Evaluation of Air Quality Impacts from Addition of Boiler 5 at Naval Reactors Facility

A Jeffrey Sondrup

October 2018

INL

Idaho National Laboratory

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http://www.inl.gov

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1.	Does this ECAR involve a Safety SSC?	N/A	**Professional Engineer's Stamp**
2.	Safety SSC Determination Document ID	N/A	
3.	Engineering Job (EJ) No.	N/A	PE Stamp Not Required per LWP-10010.
4.	SSC ID	N/A	
5.	Building	N/A	
6.	Site Area	Naval Reactors Facility	

7. Objective/Purpose:

This report documents an air-quality impact analysis of criteria air-pollutant emissions from the addition of Boiler 5 at NRF to support the permit application. Maximum increases in criteria air-pollutant concentrations resulting from Boiler 5 emissions were modeled and compared to significant contribution levels, as defined in IDAPA 58.01.01. Concentrations were calculated at each of 1352 potential public receptor locations on and around the INL Site, and reported at 1) receptor locations where the maximum concentrations occurred as a result of operating only Boiler 5, and 2) receptor locations where the maximum concentrations occurred as a result of baseline actual emissions (BAEs) from all significant INL sources considered in the *INL Application for a Synthetic Minor Sitewide Air Quality Permit to Construct with Facility Emission Cap Component* (DOE-ID 2017).

8. If revision, please state the reason and list sections and/or pages being affected:

NA.

9. Conclusions/Recommendations

Increases in criteria air pollutant concentrations resulting from operation of NRF Boiler 5 are considerably less than significant contribution levels at all INL public receptor locations.

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PROJECT ROLES AND RESPONSIBILITIES

Project Role	Name (Typed)	Organization	Pages covered (if applicable)
Performer	A. Jeffrey Sondrup	B360	eCR 663679
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Nuclear Safety[e]	N/A	N/A	
Document Owner[e]	A. Jeffrey Sondrup	B360	eCR 663679

Responsibilities:

a. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.

b. Concurrence of method or approach. See definition, LWP-10106.

c. Concurrence with the document's markings in accordance with LWP-11202.

d. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.

e. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.

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SCOPE AND BRIEF DESCRIPTION

NRF proposes to add a new boiler to the sources covered by the Synthetic Minor Sitewide Air Quality Permit to Construct with Facility Emission Cap Component (DOE-ID 2017). NRF Boiler 5 was installed in 2017 and first fired in early 2018 under a permit to construct exemption determination. This report documents an air-quality impact analysis of criteria air-pollutant (CAP) emissions from the addition of Boiler 5 at NRF to show that the boiler emissions meet the criteria for adding sources to the sitewide permit.

Atmospheric dispersion modeling of Boiler 5 emissions was performed using the same computer code and model parameters used to support the INL Application for a Synthetic Minor Sitewide Air Quality Permit to Construct with Facility Emission Cap Component (DOE-ID 2017), hereafter referred to as the INL Sitewide permit application. The modeling that supports the permit application is documented in Sondrup (2015).

Maximum increases in CAP concentrations resulting from Boiler 5 emissions were modeled and compared to significant contribution levels (SCLs) defined in IDAPA 58.01.01.006.109. Concentrations were calculated at each of 1352 potential public receptor locations on and around the INL Site, and reported at 1) receptor locations where the maximum concentrations occurred as a result of operating only Boiler 5, and 2) receptor locations where the maximum concentrations occurred as a result of baseline actual emissions (BAEs) from all significant INL sources considered in the INL Sitewide permit application (DOE-ID 2017). These sources include primarily boilers, emergency generators, certain mobile equipment, and emissions from waste-retrieval and treatment operations.

DESIGN OR TECHNICAL PARAMETER INPUT AND SOURCES

Input data and sources are provided in the Discussion/Analysis section.

RESULTS OF LITERATURE SEARCHES AND OTHER BACKGROUND DATA

See Discussion/Analysis Section and References Section.

ASSUMPTIONS

See Discussion/Analysis Section.

COMPUTER CODE VALIDATION

All computer modeling was performed with the EPA-approved AERMOD dispersion-modeling system (Version 14134) (EPA 2004a). The meteorological data set was produced with the companion AERMET model (Version 14134) (EPA 2004b) using surface data from the Idaho Falls airport, and upper-air data from Boise International Airport supplied by Idaho Department of Environmental Quality (DEQ). Onsite meteorological data from the Grid 3 Mesonet tower located near the center of INL (north of INTEC) and supplied by the local National Oceanic and Atmospheric Administration (NOAA) office was used for surface wind directions and wind speeds. Surface data (i.e., land use data that define roughness, albedo, Bowen ratio, and other parameters) were processed using the AERSURFACE utility (Version 13016) (EPA 2013).

