Attachment D:
Duke Energy
Allen Steam Station
Modeling Report
For 1-hour SO_2 National Ambient Air Quality Standard (NAAQS)

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1. Purpose

On June 2, 2010, USEPA issued a final rule that revised the SO_2 National Ambient Air Quality Standard.[1] The revised SO_2 standard is 75 ppb based on a three-year average of the 99th percentile of the daily maximum hourly concentration. On August 21, 2015, EPA issued the Data Requirements Rule [2] (DRR) to implement the new standard. The DRR requires all sources of SO_2 greater than 2,000 tons/year to characterize the SO_2 concentrations where the sources are located using either a modeling or monitoring approach. The North Carolina Division of Air Quality (NCDAQ) has followed the modeling approach to demonstrate attainment for the 1-hour SO_2 NAAQS for the Duke Energy Allen Steam Station (Allen). The modeling approach was based on the modeling protocol submitted to EPA on June 30, 2016 and comments received August 10, 2016 from EPA on the modeling protocol. The modeling analysis uses hourly actual emissions and hourly meteorology from the period 2013-2015. In general, the modeling procedures are consistent with applicable guidance, including the August 2016 SO_2 NAAQS Designations Modeling Technical Assistance Document[3] (TAD) issued by the EPA.

2. Plant Information

Duke Energy's Allen Steam Station is a 1,140 MW coal-fired electric power plant located in Gaston County North Carolina. The Allen Steam Station is permitted for five coal/No. 2 fuel oil-fired electric utility boilers (ID Nos. ES-1 (U1 Boiler), ES-2 (U2 Boiler), ES-3 (U3 Boiler), ES-4 (U4 Boiler), and ES-5 (U5 Boiler)) and one No. 2 fuel oil-fired auxiliary boiler (ID No. ES-6 (AuxB)). Units 1 & 2 are Coal/No. 2 fuel oil-fired electric utility boilers (1,980 million Btu per hour heat input capacity) equipped with modified fuel burner systems (low NOx concentric firing system), separated overfire air (SOFA), lowered fired (LOFIR) low NOx technologies, and alkaline-based fuel additives. Units 3 & 4 are Coal/No. 2 fuel oil-fired electric utility boilers (3,390 million Btu per hour heat input capacity), also equipped with modified fuel burner systems (low NOx concentric firing system), separated overfire air (SOFA), lowered-fire (LOFIR) low-NOx equipment, and alkaline-based fuel additives. Unit 5 is a Coal/No. 2 fuel oil-fired electric utility boiler (3,390 million Btu per hour heat input capacity) equipped with a modified fuel burner system (low NOx concentric firing system), separated overfire air (SOFA), lowered fired (LOFIR) low-NOx equipment, and alkaline-based fuel additive.

The Allen Station is located on Lake Wylie Reservoir near the town of Belmont, Gaston County, North Carolina. A map and aerial photograph of the facility and surrounding area are provided in Figures 1 and 2, respectively.

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[1] Primary National Ambient Air Quality Standard for Sulfur Dioxide75 FR 35520–35603, Jun 22, 2010

[2] *Data Requirements Rule for the 1-Hour Sulfur Dioxide (SO2) Primary National Ambient Air Quality Standards (NAAQS): Proposed Rule, Federal Register Vol. 79 No. 92, pages 27445-27472, May 13, 2014.*

[3] https://www.epa.gov/sites/production/files/2016-06/documents/so2modelingtad.pdf

Figure 1. Location of Duke-Allen in Gaston County, NC

Figure 2. Aerial View of Duke-Allen Steam Station

3. Modeling Approach

Following the procedures in the modeling TAD, the dispersion modeling analysis evaluated the attainment status of the area in the vicinity of Allen Steam Station for the 1 hour SO_2 NAAQS. The DRR allows the use of modeling rather than monitoring to make attainment designations. Air quality modeling provides a conservative estimate of the actual air quality within the vicinity of the plant. Following EPA guidance, the modeling analysis used the preferred model AERMOD. In addition, to allow for a more accurate representation of actual ambient SO_2 concentrations, the modeling analysis was conducted as follows:

- Using hourly varying actual emissions and stack release parameters as input for assessing current actual air quality;
- Using three years of modeling results to calculate a design value consistent with the 3-year monitoring period required to develop a design value for comparison to the NAAQS;
- Placing receptors for the modeling only in locations where a monitor could be placed; and
- Using actual stack heights rather than following the Good Engineering Practice (GEP) stack height policy when modeling actual emissions.

The following sections provide an overview of the modeling procedures to be used for Allen.

4. Model Selection

The modeling analysis for the 1 hour SO_2 NAAQS was performed using AERMOD (version 15181), and pre-processing program, AERMAP (version 11130). The modeling analysis considered and included building downwash. The BPIPPRIME (version 04274) model was used to generate building downwash parameters for input to AERMOD. This modeling analysis was conducted using the AERMOD regulatory default run options. The pollutant identification was set to "SO_2" in AERMOD to allow AERMOD to properly calculate an SO_2 design value based on the 3-year average of the 99^{th} percentile of the annual distribution of the daily maximum 1-hour concentrations for comparison with the 1-hour SO_2 NAAQS of 75 ppb (196 µg/m3).

5. Rural or Urban Dispersion

Determination of rural or urban dispersion characterization was based on available satellite imagery showing that the majority of land use types within 3 km radius of the source are open water, forests, pasture, and low intensity residential. Figure 3 shows an aerial satellite image depicting land use within 3 km of the facility. The area can clearly be characterized as "rural".

Therefore, AERMOD default rural dispersion coefficients were applied to dispersion and pollutant concentration calculations.

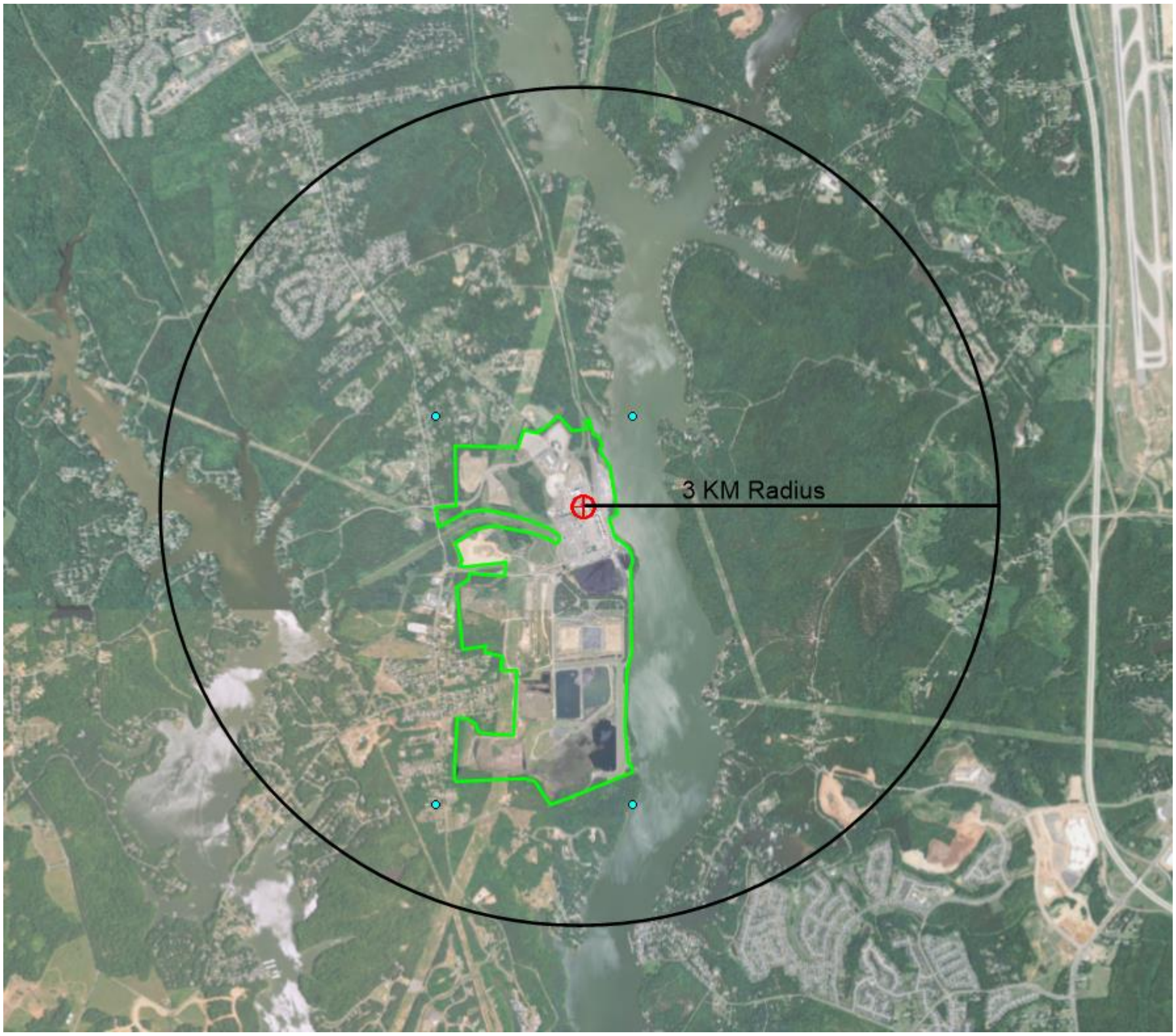

Figure 3. 3-KM Land Use Surrounding Allen Steam Station

6. Building Downwash

EPA's Building Profile Input Program (BPIP) with Plume Rise Model Enhancements (PRIME) (version 04274), was used to account for building downwash influences on the plume. Building downwash analysis is used to determine if the plume is affected by the turbulent wake from onsite buildings or other structures. The effects of downwash on the plume can result in elevated ground-level concentrations in the near wake of a building and is required for consideration in the modeling. Building downwash was also included for one nearby source (Duke Marshall Steam Station) in the modeling analysis.

