# GALLATIN FOSSIL PLANT

# MODELING RESULTS
# 1-HOUR $SO_2$ NAAQS DESIGNATION

**GALLATIN, TENNESSEE**
**JUNE 2016**

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## 1.0 PURPOSE AND BACKGROUND

The purpose of this document is to present the dispersion modeling results that were performed in support of assessing compliance with the 1-hour $SO_2$ NAAQS for designation purposes. The primary objective of the modeling analysis was to demonstrate that future allowable $SO_2$ emissions from TVA Gallatin Fossil Plant (GAF) will not cause or contribute to a violation of the 1-hour $SO_2$ NAAQS. This analysis is being performed to characterize the designation status of Sumner County, Tennessee, and surrounding areas.

## 2.0 SOURCE DESCRIPTION

GAF is located on the north bank of the Cumberland River, about five (5) miles south of Gallatin, Tennessee (Figure 1). The facility currently operates four (4) coal-fired boilers and eight (8) simple-cycle combustion turbines.

The simple-cycle combustion turbines combust either natural gas or ultra-low sulfur (15 parts per million by weight) fuel oil and are only utilized during periods of peak power demand when sufficient system generation is not available. Electrical generation output from the combustion turbines is limited while burning fuel oil.

To satisfy requirements of a Federal Facilities Compliance Agreement/Consent Decree (June 13, 2011) and the Mercury and Air Toxics Standards (MATS), TVA installed dry flue gas desulfurization (FGD) systems to control $SO_2$ emissions and acid gases on all four (4) coal-fired boilers. The dry FGD systems were in service by February 2016.

## 3.0 MODELING ANALYSIS

To determine maximum impacts of future allowable emissions from GAF on 1-hour ambient $SO_2$ concentrations in Sumner County, Tennessee, and surrounding areas, the modeling analysis focused on the contributions of $SO_2$ from the four (4) GAF coal-fired boilers (GAF01-04) and the eight (8) dual-fueled simple cycle combustion turbines (CT 1-8). Because the CTs rarely operate while firing oil, they were not expected to contribute to modeled impacts, but they were included at TDEC's request. There were no nearby sources that were expected to cause a significant concentration gradient in the vicinity of GAF. The results of this modeling analysis show that future allowable emissions at GAF will not contribute to a violation of the 1-hour $SO_2$ NAAQS.

### 3.1 EMISSIONS

Future-allowable emissions from GAF01-04 were modeled based on discussions of emissions and stack-parameter scenarios with the Tennessee Department of Environment and Conservation and the U.S. Environmental Protection Agency. Allowable emissions for GAF01-04 were assigned in two ways:

- Scenario 1 – allocated emissions based on the weighted average of each boiler's rated heat input capacity;
- Scenario 2 – assumed the current maximum allowable emissions[1] for GAF01 and GAF02 with the remainder of the coal-fired boiler emissions allocated to GAF03 and GAF04.

[1] GAF01 and GAF02 maximum emissions are the hourly emissions equivalent to the 0.20 pound per million Btu, 30-day rolling average MATS $SO_2$ limit.

Scenario 1 modeled all four coal-fired boilers at the following operating loads: 100 percent, 75 percent, and 50 percent; whereas, Scenario 2 modeled GAF03 and GAF04 at 100 percent, 75 percent, and 50 percent load, while GAF01 and GAF02 remained at 100 percent load (see Table 1).

**Table 1**
**GAF01-04 Future-Allowable Modeled Emissions [1]**

| Emission | Load (%) | | Emissions (g/s) | | |
|---|---|---|---|---|---|
| **Scenario** | **GAF01-02** | **GAF03-04** | **GAF01-02** | **GAF03-04** | **Plant Total** |
| Scenario 1 | 100 | 100 | 160.94 | 177.56 | 338.50 |
| | 75 | 75 | 141.23 | 155.72 | 296.95 |
| | 50 | 50 | 94.16 | 103.81 | 197.97 |
| Scenario 2 | 100 | 100 | 188.30 | 149.00 | 337.30 |
| | 100 | 75 | 188.30 | 149.00 | 337.30 |
| | 100 | 50 | 188.30 | 103.80 | 292.10 |

Notes:
1. Emissions exhaust to the atmosphere via one stack with four steel liners. Each liner is associated with one existing boiler. Because GAF01 and GAF02 are identical boilers and GAF03 and GAF04 are identical boilers, the four flues were modeled as two flues (GAF01-02 and GAF03-04).

Load-dependent stack parameters (velocity and temperature) corresponding to the two emission scenarios are provided in Table 2. Stack-exit velocity and stack-exit temperature for 100 percent load are design values. For 75 percent and 50 percent load, stack-exit velocity and stack-exit temperature are CEMS-based averages[2]. The CEMS data are included on the attached optical disc.

**Table 2**
**GAF01-04 Load-Dependent Stack Parameters [1]**

| Load | Stack-Exit Velocity (m/s) | | Stack-Exit Temp. (K) | |
|---|---|---|---|---|
| **(%)** | **GAF01-02** | **GAF03-04** | **GAF01-02** | **GAF03-04** |
| 100 [2] | 17.5 | 19.0 | 355 | 354 |
| 75 [3] | 15.8 | 15.2 | 392 | 376 |
| 50 [3] | 10.9 | 11.0 | 392 | 379 |

Notes:
1. One stack with four steel liners. Each liner is associated with one boiler. Stack parameters for GAF01and GAF02 are identical, and stack parameters for GAF03 and GAF04 are identical. Therefore, the four flues were modeled as two flues (GAF01-02 and GAF03-04).
2. Manufacture's design values.
3. Average of the CEMS data, while operating at these loads, since each boiler's dry-FGD system was placed in-service.

Static stack parameters (location, diameter, etc.) are provided in Table 3.

2 FGD-installed CEMS data were available for GAF01 from December 10, 2015 to March 28, 2016; GAF02 from February 7, 2016 to March 28, 2016; GAF03 from August 1, 2015 to March 16, 2016; and GAF04 from July 1, 2015 to March 23, 2016.

**Table 3**
**GAF01-04 Static Stack Parameters [1]**

| Stack Parameter | Units | GAF01-02 | GAF03-04 |
|---|---|---|---|
| UTM Zone 16 Easting (NAD83) | m | 553580 | 553580 |
| UTM Zone 16 Northing (NAD83) | m | 4019223 | 4019223 |
| Base Elevation | m | 145.1 | 145.1 |
| GEP Stack Height | m | 90.1 | 90.1 |
| Liner Inside Diameter (One Liner / Boiler) | m | 5.69 | 5.69 |

Notes:
1. One stack with four steel liners. Each liner is associated with one existing boiler. Stack parameters for GAF01and GAF02 are identical, and stack parameters for GAF03 and GAF04 are identical. Therefore, the four flues were modeled as two flues (GAF01-02 and GAF03-04).

Potential emissions associated with oil-fired CT operations are included in the modeling (Table 4). Stack parameters for these sources are provided in Tables 5 and 6. The conservative estimates for these sources in conjunction with the allowable $SO_2$ emissions from GAF01-04 will ensure that Sumner County and surrounding areas will attain the 1-hour $SO_2$ NAAQS standard.

**Table 4**
**GAF CT Potential $SO_2$ Emission Estimates**

| Emission Parameter | Units | CT 1-4 | CT 5-8 |
|---|---|---|---|
| Rated (Title V) Heat-Input Capacity [1] | $10^6$ Btu/CT-hr | 1194 | 1263 |
| $SO_2$ Emission Factor [2,3] | lb/$10^6$ Btu | $1.44\times10^{-3}$ | $1.44\times10^{-3}$ |
| Maximum $SO_2$ Emission Rate | lb/CT-hr | 1.72 | 1.82 |
| | g/CT-s | 0.22 | 0.23 |

Notes:
1. For CT 1-8, capacity represents peak-load oil-firing at 0°F. Source for all heat-input capacities: Revisions to July 1996 Title V Permit Application, GAF, Gallatin, Tennessee, May 2001.
2. CT 1-8 emission factor from EPA's AP-42, 5$^{th}$ Ed., Vol. I, Chapter 3.1 – Stationary Gas Turbines – Supplement F, April 2000 reflecting 15 parts per million (ppm) fuel-oil sulfur content and adjusting for five (5) percent formation of $SO_3$.

**Table 5**
**GAF CT 1-4 Stack Parameters [1]**

| Stack Parameter | Units | CT 1 | CT 2 | CT 3 | CT 4 |
|---|---|---|---|---|---|
| UTM Zone 16 Easting (NAD83) | m | 554181 | 554200 | 554260 | 554280 |
| UTM Zone 16 Northing (NAD83) | m | 4019164 | 4019188 | 4019263 | 4019287 |
| Base Elevation | m | 145.1 | 145.1 | 145.1 | 145.1 |
| Stack Height | m | 12 | 12 | 12 | 12 |
| Stack Diameter [2] | m | 5.5 | 5.5 | 5.5 | 5.5 |
| Stack-Exit Velocity | m/s | 37.7 | 37.7 | 37.7 | 37.7 |
| Stack-Exit Temperature | K | 785 | 785 | 785 | 785 |

Notes:
1. Revisions to July 1996 Title V Permit Application, GAF, Gallatin, Tennessee, May 2001.
2. Equivalent diameter; stack-exit is rectangular.

**Table 6**
**GAF CT 5-8 Stack Parameters [1]**

| Stack Parameter | Units | CT 5 | CT 6 | CT 7 | CT 8 |
|---|---|---|---|---|---|
| UTM Zone 16 Easting (NAD83) | m | 554312 | 554333 | 554354 | 554375 |
| UTM Zone 16 Northing (NAD83) | m | 4019367 | 4019393 | 4019420 | 4019447 |
| Base Elevation | m | 145.1 | 145.1 | 145.1 | 145.1 |
| Stack Height | m | 17.1 | 17.1 | 17.1 | 17.1 |
| Stack Diameter [2] | m | 4.3 | 4.3 | 4.3 | 4.3 |
| Stack-Exit Velocity | m/s | 45.1 | 45.1 | 45.1 | 45.1 |
| Stack-Exit Temperature | K | 810 | 810 | 810 | 810 |

Notes:
1. Revisions to July 1996 Title V Permit Application, GAF, Gallatin, Tennessee, May 2001.
2. Equivalent diameter; stack-exit is rectangular.

## 3.2 DOWNWASH

For the modeling analysis, Good Engineering Practice (GEP) stack height was used because potential emissions were modeled (USEPA, 2016). A GEP stack height analysis was conducted for the stacks and nearby structures using the USEPA's Building Profile Input Program for PRIME, BPIPPRM, Dated 04274 (USEPA, 2004d). According to the GEP technical support document, a structure is considered nearby if it is within 5L of the emissions source, where L is the lesser dimension (height or projected width) of the nearby structure (USEPA, 1985). The nearby major structures within the GAF boundary are:

- Baghouse buildings;
- Ductwork;
- Air compressor buildings;
- Activated carbon equipment.

The potential for building downwash effects was accounted for in the modeling. The direction-specific effective building widths and heights required by AERMOD were also calculated using BPIPPRM. The BPIPPRM input stack and building parameters for GAF01 through GAF04 are provided in Table 7 and building locations are shown in Figure 2. The BPIPPRM input stack and building parameters for CT 1 through CT 8 are provided in Table 8 and building locations are shown in Figure 3. The results from BPIPPRM showed that the baghouse (fabric filter) building (NID2) is the influencing structure affecting dispersion and plume rise from the FGD stack. An overall GEP summary table for the coal-fired boilers and CTs is provided in Table 9.

**Table 7**
**BPIPPRM Input Structures for GAF01-04**

| Building | BPIPPRM ID | Height (ft) | Height (m) |
|---|---|---|---|
| NID Fabric Filters | NID1 | 118.25 | 36.04 |
| NID Fabric Filters | NID2 | 118.25 | 36.04 |
| NID Fabric Filters | NID3 | 118.25 | 36.04 |
| NID Fabric Filters | NID4 | 118.25 | 36.04 |
| ID Fan and Ductwork | IDFANDCT5 | 52.00 | 15.85 |
| (Continued on Next Page) | | | |

**Table 7 (Continued)**
**BPIPPRM Input Structures for GAF01-04**

| Building | BPIPPRM ID | Height (ft) | Height (m) |
|---|---|---|---|
| ID Fan and Ductwork | IDFANDCT6 | 52.00 | 15.85 |
| ID Fan and Ductwork | IDFANDCT7 | 52.00 | 15.85 |
| ID Fan and Ductwork | IDFANDCT8 | 52.00 | 15.85 |
| Electrical Power Distribution Centers | EPDC9 | 23.00 | 7.01 |
| Electrical Power Distribution Centers | EPDC10 | 23.00 | 7.01 |
| Electrical Power Distribution Centers | EPDC11 | 23.00 | 7.01 |
| Electrical Power Distribution Centers | EPDC12 | 23.00 | 7.01 |
| Air Compressor Buildings | ACBLDG13 | 17.75 | 5.41 |
| Air Compressor Buildings | ACBLDG14 | 17.75 | 5.41 |
| Activated Carbon Injection Skids | ActCrbIS15 | 40.50 | 12.34 |
| Activated Carbon Injection Skids | ActCrbIS16 | 40.50 | 12.34 |
| GAF01-04 dry-FGD Stack | FGDSTK | 400.0 | 121.9 |

**Table 8**
**BPIPPRM Input Structures for CT 1-8**

| Building | BPIPPRM ID | Height (ft) | Height (m) |
|---|---|---|---|
| CT8 Air Intake | CT8-1 | 45.00 | 13.72 |
| CT8 Air Inlet Duct | CT8-2 | 32.00 | 9.75 |
| CT8 Exhaust Duct | CT8-3 | 20.00 | 6.10 |
| CT7 Air Intake | CT7-4 | 45.00 | 13.72 |
| CT7 Air Inlet Duct | CT7-5 | 32.00 | 9.75 |
| CT7 Exhaust Duct | CT7-6 | 20.00 | 6.10 |
| CT6 Air Intake | CT6-7 | 45.00 | 13.72 |
| CT6 Air Inlet Duct | CT6-8 | 32.00 | 9.75 |
| CT6 Exhaust Duct | CT6-9 | 20.00 | 6.10 |
| CT5 Air Intake | CT5-10 | 45.00 | 13.72 |
| CT5 Air Inlet Duct | CT5-11 | 32.00 | 9.75 |
| CT5 Exhaust Duct | CT5-12 | 20.00 | 6.10 |
| CT4 Air Inlet A | CT4-13 | 26.00 | 7.92 |
| CT4 Generator & Turbine Housing | CT4-14 | 20.00 | 6.10 |
| CT4 Air Inlet B | CT4-15 | 26.00 | 7.92 |
| CT4 Aux/Electrical/Control Building | CT4-16 | 22.00 | 6.71 |
| CT4 Air Cooler | CT4-17 | 15.00 | 4.57 |
| CT3 Air Inlet A | CT3-18 | 26.00 | 7.92 |
| CT3 Generator & Turbine Housing | CT3-19 | 20.00 | 6.10 |
| CT3 Air Inlet B | CT3-20 | 26.00 | 7.92 |
| CT3 Aux/Electrical/Control Building | CT3-21 | 22.00 | 6.71 |
| (Continued on Next Page) | | | |

**Table 8 (Continued)**
**BPIPPRM Input Structures for CT 1-8**

| Building | BPIPPRM ID | Height (ft) | Height (m) |
|---|---|---|---|
| CT3 Air Cooler | CT3-22 | 15.00 | 4.57 |
| CT2 Air Inlet A | CT2-23 | 26.00 | 7.92 |
| CT2 Generator & Turbine Housing | CT2-24 | 20.00 | 6.10 |
| CT2 Air Inlet B | CT2-25 | 26.00 | 7.92 |
| CT2 Aux/Electrical/Control Building | CT2-26 | 22.00 | 6.71 |
| CT2 Air Cooler | CT2-27 | 15.00 | 4.57 |
| CT1 Air Inlet A | CT1-28 | 26.00 | 7.92 |
| CT1 Generator & Turbine Housing | CT1-29 | 20.00 | 6.10 |
| CT1 Air Inlet B | CT1-30 | 26.00 | 7.92 |
| CT1 Aux/Electrical/Control Building | CT1-31 | 22.00 | 6.71 |
| CT1 Air Cooler | CT1-32 | 15.00 | 4.57 |

**Table 9**
**GEP Stack Height Results for GAF01-04 and CT 1-8**

| Stack | Actual Stack Height (m) | GEP Stack Height (m) | GEP Building Height (m) | GEP Projected Building Width (m) | GEP Equation Height (m) |
|---|---|---|---|---|---|
| FGDSTK | 121.9 | 90.11 | 36.04 | 36.06 | 90.11 |
| CT 1 | 12.04 | 65.00 | 6.71 | 6.97 | 16.76 |
| CT 2 | 12.04 | 65.00 | 6.71 | 6.75 | 16.76 |
| CT 3 | 12.04 | 65.00 | 6.71 | 7.47 | 16.76 |
| CT 4 | 12.04 | 65.00 | 6.71 | 7.12 | 16.76 |
| CT 5 | 17.07 | 65.00 | 13.72 | 12.72 | 32.79 |
| CT 6 | 17.07 | 65.00 | 13.72 | 12.66 | 32.70 |
| CT 7 | 17.07 | 65.00 | 13.72 | 12.66 | 32.70 |
| CT 8 | 17.07 | 65.00 | 13.72 | 12.66 | 32.70 |

The resulting building heights, widths, lengths, as well as along-flow and across-flow distances calculated by BPIPPRM were included in the AERMOD modeling to account for the building downwash effects for all sources. The BPIPPRM modeling input and output files are included on the enclosed optical disc.

