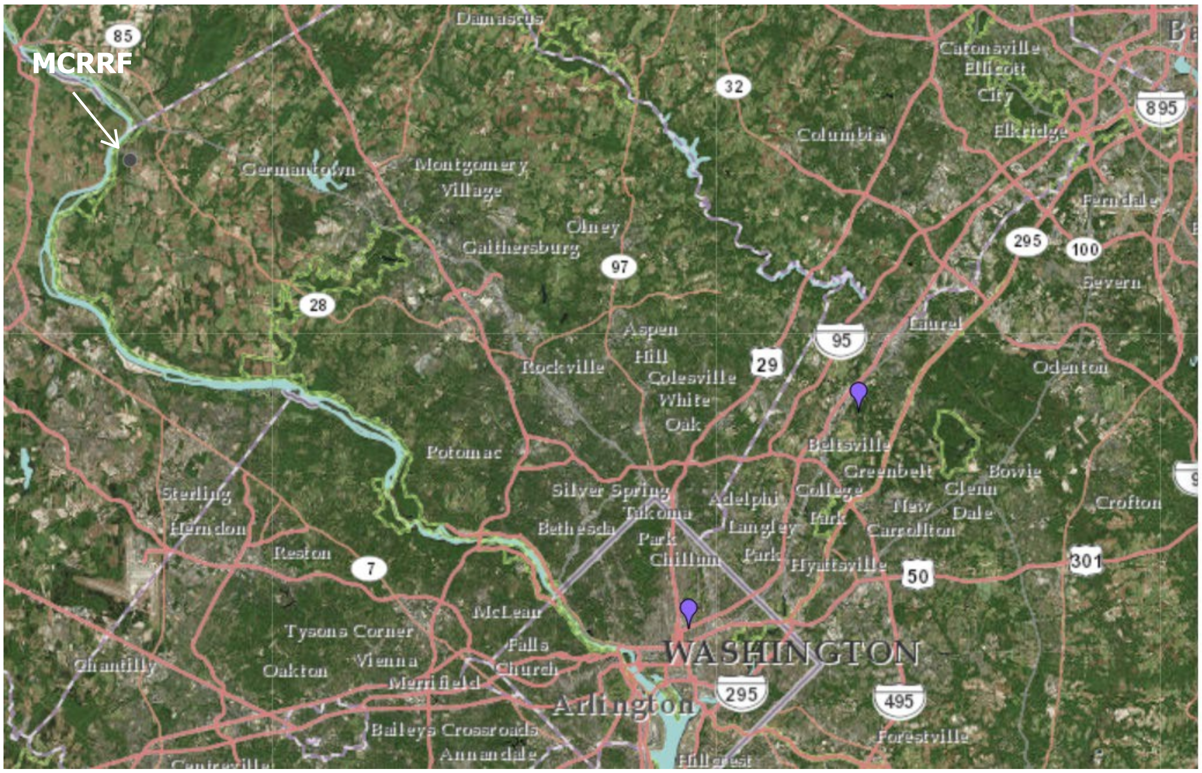
Monitoring Station	MCRRF (meters)	GenOn (meters)
Location - UTM Coordinates	Easting: 287,945.3 Northing: 4,341,922	Easting: 287,256.76 Northing: 4342832.54
Elevation	106.12	86.66
Stack Height	82.6	121.9
Stack Outlet Internal Diameter	3.66	8.05

As discussed previously, hourly readings of SO_2 emissions, stack temperatures and flows were made at both MCRRF and GenOn, and those hourly values were incorporated into AERMOD using the hourly emission file option.

2.9 Background Concentrations

In order to make a fair comparison of the modeled emission impacts and the actual concentrations measured by the monitors, ambient SO2 background (from sources other than MCRFF and GenOn) must be included. The three ambient SO_2 concentration monitors that were positioned near MCRRF could be used as a source of background SO_2 concentrations, however that runs the risk of double counting SO_2 emission impacts from both MCRRF and GenOn if the wind direction is such that the plume emitted from the sources travels towards the monitors. Apart from the three ambient SO_2 concentration monitors, the nearest active SO_2 monitors are about 30 miles away, near Washington, D.C., as can be seen in Figure 2-3. Since these monitors are near a metropolitan area; they would likely be impacted by sources of SO_2 emissions that are not representative of general background in the area surrounding MCRRF.