7. Allen Source Parameters

Allen operates five coal fired boilers. The boilers are vented through two separate stacks as follows: Stack 1 – Units 1, 2 & 5 and Stack 2 – Units 3 & 4. Figure 4 shows the facility's stack locations, buildings and fenceline. Figure 5 shows a close-up view of relative building and source locations and model input identifications. Table 1 summarizes the source parameters that were used in the modeling.

As recommended in the SO_2 modeling TAD, the hourly varying emissions and stack release parameters were used in the modeling. The hourly varying emissions and release parameters coincided with the meteorological data for the period 1/1/2013 thru 12/31/2015. The hourly SO_2 emissions, flow rates, and flow temperatures measured by the continuous emissions monitoring system located on each of the boiler stacks was used in the modeling analysis. The hourly SO_2 pounds per hour emission rates were converted to units of grams per second for input to the model. The hourly varying emissions and release parameters were input into AERMOD using the HOUREMIS keyword in the source pathway of the AERMOD control file (AERMOD.INP).

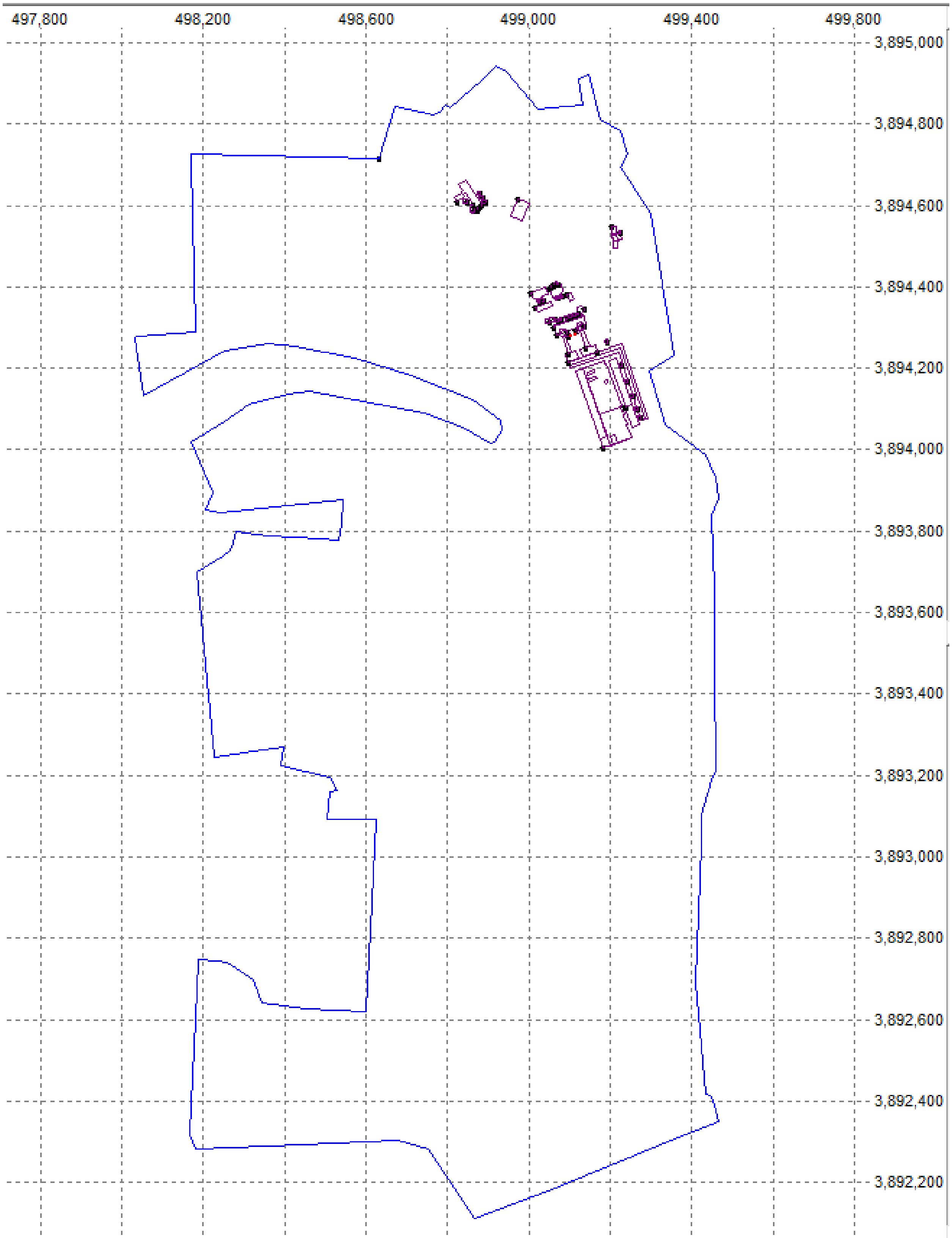

Figure 4. Layout of the Fenceline, Source and Building Locations for Duke-Allen

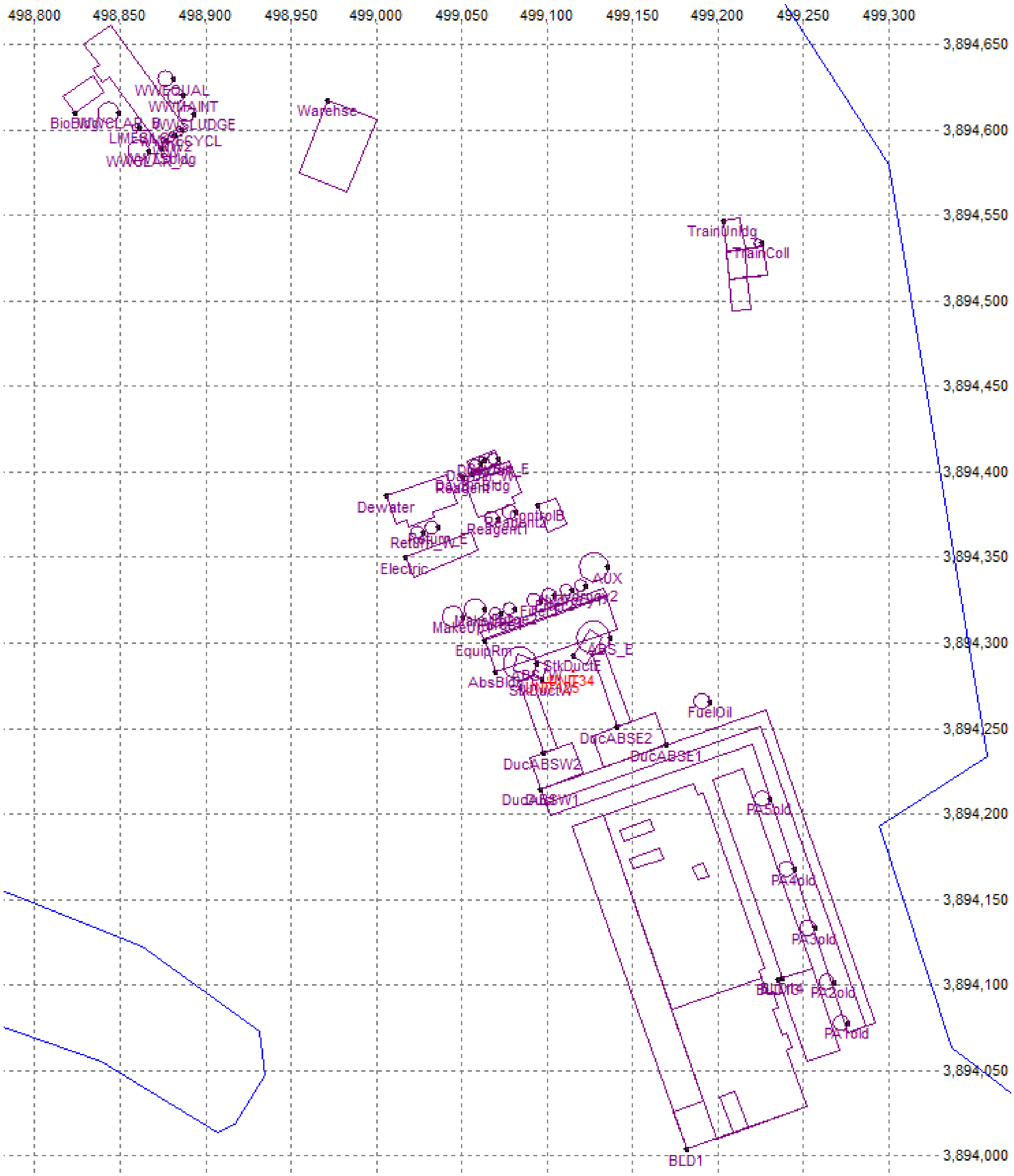

Figure 5. Close Up of Layout of Source and Building Locations for Duke-Allen

Table 1. Duke-Allen Stack Parameters

Source ID / Description	Easting (X)	Northing (Y)	Elevation	Stack Height	Exit Temp	Exit Velocity	Stack Diameter
	(m)	(m)	(m)	(m)	(K)	(m/s)	(m)
UNIT125 – Boiler Units 1, 2 & 5	499,103.61	3,894,280.43	191.74	111.25	Varying	Varying	9.0
UNIT34 – Boiler Units 3 & 4	499,114.96	3,894,284.16	191.37	111.25	Varying	Varying	9.0

