2802

From: Allan Cagnoli [cagnoli@hpba.org]
Sent: Friday, January 29, 2010 9:54 AM
To: EP, RegComments
Cc: Allan Cagnoli
Subject: Proposed Outdoor Wood-Fired Boiler Regulations by the Commonwealth of Pennsylvania
Attachments: State of Pennsylvania comments letter - ltrhd FINAL.doc; State of Pennsylvania_HPBA comments FINAL.doc; RTP Environmental Associates Inc. - Review 8-21-07.pdf; STATE OF MAINE - OWB_Modeling 06062007.xls; State of Maine_modeling Round 2 5_30_07.pdf; Air Dispersion Report 06_12_09 Phase 2.pdf; 16th Annual InternationalEmission Inventory Conference - Session 5 Guldberg - Paper.pdf; Air Dispersion Modeling Report 041007.pdf; Green Letter Review.pdf

Hearth,Patio&BarbecueAssociation (HPBA)
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www.hpba.org hpbamail@hpba.org

January 29, 2010

The Environmental Quality Board
P.O. Box 8477
Harrisburg, PA 17105-8477

Email: RegComments@state.pa.us

Re: Proposed Outdoor Wood-Fired Boiler Regulations by the Commonwealth of Pennsylvania

Dear Environmental Quality Board:

The Hearth, Patio & Barbecue Association ("HPBA") is the principal national trade association representing manufacturers, dealers and distributors of solid fuel-fired home heating appliances, including outdoor hydronic heaters ("OHHs"), which are also referred to as outdoor boilers and outdoor furnaces. I am writing to you on behalf of our OHH Caucus ("Caucus") to submit comments (attached) on the proposal by the Commonwealth of Pennsylvania (the "Commonwealth") to regulate emissions from OHHs (the "Draft Regulation").

HPBA has a long track record of working cooperatively with the U.S. Environmental Protection Agency ("EPA") and the states on wood smoke issues of common concern. This partnering started with the Regulatory Negotiation in the late 1980's that produced the federal New Source Performance Standards ("NSPS") for wood stoves, which is still in effect [40 CRF, Part 60, Subpart AAA] and which is currently being revised. Other accomplishments worthy of note are numerous wood stove changeout (i.e., replacement) programs including, most recently, a program in Libby, Montana, that changed out over 1,000 uncontrolled (i.e., not EPA-Certified) stoves, resulting in remarkable improvements in air quality both inside and outside.

Believing that OHHs could be another effort to add to the long list of successful partnerships between our industry, EPA, and state air pollution control agencies, HPBA's OHH caucus entered into a stakeholder dialogue process several years ago with EPA and numerous states. This process resulted in agreement on an EPA voluntary program for these appliances, Phase 1 of which took effect on January 29, 2007 and Phase 2 took effect on October 23, 2008.

Currently, the EPA is revising the NSPS. The EPA has set an aggressive timetable in which it expects to federally regulate several previously exempt wood heating devices, such as OHHs. The NSPS revision proposal is expected by September 2010, with promulgation of the revision by September 2011.

As previously mentioned, Phase 2 of EPA's voluntary program for hydronic heaters was announced in October, 2008. That program has two emission targets: the new 0.32 lbs/MMbtu output target (coupled with a cap on the highest emission rate during testing), and the Phase 1 target of 0.60 lbs/MMbtu input, which will continue to be part of the program until March 31, 2010. Our manufacturers are working hard to develop appliances that meet these emission targets. As EPA's website shows, there are currently about 10 models that have qualified under the Phase 1 target, and 10 that have qualified under the Phase 2 target, with 3 of these being pellet-fueled models. However, qualifying a model under the EPA program is not synonymous with wide availability of that model in the marketplace. Often, a manufacturer will only offer limited quantities of a newly qualified model for sale for one or more heating seasons after its qualification, in order to gather field experience with the model before producing it in large quantities. In addition, manufacturers sometimes need time to obtain safety certifications before offering the model for sale even in limited quantities.

As you will see, the Caucus comments rely strongly on modeling studies evaluating the ambient impacts of OHH emissions (copies of these studies are also attached to the Comments). The modeling that HPBA has done to evaluate the ambient impacts of models that qualify under the EPA Phase 1 emission target is particularly emphasized. This study clearly shows that even these models, when installed with stack heights consistent with manufacturer's instructions, have ambient impacts well below the revised 24 hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS), at the closest receptor to the unit (10 meters or roughly 30 feet) that can be modeled.

Since the Phase 2 emission target is lower, the ambient impacts of Phase 2 units would be lower still. These findings obviously have implications both for stack height and set back requirements, as the OHH comments point out.

Finally, it should be recognized that more is at stake than just air quality improvements. As we strive to achieve energy independence, providing a greater focus on biomass fuels and renewable energy sources, OHHs and other solid fuel appliances have an important role to play in our nation's energy policy as part of the emerging national program to address global climate change.

Thank you for considering our comments. If you have any questions, or desire any additional information, please feel free to contact me.

Sincerely yours,

(signed)

W. Allan Cagnoli
Director, Government Affairs, HPBA

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Believing that OHHs could be another effort to add to the long list of successful partnerships between our industry, EPA, and state air pollution control agencies, HPBA's OHH caucus entered into a stakeholder dialogue process several years ago with EPA and numerous states. This process resulted in agreement on an EPA voluntary program for these appliances, Phase 1 of which took effect on January 29, 2007 and Phase 2 took effect on October 23, 2008.

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EPA program is not synonymous with wide availability of that model in the marketplace. Often, a manufacturer will only offer limited quantities of a newly qualified model for sale for one or more heating seasons after its qualification, in order to gather field experience with the model before producing it in large quantities. In addition, manufacturers sometimes need time to obtain safety certifications before offering the model for sale even in limited quantities.

As you will see, the Caucus comments rely strongly on modeling studies evaluating the ambient impacts of OHH emissions (copies of these studies are also attached to the Comments). The modeling that HPBA has done to evaluate the ambient impacts of models that qualify under the EPA Phase 1 emission target is particularly emphasized. This study clearly shows that even these models, when installed with stack heights consistent with manufacturer's instructions, have ambient impacts well below the revised 24 hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS), at the closest receptor to the unit (10 meters or roughly 30 feet) that can be modeled.

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Thank you for considering our comments. If you have any questions, or desire any additional information, please feel free to contact me.

Sincerely yours,

W. Allan Cagnoli

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Director, Government Affairs

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COMMENTS
on the
Proposed Outdoor Wood-Fired Boiler Regulations
for the
Commonwealth of Pennsylvania
by the
Hearth, Patio & Barbecue Association (HPBA)
to the
Pennsylvania Environmental Quality Board

January 29, 2010

The following comments regarding the proposed regulation were presented to the Pennsylvania Department of Environmental Protection ("PaDEP") by the Outdoor Hydronic Heater (OHH) Caucus (the "Caucus") of the Hearth, Patio & Barbecue Association ("HPBA") during a teleconference on November 23, 2009. The Caucus held the teleconference with the PaDEP to provide this information to PaDEP prior to it formally proposing regulations.

IMPLEMENT A SELL-THROUGH EXEMPTION FOR IN-STATE BUSINESSES SELLING "OUTDOOR WOOD-BURNING BOILERS" IN THE COMMONWEALTH OF PENNSYLVANIA

The Caucus recommends that PaDEP establish a sell-through exemption similar to sell-through exemptions in State regulations/laws in the northeast (Maine, Vermont, and New Hampshire). This will allow business owners in the Commonwealth of Pennsylvania (the "Commonwealth") an opportunity to move their existing inventory, within the Commonwealth, not just outside of the Commonwealth, without being financially burdened.

The following is a recommended revision to the proposed regulation to allow in-state dealers to reduce their existing inventory of non-certified Phase 2 outdoor wood-fired boilers. The installations must meet applicable sections of the regulation including setback and chimney height requirements, immediately upon passage.

§ 123.14. Outdoor wood-fired boilers.
Exception.
(1) If the non-Phase 2 outdoor wood-fired boiler was purchased and received by any person in the Commonwealth of Pennsylvania, other than the manufacturer, before April 1, 2010, and the "outdoor wood-fired boiler" is sold and installed in the Commonwealth, it shall be installed in accordance with the following requirements:
(i) The outdoor wood-fired boiler is installed more than 200 feet from any residence other than a residence served by the outdoor wood-fired boiler or owned by the owner or lessee of the outdoor wood-fired boiler; and
(ii) Has an attached permanent stack extending two (2) feet higher than the peak of the roof of the structure(s) being served by the outdoor wood-fired boiler, if any residence is located more than 200 but less than 500 feet from the outdoor wood-fired boiler other than a residence owned by the owner or lessee of such outdoor wood-fired boiler; and

(iii) Complies with all applicable laws, including but not limited to local ordinances, and its operation does not create a public nuisance.

With these changes we suggest adding the following definition:

Non-Phase 2 outdoor wood-fired boiler: An outdoor wood-fired boiler that has not been certified or qualified by the EPA as meeting a particulate matter emission limit of 0.32 pounds per million Btu output.

The following is a summary of "sell-through" exemptions in other northeast States:

State of Vermont – Allowed an indefinite period of time for non-emission compliant outdoor wood-fired boilers to be sold on a dealer's lot before October 1, 2007. Outdoor wood-fired boilers received by dealers after October 1, 2007 were only allowed until March 31, 2008 to move their existing inventory. Vermont already had established setback and chimney height requirements for outdoor wood-fired boilers: *"200 feet from any residence other than a residence served...stack extending higher than the peak of the roof of the structure(s) being served...if any residence is located more than 200 but less than 500 feet from the outdoor wood-fired boiler..."*

State of Maine – Allowed dealers one (1) year to move existing non-emissions compliant outdoor wood-fired boilers to be sold if they were received by dealers before April 1, 2008. The end date for selling those appliances was April 1, 2009. The State established setback and chimney height requirements that were applicable immediately upon passage for these appliances: *"250 feet from the nearest property line or at least 270 feet from the nearest dwelling that is not on the same property...minimum stack height of 10 feet above the ground...or...two feet higher than the peak of the roof of the structure being served..., if an abutting residence is located less than 500 feet from the outdoor wood boiler."*

State of New Hampshire – The law was effective in August 2008 and dealers were allowed to move their existing inventory on non-emission compliant outdoor wood-fired boilers until January 1, 2009. Immediately upon passage setback and chimney height requirements were established for these appliances: *"200 feet from the nearest abutting residence and has an...attached stack that is at least 2 feet higher than the peak of the roof of a residence or place of business not served...within 300 feet..."*

SETBACK REQUIREMENTS FOR EPA HYDRONIC HEATER PHASE 2 APPLIANCES IS EXCESSIVE

The PaDEP proposed setback for Phase 2 appliances is:

(b) Phase 2 outdoor wood-fired boilers.

(c) Setback requirements for Phase 2 outdoor wood-fired boilers. A person may not install a Phase 2 outdoor wood-fired boiler in this Commonwealth unless the boiler is installed a minimum of 150 feet from the nearest property line.

The Caucus recommends that the Commonwealth of Pennsylvania establish setback requirements based upon the State of Maine regulations for outdoor wood-burning boilers. A setback requirement of 150 feet from a property line is unnecessary for appliances that qualify for the EPA Hydronic Heater Phase 2 Program. The following are setback requirements already established for Phase 2 appliances in other States:

State of Maine –50 feet from a property line **or** 70 feet from a neighboring residence

State of New Hampshire – 50 feet from a property line

State of Massachusetts –50 feet from a property line and 75 feet from a neighboring residence

State of Vermont –100 feet from neighboring residences but Vermont does not want to regulate chimney height requirements for the appliances

Supporting material

- Modeling completed by HPBA[1] to evaluate the ambient impacts of models that qualify under the EPA phase 1 emission target clearly shows that these models, when installed with stack heights consistent with manufacturer's instructions, have ambient impacts well below the revised 24 hour $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS), at the closest receptor to the unit (10 meters, or roughly thirty feet) that can be modeled. A copy of that modeling study is attached for review.
    - Accordingly, there is no justification, from the standpoint of protection of the NAAQS, to require outdoor wood-burning boilers that meet the emissions limit of 0.32 lbs/MMBtu heat output to be installed at a distance of 150 feet from the property line.
- Modeling completed by the State of Maine[2] demonstrated that the setback requirements and chimney height requirements for Phase 2 appliances is reasonable.
    - Maine's setback requirements provide two options for placement (property line or nearest neighboring residence). Limiting the location of the appliance based upon property lines only, can prove to be very costly, time consuming and difficult for consumers to determine.
    - With modern day range finders and local government GIS mapping systems the option of locating the unit based upon neighboring residences is cost effective and reasonable for consumers.
- Peter Guldberg's Modeling of a Phase 2 Qualified Hydronic Heater[3]
    - Guldberg's air dispersion modeling reveals that OWHH operation produces $PM_{2.5}$ concentrations ranging from 0.48 to 2.86 μg/m3 under the 20 modeled scenarios. The results are summarized in Table 3, and the model output is presented in Appendix B of this report. The results are also shown graphically on $PM_{2.5}$ contour maps presented in Figures 3 through 22. All maximum predicted $PM_{2.5}$ concentrations are in compliance with the National Ambient Air Quality Standards (NAAQS) and all are below the Significant Impact Levels (SIL).
- Nine (9) of ten (10) EPA Hydronic Heater Phase 2 Program (the "EPA Program") Qualified Appliances have been shown to have lower emissions than the federal regulations limit for indoor woodstoves (7.5 g/hr).

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1 RTP Environmental Associates, Inc. 'Review of NYSDEC Modeling Study for NESCAUM Model Rule and NAAQS Compliance Evaluation for EPA Voluntary Phase 1 Compliance Outdoor Hydronic Heater' April 21, 2007

2 Maine Air Dispersion Modeling – Summary for OWB ISC-PRIME Modeling, Round 2, 05/30/07

3 Air Quality Dispersion Modeling of the E-Classic 2300 Outdoor Wood Hydronic Heater June 2009

- The maximum allowable individual test run of 18 g/hr established in the EPA Program is the same g/hr cap established in the New Source Performance Standards ("NSPS") for indoor wood stoves.
- The EPA Program output-based emissions limit ensures that not only does the appliance have to be clean, but it must also be extremely efficient. Efficiency numbers reported in the EPA Program are actual efficiency numbers calculated from testing.
- "Outdoor wood-fired boilers" that qualify under the EPA Program generally emit less particulate matter than indoor wood stoves that meet current federal NSPS which may be installed in the Commonwealth without *any* setbacks. Since there are no required setbacks in the Commonwealth for the installation of NSPS indoor wood stoves, any setback requirement applicable to Phase 2 OWBs lacks a rational basis and is discriminatory. The Commonwealth's proposed setback requirement is also more restrictive than setbacks required by other northeast States
    - The proposed setback requirement would actually prevent residents of the Commonwealth from installing lower emission Phase 2 OWBs to replace an existing higher emission OWB or indoor wood stove(s).

<u>CHIMNEY HEIGHT REQUIREMENTS ARE EXCESSIVE FOR EPA HH PHASE 2 QUALIFIED APPLIANCES</u>

(d) Stack height requirements for Phase 2 outdoor wood-fired boilers. A person may not install, use or operate a Phase 2 outdoor wood-fired boiler in this Commonwealth unless the boiler has a permanently attached stack. The stack <u>must meet both</u> of the following height requirements:

(1) Extend a minimum of 10 feet above the ground.

(2) <u>Extend at least two feet above the highest peak of the highest residence located within 150 feet of the outdoor wood-fired boiler.</u>

The Caucus recommends that the proposed language should be revised to be more consistent with other northeast States' requirements, such as Maine, which is based upon modeling completed for Phase 2 outdoor wood-fired boilers. The proposed chimney height requirements are excessive for EPA Program appliances, especially for rural owners.

The chimney height requirements for the State of Maine are:

(1) has an attached stack with a minimum stack height of 10 feet above ground level; or

(2) has an attached stack extending two feet higher than the peak of the roof of the structure being served by the outdoor wood-fired boiler, if an abutting residence is located less than 300 feet from the outdoor wood-fired boiler.

The proposed language in Chapter 121 should be revised to be more consistent with other northeast States.

Below are suggested revisions to the proposed regulations:

(1) Extend a minimum of 10 feet above the ground; or

(2) Extend at least two feet above the structures served by the outdoor wood-fired boiler, if abutting residences are located within 150 feet of the outdoor wood-fired boiler.

Supporting material

- Same information as listed above in comments regarding setbacks for EPA HH Phase 2 Qualified appliances.

CHIMNEY HEIGHT REQUIREMENTS FOR CONVENTIONAL OR NON-PHASE 2 OUTDOOR WOOD-FIRED BOILERS IS EXCESSIVE

(e) Stack height requirements for existing outdoor wood-fired boilers. A person may not use or operate an outdoor wood-fired boiler that was installed before________ [Editor's note: The blank refers to the effective date of adoption of this proposed rulemaking.] unless the boiler has a permanently attached stack.

(1) The stack must meet both of the following height requirements:

(i) Extend a minimum of 10 feet above the ground.

(ii) Extend at least two feet above the highest peak of the highest residence located within 500 feet of the outdoor wood-fired boiler.

The Caucus recommends that the Commonwealth of Pennsylvania establish a chimney height requirement for existing appliances that have been investigated and found to be creating a nuisance, whereby those owners should be required to increase their chimney's height to eliminate the nuisance. The proposed chimney height requirement to "extend at least two feet above the highest peak of the highest residence located within 500 feet of the outdoor wood-fired boiler" for existing installations is unnecessary.

Supporting material

- EPA Report – EPA/600/SR-98/017
  - "Compared to a wide range of residential heating options, these furnaces' emissions were of the same order as other stick wood burning appliances."
- 16th Annual International Emission Inventory Conference - *Emission Inventories: "Integration, Analysis, and Communications"* - Raleigh, May 14 - 17, 2007 Outdoor Wood Boilers - New Emissions Test Data and Future Trends, P. Guldberg, C.C.M.
  - "Mass emissions from the OWB tests were analyzed with dispersion modeling and the results demonstrate a properly installed OWB can operate year-round next to a residence and fully comply with the new $PM_{2.5}$ air quality standards."
- Modeling completed by the State of Maine[2,4] show that that the proposed setback requirements and chimney height requirements are unreasonable.
- It is unreasonable to suggest that chimney height requirements could be applied retroactively to an estimated 15,000 furnace owners in the Commonwealth who purchased and installed their outdoor wood-burning boilers in good faith, when no regulations existed in the Commonwealth.

[4] ISC-PRIME OWB Results, 3 Newest Scenarios 06/06/07

- It is unreasonable and unsupported to suggest that furnace owners in rural areas with no close neighbors need to increase their chimney to the height proposed in the regulation.

LOCAL REGULATIONS CAN BE MORE RESTRICTIVE BUT THEY MUST BE SUPPORTED BY SCIENCE AND BE REASONABLE

(i) *Written notice.*

(v) A written statement that even if the requirements set forth in this section are met, the installation and operation of the outdoor wood-fired boiler may be subject to local regulations or local stack height or setback requirements that will further limit or prohibit the use of the purchased or leased outdoor wood-fired boiler.

The Caucus recommends that the PaDEP include a requirement that limits local jurisdiction from establishing requirements that are not reasonable. The Caucus recommends that the language used in the State of New Hampshire regarding "municipal authority" be incorporated into the regulations for the Commonwealth. In New Hampshire, local jurisdictions are limited to creating local laws that are reasonable by stating, "a municipality shall not unreasonable limit the installation of or hinder the operation of OWHHs."

Local jurisdictions have the ability to limit outdoor wood-burning boilers by adopting local laws that are more restrictive than state regulations. However, it is our experience that some local jurisdictions in the Commonwealth of Pennsylvania have proposed or passed regulations that are extremely unreasonable, lack science based requirements, lack basic knowledge of wood heating appliances and are based upon misleading and one-sided information regarding the outdoor wood-burning boiler industry.

State of New Hampshire Law

125-R: 7 Municipal Authority. Nothing in this chapter shall be construed to limit the authority of a municipality or the department of health and human services to prevent and remove nuisances and protect public health in accordance with RSA 147, or of a municipality to adopt and enforce land use ordinances and regulations pursuant to RSA 674 and 675 relative to OWHHs, including but not limited to provisions relative to setbacks and stack heights that are more restrictive than RSA 125-R:3, prohibiting the installation of OWHHs in one or more zoning districts, or requiring in one or more zoning districts the installation of lower emitting versions of OWHHs that have been certified or qualified under this chapter. ***A municipality shall not establish quantifiable emission limits, require testing, monitoring, or certification, or specify the types of fuels used. In exercising its authority under this section, a municipality shall not unreasonably limit the installation of or hinder the operation of OWHHs.***

Supporting material

The following are some examples of local laws that have been passed or proposed in the Commonwealth that are unreasonable, impossible with which to comply and discriminatory:

- Requiring add-on devices that do not exist (scrubber, filters, etc.) or forcing homeowners to add a blower on the premise that will make all appliances "more efficient," which is often dependent upon design. (Canton Borough, Berrysburg Borough, Cranberry Township, Punxsutawney Township, etc.)
- Requiring retrofit devices (that do not exist) to make existing appliances meet unforeseen future emissions regulations and emissions limits or force the removal of those appliances. (Monroe Township, etc.)
- Unreasonably restricting appliances that meet very stringent emissions limits through unnecessary setbacks requirements that are not based upon science, such as setbacks of 500 feet for EPA Hydronic Heater Phase 2 Qualified appliances.

OPACITY SHOULD NOT BE APPLICABLE TO RESIDENTIAL HOMEOWNERS

(4) 25 Pa. Code § 123.41 (relating to limitations)

VISIBLE EMISSIONS

§ 123.41. Limitations.

A person may not permit the emission into the outdoor atmosphere of visible air contaminants in such a manner that the opacity of the emission is either of the following:

(1) Equal to or greater than 20% for a period or periods aggregating more than 3 minutes in any 1 hour.

(2) Equal to or greater than 60% at any time.

§ 123.42. Exceptions.

The limitations of § 123.41 (relating to limitations) shall not apply to a visible emission in any of the following instances:

(1) When the presence of uncombined water is the only reason for failure of the emission to meet the limitations.

The Caucus recommends that the limitation on opacity of emissions from "outdoor wood-fired boilers" be deleted from the proposed Regulation.

Supporting material

- Compliance with emission limitations, installation, siting and operating requirements contained in the draft Title 25 Chapter 121 can be readily determined by both the homeowner and the PaDEP (i.e., there will be a process for determining which new units meet the new emission limits and the installation). Siting and operational requirements are relatively straight-forward and the diligent homeowner can readily implement these with the assurance of compliance with the applicable requirements. That is not the case, however, with the draft limit on the opacity of emissions.
- Not only can opacity be variable due to conditions that are not readily controllable, but the nature of emissions from outdoor wood boilers makes it extremely difficult to obtain reliable opacity readings. USEPA Method 9 (described at 40 C.F.R. Part 60, Appendix A) requires that the opacity observation be made at a point in the emission plume where condensed water vapor is not visible. Indeed, the method requires that

the observer identify the point in the plume where the condensed water vapor is no longer visible and make the opacity reading at that point. Condensed water vapor interference in emissions from an outdoor wood boiler is to be expected, however, since the wood itself is expected to be at least 20% water by weight (the dimensional lumber used in USEPA Draft Method 28 OWHH tests typically contains greater than 20% water by weight—cordwood would be expected to contain as much or more water). In addition, the water jacket surrounding the boiler and a long stack would be expected to reduce the temperature of the emission plume below its dew point, creating a long condensed vapor trail. Because the emission plume is of relatively low emission velocity by the time the condensed vapor trail has disappeared, the emission plume has largely dissipated, making it very difficult to obtain a reliable and proper opacity reading which, in turn, can lead to disagreements among certified opacity observers and contentious litigation.

- Residential sources are also not typically subject to opacity limitations, e.g., indoor wood stoves, fireplaces, barbeques, outdoor fireplaces, bonfires, leaf-burning and other residential sources have not typically been subject to opacity limitations. Although the reasons for this are numerous, one reason is that none of these residential sources have emission controls that can be continuously used to maintain emissions below a specified opacity limit and all are subject to variables that can result in higher than typical opacity.
- Under all of these circumstances, the Caucus urges that the limitation on opacity of emissions from "outdoor wood-fired boilers" be deleted from the proposed Regulation.

ADDITIONAL CHANGE RECOMMENDATION

(ii) The fuel-burning device may also be known as:

(D) Outdoor water stove.

The Caucus recommends that "outdoor water stove" should be deleted, as this term is outdated and has been abandoned by the State of Vermont, the state that first used the term in the 1997 regulations.

End of Comments

RTP ENVIRONMENTAL ASSOCIATES, INC.®

August 21, 2007

Mr. Greg Green, Director
USEPA Outreach and Information Division
109 T.W. Alexander Drive
Mail Drop C 304-01
Research Triangle Park, NC 27711

Subject: Review of NYSDEC Modeling Study for NESCAUM Model Rule and NAAQS Compliance Evaluation for EPA Voluntary Phase 1 Compliant Outdoor Hydronic Heater

Dear Mr. Green,

As requested by the Hearth, Patio & Barbecue Association ("HPBA"), RTP Environmental ("RTP") has reviewed the January 26, 2007 air dispersion modeling report prepared by the New York State Department of Environmental Conservation ("NYSDEC"). The modeling report describes the results of an evaluation conducted in support of the NESCAUM model rule ("Model Rule") for outdoor wood-fired hydronic heaters ("OWHH").[1] RTP has also modeled a large OWHH with $PM_{2.5}$ mass emissions that are compliant with the 0.60 lb/MMBtu emission level of EPA's Voluntary Phase 1 Partnership Agreement to assess compliance with the revised, 24-hour average $PM_{2.5}$ National Ambient Air Quality Standard ("NAAQS") of 35 µg/m^3.

The NYSDEC modeled OWHHs in a variety of stack-structure relationships, stack heights, and emission rates in efforts to assess the influence of OWHH placement, stack height, and the proposed model rule emission standards on ground level concentrations. Three different meteorological datasets were also evaluated to assess the influence of a wide variety of meteorological conditions. In addition, the NYSDEC evaluated the affects of elevated terrain on pollutant concentrations. In assessing impacts, the NYSDEC compares the model results to the revised, 24-hour average, $PM_{2.5}$ NAAQS.

[1] The NYSDEC referred to outdoor wood-fired hydronic heaters as outdoor wood boilers, or OWBs, in the January 26, 2007 report.

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RTP obtained the electronic model input and output files as well as the meteorological data files used in the January 2007 analysis from the NYSDEC. The model procedures and inputs were evaluated and the models were re-run to verify results. RTP concludes that the appropriate model was employed and that the model was set-up and executed according to procedures that are widely accepted in the regulatory modeling arena. The model inputs and results were also consistent with those described in the January report.

While the NYSDEC model approach and procedures are consistent with common industry practice, the modeled input pertaining to stack and building configurations deviate from expected OWHH manufacturer installation recommendations for Phase 1 units. In addition, the modeled mass emissions were overstated for the heater sizes evaluated by the NYSDEC and are in excess of the emissions anticipated from a large OWHH. Based upon these discrepancies, RTP does not agree with one of the NYSDEC's conclusions that the majority of impacts associated with Model Rule Phase 1 compliant OWHHs exceed the $PM_{2.5}$ NAAQS.

In addition, the NYSDEC used the maximum value in lieu of the 3-year average of the 8^{th} high value as representative of the design $PM_{2.5}$ value. The NYSDEC found that the use of the maximum value did not influence their conclusion that Phase 1 units do not comply with the $PM_{2.5}$ 24-hour NAAQS. However, this finding is premised on the model results obtained from an OWHH with a stack height that is not constructed according to expected manufacturer recommendations for Phase 1 units and with an emission rate that was overstated. The elevated concentrations projected from the NYSDEC modeled unit in this case would indeed not be reduced below the NAAQS if the 8^{th} high value were used instead of the maximum value. However, use of the 8^{th} high value is the appropriate design value and, in certain circumstances, could influence conclusions when an OWHH is modeled at a stack top elevation that conforms to vendor specifications and with a more realistic $PM_{2.5}$ emission rate.

NYSDEC OWHH Stack Height Lower Than Expected Manufacturer Recommendations for Phase 1 Units

The discrepancies noted in the NYSDEC modeling input are twofold. Primarily, in the majority of the NYSDEC modeling scenarios, the height of the heater stack was below the peak height of the adjacent structure. The NYSDEC used the dispersion model AERMOD to model both a 10 and 18 foot OWHH stack. The stacks were placed adjacent to either a 20 foot tall house or a 43 foot tall barn. These stack configurations are not consistent with the expected manufacturer installation recommendations for Phase 1 units. These recommendations will stipulate that the OWHH stack be constructed at least 2 feet taller than the roofline of nearby structures. The ground level concentrations from low level releases like an OWHH are heavily influenced by the aerodynamic influence of nearby structures. Therefore, the height of the OWHH is a very important element in evaluating the air quality impacts attributable to an OWHH.

NYSDEC Modeled Mass Emission Rate Was Overstated

The second discrepancy noted in the NYSDEC model pertains to the mass emission rate employed for assessing compliance with the Model Rule Phase 1 standard. In calculating the Model Rule Phase 1 mass emission rates input to the model, the NYSDEC used the Phase 1 emission standard of 0.44 lb PM/MMBtu heat input. This emission standard was converted to a maximum lb $PM_{2.5}$/hr emission rate and an average lb/hr emission rate using heater heat input rates of 350,000 and 215,000 Btu/hr, respectively. The resultant mass emission rates of 70 and 43 g/hr were input to the model and used to assess compliance.