### 3.3 MODEL SELECTION

For area designations under the 1-hour $SO_2$ primary NAAQS, the American Meteorological Society / Environmental Protection Agency Regulatory Model (AERMOD) should be used unless use of an alternative model can be justified (USEPA, 2005). Air quality dispersion modeling was performed using AERMOD (Version 15181) to obtain estimates of maximum ambient impacts (USEPA, 2004a; USEPA, 2015b). The options used within the model were the recommended default regulatory options, which included the following:

- Appropriate treatment of calms and use of missing meteorological data routines;
- Inclusion of actual receptor elevations;
- Incorporation of complex / intermediate terrain algorithms;
- Calculations of stack tip downwash and direction-specific building downwash.

According to the $SO_2$ TAD, the "urban" or "rural" determination of a source is important in determining the boundary layer characteristics that affect AERMOD's prediction of downwind concentrations as well as the possible invocation of the 4-hour half-life for urban $SO_2$ sources (USEPA, 2016). In order to determine the rural / urban characterization of a modeling study area and the dispersion coefficients to use in AERMOD, a land use analysis is required (USEPA, 2005). The USEPA guidance recommends the use of the Auer land use scheme within three (3) kilometers of a source to classify the predominant dispersion regime (USEPA, 2005). If the percentage of land use types that are characteristic of heavy industrial, light-moderate industrial, commercial, or compact residential account for 50 percent or more within the three kilometers, the modeling area is classified as urban, and the urban dispersion options in AERMOD should be used. Otherwise, the area is classified and modeled as rural.

The Auer method was used to determine the land use status of the area around GAF. A three-kilometer radius was centered on the GAF stack, and the land use was categorized based on the Auer classifications (Auer, 1978). The data source for the land cover was the 2011 National Land Cover Database (NLCD), with a data cell size (raster) of 30 meters by 30 meters. The results of the Auer land use analysis for the GAF study area are presented in Figure 4 and Table 10. The analysis indicates that the GAF study area is approximately 98.5% rural and 1.5% urban. Therefore, the rural option was used in AERMOD.

**Table 10**
**Auer Land Use Percentages by Category: GAF Study Area**

| $SO_2$ Modeling Auer's Analysis - NLCD 2011 | | | | Gallatin - 3 km Ring | | |
|---|---|---|---|---|---|---|
| **NLCD Value** | **NLCD 2011 Descriptions** | **Auer's Code** | **Auer's Class** | **Area (Sq. Meters)** | **Pecentage** | **Totals** |
| 23 | Developed, Medium Intensity | R2/R3 | *Urban | 233,619.54 | 0.83% | 1.51% |
| 24 | Developed, High Intensity | I1/I2/C1 | | 193,335.79 | 0.68% | |
| 11 | Open Water | A5 | Rural | 5,720,510.37 | 20.23% | 98.49% |
| 21 | Developed, Open Space | A1/R4 | | 1,549,850.76 | 5.48% | |
| 22 | Developed, Low Intensity | R1 | | 513,448.97 | 1.82% | |
| 31 | Barren Land (Rock/Sand/Clay) | A3 | | 357,330.82 | 1.26% | |
| 41 | Deciduous Forest | A4 | | 7,834,588.83 | 27.71% | |
| 42 | Evergreen Forest | A4 | | 1,835,691.61 | 6.49% | |
| 43 | Mixed Forest | A4 | | 830,798.31 | 2.94% | |
| 52 | Shrub/Scrub | A4 | | 613,038.45 | 2.17% | |
| 71 | Grassland/Herbaceous | A3 | | 819,745.38 | 2.90% | |
| 81 | Pasture/Hay | A3 | | 6,342,797.92 | 22.43% | |
| 82 | Cultivated Crops | A2 | | 928,465.46 | 3.28% | |
| 90 | Wood Wetlands | A4 | | 184,038.13 | 0.65% | |
| 95 | Emergent Herbaceous Wetlands | A3 | | 315,818.47 | 1.12% | |
| Analysis based on 30 meter by 30 meter raster cells extracted for each area. | | | *Grand Totals:* | *28,273,078.80* | *100.00%* | |

* The NLCD 2011 did not account for recent FGD construction at GAF; therefore, there was a lack of "Developed" area designated near the stack location. Comparison with imagery revealed that reclassifying the cells in this area would have been inconsequential to the analysis producing only about a 0.09% increase in total Urban designation within the 3 km ring area. There were other questionable classifications in the NLCD 2011 noticed around GAF; however, they involved Rural classes only and were inconsequential to the analysis.

## 3.4 METEOROLOGY

Given that site-specific meteorological data are not available for the GAF site, surface data collected by the NWS at the Nashville International Airport (BNA) in Nashville, Tennessee, were used. The NWS BNA site is located approximately 22 miles west of the GAF site. Data for the most recent years (2012-2014) were used. Twice-daily soundings from the BNA airport during the same time period were used for the upper air data.

The data were processed using the AERMET (Version 15181) meteorological data preprocessor for AERMOD (USEPA, 2004b; USEPA, 2015a). In addition, 1-minute ASOS wind data available from the National Climatic Data Center (NCDC) for the BNA NWS site was processed with AERMINUTE (Version 15272) to generate hourly averaged wind speed and wind direction to supplement the standard hourly NWS observations. Because the BNA NWS site is an Ice Free Wind (IFW) station with a commission date of April 5, 2007, AERMINUTE flagged the 2012-2014 winds as non-calm. The wind speeds were converted from knots to meters per second (m/s) because the threshold for sonic anemometers is effectively zero. No minimum wind speed threshold values were set in AERMET.

When processing meteorological data in AERMET, the surface characteristics of the meteorological site should be used (USEPA, 2005; USEPA, 2004c). Calculations of the boundary layer parameters are dependent on the surface characteristics in the vicinity of the modeled facility. The surface characteristics are quantified by the assignment of three variables: surface albedo, Bowen ratio, and surface roughness length. These variables were set to vary by season using 12 sectors. The surface characteristics were obtained using the USEPA tool, AERSURFACE (Version 13016), which uses land cover data from the U.S. Geological Survey (USGS) National Land Cover Data 1992 archives and look-up tables of surface characteristics that vary by land cover type and season.

To address the spatial representativeness of the NWS data for determining surface characteristics of the site, separate AERSURFACE runs were performed to produce surface characteristics based on a one-kilometer radius centered on the GAF site and another one-kilometer radius centered on the NWS BNA site. In addition, an analysis of land cover and terrain characteristics of both sites were compared. Based on the AERSURFACE results, the surface characteristics, and the close proximity of the two sites, the NWS BNA site was adequately representative of the GAF site (Appendix A). AERMET stage 3 was run using both sets (GAF and NWS BNA) of AERSURFACE results to produce two sets of meteorology, one set using onsite surface characteristics and one using the surface characteristics of the NWS station.

A table of the characterization of surface moisture conditions assumptions for the NWS GAF site and the BNA site for each year of meteorology is presented in Appendix B. The surface moisture conditions for the NWS BNA were determined by comparing precipitation for the 2012-2014 period to the 30-year climatological record, selecting “wet” conditions if precipitation is in the upper $30^{th}$ percentile, “dry” conditions if precipitation is in the lower $30^{th}$ percentile, and “average” conditions if precipitation is in the middle $40^{th}$ percentile (USEPA, 2016). Both the 30-year precipitation record and the annual precipitation amounts were obtained from the National Oceanic Aviation Administration (NOAA) National Centers for Environmental Information for Nashville, Tennessee. Because annual precipitation amounts at the GAF site were unknown, the surface moisture conditions were determined from analysis of annual precipitation departures (percent of normal) for the GAF location in Sumner County, Tennessee, as provided from the NWS Advanced Hydrologic Prediction Service (AHPS).

The AERMINUTE, AERSURFACE, and AERMET input and output files are included on the enclosed optical disc.

### 3.5 MODELING DOMAIN AND RECEPTORS

For the purposes of 1-hour $SO_2$ designation determination, the modeling domain was a Cartesian grid centered at the GAF site. This grid extended out 10 kilometers (km) in each direction. No other $SO_2$ sources are located within the domain or are expected to cause a significant concentration gradient within the domain.

The GAF modeling was performed using a series of nested gridded receptor sets. Boundary receptors were placed along the perimeter of the fenced area of the property and spaced 50 meters (m) apart. These boundary receptors corresponded to a permanent fence surrounding the property.

The nested receptor grids surrounded the facility site with the exception of those falling inside the fenced boundary area, which were removed. Because concentration gradients are most pronounced near a source, the receptor spacing varied with distance from the site with those nearest the site more closely spaced than those further away. There were a total of 6,082 receptors. The origin of each grid was located in the southwest corner. The receptor spacing is provided in Table 11.

**Table 11**
**Receptor Grid Size and Spacing**

| Receptor Spacing (m) | Grid Size (km) | Grid Origin (km south and west of site) |
|---|---|---|
| 100 | 6 × 6 | 3 |
| 250 | 10 × 10 | 5 |
| 500 | 20 × 20 | 10 |

Elevations for all receptors were extracted from U.S. Geological Survey (USGS) National Elevation Dataset (NED) files using the AERMAP terrain processor (Version 11103) of the AERMOD modeling system (USEPA, 2004c; USEPA 2011). A plot of the receptor elevations is presented in Figure 5. The AERMAP input and output files are included on the enclosed optical disc.

### 3.6 BACKGROUND AIR QUALITY

The $SO_2$ TAD states that the inclusion of ambient monitored background concentrations in the model results is important in determining the cumulative impact of the target source and other contributing nearby sources impacts (USEPA, 2016). The document also describes an appropriate methodology of calculating temporally varying background monitored concentrations for $SO_2$ designations modeling based on use of the $99^{th}$ percentile by hour of day and season for background concentration excluding periods when the dominant source(s) are influencing the monitored concentration.

An assessment of nearby $SO_2$ monitors was performed in order to determine the best monitor to represent ambient $SO_2$ background concentrations for the 2012-2014 GAF modeling analysis (Table 12). The choice of nearby background monitors for GAF was limited, since many monitors did not meet the data completeness requirements for determining compliance with the NAAQs. The Trinity Lane monitor located in Davidson County (Nashville), Tennessee, is the closest to the GAF site; however, the monitor did not meet the USEPA completeness criteria in 2012 and 2013. As a result, the site did not have a valid 3-year design value for the 2012-2014 period and could not be used as the representative background value for the modeling. The Christian County monitor in Christian County, Kentucky, also did not meet the USEPA data completeness criteria in 2012 and 2014. The Paducah monitor in Paducah, Kentucky; and the Shelby Farms monitor in Memphis, Tennessee; have three years of complete and valid data. However, they are located at farther distances from GAF and are impacted by numerous large nearby sources, making them unsuitable for characterizing air quality beyond the immediate vicinity of the monitors.

The Mammoth Cave National Park (AIRS ID 21-061-0501) monitor in Mammoth Cave, Kentucky, was determined to be the best choice for representing ambient $SO_2$ background concentrations in the vicinity of GAF. It is close to GAF, meets the data completeness requirements for 2012-2014, and is not influenced by nearby large sources. This monitor is located approximately 58 miles north-northeast of GAF (Figure 1).

**Table 12**
**Ambient $SO_2$ Monitors in the Vicinity of GAF [1]**

| Monitor | Distance to GAF (miles) | 3-yr Avg DV (ppb)[2] | Maximum Seasonal Hourly Concentration (ppb)[3] | Monitor Scale | Large Nearby Sources? |
|---|---|---|---|---|---|
| Trinity Lane | 21 | Does not meet data completeness requirements | | | |
| Mammoth Cave | 58 | 10.3 | 7.2 | IMPROVE, expected to be Regional | No |
| Christian County | 65 | Does not meet data completeness requirements | | | |
| Paducah | 130 | 20.7 | 13.0 | Neighborhood (500m - 4 km) | Yes, over 50,000 tpy |
| Shelby Farms NCore | 209 | 9.3 | 6.7 | Urban (4 km-50 km) | Yes, nearly 14,000 tpy |

Notes:
1. USEPA Air Quality System (AQS) Data Mart: http://www3.epa.gov/airquality/airdata/.
2. The 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour average $SO_2$ concentrations for the 2012-2014 period.
3. The 3-year average of the 2nd highest measured 1-hour $SO_2$ concentration for each hour of the day and each season for the 2012-2014 period.

Following TAD guidance, the 2nd highest measured 1-hour $SO_2$ concentration for each hour of the day by season averaged across the 2012-2014 period was used to capture the impact of natural sources, minor nearby sources, and distant major nearby sources in the vicinity of GAF which were not included in the modeling (Table 13). No attempt to remove the impact of GAF on the monitor by excluding data when the wind blows from the direction of GAF was made. This approach is conservative since it potentially "double counts" impacts from GAF.

**Table 13**
**Seasonal Hourly Background Concentrations Measured at Mammoth Cave Monitor [1,2,3]**

| Hour | Background Concentration (ppb) | | | |
|---|---|---|---|---|
| | Winter | Spring | Summer | Fall |
| 0 | 4.6 | 2.6 | 1.5 | 3.4 |
| 1 | 2.6 | 1.6 | 2.7 | 2.7 |
| 2 | 5.1 | 1.8 | 1.5 | 1.9 |
| 3 | 3.9 | 2.2 | 1.7 | 2.4 |
| 4 | 3.9 | 2.6 | 1.3 | 2.8 |
| 5 | 4.5 | 3.1 | 1.6 | 3.0 |
| 6 | 4.6 | 3.1 | 1.7 | 3.1 |
| 7 | 5.5 | 3.5 | 2.9 | 3.9 |
| 8 | 5.2 | 3.4 | 4.2 | 4.5 |
| 9 | 7.2 | 4.2 | 4.3 | 4.8 |
| 10 | 6.6 | 3.6 | 3.0 | 5.0 |
| (Continued on Next Page) | | | | |

**Table 13 (Continued)**
**Seasonal Hourly Background Concentrations Measured at Mammoth Cave Monitor [1,2,3]**

| Hour | Background Concentration (ppb) | | | |
|---|---|---|---|---|
| | Winter | Spring | Summer | Fall |
| 11 | 5.6 | 3.4 | 3.0 | 5.3 |
| 12 | 5.8 | 2.6 | 2.7 | 5.1 |
| 13 | 5.3 | 2.5 | 2.7 | 3.9 |
| 14 | 5.7 | 2.6 | 2.7 | 4.0 |
| 15 | 6.4 | 2.6 | 2.1 | 3.5 |
| 16 | 5.9 | 3.1 | 2.4 | 4.8 |
| 17 | 5.1 | 3.0 | 2.7 | 4.4 |
| 18 | 5.6 | 2.7 | 2.6 | 3.6 |
| 19 | 5.2 | 2.5 | 2.6 | 3.9 |
| 20 | 4.9 | 2.6 | 2.2 | 3.4 |
| 21 | 5.8 | 2.8 | 1.9 | 3.3 |
| 22 | 5.7 | 2.9 | 1.7 | 3.6 |
| 23 | 6.3 | 2.9 | 1.5 | 3.8 |

Notes:
1. USEPA Air Quality System (AQS) Data Mart: http://www3.epa.gov/airquality/airdata/.
2. The 2nd highest measured 1-hour $SO_2$ concentration for each hour of the day and each season were averaged across the 2012-2014 period.
3. Impact of GAF was not removed by excluding any wind directions.