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Building wake-effect parameters for the Boiler 5 stack were determined with the EPA Building Profile Input Program with Plume Rise Enhancement (BPIP-PRIME) (EPA 2004c), Version 04274, designed for use with the AERMOD model. BPIP-PRIME was run under the BEEST for Windows platform (BEE-Line Software, Version 9.95).

A Perl script (aermodpp.pl) was used to post-process the pollutant-concentration output files generated by AERMOD using the PLOTFILE command. The script extracts concentrations for each averaging period and writes the results to a text file that was imported into a spreadsheet. This script is included as Appendix A.

Microsoft Excel 2013 (15.0.5041.1000) MSO (15.0.5031.1000) 32 bit, part of Microsoft Office Professional Plus 2013, was used for supporting calculations. Cell formulas were checked for accuracy, and a sample of the calculations was checked by hand. All formula cells have been locked for editing and password protected.

Except for a few modifications, the models and modeling methodology performed is the same as was performed for the INL Sitewide permit application (DOE-ID 2017). The INL Sitewide permit modeling (Sondrup 2015) and the protocol document for conducting the modeling (Sondrup and Verdoorn 2015) were reviewed extensively and approved by Idaho DEQ personnel for purposes of issuing the permit.

All electronic files, including computer code input, output, and spreadsheet files are contained in a zip file that can be accessed by selecting "Additional Information" (select Native File) in the INL Electronic Document Management System.

DISCUSSION/ANALYSIS

Atmospheric Dispersion Modeling

The atmospheric dispersion modeling is based on the methodology used for the INL Sitewide permit application (DOE-ID 2017). The same base AERMOD input files were used with some modifications and the same meteorological data files were used. The modifications are described in this section with a basic description of the modeling methodology. For a complete description of the modeling methodology, see Sondrup (2015).

Meteorological Data

Five years of onsite meteorological data (2000 to 2004) from the INL Site Grid 3 Mesonet tower was provided by R. Eckman of the Idaho Falls' NOAA office in five files (GRI2000.MET, GRI2001.MET, GRI2002.MET, GRI2003.MET and GRI2004.MET). The Grid 3 Mesonet tower is the most central tower to all INL facilities and located only 6.3 km from NRF. The data include delta temperature (°C), precipitation amount (cm), insolation (total amount of solar radiation energy received per unit area measured in watts/m^2), pressure (millibars × 10), measurement height (m), wind speed (m/s), wind direction (degrees), temperature (°C), and standard deviation of the horizontal wind angle. These data were converted to the AERMET units and wind speed measured at the 15 m height was extrapolated to 10 m by NOAA and read into AERMET (Version 14134).

Surface data from the Idaho Falls Airport was obtained from the National Climatic Data Center (http://www1.ncdc.noaa.gov/pub/data/noaa/) in TD-3503 (ISH) format, which is read directly by AERMET. Upper air data from the Boise International Airport in the FSL format were provided by Idaho

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DEQ and were used without modification. The onsite, surface, and upper air data files were processed with AERMET (Version 14134) to provide a 5-year surface-data file (grd35yr.sfc) and upper-air-data file (grd35yr.pfl) for running AERMOD.

Terrain Effects

Terrain data for AERMOD were processed using the AERMAP pre-processor. The processed data consists of terrain elevation and hill heights for each defined receptor. These data were generated by Idaho DEQ modeling staff using AERMAP (Version 11103) and provided to INL in the file *AERMAP723.rcf* for the 1,352 public receptor locations. Receptor locations are defined in UTM coordinates (Zone 12) based on datum NAD 83. The terrain data were extracted from 1 arc-second seamless National Elevation Database files covering the area between -112.005 and -113.644 degrees longitude and 42.967 and 44.287 degrees north latitude. All coordinates and elevations are in meters. The provided file *AERMAP723.rcf* is a text file written in AERMOD input format and was used in each AERMOD input file.

Land surface data (e.g., roughness height, albedo, and terrain) were processed for the Grid 3 Mesonet station using the AERSURFACE utility (Version 13016) (EPA 2013) and National Land Cover Data file, idaho_NLCD92.tif. The National Land Cover Data are derived from the early to mid-1990s Landsat Thematic Mapper satellite data and have a 21-class land-cover classification scheme applied consistently over the United States. The spatial resolution of the data is 30 m and mapped in the Albers Conic Equal Area projection, NAD 83. The National Land Cover Data are provided on a state-by-state basis in the website http://www.webgis.com/nlcd92.html.