This calculation overestimates the maximum emissions that would be anticipated from an OWHH for two reasons. Primarily, the $PM_{2.5}$ emission rate modeled by the NYSDEC for Phase 1 compliant OWHHs represents a maximum, worst-case hourly emission rate. A maximum hourly emission rate does not account for the variability in emissions attributable to the variation in heat demand placed on the unit and the combustion conditions within the unit that occur over the course of a 24-hour period. A maximum hourly emission rate is also not consistent with the either the averaging time of the underlying emissions standard (i.e., the $PM_{2.5}$ NAAQS is a 24-hour average) or the averaging time required by the test method (i.e., Method 28 OWHH) that the model rule mandates for evaluating compliance. Method 28 OWHH requires a weighted average calculation of emissions based upon the total time spent in each of four heat output categories, with the fourth category being the maximum achievable heat output of the unit. Since the $PM_{2.5}$ NAAQS is a 24-hour standard, the emissions should reflect a reasonable worst-case estimate of the average emissions during the averaging period, not the maximum emissions anticipated in any 1-hour period. The weighted average emission rates produced by the Method 28 OWHH test method are suitable for this purpose.

Secondly, the higher heat input of 350,000 Btu/hr used by the NYSDEC in calculating the maximum, hourly emission rate exceeds the typical heat input rating of a residential OWHH. A 350,000 Btu/hr heat input unit will produce between 170,000 and 220,000 Btu/hr heat output, depending upon the unit's heat transfer efficiency. The majority of OWHHs have a heat output rating of approximately 100,000 Btu/hr. A 100,000 Btu/hr heat output heater would be used to heat a typical 4-4,500 square foot house. The large, 350,000 Btu/hr heat input unit modeled by the NYSDEC approaches the size of a commercial unit that could be used to heat up to 10,000 square feet, or multiple smaller structures.[2] Since the estimated emissions are a direct function of the size of the heater, the emission rate modeled by the NYSDEC in assessing compliance with the $PM_{2.5}$ NAAQS under the Phase 1 standard is overstated.

HPBA Estimate of Mass Emission Rate for Compliant OWHHs

The HPBA has calculated the maximum mass emission rate from a large OWHH (i.e., 200,000 Btu/hr heat output) that would comply with the NESCAUM model rule standard of 0.44 lb/MMBtu heat input. The calculation uses the total energy input, heater efficiency, and the target emission factor as input. The calculation outputs the necessary Method 28 OWHH test duration, the burn rate, and the weighted average emission rate. The calculation uses the same four test heat output categories and the weighting factors as required by Method 28 OWHH. The calculated emission value is therefore directly comparable to the emission value that would be used to assess compliance with the Phase 1 emission standard. The calculation indicates that the heating season weighted average emission rate that would be anticipated from a 200,000 Btu/hr (heat output) unit meeting a 0.44 lb/MMBtu emission standard is 20.5 g/hr. The calculation and a more detailed description of it can be found in Attachment A.

The HPBA also calculated the mass emissions from a 200,000 Btu/hr heat output OWHH that complies with the 0.60 lb/MMBtu EPA Phase 1 Partnership Agreement. Two heater efficiencies (63% weighted average efficiency which has a Method 28 OWHH Category 4 heat output efficiency of 75% and 48% weighted average efficiency which has a Category 4 heat output efficiency of 60%) were evaluated at the 0.60 lb/MMBtu emission level due to uncertainties about combustion and heat exchanger efficiency for Phase 1 units. The heating season weighted average emission rates, as calculated according to the Method 28 OWHH weighting scheme, under this program are 29.8 g/hr, assuming 63% weighted average efficient heater, and 38.9 g/hr, assuming a 48% weighted average efficient heater.

The 3-yr Average of the Highest 8^{th} High Values Should be Used to Assess Compliance with the $PM_{2.5}$ 24-hour NAAQS

For the vast majority of scenarios modeled, the NYSDEC used the maximum $PM_{2.5}$ modeled concentration from a single year of meteorology as the design value in assessing compliance with the $PM_{2.5}$ NAAQS. The NYSDEC used five years of meteorology from Syracuse to evaluate whether the high value accurately represented the 3-year average of the 8^{th} highest values. The NYSDEC concludes that the use of the 8^{th} high value can reduce the design concentration by 25-33%, as compared the maximum value, but that this

[2] A general industry assumption is that 22 Btu/hr (heat output) is required to heat each square foot of a typical residence.

reduction does not affect the overall conclusions of the study. While the conclusions under the conditions modeled by the NYSDEC may not be affected, the 3-yr average of the 8th high value is the design value mandated by the revised PM2.5 NAAQS. In addition, a 25-33% reduction in modeled impacts (as demonstrated my the NYSDEC) could influence the ultimate determination of NAAQS compliance once vendor recommendations regarding stack top elevation and more realistic emission rates are modeled, if background pollutant concentrations are also considered.

Modeling Using Typical Manufacture's Recommended Stack Height and Average Emissions

RTP re-modeled using the NYSDEC model as the basis for all inputs (i.e., the OWHH stack was located 25' away from the adjacent structure, and stack parameters and receptors were identical to the NYSDEC model).[3] Only the stack heights, building heights, and OWHH mass emission rates have been altered. Five years of Syracuse data were used so that the 98th percentile value could also be calculated. Two stack/building configurations and three emission rates were evaluated. A 35 foot stack adjacent to a 33 foot tall structure (a typical 2 story house) and a 22 foot stack adjacent to a 20 foot structure (a typical single story house) were considered. In addition, the NESCUAM model rule Phase 1 standard of 0.44 lb/MMBtu standard as well as the EPA voluntary emission level of 0.60 lb/MMBtu were evaluated for each of the stack/building configurations. The mass emissions associated with two boiler efficiencies were evaluated at the 0.60 lb/MMBtu emission level. A large residential heater with a rated heat output equal to 200,000 Btu/hr was assumed in calculating the weighted average lb/hr $PM_{2.5}$ emission rates. To simplify the analysis, a one gram per second emission rate was modeled for each stack and building configuration and ambient impacts at each mass emission level were scaled from the results.

The modeled stack parameters and mass emission rates are presented in Table 1. The results of the modeling are shown in Table 2. As can be seen, each of the modeled scenarios is compliant with the revised $PM_{2.5}$ NAAQS of 35 $\mu g/m^3$. The modeling demonstrates that large OWHHs constructed according to expected manufacturer installation recommendations for Phase 1 units (e.g., at least two feet above the height of adjacent structures) are compliant with the revised $PM_{2.5}$ NAAQS at both the NESCAUM Phase 1 standard of 0.44 lb/MMBtu

[3] Please note that the stack gas exit temperature and flow rate modeled by the NYSDEC are not typical of the majority of OWBs. A more typical stack gas exit temperature is 350F, while a more typical gas exit velocity is 6.5 ft/sec with an 8" diameter stack. However, RTP determined that the NYSDEC modeled parameters did little to influence concentrations when compared to more typical values and that building downwash has a much greater influence on maximum modeled concentrations.

heat input and the EPA Phase 1 Partnership Agreement emission level of 0.60 lb/MMBtu heat input.[4]

Figure 1 shows the 24-hour impacts for the 22' stack and 20' structure scenario with a 0.60 lb/MMBtu compliant, 63% weighted average efficient OWHH. As shown in the figure, the maximum concentrations occur within 30m (approximately 100 ft) of the OWHH and are reduced by one half their original value less than 20m (approximately 60 ft) from the point of maximum. Such a rapid decrease in concentration in such a short distance indicates that the maximum concentrations near the source are due the downwash caused by the influence of the nearby structures. Since such concentrations tend to diminish very rapidly downwind, they are not likely to affect a large area. The model summary results are provided in Attachment B.

Please call me at (919) 845-1422 x31 if you have any questions regarding our evaluation.

Sincerely,

David Keen

David Keen
RTP Environmental

cc: Mr. Alan Cagnoli, HPBA
Mr. David Menotti, Pillsbury Winthrop Shaw Pittman
Mr. John K Kehrwald, Heatmor, Inc

[4] Please also note that RTP Environmental also modeled a more typically sized, 100,000 Btu/hr (heat output) OWB. The modeled impacts were one half of the impacts calculated with a 200,000 Btu/hr (heat output) OWB and also compliant with the revised $PM_{2.5}$ NAAQS.

Table 1. Modeled Input Data

Source Description	UTM Easting (m)	UTM Northing (m)	Base Elevation (ft)	Release Height (ft)	Exit Temp. (F)	Velocity (m/sec)	Diameter (ft)	$PM_{2.5}$ Emission Rate (g/sec)
0.44 lb/MMBtu Compliant OWHH	0.0	0.0	0.0	22[a]	294	1.05 (3.4 ft/sec)	0.5	5.7×10^{-3} (20.5 g/hr)
0.60 lb/MMBtu Compliant OWHH (63% Efficient)	0.0	0.0	0.0	22[a]	294	1.05 (3.4 ft/sec)	0.5	8.3×10^{-3} (29.8 g/hr)
0.60 lb/MMBtu Compliant OWHH (48% Efficient)	0.0	0.0	0.0	22[a]	294	1.05 (3.4 ft/sec)	0.5	1.08×10^{-2} (38.9 g/hr)

[a]A 22' stack was modeled with an adjacent 20' tall structure. In addition, a 35' stack was modeled with an adjacent 33' structure.

Table 2. 24-Hour $PM_{2.5}$ Model Summary Results

Building/Stack Scenario	Mass Emissions	3-yr Average of H8H ($\mu g/m^3$)[a]	Revised $PM_{2.5}$ NAAQS ($\mu g/m^3$)
22' stack, 20' Structure	0.44 lb/MMBtu Compliant OWHH	9.26	35
	0.60 lb/MMBtu Compliant OWHH (63% Efficient)	13.4	
	0.60 lb/MMBtu Compliant OWHH (48% Efficient)	17.6	
35' stack, 33' Structure	0.44 lb/MMBtu Compliant OWHH	4.03	
	0.60 lb/MMBtu Compliant OWHH (63% Efficient)	5.86	
	0.60 lb/MMBtu Compliant OWHH (48% Efficient)	7.65	

[a] The 1988-1990 years of meteorology were used in calculating the three year, 24-hr average impacts as this year range yielded the maximum results.

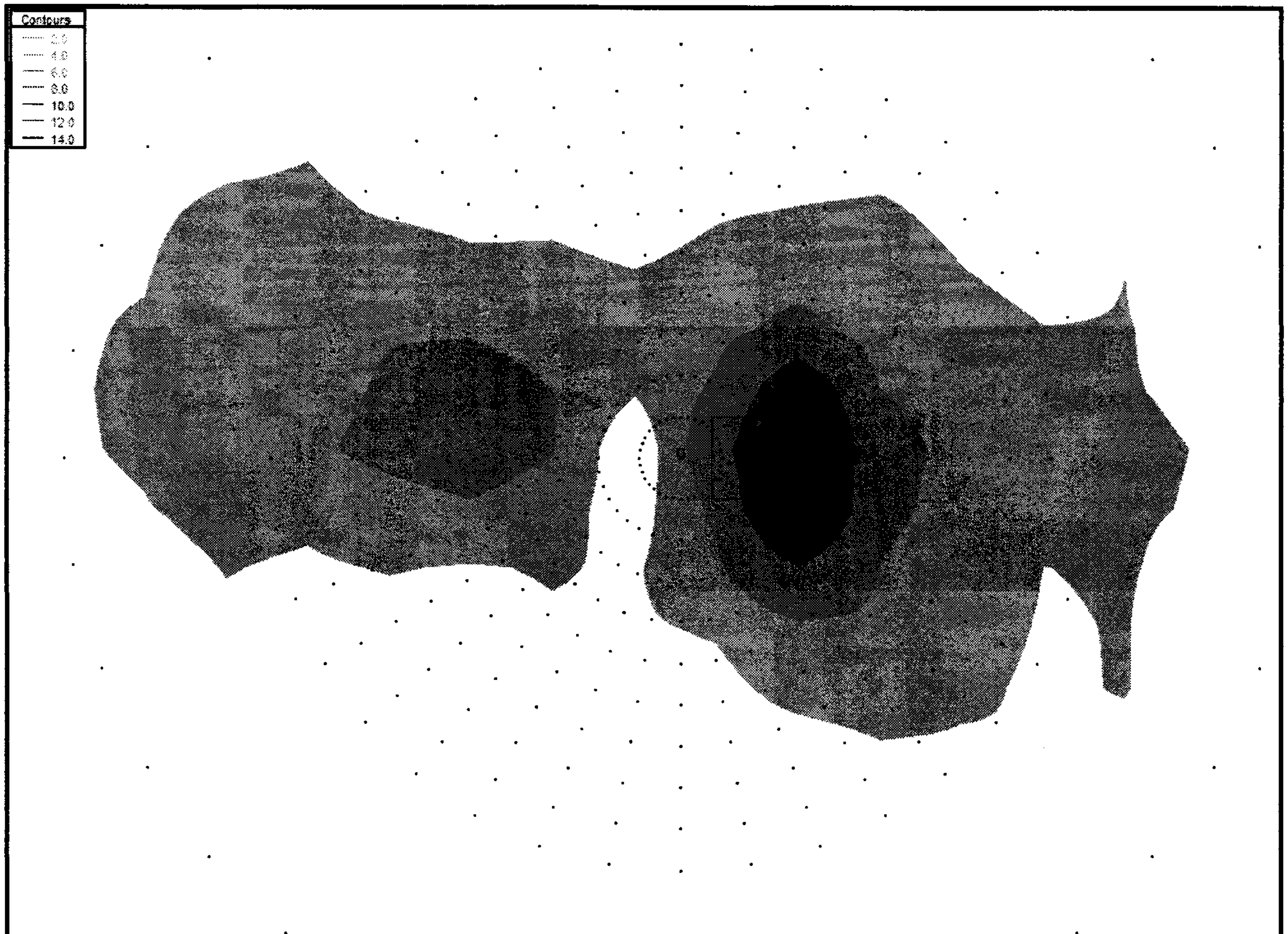


Figure 1. Maximum 8th High $PM_{2.5}$ 24-Hour Impact (22' Stack, 0.60 lb/MMBtu)

Attachment A
OWHH Emission Rate Modeling Tool

EMISSIONS MODELING

Firebox Volume	20	Cubic Feet	Fuel Wt (wet)	200	Lb
Fuel Moisture Content	22%	%	Fuel Wt (dry)	163.93	Lb
				74.36	Kg
Rated Output	200,000	Btu/Hr			

This will be the CAT 4 Output

Efficiency @ Rated Output	75%	%
Slope of Efficiency Curve		

If unknown, leave blank, Default is .2

Target Emissions Value	0.44	→
Slope of Emissions Curve		

If unknown, leave blank; Default is -1 for Lb/MMBtu, 20 for g/Hr

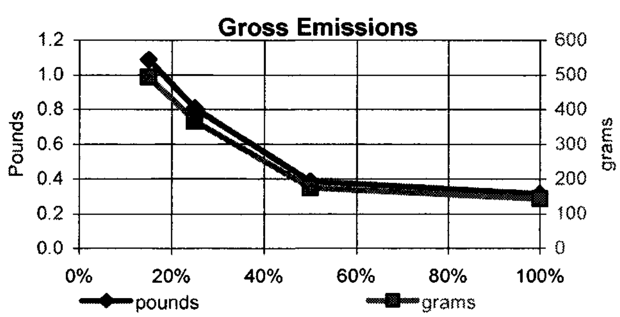
Lb/MMBtu input
g/Hr
At Rated Outpt
Wtd Avg (Htg)
Wtd Avg (Yr Rd)

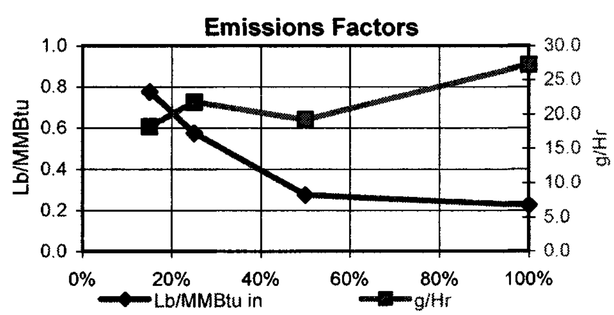
CAT	Input Btu	Output Btu	Efficiency	Percent of Rated Output	Output Rate Btu/Hr	Burn Rate Kg/Hr	Duration Hr
1	1,401,639	812,951	58%	15%	30,000	2.74	27.10
2	1,401,639	840,984	60%	25%	50,000	4.42	16.82
3	1,401,639	911,066	65%	50%	100,000	8.16	9.11
4	1,401,639	1,051,230	75%	100%	200,000	14.15	5.26

	Total Emission Capture		Emissions Values				
CAT	Lb	g	Lb/MMBtu in	Lb/MMBtu out	g/Hr	g/Kg	g/MJ
1	1.09	492.72	0.78	1.34	18.18	6.63	0.57
2	0.81	365.57	0.58	0.96	21.73	4.92	0.41
3	0.39	174.84	0.28	0.42	19.19	2.35	0.18
4	0.32	143.05	0.23	0.30	27.22	1.92	0.13

Weighted Average

		Burn Rate	Emissions Values				
	Efficiency	Kg/Hr	Lb/MMBtu in	Lb/MMBtu out	g/Hr	g/Kg	g/MJ
Htg	63%	6.78	0.44	0.72	20.52	3.76	0.31
Yr Rd	61%	5.20	0.56	0.94	19.76	4.81	0.41





EMISSIONS MODELING

Firebox Volume: 20 Cubic Feet | Fuel Wt (wet): 200 Lb

Fuel Moisture Content: 22% % | Fuel Wt (dry): 163.93 Lb

74.36 Kg

Rated Output: 200,000 Btu/Hr

This will be the CAT 4 Output

Efficiency @ Rated Output: 75% %

Slope of Efficiency Curve:

If unknown, leave blank, Default is .2

Target Emissions Value: 0.6 →

Slope of Emissions Curve:

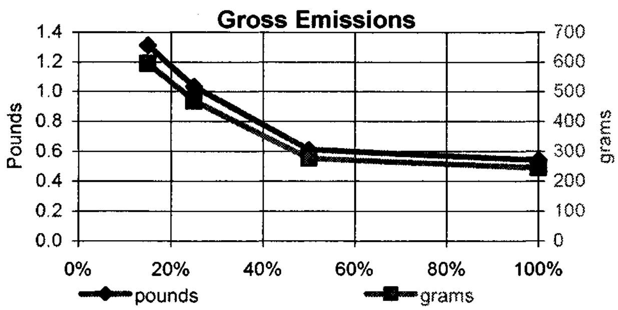
If unknown, leave blank; Default is -1 for Lb/MMBtu, 20 for g/Hr

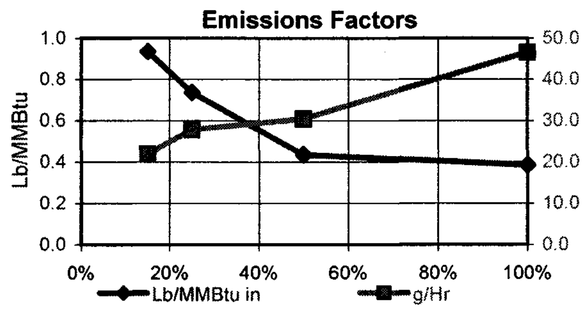
- [x] Lb/MMBtu input
- [ ] g/Hr
- [ ] At Rated Outpt
- [x] Wtd Avg (Htg)
- [ ] Wtd Avg (Yr Rd)

CAT	Input Btu	Output Btu	Efficiency	Percent of Rated Output	Output Rate Btu/Hr	Burn Rate Kg/Hr	Duration Hr
1	1,401,639	812,951	58%	15%	30,000	2.74	27.10
2	1,401,639	840,984	60%	25%	50,000	4.42	16.82
3	1,401,639	911,066	65%	50%	100,000	8.16	9.11
4	1,401,639	1,051,230	75%	100%	200,000	14.15	5.26

	Total Emission Capture		Emissions Values				
CAT	Lb	g	Lb/MMBtu in	Lb/MMBtu out	g/Hr	g/Kg	g/MJ
1	1.31	594.45	0.94	1.61	21.94	7.99	0.69
2	1.03	467.29	0.74	1.23	27.78	6.28	0.53
3	0.61	276.56	0.44	0.67	30.36	3.72	0.29
4	0.54	244.77	0.39	0.51	46.57	3.29	0.22

Weighted Average		Burn Rate	Emissions Values				
	Efficiency	Kg/Hr	Lb/MMBtu in	Lb/MMBtu out	g/Hr	g/Kg	g/MJ
Htg	63%	6.78	0.60	0.97	29.80	5.13	0.42
Yr Rd	61%	5.20	0.72	1.21	26.87	6.18	0.52





EMISSIONS MODELING

Firebox Volume	20	Cubic Feet	Fuel Wt (wet)	200	Lb
Fuel Moisture Content	22%	%	Fuel Wt (dry)	163.93	Lb
				74.36	Kg

Rated Output | 200,000 | Btu/Hr

This will be the CAT 4 Output

Efficiency @ Rated Output | 60% | %

Slope of Efficiency Curve | |

If unknown, leave blank, Default is .2

Target Emissions Value | 0.6 | →

Slope of Emissions Curve | |

If unknown, leave blank; Default is -1 for Lb/MMBtu, 20 for g/Hr

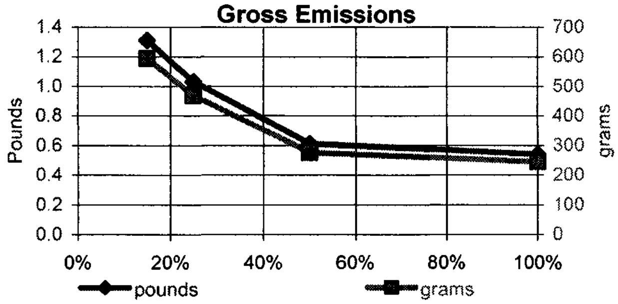
- [x] Lb/MMBtu input
- [ ] g/Hr
- [ ] At Rated Outpt
- [x] Wtd Avg (Htg)
- [ ] Wtd Avg (Yr Rd)

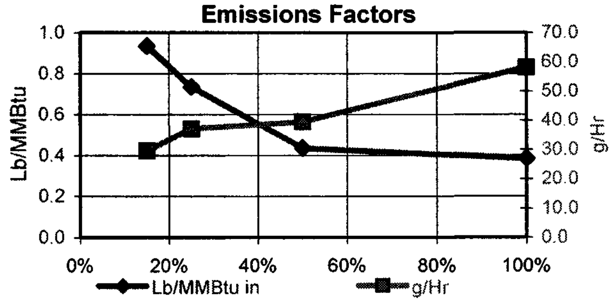
CAT	Input Btu	Output Btu	Efficiency	Percent of Rated Output	Output Rate Btu/Hr	Burn Rate Kg/Hr	Duration Hr
1	1,401,639	602,705	43%	15%	30,000	3.70	20.09
2	1,401,639	630,738	45%	25%	50,000	5.89	12.61
3	1,401,639	700,820	50%	50%	100,000	10.61	7.01
4	1,401,639	840,984	60%	100%	200,000	17.68	4.20

CAT	Total Emission Capture		Emissions Values				
	Lb	g	Lb/MMBtu in	Lb/MMBtu out	g/Hr	g/Kg	g/MJ
1	1.31	594.45	0.94	2.17	29.59	7.99	0.94
2	1.03	467.29	0.74	1.63	37.04	6.28	0.70
3	0.61	276.56	0.44	0.87	39.46	3.72	0.37
4	0.54	244.77	0.39	0.64	58.21	3.29	0.28

Weighted Average

	Efficiency	Burn Rate Kg/Hr	Emissions Values				
			Lb/MMBtu in	Lb/MMBtu out	g/Hr	g/Kg	g/MJ
Htg	48%	8.81	0.60	1.29	38.94	5.13	0.55
Yr Rd	46%	6.82	0.72	1.61	35.51	6.18	0.69





OWHH Emission Rate Modeling Tool

PURPOSE:
Develop a spreadsheet based tool to allow theoretical modeling of several emissions profiles for comparison of emissions factors reported in various units of measure and various weighting schemes.

INPUTS:
Total Energy Input (based on Wood Weight (dry) and Moisture Content)
Total Efficiency (including an assumption as to the shape of the efficiency curve)
Target Emission Factor/Rate (either as a single point or a weighted average)

OUTPUTS:
Test Duration
Burn Rate
Total Emission Capture
Weighted Emission Factor/Rate

DEFINITIONS:

Vfb	Fire Box Volume (cubic feet)
MC	Moisture Content (%)
r	Fire Box Loading Density (10 lb wood/cubic foot)
HHV	Higher Heating Value of wood input (8550 Btu/cubic foot)
WWwet	Weight of Wood on a wet basis (lb)
WWdry	Weight of Wood on a dry basis – moisture correctec (lb or Kg)
Qin	Total Energy Input (Btu)
N	Efficiency
Qout	Total Energy Output (Btu)
q	Energy Output Rate (Btu/Hr)
f	Emissions Weighting Factor
E	Emissions Factor (Lb/MMBtu or g/Hr)
WA	Emissions Weighted Average
D	Burn Duration (Hr)
BR	Burn Rate (Kg/Hr)
m	Slope of a linear curve

WEIGHTING SCHEMES:

CAT		Htg	Yr Rd
1	15%	17.5%	43.7%
2	25%	27.5%	23.8%
3	50%	45.0%	27.5%
4	100%	10.0%	5.0%

I. CALCULATE PERFORMANCE VALUES

A. WWwet = Vfb x r
   WWdry = WWwet / (1 + MC) … note MC is a percentage, i.e. .25
      This gives WWdry in pounds
   Qin = WWdry x HHV

   WWdry = WWdry x .45359237 … This gives WWdry in Kg for calculating Burn Rates

B. Calculate the Efficiency at each of the Output Rates
   Assuming that the efficiency curve is linear, then based on y = mx + b
   Therefore: b = y – mx

   Given that x = 100% (max output rate)
   And that slope (m) = -.2 (unless entered by the operator)
   And that y = N (operator entered efficiency at the max burn rate)

   B = N + (.2 x 1.0) = N + .2

   Ni = (-.2 x Xi) + B …. Calculate Efficiency at each Output Rate
      (Xi = .15, .25, .5, 1.0)

C. Calculate the Total Output at each Output Rate (based on Efficiency)
   Qouti = Qin x Ni

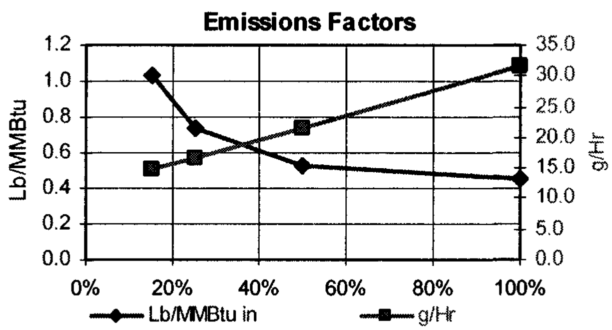
D. Calculate Target Output Rates based on the Maximum (Rated) Output Rate
   qi = Xi x q4 …. Note: q4 is the Rated Output Rate entered by the operator

E. Calculate Burn Durations at each Output Rate
   Di = Qouti / qi

F. Calculate Burn Rates at each Output Rate
   BRi = WWdry / Di … Note: WWdry is in Kg to give a solution in Kg/Hr

II. CALCULATE EMISSIONS VALUES

The target emissions value is input as either Lb/MMBtu in or as g/Hr. Further, the operator selects whether this value is a Weighted Average value or the value at the Rated Output rate. The input value is used to calculate the Total Emissions capture at each Output Category. The shape of the emissions curve (Lb/MMBtu in or g/Hr) must be assumed … linear models have been chosen to ease the calculations.



The g/Hr curve is assumed to be linear with a slope of 20 (unless input by operator). The y intercept = E4 – m.

The Lb/MMBtu in curve is assumed to consist of a family of linear curves related as follows: (Slope m is assumed to be -1 unless entered by the operatore)

CAT 1 to CAT 2 (15% to 25%)	2 x m
CAT 2 to CAT 3 (25% to 50%)	m
CAT 3 to CAT 4 (50% to 100%)	.1 x m

A. Calculate the Total Emissions Capture:

Calculate the individual emissions factors based on the selected input emissions. If the input is simply the CAT 4 value, then (obviously) the CAT 4 value is known and the CAT 1 through 3 values can be determined based on the assumed shape of the curve (slopes given above).

If the input emission factor is a Weighted Average value (WA), then the estimated shape of the emissions curve is used determine the relationship of the various emissions factors.