## 4.0 MODELING RESULTS

The modeling analysis evaluated two allowable emissions scenarios, as described in Section 3.1. Each scenario and load combination was modeled using both onsite and NWS surface characteristics for a total of 12 model runs. All of the runs included potential emissions from oil-fired CT operations and seasonal hourly background concentrations from Mammoth Cave.

The 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour average $SO_2$ concentrations was calculated for each receptor. The value for the receptor with the highest concentration is the maximum modeled impact which is presented in Table 14. Maximum impacts for all of the scenarios are below the 1-hour $SO_2$ NAAQS, indicating that emissions from future allowable emissions from GAF will not cause or contribute to a violation of the NAAQS.

**Table 14**
**Maximum Modeled Impacts of GAF Future Allowable Emissions**

| Scenario | Load | Met Surface Char | Receptor Location | | | 1-hour $SO_2$ | |
|---|---|---|---|---|---|---|---|
| | | | UTM E (m) | UTM N (m) | Elev (m) | Maximum Modeled Impact (ppb) | NAAQS (ppb) |
| Scenario 1 | 100% | Onsite | 556280 | 4020223 | 171.81 | 73.1 | 75 |
| Scenario 1 | 100% | BNA | 551580 | 4018523 | 172.18 | 75.0 [1] | 75 |
| Scenario 1 | 75% | Onsite | 556280 | 4020223 | 171.81 | 59.2 | 75 |
| Scenario 1 | 75% | BNA | 551780 | 4018023 | 169.31 | 62.8 | 75 |
| Scenario 1 | 50% | Onsite | 556280 | 4020223 | 171.81 | 48.3 | 75 |
| Scenario 1 | 50% | BNA | 553880 | 4019823 | 149.27 | 50.3 | 75 |
| Scenario 2 | 100% | Onsite | 556280 | 4020223 | 171.81 | 73.1 | 75 |
| Scenario 2 | 100% | BNA | 551580 | 4018523 | 172.18 | 74.9 | 75 |
| Scenario 2 | 75% | Onsite | 556280 | 4020223 | 171.81 | 72.5 | 75 |
| Scenario 2 | 75% | BNA | 551580 | 4018523 | 172.18 | 74.7 | 75 |
| Scenario 2 | 50% | Onsite | 556280 | 4020223 | 171.81 | 66.5 | 75 |
| Scenario 2 | 50% | BNA | 551580 | 4018523 | 172.18 | 68.3 | 75 |

Note:
1. Maximum modeled impact has been rounded to three (3) significant figures. The actual concentration rounded to four (4) significant figures is 196.4 $\mu g/m^3$, which is equivalent to 74.96 ppb.

Plots showing the spatial distribution of the modeled impacts for each combination of emissions allocation scenario, load, and meteorological surface characteristics are presented in Figures 6-17. For the worst-case scenario, which was allowable emissions allocated by heat input at 100 percent load with NWS surface characteristics, the distance to the receptor with the highest concentration was 2.12 km. For all of the scenarios, maximum impacts occurred within the finest receptor grid (6 km by 6 km) with 100 m spacing.

The input and output files for the AERMOD model runs provide additional details on the dispersion modeling and are included on the enclosed optical disc.

These results demonstrate that a total emission rate of 337.3 grams/second (g/s) for GAF01-04, even with the worst-case allocation, will not cause or contribute to a violation of the 1-hour $SO_2$ NAAQS and will support an attainment designation for Sumner County and surrounding areas.

Following the approach described in Guidance for 1-Hour $SO_2$ Nonattainment Area SIP Submissions (USEPA, 2014), a 30-day rolling average emission rate of an equivalent stringency to the modeled emission rate was calculated (Table 15). Therefore, a future allowable emission rate of 1,971 pounds / hour (lb/hr) for GAF01-04 on a 30-day rolling average basis will support an attainment designation for Sumner County and surrounding areas.

**Table 15**
**Calculation of an Equivalent 30-day Rolling Average Emission Rate [1]**

| Emission Rate | Units | Emissions Allocation Scenario 1 | Emissions Allocation Scenario 2 |
|---|---|---|---|
| Modeled hourly emissions - plant total[2] | g/s | 338.5 | 337.3 |
| Modeled hourly emission - plant total[2] | lb/hr | 2,687 | 2,677 |
| 99th percentile of hourly emissions[3] | lb/hr | 4,916 | 4,916 |
| 99th percentile of 30-day rolling average emissions[3] | lb/hr | 3,620 | 3,620 |
| Ratio of 1-hour to 30-day emissions[3] | NA | 0.736 | 0.736 |
| Equivalent 30-day rolling average emission rate | lb/hr | 1,978 | 1,971 |

Notes:
1. Method described in Guidance for 1-Hour $SO_2$ Nonattainment Area SIP Submissions (USEPA, 2014).
2. Plant-wide emissions for worst-case scenario: emissions allocated by heat rate at 100% load using NWS surface characteristics.
3. Calculated from CEMS data at Cumberland Steam Plant between 6/13/2011, the data that continuous operation of the scrubber began, and 12/31/2014.

## 5.0 REFERENCES


USEPA, 1985: Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations), Revised. EPA-450/4-80-023R. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

USEPA, 2004a: User's Guide for the AMS/EPA REGULATORY MODEL - AERMOD. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

USEPA, 2004b: User's Guide for the AERMOD Meteorological Preprocessor (AERMET). EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

USEPA, 2004c: User's Guide for the AERMOD Terrain Preprocessor (AERMAP). EPA-454/B-03-003. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

USEPA, 2004c: User's Guide to the Building Profile Input Program. EPA-454/R-93-038. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

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USEPA, 2005: *Guideline on Air Quality Models*. 40 CFR Part 51 Appendix W.

USEPA, 2011: Addendum User's Guide for the AERMOD Terrain Preprocessor (AERMAP). EPA-454/B-03-002. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711

USEPA, 2015a: Addendum User's Guide for the AERMOD Meteorological Preprocessor (AERMET). EPA-454/B-03-002. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

USEPA, 2015b: Addendum User's Guide for the AMS/EPA REGULATORY MODEL - AERMOD. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

USEPA, 2016: $SO_2$ NAAQS Designations Modeling Technical Assistance Document, February 2016. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711.

