Minnesota Pollution Control Agency
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AQDM-06sp

Air Quality Dispersion Modeling Report
Report Form for Special Project Modeling

Doc Type: Air Dispersion Modeling

Acronym Information on Page 7

Facility Information

Today's date (mm/dd/yyyy): 07/05/2016

Project name: AERMOD Evaluation of Outdoor Wood Boiler Stack Height and Setback Distance

Date Charter Created: 11/18/2015

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This report is associated with (check all that apply):

- ☐ Permit application
- ☐ Permit requirement
- ☐ SIL-only analysis
- ☒ Other: Air dispersion modeling to evaluate outdoor wood boiler (OWB) stack height and set back distances based on the EPA certification status.

Project Description (50 words or less)

AERMOD was used to evaluate air quality based on changes in outdoor wood boiler (OWB) stack height and setback distance using the 24-hour particulate matter less than 2.5 microns (PM2.5) National Ambient Air Quality Standards (NAAQS).

Files to Accompany Modeling Report

Include the following files with the completed modeling report form. Use checkbox to indicate that all applicable files are included.

1. ☒ AERMOD input files (*.inp, *.adi, *.ami)
   ☒ AERMOD output files (*.out, *.ado, *.amo)
   ☒ AERMOD plot files (*.plt)
   ☐ AERMOD post files (*.pst) (If applicable)
   ☐ AERMOD event files (*.evi, *.evo) (If applicable)
   ☒ AERMOD miscellaneous/other files (MAXDCONT, ?, ?, etc.) (If applicable)
2. AERMET files: ☒ *.sfc ☒*.pfl
3. BPIP-PRIME files: ☒ Input (*.bpi) ☒ Output (*.bpo, *.sum) (If applicable)
4. AERMAP files: ☒ Terrain (*.dem(s), *.tif (NED files)), ☒ Input (*.ami), ☒ Output (*.rou, *.sou, etc.) (If applicable)
5. Background data files: ☐ Background concentrations for applicable pollutants (seasonal, monthly, daily, hourly, etc.) (If applicable)
6. Modeling Results: ☒ Figures (*.jpeg, *.pdf), ☐ GIS Maps (*.shp)

aq2-204

7. AQDM-02 spreadsheet*: ☒

8. Other files and supporting documents (paved roads fugitive dust modeling output files, etc.):

**Provide the final spreadsheet (i.e. AQDM-02) and indicate/highlight changes.*

Section 1. Modeling Protocol

1. The Air Dispersion Modeling presented in this report is based on a Protocol that has been:
   ☒ Approved ☐ Conditionally approved ☐ *MPCA approval date (mm/dd/yyyy): 02/01/2016
   **This is the date given on AQDM-04 form*

2. Does this Modeling submittal **completely** follow the Approved Protocol? ☒ Yes ☐ No
   If yes, proceed to Section 3.
   If no, proceed to Section 2.

Section 2. Changes to Modeling Protocol

Table 1: Protocol Changes (Please indicate which sections in Approved Protocol contain changes.)

Modeling protocol by sections

Section and section name	Change/No change
Files to accompany protocol	No change
Section A *Purpose for Air Dispersion Modeling and Related Information*	No change
Section B *EPA Pre-Processors and EPA Post-Processors*	No change
Section C *Model Selection and Options (Key CO Pathway Inputs)*	No change
Section D *Emission Source Characterizations and Parameters (Key SO Pathway Inputs)*	No change
Section E *Paved Roads Fugitive Dust (as per MPCA April 25, 2011 Policy)*	No change
Section F *Receptors (RE Pathway)*	No change
Section G *Meteorological Data (ME Pathway)*	No change
Section H *SIL Analysis and Results*	No change
Section I *Background Values*	No change
Section J *Nearby Sources*	No change
Section K *Pollutant-based Considerations*	No change

Section 2.1: Detailed Changes to Modeling Protocol

Please provide specific information corresponding to those sections in Table 1 where changes are indicated.

Not applicable

Section A. Purpose for air dispersion modeling and related information

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section B. EPA pre-processors and EPA post-processors

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section C. Model selection and options (Key CO pathway inputs)

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section D. Emission source characterizations and parameters (Key SO pathway inputs)

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section E. Paved roads fugitive dust

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section F. Receptors (RE pathway)

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section G. Meteorological data (ME pathway)

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section H. SIL analysis and results

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section I. Background values

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section J. Nearby sources

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section K. Pollutant-based Considerations

MPCA approved change: ☐ Yes ☐ No Date (mm/dd/yyyy): _____

Describe changes and/or indicate section item number(s):

Not applicable

Section 3. Modeling Results

Table 1: Pollutants and averaging periods (Check all the boxes for each pollutant and averaging period(s) modeled.)

Pollutant	Averaging Period	Standard		Increment	SIL-only
		NAAQS	MAAQS		
CO	1-hr	☐	☐	☐	☐
	8-hr	☐	☐	☐	☐
Lead	Rolling 3 mo. Avg	☐	☐	☐	☐
	Quarterly Avg	☐	☐	☐	☐
NO_2	1-hr	☐	☐	☐	☐
	Annual	☐	☐	☐	☐
SO_2	1-hr	☐	☐	☐	☐
	3-hr	☐	☐	☐	☐
	24-hr	☐	☐	☐	☐
	Annual	☐	☐	☐	☐
PM_{10}	24-hr	☐	☐	☐	☐
	Annual	☐	☐	☐	☐
$PM_{2.5}$	24-hr	☒	☐	☐	☐
	Annual	☒	☐	☐	☐

Table 2: NAAQS/MAAQS modeling results (Enter modeling results along with the percent of standard.)

Pollutant	Averaging period	NAAQS standard (ug/m^3)	MAAQS standard (ug/m^3)	Total modeled concentration (includes background and nearby sources) (ug/m^3)	Percent of standard (%)	
					NAAQS	MAAQS
CO	1-hr	40,000	35,000			
	8-hr	10,000	10,000			
Lead	Rolling 3 mo. Avg	0.15	***			
	Quarterly Avg	1.5	1.5			
NO_2	1-hr	188	***			
	Annual	100	100			
SO_2	1-hr	196	1300			
	3-hr	***	1300/*915			
	24-hr	365	365			
	Annual	80	60			
PM_{10}	24-hr	150	150			
	Annual	***	50			
$PM_{2.5}$	24-hr	35	65			
	Annual	12	15			

**SO2 3-hr for Northern Minnesota is 915 ug/m3.*

Section 4. Discussion

Enter any discussion or comments on the information provided in this form (this can be used as a substitute for a written report):

Purpose

The purpose of this analysis was to evaluate setback distances for a model zoning ordinance for outdoor wood boilers. The evaluation will consider the results of an air quality dispersion modeling evaluation of stack and building height using the $PM_{2.5}$ at the property line of the nearest downwind neighbor using the 24-hour and Annual National Ambient Air Quality Standard (NAAQS) as a health-based evaluation metric.