Stack and Emission Parameters

Figure 1 shows the approximate Boiler 5 stack location. The stack parameters for Boiler 5 were provided by NRF (R. Brown email to A.J. Sondrup, October 10, 2017) and shown in Table 1.

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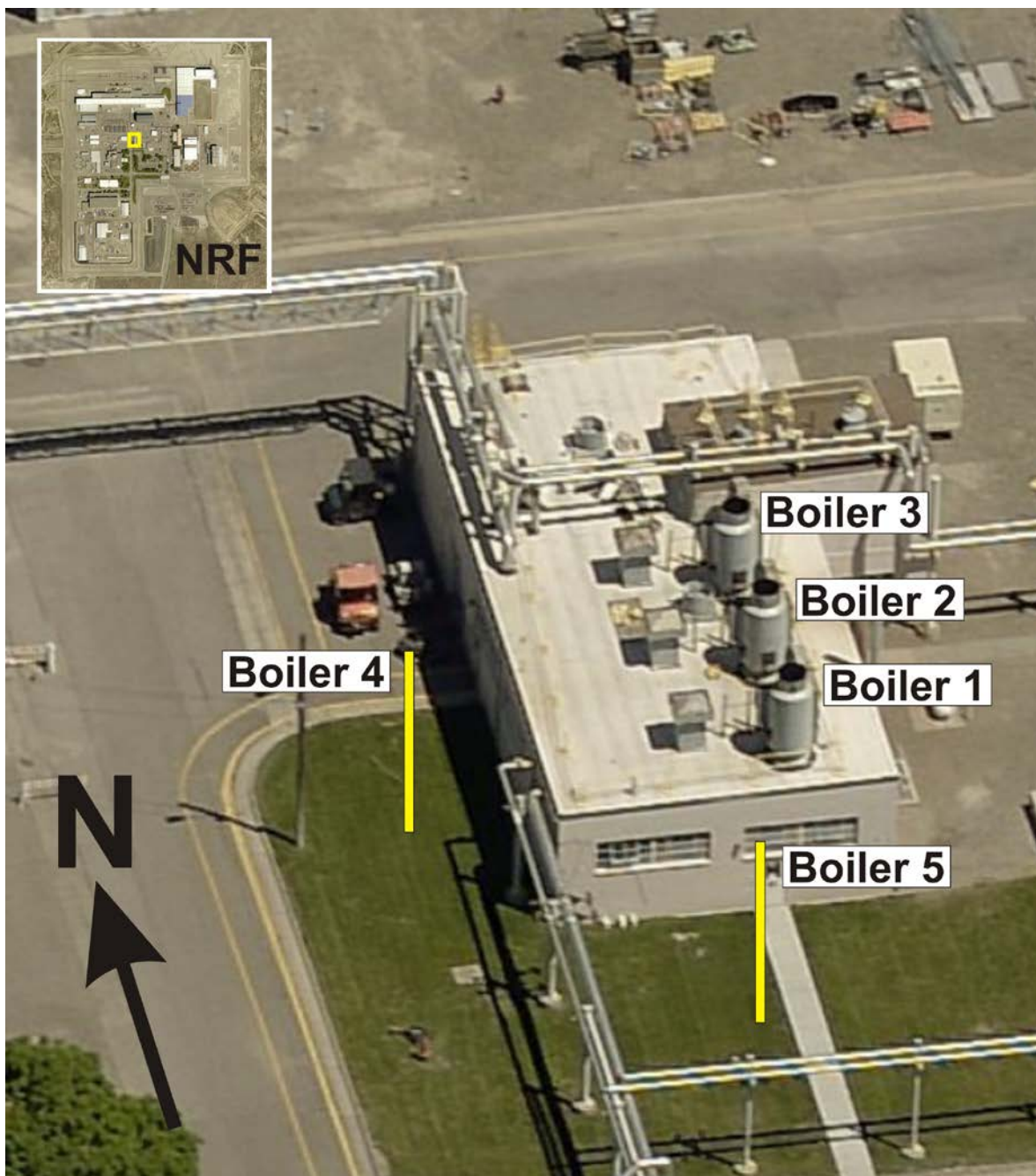ECAR No.:   4264   Rev. No.: 1   Project No.:   N/A   Date: 10/16/2018

Figure 1. Location of NRF Boiler stacks 1-3 and approximate location of Boiler stacks 4 and 5. The area shown in the photo is indicated by the yellow highlighted area in the facility map inset (upper left).

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Table 1. Boiler 5 stack parameters.