Figure 2-3. Locations of Active Ambient SO_2 Concentration Monitors Relative to MCRRF[19]



Therefore, there is not an ambient SO_2 monitor that is situated at an appropriate position relative to MCRRF that would always provide a representative ambient background concentration. As such, an exclusion technique was applied for determining background SO_2 concentrations in cases where the wind is coming from a direction that might intersect MCRRF prior to reaching the monitor.

The exclusion zone was determined based on the direction of the monitors relative to the sources. The exclusion zone defines the range of wind directions (defined by a 90 degree sector) for which a given monitor is downstream of the sources.[20] Therefore, if the wind direction is within the exclusion zone, it is expected that emissions from the sources will impact the SO_2 concentrations measured at the monitoring locations. If the wind direction is such that the monitor is upstream of the sources, then the SO_2 concentrations measured by the ambient monitor can be considered representative of the background and can be added directly to the modeled concentration at that particular hour.

The exclusion zone was defined as shown in Table 2-4 for each monitoring station according to their position relative to MCRRF and GenOn. An example of the exclusion zone for monitoring station 2 can be seen in Figure 2-4.

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[19] https://www.epa.gov/outdoor-air-quality-data/interactive-map-air-quality-monitors
[20] https://www.tceq.texas.gov/assets/public/permitting/air/Modeling/guidance/airquality-mod-guidelines6232.pdf

Table 2-4. Exclusion Zones

Monitoring Station	Wind Direction (degrees)
Station 1	280° - 10°
Station 2	300° - 30°
Station 3	165° - 255°

In order to estimate the background SO_2 concentration to be added to the modeled concentrations for a given monitor during hours when the wind direction is within the exclusion zone, the background is assumed to be the measured SO_2 concentration during the same hour for a monitor that is located outside of the exclusion zone (where available). In this case, when the wind direction is in the exclusion zone for Station 1 or 2, it is outside the exclusion zone for Station 3.

For example, when comparing the modeled to the measured concentrations at monitoring station 2, the background when the wind direction is within the exclusion zone is assumed to be the concentration at monitoring station 3 (which is outside the wind exclusion zone) is used for that hour. Table 2-5 provides a list of monitoring stations used as background when wind direction is in the exclusion zone of the monitoring station undergoing analysis. Removing the potential for double-counting modeled source emissions in the background in this manner is a reasonable approach for determining the total model impacts that are to be compared to the monitor observations.