Table #1 - National Ambient Air Quality Standards for Particulate Matter		
Averaging Time	Numeric Value	Form
1 year	12.0 $\mu g/m^3$	Annual mean, averaged over 3 years
24 hours	35 $\mu g/m^3$	98th percentile, averaged over 3 years

The modeling approach as presented below reflects previous work conducted by the states of Maine, Vermont, New York, Michigan, Linn County, Iowa, and an industry-sponsored demonstration from Central Boiler, Inc. Nearly all of the previous air quality dispersion modeling demonstrations noted above was conducted between 2006 and 2009. The current MPCA modeling approach integrates elements of the previous work by the organizations identified above, incorporating updates to the air quality dispersion model version and related inputs, (e.g., adoption of federal emission standards), which have not previously been applied to evaluate setback distances based on the current state of OWB technology and emission information.

Assumptions, Limitations, and Delimitations

The development of an air dispersion modeling design, consistent with the MPCA project charter, included a variety of decisions that reflect available resources, assumptions, limitations, and delimitations of this work. They support and complete the explanation of the modeling design and assist in the interpretation of modeled results.

- The modeled OWB units are considered to operate in an optimal fashion throughout the five-year modeling period. In practice, under normal use, OWB's become less efficient over time.
- The air quality dispersion modeling was conducted to evaluate *general* versus *specific* conditions. The goal of this work is to assist local units of government in the planning process. It is not intended as a regulatory or air quality health-modelling demonstration.
    - Consistent with the *general* versus *specific* nature of the air quality dispersion modeling, flat terrain and a generalized meteorology was used to approximate conditions throughout the state of Minnesota.
- The modeled setback distances are based on distance to property line and are consistent with legal constructs of nuisance and public health nuisance, as well as the Minnesota Ambient Air Quality Standards (MAAQS). In an effort to quantify the ambient air quality evaluation, the 24-hour and annual values of the $PM_{2.5}$ NAAQS were used, along with the form of the standard, as a measureable metric with a known inhalation health based component. It is recognized that $PM_{2.5}$ is not the only pollutant present in wood smoke – just a very commonly measured one – making it a suitable surrogate for air quality dispersion modeling purposes.
- Four outdoor wood boiler (OWBs) classifications were modeled to represent devices that are a) not certified under promulgated NSPS 40 CFR 60 Subpart QQQQ for hydronic heaters; b) Phase I of EPA's voluntary hydronic heater partnership program to qualify them for the orange tag; c) EPA Step 1 and d) EPA Step 2, the two-tiered emission limits of Subpart QQQQ. New hydronic heaters including OWBs must meet the Step 1 emission limits by May 15, 2015. New hydronic heaters including OWBs sold as of May 15, 2020 must meet the Step 2 emission limits.
- The emission rates used for uncertified OWB's may not be representative estimates of all uncertified OWB units due to the variability in unit design and operation. Based on a review of the literature, EPA emission limits may not be reflective of actual operation.
- A variety of stack heights were modeled to address the question of whether a stack height greater than the nearest neighbor roof line was an appropriate assumption for land use planning and OWB siting. It is well known that changes in stack height will result in changes in stack temperature and exit velocity. The modeling

did not account for the changes in stack temperature and exit velocity as a result in the change in stack height. Variability of stack composition, compounded with boiler design and operation made this adjustment impractical. Additionally, stacks were modeled with two conditions. The first condition was a stack that included a spark arrestor/rain cap. This assumption results in a lower exit velocity and reduced dispersion. The second condition was a model run with no spark arrestor or rain cap. This practice allowed for a "status quo" condition (i.e., unimpeded emissions) that offered greater exit velocities and better dispersion.

- Each modeling evaluation assumed one residential OWB unit with no other solid fuel combustion occurring within the modeling domain. In reality, it is possible that there are other sources of wood combustion within the OWB operating area. An ambient air quality background concentration was added to the modeled concentrations to account for other sources of wood combustion that were not modeled. The modeled results plus ambient air quality background concentration result in the setback distances reported in the Appendix A tables.
- Annual OWB use is based on typical cold weather periods in Minnesota, meaning that the modeling assumed OWB's were used continuously from October through the month of April.
- OWB's used for commercial purposes were not considered. If commercial units produce higher emission rates than modeled, the modeled setbacks may be under-protective.
- Modeled concentrations of $PM_{2.5}$ on the OWB Residence were not considered in this evaluation. While this evaluation was not intended to evaluate ambient air conditions at the OWB Residence, modeling results identified a number of stack and building configurations that resulted in predicted ambient air $PM_{2.5}$ concentrations greater than the evaluation criteria.

Future revisions of this modeling exercise are anticipated. The modeling assumptions, limitations, and delimitations provided in this modeling report will be reviewed and adjusted in the next revision to reflect changes in modeling software, meteorological data, emissions data, and available resources.

Dispersion Model and related Inputs

The MPCA used the most current version of AERMOD (15181) and AERMET.

The representative meteorological data selected for the modeling evaluation was the 2009 through 2013 Saint Cloud, Minnesota, Automated Weather Observing System (AWOS) site. Receptor placement relied on a dense, nested grid containing three tiers. The initial grid tier extended from the source to a distance of 350 meters and featured a receptor grid of 10 meters by 10 meters. The second tier extended from the boundary of the first tier by 150 meters and featured a receptor placement of 50 meters by 50 meters. The third and final tier extended from the boundary of tier 2 by 400 meters and featured a receptor placement of 200 meters by 200 meters.

The model features a total of five structures. The "Residence" was modeled as the source of emissions from the OWB. The Residence included a home (one, one and one-half, or two story), a garage or barn, and the OWB unit. The OWB unit was located downwind of the Residence home approximately 30 feet. The downwind "Neighbor", located at the property line, included a home (one, one and one-half, or two story), and detached garage or barn. The roof heights of the Residential and Neighbor dwellings, as well as their setbacks from one another, varied throughout the modeling to evaluate the impact of building downwash on the dispersion of OWB emissions. Table #2 provides a review of the building dimensions used in the modeling. The nearest neighbor property line setback distances included 100, 200, and 300 feet from the OWB. In situations where predicted concentrations exceeded the numeric value of the 24-hour $PM_{2.5}$ NAAQS, the downwind receptors were evaluated to determine the distance that predicted values were below the applicable NAAQS. This approach was applied to the modeled uncertified OWB summary. An example of the spatial layout between the Resident and Neighbor is included in Figure #1.

Table #2. Building Types and Dimensions

Residence/Neighbor	Footprint Dimensions	Roof Ridge (peak) height
One-story (Ranch)	40' x 28'	16'
One and one-half story (Cape)	40' x 28'	22'
Two story (Colonial)	40' x 28'	28'
Barn/Garage	65' x 50'	20'
OWB structure (residence only)	4' x 6'	6.5'

Model Scenarios

The modeling demonstration was designed to evaluate the relationship between stack height and setback distance using typical building and stack configurations, typical OWB classifications and related emission rates, along with defined setback distances. As noted above, the short-term 24-hour and long-term Annual $PM_{2.5}$ NAAQS were used as an evaluation metric for each of the defined distances and modeled arrangement. Each OWB category was evaluated, for a total of 54 separate modeling evaluations.