Stack Parameter	Value
UTM Easting (datum NAD 83)	345,438 m
UTM Northing (datum NAD 83)	4,834,667 m
Base Elevation	1,479 m
Height	6.81 m
Exit Temperature	509 K
Exit Velocity	20 m/s
Diameter	0.61 m
Orientation	Vertical
Rain Cap	Yes

a.   Exit velocity for stacks with rain caps is set to 0.001 m/s in AERMOD
     per Idaho DEQ modeling guidelines (DEQ 2013).

Boiler 5 has a rated capacity of 29.3 MMBtu/hr and a design-rated fuel-consumption rate of 209.2 gal/hr #2 Diesel. Emission rates were calculated using the design-rated fuel-consumption rate and appropriate emission factors using the following formula:

$$ER\left(\frac{lb}{hr}\right) = \frac{FR\left(\frac{gal}{hr}\right)EF\left(\frac{lb}{1000\ gal}\right)}{1000\left(\frac{gal}{1000\ gal}\right)}$$

Where

   ER = emission rate

   FR = design rated fuel consumption rate

   EF = emission factor

   HV = heating value of fuel oil (140,000 Btu/gal)

Emission factors were taken from AP-42 (EPA 2009). The emission factors and emission rates are shown in Table 2. Emission rates were converted from lb/hr to g/s for input to AERMOD.

Table 2. CAP emission factors and rates.

CAP	Emission Factor (lb/1000 gal)	Emission Rate (lb/hr)	Emission Rate (g/s)
SO_2	0.213[a]	0.0445	0.00561
NO_X	20[a]	4.18	0.527
CO	5[a]	1.05	0.132
PM-10/2.5[c]	2.3[b,c]	0.481	0.0606

a. SO_2, NO_X, CO emission factor from AP-42 (EPA 2009) Table 1.3-1.
b.   PM-10 emission factor from AP-42 (EPA 2009) Table 1.3-2 (Condensable) and 1.3-6.
c.   The PM-10 emission factor was also used for PM-2.5.

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Building Wake Effects

Although public receptors are far enough away from NRF that wake effects are likely to be small, wake effects were included to be conservative and to be consistent with the INL sitewide permit modeling (Sondrup 2015). Wake-effect parameters were determined using the EPA Building Profile Input Program with Plume Rise Enhancement (BPIP-PRIME) (EPA 2004c), Version 04274, designed for use with the AERMOD model. BPIP-PRIME was run under the BEEST for Windows platform (BEE-Line Software, Version 9.95).

Wake-effect parameters were obtained by importing an aerial map of NRF buildings and structures into the BEEST program. The map was generated using the INL iMAP application (https://maps.inl.gov). iMAP is a web-based GIS (geographic information system) application that provides access to map layers and other information about INL facilities and structures. The map was imported into BEEST and positioned (georeferenced) using UTM coordinates. Building, tank, and other structure outlines were created within BEEST.

According to the BPIP user guide (EPA 2004c); structures produce an area of wake effect that extends to a distance of 5L where L is the lesser of the building height or projected building width. Building heights were determined using the measuring tools and the Pictometry® feature in iMAP. Pictometry® is a patented aerial image capture process that produces imagery showing the fronts and sides of buildings and locations on the ground.

Figure 2 shows a three-dimensional (3-D) wireframe building image from the BEEST software. Stack locations are shown in red and labeled. All buildings that could potentially cause a wake effect for each CAP stack source at NRF are shown even though Boiler 5 was the only stack considered. For multi-tiered structures, the tiers were included, or the entire building height was assumed to be equal to the height of the tallest tier. This was very conservative for some buildings.