Figure 2-4. Representation of Monitoring Station 2 Exclusion Zone

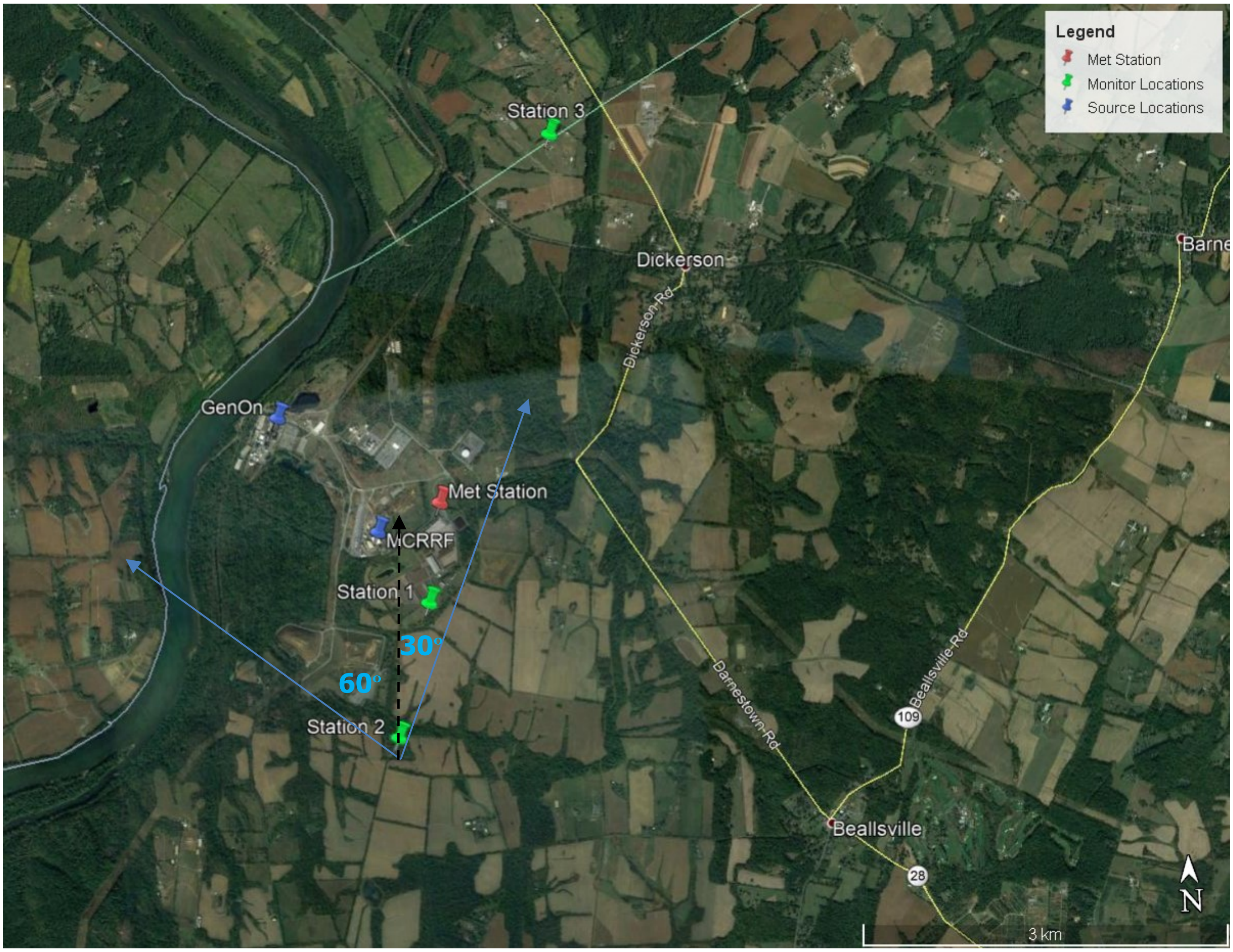


Table 2-5. Exclusion Zone Background Determination

Ambient SO_2 Monitor	Monitoring Station Used as Background
Station 1	Station 3
Station 2	Station 3
Station 3	Station 2

3. MODEL PERFORMANCE EVALUATION RESULTS

In order to validate the model performance for each of the three evaluated monitors, the highest 25 monitor and modeled concentrations were compared as presented in Tables 3-1 to 3-3. The robust 25 highest concentration comparison is a typical methodology prescribed by EPA to evaluate model performance in relation to actual monitored concentrations.[21] The highest concentrations presented in Tables 3-1 to 3-3 were generated by considering the maximum modeled concentrations at single receptors positioned at the ambient monitor's exact location, and the percent difference between the monitor and modeled concentrations were calculated. The ranked concentrations did not necessarily occur at the same date and time. Rather, raw model performance is more appropriately determined by how well the model predicts the highest values captured by the monitor. Of note, an hourly monitored SO_2 concentration measured on March 6, 2019 at 9 AM by monitoring station 1 was much higher than modeled concentrations and other measurements taken by that monitor around that period of time. It is unknown what could have caused such an outlier event, but that hourly SO_2 concentration was excluded from this model performance evaluation. Furthermore, the determined hourly background SO_2 concentration for monitoring station 3 on May 3, 2018 at 6 PM was excluded, since it is much higher than range of measured concentrations at monitoring station 3.