Emission Inputs

The emission inputs include the emission rates for each OWB category and modeled burn phase (Table #3) as well as stack height, diameter, exit velocity, and temperature (Table #4). Particulate matter less than 2.5 microns ($PM_{2.5}$) was selected as a health-based setback evaluation metric as it is frequently used as the pollutant of interest in OWB stack tests and in air dispersion modeling evaluations. The modeling demonstration task was to use representative emission data for each OWB classification and typical operational profiles. A working assumption for each OWB classification is an effective 12-hour burn cycle. Each cycle is characterized by a higher-emitting start-up period lasting approximately 2 hours, followed by a 10 hour lower (or typical) "idle" emitting phase. Operationally, it is assumed that each OWB is in continuous use during typical cool months of the year (i.e., October through April).

Table #3. $PM_{2.5}$ Emission Rates for Start-Up and Idle Burn Periods

Outdoor Wood Boiler Classification	Start-up (Peak) burn	Idle burn
[1]Uncertified/Conventional	0.0909 g/s	0.0447 g/s
[2]EPA Phase I OWB	0.0094 g/s	0.0058 g/s
[3]EPA Step 1 (2015 std)	0.0049 g/s	0.0020 g/s
[4]EPA Step 2 (2020 std)	0.0029 g/s	0.0008 g/s

Table #4. Stack Inputs

Stack Height		Stack Diameter	Exit Velocity	Temperature
8' 10'	Typical Manufacturer chimney	***Conventional*** 8" diameter	***Spark Arrestor/Rain Cap[a]*** 0.001 m/s ***Without Spark Arrestor/ Rain Cap[2]*** 1.98 m/s start-up burn 0.74 m/s idle burn	491°F (528.15 K) in start-up burn mode 228°F (382.04 K) in idle mode
18' 24' 30'	Assumed 2' taller than roof height for OWB, ranch, cape and colonial home in Table #2.			

[a] EPA AERMOD assumption for rain caps[5]

[1] Based on stack test data collected by Northeast States for Coordinated Air Use Management (NESCAUM) 2007 http://www.vtwoodsmoke.org/pdf/ny-modeling.pdf.

[2] See page 2, Dispersion Modeling Assessment of Impacts of Outdoor Wood Boiler Emissions in Support of NESCAUM's Model Rule. Prepared by Impact Assessment and Meteorology Section Division of Air Resources NYSDEC. January 26, 2007.

[3] Riley, D. (2008). Air Pollution Dispersion Modeling for Outdoor Wood Boilers in a Complex Terrain Setting. Vermont Agency of Natural Resources – Department of Environmental Conservation, Air Pollution Control Division. http://dec.vermont.gov/sites/dec/files/aqc/compliance/documents/S20%20OWB-VTmodeling-7-21-08-final.pdf

[4] Peak emissions are represented as the highest hourly emissions rate measured from stack testing of a hydronic heater that met the 2020 Step 2 emissions limit in federal regulation 40 CFR 60 Subpart QQQQ. Idle burn is assumed to be at the 2020 Step 2 annual weighted emissions rate for hydronic heaters in the same federal regulation. http://dec.vermont.gov/sites/dec/files/aqc/compliance/documents/vt%20certified.pdf

[5] EPA Model Clearinghouse Memorandum dated July 9, 1993, "Proposal for Calculating Plume Rise for Stacks with Horizontal Releases or Rain Caps for Cookson Pigment, Newark, New Jersey." This memo appears in Appendix D of the Addendum to the User's Guide for the AMS/EPA Regulatory Model – AERMOD, EPA-454/B-03-001, September 2004.

Model Results

A summary of the OWB modeling results are provided in Appendix A. The results are provided in the following tables:

Table #1	Uncertified OWB - Approximate distance (feet) from OWB stack to nearest downwind receptor that modeled compliance with the $PM_{2.5}$ Daily NAAQS (35 µg/m^3) using a Daily $PM_{2.5}$ Ambient Air Quality Background Concentration of 23 µg/m^3.
Table #2	Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 23 micrograms per cubic meter (daily) and 9.3 micrograms per cubic meter (annual) for Step 1 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure). Highlighted cells indicate modeled exceedance of the applicable standard at the assigned distance.
Table #3	Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 23 micrograms per cubic meter (daily) and 9.3 micrograms per cubic meter (annual) for Step 2 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure). Highlighted cells indicate modeled exceedance of the applicable standard at the assigned distance.
Table #4	Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 14 micrograms per cubic meter (daily) and 4.8 micrograms per cubic meter (annual) for Step 1 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure). Highlighted cells indicate modeled exceedance of the applicable standard at the assigned distance.
Table #5	Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 14 micrograms per cubic meter (daily) and 4.8 micrograms per cubic meter (annual) for Step 2 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure).
Table #6	Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 23 micrograms per cubic meter (daily) and 9.3 micrograms per cubic meter (annual) for Phase I OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure).
Table #7	Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 14 micrograms per cubic meter (daily) and 4.8 micrograms per cubic meter (annual) for Phase I OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure).

Findings based on OWB Modeling

The 2016 OWB air dispersion modeling resulted in five findings for future program development consideration:

1. **The air quality dispersion modeling should be updated periodically to account for changes in OWB emission data or related stack parameters as well as changes to meteorology and modeling software.** Changes in the AERMOD dispersion modeling software platform are expected to happen over the next few years, as well as new information on emissions and stack parameters. It is suggested the setback distances generated from this evaluation be reviewed and updated every two years to account for these changes.
2. **A gap exists between EPA certification test emission rates and actual operation of these units.** Based on published values, especially more recent publications, there is a difference in the regulatory based emission rates from the certification testing of the OWB units, and the actual operational emissions observed in the field. This is due, in part, to the nature of the test method used to evaluate OWB emissions.
3. **A greater effort is needed to better characterize the type and operation of uncertified and new OWB units in Minnesota.**
   The OWB classification contains a variety of wood burning units. It was recognized that many of these units are older systems, pre-dating EPA regulation, as well as some units built by the user. Further, because the certification testing requirements are not necessarily capturing representative operations in the field, new units are suspected to be emitting PM at rates above those measured during testing. Finally, representative stack parameters and operational characteristics are difficult to estimate for this category. Additional data is needed to develop more representative modeling input estimates. The MPCA should consider working with our local and regional partners to develop a voluntary OWB data collection program that features the collection of key emission and stack-related information. This information can be used to enhance understanding of the operations and use of this diverse group of OWB equipment and support better informed air quality dispersion modeling demonstrations.
4. **Height of wood-burning residence and its impact on ambient air quality concentrations.**
   Based on the modeled results, the height of the wood-burning residence had the greatest impact on ambient $PM_{2.5}$ concentrations. The proximity of the neighboring home affected ambient air concentrations; however, the height of the neighboring home had little impact on modeled air quality in comparison to the height of the home of the wood-burning resident. The explanation for this relationship has to do with the dominating influence of "building downwash," a term that describes the effect that wind flowing over or around buildings has on plumes released from a nearby stack. The modeled OWB was placed approximately 30 feet from the

wood-burning residence in the seasonal downwind direction. The separation distance between the OWB and the residence provided for substantial downwash impact, whereas the neighbor's home height did not affect ambient concentrations.