**Figure 1**
**Site Locality Map**

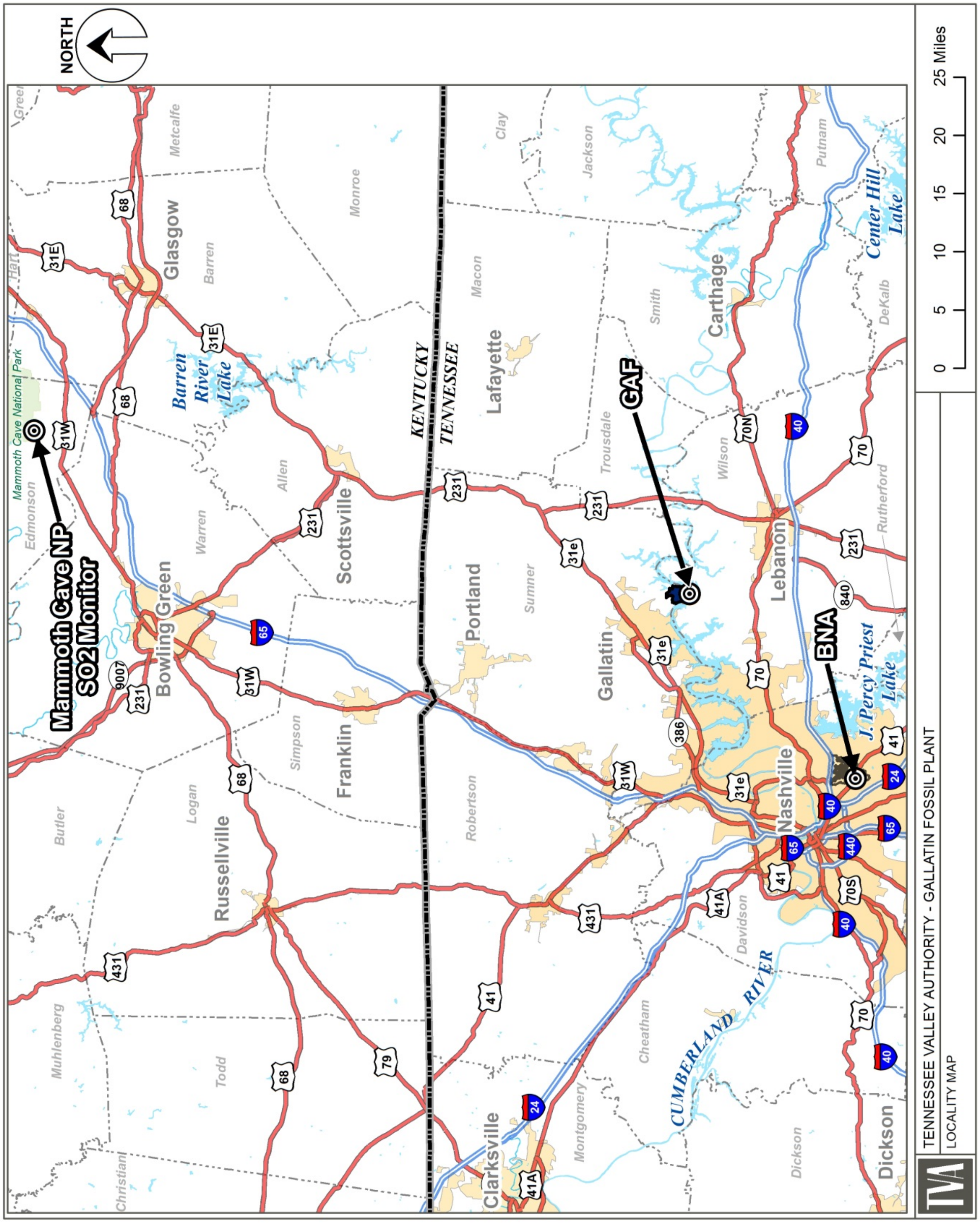


**Figure 2**
**Building Locations for GAF01-04 Downwash Analysis**

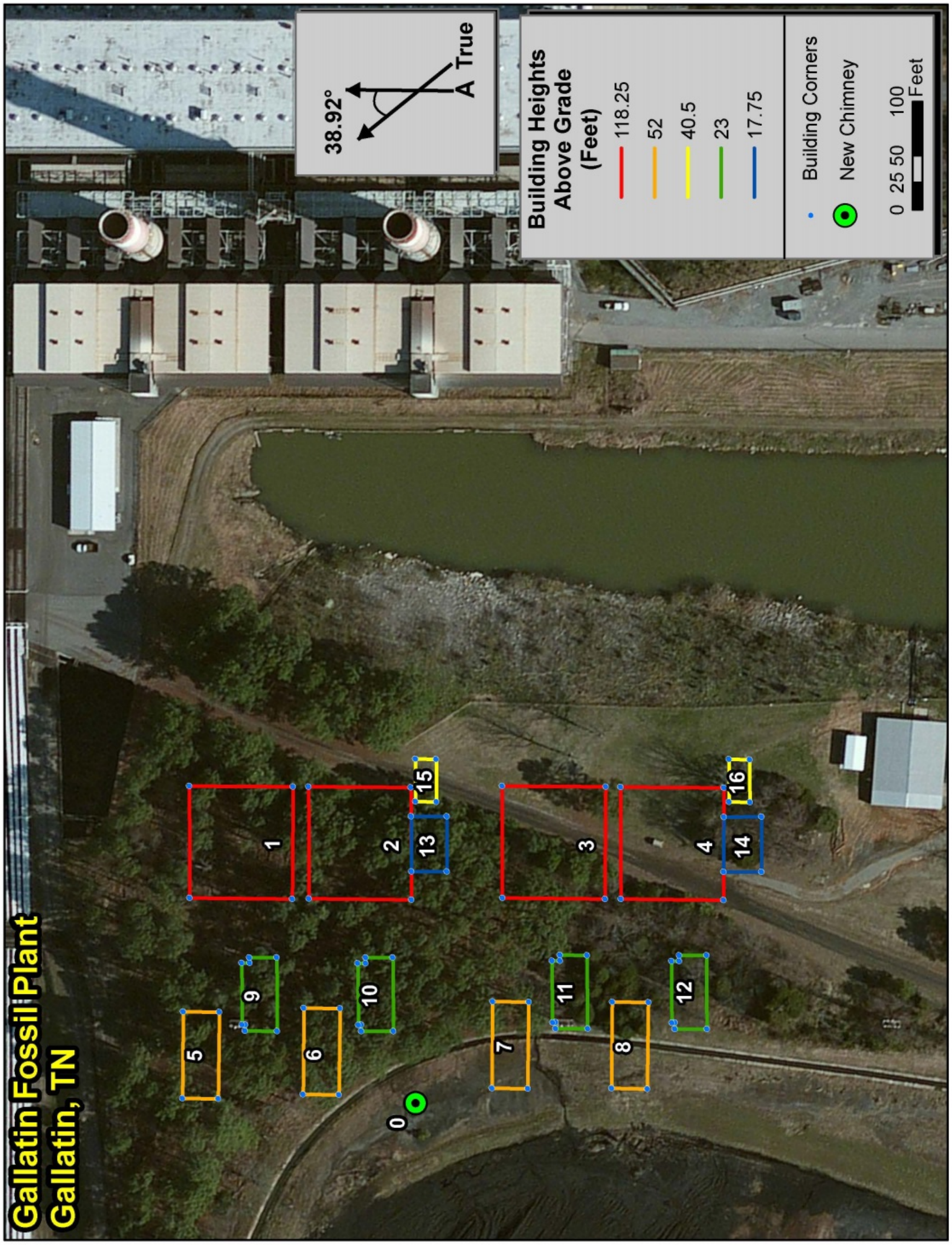


**Figure 3**
**Building Locations for CT 1-8 Downwash Analysis**

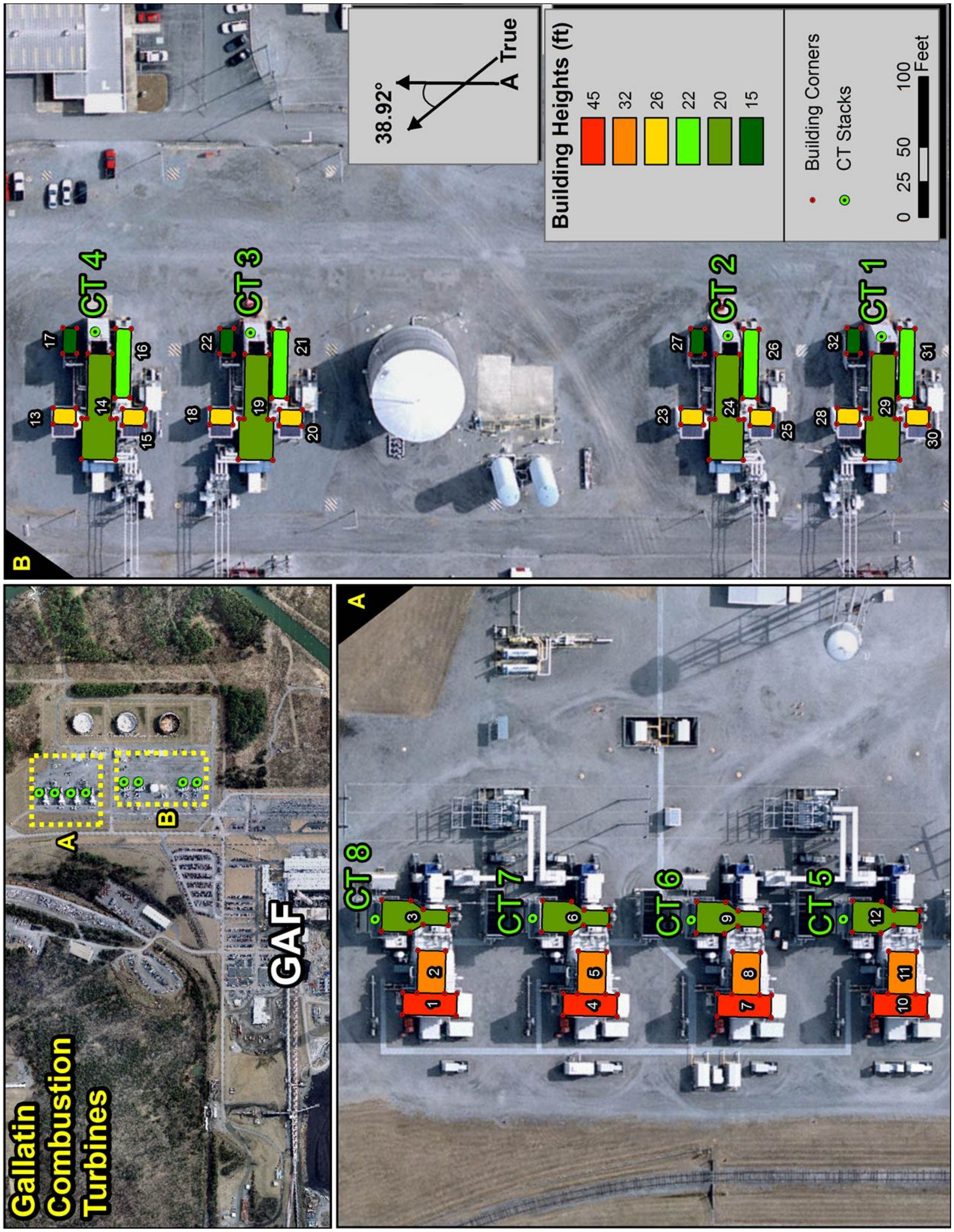


**Figure 4**
**Auer Land Use Analysis - GAF Study Area**

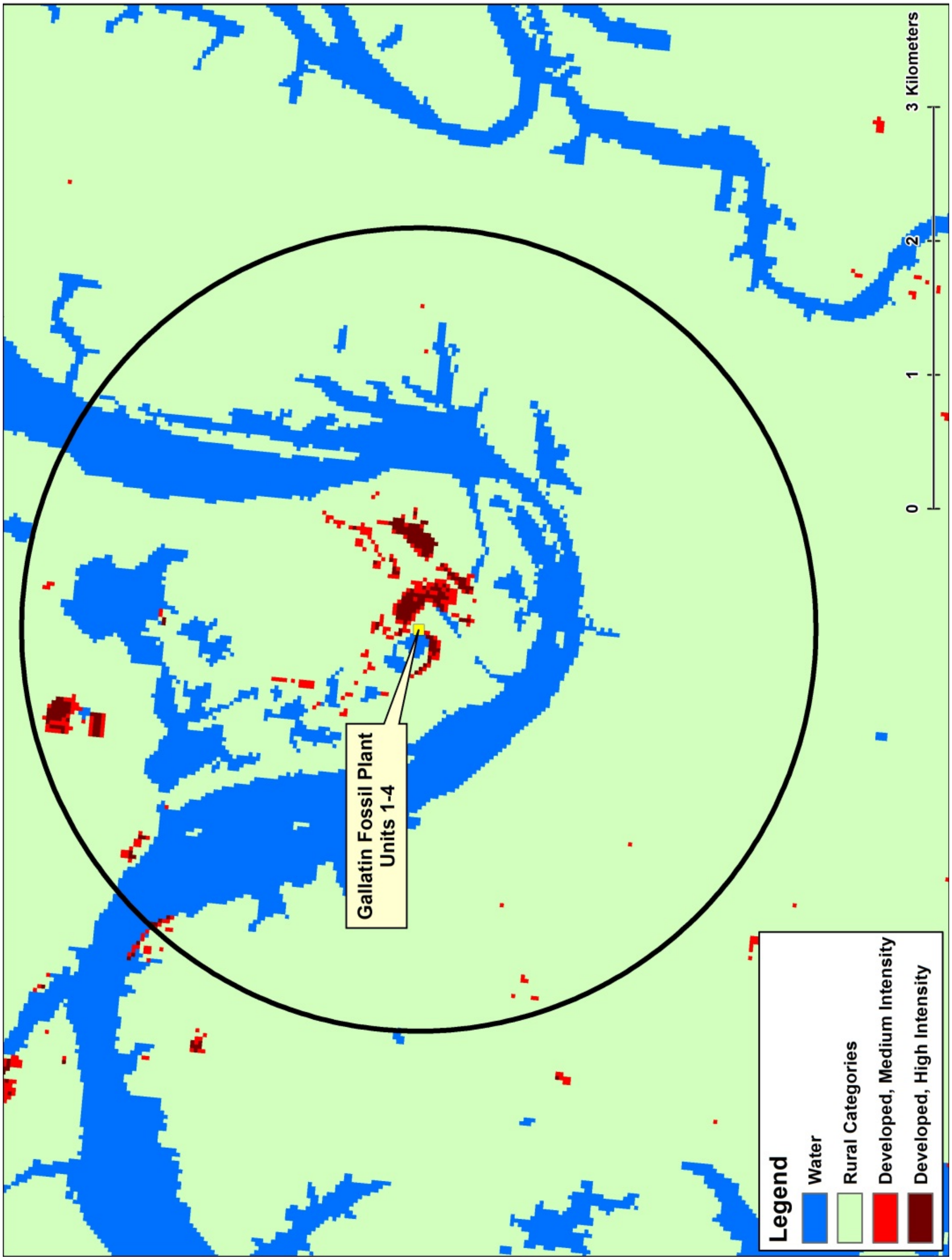


**Figure 5**
**GAF Receptor Elevation Plot**

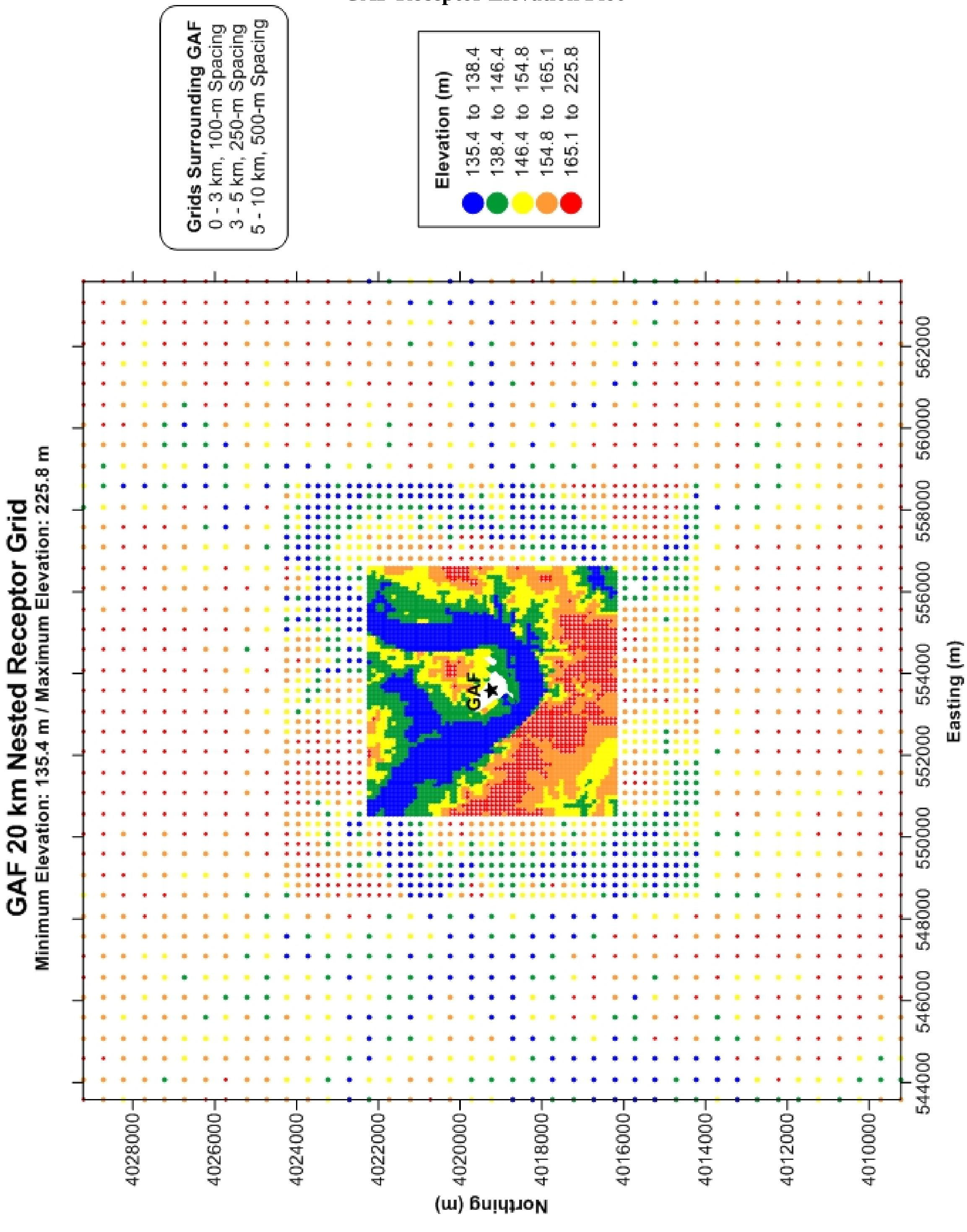


**Figure 6**
**$99^{th}$ Percentile 1-hour $SO_2$ Concentrations**
**Allowable Emissions Allocated by Heat Input at**
**100% Load Operations using**
**Onsite Surface Characteristics**

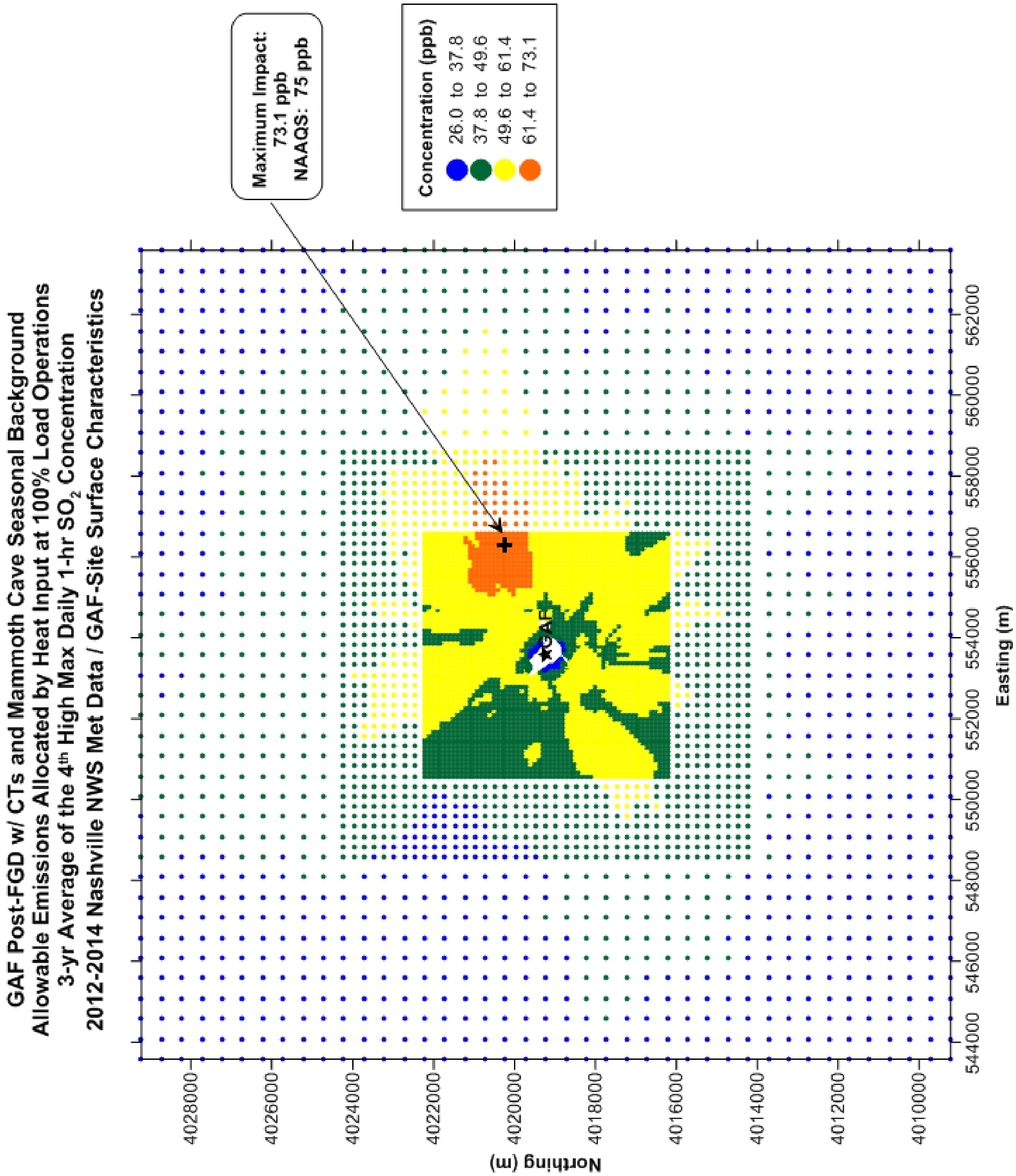


**Figure 7**
**99th Percentile 1-hour $SO_2$ Concentrations**
**Allowable Emissions Allocated by Heat Input at**
**100% Load Operations using**
**NWS Surface Characteristics**

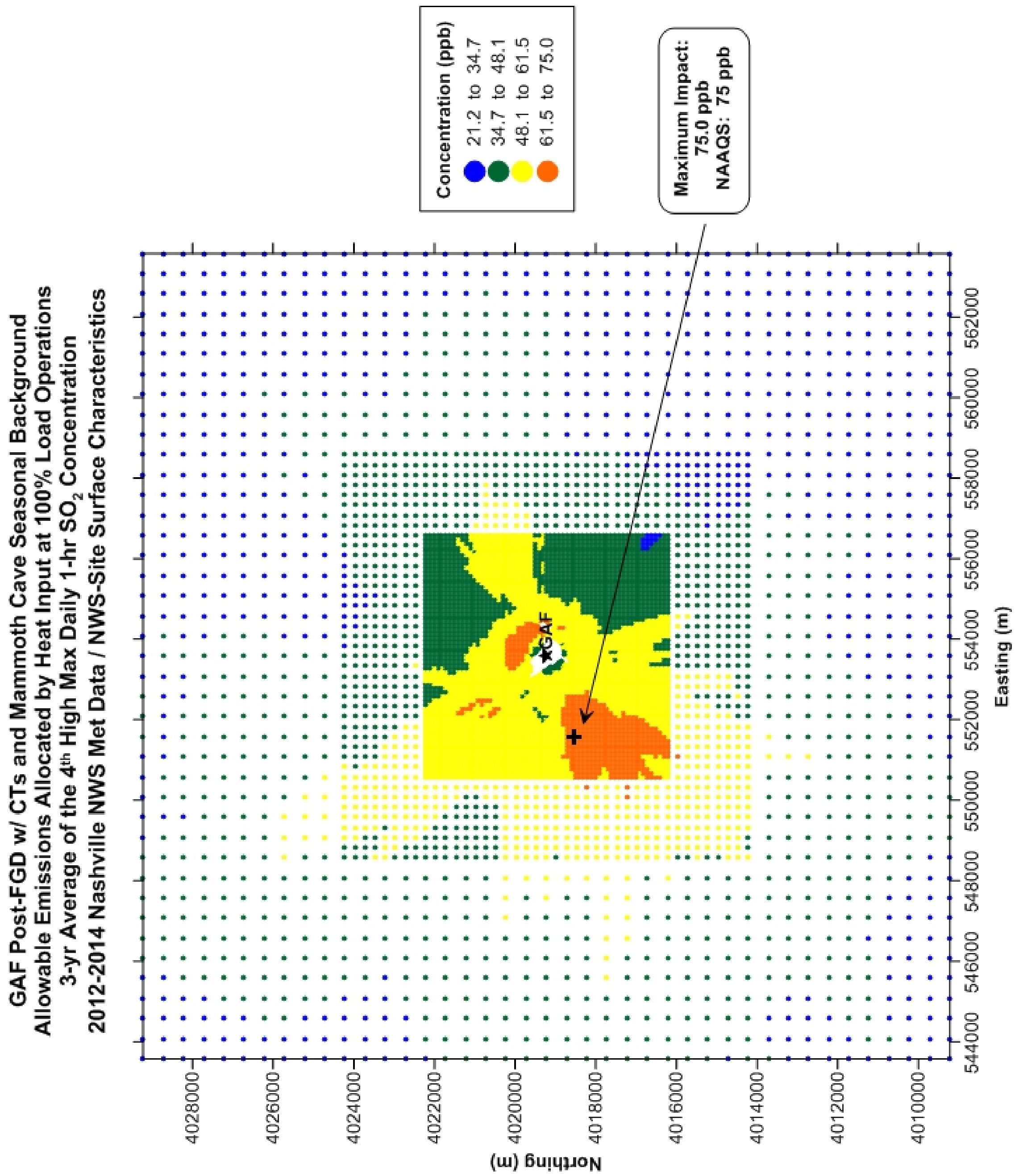


**Figure 8**
**99th Percentile 1-hour $SO_2$ Concentrations**
**Allowable Emissions Allocated by Heat Input at**
**75% Load Operations using**
**Onsite Surface Characteristics**