$WA = (E1 \times f1) + (E2 \times f2) + (E3 \times f3) + (E4 \times f4)$

For g/Hr (based on a fixed slope as discussed above)
$y\ intercept = WA - m \times ((.15 \times f1) + (.25 \times f2) + (.5 \times f3) + (1 \times f4))$

and the individual Emissions Factors can be found from:
$E = m \times X + y\ intercept$

Combining the equations yields:

$$E1 = WA - m \times ((.15 \times (1 + f1)) + (.25 \times f2) + (.5 \times f3) + (1 \times f4))$$
$$E2 = E1 + (m \times (X2 - X1) = E1 + (.1 \times m)$$
$$E3 = E1 + (.35 \times m)$$
$$E4 = E1 + (.85 \times m)$$

The derivation is similar for Lb/MMBtu, except that the slope changes between each pair of points. So:

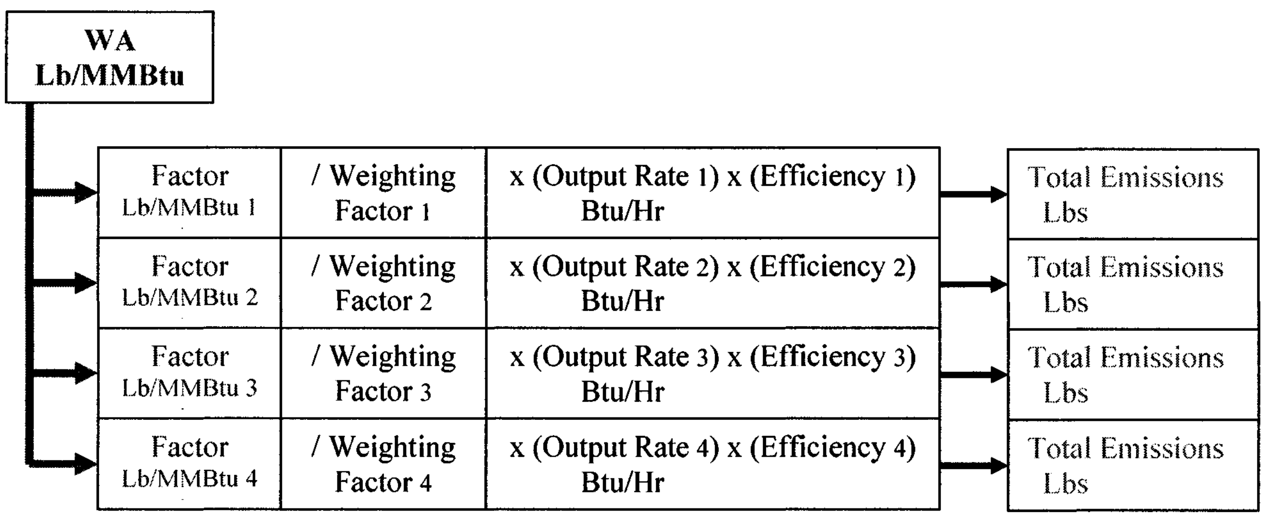
$$WA = (E1 \times f1) + (E2 \times f2) + (E3 \times f3) + (E4 \times f4)$$

Where the relationship of the points is:

$$E2 = E1 + (m1\text{-}2) \times (X2 - X1) = E1 + (2.5 \times m) \times (.25 - .15) = E1 + (.25 \times m)$$
$$E3 = E2 + (m2\text{-}3) \times (X3 - X2) = E1 + (.5 \times m)$$
$$E4 = E3 + (m3\text{-}4) \times (X4 - X3) = E1 + (.55 \times m)$$

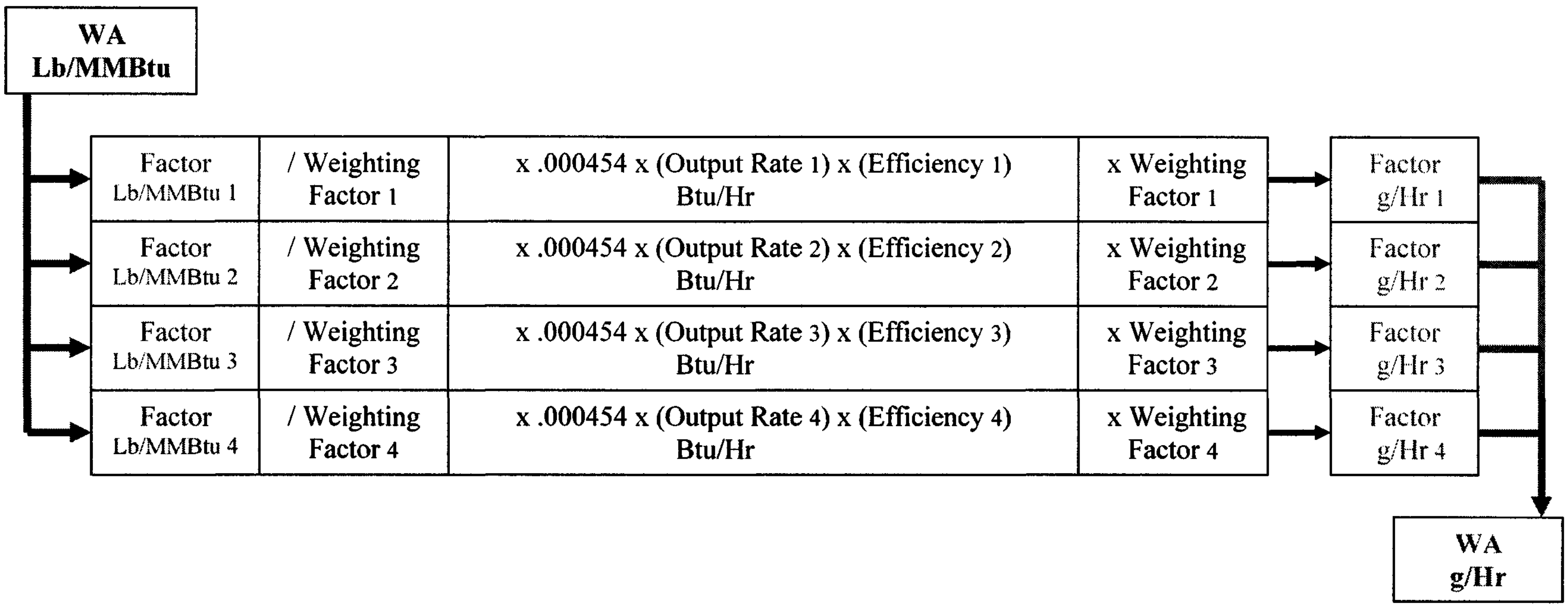
Substituting yields:

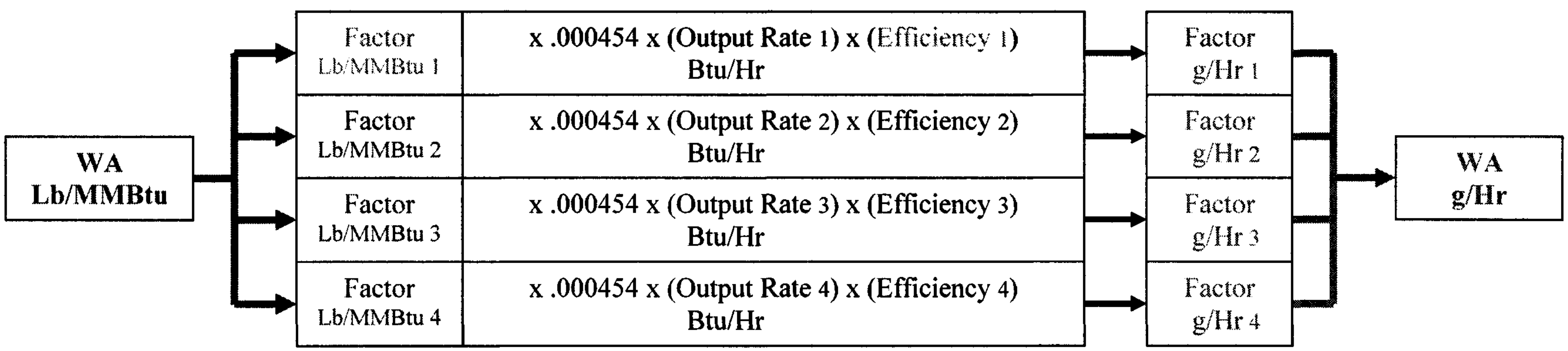
$$E1 = WA / (f1 + (m \times ((.2 \times f2) + (.5 \times f3) + (.55 \times f4))))$$
$$E2 = E1 + (.2 \times m)$$
$$E3 = E1 + (.5 \times m)$$
$$E4 = E1 + (.55 \times m)$$



B. Calculate various Emissions Values

Once the Total Emissions Capture is known (Lb or g), it is fairly easy to convert to Lb/MMBtu in, Lb/MMBtu out, g/Hr, g/Kg, g/MJ and to apply any desired weighting scheme.


WA
Lb/MMBtu
Factor Lb/MMBtu 1
/ Weighting Factor 1
x .000454 x (Output Rate 1) x (Efficiency 1) Btu/Hr
x Weighting Factor 1
Factor g/Hr 1
Factor Lb/MMBtu 2
/ Weighting Factor 2
x .000454 x (Output Rate 2) x (Efficiency 2) Btu/Hr
x Weighting Factor 2
Factor g/Hr 2
Factor Lb/MMBtu 3
/ Weighting Factor 3
x .000454 x (Output Rate 3) x (Efficiency 3) Btu/Hr
x Weighting Factor 3
Factor g/Hr 3
Factor Lb/MMBtu 4
/ Weighting Factor 4
x .000454 x (Output Rate 4) x (Efficiency 4) Btu/Hr
x Weighting Factor 4
Factor g/Hr 4
WA
g/Hr


WA
Lb/MMBtu
Factor Lb/MMBtu 1
x .000454 x (Output Rate 1) x (Efficiency 1) Btu/Hr
Factor g/Hr 1
Factor Lb/MMBtu 2
x .000454 x (Output Rate 2) x (Efficiency 2) Btu/Hr
Factor g/Hr 2
Factor Lb/MMBtu 3
x .000454 x (Output Rate 3) x (Efficiency 3) Btu/Hr
Factor g/Hr 3
Factor Lb/MMBtu 4
x .000454 x (Output Rate 4) x (Efficiency 4) Btu/Hr
Factor g/Hr 4
WA
g/Hr

x .000454

Attachment B
Model Summary Results

HPBA Model Summary Results

5 yr Syracuse MET, OWHH 8m from house, 35' and 22' stacks (2' taller than house), receptors 10m from stack, flat terrain, NYSDEC and Caucus stack parameters, 1 gps emissions

Model	File	Pol	Average	Group	Rank	1 gps Conc.	East(X)	North(Y)	Elev	Time	Met File	Sources	Groups	Rec.
AERMOD	OWB Final-22'_88_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	1695.81189	30	0	515.7	88091024	SYR88.SFC	2	2	648
AERMOD	OWB Final-22'_89_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	1373.11377	29.54	-5.21	515.7	89080724	SYR89.SFC	2	2	648
AERMOD	OWB Final-22'_90_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	1314.40393	29.54	-5.21	515.7	90021024	SYR90.SFC	2	2	648
AERMOD	OWB Final-22'_91_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	1163.51135	30	0	515.7	91082224	SYR91.SFC	2	2	648
AERMOD	OWB Final-22'_92_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	1167.46375	30	0	515.7	92080924	SYR92.SFC	2	2	648
AERMOD	OWB Final-35'_88_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	747.27191	28.19	-10.26	515.7	88041124	SYR88.SFC	2	2	648
AERMOD	OWB Final-35'_89_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	627.36523	30	0	515.7	89022724	SYR89.SFC	2	2	648
AERMOD	OWB Final-35'_90_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	582.10529	29.54	-5.21	515.7	90062824	SYR90.SFC	2	2	648
AERMOD	OWB Final-35'_91_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	531.20532	30	0	515.7	91081524	SYR91.SFC	2	2	648
AERMOD	OWB Final-35'_92_PM2.5.USF	PM2.5	24-HR	CAUCUS	8TH	504.08752	29.54	-5.21	515.7	92073024	SYR92.SFC	2	2	648
AERMOD	OWB Final-22'_88_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	1913.18982	30	0	515.7	88061124	SYR88.SFC	2	2	648
AERMOD	OWB Final-22'_89_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	1525.54895	30	0	515.7	89082224	SYR89.SFC	2	2	648
AERMOD	OWB Final-22'_90_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	1434.08936	29.54	-5.21	515.7	90021024	SYR90.SFC	2	2	648
AERMOD	OWB Final-22'_91_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	1241.95642	30	0	515.7	91081524	SYR91.SFC	2	2	648
AERMOD	OWB Final-22'_92_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	1272.15588	30	0	515.7	92062124	SYR92.SFC	2	2	648
AERMOD	OWB Final-35'_88_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	819.82117	30	0	515.7	88061124	SYR88.SFC	2	2	648
AERMOD	OWB Final-35'_89_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	682.10443	30	0	515.7	89022724	SYR89.SFC	2	2	648
AERMOD	OWB Final-35'_90_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	621.49976	29.54	-5.21	515.7	90111924	SYR90.SFC	2	2	648
AERMOD	OWB Final-35'_91_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	580.85205	30	0	515.7	91081524	SYR91.SFC	2	2	648
AERMOD	OWB Final-35'_92_PM2.5.USF	PM2.5	24-HR	NYSDEC	8TH	545.22699	29.54	-5.21	515.7	92073024	SYR92.SFC	2	2	648

5-yr Summary

					24hr Concentration (ug/m3)		
Average	Scenario	Rank	3-yr avg H8H 1 g/sec Conc. (ug/m3)	g/hr --> g/sec -->	.44 lb/MMBtu 20.52 0.0057	.60 lb/MMBtu @ 63% Efficiency 29.8 0.0083	.60 lb/MMBtu @ 48% Efficiency 38.9 0.0108
24-HR	NYSDEC - 22' Stack, 20' Building	8TH	1624.276		9.26	13.4	17.6
	CAUCUS - 22' Stack, 20' Building		1461.110		8.33	12.1	15.8
24-HR	NYSDEC - 35' Stack, 33' Building	8TH	707.808		4.03	5.86	7.65
	CAUCUS - 35' Stack, 33' Building		652.247		3.72	5.40	7.05

Note: A weighted average efficiency of 63% corresponds to a Method 28 OWHH Category 4 Heat Output Efficiency of 75%.
A weighted average efficiency of 48% corresponds to a Method 28 OWHH Category 4 Heat Output Efficiency of 60%.

ISC-PRIME OWB RESULTS, 3 NEWEST SCENARIOS (161, 120, 60 grams/hour), 3 STA

SCENARIO #1 Stack Height (ft)	MET YEAR	161 grams/hour 0.0447 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	120 grams/hour 0.0333 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
26.00	**1984**	17.59	0	13.10	0
	1985	19.79	0	14.74	0
Building Type (ft)	**1986**	17.54	0	13.07	0
28x40x16	**1987**	18.16	0	13.53	0
Ranch	**1988**	18.46	0	13.75	0

SCENARIO #2 Stack Height (ft)	MET YEAR	161 grams/hour 0.0447 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	120 grams/hour 0.0333 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
32.00	**1984**	13.84	0	10.31	0
	1985	13.99	0	10.42	0
Building Type (ft)	**1986**	12.46	0	9.28	0
28x40x22	**1987**	13.67	0	10.19	0
Cape	**1988**	12.75	0	9.50	0

SCENARIO #3 Stack Height (ft)	MET YEAR	161 grams/hour 0.0447 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	120 grams/hour 0.0333 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
38.00	**1984**	9.93	0	7.40	0
	1985	9.80	0	7.30	0
Building Type (ft)	**1986**	9.22	0	6.87	0
28x40x28	**1987**	10.19	0	7.59	0
Colonial	**1988**	8.82	0	6.57	0

CK HEIGHTS (26, 32, 38 feet)

60 grams/hour 0.0167 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
6.57	0
7.39	0
6.55	0
6.79	0
6.89	0

60 grams/hour 0.0167 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
5.17	0
5.23	0
4.66	0
5.11	0
4.77	0

60 grams/hour 0.0167 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
3.71	0
3.66	0
3.44	0
3.81	0
3.29	0

5/31/07

Summary for OWB ISC-PRIME modeling, Round 2

"Two-foot-above-roofline analysis"

Test cases were largely modeled upon assumptions used in 2006 NYSDEC modeling

$PM_{2.5}$ modeling performed for 24-hour averaging period only

Predicted modeling impacts were compared to 21 μg/m^3, (the federal standard of 35 μg/m^3 minus the rural background value for Central Maine (14 μg/m^3)

Given the large variation of terrain in Maine, flat terrain was assumed.

Receptor Grid

Polar grid receptor placement every 10 degrees at the following spacing:

10 meter spacing from 0 to 200 meters
50 meter spacing from 200 to 500 meters
100 meter spacing from 500 to 1000 meters

Stack Parameters

Stack Heights:	18 feet, 24 feet, 30 feet
Stack Diameter:	0.66 feet (8 inches, suggested to be the industry standard)
Stack Temp:	294° F (418.71K), acceptable range 300° – 500° F
Stack Velocity:	3.44 feet/sec (1.05 m/s), number more likely to be in the vicinity of 2-4 m/s, but using 1.05 m/s will add conservatism

Building Downwash

OWB modeled as a 4 foot x 6 foot x 6.5 foot structure

3 house configurations:

Ranch (1 story): 40 feet long x 28 feet wide x 16 feet high
Cape (1 ½ stories): 40 feet long x 28 feet wide x 22 feet high
Colonial (2 stories): 40 feet long x 28 feet wide x 28 feet high

OWB Stack was assumed to be located on OWB within 20 feet of buildings

Meteorological Data

5/30/07

5 years of hourly Augusta meteorological data, 1984-1988

Emission Rate

3 different emission rates (g/s):

- 120 grams/hour (0.0333 g/s) – Current reasonable actual "upper limit" OWB emission rate, based upon manufacturers data and recommendations
- 60 grams/hour (0.0167 g/s) – just below Phase I upper limit of 70 grams/hour
- 15 grams/hour (0.0042 g/s) – Phase II limit

Conclusions

Furthest modeled distance (for all H8H modeling runs) to reach $< 21\ \mu g/m^3$ was 361 feet, based upon the current 120 g/h emission rate and 18' stack (with structure present). Some setback to be required for all 120 g/h cases.

The presence of buildings greatly affects the local dispersion pattern, regardless of stack height. The two-feet-above-roofline assumption doesn't appear to have made any real improvement in final results (compared to previous modeling). The reduction in emission rate is more of the driving factor.

When structures were present, the maximum H8H impact of almost every model runs occurred very close to the stack/boiler, due to low stack velocity/building downwash.

5-30-07

ISC-PRIME OWB MODEL RESULTS, 3 SCENARIOS (120, 60, 15 grams/hour), 3 STACK HEIGHTS (18, 24, 30 feet)

SCENARIO #1	MET YEAR	120 grams/hour 0.0333 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	60 grams/hour 0.0167 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	15 grams/hour 0.00417 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
Stack Height (ft) 18.00	1984	49.51	98	24.83	66	6.20	0
	1985	56.05	131	28.11	66	7.02	0
Building Type (ft)	1986	52.09	98	26.12	66	6.52	0
28x40x16	1987	51.20	361	25.68	66	6.41	0
Ranch	1988	49.49	98	24.82	66	6.20	0

SCENARIO #2	MET YEAR	120 grams/hour 0.0333 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	60 grams/hour 0.0167 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	15 grams/hour 0.00417 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
Stack Height (ft) 24.00	1984	36.70	98	18.40	0	5.46	0
	1985	41.21	98	20.67	0	6.29	0
Building Type (ft)	1986	39.22	98	19.67	0	6.08	0
28x40x22	1987	38.36	98	19.24	0	5.62	0
Cape	1988	36.87	98	18.49	0	5.60	0

SCENARIO #3	MET YEAR	120 grams/hour 0.0333 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	60 grams/hour 0.0167 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3	15 grams/hour 0.00417 g/s Max Impact	Downwind Distance (ft) < 21 ug/m3
Stack Height (ft) 30.00	1984	27.19	98	13.64	0	3.41	0
	1985	29.61	98	14.85	0	3.71	0
Building Type (ft)	1986	27.82	66	13.95	0	3.48	0
28x40x28	1987	28.61	66	14.35	0	3.58	0
Colonial	1988	26.45	66	13.26	0	3.31	0

5/30/07

DRAFT SETBACK PROPOSAL

Emission Limit	Installation Date	Setback	Nearest residence	Stack Height
greater than 0.60 MMBTU/hr input	up to April 2008 (except for sell through)	200 feet nearest property line	greater than 500 feet	10 feet above ground
			200-500 feet	2 feet higher than peak of structure being served
0.60 to 0.32 pound per MMBTU per hour input	up to April 2010	100 feet nearest property line	greater than 300 feet	10 feet above ground
			100-300 feet	2 feet higher than peak of structure being served
less than or equal to 0.32 pound per MMBTU per hour output	anytime	50 feet nearest property line	greater than 300 feet	10 feet above ground
			50-300 feet	2 feet higher than peak of structure being served

5/30/2007

AIR QUALITY DISPERSION MODELING OF THE E-CLASSIC 2300 OUTDOOR WOOD HYDRONIC HEATER

June 2009

TECH ENVIRONMENTAL
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

AIR QUALITY DISPERSION MODELING OF
THE E-CLASSIC 2300
OUTDOOR WOOD HYDRONIC HEATER

Prepared for:

Central Boiler
20502 160th Street
Greenbush, MN 56726

Prepared by:

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June 12, 2009

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4.0	MODELING RESULTS AND CONCLUSIONS	10

APPENDIX A – BEST BURN PRACTICES

APPENDIX B – AIR MODELING SUMMARY OUTPUTS

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13 Case 2A-10 – 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 10 Feet from House 23

14 Case 2A-20 – 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 20 Feet from House 24

15 Case 2A-30 – 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 30 Feet from House 25

16 Case 2A-40 – 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 40 Feet from House 26

17 Case 2A-50 – 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 50 Feet from House 27

18 Case 2B-10 – 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 10 Feet from House 28

19 Case 2B-20 – 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 20 Feet from House 29

20 Case 2B-30 – 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 30 Feet from House 30

21 Case 2B-40 – 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 40 Feet from House 31

22 Case 2B-50 – 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 50 Feet from House 32

EXECUTIVE SUMMARY

Air dispersion modeling was performed with the U.S. AERMOD model and following EPA guidance to determine the effect of a Central Boiler Outdoor Wood Hydronic Heater (OWHH) E-Classic Model 2300 on air quality. Air dispersion modeling assumed the OWHH was located at one of five distances (10, 20, 30, 40, or 50 feet) from either a one-story or a two-story house and had a stack height of two-feet above the roof peak, as recommended by Central Boiler's installation recommendations and Best Burn Practices for Phase 2 stick wood models (see Appendix A). Five years of hourly meteorological data for Burlington, Vermont were utilized in the modeling.

The principal air pollutant emitted by OWHHs is particulate matter (PM). The E-Classic 2300 was assumed to emit a maximum of 17.6 grams per hour (g/hr) of PM based on the highest individual test run result from the certification test for the U.S. Environmental Protection Agency (EPA) "List of Cleaner Hydronic Heaters, Phase 2 White Tag Models" table.[1] The EPA-certified annual average emissions level of 6.4 g/hr for the E-Classic 2300 was also modeled. As a conservative assumption in this study, all PM emissions were assumed to be $PM_{2.5}$.

The modeling results demonstrate that maximum predicted 24-hour $PM_{2.5}$ concentrations from operation of a Central Boiler E-Classic 2300 model are in the range of 0.5 to 2.9 $\mu g/m^3$, and therefore, are safely in compliance with the 24-hour National Ambient Air Quality Standards (NAAQS) for fine particulate matter ($PM_{2.5}$) of 35 $\mu g/m^3$. The NAAQS have been established by EPA to protect the most sensitive individuals[2] in the population from any adverse effects, with a margin of safety.

The highest predicted concentrations were obtained using the maximum 17.6 g/hr emission rate and a 20-foot stack height next to a one-story house. For this combination, the $PM_{2.5}$ level was 2.47 ug/m^3 for a stack-house distance of 50 feet, and rose slightly as the stack was moved closer to the house, to a maximum level of 2.86 ug/m^3 for a stack-house distance of 10 feet. Figure 2

[1] (http://www.epa.gov/woodheaters/models.htm) downloaded March 21, 2009.

[2] For Particulate Matter, these are people with asthma and respiratory disease.

illustrates how predicted $PM_{2.5}$ concentrations vary only slightly as the stack-house distance changes. Thus, no minimum stack-to-house distance is required so long as the stack height is two feet above the roof peak, per Central Boiler's installation recommendations and Best Burn Practices for Phase 2 wood stick models.

EPA has also established Significant Impact Levels (SIL) under the New Source Review (NSR)/Prevention of Significant Deterioration (PSD) Rule. The 24-hour SIL for particulate matter (PM) is 5 $\mu g/m^3$. Air concentrations below the SIL are considered "insignificant" by EPA and can be ignored, even in cases where existing air quality does not comply with the standard. For all of the cases analyzed, the maximum $PM_{2.5}$ concentrations, both on the homeowner's property and off-site, are below the SIL (i.e., are insignificant).

In conclusion, operation of a Central Boiler E-Classic 2300 OWHH with a stack height two feet above the roof peak does not adversely affect air quality or public health, either on the homeowner's property or off-site. For all 20 configurations of stack and building heights, the maximum $PM_{2.5}$ concentrations from the E-Classic 2300 fully comply with the NAAQS. In addition, all maximum predicted $PM_{2.5}$ concentrations are below the EPA PM SIL of 5 $\mu g/m^3$ and are therefore insignificant.

1.0 INTRODUCTION

Central Boiler, Inc. of Greenbush, Minnesota is the manufacturer of Outdoor Wood Hydronic Heaters (OWHH) E-Classic 2300 model. These are freestanding units that are located outside the structure being heated and consist of a firebox, water reservoir and ancillary mechanical equipment. The combustion of wood heats water that is pumped from the furnace to a heat exchanger located inside the structure. Combustion gasses are passed over or through heating tubes before being vented to the atmosphere through a metal stack. While similar in principle to other stick wood burning devices, these units are designed to provide continuous on-demand heat and very low stack emissions. The design allows the unit to be placed near the location of the wood supply. The thermal output for an E-Classic 2300 model is listed by EPA as 160,001 Btu/hr. Figure 1 shows a typical installation of a Central Boiler OWHH.

The purpose of this study is to evaluate the air pollutant concentrations resulting from Central Boiler E-Classic 2300 units when installed and operated according to manufacturer's instructions that are shipped with every new unit. The unit is typically installed within 50 feet of the residence served. A stack height 2 feet above the peak of the residence served is recommended. Both a one-story house (roof peak 18 feet and stack height 20 feet) and a two-story house (roof peak 33 feet, stack height 35 feet) were studied, along with five different distances for the OWHH from the side of the house (10, 20, 30, 40 and 50 feet). The modeling analysis was performed using the EPA AERMOD model for PM emission rates of 17.6 (maximum) and 6.4 (annual average) grams per hour (g/hr). These emissions rates were obtained from the certification test results given in the EPA "List of Cleaner Hydronic Heaters, Phase 2 White Tag Models" table for the Central Boiler E-Classic 2300 unit.

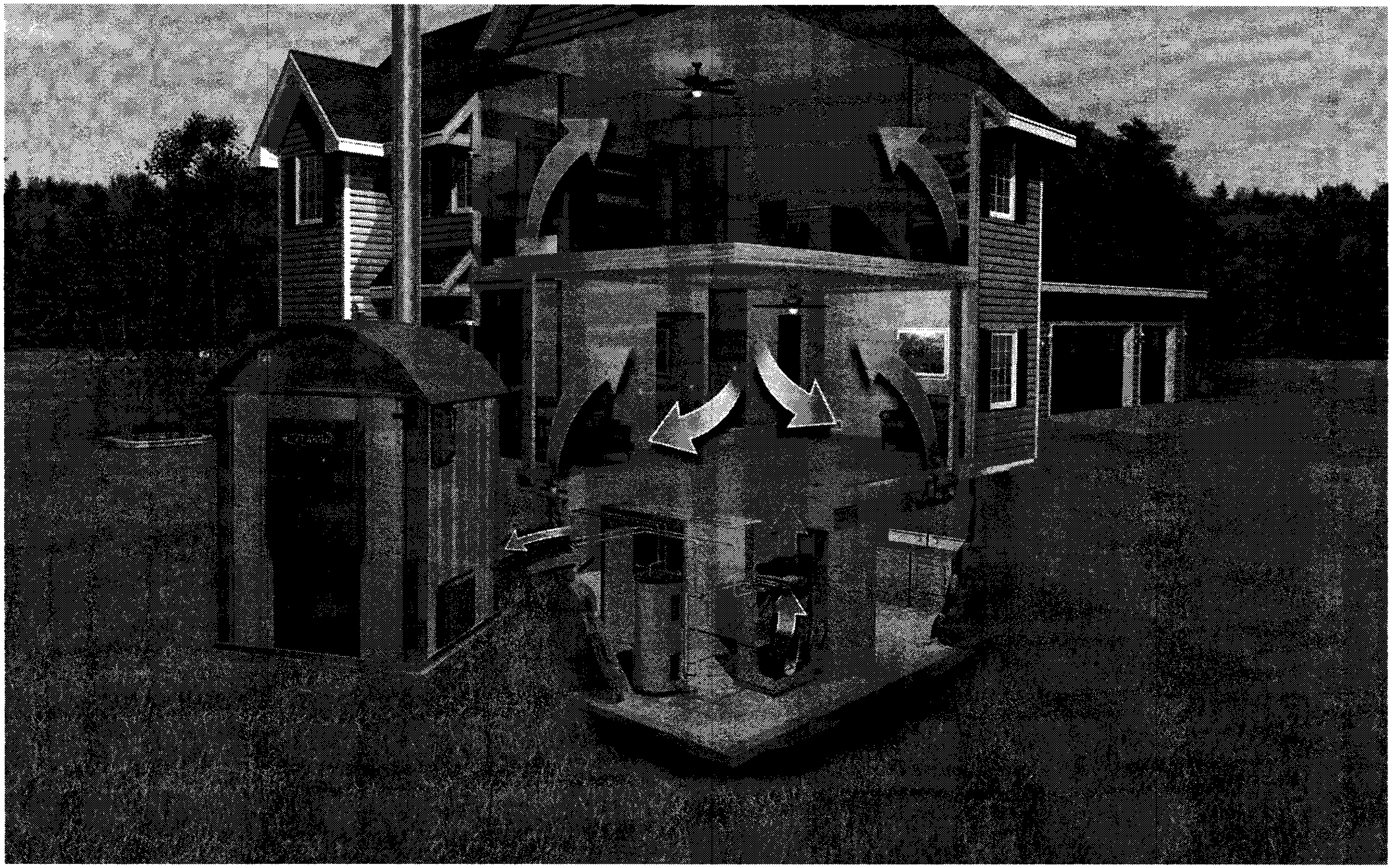

Figure 1: Concept Rendering Showing a Typical Installation of an Outdoor Wood Hydronic Heater Installation

2.0 AIR QUALITY STANDARDS

The principal air pollutant emitted by OWHHs is particulate matter (PM). EPA has established National Ambient Air Quality Standards (NAAQS) for both coarse (PM_{10}) and fine ($PM_{2.5}$) particulate matter. The PM_{10} standard applies to particles with a mass-mean diameter of 10 microns or less, while the $PM_{2.5}$ standard is keyed to particles 2.5 microns in diameter or less. While both long-term (annual) and short-term (24-hour) standards have been established, the 24-hour standards are the controlling set because of their more stringent limits. Also, the $PM_{2.5}$ standard is more stringent than the PM_{10} standard. Thus, only the 24-hour $PM_{2.5}$ levels are examined in this study.