5. **Terrain Impacts.**
   Several terrain configurations were evaluated to determine if the modeled "flat terrain" assumption required additional adjustment to account for situations that exist outside a "simple" or flat terrain scenario. The terms "simple" and "complex" terrain reflect the relationship between the elevation of the surrounding landscape and the stack height. A landscape that is greater in elevation than the stack height is considered "complex," while landscape elevation that is below the stack height is considered "simple." Two terrain examples were modeled in addition to the flat terrain evaluations presented above: rolling (simple terrain) and steep-sided (complex terrain). A flat terrain assumption is sufficient to address most of the state of Minnesota. Rolling terrain is a common geographic feature in some glaciated portions of the state of Minnesota. Steep-sided terrain conditions are considerably less frequent, restricted to locations along the Upper Mississippi River Valley and the North Shore of Lake Superior. Using the "typical" proximity between the wood-burning residence and neighbor (100 to 300 foot setbacks) in the modeling, it was determined that terrain was not a significant factor in modeled ambient air pollutant concentrations; however, this is a preliminary finding and may not be suitable for all OWB siting decisions.

Section 5. Modeling Results Figures/Maps

Insert a figure or map showing the facility emission sources, receptors, and the location of the modeled maximum concentration(s) for each applicable pollutant, corresponding averaging periods, and operating scenarios. Figures or maps should correspond to Section 3 NAAQS and Increment results.

Acronyms

AERMAP	AERMOD Terrain Preprocessor
AERMET	AERMOD Meteorological Preprocessor
AERMOD	AMS/EPA Regulatory Model
AQ	Air Quality
AQDMP-01	Air Quality Dispersion Modeling Protocol form
AQDMPS-01	Air Quality Dispersion Modeling Protocol Spreadsheet
BPIP-PRIME	Building Profile Input Program for PRIME
CO	Carbon Monoxide
EPA	U.S. Environmental Protection Agency
FAC	3-letter facility ID
MAAQS	Minnesota State Ambient Air Quality Standard
MPCA	Minnesota Pollution Control Agency
NAAQS	National Ambient Air Quality Standard
NO_2	Nitrogen Dioxide
OU	Operable Unit
Pb	Lead
PM_{10}	Particulate Matter less than 10 um in size
$PM_{2.5}$	Particulate Matter less than 2.5 um in size
PRIME	Plume Rise Model Enhancements
PSD	Prevention of Significant Deterioration Program
SIL	Significant Impact Level
SO_2	Sulfur Dioxide
SIP	State Implementation Plan
SMS	Standardized Mobile Source
$\mu g/m^3$	Micrograms per cubic meter ($\mu g/m^3$)
UTM	Universal Transverse Mercator

Table #1 - Uncertified OWB Approximate distance (feet) from OWB stack to nearest downwind receptor that modeled compliance with the $PM_{2.5}$ Daily NAAQS (35 µg/m^3) using a Daily $PM_{2.5}$ Ambient Air Quality Background Concentration of 23 µg/m^3.			
	1 Story Resident	**1.5 Story Resident**	**2 Story Resident**
	Distance from stack to receptor	Distance from stack to receptor	Distance from stack to receptor
8' Stack Release	1,900	2,182	2,133
10' Stack Release	1,456	2,151	1,929
18' Stack Release	1,043	1,542	1,526
24' Stack Release	732	1,172	1,329
30' Stack Release	458	830	1,060
8' Stack with rain cap	2,621	2,657	2,231
10' Stack with rain cap	2,526	1,988	1,942
18' Stack with rain cap	1,433	2,168	1,676
24' Stack with rain cap	1,215	1,680	1,816
30' Stack with rain cap	641	1,299	1,306
Note: The daily $PM_{2.5}$ NAAQS provides more protective setback distances than the annual $PM_{2.5}$ NAAQS.			

1 Story Resident Step 1 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	27.8	29.5	31.6	31.6	30.2	28.5	9.71	9.97	10.1	10.08	9.79	9.63
10' Stack Release	24	29.8	30.9	30.7	29.3	27.9	9.36	9.83	9.99	10.01	9.75	9.61
18' Stack Release	23	23.6	24.8	25.5	26	25.6	9.3	9.34	9.43	9.51	9.53	9.49
24' Stack Release	23	23	23.2	23.6	24.4	24.5	9.3	9.3	9.32	9.35	9.41	9.41
30' Stack Release	23	23	23	23.1	23.6	23.7	9.3	9.3	9.3	9.31	9.34	9.36
8' Stack w/raincap	46.2	62.2	54.2	47	33.5	30.5	11.55	12.04	11.36	10.77	9.96	9.69
10' Stack w/raincap	27.8	56.8	55.9	49.8	37.7	32.1	9.85	12.31	12.02	11.41	10.2	9.84
18' Stack w/raincap	23.1	24.6	27.9	30.2	29.8	28.1	9.3	9.45	9.76	9.91	9.78	9.63
24' Stack w/raincap	23	23.1	23.4	24.1	25.7	25.7	9.3	9.3	9.34	9.41	9.51	9.49
30' Stack w/raincap	23	23	23.1	23.2	23.9	24.1	9.3	9.3	9.3	9.31	9.37	9.39
1.5 Story Resident Step 1 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	30.2	28.2	29.5	30.6	29.5	27.6	10.13	9.95	9.96	9.94	9.72	9.59
10' Stack Release	29.8	27.7	28.5	29.1	28.7	27.1	10.06	9.85	9.84	9.85	9.68	9.56
18' Stack Release	23	24.2	25.9	26.7	26.8	26.3	9.3	9.38	9.54	9.63	9.59	9.52
24' Stack Release	23	23.1	23.9	24.4	25.4	25.1	9.3	9.31	9.36	9.43	9.48	9.45
30' Stack Release	23	23	23.1	23.4	24.2	24.3	9.3	9.3	9.31	9.33	9.39	9.39
8' Stack w/raincap	43.3	37.4	34	29.7	28.1	26.6	11.37	10.8	10.35	10.09	9.69	9.55
10' Stack w/raincap	42.7	36.8	33.3	31	27.8	26.4	11.23	10.67	10.27	10.02	9.65	9.53
18' Stack w/raincap	23.1	26.4	31.8	32.9	30.7	28.2	9.3	9.64	10.09	10.17	9.83	9.64
24' Stack w/raincap	23	23.3	24.8	26.5	27.7	26.6	9.3	9.33	9.48	9.61	9.64	9.54
30' Stack w/raincap	23	23	23.2	23.7	25.1	25.2	9.3	9.3	9.32	9.35	9.47	9.45
2 Story Resident Step 1 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	32.8	29.5	29.4	29.4	26.3	26.9	10.36	10	9.92	9.87	9.66	9.54
10' Stack Release	32.2	28.8	28.3	28.8	25.9	26.5	10.31	9.92	9.84	9.8	9.63	9.52
18' Stack Release	29.8	26.8	26.3	26.2	25.1	25.6	10.07	9.71	9.62	9.6	9.54	9.47
24' Stack Release	23	23.2	24.3	25.1	24.9	25.5	9.3	9.32	9.4	9.49	9.53	9.47
30' Stack Release	23	23	23.3	23.8	24.2	24.7	9.3	9.3	9.33	9.37	9.44	9.43
8' Stack w/raincap	40.6	34.4	31.8	30	25.5	25.9	11.17	10.54	10.18	9.96	9.63	9.52
10' Stack w/raincap	39.9	33.7	31.2	29.4	25.4	25.8	11.04	10.42	10.11	9.9	9.6	9.5
18' Stack w/raincap	39.5	32.4	30.2	28.5	25	25.2	10.95	10.23	9.96	9.8	9.54	9.45
24' Stack w/raincap	23	23.5	26.1	27.9	26.2	26.7	9.3	9.35	9.6	9.75	9.68	9.55
30' Stack w/raincap	23	23.1	23.6	24.6	25	25.7	9.3	9.3	9.36	9.46	9.55	9.49