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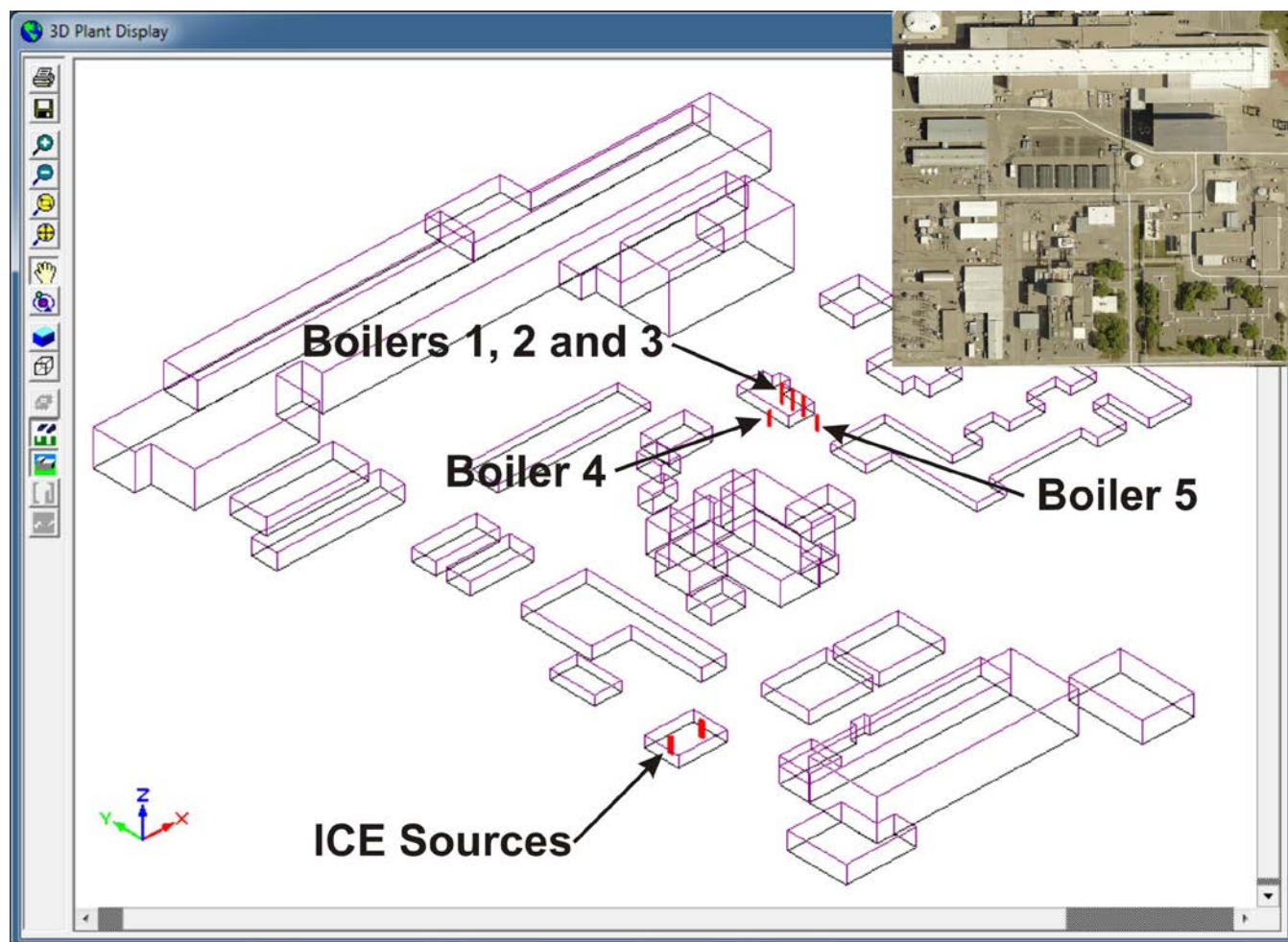

Figure 2. Wireframe image of buildings at NRF used for calculating wake effects. Facility map shown in upper right corner.

Receptor Network

Receptor locations defined in UTM coordinates (Zone 12) based on datum NAD 83, were provided by Idaho DEQ modeling staff in the file *AERMAP723.rcf*. This is a text file written in AERMOD format and was used directly in each AERMOD input file. The 1,352 receptor locations shown in Figure 3 are spaced approximately every 500 meters around the INL boundary and along highways that transect the INL. Finer spacing (~100 meters) was used near facilities where concentrations may be higher (i.e., along Highway 20/26 between AMWTP and CFA, from Highway 20 to the MFC guard gate, and along Highway 33 near the entrance to SMC. Finer spacing was also used in gridded areas around EBR-I (~40 m) and Atomic City (~200 meters). All receptors were considered for each pollutant and averaging period for determining maximum impacts.