The 24-hour $PM_{2.5}$ standard is 35 $\mu g/m^3$, measured as a 3-year average of 98^{th}-percentile concentrations. In a one-year period, the 8th-highest 24-hour value represents the 98^{th}-percentile concentration. For compliance purposes, the $PM_{2.5}$ design concentration is the 3-year average of the highest, 8^{th}-highest (H8H) values in each year at any receptor location. EPA has also established Significant Impact Levels (SILs) under the New Source Review (NSR)/Prevention of Significant Deterioration (PSD) Rule. Air concentrations below the SIL are considered "insignificant" by EPA and can be ignored, even in cases where existing air quality does not comply with the standard. Currently, EPA is working towards establishing a 24-hour SIL for $PM_{2.5}$. Until EPA does adopt a 24-hour SIL for $PM_{2.5}$, their policy is to use the existing 24-hour PM_{10} SIL of 5 $\mu g/m^3$ (PM SIL) as a surrogate for $PM_{2.5}$. Some Northeast states are working towards establishing their own $PM_{2.5}$ SILs, which may be lower. For the purposes of this modeling analysis, the EPA 5-$\mu g/m^3$ threshold was used.

The EPA added special processing for $PM_{2.5}$ in the latest versions of AERMOD (versions 06341 and 07026) to predict the design concentrations for each receptor. AERMOD now calculates the N-year average H8H 24-hour average $PM_{2.5}$ concentration at each receptor over the N years of meteorological data provided. EPA considers the five-year average of the H8H 24-hour $PM_{2.5}$ values at each receptor to be unbiased estimates of the 3-year average H8H values, since EPA guidance requires the use of five years of meteorological data when the data are from an off-site

National Weather Service meteorological station.[3] Thus, the five-year average H8H values from the AERMOD model are the design values used to establish compliance with the NAAQS and SIL.

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[3] US EPA, "Addendum User's Guide for the AMS/EPA Regulatory Model – AERMOD (EPA-454/B-03-001, September 2004)", pp. 5 – 7, December 2006.

3.0 AIR DISPERSION MODELING METHODOLOGY

Particulate matter from a fuel combustion process contains a wide distribution of particle sizes. For wood combustion, these range from relatively larger carbon particles (soot) down to sub-micron organic compound aerosols. Research studies of OWHH emissions have used sampling methods that capture the full size distribution of PM, solid particles and condensible organics. EPA particle size distribution data for wood boilers reveal that typically 90% of the total PM mass has a diameter of 10 microns or less, and 76% has a diameter of 2.5 microns or less.[4] As a conservative assumption in this study, all PM emissions were assumed to be $PM_{2.5}$.

Air dispersion modeling assumed the OWHH was located near a one-story (Case 1) or two-story (Case 2) house having a 30-foot by 50-foot footprint. The OWHH building had dimensions of approximately 5.0 feet by 5.3 feet and stood 7.3 feet high (a Central Boiler Model E-Classic 2300). Both the maximum emission rate (Case A) and annual average emission rate (Case B) were examined, for five different stack distances from the house (10, 20, 30, 40 or 50 feet). The EPA AERMOD dispersion model calculated the aerodynamic downwash effects of the house near the OWHH stack.. Twenty modeling cases were examined as described in Table 1.

The stack gas exit temperature and exit velocity used in this analysis represent typical values measured in Central Boiler's emissions test laboratory in Greenbush, Minnesota for the OWHHs. All stack and emission values used in this study are summarized in Table 2.

[4] EPA publication AP-42, Section 1.6.

TABLE 1

CENTRAL BOILER E- CLASSIC 2300 MODEL
MODELING SCENARIOS

Case No.	No. of Stories on House	Roof Peak (ft)	Stack Height (ft)	PM Emissions (grams/hr)	Stack Distance from House (ft)
1A-10	1	18	20	17.6	10
1A-20	1	18	20	17.6	20
1A-30	1	18	20	17.6	30
1A-40	1	18	20	17.6	40
1A-50	1	18	20	17.6	50
1B-10	1	18	20	6.4	10
1B-20	1	18	20	6.4	20
1B-30	1	18	20	6.4	30
1B-40	1	18	20	6.4	40
1B-50	1	18	20	6.4	50
2A-10	2	33	35	17.6	10
2A-20	2	33	35	17.6	20
2A-30	2	33	35	17.6	30
2A-40	2	33	35	17.6	40
2A-50	2	33	35	17.6	50
2B-10	2	33	35	6.4	10
2B-20	2	33	35	6.4	20
2B-30	2	33	35	6.4	30
2B-40	2	33	35	6.4	40
2B-50	2	33	35	6.4	50

TABLE 2

STACK PARAMETERS AND EMISSIONS FOR AIR DISPERSION MODELING

Parameter	English Units	Metric Units
Stack Height		
Case 1	20 feet	6.1 meters
Case 2	35 feet	10.7 meters
Stack Exit Diameter	8 inches	0.2 m
Stack Exit Velocity	7.2 feet/sec.	2.2 m/s
Stack Exit Temperature	350° F	449.9° K
$PM_{2.5}$ Emission Rate		
E-Classic 2300 Model EPA Phase 1 Limit	0.014 lb/hr	6.4 g/hr
E-Classic 2300 Model Highest Test Run	0.039 lb/hr	17.6 g/hr

4.0 MODELING RESULTS AND CONCLUSIONS

The air dispersion modeling reveals that OWHH operation produces $PM_{2.5}$ concentrations ranging from 0.48 to 2.86 μg/m^3 under the 20 modeled scenarios. The results are summarized in Table 3, and the model output is presented in Appendix B of this report. The results are also shown graphically on $PM_{2.5}$ contour maps presented in Figures 3 through 22. All maximum predicted $PM_{2.5}$ concentrations are in compliance with the NAAQS and all are below the SIL.

The highest predicted concentration of 2.86 μg/m^3 was obtained using the 17.6 g/hr emission rate and a 20-foot stack height, 10 feet from a one-story house (Case No. 1A-10). As shown in Figure 2, for each additional 10 feet the stack was moved from the one-story house, the predicted maximum concentration changed only slightly. Thus, no minimum stack-to-house distance is required so long as the stack height is two feet above the roof peak.

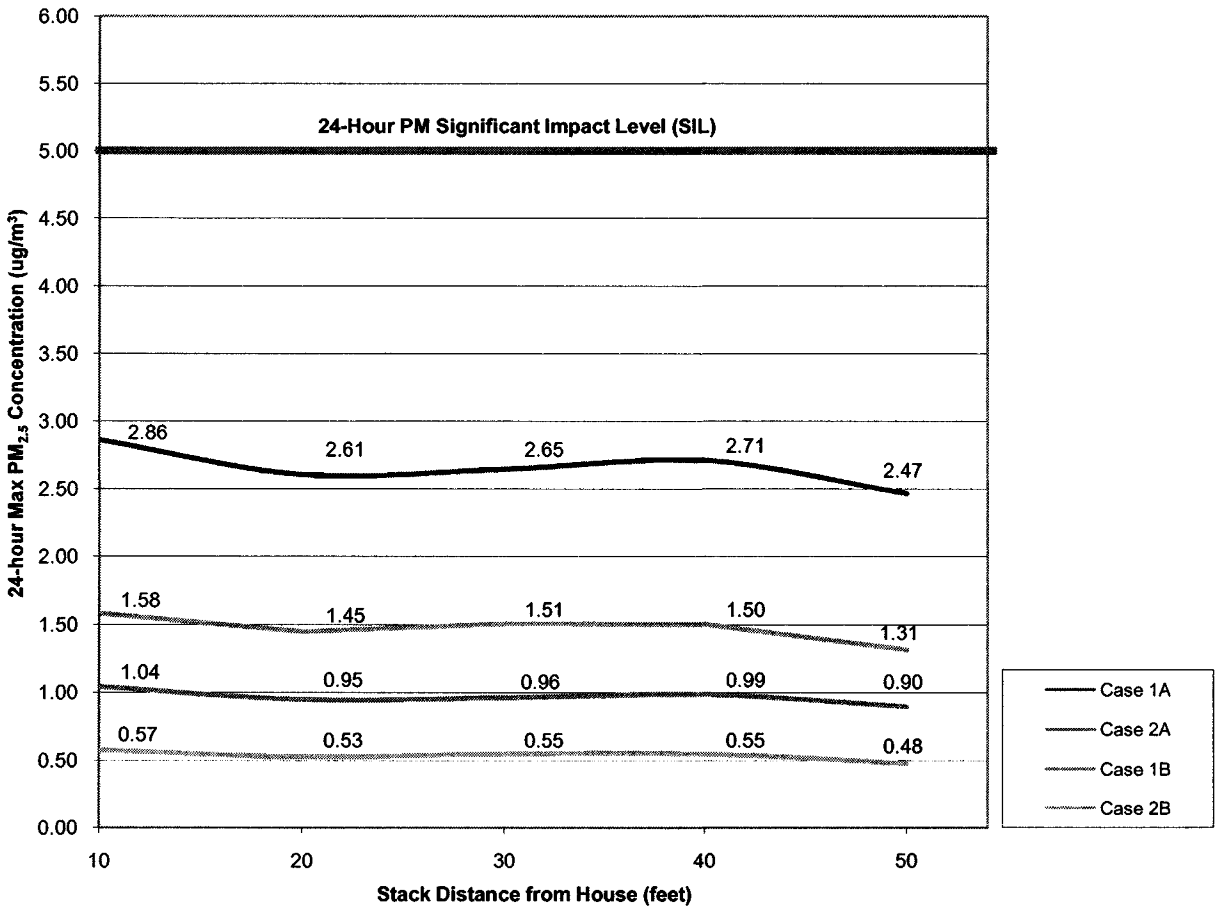
The results reveal that increasing the stack height and increasing the stack distance from the residence served both reduce the expected $PM_{2.5}$ concentration. The lowest concentration was predicted assuming the 6.4 g/hr annual average emission rate and a 35-foot stack height, 50 feet from a two-story house. The modeling results are presented without background levels. The introduction of 2.86 μg/m^3 or less from an OWHH (an amount classified as insignificant) would not adversely affect air quality, and total $PM_{2.5}$ concentrations would remain safely in compliance with the $PM_{2.5}$ NAAQS of 35 μg/m^3.

TABLE 3

24-HOUR $PM_{2.5}$ AIR MODELING RESULTS FOR CENTRAL BOILER E- CLASSIC 2300 MODEL ($\mu g/m^3$)

Case No.	No. of Stories on House	Roof Peak (ft)	Stack Height (ft)	PM Emissions (grams/hr)	5-Year Average of H8H	24-hr NAAQS	24-hr PM SIL
1A-10	1	18	20	17.6	2.86	35	5
1A-20	1	18	20	17.6	2.61	35	5
1A-30	1	18	20	17.6	2.65	35	5
1A-40	1	18	20	17.6	2.71	35	5
1A-50	1	18	20	17.6	2.47	35	5
1B-10	1	18	20	6.4	1.04	35	5
1B-20	1	18	20	6.4	0.95	35	5
1B-30	1	18	20	6.4	0.96	35	5
1B-40	1	18	20	6.4	0.99	35	5
1B-50	1	18	20	6.4	0.90	35	5
2A-10	2	33	35	17.6	1.58	35	5
2A-20	2	33	35	17.6	1.45	35	5
2A-30	2	33	35	17.6	1.51	35	5
2A-40	2	33	35	17.6	1.50	35	5
2A-50	2	33	35	17.6	1.31	35	5
2B-10	2	33	35	6.4	0.57	35	5
2B-20	2	33	35	6.4	0.53	35	5
2B-30	2	33	35	6.4	0.55	35	5
2B-40	2	33	35	6.4	0.55	35	5
2B-50	2	33	35	6.4	0.48	35	5

Figure 2
Maximum 24-Hour $PM_{2.5}$ Concentration vs. Stack Distance from House



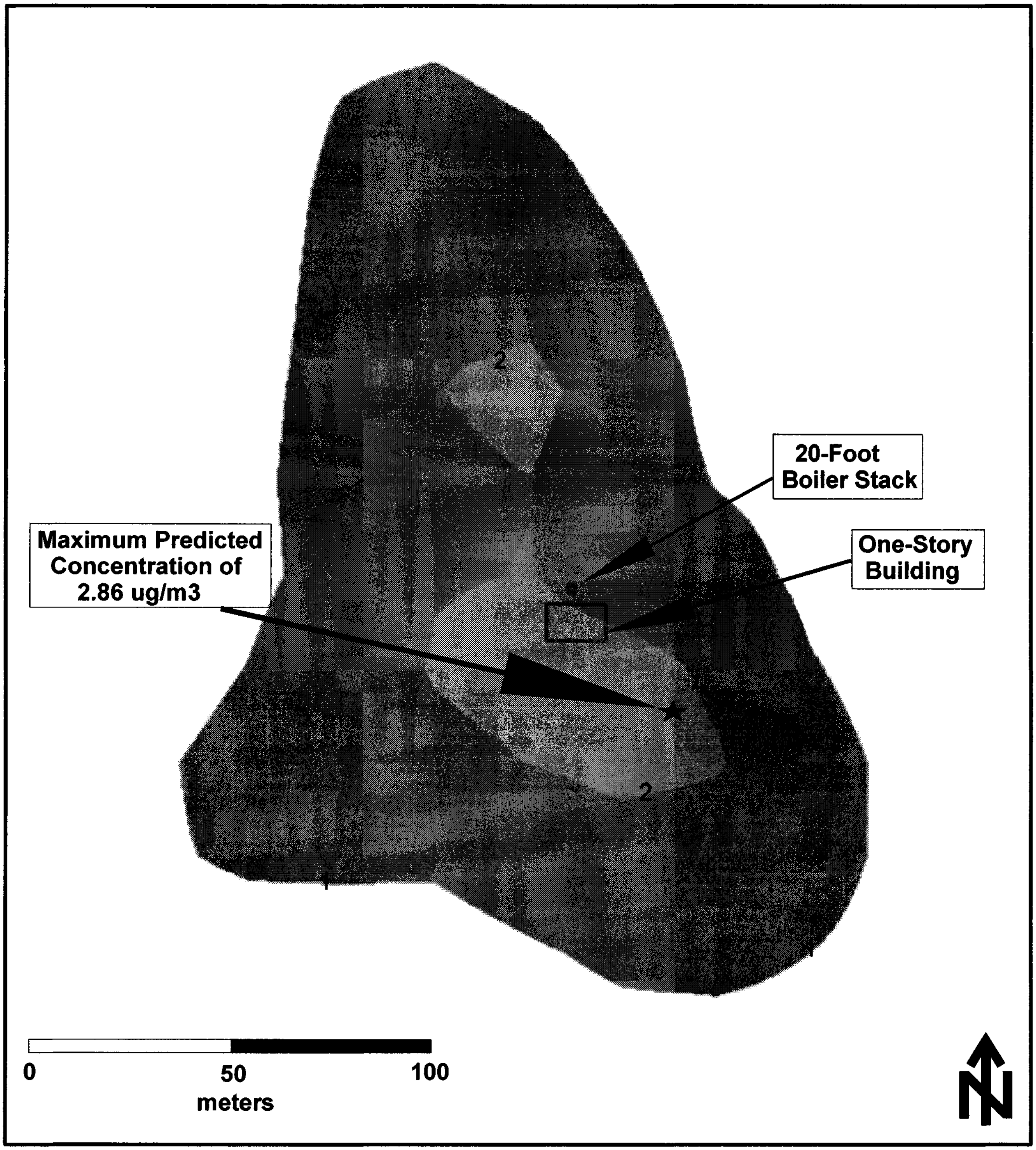


Figure 3
Case 1A-10 - 20-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 10 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

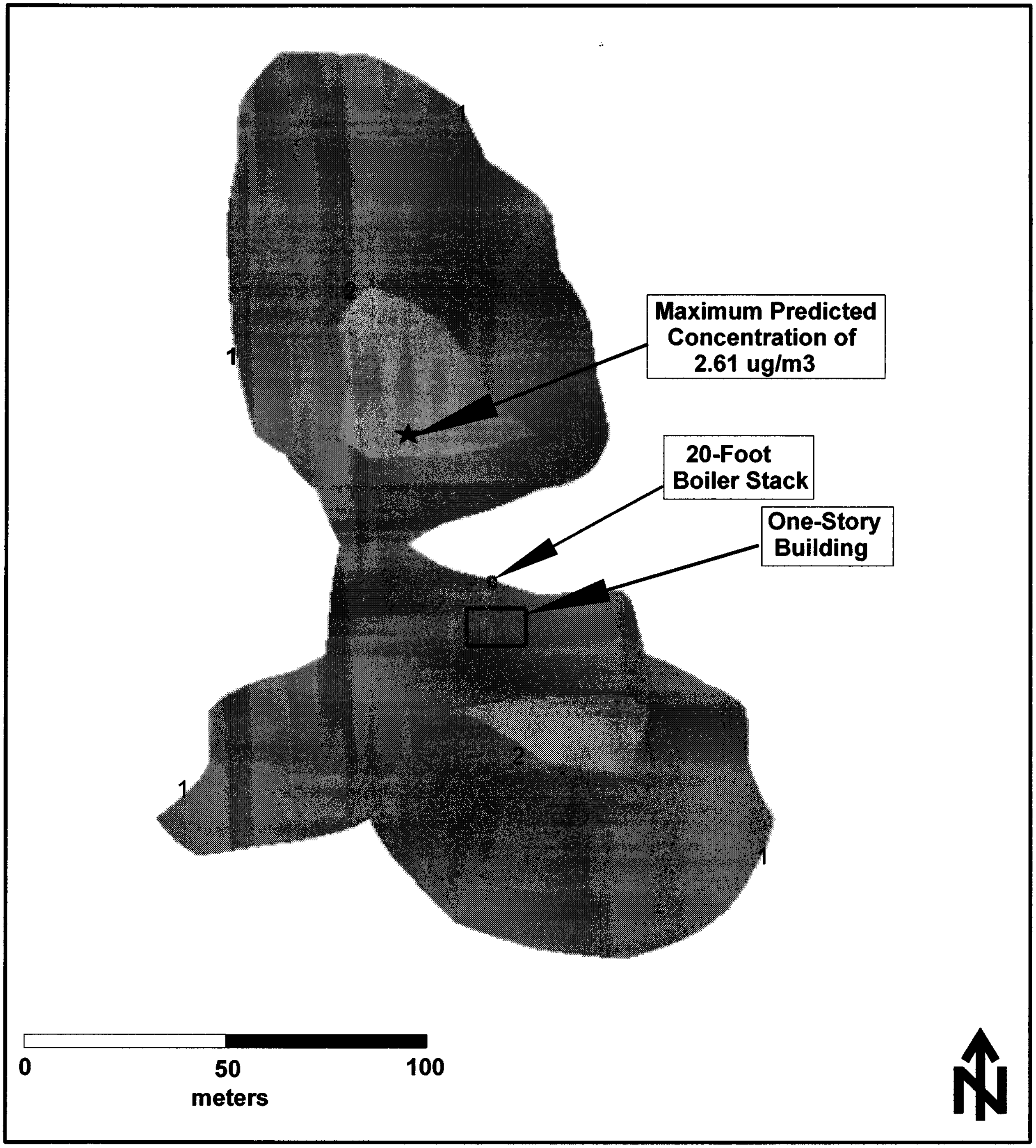


Figure 4
Case 1A-20 - 20-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 20 Feet from House

Tech environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

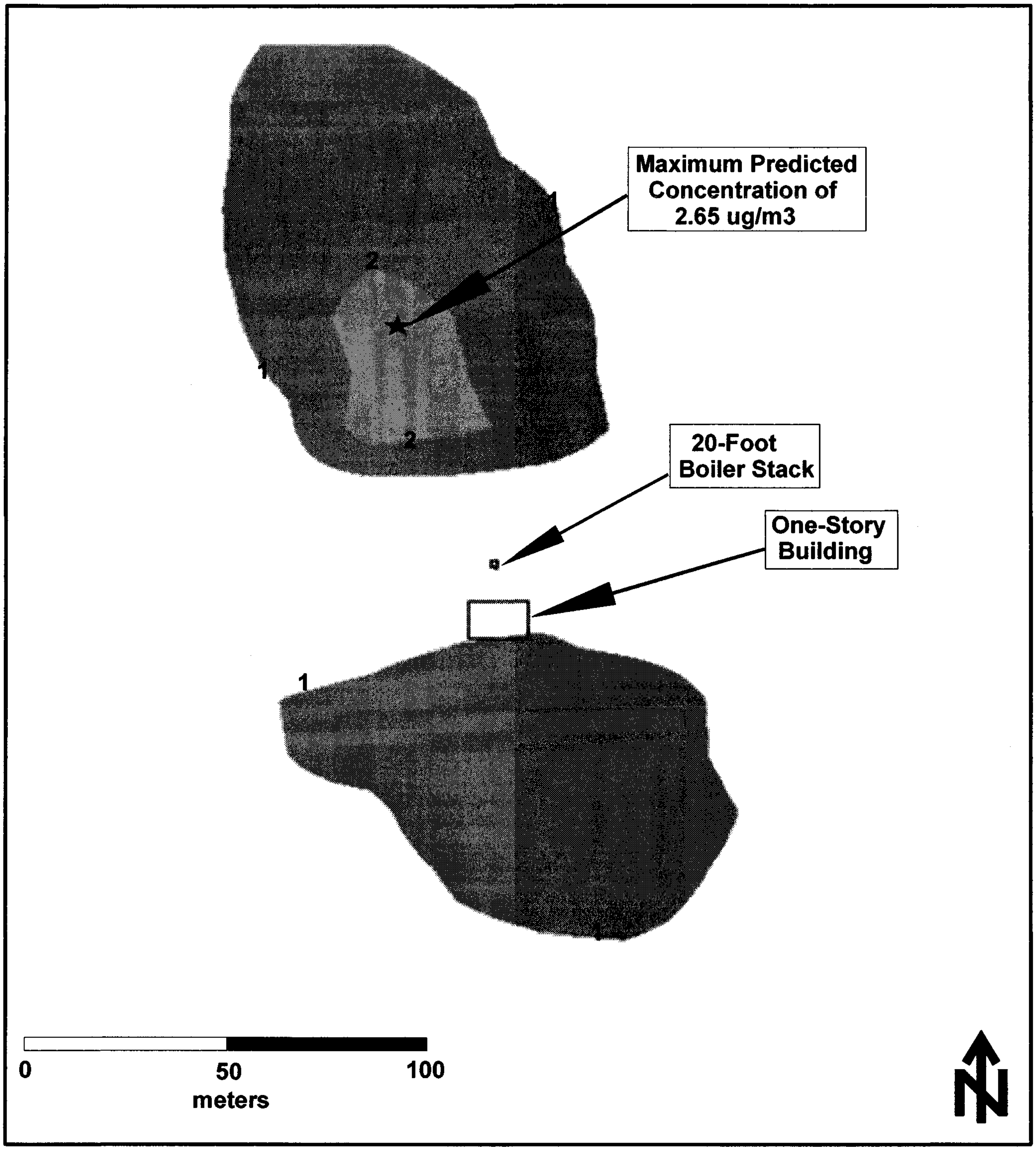


Figure 5
Case 1A-30 - 20-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 30 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

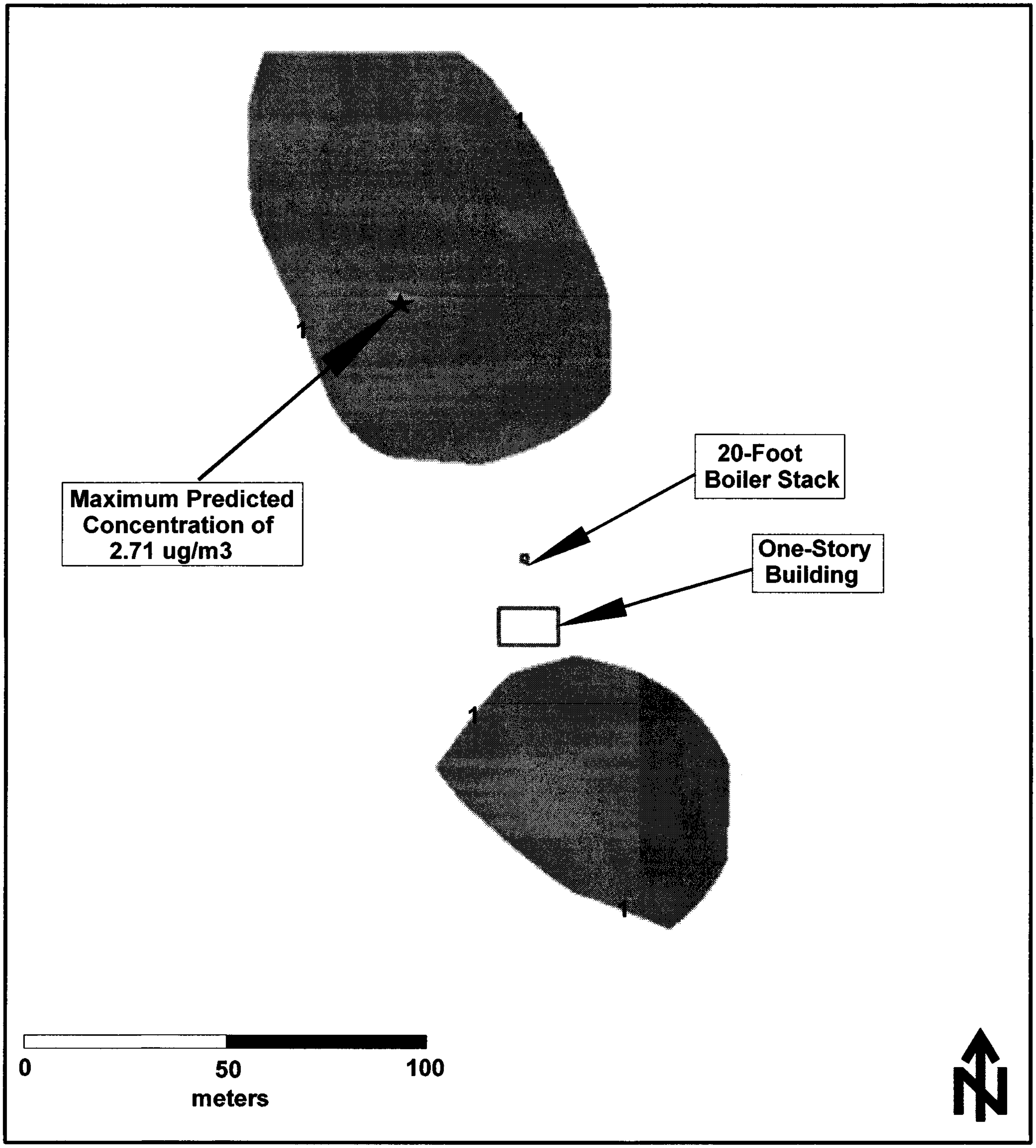


Figure 6
Case 1A-40 - 20-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 40 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