Table #2 –**Step 1 OWB with 23 ug/m3 background PM2.5 conc.** Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 23 micrograms per cubic meter (daily) and 9.3 micrograms per cubic meter (annual) for Step 1 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure). Highlighted cells indicate modeled exceedance of the applicable standard at the assigned distance.

1 Story Resident Step 2 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	24.99	26.03	26.7	27.06	26.3	25.5	9.4	9.6	9.66	9.65	9.53	9.45
10' Stack Release	23.56	26.7	27.76	27.59	25.8	25.2	9.33	9.53	9.6	9.62	9.51	9.44
18' Stack Release	23	23.25	23.78	24.08	24.4	24.2	9.3	9.32	9.36	9.39	9.4	9.39
24' Stack Release	23	23.01	23.1	23.25	23.6	23.6	9.3	9.3	9.31	9.32	9.35	9.35
30' Stack Release	23	23	23.01	23.04	23.2	23.3	9.3	9.3	9.3	9.3	9.32	9.32
8' Stack w/raincap	34.33	43.82	39.61	35.11	28.7	26.9	10.36	10.59	10.27	9.99	9.61	9.49
10' Stack w/raincap	25.34	39.55	40.08	36.29	30.4	27.5	9.55	10.72	10.58	10.3	9.73	9.56
18' Stack w/raincap	23.03	23.71	25.35	26.41	26.4	25.6	9.3	9.37	9.51	9.58	9.53	9.46
24' Stack w/raincap	23	23.04	23.2	23.53	24.3	24.3	9.3	9.3	9.32	9.35	9.4	9.39
30' Stack w/raincap	23	23.01	23.05	23.09	23.4	23.5	9.3	9.3	9.3	9.31	9.33	9.34
1.5 Story Resident Step 2 OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	26.3	25.33	26.01	26.4	26	25.3	9.66	9.59	9.59	9.59	9.49	9.43
10' Stack Release	26.02	25.13	25.55	25.71	25.6	25	9.63	9.54	9.54	9.55	9.47	9.42
18' Stack Release	23	23.54	24.29	24.7	24.8	24.5	9.3	9.34	9.41	9.45	9.43	9.4
24' Stack Release	23	23.05	23.37	23.65	24.1	24	9.3	9.35	9.33	9.36	9.38	9.37
30' Stack Release	23	23	23.05	23.16	23.6	23.6	9.3	9.3	9.3	9.31	9.34	9.34
8' Stack w/raincap	32.53	30.11	28.44	27.31	25.6	24.7	10.26	9.99	9.78	9.66	9.48	9.42
10' Stack w/raincap	32.04	29.73	28.2	27.04	25.4	24.6	10.2	9.93	9.75	9.63	9.47	9.41
18' Stack w/raincap	23.03	24.57	27.16	27.86	26.9	25.6	9.3	9.46	9.67	9.71	9.55	9.46
24' Stack w/raincap	23	23.13	23.86	24.63	25.3	24.8	9.3	9.31	9.38	9.45	9.46	9.42
30' Stack w/raincap	23	23.01	23.09	23.31	24	24	9.3	9.3	9.31	9.33	9.38	9.37
2 Story Resident Step 2 OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	27.34	25.8	25.87	25.98	25.5	24.9	9.77	9.61	9.58	9.56	9.47	9.41
10' Stack Release	27.22	25.55	25.32	25.65	25.2	24.7	9.75	9.58	9.54	9.53	9.45	9.4
18' Stack Release	26.04	24.65	24.46	24.48	24.6	24.4	9.64	9.48	9.44	9.44	9.41	9.38
24' Stack Release	23	23.1	23.55	23.92	24.3	24.2	9.3	9.31	9.35	9.38	9.4	9.38
30' Stack Release	23	23.01	23.15	23.37	23.9	23.2	9.3	9.3	9.31	9.33	9.36	9.36
8' Stack w/raincap	31.26	28.63	27.29	26.42	25	24.4	10.16	9.88	9.71	9.61	9.45	9.4
10' Stack w/raincap	30.88	28.21	27.08	26.24	24.9	24.3	10.11	9.82	9.67	9.58	9.44	9.39
18' Stack w/raincap	30.56	27.5	26.52	25.77	24.6	24.1	10.07	9.73	9.61	9.53	9.41	9.37
24' Stack w/raincap	23.02	23.25	24.41	25.33	25.6	24.8	9.3	9.32	9.44	9.51	9.48	9.42
30' Stack w/raincap	23	23.02	23.28	23.79	24.6	24.3	9.3	9.3	9.33	9.37	9.41	9.39

Table #3 – **Step 2 OWB with 23 ug/m3 background PM2.5 conc.** Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 23 micrograms per cubic meter (daily) and 9.3 micrograms per cubic meter (annual) for Step 2 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure). Highlighted cells indicate modeled exceedance of the applicable standard at the assigned distance.