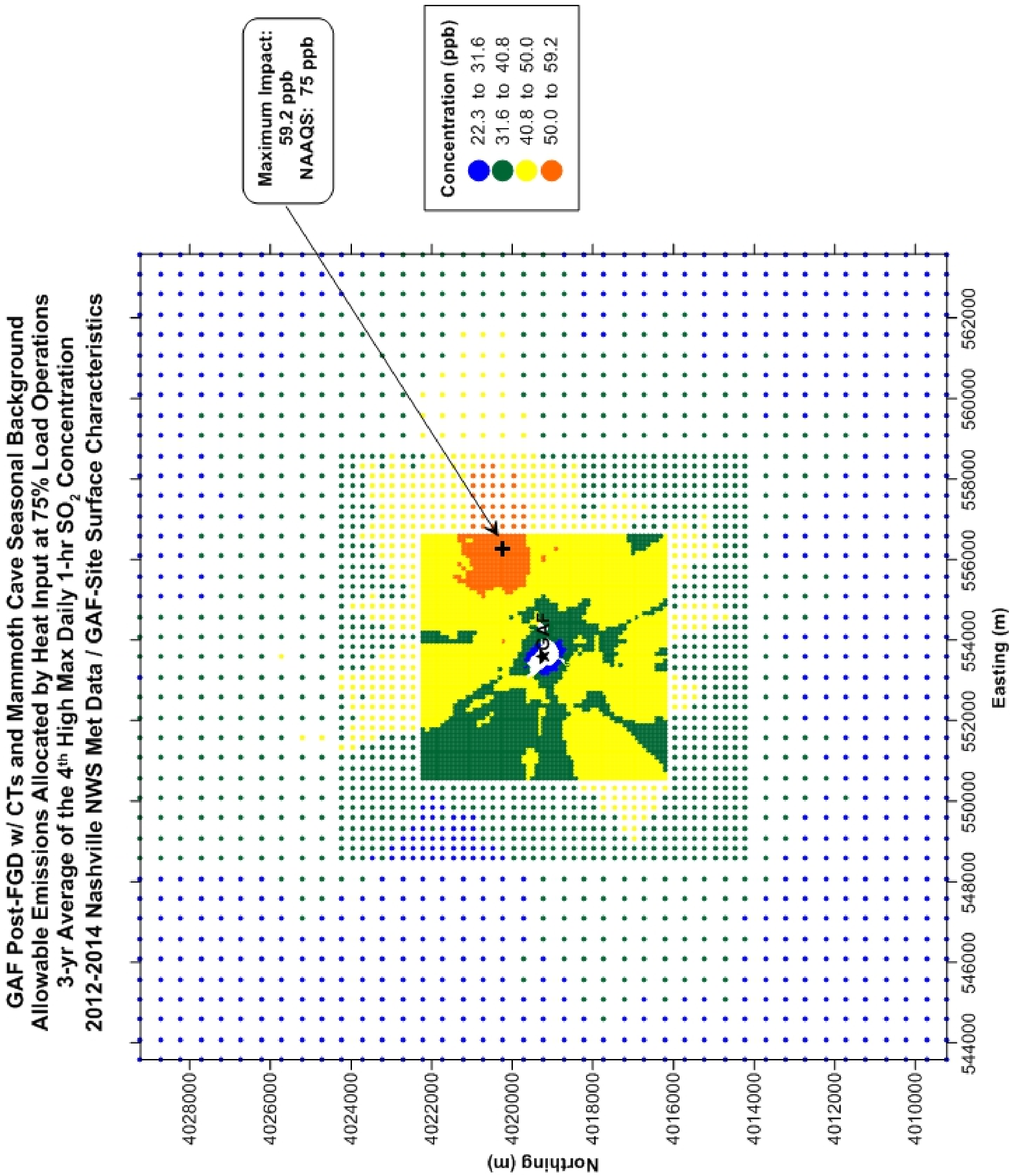


**Figure 9**
**$99^{th}$ Percentile 1-hour $SO_2$ Concentrations**
**Allowable Emissions Allocated by Heat Input at**
**75% Load Operations using**
**NWS Surface Characteristics**

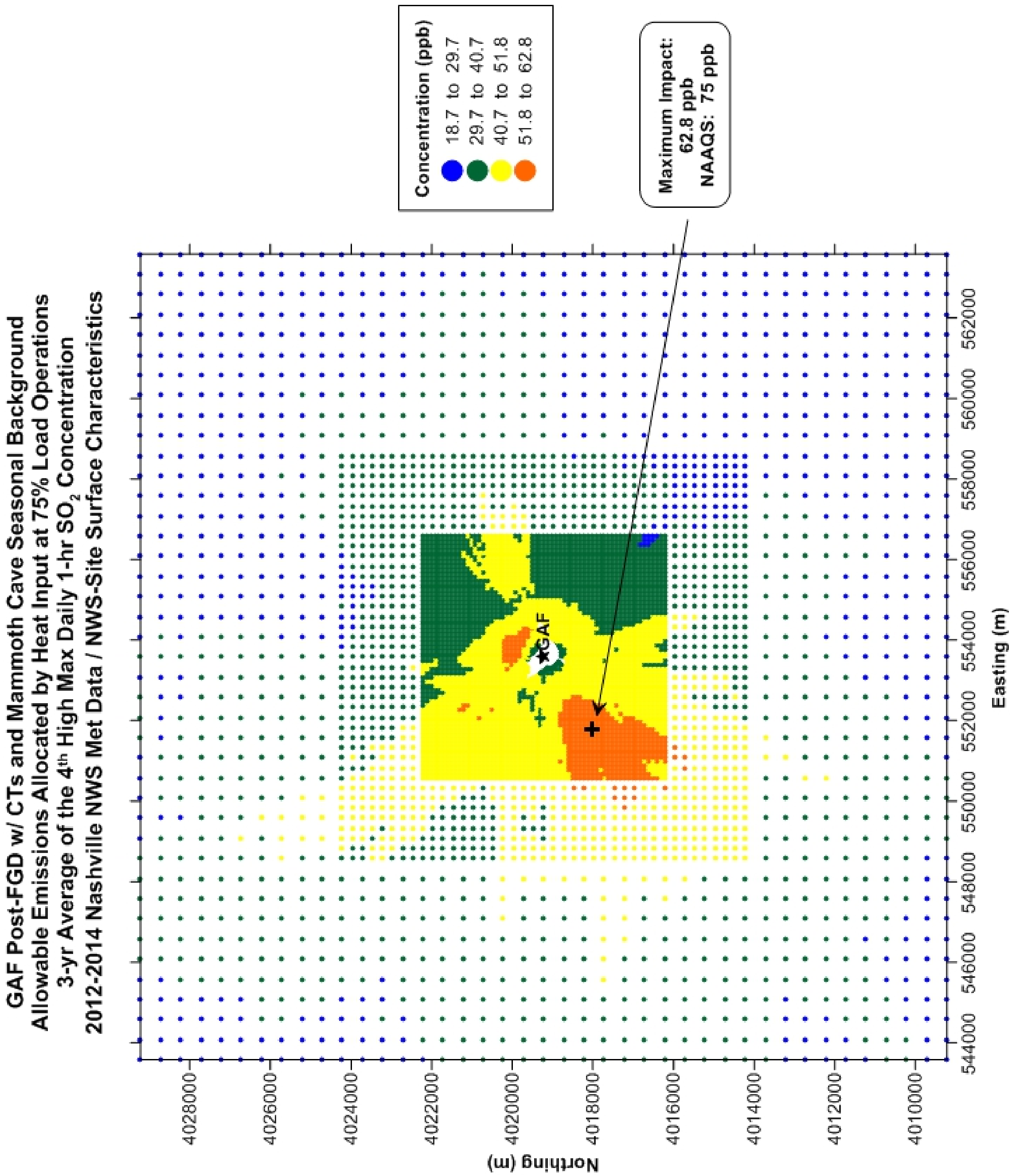


**Figure 10**
**99th Percentile 1-hour $SO_2$ Concentrations**
**Allowable Emissions Allocated by Heat Input at**
**50% Load Operations using**
**Onsite Surface Characteristics**

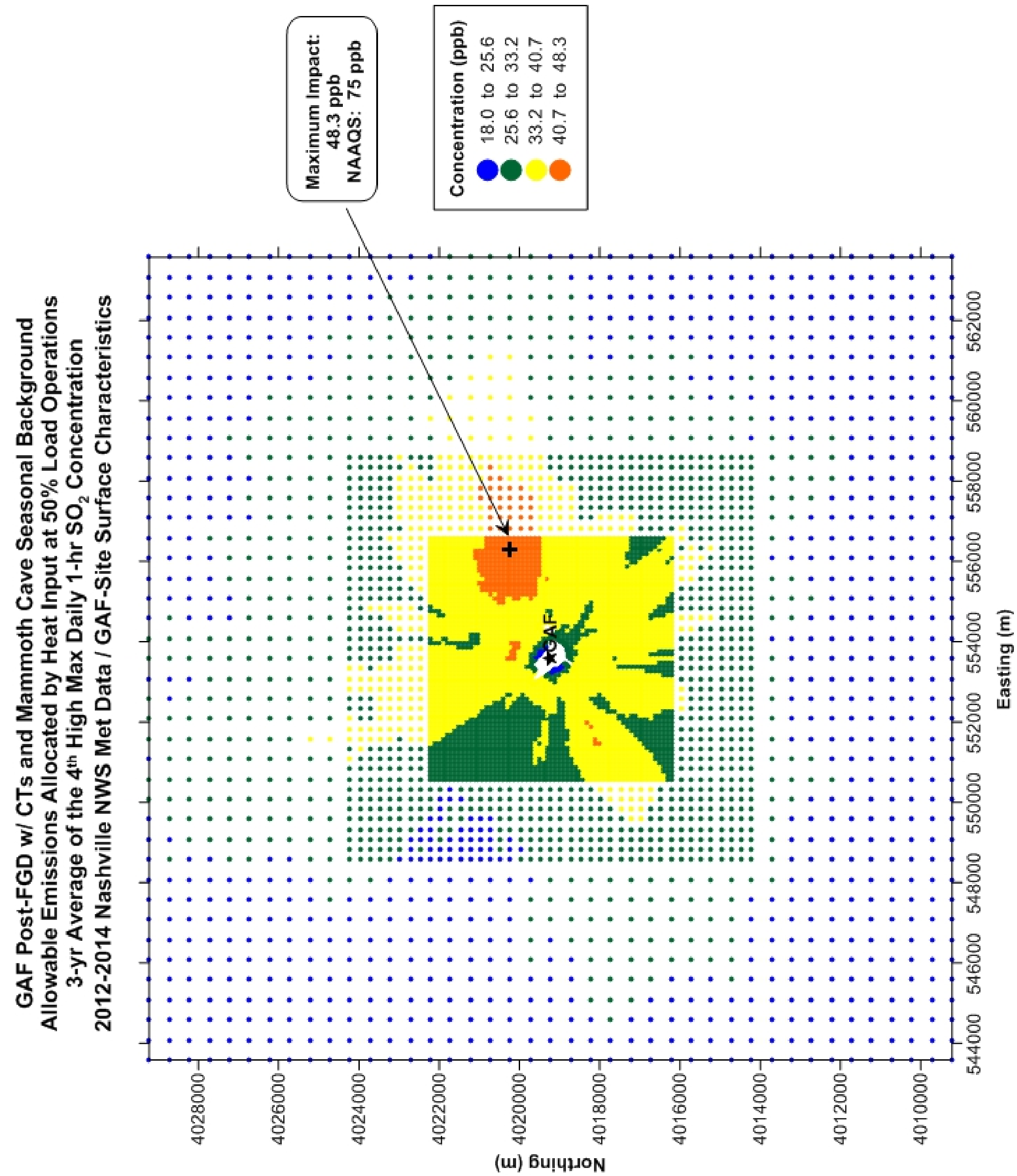


**Figure 11**
**99th Percentile 1-hour $SO_2$ Concentrations**
**Allowable Emissions Allocated by Heat Input at**
**50% Load Operations using**
**NWS Surface Characteristics**

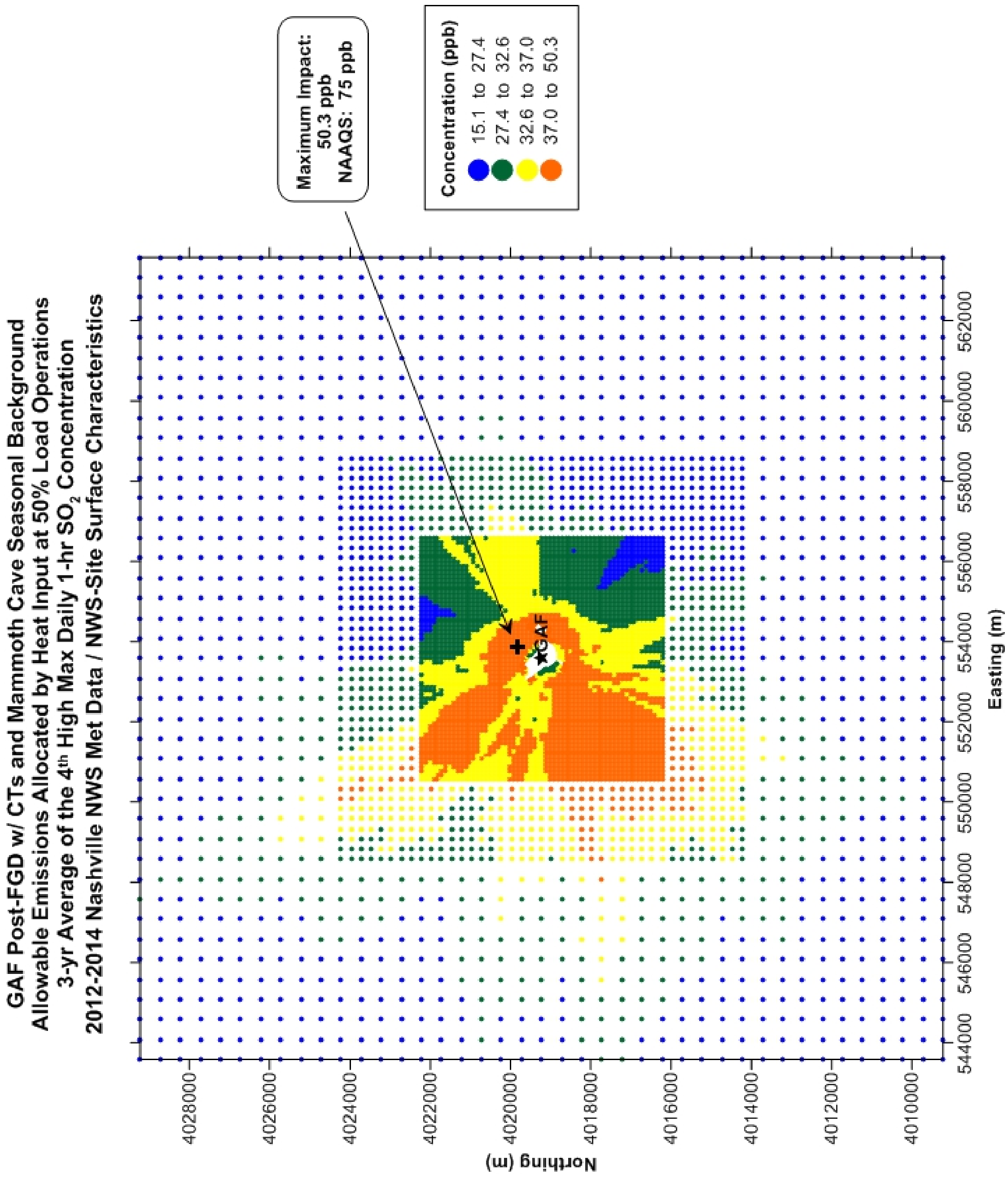


**Figure 12**
**99th Percentile 1-hour $SO_2$ Concentrations**
**GAF01-02 at MATS Limit and GAF03-04 at Allowable Emissions at 100% Load Operations using Onsite Surface Characteristics**