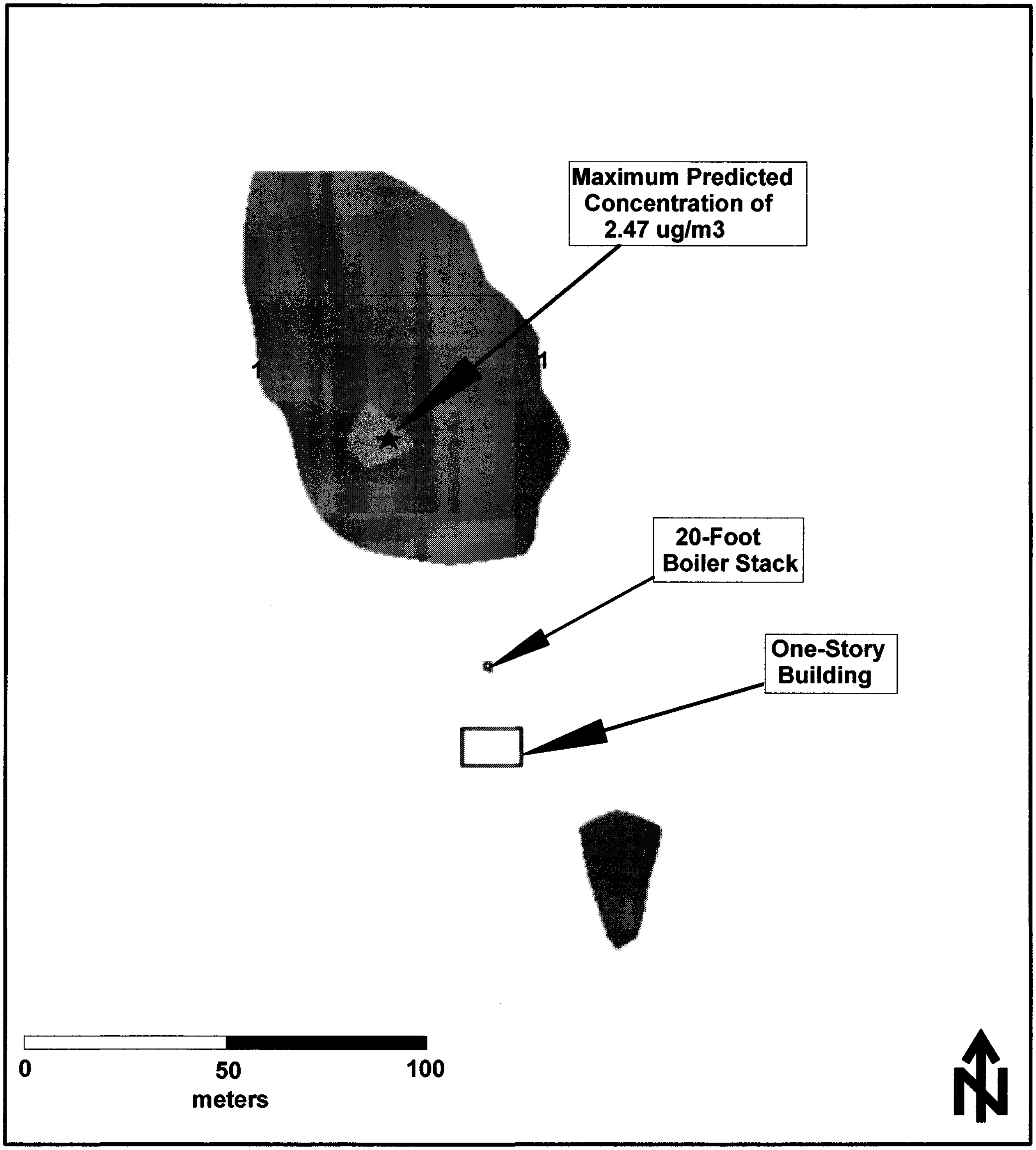


Figure 7
Case 1A-50 - 20-Foot Wood Boiler Stack
with Emission Rate of 17.6 g/hour and 50
Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

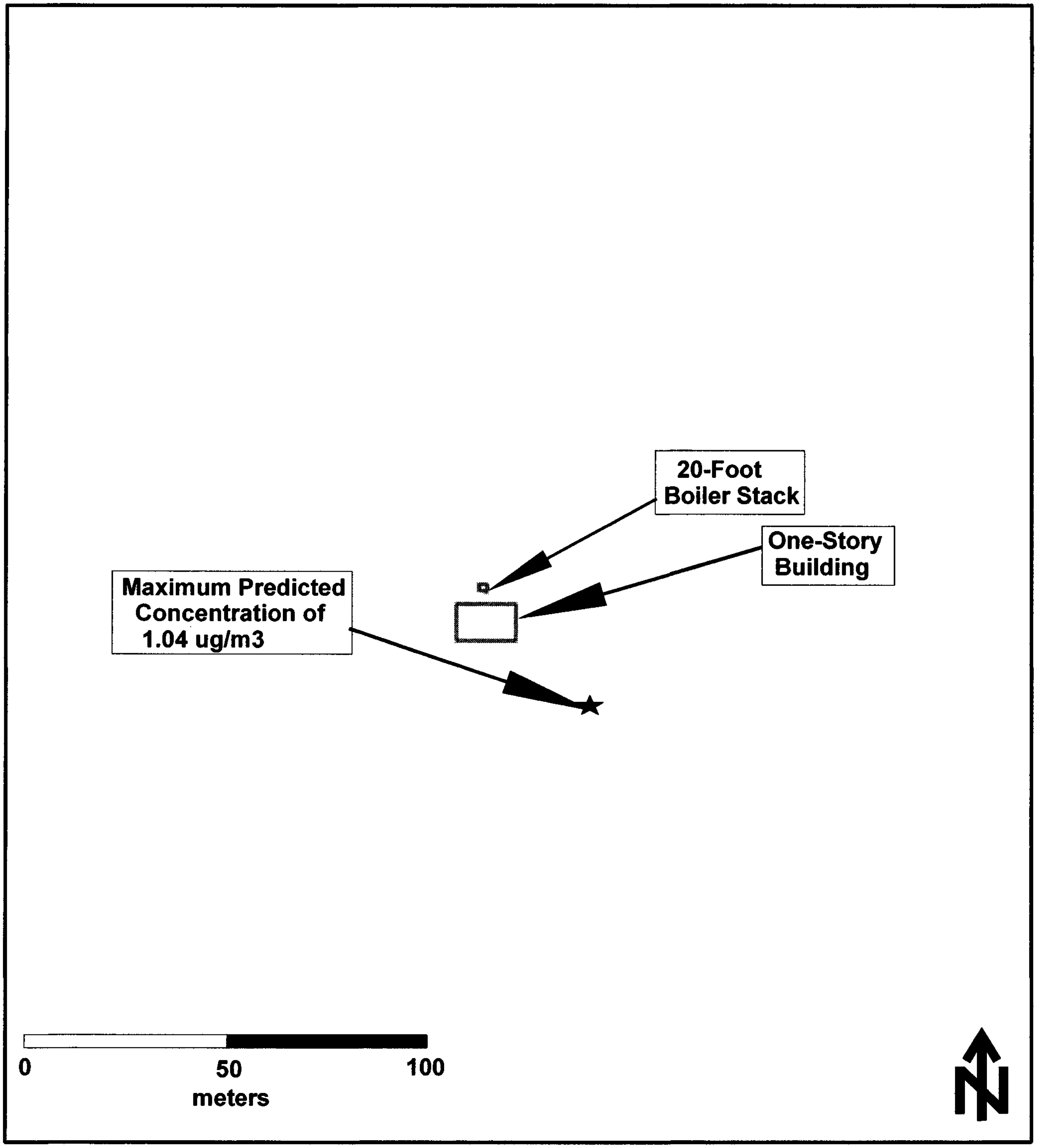


Figure 8
Case 1B-10 - 20-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 10 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

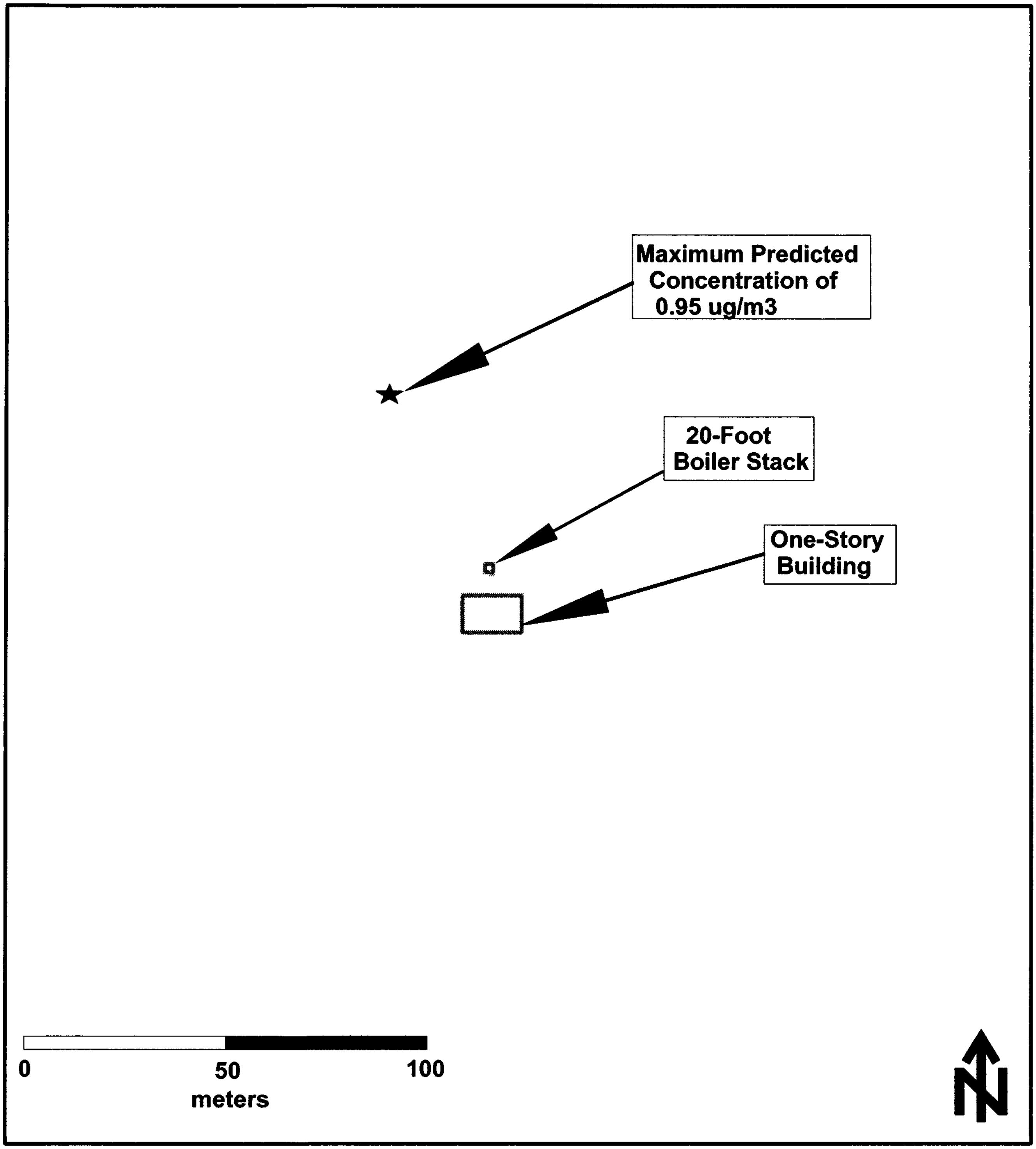


Figure 9
Case 1B-20 - 20-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 20 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

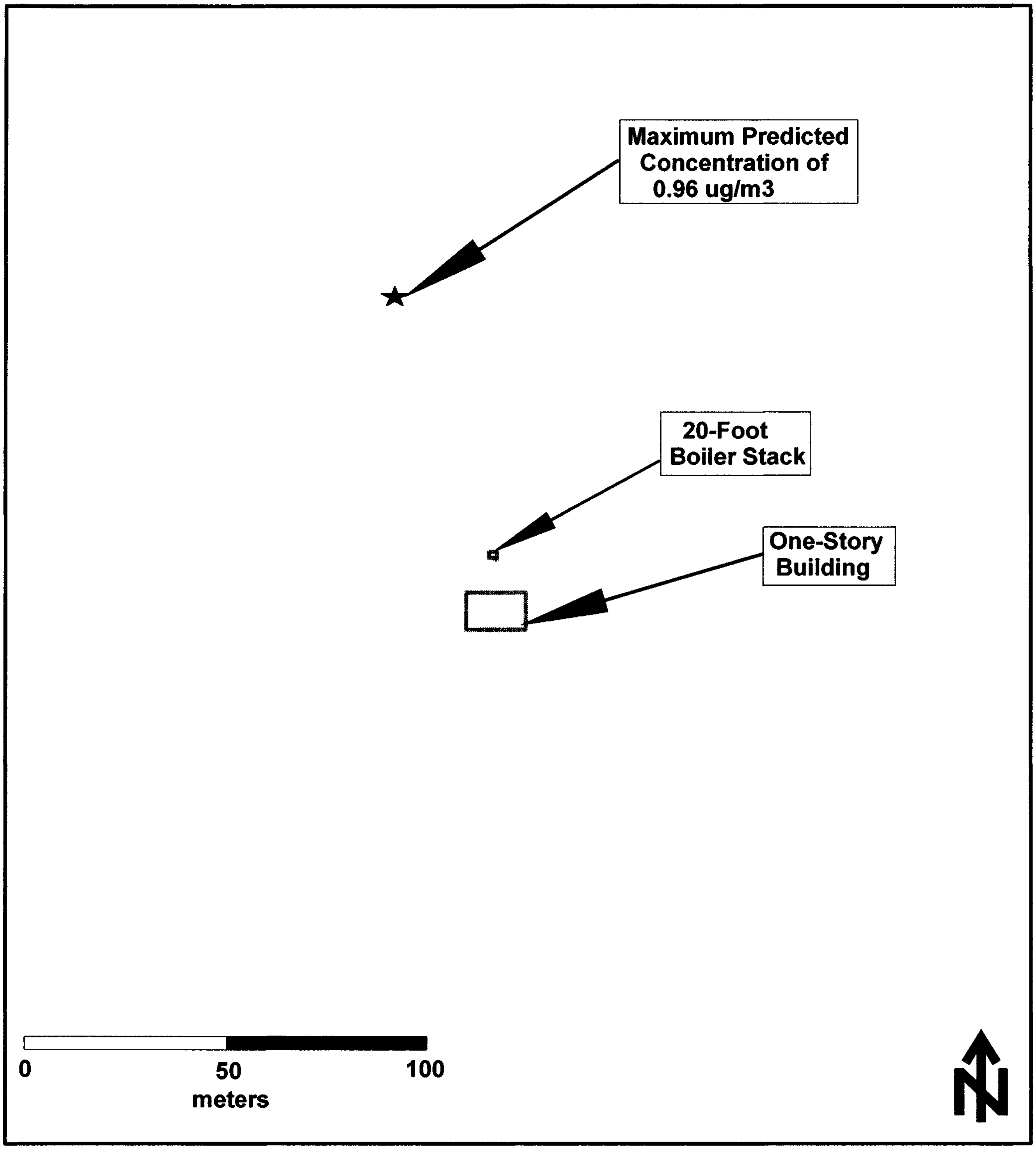


Figure 10
Case 1B-30 - 20-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 30 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

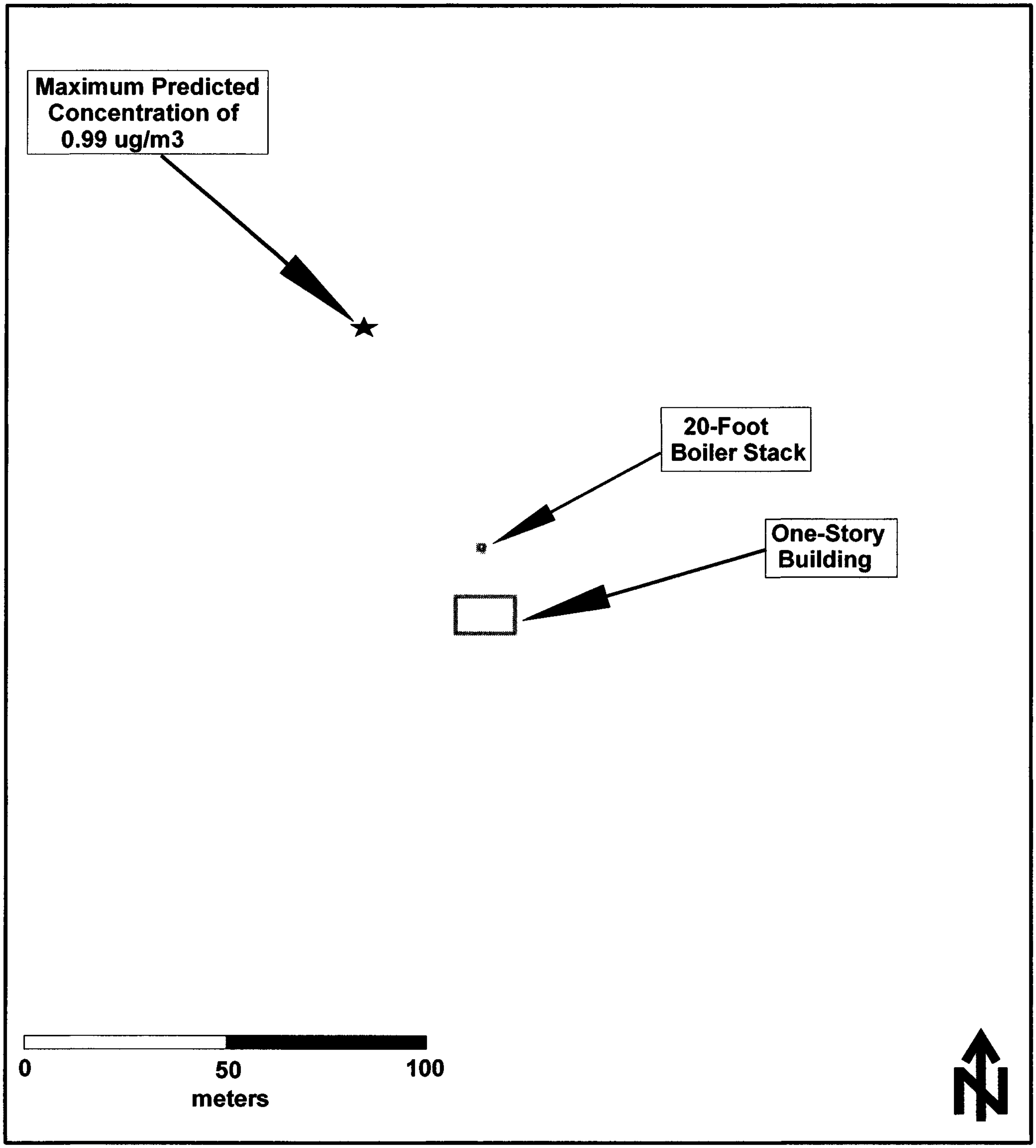


Figure 11
Case 1B-40 - 20-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 40 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

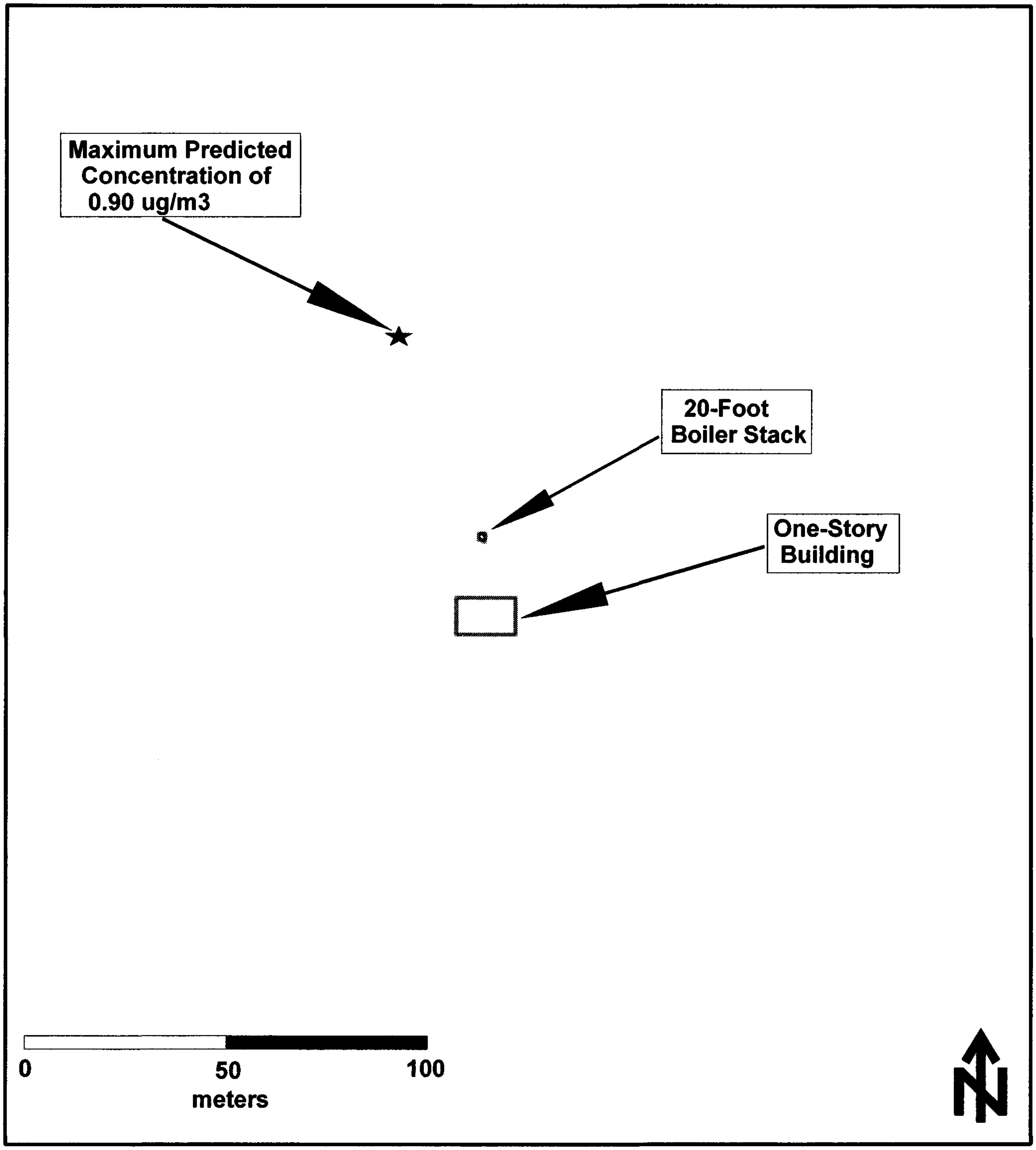


Figure 12
Case 1B-50 - 20-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 40 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

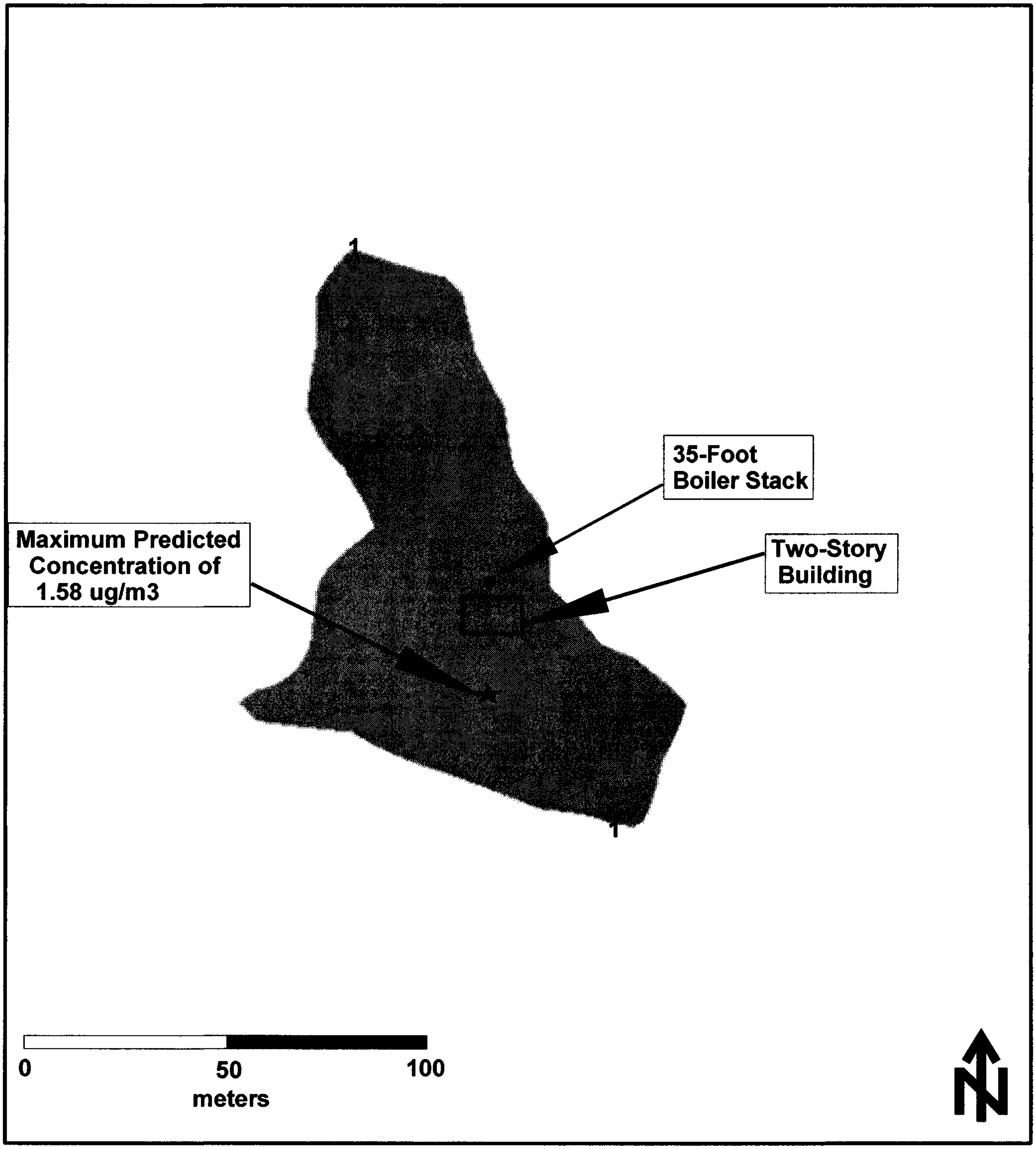


Figure 13
Case 2A-10 - 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 10 Feet from House

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FOCUSED KNOWLEDGE. REAL SOLUTIONS.

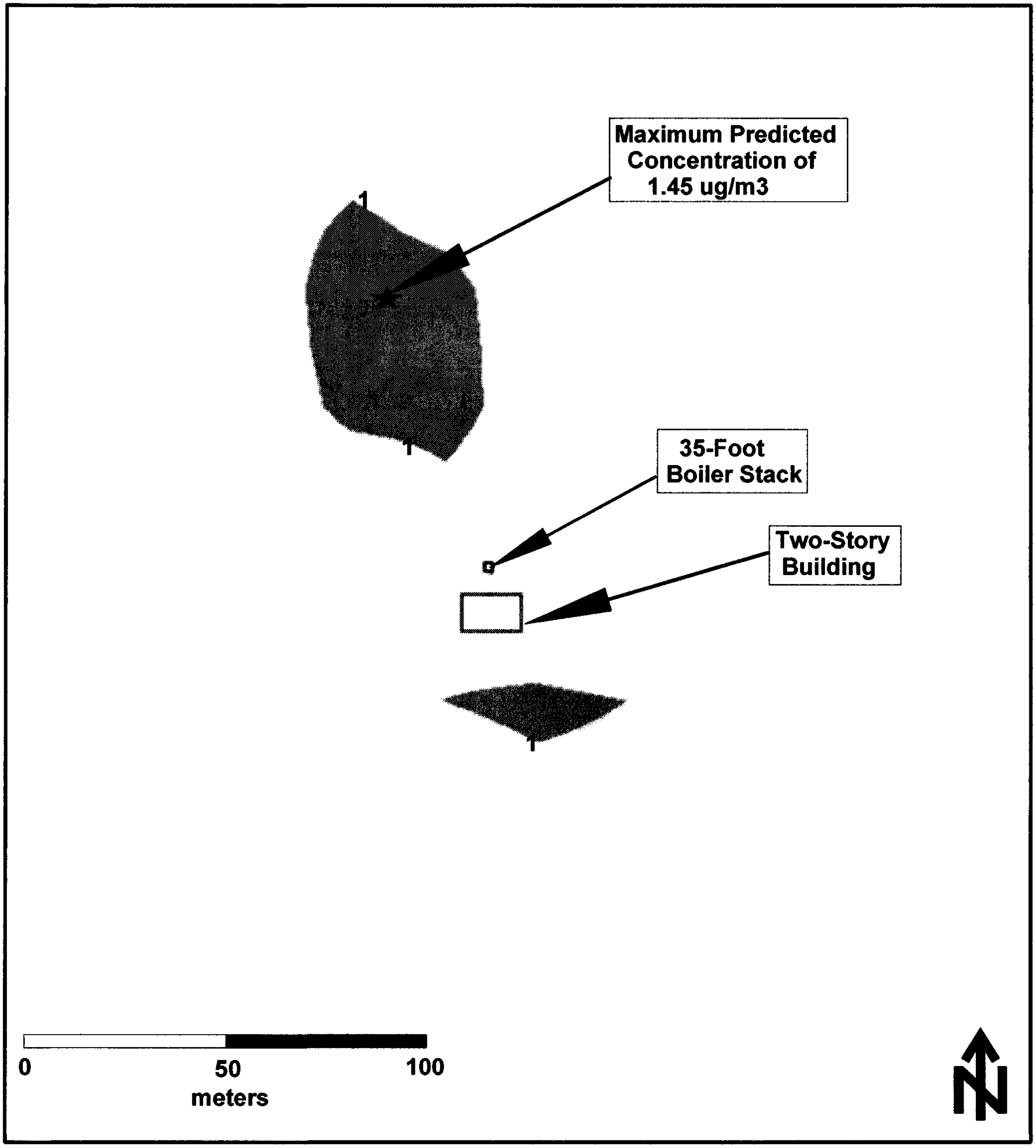


Figure 14
Case 2A-20 - 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 20 Feet from House

TECH environmental FOCUSED KNOWLEDGE. REAL SOLUTIONS.