1 Story Resident Step 1 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	18.78	20.52	22.55	22.63	21.17	19.47	5.21	5.47	5.6	5.58	5.29	5.13
10' Stack Release	14.96	20.81	21.93	21.74	20.31	18.88	4.86	5.33	5.49	5.51	5.25	5.11
18' Stack Release	14	14.58	15.75	16.48	16.99	16.63	4.8	4.84	4.96	5.01	5.03	4.99
24' Stack Release	14	14.02	14.22	14.55	15.43	15.45	4.8	4.8	4.82	4.85	4.91	4.91
30' Stack Release	14	14.01	14.02	14.09	14.55	14.74	4.8	4.8	4.8	4.81	4.84	4.86
8' Stack w/raincap	37.24	53.22	45.17	37.96	24.45	21.46	7.05	7.53	6.84	6.25	5.46	5.19
10' Stack w/raincap	18.82	47.78	46.91	40.75	28.71	23.07	5.35	7.81	7.51	6.91	5.7	5.34
18' Stack w/raincap	14.07	15.55	18.9	21.47	20.81	19.08	4.8	4.95	5.26	5.41	5.28	5.13
24' Stack w/raincap	14	14.11	14.44	15.13	16.73	16.72	4.8	4.8	4.84	4.91	5.01	4.99
30' Stack w/raincap	14	14.04	14.12	14.2	14.85	15.1	4.8	4.8	4.8	4.81	4.87	4.89
1.5 Story Resident Step 1 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	21.16	19.2	20.5	21.63	20.47	18.59	5.63	5.45	5.45	5.44	5.22	5.09
10' Stack Release	20.77	18.66	19.51	20.05	19.69	18.09	5.56	5.35	5.34	5.34	5.18	5.06
18' Stack Release	14	15.18	16.87	17.71	17.77	17.29	4.8	4.88	5.04	5.13	5.09	5.02
24' Stack Release	14	14.12	14.83	15.44	16.41	16.12	4.8	4.81	4.86	4.93	4.98	4.95
30' Stack Release	14	14.01	14.11	14.36	15.18	15.29	4.8	4.8	4.81	4.83	4.89	4.89
8' Stack w/raincap	34.27	28.43	24.98	22.63	19.11	17.57	6.87	6.29	5.84	5.57	5.19	5.05
10' Stack w/raincap	33.98	27.81	24.27	21.95	18.83	17.38	6.73	6.17	5.76	5.52	5.15	5.03
18' Stack w/raincap	14.07	17.38	22.76	23.91	21.69	19.2	4.8	5.14	5.59	5.67	5.33	5.14
24' Stack w/raincap	14	14.27	15.84	17.46	18.67	17.56	4.8	4.83	4.98	5.11	5.14	5.04
30' Stack w/raincap	14	14.04	14.21	14.65	16.12	16.17	4.8	4.8	4.82	4.86	4.97	4.95
2 Story Resident Step 1 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	23.8	20.45	20.41	20.38	19.29	17.85	5.86	5.5	5.42	5.37	5.16	5.04
10' Stack Release	23.17	19.8	19.27	19.82	18.77	17.48	5.81	5.42	5.34	5.3	5.13	5.02
18' Stack Release	20.78	17.75	17.28	17.18	17.4	16.64	5.57	5.21	5.12	5.1	5.04	4.97
24' Stack Release	14.01	14.22	15.25	16.1	16.8	16.5	4.8	4.82	4.9	4.99	5.02	4.97
30' Stack Release	14	14.02	14.34	14.81	15.85	15.73	4.8	4.8	4.83	4.87	4.94	4.93
8' Stack w/raincap	31.6	25.35	22.75	20.99	18.18	16.93	6.67	6.04	5.68	5.46	5.13	5.02
10' Stack w/raincap	30.89	24.73	22.16	20.44	17.9	16.75	6.54	5.92	5.61	5.4	5.1	5
18' Stack w/raincap	30.48	23.4	21.15	19.48	17.38	16.23	6.45	5.73	5.46	5.3	5.04	4.95
24' Stack w/raincap	14.04	14.52	17.08	18.89	19.01	17.65	4.8	4.85	5.1	5.25	5.18	5.05
30' Stack w/raincap	14	14.05	14.63	15.64	17.26	16.67	4.8	4.8	4.86	4.96	5.05	4.99

Table #4 – **Step 1 OWB with 14 ug/m3 background PM2.5 conc.** Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 14 micrograms per cubic meter (daily) and 4.8 micrograms per cubic meter (annual) for Step 1 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure). Highlighted cells indicate modeled exceedance of the applicable standard at the assigned distance.

1 Story Resident Step 2 OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	15.99	17.03	17.7	18.06	17.27	16.46	4.97	5.1	5.16	5.15	5.03	4.95
10' Stack Release	14.41	17.06	17.61	17.56	16.78	16.24	4.83	5.03	5.1	5.11	5.01	4.94
18' Stack Release	14	14.25	14.78	15.08	15.38	15.19	4.8	4.82	4.86	4.89	4.9	4.89
24' Stack Release	14	14.01	14.1	14.25	14.64	14.64	4.8	4.8	4.81	4.82	4.85	4.85
30' Stack Release	14	14	14.01	14.04	14.24	14.33	4.8	4.8	4.8	4.8	4.82	4.82
8' Stack w/raincap	25.33	34.82	30.61	26.11	19.74	17.87	5.85	6.09	5.77	5.49	5.11	4.99
10' Stack w/raincap	16.34	30.55	31.08	27.29	21.39	18.47	5.05	6.22	6.08	5.8	5.23	5.06
18' Stack w/raincap	14.03	14.71	16.35	17.41	17.43	16.6	4.8	4.87	5.01	5.08	5.03	4.96
24' Stack w/raincap	14	14.05	14.2	14.53	15.3	15.3	4.8	4.8	4.82	4.85	4.9	4.89
30' Stack w/raincap	14	14.1	14.05	14.09	14.41	14.51	4.8	4.8	4.8	4.81	4.83	4.84
1.5 Story Resident Step 2 OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	17.3	16.33	17.01	17.4	17.01	16.32	5.16	5.09	5.09	5.09	4.99	4.93
10' Stack Release	17.02	16.13	16.55	16.71	16.64	16.04	5.13	5.04	5.04	5.05	4.97	4.92
18' Stack Release	14	14.54	15.29	15.7	15.78	15.49	4.8	4.84	4.91	4.95	4.93	4.9
24' Stack Release	14	14.05	14.37	14.65	15.11	15	4.8	4.85	4.83	4.86	4.88	4.87
30' Stack Release	14	14	14.05	14.16	14.55	14.58	4.8	4.8	4.8	4.81	4.84	4.84
8' Stack w/raincap	23.53	21.11	19.44	18.31	16.58	15.74	5.76	5.49	5.28	5.16	4.98	4.92
10' Stack w/raincap	23.04	20.73	19.2	18.04	16.38	15.63	5.7	5.43	5.25	5.13	4.97	4.91
18' Stack w/raincap	14.03	15.57	18.16	18.86	17.91	16.58	4.8	4.96	5.17	5.21	5.05	4.96
24' Stack w/raincap	14	14.13	14.86	15.63	16.28	15.79	4.8	4.81	4.88	4.95	4.96	4.92
30' Stack w/raincap	14	14.01	14.09	14.31	15.01	15.04	4.8	4.8	4.81	4.83	4.88	4.87
2 Story Resident Step 2 OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	18.34	16.8	16.87	16.98	16.48	15.89	5.27	5.11	5.08	5.06	4.97	4.91
10' Stack Release	18.22	16.55	16.32	16.65	16.17	15.7	5.25	5.08	5.04	5.03	4.95	4.9
18' Stack Release	17.04	15.65	15.46	15.48	15.58	15.37	5.14	4.98	4.94	4.94	4.91	4.88
24' Stack Release	14	14.1	14.55	14.92	15.31	15.15	4.8	4.81	4.85	4.88	4.9	4.88
30' Stack Release	14	14.01	14.15	14.37	14.86	14.18	4.8	4.8	4.81	4.83	4.86	4.86
8' Stack w/raincap	22.26	19.63	18.29	17.42	16.03	15.38	5.66	5.38	5.21	5.11	4.95	4.9
10' Stack w/raincap	21.88	19.21	18.08	17.24	15.91	15.3	5.61	5.32	5.17	5.08	4.94	4.89
18' Stack w/raincap	21.56	18.5	17.52	16.77	15.61	15.11	5.57	5.23	5.11	5.03	4.91	4.87
24' Stack w/raincap	14.02	14.25	15.41	16.33	16.59	15.83	4.8	4.82	4.94	5.01	4.98	4.92
30' Stack w/raincap	14	14.02	14.28	14.79	15.57	15.34	4.8	4.8	4.83	4.87	4.91	4.89

Table #5 – **Step 2 OWB with 14 ug/m3 background PM2.5 conc.** Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 14 micrograms per cubic meter (daily) and 4.8 micrograms per cubic meter (annual) for Step 2 OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure).