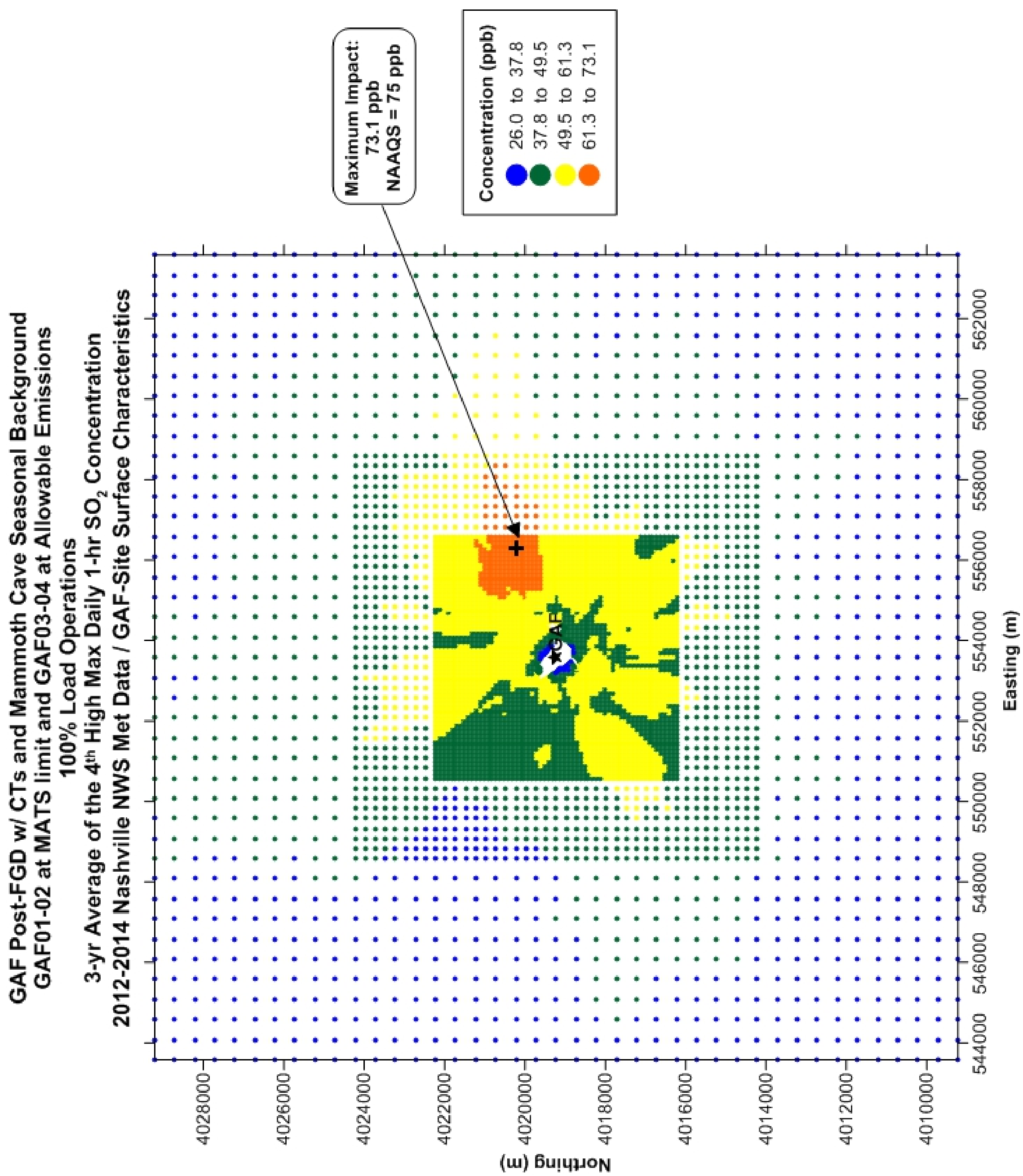


**Figure 13**
**99th Percentile 1-hour $SO_2$ Concentrations**
**GAF01-02 at MATS Limit and GAF03-04 at Allowable Emissions at 100% Load Operations using NWS Surface Characteristics**

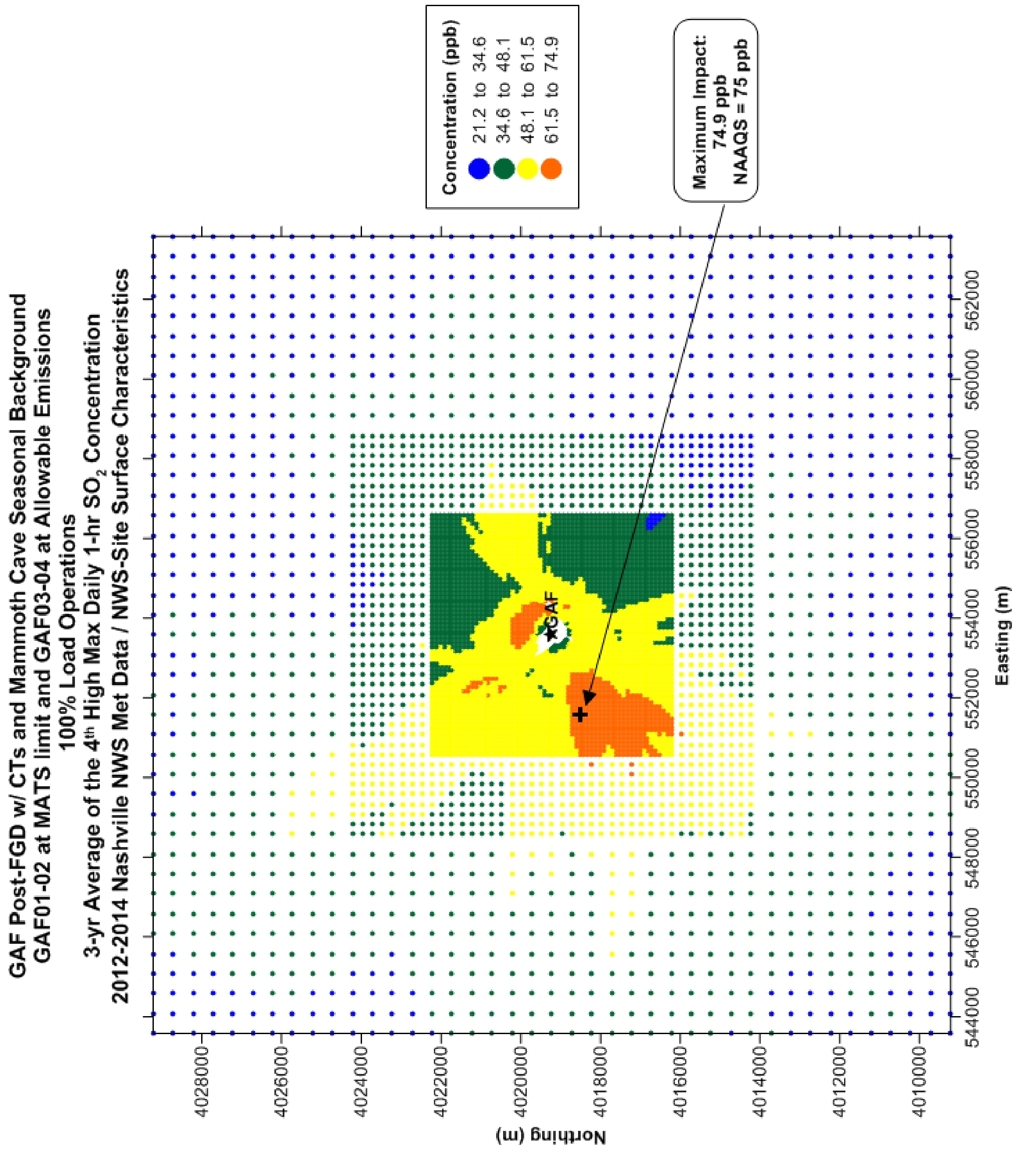


**Figure 14**
**$99^{th}$ Percentile 1-hour $SO_2$ Concentrations**
**GAF01-02 at MATS Limit and GAF03-04 at Allowable Emissions at 75% Load Operations using Onsite Surface Characteristics**

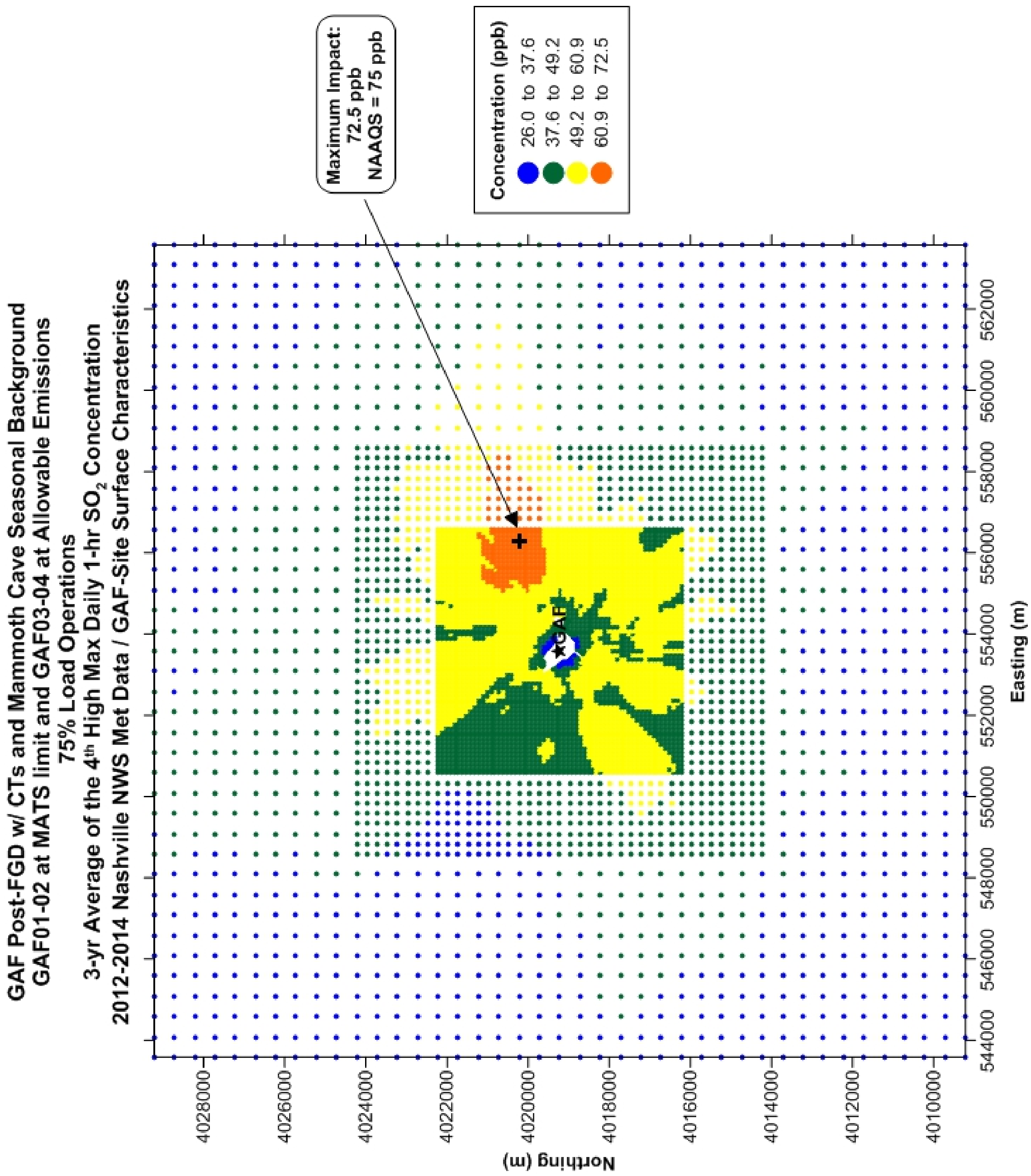


**Figure 15**
**$99^{th}$ Percentile 1-hour $SO_2$ Concentrations**
**GAF01-02 at MATS Limit and GAF03-04 at Allowable Emissions at**
**75% Load Operations using**
**NWS Surface Characteristics**

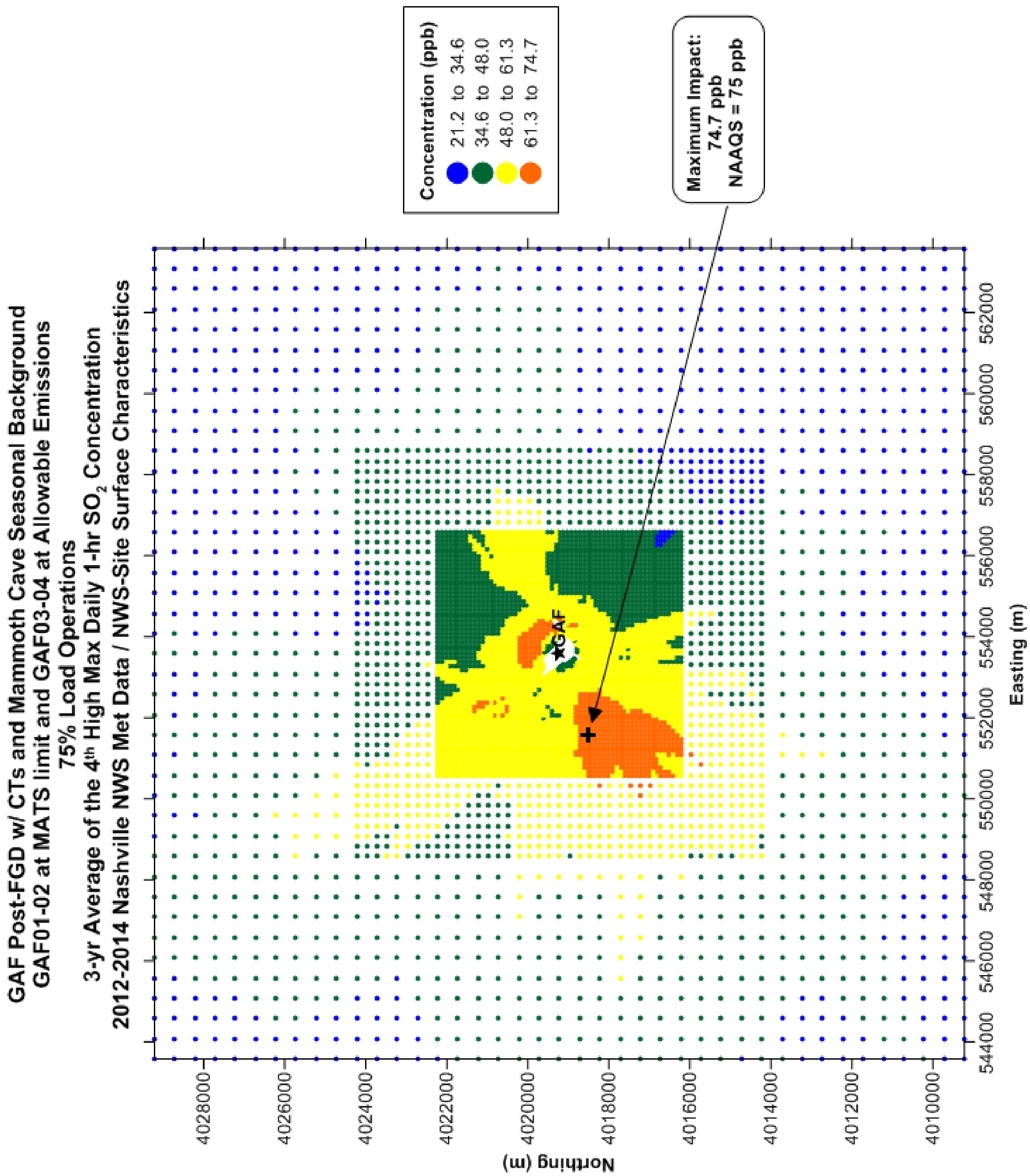


**Figure 16**
**99th Percentile 1-hour $SO_2$ Concentrations**
**GAF01-02 at MATS Limit and GAF03-04 at Allowable Emissions at**
**50% Load Operations using**
**Onsite Surface Characteristics**