8. Intermittent Sources

Most other emitting sources at Duke-Allen are associated with coal and ash handling, conveying, and transport and do not emit SO_2. Duke-Allen also operates one emergency generator, one auxiliary boiler, an emergency fire pump, and an emergency quench pump which operate infrequently, combust ultra-low sulfur diesel (ULSD), and emit small quantities of SO_2. According to Section 5.4 of the modeling TAD, EPA states that it is most appropriate to include sources of emissions which operate continuously or frequent enough to contribute to the annual distribution of the daily maximum concentrations. Table 2 summarizes the emissions and operation of the intermittent sources. As shown in the table, total max annual emissions of SO_2 from these sources during the period 2013-2015 is 500 pounds per year, with max hourly emission rates well below the hundreds of pounds per hour continuously emitted from the coal-fired boilers. Thus, these intermittent sources operate at neither a frequency or magnitude great enough to contribute to the annual distribution of the daily maximum concentrations, and therefore, were not included in the analysis.

Table 2. Intermittent Sources of SO_2 at Duke-Allen

Source ID	**Emissions Source**	**Capacity**	**Max. Hourly Emission Rate* (lbs/hr)**	**Max Annual Emissions 2013-2015 (lbs)**	**Max Annual Fuel Use 2013-2015 (gal)**
ES-6(AuxB)	No. 2 Fuel Oil Auxiliary Boiler	14.6 MMBtu/hr	0.023	500	6250
ES-7(EmGen)	No.2 Fuel Oil Fired Emergency Generaor	2681 hp	0.037	0.44	450
ES−EmFP	Diesel Fired Emergency Fire Pump	288 hp	0.003	0.093	350
ES−EmQP	Diesel Fired Emergency Quench Pump	440 hp	0.005	0.043	150

* Based on NC DAQ IC Engine Spreadsheets using 0.0015% ULSD

9. Nearby Emissions Sources

An evaluation was conducted to determine if other sources of SO_2 emissions in the area surrounding Duke-Allen should be included in the modeling to fully characterize the air quality in the area. According to the EPA March 1, 2011 Memorandum[4] and the analysis presented at the 2011 EPA modeling workshop,[5] selection of regional background sources should be focused on sources located within 10 kilometers from Allen. According to the NCDAQ's Emissions Inventory for 2013-2015, there were no other sources of SO_2 located within 10 km of the Allen plant; however, based on EPA comments, large sources that were more than 10 km from Allen were evaluated to determine if they should be included in the analysis. As shown in Table 3, two sources were identified within the 50 km AERMOD modeling range as having significant SO_2 emissions - the Resolute Paper facility, located approximately 40 km south-southeast of the Duke-Allen facility, and the Duke Marshall facility, located approximately 45 km north of the Duke-Allen facility.

Duke-Marshall's hourly varying emissions and hourly varying stack release parameters were readily available, and the Q/D ratio is nearly double that of Resolute Paper. Therefore, Duke-Marshall SO_2 modeled impacts were included in the Duke-Allen modeling analysis under DRR.

Resolute Paper emissions and stack parameter data were not readily available for input to the model, however a comparison between Duke-Marshall emissions and modeled impacts show that inclusion of Resolute Paper facility SO_2 emissions should not significantly affect the 1-hour SO_2 model design concentrations for the Duke-Allen air quality analysis. For example, the maximum 1-hour SO_2 model impacts from Duke-Marshall were predicted at 90 $\mu g/m^3$ (see Section 15), and occurred roughly 40 km north of the Duke-Allen facility. The Resolute Paper annual emissions (and Q/D value) are nearly half of Duke-Marshall emissions, and dispersion of emissions occurs over the same distance for both Resolute Paper and Duke-Marshall with respect to the location of the Duke-Allen facility and modeling domain. Furthermore, Duke-Marshall emissions contribute only 0.2 $\mu g/m^3$ to the total model design concentration for the Duke-Allen analysis (see Section 13). Therefore, NCDAQ assumed that 1-hour SO_2 impacts from Resolute Paper would be less than those impacts predicted for Duke-Marshall. Additionally, Resolute Paper is located south-southeast of the Duke-Allen facility, and therefore, prevailing southwest winds would likely carry Resolute Paper emissions and impacts eastward and away from the Duke-Allen modeling domain under most meteorological conditions. Thus, NCDAQ has excluded Resolute Paper from the Duke-Allen 1-hour SO_2 modeling demonstration based on the reasonable assumption that similar dispersion of comparably lower emissions from Resolute Paper would not result in modeled impacts greater than those shown for Duke-Marshall.

[4] http://www.epa.gov/scram001/guidance/clarification/Additional_Clarifications_AppendixW_Hourly-NO2-NAAQS_FINAL_03-01-2011.pdf

[5] http://www.cleanairinfo.com/regionalstatelocalmodelingworkshop/archive/2011/Presentations/6-Thursday_AM/6-3_AB-3_Presentation_at_EPA_Modeling_Workshop.pdf,

Table 3. Sources of SO_2 Near Duke-Allen Within the 50 km AERMOD Modeling Range

Facility Name	Emissions TPY (Q)	Year	Distance km (D)	Q/D
Resolute Paper, Catawba, SC	2,621	2014	40	66
Duke Marshall Steam Station	4,624	2015	45	103

10. Receptor Grid

The size, spacing, and location of the receptor grid is unique to the modeling analysis. The receptor grid takes into account the location of the sources to be modeled, terrain features, and areas where the public generally has access. In accordance with the modeling TAD, receptors were not located in an area where it is not technically feasible to locate a monitor.

Receptor density was setup to detect the significant concentration gradient. Typically, the receptor spacing is closer near the source and further apart farther from the source. Receptor elevations were included in the modeling analysis. The receptor elevations were determined by AERMAP processing of 1-arc-second resolution terrain data from the USGS National Elevation Dataset (NED). Flagpole receptor height for this analysis was set at 0 meters. Figure 6 shows the placement of receptors modeled around Duke-Allen.

The grid receptor spacing for the area of analysis is as follows:

- Receptors along the fence line every 50 meters
- Receptors every 100 meters from fence line to 3 km
- Receptors every 250 meters from 3 km to 5 km
- Receptors every 500 meters from 5 km to 10 km
- Receptors every 1000 meter from 10 km to 20 km
- Receptors every 2000 meter from 20 km to 50 km

Figures 7 and 8 show receptor grids overlaying townships and counties depicted at both small and large scales, respectively. Figure 7 captures receptor grids extending out to 5 km. Figure 8 captures all receptor grids extending out to 50 km. The receptor grids, as shown, cover all or portions of the following North Carolina counties: Burke, Catawba, Cleveland, Lincoln, Gaston, Mecklenburg, Iredell, Rowan, Cabarrus, Union, and Stanly.