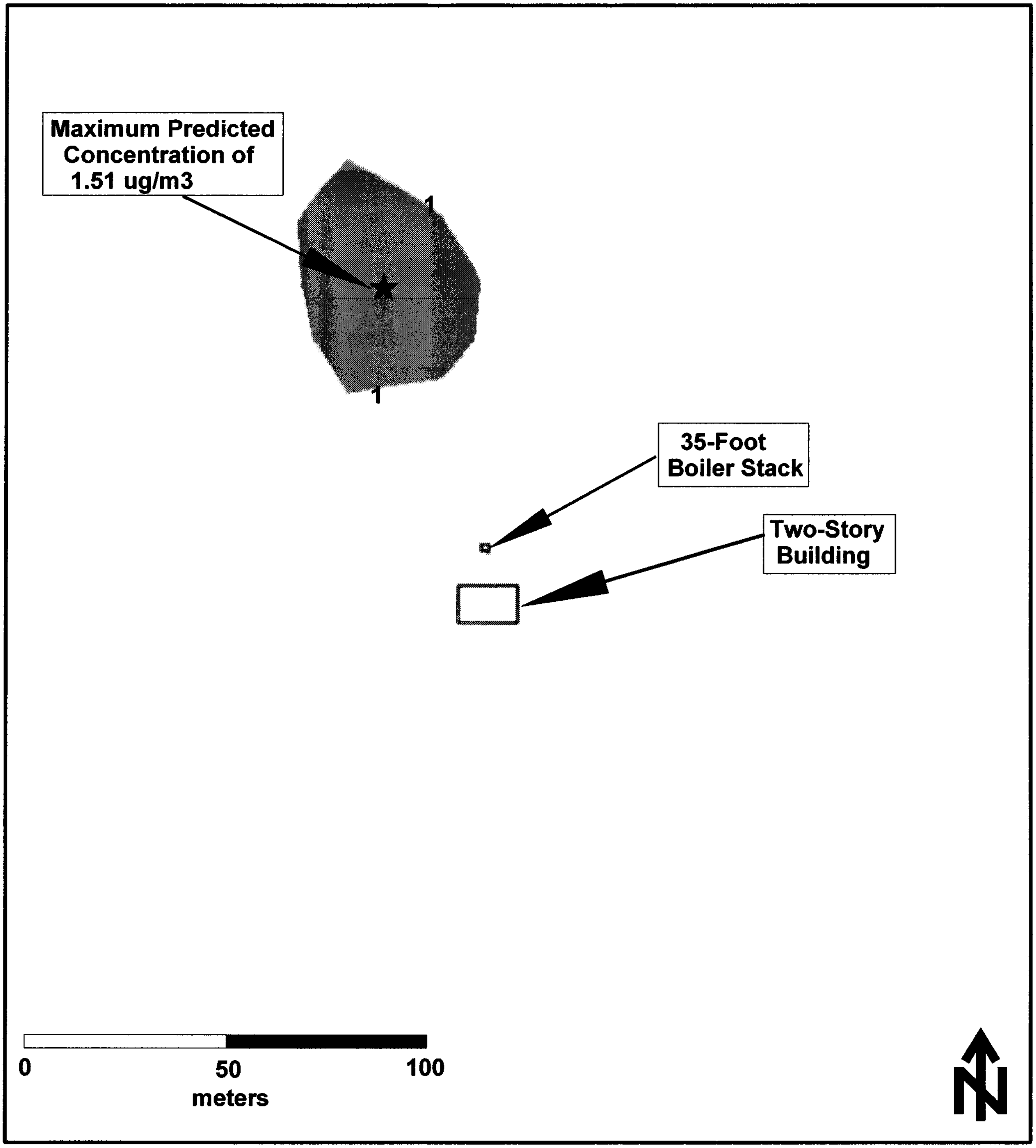


Figure 15
Case 2A-30 - 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 30 Feet from House

TECH environmental
FOCUSED KNOWLEDGE.
REAL SOLUTIONS.

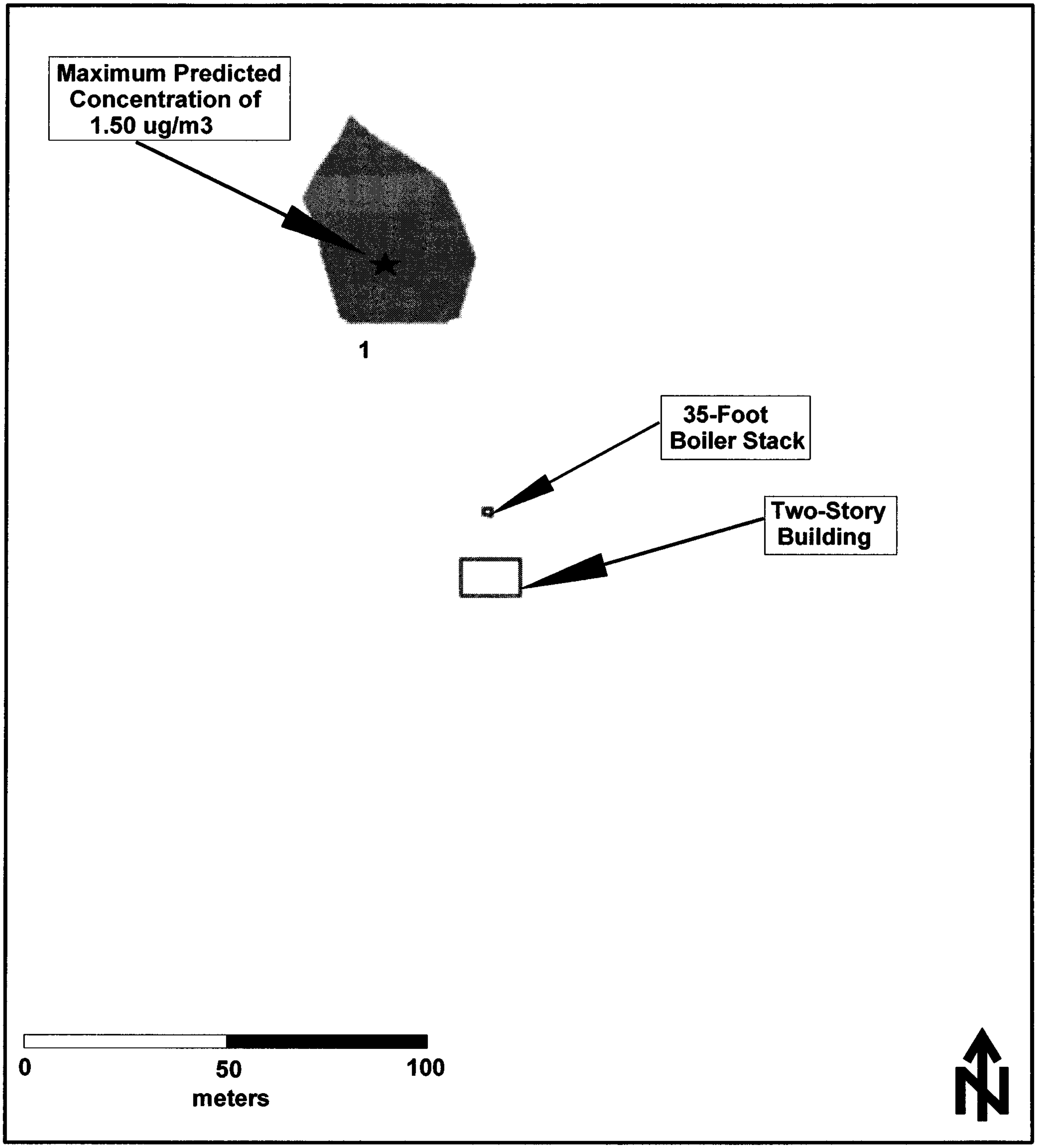


Figure 16
Case 2A-40 - 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 40 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

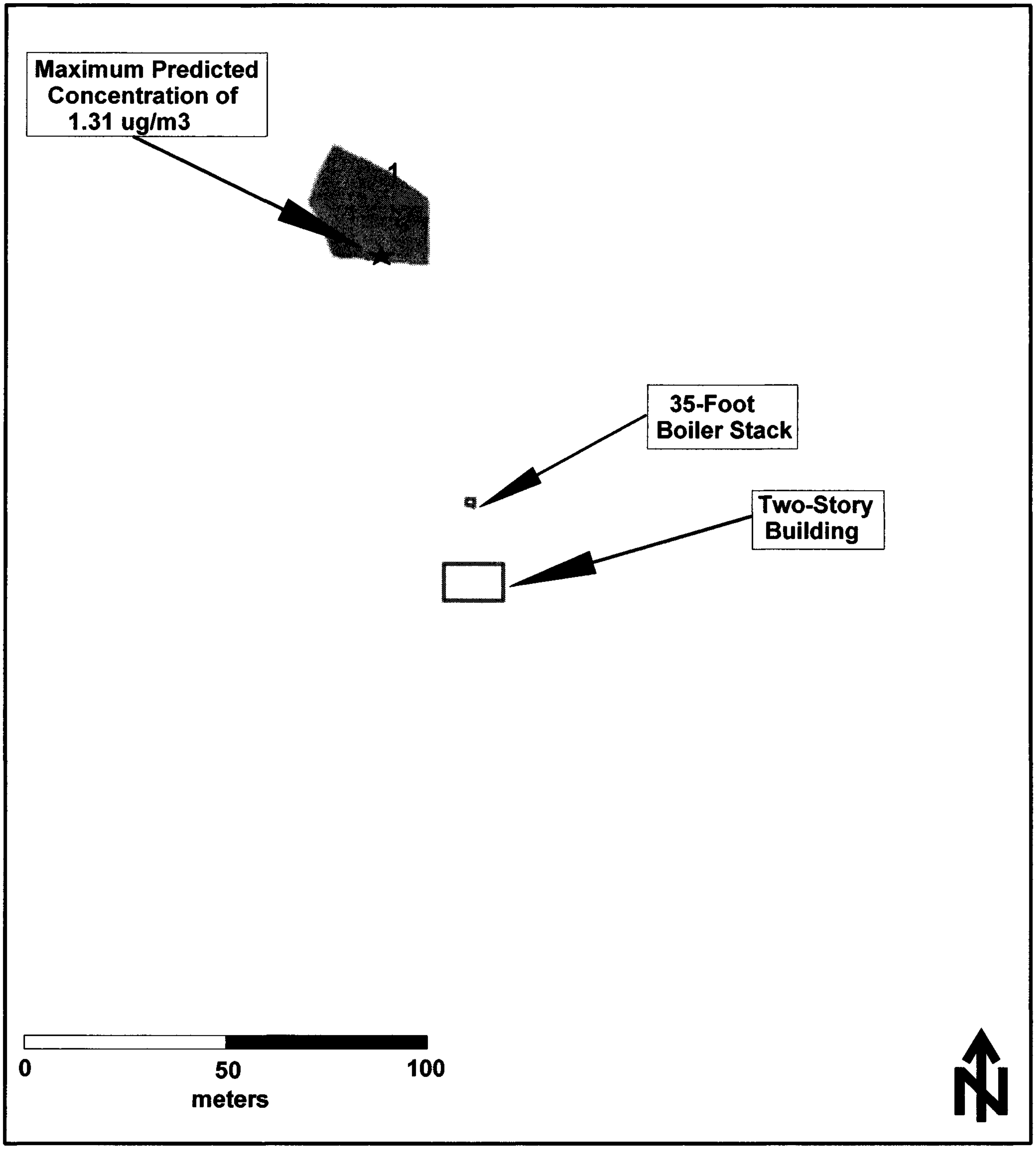


Figure 17
Case 2A-50 - 35-Foot Wood Boiler Stack with Emission Rate of 17.6 g/hour and 50 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

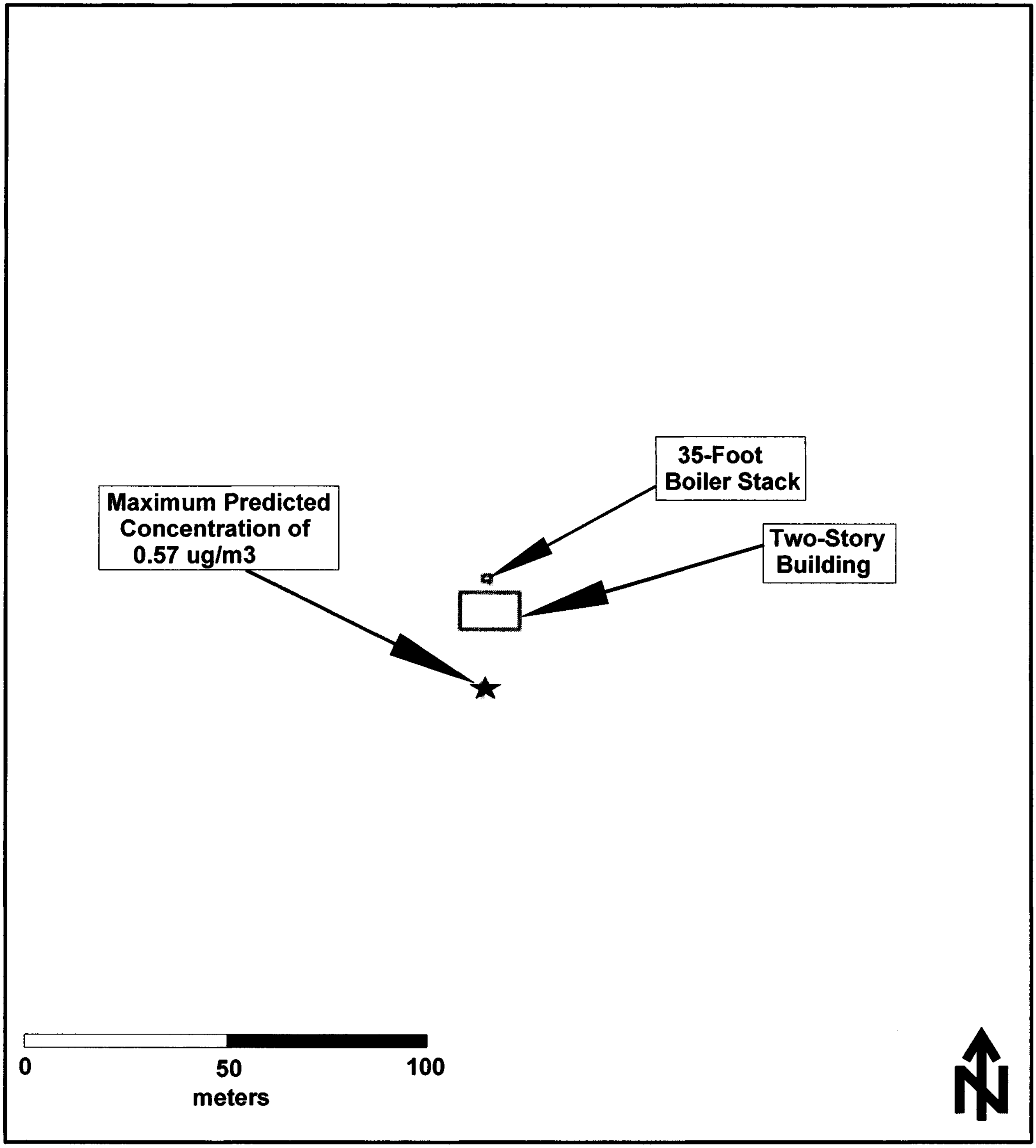


Figure 18
Case 2B-10 - 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 10 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

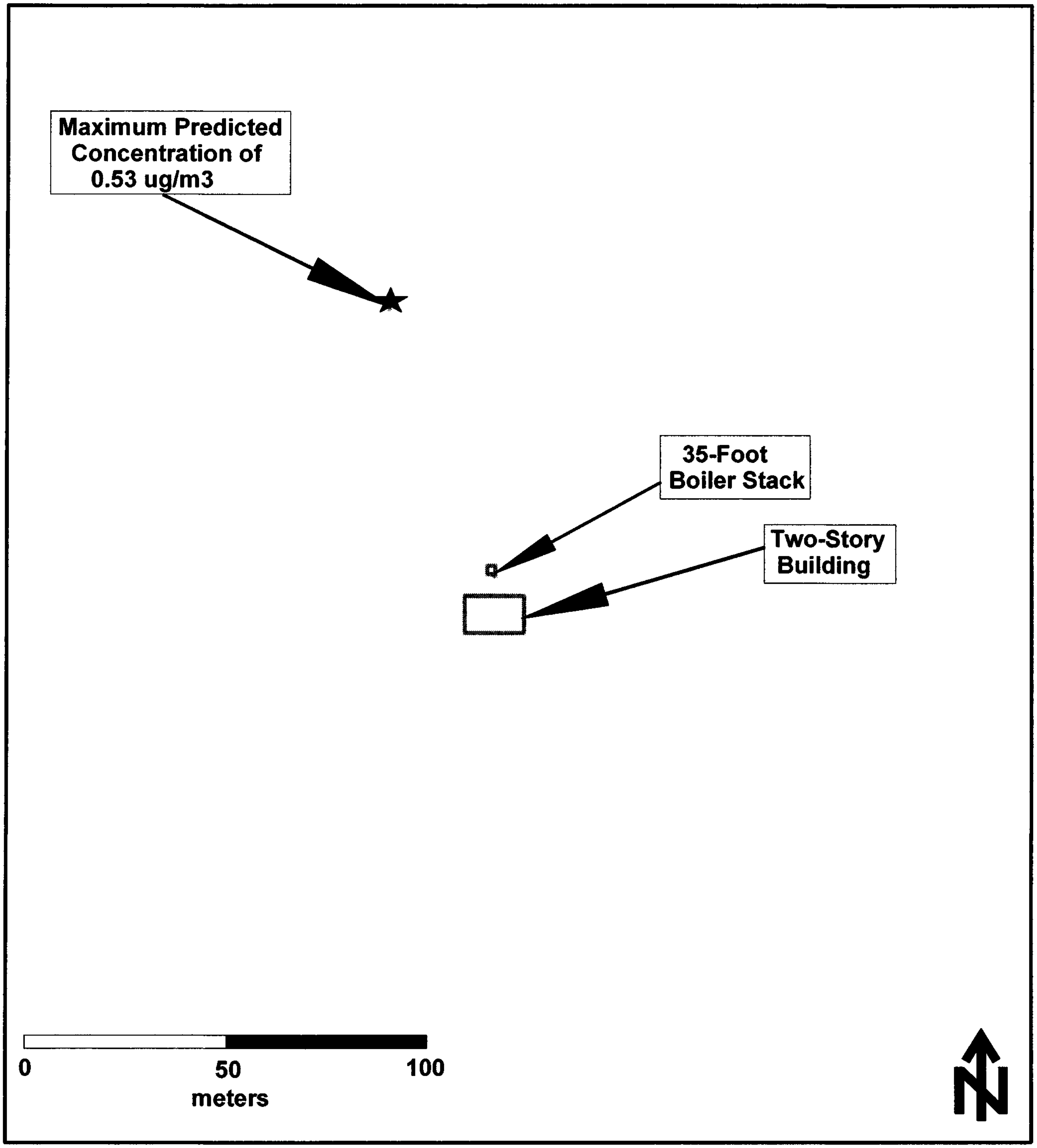


Figure 19
Case 2B-20 - 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 20 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

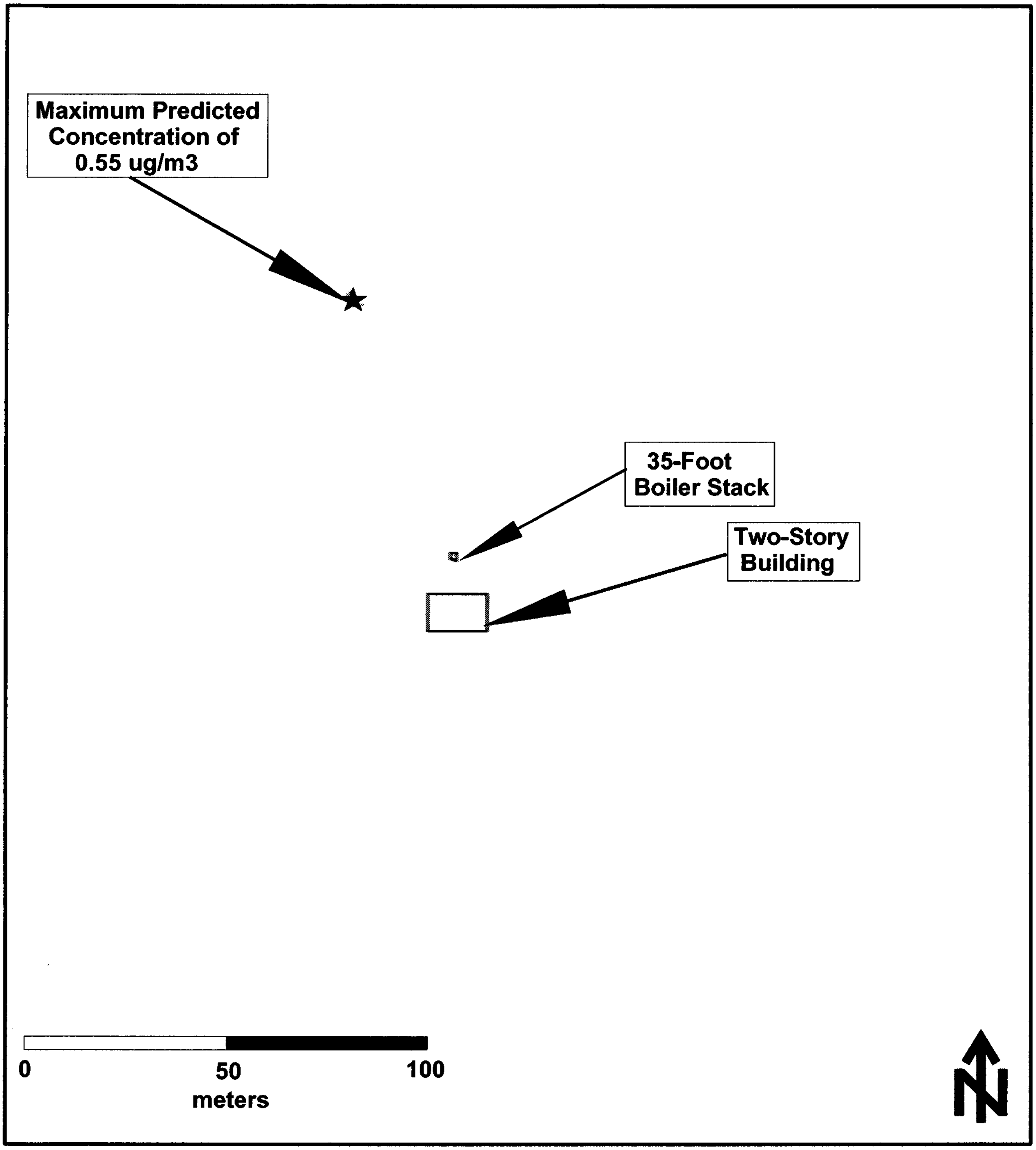


Figure 20
Case 2B-30 - 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 30 Feet from House

TECH environmental FOCUSED KNOWLEDGE. REAL SOLUTIONS.

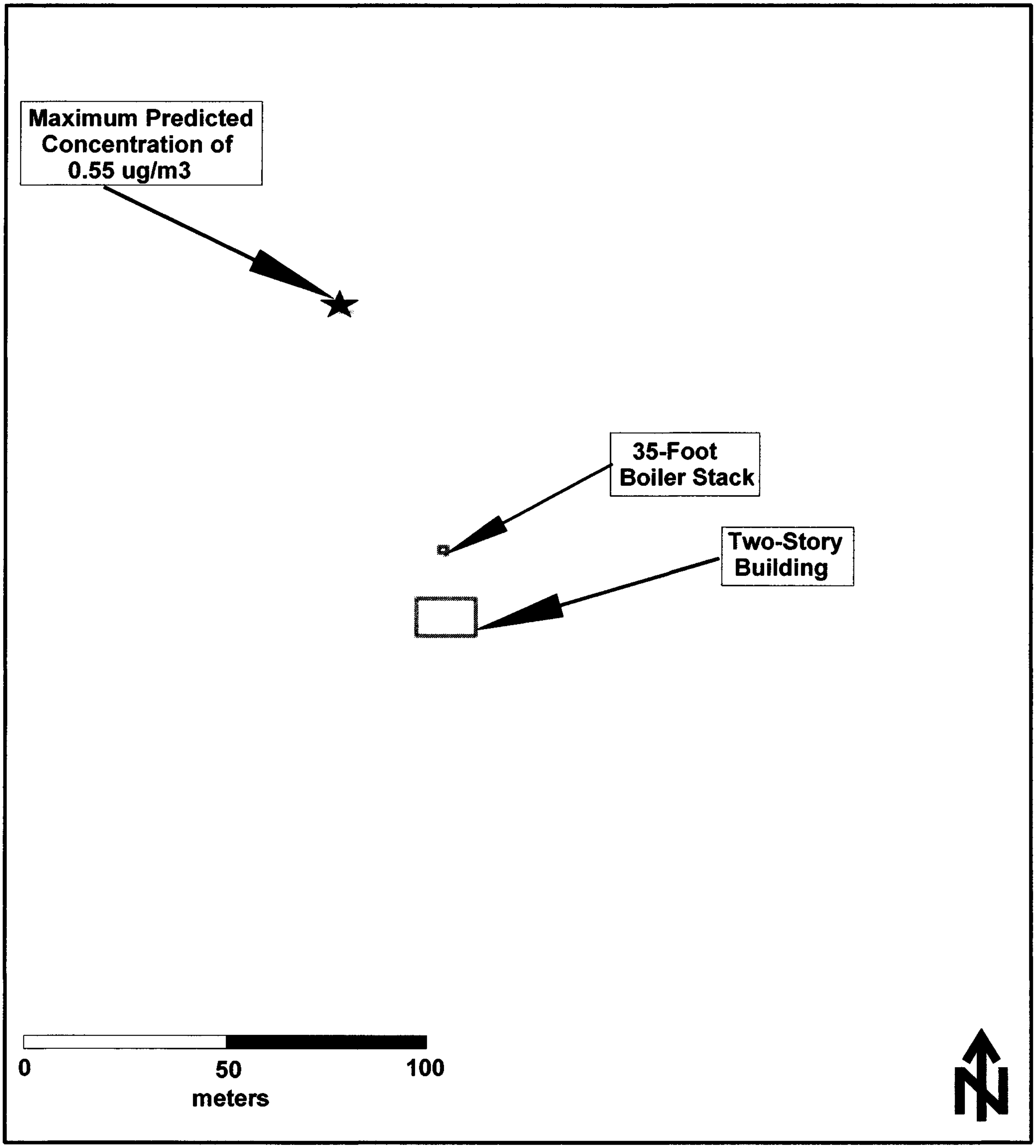


Figure 21
Case 2B-40 - 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 40 Feet from House

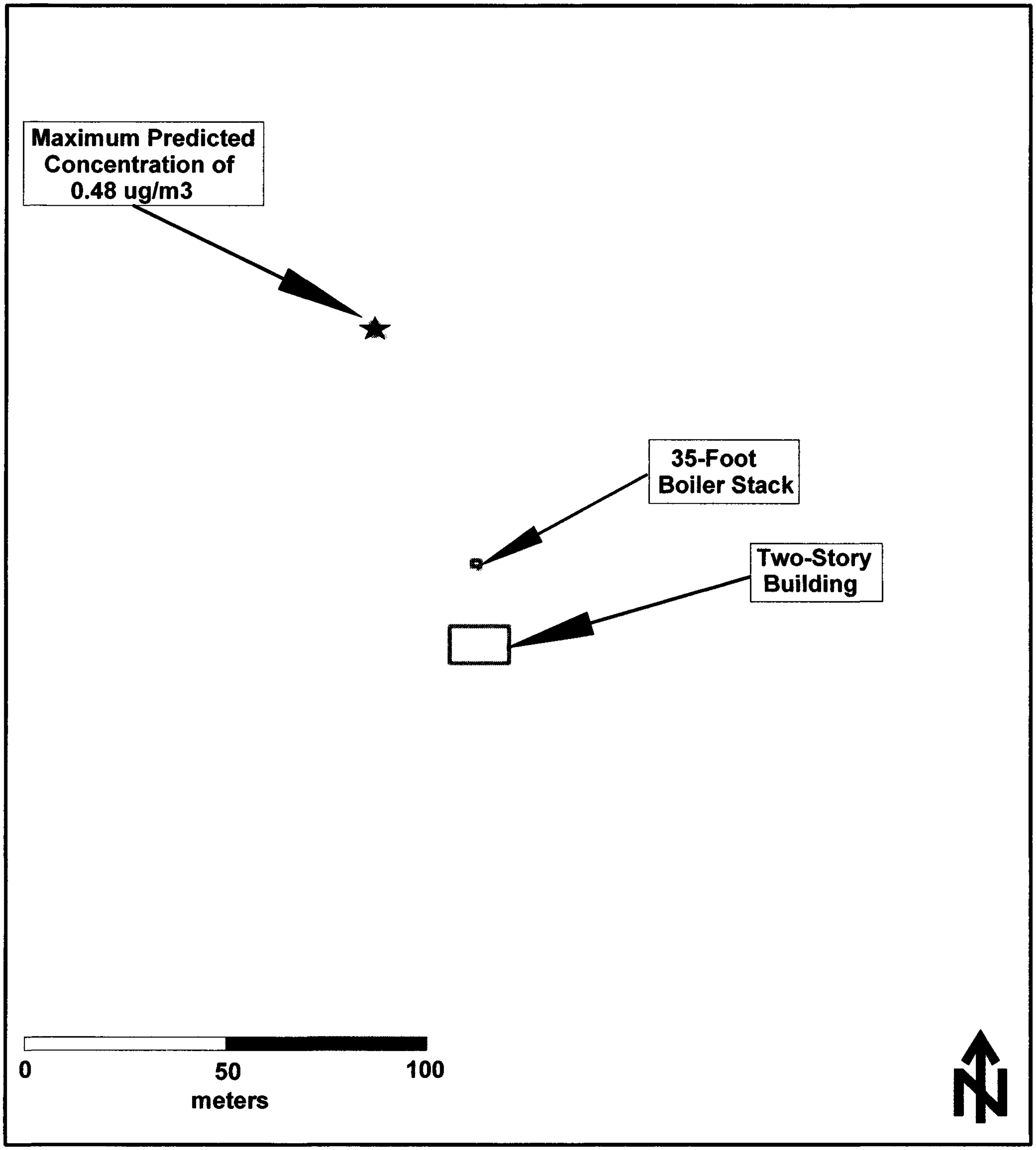


Figure 22
Case 2B-50 - 35-Foot Wood Boiler Stack with Emission Rate of 6.4 g/hour and 50 Feet from House

TECH environmental
FOCUSED KNOWLEDGE. REAL SOLUTIONS.