1 Story Resident Phase I OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	36.35	40.21	46.12	46.5	41.5	36.6	10.46	11.12	11.42	11.36	10.57	10.15
10' Stack Release	25.61	41.38	43.57	43.92	39.1	35.3	9.47	10.75	11.17	11.19	10.48	10.11
18' Stack Release	23.04	24.59	27.78	29.52	30.8	29.7	9.3	9.4	9.66	9.86	9.91	9.79
24' Stack Release	23	23.05	23.57	24.51	26.8	26.7	9.3	9.3	9.34	9.42	9.59	9.58
30' Stack Release	23	23.02	23.07	23.23	24.5	24.9	9.3	9.3	9.3	9.32	9.42	9.45
8' Stack w/raincap	81.26	110.6	98.37	78.61	49	39.1	15.06	16.23	14.5	13	10.97	10.27
10' Stack w/raincap	35.12	107	106	89.67	57.3	44.2	10.7	16.93	16.18	14.65	11.55	10.66
18' Stack w/raincap	23.16	26.91	35.43	40.93	40	35.7	9.3	9.68	10.47	10.86	10.52	10.14
24' Stack w/raincap	23.01	23.31	24.16	25.87	29.8	29.8	9.3	9.31	9.41	9.57	9.84	9.77
30' Stack w/raincap	23	23.1	23.34	23.57	25.1	25.8	9.3	9.3	9.31	9.34	9.49	9.52
1.5 Story Resident Phase I OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	42.26	37.68	40.61	42.8	39.4	34.8	11.52	11.04	11.04	10.98	10.37	10.02
10' Stack Release	41.38	35.51	37.17	39.15	37.4	33.9	11.34	10.78	10.74	10.73	10.26	9.96
18' Stack Release	23.01	26.2	30.72	32.39	32.8	31.2	9.3	9.53	9.95	10.18	10.07	9.86
24' Stack Release	23	23.34	25.22	26.9	29.2	28.5	9.3	9.32	9.47	9.65	9.78	9.7
30' Stack Release	23	23.02	23.29	23.96	26.1	26.3	9.3	9.3	9.32	9.38	9.54	9.55
8' Stack w/raincap	74.54	58.85	49.37	43.62	35.7	31.7	14.64	13.16	12.01	11.32	10.28	9.94
10' Stack w/raincap	71.44	56.91	48.33	41.55	34.9	31.2	14.25	12.82	11.8	11.16	10.19	9.88
18' Stack w/raincap	23.16	31.96	45.09	47.54	40.9	35.7	9.3	10.18	11.31	11.52	10.64	10.15
24' Stack w/raincap	23.01	23.68	27.69	31.59	34.2	32.1	9.3	9.37	9.75	10.11	10.15	9.92
30' Stack w/raincap	23	23.1	23.54	24.65	28.3	28.4	9.3	9.3	9.35	9.46	9.72	9.69
2 Story Resident Phase I OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	49.29	39.54	39.98	39.59	35.8	32.2	12.12	11.17	10.94	10.78	10.2	9.9
10' Stack Release	48.03	38.29	37.4	37.76	34.3	31.3	11.99	10.97	10.72	10.6	10.12	9.85
18' Stack Release	41.55	33.82	31.72	31.22	31.4	29.4	11.36	10.41	10.15	10.1	9.79	9.74
24' Stack Release	23.01	23.61	26.39	28.47	30.2	29.4	9.3	9.34	9.58	9.8	9.88	9.75
30' Stack Release	23	23.05	23.98	25.17	27.8	27.4	9.3	9.3	9.37	9.5	9.67	9.63
8' Stack w/raincap	67.62	52.39	44.35	39.43	33	30.2	14.11	12.51	11.57	10.99	10.13	9.84
10' Stack w/raincap	66.91	49.88	42.9	38.58	32.4	29.8	13.78	12.2	11.38	10.85	10.05	9.79
18' Stack w/raincap	65.53	45.89	40.81	36.69	30.8	28.4	13.53	11.68	10.99	10.58	9.89	9.68
24' Stack w/raincap	23.09	24.32	30.81	35.46	35.3	32.1	9.31	9.44	10.06	10.45	10.24	9.94
30' Stack w/raincap	23	23.13	24.65	27.25	30.8	29.7	9.3	9.31	9.46	9.71	9.92	9.78

Table #6 – **Phase 1 OWB with 23 ug/m3 background PM2.5 conc.** Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 23 micrograms per cubic meter (daily) and 9.3 micrograms per cubic meter (annual) for Phase I OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure).