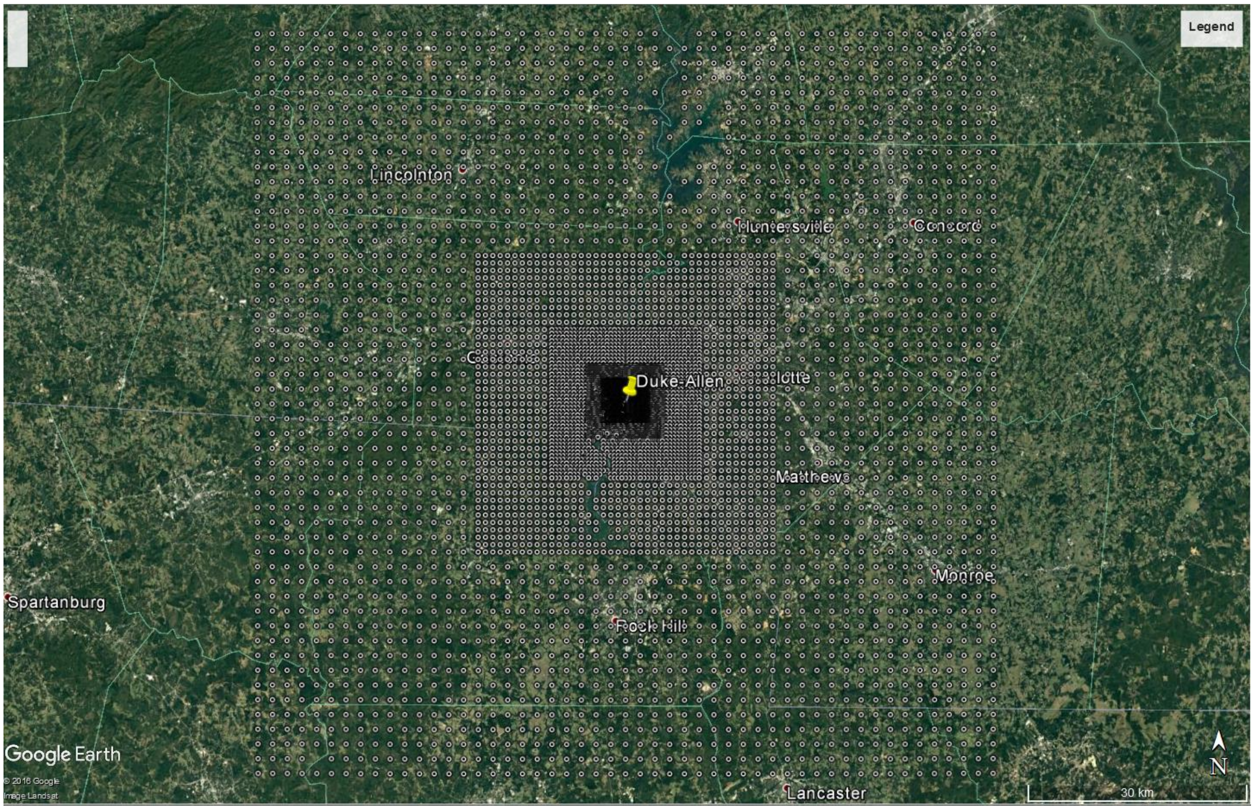

Figure 6. Receptor Layout for the Duke-Allen Analysis

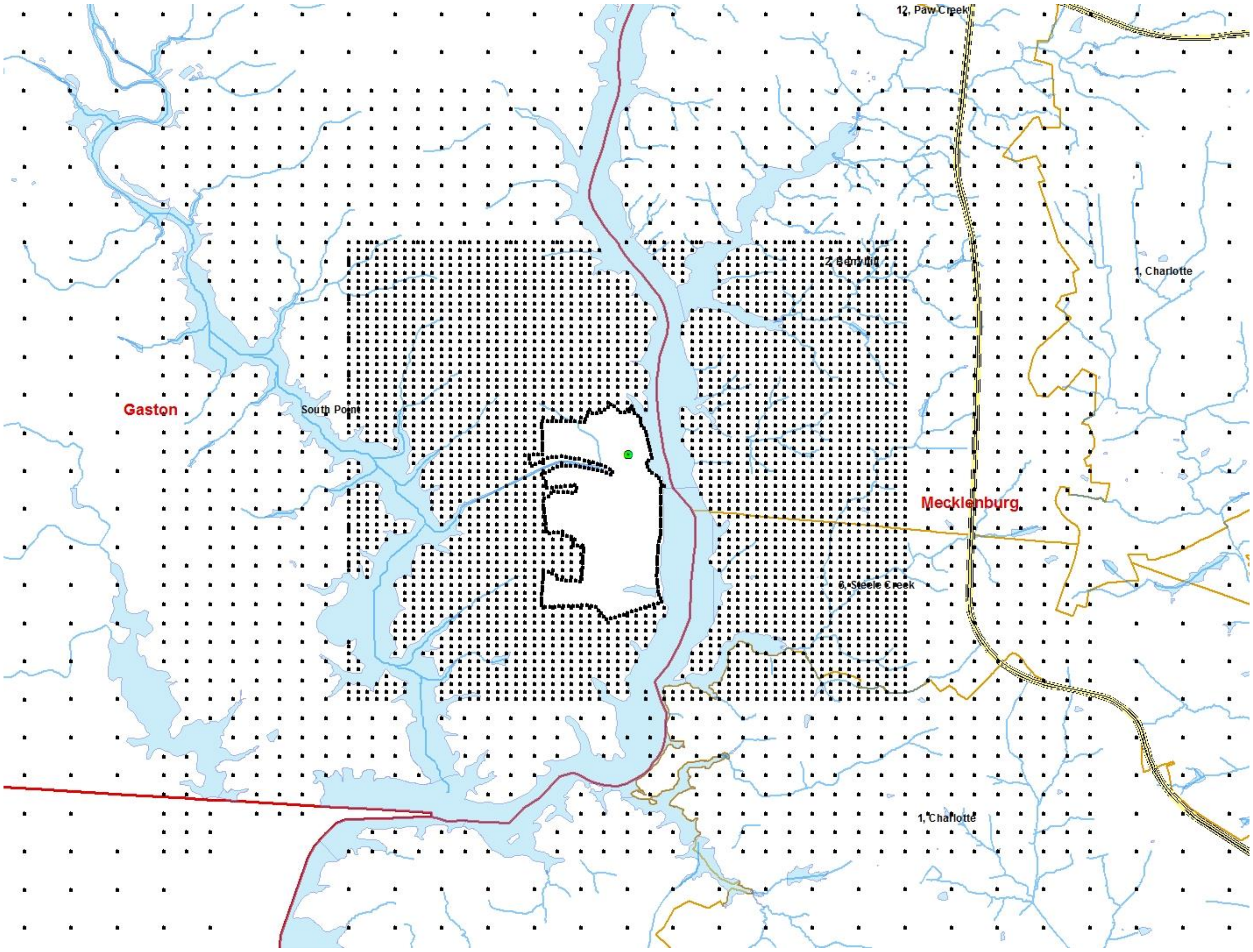

Figure 7. Receptor Grids Extending 5 km Overlaying Counties and Townships.

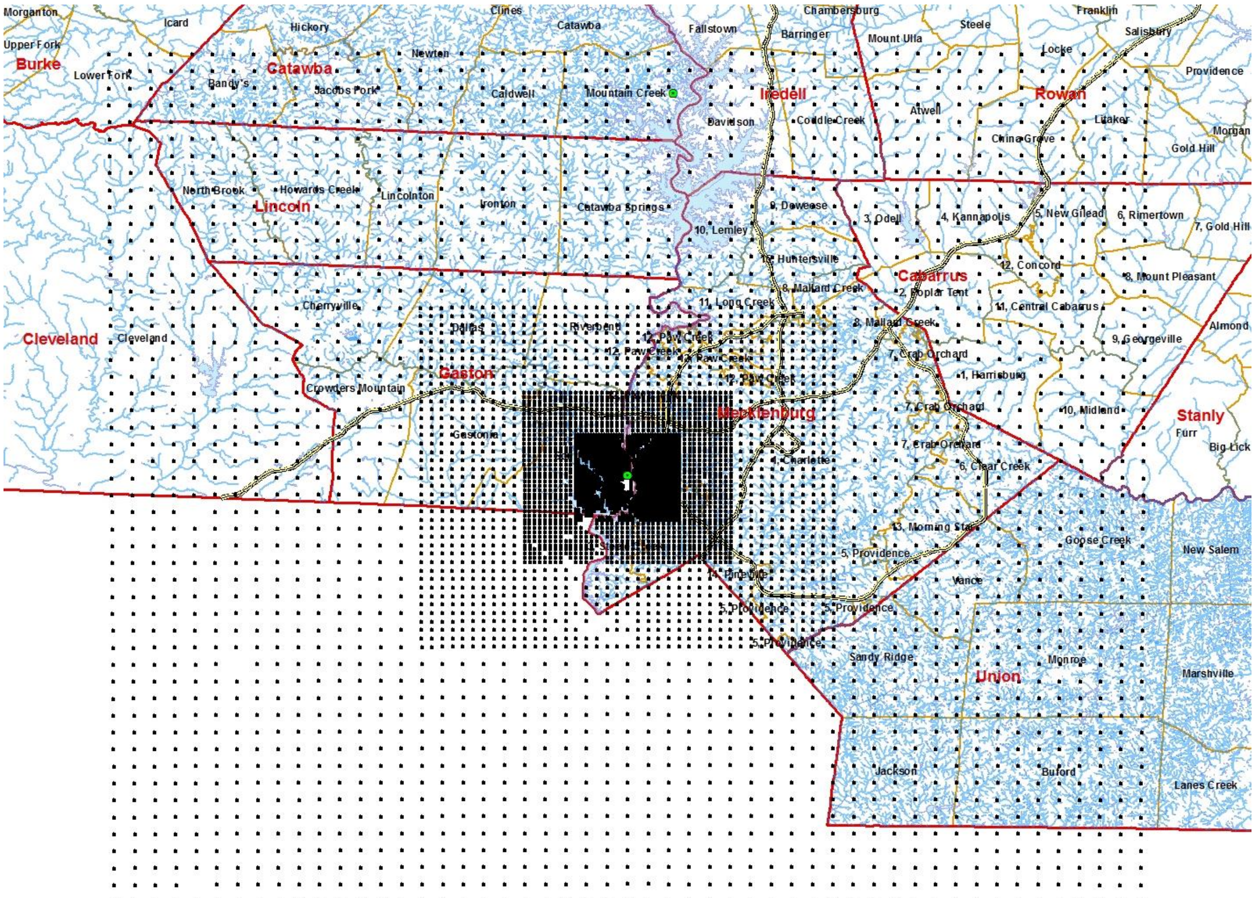

Figure 8. Receptor Grids Extending 50 km Overlaying Counties and Townships

11. Meteorological Data

For the purpose of modeling for attainment designation demonstration, three years of National Weather Service (NWS) data was used. The years used in the analysis were 2013-2015. The NWS surface and upper air observation sites used in the analysis are spatially and climatologically representative of the Allen Station. Representativeness of observation sites was determined based on similarities in surrounding terrain, proximity, climatology, and availability of meteorological data meeting modeling application quality objectives and completeness criteria as specified by U.S. EPA guidance.[6] Thus, surface observation site data from the Charlotte International Airport, located approximately 6 kilometers east of Allen, was selected for application to AERMOD dispersion modeling at the Allen Station. Upper air data from the Greensboro Airport was selected for application to AERMOD dispersion modeling at the Allen Station based on comparable surrounding terrain and similar relative proximity of the Appalachian Mountains to the west and the Atlantic Ocean coast to the east.