Table 3-1. Highest 25 Monitor-to-Model Comparison: Station 1

Rank	1-hr Max Monitor Concentration (ug/m^3)	1-hr Max Modeled Concentration Including Background (ug/m^3)	Difference (%)
1	66.93	66.93	0.0%
2	60.83	48.06	-23.5%
3	38.32	34.77	-9.7%
4	34.77	26.11	-28.4%
5	28.44	24.08	-16.6%
6	22.32	21.53	-3.6%
7	21.58	20.22	-6.5%
8	20.22	19.72	-2.5%
9	20.21	19.63	-2.9%
10	19.99	18.16	-9.6%
11	19.63	17.16	-13.5%
12	18.97	15.75	-18.6%
13	17.38	15.49	-11.5%
14	16.95	13.34	-23.8%
15	16.95	12.28	-31.9%
16	16.34	11.84	-31.9%
17	15.78	11.66	-30.0%
18	15.18	10.90	-32.9%
19	14.92	10.03	-39.2%
20	13.69	9.69	-34.3%
21	13.39	8.73	-42.1%
22	12.98	8.16	-45.6%
23	12.96	8.12	-45.9%
24	12.41	8.07	-42.4%
25	11.78	7.79	-40.8%

[21] U.S. Environmental Protection Agency. 1992. "Protocol for Determining the Best Performing Model". EPA-454/R-92-025, September 1992).

Table 3-2. Highest 25 Monitor-to-Model Comparison: Station 2

Rank	1-hr Max Monitor Concentration (ug/m^3)	1-hr Max Modeled Concentration Including Background (ug/m^3)	Difference (%)
1	116.49	116.49	0.0%
2	60.49	60.51	0.0%
3	49.61	49.61	0.0%
4	31.06	31.07	0.0%
5	30.22	30.22	0.0%
6	19.95	26.26	27.3%
7	19.41	23.44	18.8%
8	15.04	19.95	28.1%
9	13.45	18.13	29.7%
10	12.09	13.59	11.7%
11	11.39	12.37	8.3%
12	10.19	12.25	18.4%
13	10.04	11.39	12.6%
14	10.03	10.40	3.7%
15	9.90	10.04	1.4%
16	9.75	9.91	1.7%
17	9.60	9.61	0.1%
18	9.12	9.35	2.5%
19	8.99	9.17	2.0%
20	8.91	9.17	2.8%
21	7.10	8.99	23.5%
22	7.07	8.17	14.4%
23	6.95	7.63	9.4%
24	5.60	7.62	30.7%
25	5.40	7.58	33.5%

Table 3-3. Highest 25 Monitor-to-Model Comparison: Station 3

Rank	1-hr Max Monitor Concentration (ug/m^3)	1-hr Max Modeled Concentration Including Background (ug/m^3)	Difference (%)
1	30.50	49.99	48.4%
2	27.74	31.40	12.4%
3	23.28	30.22	25.9%
4	21.31	23.35	9.1%
5	20.11	17.85	-11.9%
6	17.15	17.16	0.1%
7	15.99	16.76	4.7%
8	15.01	16.06	6.7%
9	14.84	12.98	-13.4%
10	14.23	11.39	-22.2%
11	12.59	11.27	-11.0%
12	12.40	11.12	-10.9%
13	11.77	10.66	-10.0%
14	11.18	10.28	-8.4%
15	10.97	10.24	-6.9%
16	10.37	9.77	-6.0%
17	9.19	9.62	4.6%
18	9.11	9.53	4.5%
19	8.37	6.99	-18.1%
20	6.21	6.83	9.5%
21	6.19	6.80	9.3%
22	6.14	6.39	4.0%
23	5.80	6.14	5.6%
24	5.79	6.13	5.6%
25	5.58	5.99	7.0%

To illustrate the correlation more clearly between the model-predicted and actual concentrations for each monitoring station, the highest 25 modeled and monitor concentrations in Tables 3-1 to 3-3 were plotted as can be seen in Figures 3-1 to 3-3. The solid line in each figure is a 1:1 line representing an exact match between modeled and monitored concentrations. Model performance is generally deemed acceptable if modeled-to-monitor concentrations fall within a factor of two (2) of monitor concentrations. In the figures, dotted (2:1 and 1:2) lines show those boundaries of acceptable performance. As shown in the figures, the datapoints fall within the area between the 1:2 and 2:1 lines, indicating a strong correlation between the 25 highest monitored and modeled concentrations, and thus validating the model. The data from Station 3, as shown in Figure 3-3, have the most variability which is expected given the larger distance between the sources and that monitor. The highest values at station 3 are also the farthest above the 1:1 (perfect prediction) line so AERMOD tends to conservatively overestimate impacts at that location.