1 Story Resident Phase I OWB	Daily 25'	Daily 50'	Daily 75'	Daily 100'	Daily 200'	Daily 300'	Annual 25'	Annual 50'	Annual 75'	Annual 100'	Annual 200'	Annual 300'
8' Stack Release	27.35	31.21	37.12	37.5	32.47	27.58	5.96	6.62	6.92	6.86	6.07	5.65
10' Stack Release	16.61	32.38	34.57	34.92	30.13	26.26	4.97	6.25	6.67	6.69	5.98	5.61
18' Stack Release	14.04	15.59	18.78	20.52	21.75	20.73	4.8	4.9	5.16	5.36	5.41	5.29
24' Stack Release	14	14.05	14.57	15.51	17.75	17.73	4.8	4.8	4.84	4.92	5.09	5.08
30' Stack Release	14	14.02	14.07	14.23	15.53	15.9	4.8	4.8	4.8	4.82	4.92	4.95
8' Stack w/raincap	72.26	101.56	89.37	69.61	40.01	30.07	10.56	11.73	10	8.5	6.47	5.77
10' Stack w/raincap	26.12	97.99	97.03	80.67	48.28	35.23	6.2	12.43	11.68	10.15	7.05	6.16
18' Stack w/raincap	14.16	17.91	26.43	31.93	31	26.74	4.8	5.18	5.97	6.36	6.02	5.64
24' Stack w/raincap	14.01	14.31	15.16	16.87	20.82	20.78	4.8	4.81	4.91	5.07	5.34	5.27
30' Stack w/raincap	14	14.1	14.34	14.57	16.13	16.77	4.8	4.8	4.81	4.84	4.99	5.02
1.5 Story Resident Phase I OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	33.26	28.68	31.61	33.8	30.38	25.79	7.02	6.54	6.54	6.48	5.87	5.52
10' Stack Release	32.38	26.51	28.17	30.15	28.41	24.92	6.84	6.28	6.24	6.23	5.76	5.46
18' Stack Release	14.01	17.2	21.72	23.39	23.83	22.16	4.8	5.03	5.45	5.68	5.57	5.36
24' Stack Release	14	14.34	16.22	17.9	20.22	19.46	4.8	4.82	4.97	5.15	5.28	5.2
30' Stack Release	14	14.02	14.29	14.96	17.05	17.33	4.8	4.8	4.82	4.88	5.04	5.05
8' Stack w/raincap	65.54	49.85	40.37	34.62	26.66	22.74	10.14	8.66	7.51	6.82	5.78	5.44
10' Stack w/raincap	62.44	47.91	39.33	32.55	25.92	22.16	9.75	8.32	7.3	6.66	5.69	5.38
18' Stack w/raincap	14.16	22.96	36.09	38.54	31.9	26.73	4.8	5.68	6.81	7.02	6.14	5.65
24' Stack w/raincap	14.01	14.68	18.69	22.59	25.19	23.05	4.8	4.87	5.25	5.61	5.65	5.42
30' Stack w/raincap	14	14.1	14.54	15.65	19.32	19.39	4.8	4.8	4.85	4.96	5.22	5.19
2 Story Resident Phase I OWB	**Daily 25'**	**Daily 50'**	**Daily 75'**	**Daily 100'**	**Daily 200'**	**Daily 300'**	**Annual 25'**	**Annual 50'**	**Annual 75'**	**Annual 100'**	**Annual 200'**	**Annual 300'**
8' Stack Release	40.29	30.54	30.98	30.59	26.82	23.2	7.62	6.67	6.44	6.28	5.7	5.4
10' Stack Release	39.03	29.29	28.4	28.76	25.26	22.26	7.49	6.47	6.22	6.1	5.62	5.35
18' Stack Release	32.55	24.82	22.72	22.22	22.39	20.36	6.86	5.91	5.65	5.6	5.29	5.24
24' Stack Release	14.01	14.61	17.39	19.47	21.17	20.44	4.8	4.84	5.08	5.3	5.38	5.25
30' Stack Release	14	14.05	14.98	16.17	18.78	18.43	4.8	4.8	4.87	5	5.17	5.13
8' Stack w/raincap	58.62	43.39	35.35	30.43	23.96	21.24	9.61	8.01	7.07	6.49	5.63	5.34
10' Stack w/raincap	57.91	40.88	33.9	29.58	23.43	20.75	9.28	7.7	6.88	6.35	5.55	5.29
18' Stack w/raincap	56.53	36.89	31.81	27.69	21.82	19.37	9.03	7.18	6.49	6.08	5.39	5.18
24' Stack w/raincap	14.09	15.32	21.81	26.46	26.27	23.05	4.81	4.94	5.56	5.95	5.74	5.44
30' Stack w/raincap	14	14.13	15.65	18.25	21.8	20.65	4.8	4.81	4.96	5.21	5.42	5.28

Table #7 – **Phase 1 OWB with 14 ug/m3 background PM2.5 conc.** Ambient $PM_{2.5}$ Concentrations and setback distances using a high ambient air quality background concentration of 14 micrograms per cubic meter (daily) and 4.8 micrograms per cubic meter (annual) for Phase I OWB units by stack height and residential dwelling (assumed to be the OWB-heated structure).

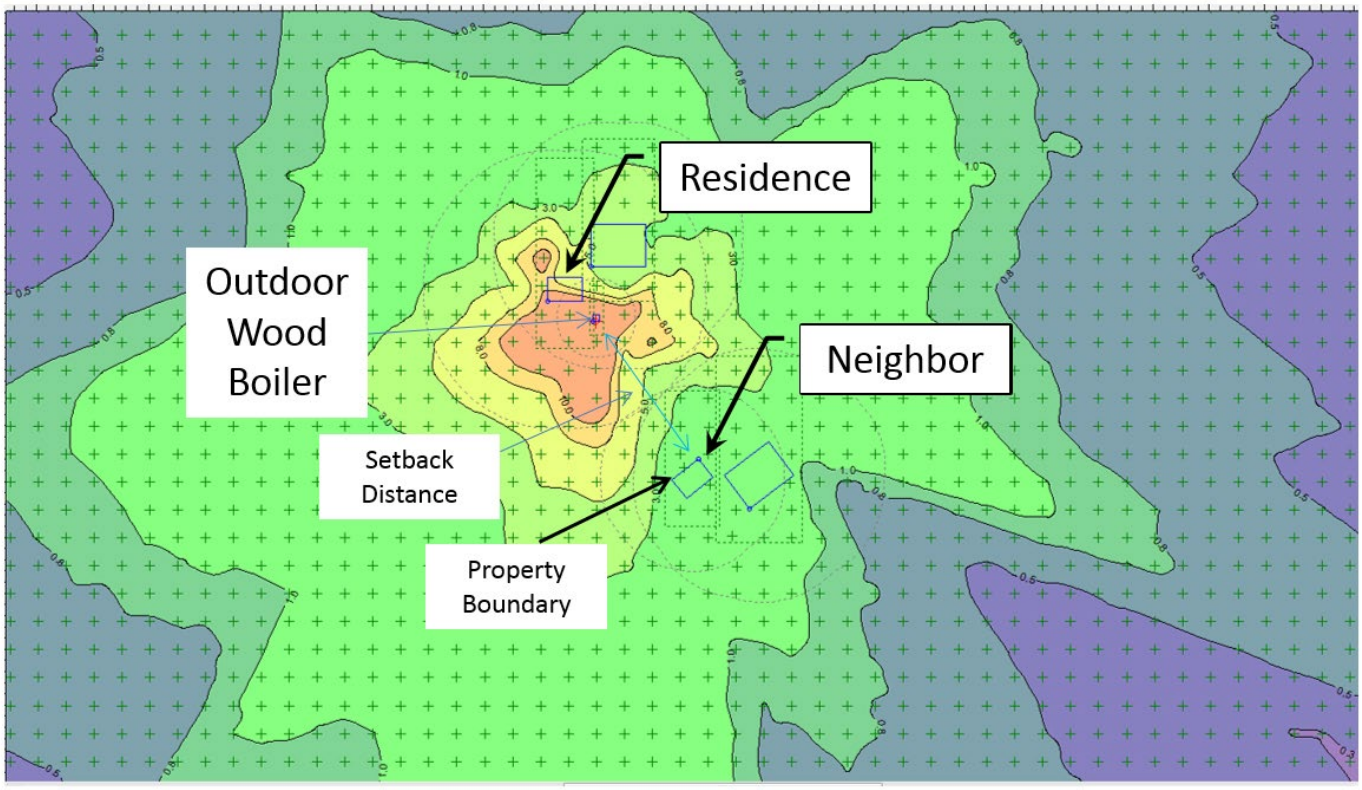

Figure #1 – Example of Outdoor Wood Boiler Modeling Simulation Building Arrangement. Featured is a Step 1 EPA Certified OWB using a 100 foot setback distance from Stack Tip to Nearest Neighbor Property Boundary.