AERMET (version 15181) was used to process, quality assure, and merge surface and upper air meteorological data. AERMET pre-processes the surface and upper air data to produce hourly surface and vertical profile meteorological and turbulence parameter inputs to AERMOD for calculation of air pollutant concentrations.

Hourly surface meteorological data collected at the Charlotte International Airport site was obtained from the U.S. National Climatic Data Center (NCDC) for the modeling period 2013-2015 in the standard integrated surface hourly data (ISHD) format, and processed by AERMET.[7] The hourly data was supplemented, as recommended by the U.S. EPA, with TD-6405 format (so-called "1-minute") wind data also from the archives[8] and processed using the latest version of the AERMINUTE pre-processing tool (version 15272).

In addition to surface meteorological data, AERMET requires the use of data from an upper air sounding to estimate mixing heights and other boundary layer turbulence parameters. Upper air data from the nearest U.S. NWS radiosonde equipped station was utilized in the modeling analysis. In this case, upper air data from Greensboro was obtained from the National Oceanic and Atmospheric Administration (NOAA) in Forecast Systems Laboratory (FSL) format and used in the analysis.[9]

[6] U.S. Environmental Protection Agency. 2000. "Meteorological Monitoring Guidance for Regulatory Modeling Applications." EPA-454/R-99-005, February 2000.
[7] ftp://ftp.ncdc.noaa.gov/pub/data/noaa/
[8] ftp://ftp.ncdc.noaa.gov/pub/data/asos-onemin
[9] http://www.esrl.noaa.gov/raobs/

12. Land Use Analysis

AERMET requires land use parameters to derive wind and temperature vertical profiles that directly influence the dispersive capacity of the atmosphere and resultant model concentrations. These land use parameters include surface roughness, Bowen ratio, and albedo. Surface roughness is more important to characterization of mechanical turbulence under stable atmospheric conditions (e.g., calm winds during daytime or nighttime), whereas Bowen ratio and albedo are more important to characterization of convective turbulence under neutral and/or unstable atmospheric conditions (e.g., windy, daytime). In general, AERMOD is formulated to predict higher concentrations under stable atmospheric conditions, and thus, surface roughness is generally the most important of the three land use parameters in terms of determining the highest hourly concentrations.

The methodology outlined in Section 3.1.2 and 3.1.3 of the AERMOD Implementation Guide (AIG)[10] was applied using AERSURFACE (version 13016)[11] to determine surface roughness, Bowen ratio and albedo. AERSURFACE reads digital land cover data obtained from the USGS. USGS land cover data inputs to AERSURFACE were taken from the National Land Cover Dataset 1992 (NLCD92). AERSURFACE converts this data to the surface parameters listed above. These surface parameters are ultimately used by AERMET and AERMOD in calculation of hourly vertical wind and temperature profiles that are needed for calculation of hourly ambient concentrations at each receptor.

AERSURFACE processed NLCD land use data using location coordinates for the NWS surface site, seasonal defaults, 12 flow sectors of 30 degrees each, and airport location characterization. Surface roughness was analyzed for each of the 12 flow sectors within a 1 km radius circular land use area. Albedo and Bowen ratio were analyzed based on a 10 km by 10 km square land use area centered on the surface meteorological station. The surface moisture at the NWS surface site was classified as "wet" based on comparison of the model period (2013-2015) monthly precipitation totals to the statistical distribution of 30-year precipitation data. The surface moisture classification is used to adjust the seasonal Bowen ratios estimated by AERSURFACE.

Some land use surface characteristics found at the selected airport meteorological station are different than those found surrounding the model application site (Allen Steam Station). Land use characteristics at the airport and facility are shown in Figures 9 and 10, respectively. The U.S. EPA recommends that these differences be evaluated to determine representativeness of the surface characteristics and to determine influences of surface characteristics on model

[10] US Environmental Protection Agency. 2015 "AERMOD Implementation Guide" revised August 3,2015. Available online https://www3.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_3August2015.pdf

[11] 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

concentrations.[12] The U.S. EPA further recommends that consideration of surface roughness is most important due to model sensitivities to that particular surface parameter under stable atmospheric conditions. Differences between albedo and Bowen ratio are less significant than surface roughness in terms of influencing the highest hourly model concentrations due to the intrinsic role of albedo and Bowen ratio characterizing dispersion under neutral and/or unstable atmospheric conditions, when hourly model concentrations are expected to be relatively lower.

Differences in surface characteristics at the meteorological observation site and modeling application site were reviewed and compared to evaluate representativeness of the surface characteristics values. Seasonal surface characteristic values calculated by AERSURFACE at the airport and facility for each flow sector are provided in Table 4. As shown, the seasonal albedo and Bowen ratio values are similar, and therefore, are not expected to bias model predictions during unstable and/or neutral atmospheric conditions. Therefore, albedo and Bowen ratio values taken from the airport land use data are representative at the facility.

The overall average surface roughness values at the airport are similar to those estimated by AERSURFACE at the facility. The lower surface roughness values at the airport are expected to influence decreased dispersion and higher model concentrations, based on AERMOD conservative formulations applied under stable atmospheric conditions. Thus, lower surface roughness values at the airport introduce a degree of conservatism to the modeled concentrations predicted under stable atmospheric conditions. Figures 11 and 12 show surface roughness values at the airport and facility, respectively, during summertime when differences in surface roughness are greatest. The largest differences in surface roughness at the airport compared to the facility occur in the northeastern quadrant where there is notable disparity in the spatial distribution of land and water. However, prevailing winds in the area are primarily observed from the south and southwest where surface roughness at the airport and facility are very similar. Model design concentrations and upper distribution of predicted concentrations were found to coincide with prevailing wind directions where dispersion calculations rely on upwind surface roughness values derived from the south and southwestern flow sectors. As such, airport surface roughness values were determined to be representative at the facility owing to the similar influence of prevailing upwind surface roughness values on model design concentrations occurring predominantly downwind of the facility.

[12] https://www3.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_3August2015.pdf, Section 3.1.

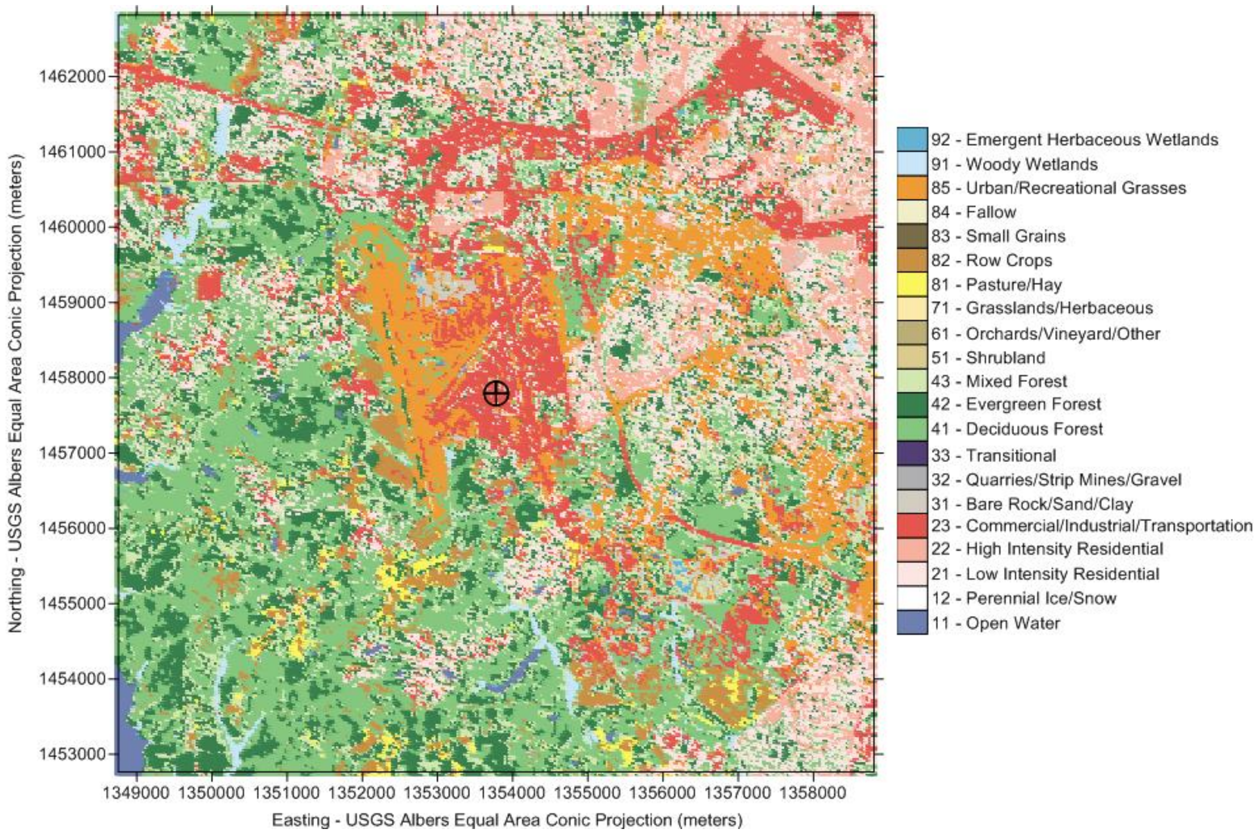

Figure 9. Charlotte International Airport Land Use (10km x 10km Area)