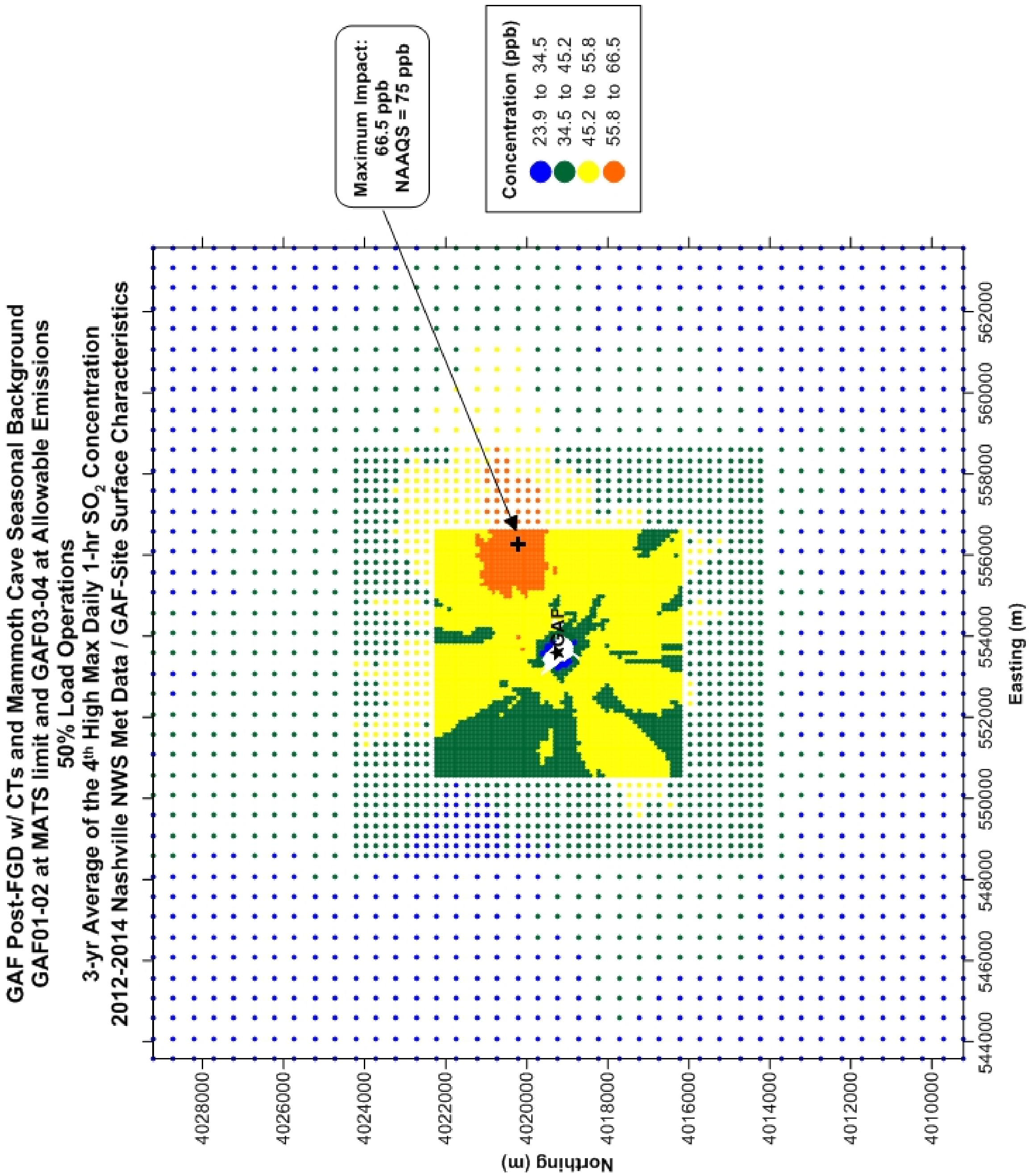
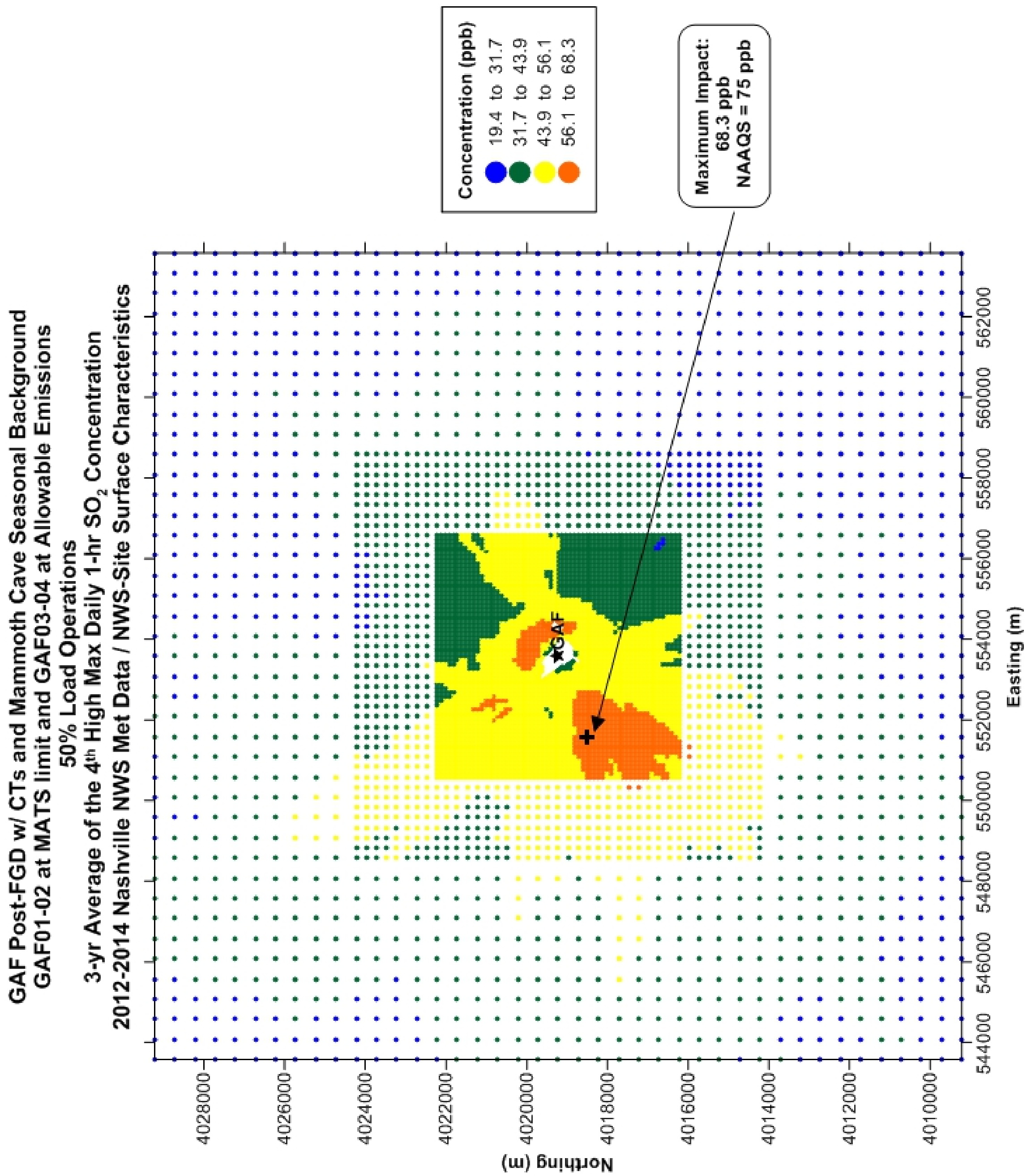


**Figure 17**
**99th Percentile 1-hour $SO_2$ Concentrations**
**GAF01-02 at MATS Limit and GAF03-04 at Allowable Emissions at 50% Load Operations using NWS Surface Characteristics**



**APPENDIX A**
**GAF ONSITE AND BNA AERSURFACE OUTPUT**

**GAF Onsite AERSURFACE Output (Average Moisture)**

```
** Generated by AERSURFACE, dated 13016
** Generated from "tennessee_NLCD_erd050500.tif"
** Center Latitude (decimal degrees):     36.316500
** Center Longitude (decimal degrees):   -86.403100
** Datum: NAD83
** Study radius (km) for surface roughness:   1.0
** Airport? N, Continuous snow cover? N
** Surface moisture? Average, Arid region? N
** Month/Season assignments? Default
** Late autumn after frost and harvest, or winter with no snow: 12 1 2
** Winter with continuous snow on the ground: 0
** Transitional spring (partial green coverage, short annuals): 3 4 5
** Midsummer with lush vegetation: 6 7 8
** Autumn with unharvested cropland: 9 10 11

   FREQ_SECT  SEASONAL 12
   SECTOR   1    0   30
   SECTOR   2   30   60
   SECTOR   3   60   90
   SECTOR   4   90  120
   SECTOR   5  120  150
   SECTOR   6  150  180
   SECTOR   7  180  210
   SECTOR   8  210  240
   SECTOR   9  240  270
   SECTOR  10  270  300
   SECTOR  11  300  330
   SECTOR  12  330  360
**           Season   Sect    Alb      Bo        Zo
   SITE_CHAR    1       1     0.16     0.52     0.143
   SITE_CHAR    1       2     0.16     0.52     0.238
   SITE_CHAR    1       3     0.16     0.52     0.155
   SITE_CHAR    1       4     0.16     0.52     0.315
   SITE_CHAR    1       5     0.16     0.52     0.280
   SITE_CHAR    1       6     0.16     0.52     0.088
   SITE_CHAR    1       7     0.16     0.52     0.090
   SITE_CHAR    1       8     0.16     0.52     0.036
   SITE_CHAR    1       9     0.16     0.52     0.012
   SITE_CHAR    1      10     0.16     0.52     0.024
   SITE_CHAR    1      11     0.16     0.52     0.011
   SITE_CHAR    1      12     0.16     0.52     0.073
   SITE_CHAR    2       1     0.14     0.33     0.170
   SITE_CHAR    2       2     0.14     0.33     0.269
   SITE_CHAR    2       3     0.14     0.33     0.177
   SITE_CHAR    2       4     0.14     0.33     0.353
   SITE_CHAR    2       5     0.14     0.33     0.322
   SITE_CHAR    2       6     0.14     0.33     0.097
   SITE_CHAR    2       7     0.14     0.33     0.103
   SITE_CHAR    2       8     0.14     0.33     0.040
   SITE_CHAR    2       9     0.14     0.33     0.013
   SITE_CHAR    2      10     0.14     0.33     0.028
```

```
   SITE_CHAR    2      11     0.14     0.33     0.012
   SITE_CHAR    2      12     0.14     0.33     0.082
   SITE_CHAR    3       1     0.16     0.31     0.210
   SITE_CHAR    3       2     0.16     0.31     0.316
   SITE_CHAR    3       3     0.16     0.31     0.222
   SITE_CHAR    3       4     0.16     0.31     0.405
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   SITE_CHAR    3       6     0.16     0.31     0.105
   SITE_CHAR    3       7     0.16     0.31     0.112
   SITE_CHAR    3       8     0.16     0.31     0.045
   SITE_CHAR    3       9     0.16     0.31     0.014
   SITE_CHAR    3      10     0.16     0.31     0.037
   SITE_CHAR    3      11     0.16     0.31     0.014
   SITE_CHAR    3      12     0.16     0.31     0.094
   SITE_CHAR    4       1     0.16     0.52     0.210
   SITE_CHAR    4       2     0.16     0.52     0.316
   SITE_CHAR    4       3     0.16     0.52     0.212
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   SITE_CHAR    4       5     0.16     0.52     0.358
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   SITE_CHAR    4       9     0.16     0.52     0.014
   SITE_CHAR    4      10     0.16     0.52     0.037
   SITE_CHAR    4      11     0.16     0.52     0.014
   SITE_CHAR    4      12     0.16     0.52     0.094
```

**NWS Nashville, Tennessee (BNA) AERSURFACE Output (Average Moisture)**

```
** Generated by AERSURFACE, dated 13016
** Generated from "tennessee_NLCD_erd050500.tif"
** Center Latitude (decimal degrees):     36.110535
** Center Longitude (decimal degrees):   -86.688137
** Datum: NAD83
** Study radius (km) for surface roughness:   1.0
** Airport? Y, Continuous snow cover? N
** Surface moisture? Average, Arid region? N
** Month/Season assignments? Default
** Late autumn after frost and harvest, or winter with no snow: 12 1 2
** Winter with continuous snow on the ground: 0
** Transitional spring (partial green coverage, short annuals): 3 4 5
** Midsummer with lush vegetation: 6 7 8
** Autumn with unharvested cropland: 9 10 11

   FREQ_SECT  SEASONAL 12
   SECTOR   1    0   30
   SECTOR   2   30   60
   SECTOR   3   60   90
   SECTOR   4   90  120
   SECTOR   5  120  150
   SECTOR   6  150  180
   SECTOR   7  180  210
   SECTOR   8  210  240
   SECTOR   9  240  270
   SECTOR  10  270  300
   SECTOR  11  300  330
   SECTOR  12  330  360
```

```
**           Season   Sect    Alb      Bo        Zo
   SITE_CHAR    1       1     0.17     0.98     0.024
   SITE_CHAR    1       2     0.17     0.98     0.027
   SITE_CHAR    1       3     0.17     0.98     0.032
   SITE_CHAR    1       4     0.17     0.98     0.023
   SITE_CHAR    1       5     0.17     0.98     0.020
   SITE_CHAR    1       6     0.17     0.98     0.143
   SITE_CHAR    1       7     0.17     0.98     0.213
   SITE_CHAR    1       8     0.17     0.98     0.078
   SITE_CHAR    1       9     0.17     0.98     0.076
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   SITE_CHAR    2       2     0.15     0.74     0.035
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   SITE_CHAR    2       4     0.15     0.74     0.031
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   SITE_CHAR    2       9     0.15     0.74     0.105
   SITE_CHAR    2      10     0.15     0.74     0.143
   SITE_CHAR    2      11     0.15     0.74     0.077
   SITE_CHAR    2      12     0.15     0.74     0.046
   SITE_CHAR    3       1     0.16     0.58     0.053
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   SITE_CHAR    3       3     0.16     0.58     0.046
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   SITE_CHAR    3       7     0.16     0.58     0.488
   SITE_CHAR    3       8     0.16     0.58     0.226
   SITE_CHAR    3       9     0.16     0.58     0.194
   SITE_CHAR    3      10     0.16     0.58     0.227
   SITE_CHAR    3      11     0.16     0.58     0.123
   SITE_CHAR    3      12     0.16     0.58     0.068
   SITE_CHAR    4       1     0.16     0.98     0.046
   SITE_CHAR    4       2     0.16     0.98     0.042
   SITE_CHAR    4       3     0.16     0.98     0.041
   SITE_CHAR    4       4     0.16     0.98     0.048
   SITE_CHAR    4       5     0.16     0.98     0.042
   SITE_CHAR    4       6     0.16     0.98     0.323
   SITE_CHAR    4       7     0.16     0.98     0.481
   SITE_CHAR    4       8     0.16     0.98     0.213
   SITE_CHAR    4       9     0.16     0.98     0.178
   SITE_CHAR    4      10     0.16     0.98     0.221
   SITE_CHAR    4      11     0.16     0.98     0.121
   SITE_CHAR    4      12     0.16     0.98     0.061
```