Figure 3-1. Monitoring Station 1 to Modeled Concentrations Hourly Comparison

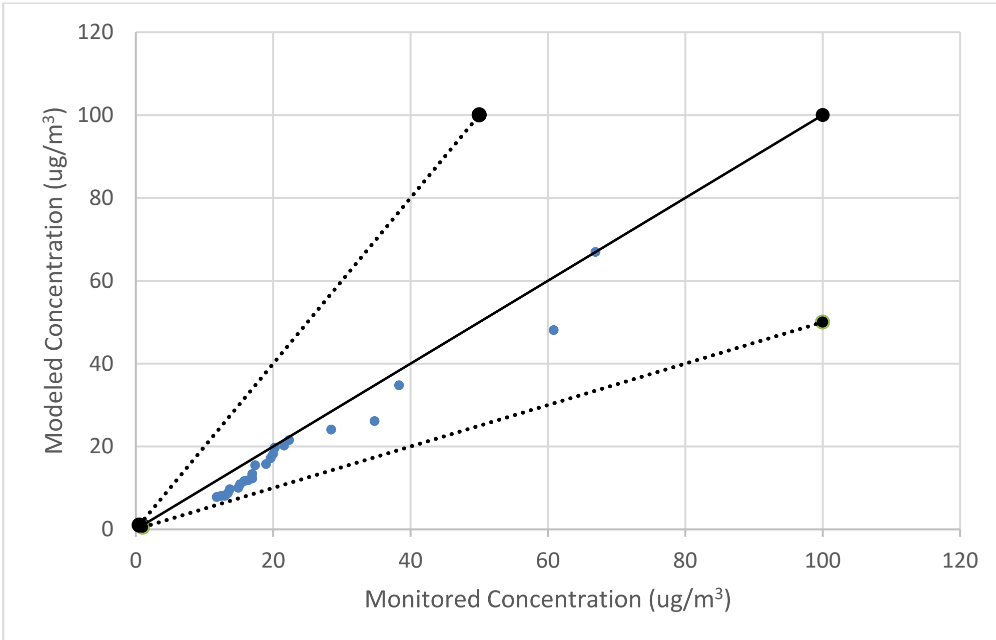


Figure 3-2. Monitoring Station 2 to Modeled Concentrations Hourly Comparison

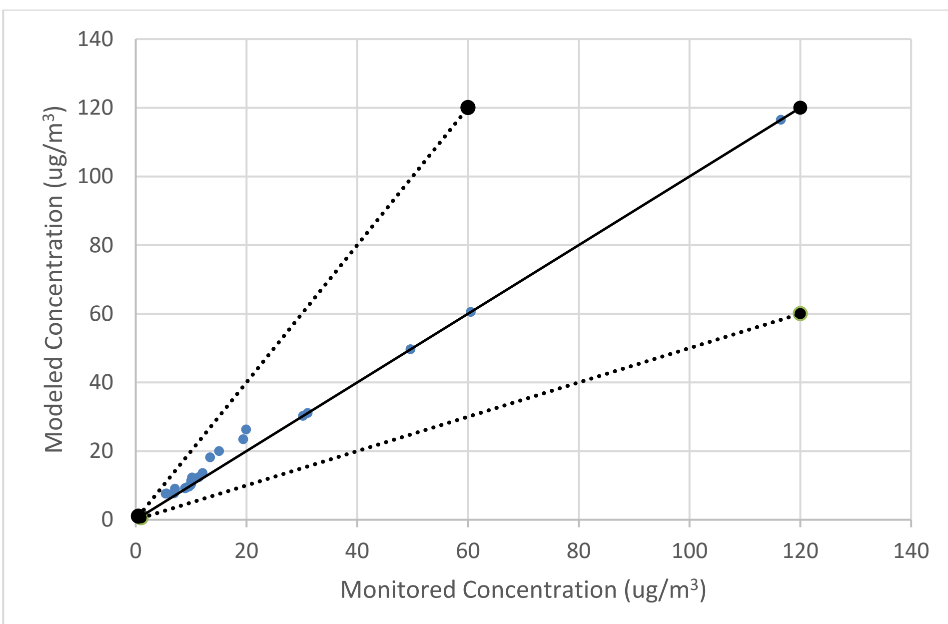
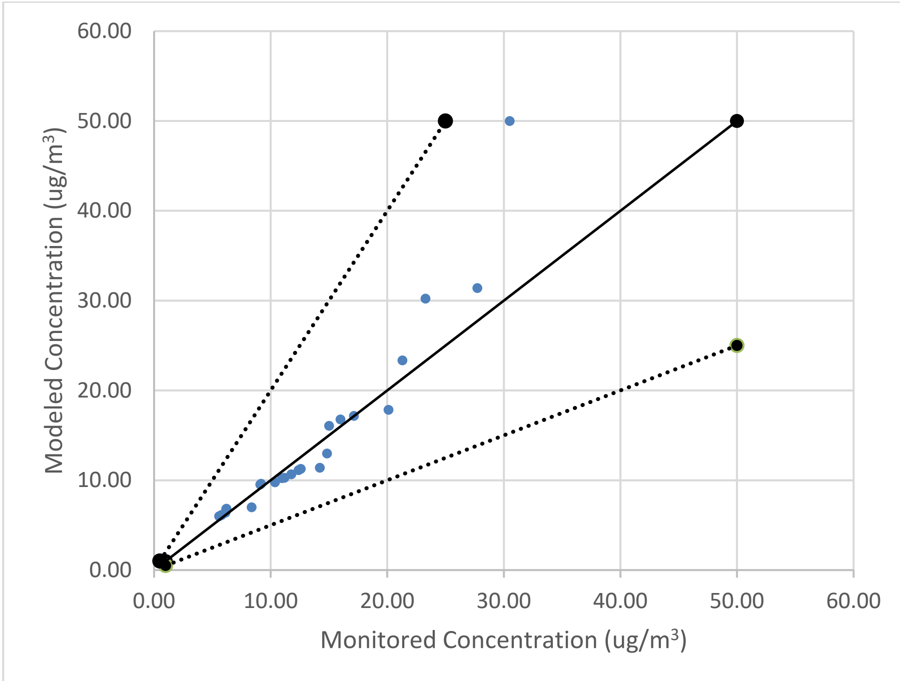


Figure 3-3. Monitoring Station 3 to Modeled Concentrations Hourly Comparison



To further evaluate the correlation between the modeled and monitored concentrations datasets, four specific statistical metrics, that provide a measure for the level of similarity between datasets, were calculated.

These statistical measures are provided in Table 3-4 below. Based on the percent deviation of the calculated metrics from the ideal values, with 0% indicating a perfect match, it can be inferred that the AERMOD predicted SO_2 concentrations align well with the monitor concentrations when drawing a comparison between the 25 highest concentrations and factoring in background.

Table 3-4. Statistical Model Performance Evaluation in Comparison to Monitored SO2 Concentrations

	Station 1	Station 2	Station 3	Ideal Values
Fractional Bias of Averages	-0.18	0.07	0.07	0.00
Normalized Mean Square Error (NMSE)	0.03	0.005	0.005	0.00
Fraction within a factor of two (FAC2)	1.00	1.00	1.00	1.00
R – Correlation Factor	0.96	0.99	0.89	1.00

$$FB = \frac{\overline{C_o} - \overline{C_p}}{0.5(\overline{C_o} + \overline{C_p})}$$

$$NMSE = \frac{(\overline{C_o} - \overline{C_p})^2}{\overline{C_o} \times \overline{C_p}}$$

Where FB is the fractional bias of averages, NMSE is the normalized mean square error, and $\overline{C_o}$ and $\overline{C_p}$ refer to the averages of the observed and predicted 25 highest values respectively.