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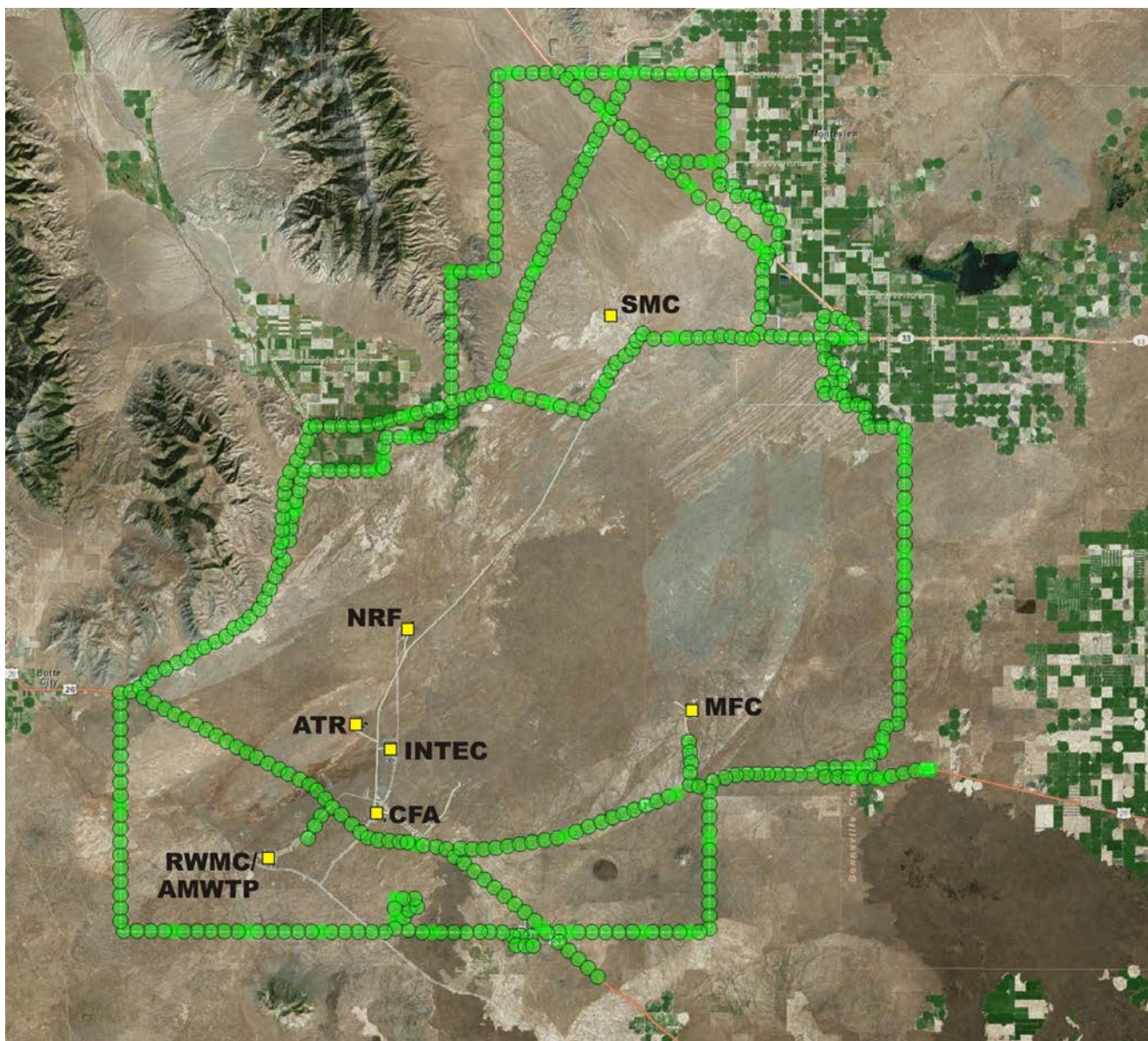ECAR No.: 4264   Rev. No.: 1   Project No.:   N/A   Date: 10/16/2018

Figure 3. Public receptor locations (green circles) for INL AERMOD modeling. Most circles indicate two or more locations.

RESULTS

IDAPA 58.01.01 defines a significant contribution as any increase in ambient concentration which would exceed the SCL values in Table 3. This section presents the increases in ambient concentration resulting from only Boiler 5 emissions. The increases are the maximum (overall first highest) values during the 5-year period considered. The concentration results for each CAP and averaging period are presented at the following two locations in Tables 3 and 4 respectively.

1.   Table 3 contains maximum concentration increases at any of the 1352 public receptor locations. The table also contains the receptor locations where the maximums occurred (see Figure 4).

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2.   Table 4 contains maximum concentration increases at receptor locations where the maximum concentrations occurred from baseline actual emissions (BAEs) from all significant INL sources considered in the INL Sitewide permit application (DOE-ID 2017). These sources include primarily boilers, emergency generators, certain mobile equipment, and emissions from waste-retrieval and treatment operations. The maximum concentrations from these sources are also shown in the table, along with the receptor locations where they occurred (see Figure 4 for receptor locations).

Table 3 shows that the maximum concentration increases from Boiler 5 emissions at all receptor locations are much less than the SCLs. The largest is the PM-2.5 24-hr concentration at 15.4% of the SCL. The receptor locations where the maximum increases occur are located north of NRF.

Table 4 shows that the maximum concentration increases from Boiler 5 at the maximum concentration locations from INL BAEs are also much less than SCLs. The largest is the PM-2.5 24-hr concentration at 2.7% of the SCL. As expected, the concentration increases in Table 4 are less than the values in Table 3.