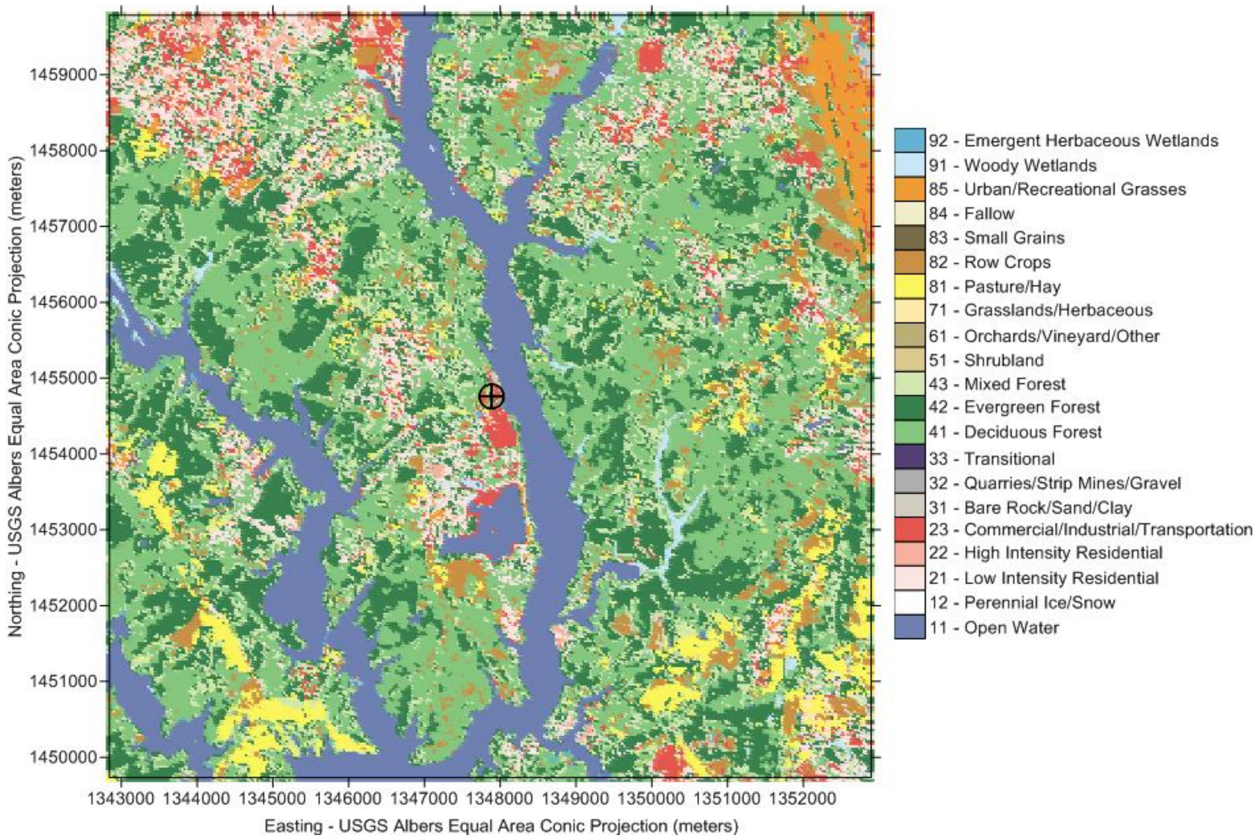

Figure 10. Duke-Allen Land Use (10km x 10km Area)

Table 4. Surface Characteristics Comparison and Evaluation

Season	Flow Sector	Charlotte Intl. Airport			Allen Steam Station		
		Albedo	Bowen Ratio	Surface Roughness (m)	Albedo	Bowen Ratio	Surface Roughness (m)
Winter	(0 - 30)	0.16	0.46	0.345	0.15	0.33	0.031
Winter	(30 - 60)	0.16	0.46	0.356	0.15	0.33	0.013
Winter	(60 - 90)	0.16	0.46	0.459	0.15	0.33	0.041
Winter	(90 - 120)	0.16	0.46	0.396	0.15	0.33	0.031
Winter	(120 - 150)	0.16	0.46	0.371	0.15	0.33	0.011
Winter	(150 - 180)	0.16	0.46	0.250	0.15	0.33	0.335
Winter	(180 - 210)	0.16	0.46	0.485	0.15	0.33	0.396
Winter	(210 - 240)	0.16	0.46	0.300	0.15	0.33	0.242
Winter	(240 - 270)	0.16	0.46	0.186	0.15	0.33	0.447
Winter	(270 - 300)	0.16	0.46	0.159	0.15	0.33	0.483
Winter	(300 - 330)	0.16	0.46	0.112	0.15	0.33	0.575
Winter	(330 - 360)	0.16	0.46	0.145	0.15	0.33	0.539
Spring	(0 - 30)	0.15	0.38	0.377	0.14	0.27	0.034
Spring	(30 - 60)	0.15	0.38	0.376	0.14	0.27	0.014
Spring	(60 - 90)	0.15	0.38	0.482	0.14	0.27	0.047
Spring	(90 - 120)	0.15	0.38	0.458	0.14	0.27	0.035
Spring	(120 - 150)	0.15	0.38	0.408	0.14	0.27	0.012
Spring	(150 - 180)	0.15	0.38	0.287	0.14	0.27	0.382
Spring	(180 - 210)	0.15	0.38	0.540	0.14	0.27	0.490
Spring	(210 - 240)	0.15	0.38	0.336	0.14	0.27	0.313
Spring	(240 - 270)	0.15	0.38	0.211	0.14	0.27	0.563
Spring	(270 - 300)	0.15	0.38	0.187	0.14	0.27	0.636
Spring	(300 - 330)	0.15	0.38	0.135	0.14	0.27	0.752
Spring	(330 - 360)	0.15	0.38	0.171	0.14	0.27	0.759
Summer	(0 - 30)	0.16	0.34	0.394	0.14	0.22	0.036
Summer	(30 - 60)	0.16	0.34	0.386	0.14	0.22	0.014
Summer	(60 - 90)	0.16	0.34	0.492	0.14	0.22	0.051
Summer	(90 - 120)	0.16	0.34	0.490	0.14	0.22	0.039
Summer	(120 - 150)	0.16	0.34	0.426	0.14	0.22	0.012
Summer	(150 - 180)	0.16	0.34	0.308	0.14	0.22	0.425
Summer	(180 - 210)	0.16	0.34	0.589	0.14	0.22	0.568
Summer	(210 - 240)	0.16	0.34	0.360	0.14	0.22	0.475
Summer	(240 - 270)	0.16	0.34	0.231	0.14	0.22	0.824
Summer	(270 - 300)	0.16	0.34	0.207	0.14	0.22	0.919
Summer	(300 - 330)	0.16	0.34	0.153	0.14	0.22	0.948
Summer	(330 - 360)	0.16	0.34	0.190	0.14	0.22	1.008

Fall	(0 - 30)	0.16	0.46	0.380	0.14	0.33	0.036
Fall	(30 - 60)	0.16	0.46	0.377	0.14	0.33	0.014
Fall	(60 - 90)	0.16	0.46	0.484	0.14	0.33	0.051
Fall	(90 - 120)	0.16	0.46	0.474	0.14	0.33	0.039
Fall	(120 - 150)	0.16	0.46	0.411	0.14	0.33	0.012
Fall	(150 - 180)	0.16	0.46	0.291	0.14	0.33	0.425
Fall	(180 - 210)	0.16	0.46	0.581	0.14	0.33	0.563
Fall	(210 - 240)	0.16	0.46	0.342	0.14	0.33	0.473
Fall	(240 - 270)	0.16	0.46	0.212	0.14	0.33	0.824
Fall	(270 - 300)	0.16	0.46	0.190	0.14	0.33	0.919
Fall	(300 - 330)	0.16	0.46	0.137	0.14	0.33	0.946
Fall	(330 - 360)	0.16	0.46	0.173	0.14	0.33	1.008
Average:		**0.16**	**0.41**	**0.329**	**0.14**	**0.29**	**0.371**