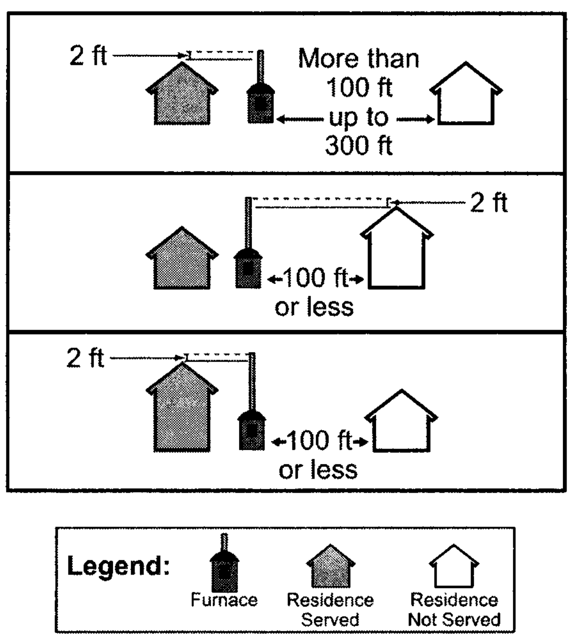
APPENDIX A

BEST BURN PRACTICES

OUTDOOR WOOD FURNACE
BEST BURN PRACTICES EPA HH PHASE 2
(0.32 LBS/MM BTU OUTPUT)

1. Read and follow all operating instructions supplied by the manufacturer.
2. FUEL USED: Only those listed fuels recommended by the manufacturer of your unit. Never use the following: trash, plastics, gasoline, rubber, naphtha, household garbage, material treated with petroleum products (particle board, railroad ties and pressure treated wood), leaves, paper products, and cardboard.
3. LOADING FUEL: For a more efficient burn, pay careful attention to loading times and amounts. Follow the manufacturer's written instructions for recommended loading times and amounts.
4. STARTERS: Do not use lighter fluids, gasoline, or chemicals.
5. LOCATION: It is recommended that the unit be located with due consideration to the prevailing wind direction.
   - If located within 300 feet to any residence not served by the furnace, it is recommended that the chimney be at least 2 feet higher than the peak of the residence served.
   - If located within 100 feet to any residence not served by the furnace, the chimney must be 2 feet higher than the peak of the residence served or not served, whichever is higher.

Chimney Height Installation Scenario



6. Always remember to comply with all applicable state and local codes.

Be considerate of neighbors when operating your furnace. If you use your furnace in the summer months, be certain your chimney exhaust is not adversely affecting neighbors with open windows.

APPENDIX B
AIR MODELING SUMMARY OUTPUTS

CENTRAL BOILER
OUTDOOR WOOD HYDRONIC HEATER
GREENBUSH, MN

20-FOOT STACK WITH ONE-STORY BULDING, 10 FEET FROM HOUSE (CASE 1A-10) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1A - 1 STORY BLDG; 20-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 14:45:38 ***
  Input File - W:\Apps\aermod\2618\March 2009\1A-10_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1A-10_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	7.6	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	2.85825 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	2.65622 AT (	-25.00,	0.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	2.61116 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	2.54329 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	2.50624 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	2.19856 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	2.19222 AT (	-25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.99889 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.98474 AT (	25.00,	0.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.95760 AT (	-25.00,	25.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 20 FEET FROM HOUSE (CASE 1A-20) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1A - 1 STORY BLDG; 20-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:05:21 ***
  Input File - W:\Apps\aermod\2618\March 2009\1A-20_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1A-20_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -         1
 Number of source groups -         1
     Number of receptors -       440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	10.7	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)					OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	2.60535 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	2.53124 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	2.50774 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	2.44691 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	2.19542 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.82988 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.81386 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.75724 AT (	-25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.67909 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.64784 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 30 FEET FROM HOUSE (CASE 1A-30) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1A - 1 STORY BLDG; 20-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:07:37 ***
  Input File - W:\Apps\aermod\2618\March 2009\1A-30_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1A-30_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	13.7	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)					NETWORK OF TYPE	GRID-ID
ALL	1ST HIGHEST VALUE IS	2.64676 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	2.57735 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	2.22694 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	2.05970 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	1.99064 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.98178 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.84955 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.51622 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.46327 AT (	0.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.43109 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 40 FEET FROM HOUSE (CASE 1A-40) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1A - 1 STORY BLDG; 20-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:09:47 ***
  Input File - W:\Apps\aermod\2618\March 2009\1A-40_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1A-40_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	16.8	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	2.70865 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	2.05440 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	1.95646 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	1.83472 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	1.74868 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.69450 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.49825 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.46939 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.45814 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.44357 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 50 FEET FROM HOUSE (CASE 1A-50) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1A - 1 STORY BLDG; 20-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 17:00:20 ***
  Input File - W:\Apps\aermod\2618\March 2009\1A-50_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1A-50_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	19.8	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	2.46707 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	2.02292 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	1.59347 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	1.46540 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	1.26390 AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.24776 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.22053 AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.21706 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.19970 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.11654 AT (	-50.00,	150.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 10 FEET FROM HOUSE (CASE 1B-10) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1B - 1 STORY BLDG; 20-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:13:45 ***
  Input File - W:\Apps\aermod\2618\March 2009\1B-10_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1B-10_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -        1
 Number of source groups -        1
     Number of receptors -      440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	7.6	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	1.04043 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.96689 AT (	-25.00,	0.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.95048 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.92578 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.91229 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.80029 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.79799 AT (	-25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.72761 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.72246 AT (	25.00,	0.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.71258 AT (	-25.00,	25.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 20 FEET FROM HOUSE (CASE 1B-20) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1B - 1 STORY BLDG; 20-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:16:05 ***
  Input File - W:\Apps\aermod\2618\March 2009\1B-20_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1B-20_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	10.7	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	0.94837 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.92139 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.91284 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.89069 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.79915 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.66609 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.66026 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.63965 AT (	-25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.61120 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.59983 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 30 FEET FROM HOUSE (CASE 1B-30) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1B - 1 STORY BLDG; 20-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:18:19 ***
  Input File - W:\Apps\aermod\2618\March 2009\1B-30_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1B-30_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Bur186-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440


                                        *** POINT SOURCE DATA ***

              NUMBER EMISSION RATE                      BASE     STACK   STACK    STACK     STACK    BLDG   URBAN  CAP/
EMIS RATE
    SOURCE     PART.  (GRAMS/SEC)     X         Y      ELEV.    HEIGHT  TEMP.   EXIT VEL. DIAMETER  EXISTS SOURCE HOR
SCALAR
      ID       CATS.              (METERS) (METERS) (METERS) (METERS) (DEG.K)  (M/SEC)  (METERS)
VARY BY
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - -

   BOILER       0   0.17800E-02      0.0      13.7      0.0     6.10   449.90     2.20     0.20   YES     NO     NO

                                 *** SOURCE IDs DEFINING SOURCE GROUPS ***

 GROUP ID                                              SOURCE IDs


  ALL       BOILER  ,


                         *** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER   5 YEARS ***

                                ** CONC OF PM25      IN MICROGRAMS/M**3                            **

NETWORK
 GROUP ID                        AVERAGE CONC               RECEPTOR  (XR, YR, ZELEV, ZHILL, ZFLAG)      OF TYPE  GRID-
ID
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- -

 ALL      1ST HIGHEST VALUE IS        0.96344 AT (    -25.00,       75.00,      0.00,      0.00,      0.00)  DC
          2ND HIGHEST VALUE IS        0.93818 AT (    -25.00,       50.00,      0.00,      0.00,      0.00)  DC
          3RD HIGHEST VALUE IS        0.81063 AT (      0.00,       50.00,      0.00,      0.00,      0.00)  DC
          4TH HIGHEST VALUE IS        0.74975 AT (      0.00,      -25.00,      0.00,      0.00,      0.00)  DC
          5TH HIGHEST VALUE IS        0.72461 AT (     25.00,      -25.00,      0.00,      0.00,      0.00)  DC
          6TH HIGHEST VALUE IS        0.72138 AT (    -25.00,      100.00,      0.00,      0.00,      0.00)  DC
          7TH HIGHEST VALUE IS        0.67325 AT (      0.00,       75.00,      0.00,      0.00,      0.00)  DC
          8TH HIGHEST VALUE IS        0.55192 AT (     25.00,      -50.00,      0.00,      0.00,      0.00)  DC
          9TH HIGHEST VALUE IS        0.53264 AT (      0.00,      -50.00,      0.00,      0.00,      0.00)  DC
         10TH HIGHEST VALUE IS        0.52093 AT (    -50.00,      100.00,      0.00,      0.00,      0.00)  DC
```

20-FOOT STACK WITH ONE-STORY BULDING, 40 FEET FROM HOUSE (CASE 1B-40) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1B - 1 STORY BLDG; 20-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:20:29 ***
  Input File - W:\Apps\aermod\2618\March 2009\1B-40_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1B-40_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	16.8	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)					OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	0.98597 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.74782 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.71217 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.66785 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.63653 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.61681 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.54537 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.53487 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.53077 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.52547 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	

20-FOOT STACK WITH ONE-STORY BULDING, 50 FEET FROM HOUSE (CASE 1B-50) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1B - 1 STORY BLDG; 20-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 16:56:44 ***
  Input File - W:\Apps\aermod\2618\March 2009\1B-50_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\1B-50_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -         1
 Number of source groups -         1
     Number of receptors -       440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	19.8	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	0.89804 AT	(-25.00, 75.00, 0.00, 0.00, 0.00)	DC	
	2ND HIGHEST VALUE IS	0.73636 AT	(-25.00, 100.00, 0.00, 0.00, 0.00)	DC	
	3RD HIGHEST VALUE IS	0.58004 AT	(0.00, 75.00, 0.00, 0.00, 0.00)	DC	
	4TH HIGHEST VALUE IS	0.53342 AT	(-25.00, 125.00, 0.00, 0.00, 0.00)	DC	
	5TH HIGHEST VALUE IS	0.46007 AT	(-50.00, 125.00, 0.00, 0.00, 0.00)	DC	
	6TH HIGHEST VALUE IS	0.45419 AT	(0.00, 50.00, 0.00, 0.00, 0.00)	DC	
	7TH HIGHEST VALUE IS	0.44428 AT	(0.00, 100.00, 0.00, 0.00, 0.00)	DC	
	8TH HIGHEST VALUE IS	0.44302 AT	(-50.00, 100.00, 0.00, 0.00, 0.00)	DC	
	9TH HIGHEST VALUE IS	0.43670 AT	(25.00, -25.00, 0.00, 0.00, 0.00)	DC	
	10TH HIGHEST VALUE IS	0.40643 AT	(-50.00, 150.00, 0.00, 0.00, 0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 10 FEET FROM HOUSE (CASE 2A-10) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2A - 2 STORY BLDG; 35-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:24:27 ***
  Input File - W:\Apps\aermod\2618\March 2009\2A-10_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2A-10_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -         1
 Number of source groups -         1
     Number of receptors -       440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	7.6	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)					OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	1.57961 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	1.46006 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	1.44323 AT (	0.00,	25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	1.42365 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	1.39901 AT (	-25.00,	0.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.34709 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.16584 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.13449 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.12079 AT (	-25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.09127 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 20 FEET FROM HOUSE (CASE 2A-20) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2A - 2 STORY BLDG; 35-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:26:54 ***
  Input File - W:\Apps\aermod\2618\March 2009\2A-20_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2A-20_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -         1
 Number of source groups -         1
     Number of receptors -       440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	10.7	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	1.44750 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	1.33739 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	1.18302 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	1.15112 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	1.13875 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.13084 AT (	0.00,	25.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.06809 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.02459 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.92943 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.92557 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 30 FEET FROM HOUSE (CASE 2A-30) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2A - 2 STORY BLDG; 35-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:29:19 ***
  Input File - W:\Apps\aermod\2618\March 2009\2A-30_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2A-30_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -         1
 Number of source groups -         1
     Number of receptors -       440


                                        *** POINT SOURCE DATA ***

              NUMBER EMISSION RATE                BASE     STACK   STACK    STACK     STACK    BLDG   URBAN  CAP/
EMIS RATE
    SOURCE     PART.  (GRAMS/SEC)    X        Y     ELEV.    HEIGHT  TEMP.   EXIT VEL. DIAMETER  EXISTS SOURCE HOR
SCALAR
      ID       CATS.              (METERS) (METERS) (METERS) (METERS) (DEG.K)  (M/SEC)  (METERS)
VARY BY
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - -

   BOILER        0   0.48900E-02     0.0      13.7     0.0    10.67   449.90     2.20     0.20   YES     NO     NO

                                   *** SOURCE IDs DEFINING SOURCE GROUPS ***

 GROUP ID                                            SOURCE IDs


  ALL       BOILER  ,


                          *** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER   5 YEARS ***

                                  ** CONC OF PM25      IN MICROGRAMS/M**3                                **

NETWORK
 GROUP ID                     AVERAGE CONC              RECEPTOR  (XR, YR, ZELEV, ZHILL, ZFLAG)       OF TYPE  GRID-
ID
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- -

 ALL      1ST HIGHEST VALUE IS       1.50714 AT (     -25.00,       75.00,       0.00,       0.00,       0.00)  DC
          2ND HIGHEST VALUE IS       1.24795 AT (     -25.00,      100.00,       0.00,       0.00,       0.00)  DC
          3RD HIGHEST VALUE IS       1.19579 AT (     -25.00,       50.00,       0.00,       0.00,       0.00)  DC
          4TH HIGHEST VALUE IS       1.06337 AT (       0.00,       75.00,       0.00,       0.00,       0.00)  DC
          5TH HIGHEST VALUE IS       0.95346 AT (       0.00,      -25.00,       0.00,       0.00,       0.00)  DC
          6TH HIGHEST VALUE IS       0.94895 AT (     -50.00,      100.00,       0.00,       0.00,       0.00)  DC
          7TH HIGHEST VALUE IS       0.94848 AT (     -25.00,      125.00,       0.00,       0.00,       0.00)  DC
          8TH HIGHEST VALUE IS       0.90357 AT (      25.00,      -25.00,       0.00,       0.00,       0.00)  DC
          9TH HIGHEST VALUE IS       0.87638 AT (     -50.00,      125.00,       0.00,       0.00,       0.00)  DC
         10TH HIGHEST VALUE IS       0.87491 AT (       0.00,      100.00,       0.00,       0.00,       0.00)  DC
```

35-FOOT STACK WITH ONE-STORY BULDING, 40 FEET FROM HOUSE (CASE 2A-40) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2A - 2 STORY BLDG; 35-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:31:38 ***
  Input File - W:\Apps\aermod\2618\March 2009\2A-40_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2A-40_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440


                                          *** POINT SOURCE DATA ***

               NUMBER EMISSION RATE                   BASE     STACK   STACK    STACK     STACK    BLDG   URBAN  CAP/
EMIS RATE
   SOURCE       PART.  (GRAMS/SEC)    X         Y     ELEV.    HEIGHT  TEMP.   EXIT VEL. DIAMETER  EXISTS SOURCE HOR
SCALAR
     ID         CATS.                (METERS) (METERS) (METERS) (METERS) (DEG.K)  (M/SEC)  (METERS)
VARY BY
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- - - - - -

  BOILER        0  0.48900E-02     0.0      16.8     0.0    10.67  449.90     2.20      0.20    YES      NO     NO

                                   *** SOURCE IDs DEFINING SOURCE GROUPS ***

 GROUP ID                                      SOURCE IDs


  ALL       BOILER   ,


                          *** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER   5 YEARS ***

                                 ** CONC OF PM25      IN MICROGRAMS/M**3                         **

NETWORK
 GROUP ID                    AVERAGE CONC               RECEPTOR  (XR, YR, ZELEV, ZHILL, ZFLAG)       OF TYPE  GRID-
ID
 - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
- -