Table 3. Maximum concentration increases at any public receptor from Boiler 5 emissions.

Pollutant	Averaging Period	SCL ($\mu g/m^3$)	Maximum Concentration Increase ($\mu g/m^3$)	Receptor # of Maximum Concentration Increase[a]	Maximum Concentration Increase as % of SCL
SO$_2$	3-hr	25	0.115	651	0.5%
	24-hr	5	0.017	131	0.3%
	Annual	1	0.00049	124	0.05%
NO$_X$[b]	Annual	1	0.046	124	4.6%
CO	1-hr	2000	8.11	651	0.4%
	8-hr	500	1.04	746	0.2%
PM-2.5[c]	24-hr	1.2	0.185	131	15.4%
	Annual	0.3	0.0053	124	1.8%
PM-10[c]	24-hr	5	0.185	131	3.7%
	Annual	1	0.0053	124	0.5%

a.   See Figure 4 for receptor locations.
b.   No credit taken for reduction or conversion of NO$_X$ to NO$_2$.
c.   PM-2.5 and PM-10 modeled as total particulate matter and includes condensable PM.

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Table 4. Maximum concentration increases from Boiler 5 emissions at the overall maximum concentration locations from all INL baseline actual emissions.

Pollutant	Averaging Period	SCL ($\mu g/m^3$)	Receptor # of Maximum Concentration from all INL BAEs[a]	Maximum Concentration Increase from Boiler 5 emissions at INL BAE maximum receptor locations ($\mu g/m^3$)	Maximum Concentration Increase from Boiler 5 Emissions as % of SCL
SO_2	3-hr	25	563	0.0103	0.04%
	24-hr	5	1298	0.00301	0.06%
	Annual	1	1298	0.00014	0.01%
NO_X[b]	Annual	1	1298	0.0135	1.4%
CO	1-hr	2000	563	0.724	0.04%
	8-hr	500	1298	0.180	0.04%
PM-2.5[c]	24-hr	1.2	1298	0.033	2.7%
	Annual	0.3	1298	0.0016	0.5%
PM-10[c]	24-hr	5	1298	0.033	0.7%
	Annual	1	1298	0.0016	0.2%

a.   See Figure 4 for receptor locations.
b.   No credit taken for reduction or conversion of NO_X to NO_2.
c.   PM-2.5 and PM-10 modeled as total particulate matter and includes condensable PM.

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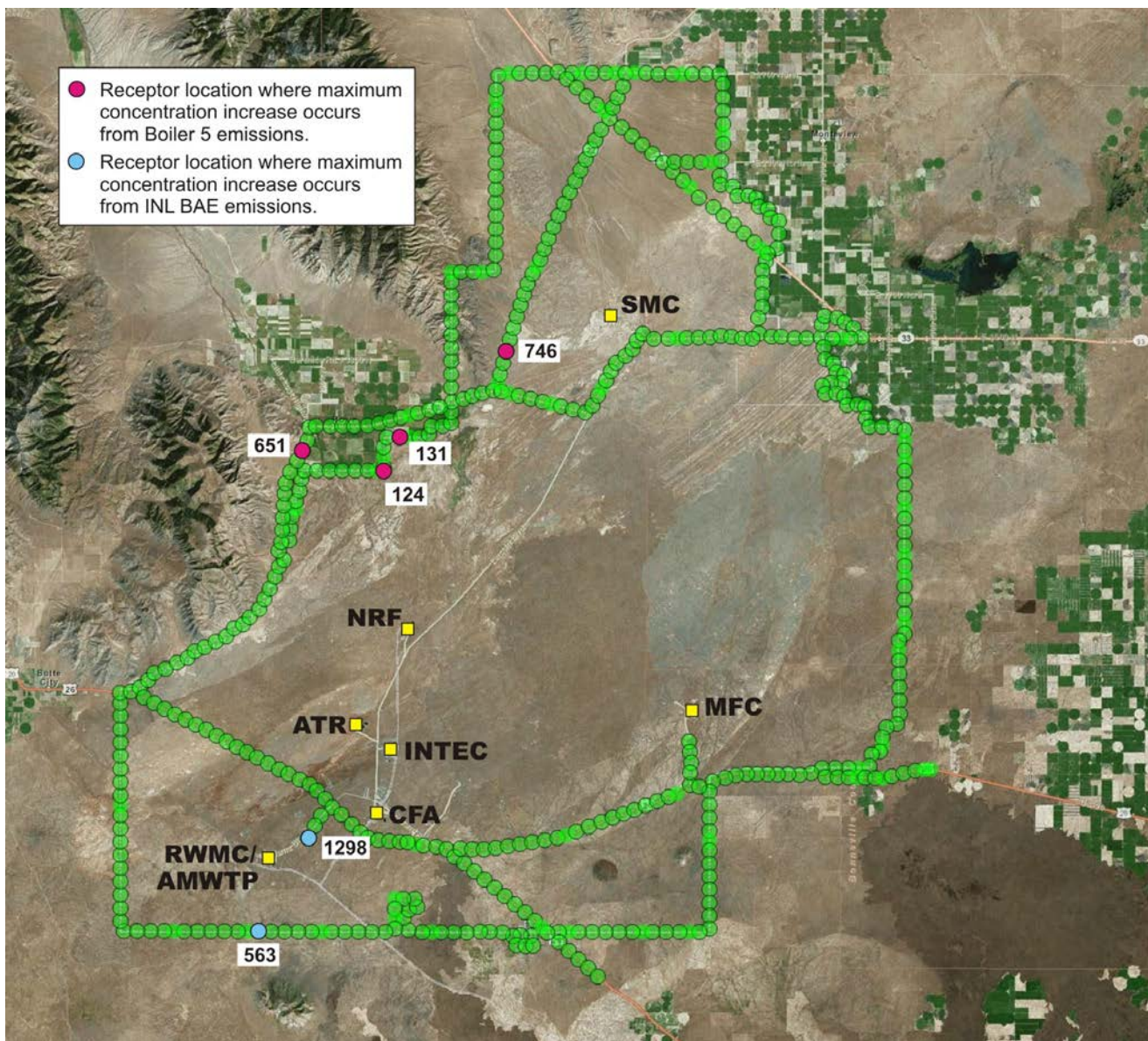