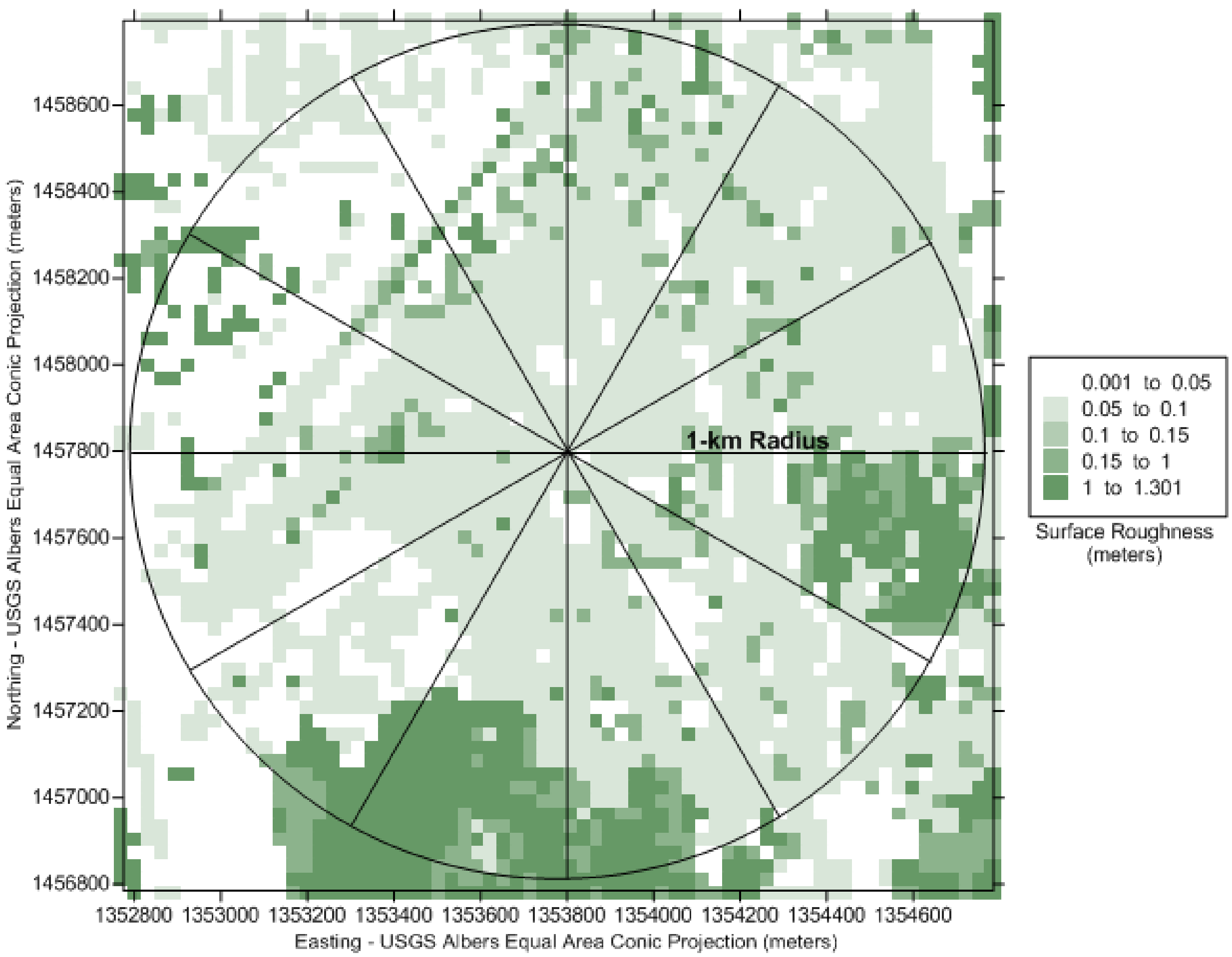

Figure 11. Charlotte International Airport Summertime Surface Roughness Analysis Area (12 Sectors, 1km-Radius)

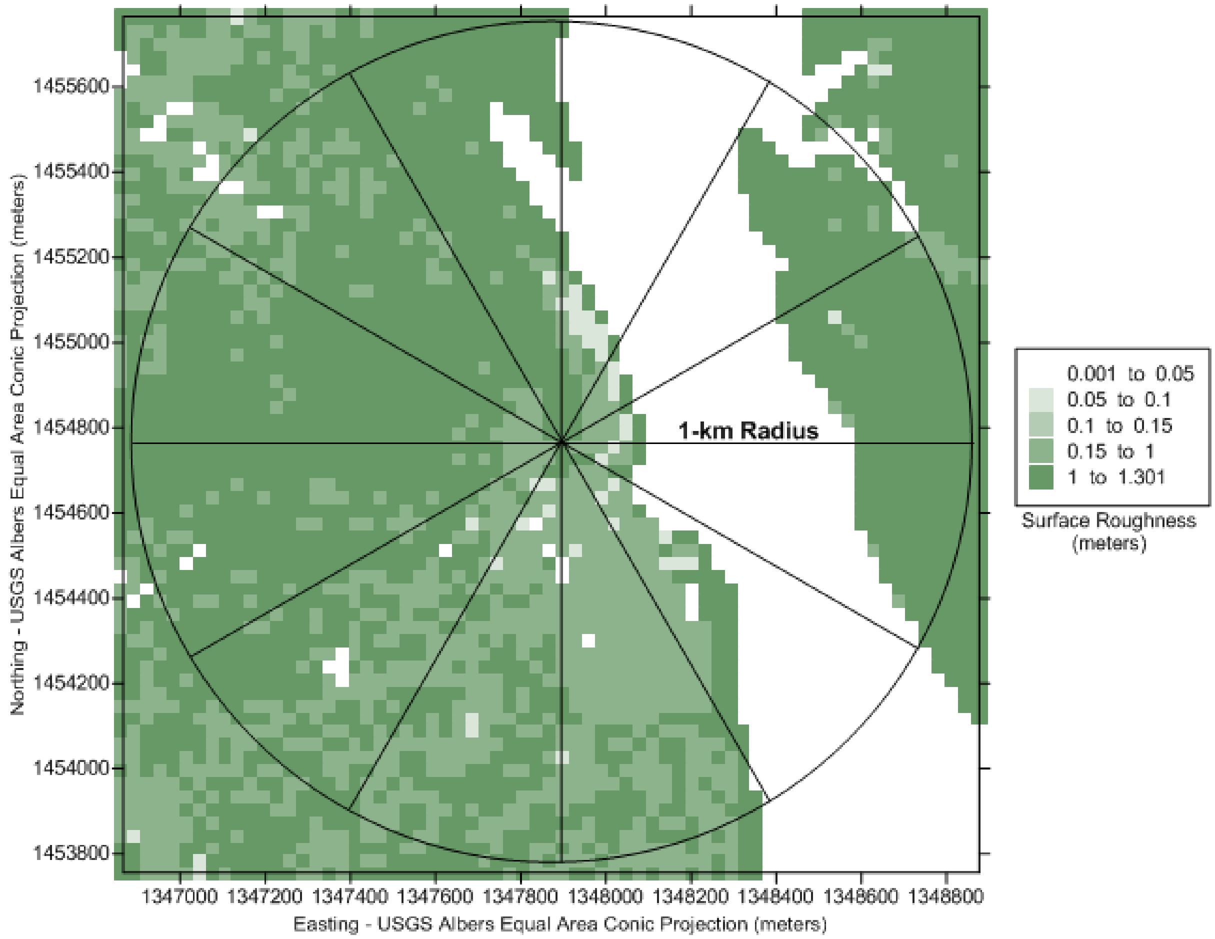

Figure 12. Duke-Allen Summertime Surface Roughness Analysis Area (12 Sectors, 1km-Radius)

13. Model Results

The model output was configured to generate 1-hour SO_2 concentration design values consistent with the 1-hour SO_2 NAAQS. As such, the model used the annual 99th percentile daily max 1-hour SO_2 values averaged over the 2013-2015 period at each receptor to determine the design concentration values needed for comparison to the 1-hour SO_2 NAAQS.

The maximum 1-hour SO_2 design concentration for Duke-Allen emissions alone was modeled at 103.4 μg/m^3. The nearby source Duke-Marshall contributes 0.2 μg/m^3 to the max design concentration resulting in a total max 1-hour SO_2 design concentration of 103.6 μg/m^3. Figure 13 shows the max design concentration occurs 1 km northeast of the Duke-Allen combined stack location. Figure 14 shows 1-hour SO_2 design concentrations for the entire modeling domain. As shown, max 1-hour SO_2 design concentrations are well below the 1-hour SO_2 NAAQS of 196 μg/m^3. For example, design concentrations throughout the majority of the modeling domain were modeled at less than 60 μg/m^3. Modeled impacts above 60 μg/m^3 extend roughly 8 km from the facility. Modeled impacts from Duke-Marshall were noted on the northern reaches of the modeling domain, however, those impacts were modeled at less than 90 μg/m^3. Note the entire modeling domain extends 50 km from the Duke-Allen facility in all directions.