## GAF ONSITE AND BNA SURFACE IMAGES

**Figure A-1**
**GAF Elevation Variation (1km radius) – Source: National Elevation Dataset (NED)**

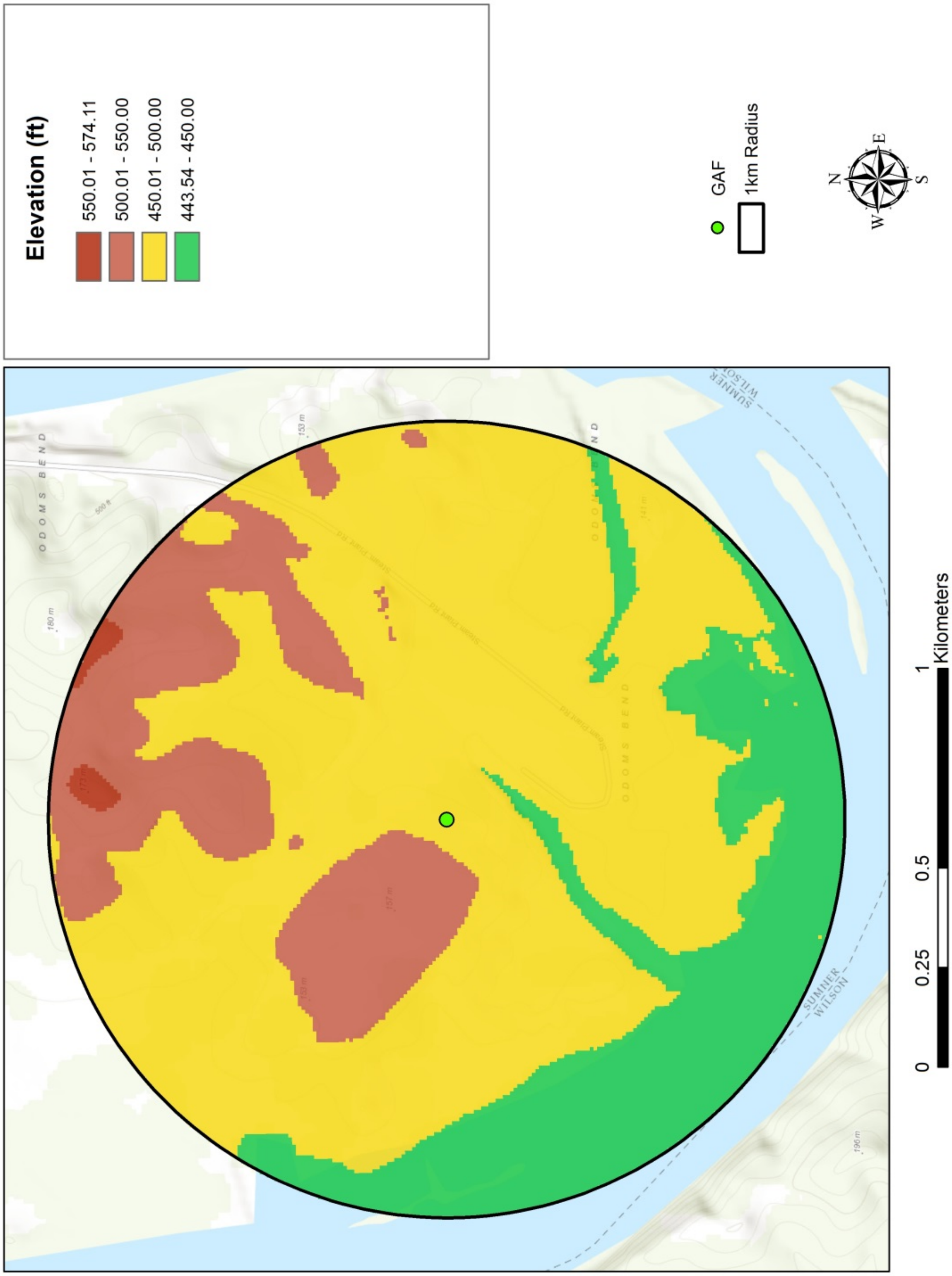


**Figure A-2**
**BNA Elevation Variation (1km radius) – Source: National Elevation Dataset (NED)**

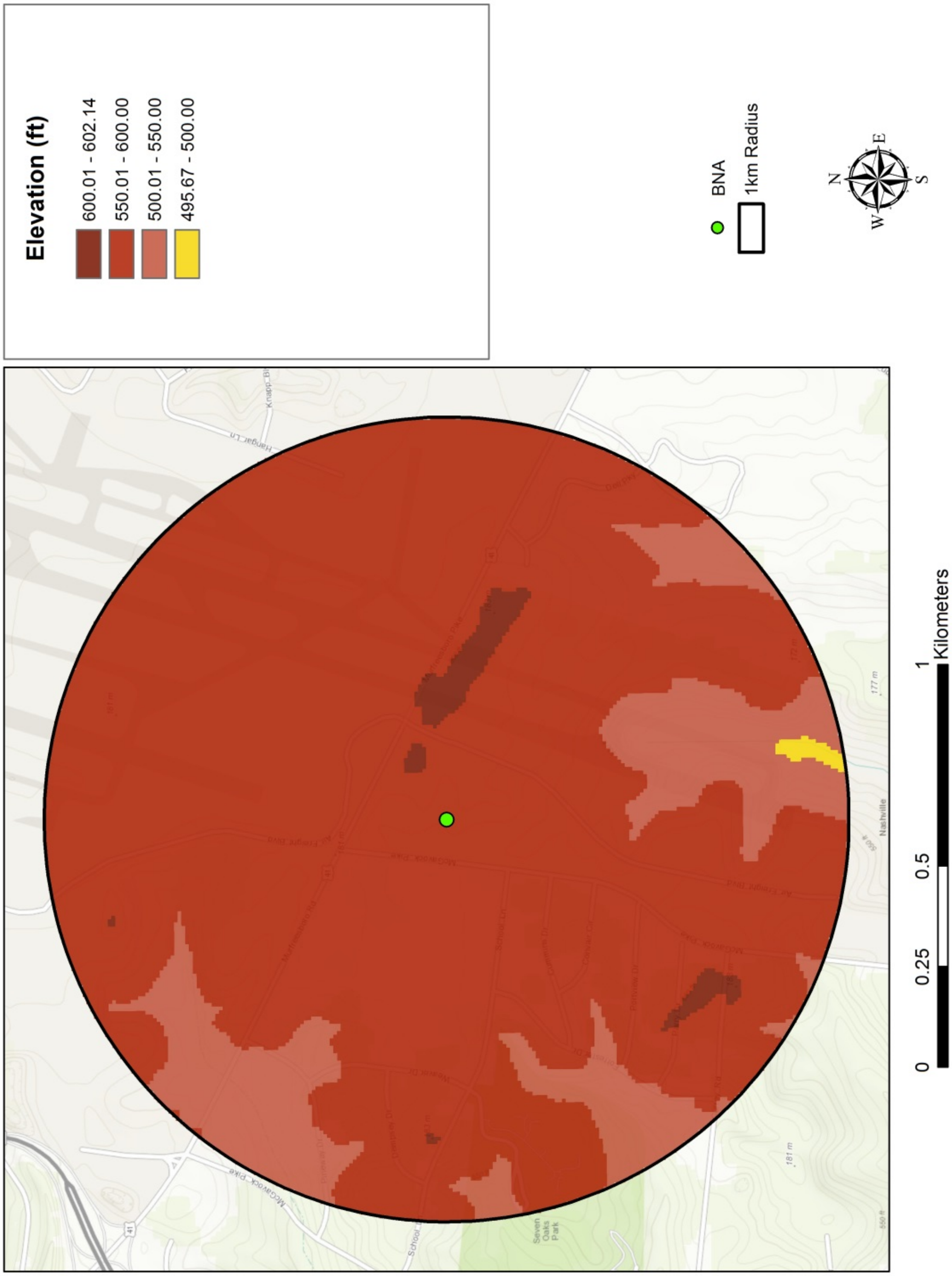


**Figure A-3**
**GAF Arial Image (1km radius) – Source: National Agriculture Imagery Program (NAIP)**

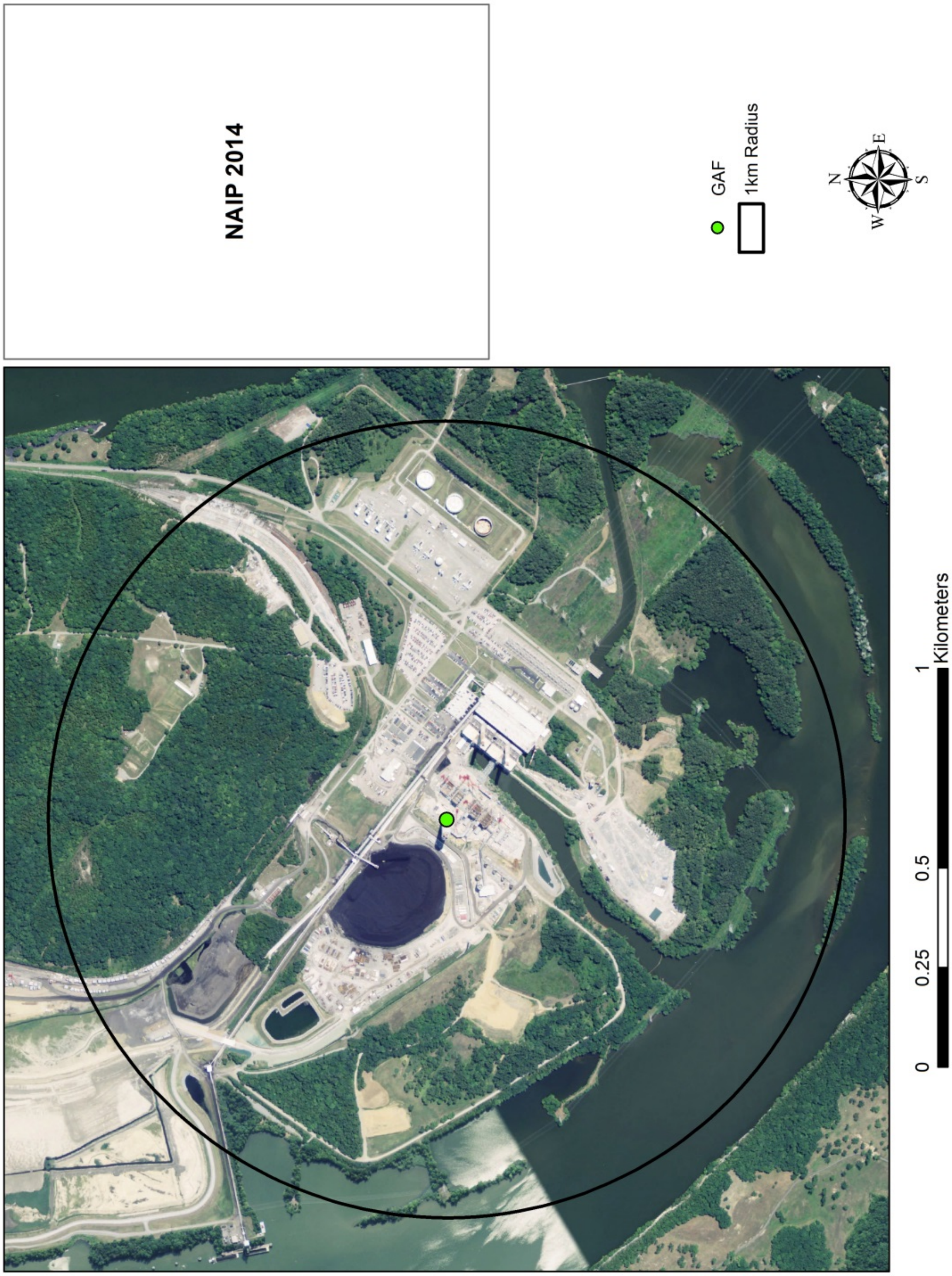
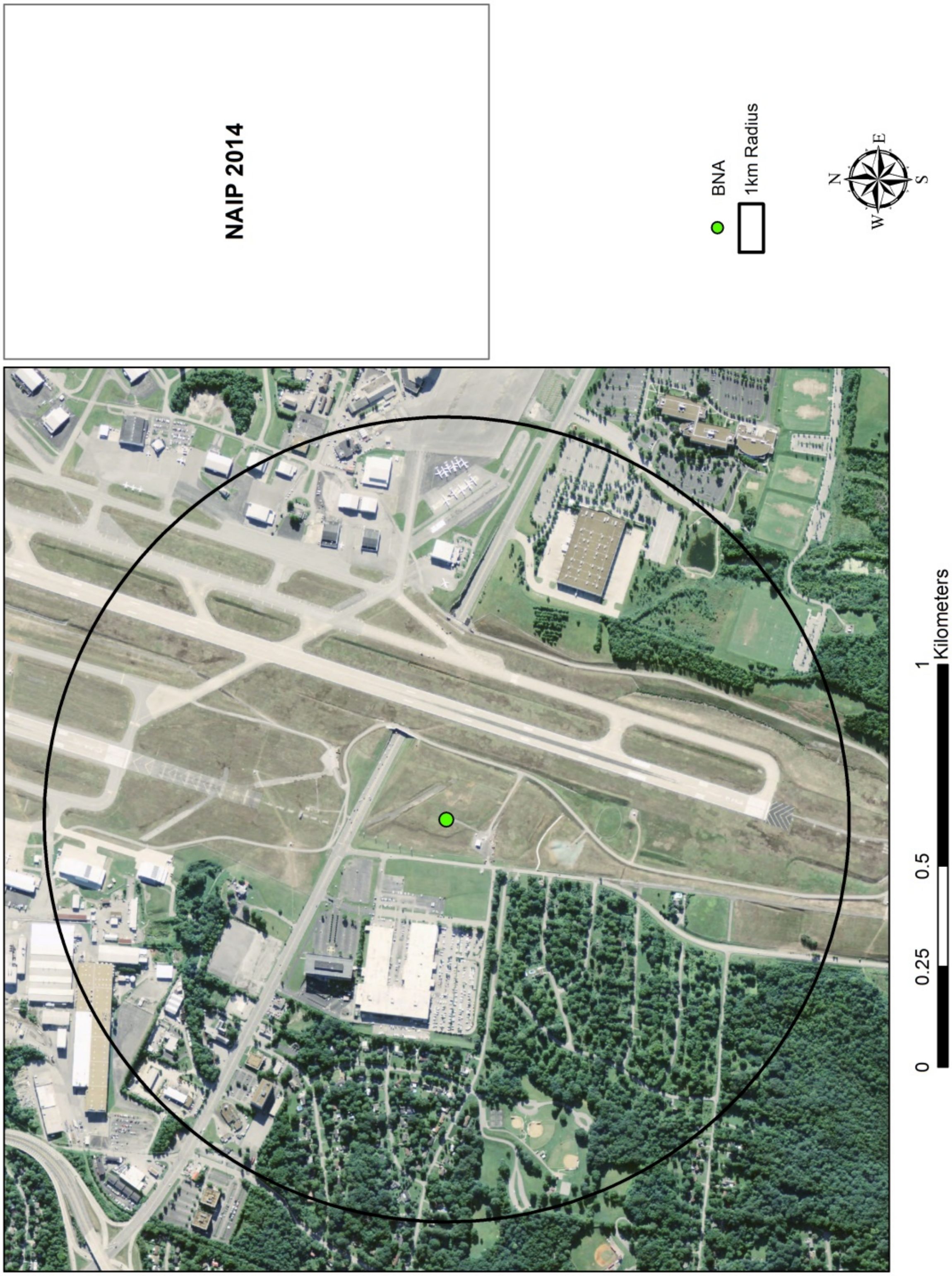


**Figure A-4**
**BNA Arial Image (1km radius) – Source: National Agriculture Imagery Program (NAIP)**



## APPENDIX B
## AVERAGE YEARLY SURFACE MOISTURE CONDITIONS: GAF AND BNA SITES

| Year | Surface Moisture Conditions | |
|---|---|---|
| | GAF [1] | BNA [2] |
| 2012 | Average | Average (45.86 in.) |
| 2013 | Wet | Wet (54.90 in.) |
| 2014 | Average | Average (50.61 in.) |

Notes:

1. The GAF moisture classification was determined from analysis of annual precipitation departures (percent of normal) provided by the NWS Advanced Hydrologic Prediction Service (http://water.weather.gov/precip/). For each year, GAF location (Lat: 36.3165, Lon: -86.4031) in Sumner County, Tennessee, was classified as wet when the annual departure was greater than 125 percent, dry when the annual departure was less than 50 percent, and normal if neither condition occurred. These wet / dry relationships were established based on a comparison of the actual annual precipitation ($30^{th}$ and $70^{th}$ percentiles) at the Nashville International Airport (BNA) with the indicated annual departure values.
2. The 30-year (1981-2010) precipitation normal for the BNA location (Lat: 36.110535, Lon: -86.688137) is 47.25 inches; the $30^{th}$ percentile is 42.29 inches; and the $70^{th}$ percentile is 52.90 inches. The $30^{th}$ and $70^{th}$ percentiles were calculated in Microsoft Excel using the percentile function. Source: http://www.ncdc.noaa.gov/cag/.

| Nashville, TN Annual Precipitation January-December 1981-2010 | | | |
|---|---|---|---|
| Date | Precipitation (in.) | Date | Precipitation (in.) |
| 1981 | 41.69 | 1996 | 48.66 |
| 1982 | 49.44 | 1997 | 54.96 |
| 1983 | 51.76 | 1998 | 52.01 |
| 1984 | 56.51 | 1999 | 41.84 |
| 1985 | 30.94 | 2000 | 42.48 |
| 1986 | 31.62 | 2001 | 48.57 |
| 1987 | 30.24 | 2002 | 56.64 |
| 1988 | 31.43 | 2003 | 59.49 |
| 1989 | 57.05 | 2004 | 59.23 |
| 1990 | 47.11 | 2005 | 39.32 |
| 1991 | 46.97 | 2006 | 45.75 |
| 1992 | 39.85 | 2007 | 35.66 |
| 1993 | 44.39 | 2008 | 48.18 |
| 1994 | 59.79 | 2009 | 57.89 |
| 1995 | 48.86 | 2010 | 59.10 |
| | | **30-year Normal** | **47.25** |
| | | **$30^{th}$ Percentile** | **42.29** |
| | | **$70^{th}$ Percentile** | **52.90** |