Figure 4. Maximum concentration increase locations for Boiler 5 emissions (red, see Table 3), and INL BAEs (blue, see Table 4).

CONCLUSION

Maximum increases in CAP concentrations resulting from the addition of NRF Boiler 5 emissions are considerably less than significant contribution levels at all INL public receptor locations.

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Appendix A

Perl Script for Post-processing AERMOD Results

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Appendix A
Perl Script for Post-processing AERMOD Results

This appendix contains the listing of the Perl script that is used to post-process the pollutant concentration output files generated by AERMOD using the PLOTFILE command. The script extracts concentrations for each averaging period and writes the results to a text file that is imported into a spreadsheet.

```perl
# Aermodpp.pl
# Units of source : g/s
# Units of conc: ug/m**3

    if($ARGV[0] eq "?")
    {
      print "USAGE: Aermodpp.pl [data file] [source name] [pollutant name] NOTE: Default units are g/s for source and ug/m3 for conc\n";
      print "If units are not default, then change $cf variable \n";
    }


# Convert from lbs/hr to g/s: 1 lb/hr=0.126 g/s
# convert from ug/m3 to g/m3: 10^6 ug per g
# cf = 1/0.126 x 10^-6 = 7.9367e-6
#     $cf=1.0e-6;   # conversion from ug/m**3 to g/m**3
#     $cf = 7.9365E-6;
# Set conversion to 1.0 so the Chi/Q values are ug/m^3 per g/s
    $cf=1.0;


    $filein=$ARGV[0];
#    $fileout=$ARGV[1];
    $fileout="output.txt";
    $srcname=$ARGV[1];
    $pollutant=$ARGV[2];
# check to see if $fileout is present
    $flag=0; # if this flag is 0, then do not print header
    open AEROUT,"<$fileout" or $flag=1;
    close (AEROUT);

    open (AERIN, "<$filein") || die "$filein could not be found";
    open (AEROUT, ">>$fileout");   # open file for append
    if($flag==1)
    {
      print AEROUT "RecID,          ChiQ,          AvgTime,      ChiQID,   PollutantType \n";
    }
    while ($line = <AERIN>)
    {

      if ($line=~/FOR A TOTAL OF/)
      {
        @field = split /[ \t]+/, $line;
        $n=$field[5];
        print "Number of receptors $field[5] \n";
        for $i (1..3)                   # skip three lines
        {
          $line=<AERIN>;
        }

        for $i (1..$n)
        {
          $line=<AERIN>;
          $line =~ s/^[ ]+//; # delete initial spaces
          chomp ($line); # remove carrige return
          @field = split /[ \t]+/, $line;
          $ChiQ=$field[2]*$cf;
          printf AEROUT " %4d,    %11.4e, %12s, %12s, %12s \n",$i,$ChiQ,$field[6],$srcname,$pollutant;

        }
      }
    }
    close (AERIN);
    close (AEROUT);
```