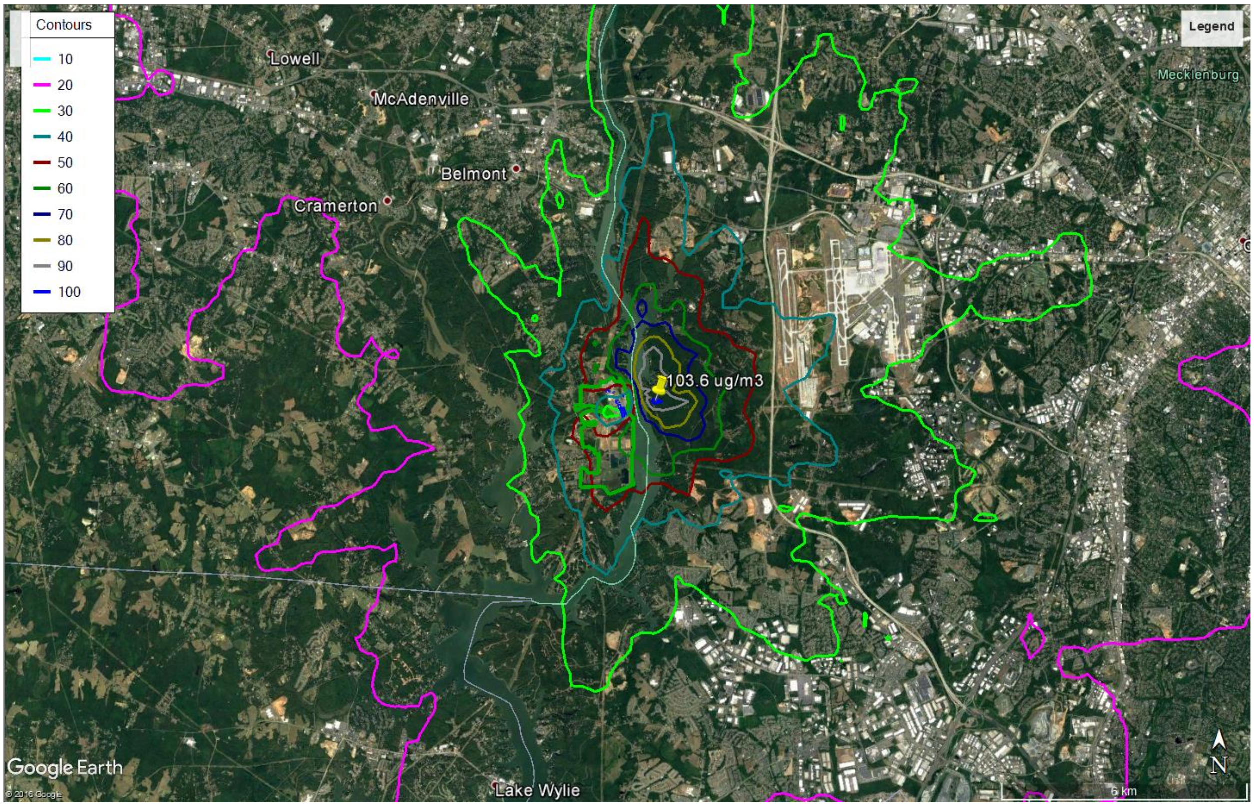

Figure 13. Close-up View of 3-Year Average, Annual 98th Percentile Daily Max 1-Hour SO_2 Concentration - Duke-Allen and Nearby Sources

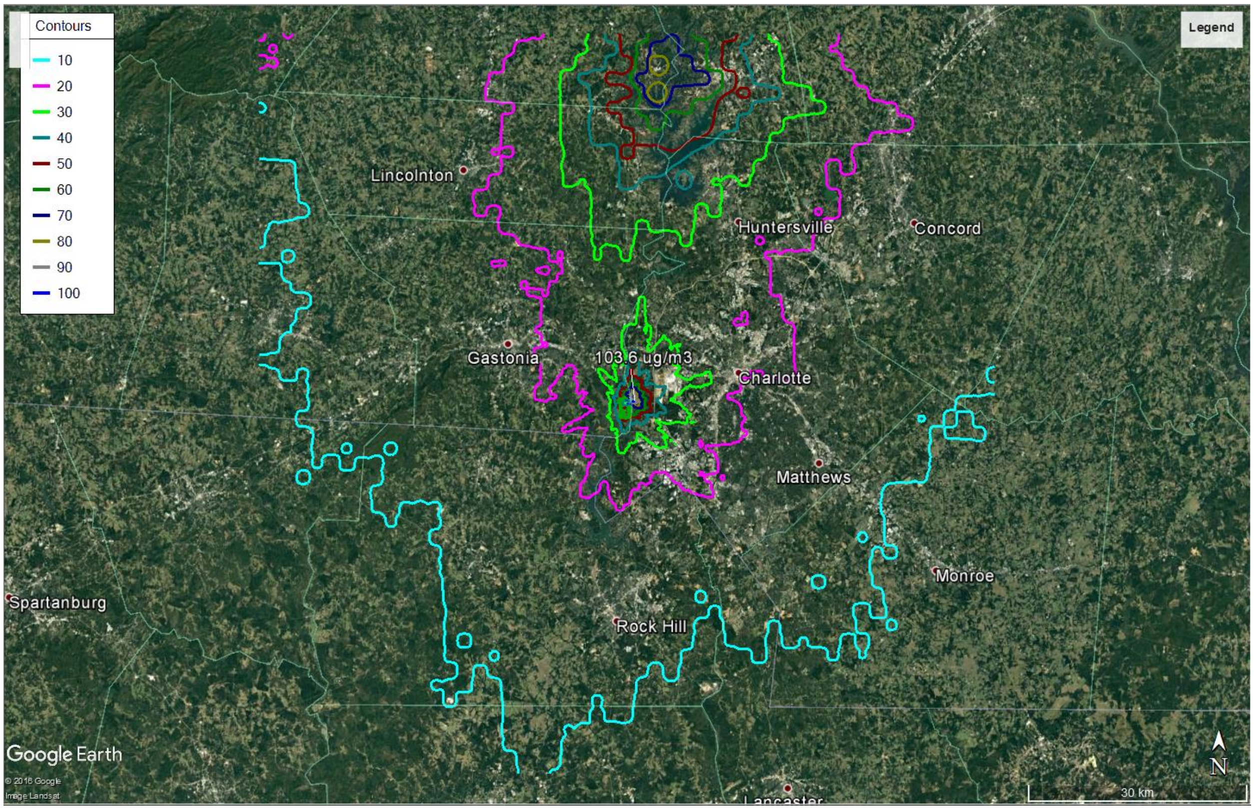

Figure 14. Full Modeling Domain View of 3-Year Average, Annual 98th Percentile Daily Max 1-Hour SO_2 Concentration - Duke-Allen and Nearby Sources

14. Background Concentrations

Background concentrations in the model results are important in determining the impacts from sources of SO_2 which are not explicitly included in the model. Background concentrations were evaluated using the EPA's March 1, 2011 memo, "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 Ambient Air Quality Standard." Table 5 summarizes the available SO_2 monitoring locations surrounding Allen with their 2013-2015 design values. The Charlotte, NC monitor was selected to represent Allen since it is the closest, and therefore, most representative. The 2013-2015 1-hour SO_2 design value for the Charlotte monitor is 18 µg/m^3 (7 ppb).

Table 5. Monitor Data Surrounding Duke-Allen for the 1-hour SO_2 NAAQS

Monitor Location	Distance from Allen (Kilometers)	ID	2013-2015 Design Value $\mu g/m^3$ (ppb)
Charlotte, NC	21	37-119-0041	18 (7)
Winston-Salem, NC	123	37-067-0022	23 (9)
Dentsville, SC	129	45-079-0007	26 (10)
Seven Oaks, SC	136	45-063-0008	99 (38)
Greenville, SC	139	45-045-0015	10 (4)
Seneca, SC	167	45-073-0001	8 (3)

15. Comparison to Standard

The background concentration was added to the model design value and the resulting values were compared to the SO_2 NAAQS of 196 $\mu g/m^3$. Table 6 shows that the sum of the background concentration and max modeled design value is 122 $\mu g/m^3$. Therefore, the total combined impacts as estimated from summation of background concentration, modeled nearby sources, and modeled Duke-Allen sources are less than the 1-hour SO_2 NAAQS. Furthermore, this modeling analysis demonstrates attainment of the 1-hour SO_2 NAAQS within the context of the Duke-Allen 1-hour SO_2 impacts to the area of interest surrounding the facility.

Table 6. Comparison of Duke-Allen Results to the NAAQS

Years Modeled	Max Modeled Design Value ($\mu g/m^3$)	Background Concentration ($\mu g/m^3$)	Background + Modeled ($\mu g/m^3$)	1-hr SO_2 NAAQS ($\mu g/m^3$)	% NAAQS	NAAQS Exceeded?
2013-2015	104	18	122	196	62%	No

The NCDAQ will provide EPA with input/out files necessary to validate the results of the modeling analysis.