 ALL      1ST HIGHEST VALUE IS       1.50253 AT (     -25.00,        75.00,       0.00,       0.00,       0.00)  DC
          2ND HIGHEST VALUE IS       1.29137 AT (     -25.00,       100.00,       0.00,       0.00,       0.00)  DC
          3RD HIGHEST VALUE IS       1.02739 AT (       0.00,       -25.00,       0.00,       0.00,       0.00)  DC
          4TH HIGHEST VALUE IS       1.01618 AT (       0.00,        75.00,       0.00,       0.00,       0.00)  DC
          5TH HIGHEST VALUE IS       0.99497 AT (     -25.00,       125.00,       0.00,       0.00,       0.00)  DC
          6TH HIGHEST VALUE IS       0.94243 AT (     -50.00,       100.00,       0.00,       0.00,       0.00)  DC
          7TH HIGHEST VALUE IS       0.90134 AT (     -50.00,       125.00,       0.00,       0.00,       0.00)  DC
          8TH HIGHEST VALUE IS       0.88085 AT (       0.00,       100.00,       0.00,       0.00,       0.00)  DC
          9TH HIGHEST VALUE IS       0.81009 AT (     -25.00,        50.00,       0.00,       0.00,       0.00)  DC
         10TH HIGHEST VALUE IS       0.79788 AT (     -50.00,       150.00,       0.00,       0.00,       0.00)  DC
```

35-FOOT STACK WITH ONE-STORY BULDING, 50 FEET FROM HOUSE (CASE 2A-50) (17.6 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2A - 2 STORY BLDG; 35-FT STK & 17 ***
 *** Model Executed on 03/27/09 at 15:33:53 ***
  Input File - W:\Apps\aermod\2618\March 2009\2A-50_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2A-50_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.48900E-02	0.0	19.8	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)					OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	1.31375 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	1.28621 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	1.06307 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	1.01917 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.89062 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.86588 AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.86255 AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.81007 AT (	-50.00,	150.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.79208 AT (	-25.00,	150.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.77921 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 10 FEET FROM HOUSE (CASE 2B-10) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2B - 2 STORY BLDG; 35-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:36:03 ***
  Input File - W:\Apps\aermod\2618\March 2009\2B-10_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2B-10_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	7.6	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	0.57499	AT (0.00, -25.00, 0.00, 0.00, 0.00)	DC	
	2ND HIGHEST VALUE IS	0.53147	AT (25.00, -25.00, 0.00, 0.00, 0.00)	DC	
	3RD HIGHEST VALUE IS	0.52535	AT (0.00, 25.00, 0.00, 0.00, 0.00)	DC	
	4TH HIGHEST VALUE IS	0.51822	AT (-25.00, 50.00, 0.00, 0.00, 0.00)	DC	
	5TH HIGHEST VALUE IS	0.50925	AT (-25.00, 0.00, 0.00, 0.00, 0.00)	DC	
	6TH HIGHEST VALUE IS	0.49035	AT (-25.00, 75.00, 0.00, 0.00, 0.00)	DC	
	7TH HIGHEST VALUE IS	0.42437	AT (0.00, 50.00, 0.00, 0.00, 0.00)	DC	
	8TH HIGHEST VALUE IS	0.41296	AT (-50.00, -25.00, 0.00, 0.00, 0.00)	DC	
	9TH HIGHEST VALUE IS	0.40798	AT (-25.00, -25.00, 0.00, 0.00, 0.00)	DC	
	10TH HIGHEST VALUE IS	0.39723	AT (25.00, -50.00, 0.00, 0.00, 0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 20 FEET FROM HOUSE (CASE 2B-20) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 1B - 2 STORY BLDG; 35-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:38:30 ***
  Input File - W:\Apps\aermod\2618\March 2009\2B-20_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2B-20_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	10.7	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	NETWORK OF TYPE	GRID-ID
ALL	1ST HIGHEST VALUE IS	0.52690 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.48682 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.43063 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.41902 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.41452 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.41164 AT (	0.00,	25.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.38879 AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.37296 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.33832 AT (	25.00,	-50.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.33692 AT (	-50.00,	-25.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 30 FEET FROM HOUSE (CASE 2B-30) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2B - 2 STORY BLDG; 35-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:40:54 ***
  Input File - W:\Apps\aermod\2618\March 2009\2B-30_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2B-30_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	13.7	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	0.54861 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.45427 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.43528 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.38708 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.34707 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.34543 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.34526 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.32891 AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.31901 AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.31847 AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 40 FEET FROM HOUSE (CASE 2B-40) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2B - 2 STORY BLDG; 35-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:43:13 ***
  Input File - W:\Apps\aermod\2618\March 2009\2B-40_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2B-40_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	16.8	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	NETWORK OF TYPE	GRID-ID
ALL	1ST HIGHEST VALUE IS	0.54693 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.47007 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.37398 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.36990 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.36218 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.34305 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.32810 AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.32064 AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.29488 AT (	-25.00,	50.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.29044 AT (	-50.00,	150.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH ONE-STORY BULDING, 50 FEET FROM HOUSE (CASE 2B-50) (6.4 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2B - 2 STORY BLDG; 35-FT STK & 6. ***
 *** Model Executed on 03/27/09 at 15:47:37 ***
  Input File - W:\Apps\aermod\2618\March 2009\2B-50_1986_PM25.DTA

 Output File - W:\Apps\aermod\2618\March 2009\2B-50_1986_PM25.LST

    Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

       Number of sources -          1
 Number of source groups -          1
     Number of receptors -        440
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.17800E-02	0.0	19.8	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)					OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	0.47822 AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	0.46819 AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	0.38697 AT (	0.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	0.37099 AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	0.32419 AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	0.31519 AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	0.31398 AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	0.29487 AT (	-50.00,	150.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	0.28832 AT (	-25.00,	150.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	0.28364 AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	

Outdoor Wood Boilers – New Emissions Test Data and Future Trends

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ABSTRACT

Outdoor Wood Boiler (OWB) Particulate Matter (PM) emissions were measured with EPA Method 5G in 48 tests done in 2005/2006. The average of the test results are within 10% of the results from eight EPA tests on two OWBs done in 1995. A comparison of the OWB test data to EPA tests of certified woodstoves as actually used by residential owners show that: 1) current OWB PM emissions are in the same range as certified woodstove emissions on a g/kg or lb/MMBtu basis and average 22 to 25 percent higher, and 2) operation of an OWB, which has a larger firebox than a woodstove, at a reduced firing rate approximating that of a woodstove does not produce high emissions. A comparison of polycyclic aromatic hydrocarbon (PAH) data reveals OWB emission rates are similar to, and lower than PAH emission rates for certified woodstoves. Mass emissions from the OWB tests were analyzed with dispersion modeling and the results demonstrate a properly installed OWB can operate year-round next to a residence and fully comply with the new $PM_{2.5}$ air quality standards. OWB manufacturers have worked with EPA to develop a voluntary Outdoor Wood-fired Heater (OWH) Program with a Phase 1 emissions target of 0.6 lb/MMBtu, representing a 60% PM emissions reduction. The Program uses EPA Draft Method 28-OWHH that incorporates EPA Method 5G. The Phase 1 emissions goal is more stringent than the current NSPS for non-catalytic woodstoves. Manufacturers will offer OWH Phase 1 Qualified Models later in 2007, and those units will have lower emissions, lb/MMBtu basis, than certified woodstoves and OWBs now in use.

INTRODUCTION

Concerns have been in by NESCAUM[1] about the emissions from Outdoor Wood Boilers (OWBs). These residential furnaces are designed to heat an entire home and in many cases replace multiple indoor wood stoves, which are typically sized to a heat a single room. Both certified woodstoves and OWB are bulk-loaded with cordwood. In both, an air damper regulates the combustion process (manual in a woodstove, automatic in an OWB tied to a thermostat), and heat transfer is through the firebox surface to either the surrounding room (in the case of a woodstove) or a surrounding water reservoir (in the case of an OWB). The usable heat produced by a stove or furnace is related to the quantity of wood burned and the heat provided to a home, thus the appropriate measure of emissions is the mass of PM per unit of fuel burned (g/kg-dry) or heat input (lb/MMBtu). Emission limits stated in lb/MMBtu are common in stationary source air permits and regulations, and reflect the fact that sources that burn more fuel produce more energy and do more work. By contrast, NESCAUM[2] compares OWB to woodstoves using g/hr emissions, an incorrect approach that fails to recognize the fact an OWB delivers 3-10 times more heat than a woodstove. An analogy to this comparison is if someone compared the hourly emissions (g/hr) of a Honda that drove 40 miles to those of a Cadillac that drove only 4 miles and complained that the Honda had 10 times the emissions of the Cadillac without disclosing that the Honda had traveled 10 times farther. In this paper, emissions data are presented using all three measures: g/kg, lb/MMBtu heat input and g/hr.

Particulate Matter (PM) and Polycyclic Aromatic Hydrocarbon (PAH) emission test data for OWB and EPA-certified woodstoves as they are actually operated in people's homes were collected and compared. The objectives were: 1) to compare OWB and woodstove emissions on a comparable heat input basis, 2) to examine the variation in OWB emissions over a wide range of burn rates and during unit cycling, and 3) to analyze the mass emissions from the OWB tests with EPA's AERMOD dispersion model to determine if a properly installed OWB, from those now available on the market, will comply with the new 24-hour $PM_{2.5}$ air quality standard of 35 $\mu g/m^3$. The maximum $PM_{2.5}$ ground-level concentrations for a properly-installed OWB meeting the EPA Phase 1 emissions target of 0.6 lb/MMBtu are also determined. All of the test data presented in this paper were collected using EPA Method 5G or other comparable EPA test methods. The one OWB emission test published by NESCAUM[3] is reviewed and compared to the other test data.

BODY

Particulate Matter Emissions Data for OWBs

The Particulate Matter (PM) emissions from six current-model OWBs were measured with EPA Method 5G in 48 tests done in 2005/2006[4,5,6,7]. These emissions are compared to eight Method 5G tests done on two OWBs in 1995 by U.S. EPA[8], and to tests done on 16 woodstoves performed in 1999 by EPA[9]. The goal was to use PM test data that represent how wood-burning appliances are actually used in a residential setting. The test data are compared in Figures 1 through 6. The mean PM emission rate for the 56 OWB tests is 12.2g/kg (1.44 lb/MMBtu).

A woodstove is designed to heat a single room and provides an average heat output of 11,000 Btu/hr.[9] By contrast, OWBs are sized to provide heat output in the rate of 25,000 to 100,000 Btu/hr, with a typical heat output rate around 50,000 Btu/hr. The "rated" heat output of these outdoor wood furnaces listed by manufacturers are often much higher, and the units are seldom used for an extended period of time at the rating. The peak heating-load on a cold January day (-20 F) for a 2,800 square foot home in a Northern State with good insulation would be approximately 55,000 Btu/hr. Thus, a typical OWB is designed to heat an entire home under all weather conditions. Dairy farmers use larger sized OWBs to heat their barns or other buildings.

Test Data for Wood Furnaces A, B and C

In the OMNI-Test Laboratories report[4], three OWBs from three different manufacturers (labeled A, B and C in Figures 1,2 and 3) were tested twice for emissions at each of two heat draw rates, corresponding to 11,000 Btu/hr ("low fire rate"), the average heat output of a wood stove, and 22,000 Btu/hr ("high fire rate"), twice that of a woodstove. These test points represent the condition where an OWB is fired at a reduced firing rate relative to its design capacity. The heat input rates during the tests varied from 23,000 to 54,000 Btu/hr. A total of 12 tests were done. Emissions were measured using EPA Method 5G (dilution tunnel sampling) with dual glass fiber filter trains, and the OWB were fired with a mixture of hard and soft cordwood having moisture contents of 20-25% (dry basis). The water circulation rate through the appliance was controlled to target the heat withdrawl rate, and mimic the cycling on and off of the air damper in a residential installation that controls the fire in the OWB.[11]

An examination of Figures 1 and 2 show the 12 test points labeled A, B and C are clustered around the previously-stated average emission rate for all 56 OWB tests of 12.1 g/kg and 1.44 lb/MMBtu, and thus very low firing of an OWB does not produce higher than normal emission rates. In Figure 3, mass emissions on a g/hr basis are at the lower of the scale reflecting the low firing rate during these tests and the fact less heat is being output. The mass emission rates from the low fire (11,000

Btu/hr) output) averaged 20.4 g/hr and the 22,000 Btu/hr output rate averaged 32.4 g/hr. The overall average on these lower output tests was 26.4 g/hr and is in the range of emissions from indoor wood stoves as tested by EPA in the home (discussed below).

Test Data for Wood Furnaces D, E and F

In the series of three Intertek Testing Services emission tests,[5,6,7] EPA Method 5G with dual filter trains was also used, and each of the three OWBs were fired with either dimensional oak wood or cordwood having moisture contents of 20-30% (dry basis). The test results are labeled D, E and F in Figures 1-3, where D represents the OWB named Rick in the test report, E represents Brian, and F is the OWB called Dan. For each OWB, 12 emission tests were done, six each at a target "low fire rate" and a "high fire rate". Within each group of six tests, three were done using cordwood and three with dimensional oak. The test results reveal no significant difference in emissions related to the two types of wood fuel. The water circulation rate through the appliance was controlled to target the heat withdrawl rate. While it is assumed that the units were cycled on and off to maintain the target heat withdrawl rate, this could not be confirmed with Intertek.

OWB Rick[6] was operated at higher than normal heat output rates, and the "high fire rate" is thought to be close to 100% of rated capacity with heat output centered on 100,000 Btu/hr, and the "low fire rate" targeting 50,000 Btu/hr heat output, the usual upper limit for consumer operation. The test points for OWB Rick (labeled D in Figures 1-3) stand out in Figures 1-3 because of the high heat input rate (124,000 to 241,000 Btu/hr) and consequently high mass emissions (42 to 116 g/hr). While the PM emission rates at these very high firing rates, 7 to 14 g/kg, are in the same range as emission tests at lower firing rates, operation of an OWB at close to its rated capacity for an extended period of time is unusual. The wood load was consumed in 4.3 hours or less in these tests. Consumers normally do not operate at this high burn rate; thus, the D-high fire rate data points should not be viewed as representative of OWB operation.

The Intertek tests on OWB Brian[5] resulted in the fuel load lasting from 5 to 6 hours at the "high fire rate" targeting 50,000 Btu/hr output; the mass emissions averaged 69.1 g/hr. The fuel load for the "low fire rate" representing 25,000 Btu/hr output lasted 9 to 10 hours and resulted in mass emissions averaging 58 g/hr. Excluding the one significant outlier, the emissions averaged 47.4 g/hr. The test points for OWB Brian (labeled E in Figures 1-3) show relatively consistent emission results in the 7 to 15 g/kg range except for one outlier with an emission rate of 25 g/kg (2.98 lb/MMBtu) and mass emissions of 111 g/hr that occurred under the lower firing rate with dimensional oak wood. The two identical tests of this unit (same fuel and heat input rate) recorded half this emission rate. No explanation for the outlier could be found in the test report.

The Intertek tests on OWB Dan[7], a smaller sized OWB, was operated more consistent with consumer use and the fuel load lasted 7 to 8 hours for the high burn rate and 9 to 11 hours for the low burn. The "high fire rate" targeted 24,000 Btu/hr heat output and the "low fire rate" produced 12,000 Btu/hr, a rate similar to that from a woodstove. The test points for OWB Dan (labeled F in Figures 1-3) reveal slightly higher emissions ranging from the 9 to 17 g/kg, and the average mass emissions were 43.8 g/hr for the high fire rate and 39.4 g/hr for the low fire rate.

Test Data for Wood Furnaces G and H

EPA performed PM emission tests[8] on two OWBs using Method 5G and a XAD sorbent trap on the sampling trains to capture PAH (discussed below). The low and high fire rates for the two OWBs labeled G and H in Figures 1-3 represent target heat outputs of 17,000 and 25,000 Btu/hr. The furnaces were fueled with cordwood having moisture contents of 10-25% (dry basis). The water circulation rate through the appliance was controlled to target the heat withdrawl rate, and mimic the cycling on and off of the air damper in a residential installation. For furnace G, the cycle was typically 8 minutes with the damper open followed by 30-60 minutes with it closed.

The PM emission rates for OWB G ranged from 9 to 13 g/kg and averaged 10.7 g/kg. EPA notes "several data quality problems" with the tests of furnace H that "may have compromised the data quality"[12]. The PM emission rates for OWB H were higher than those for OWB G and ranged from 15 to 17 g/kg except for one outlier with an emission rate of 25 g/kg (2.96 lb/MMBtu) and mass emissions of 143 g/hr. Despite the fact the EPA test report provides reasons for excluding this data point, it has been included in the Figures and overall emission statistics.

Analysis of all 56 Tests

In total, the 56 Method 5G emission tests on eight OWBs provide data for a very wide range of heat outputs from 11,000 to 110,000 Btu/hr and corresponding heat input rates of 23,000 to 242,000 Btu/hr (1.3 to 13 kg-dry/hour of wood firing). These data represent the wide variety of consumer uses and firing rates for OWBs. The mean PM emission rate for the 56 tests is 12.1 g/kg (1.44 lb/MMBtu heat input), and the mean mass emissions are 53 g/hr with a typical heat input rate of 93,000 Btu/hr. Figures 1 and 2 reveal that PM emission rates (g/kg or lb/MMBtu) do not vary for wood burn rates that span an entire order of magnitude, and that the average emission rate of 12 g/kg applies across the full range of heat inputs. These figures also show that operation of an OWB, which has a larger firebox than a woodstove, at a reduced firing rate approximating that of a woodstove does not produce high emissions. Figure 3 establishes that OWBs with higher mass emissions in g/hr emit more PM simply because of a greater fuel firing rate and not because the emission rate (g/kg) is higher.

Comparison to NESCAUM Emission Test

NESCAUM claims that a typical OWB has mass emissions of 161 g/hr from a single test done in June 2005.[21] Two significant errors were made by NESCAUM that invalidate their test results. First, the OWB was improperly fueled with green wood[22], and thus it produced excess smoke. Second, NESCAUM did not use the designated EPA test methods for PM emissions from wood heaters (Method 5G or 5H). Instead, they used a light-scattering monitor survey instrument, a DataRAM 4000, which erroneously measured water in the flue gas as PM. The Thermo Electron DataRAM 4000 uses light scattering to determine the size and number of particles in an air sample, and assumes a particle density of 2.6 g/cm^3 corresponding to surface dirt; it then estimates the particle mass in the air sample. This type of field survey instrument cannot be used for wood combustion PM measurements for two reasons. First, the density of wood combustion PM in any given test is unlikely to be 2.6 g/cm^3 and NESCAUM made no attempt to correct for this fact. EPA Methods 5G and 5H, by contrast, are gravimetric and measure particle mass directly. Second, and this is the greater error, wood combustion particles are saturated with water vapor when the gas is cooled to "near-ambient temperatures" as NESCAUM did before introducing the sample gas into the DataRAM 4000[21], and above 50% relative humidity (RH) solid particles swell due to accretion of water. Above 70% RH, this growth in particle size is so significant that the majority of the "particle mass" is water according to instrument manufacturer.[23] NESCAUM failed to use an MIE Temperature Conditioning Heater (DR-TCH) that could have removed the excess water. Thus, most of the "particle mass" NESCAUM measured with the DataRAM 4000 in their test was water, and it is not surprising that this poorly designed test produced emission estimates three times higher than the other emission tests done with EPA test methods and proper fuel.

Particulate Matter Emissions for EPA-Certified Woodstoves

Test Data for 16 Certified Woodstoves

A very comprehensive study of emissions from EPA-Phase 2 certified woodstoves, as they are operated in homes was done in Klamath Falls and Portland, Oregon in the late 1990s[9]. In that EPA study, emission sampling was done for up two months on 16 woodstoves while consumers operated the woodstoves conducting their "normal" heating practices. EPA devised an Automated Wood Emissions Sampling system for this study in which flue gas was drawn off and passed through a glass filter and then through a XAD cartridge. The test results reveal certified woodstoves emit an average of 9.7 g/kg (1.18 lb/MMBtu), with non-catalytic stoves averaging 9.2 g/kg and catalytic stoves averaging 10.8 g/kg.[13] Mass emissions for these stoves covered a wide range from 2 to 32 g/hr and averaged 11.1 g/hr, which is significantly above the certification limits for Phase 2 woodstoves of 4.1 g/hr (catalytic design) and 7.5 g/hr (non-catalytic design). A comparison of the actual PM emissions to each stove's hang-tag certification value is provided in this same EPA study and shows that actual in-use emissions from certified stoves are on average 3.3 times the certification value.[14] The two reasons for this discrepancy are: 1) EPA's stove certification Method 28 allows the air controls to be manipulated during the test to achieve lower emissions, as discussed below, and 2) in the case of the catalyst stove, the catalyst is not replaced by the homeowner as the stove ages.

Comparison of all OWB and Woodstove Test Data

The test data for the 16 certified woodstoves are graphed with the 56 tests for OWBs in Figures 4, 5 and 6 and reveal that at the low heat input rates characteristic of woodstoves, PM emission rates from OWBs and certified woodstoves are very similar. The mean values for the set of OWB and woodstove tests are separately noted by larger symbols in Figures 4, 5 and 6. The average OWB emission rate of 12.1 g/kg is 25% above the average woodstove emission rate of 9.7 g/kg. Expressed in units of heat input, the average OWB emission rate of 1.44 lb/MMBtu is 22% above the average woodstove emission rate of 1.18 lb/MMBtu. The mean heat input values represented in the two sets of test data are 93,000 Btu/hr for the OWBs and 19,000 Btu/hr for the woodstoves. This ratio of 5:1 in heat input explains most of the difference in the 5:1 ratio of mass emissions (g/hr) between OWBs and woodstoves seen in Figure 6.

One Reason Why Actual Woodstove Emissions are 3 Times Hang-Tag Certification Values

PM emissions increase dramatically when a new load of wood is added to a woodstove unless the primary air control is left wide open for 5-15 minutes to bring the internal temperature back up to the high level required for secondary combustion of pollutants.[15] Tests by EPA of one of its "cleanest" non-catalytic woodstoves found that the stove achieved low PM emissions (2 to 4 g/hr) if the air supply control was left wide open for 10-15 minutes each time wood was loaded into the stove. When the air control was turned down for a slower burn rate before 5 minutes had elapsed, however, emissions soared 5 to 10 times higher into the 15-20 g/hr range.[16] Because of this emissions spiking characteristic of woodstoves, Method 28 allows the test operator to leave the air damper wide open for the first 5 minutes of the test to artificially raise the stove temperature and then turn it down to match the test's prescribed burn rate (see Section 8.12.1.4 in Method 28). Method 28 also allows the air control to be manipulated during the test to minimize PM emissions (see Sections 8.12.4 and 8.10). A leading woodstove manufacturer confirmed to EPA that many stoves are designed to pass the test and have higher emissions in actual in-home use.[17]

Homeowners do not do the air control manipulations employed during a Method 28 test, adjustments that are crucial to a woodstove passing the EPA certification. When a stove is refueled in the home, the wood is added, the air control might be adjusted, and the homeowner walks away. Thus, actual in-home use of a woodstove produces substantially higher emissions than the hang-tag certification value, as documented in the EPA woodstove study.[14]

PAH Emissions for OWBs and Woodstoves

The previous-cited EPA OWB study[8] also produced test data on PAH emission rates and compared these to PAH emission rates for EPA-certified woodstoves, on a g/MJ heat input basis. The EPA test data reveal that OWBs labeled G and H in this paper produce 16.1 and 15.6 mg/MJ of PAH, respectively, and those values are similar to, and lower, than emission rates EPA gives for certified woodstoves of 24-28 g/MJ.[18]

Dispersion Modeling Analysis of OWB PM Emissions

Air dispersion modeling was performed with the EPA AERMOD model and following EPA guidance to determine whether a properly installed and operated OWB complies with the new, more stringent 24-hour $PM_{2.5}$ National Ambient Air Quality Standard of 35 $\mu g/m^3$. Persons who buy an OWB typically have an ample and inexpensive wood supply and the land on which to split and store the wood fuel, and hence OWBs are most often found in rural areas. The air dispersion modeling assumed the OWB was located in flat terrain at a typical distance of 50 feet from a house (50' x 40' footprint) with an 18-foot roof peak and the OWB stack was 20 feet above grade, or two feet above the roof peak of the nearest structure, following manufacturer installation instructions and industry guidelines.[19] Five years of hourly meteorological data for Burlington, Vermont were utilized in the modeling and the AERMOD model considered the wake cavity effects from house and the OWB firebox on the furnace stack.

The OWB that was modeled is a Central Boiler Model 6048, a popular model sold by the leading manufacturer. The test data presented in this paper for OWB G are for a similar Central Boiler furnace that EPA tested and the average emission rate for that unit was 10.7 g/kg-dry. Assuming a 5.6 kg-dry/hr firing rate (7.4 kg/hr of wood with 24% moisture), which corresponds to a heat input rate of 99,600 Btu/hour, the emission rate is 60 g/hr of PM. The dispersion modeling assumed this as a 24-hour average emission rate because the air concentrations being predicted were for a 24-hour time period. This emission rate is slightly higher than the mean value of 52 g/hr for the shorter time period OWB emission tests presented in Figure 3. Two emission rates were analyzed for the OWB: 1) 60 g/hr of PM (1.33 lb/MMBtu) representing typical winter operation of an OWB now on the market, and 2) 27 g/hr of PM (0.60 lb/MMBtu) corresponding to the new EPA Phase 1 guideline for OWBs, some of which will be available to consumers later in 2007. As a conservative assumption, all PM emissions were assumed to be $PM_{2.5}$, even though EPA data suggest only 76% of the total PM mass has a mass mean diameter of 2.5 microns or less.[20] Following the latest EPA guidance, the five-year average of the highest, 8^{th}-highest 24-hour $PM_{2.5}$ concentrations were predicted as the design concentrations for compliance assessment.

The modeling results reveal a single peak concentration of 8.4 $\mu g/m^3$ for the 60-g/hr-emission rate with most concentration values in the range of 1 to 3 $\mu g/m^3$ at distances up to 150 meters from the OWB. For the lower 27-g/hr-emission rate representing the new EPA Phase 1 emissions goal, the modeling results show a peak concentration of 3.8 $\mu g/m^3$ with concentrations below 1 $\mu g/m^3$ at distances over 150 meters from the OWB. In a rural area where OWBs are typically found, background levels of

$PM_{2.5}$ are sufficiently low that the sum of background and OWB concentrations will definitely comply with the new 24-hour NAAQS of 35 $\mu g/m^3$ for both existing OWBs (60 g/hr) and the new EPA Phase 1 models (27 g/hr). Note that the peak concentration for the EPA Phase 1 OWB of 3.8 $\mu g/m^3$ is below the 5-$\mu g/m^3$ EPA significance threshold for 24-hour Particulate Matter.[24] Thus, it can be concluded that a properly installed and operated OWB that meets the new EPA Phase 1 guideline of 0.6 lb/MMBtu will have an insignificant effect on local air quality.

New OWBs Meeting the EPA Phase 1 Guideline Are Cleaner Than Certified Woodstoves

In January, EPA announced a partnership agreement with OWB manufacturers to make lower-emission OWBs. Under the EPA Outdoor Wood-Fired Heater Program Phase 1, manufacturers are building units to meet an emission goal of 0.6 lb/MMBtu and will be certified at that level with the EPA Test Method 28 OWHH. Some manufacturers expect to have at least one model available for purchase by consumers this fall that meets the Phase 1 limit. The Phase 1 OWBs with PM emissions of 0.6 lb/MMBtu will have 60% less emissions than the typical OWB in use today (1.44 lb/MMBtu, see Figure 5) and will have 50% less emissions than the typical woodstove (1.18 lb/MMBtu average as operated, see Figure 5). In a recent letter, EPA stated that "most current EPA-certified woodstoves emit 0.8 – 1.5 lb/million BTU heat input [particulate matter]"[25], which confirms that the new Phase 1 OWBs will have an emission rate that is 25% to 60% less than a certified woodstove. In addition, the Phase 1 emissions goal of 0.6 lb/MMBtu is more stringent than the current NSPS for non-catalytic woodstoves of 7.5 g/hr, which equates to 0.74 lb/MMBtu.[26]

CONCLUSIONS

Concerns have been raised by NESCAUM about the emissions from Outdoor Wood Boilers (OWB). These residential furnaces are designed to heat an entire home and in many cases replace multiple indoor wood stoves, which are typically sized to a heat a single room. To properly compare OWB and woodstove emissions, the measure is emissions per unit of fuel burned (g/kg-dry) or heat input (lb/MMBtu). To meet an emissions goal on a g/kg or lb/MMBtu basis requires the furnace to have good combustion efficiency. By contrast, use of a mass-per-time limit (g/hr) does not impose this requirement because the firing rate can simply be limited, an approach taken by some wood stove manufacturers in gaining EPA certification.

Particulate Matter (PM) emissions from six current-model OWB were measured with EPA Method 5G in 48 tests done in 2005/2006. The results reveal PM emission rates do not vary over a wide range of burn rates (1.3 to 13 kg-dry/hour) and operation of an OWB with larger firebox than a woodstove at a reduced firing rate, when heat demand is low, does not produce high emissions. The average of the test results are within 10% of the results from EPA tests on two OWBs done in 1995. A comparison of the OWB test data to EPA tests of certified woodstoves as actually used by residential owners show that: 1) current OWB PM emissions are in the same range as certified woodstove emissions on a g/kg basis and average 22 to 25 percent higher, and 2) cycling of the OWB fire by the thermostat in a home does not produce high emissions. A comparison of polycyclic aromatic hydrocarbon (PAH) data reveals OWB emissions are similar to, and lower than PAH emissions from certified woodstoves.

Mass emissions from the OWB tests were analyzed in a dispersion modeling analysis to produce contour maps of maximum 24-hour $PM_{2.5}$ concentrations for two OWB emission rates representing current models and lower emission models meeting the EPA Phase 1 emissions goal. The results demonstrate that: 1) a properly installed OWB can operate year-round next to a residence and fully comply with the new $PM_{2.5}$ air quality standards, and 2) a properly installed and operated OWB that meets the new EPA Phase 1 guideline of 0.6 lb/MMBtu will have an insignificant effect on local air quality. OWB manufacturers have worked with EPA to develop a voluntary Outdoor Wood-fired Heater (OWH) Program with a Phase 1 emissions target of 0.6 lb/MMBtu, representing a 60% reduction in PM emissions from existing OWB. The Program uses EPA Standard Test Method 28 OWHH that incorporates EPA Method 5G. The Phase 1 emissions goal is more stringent than the current New Source Performance Standard (NSPS) for wood stoves. Manufacturers will be bringing OWH Phase 1 Qualified Models to market starting in 2007, and those units will have lower emissions, lb/MMBtu, basis than certified woodstoves now in use.

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KEY WORDS

Particulate matter
PM
Outdoor Wood Boilers
Outdoor Wood Hydronic Heaters
Outdoor Wood Furnaces
PAH
Certified Woodstoves
Emission Factors

Figure 1. PM emissions (g/kg) vs heat input rate of eight outdoor wood boilers (56 tests)

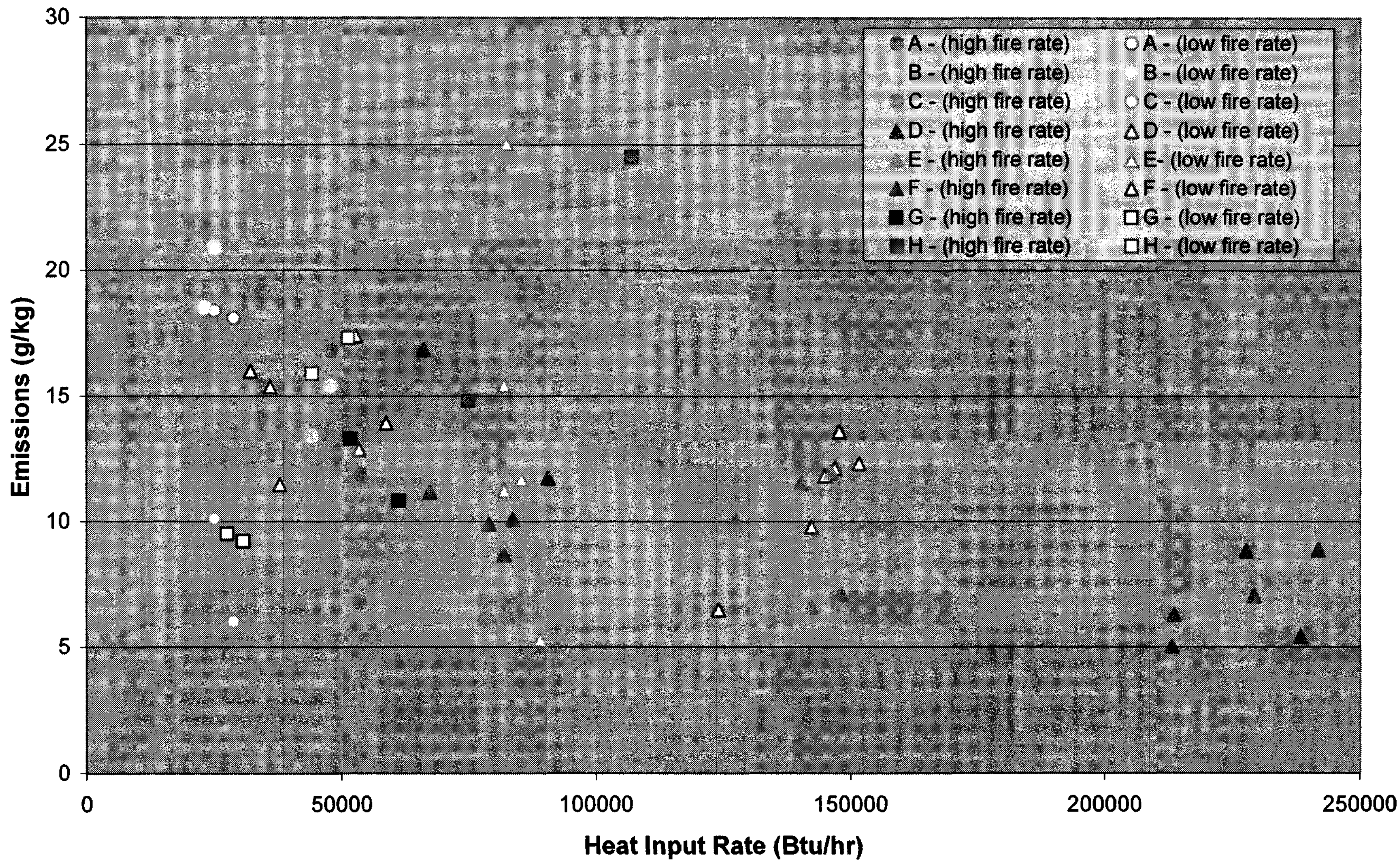


Figure 2. PM emissions (lb/million Btu) vs heat input rate of eight outdoor wood boilers (56 tests)

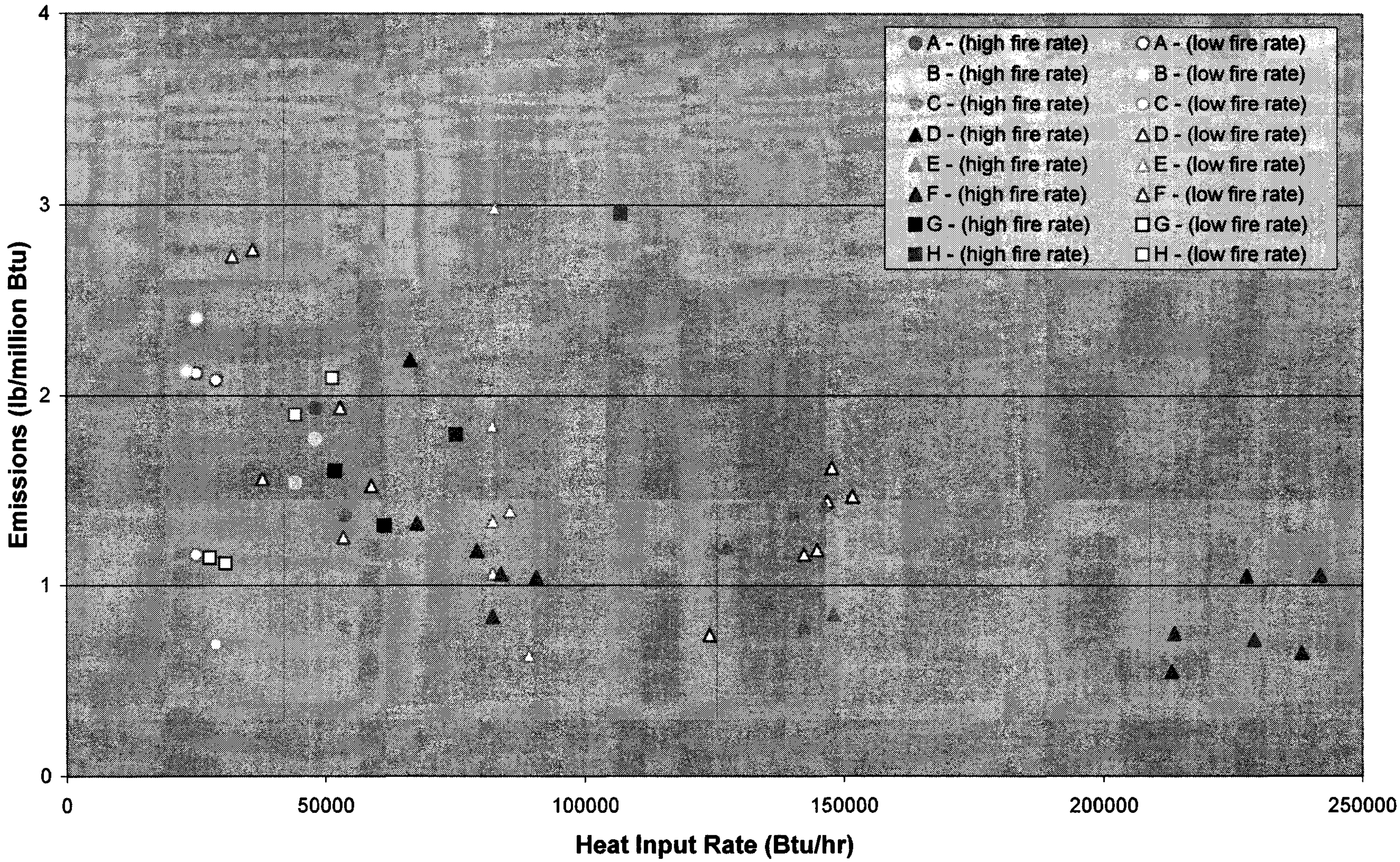


Figure 3. PM emissions (g/kg) vs emissions (g/hr) of eight outdoor wood boilers (56 tests)

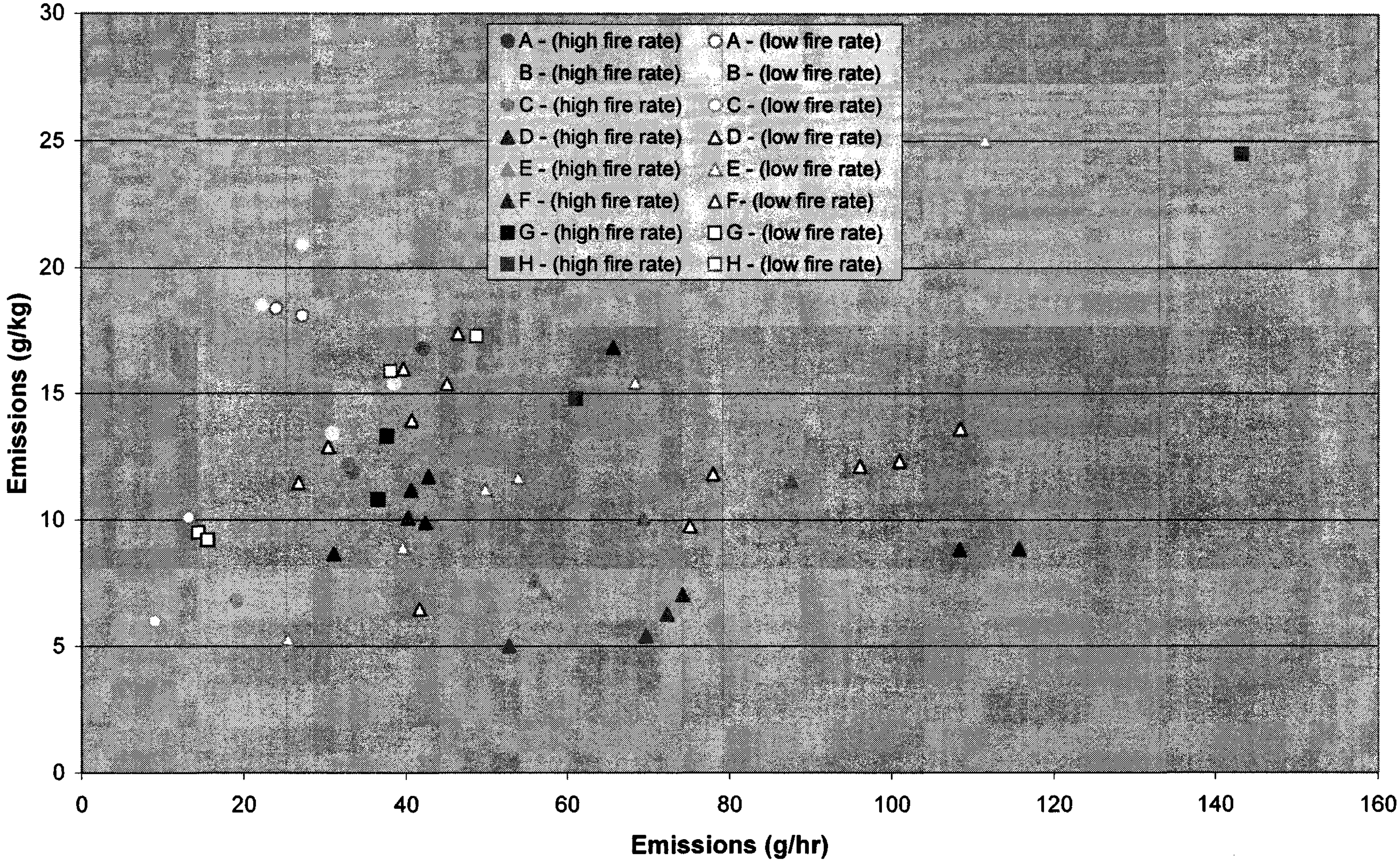


Figure 4. PM emissions (g/kg) vs heat input rate of outdoor wood boilers vs. certified woodstoves

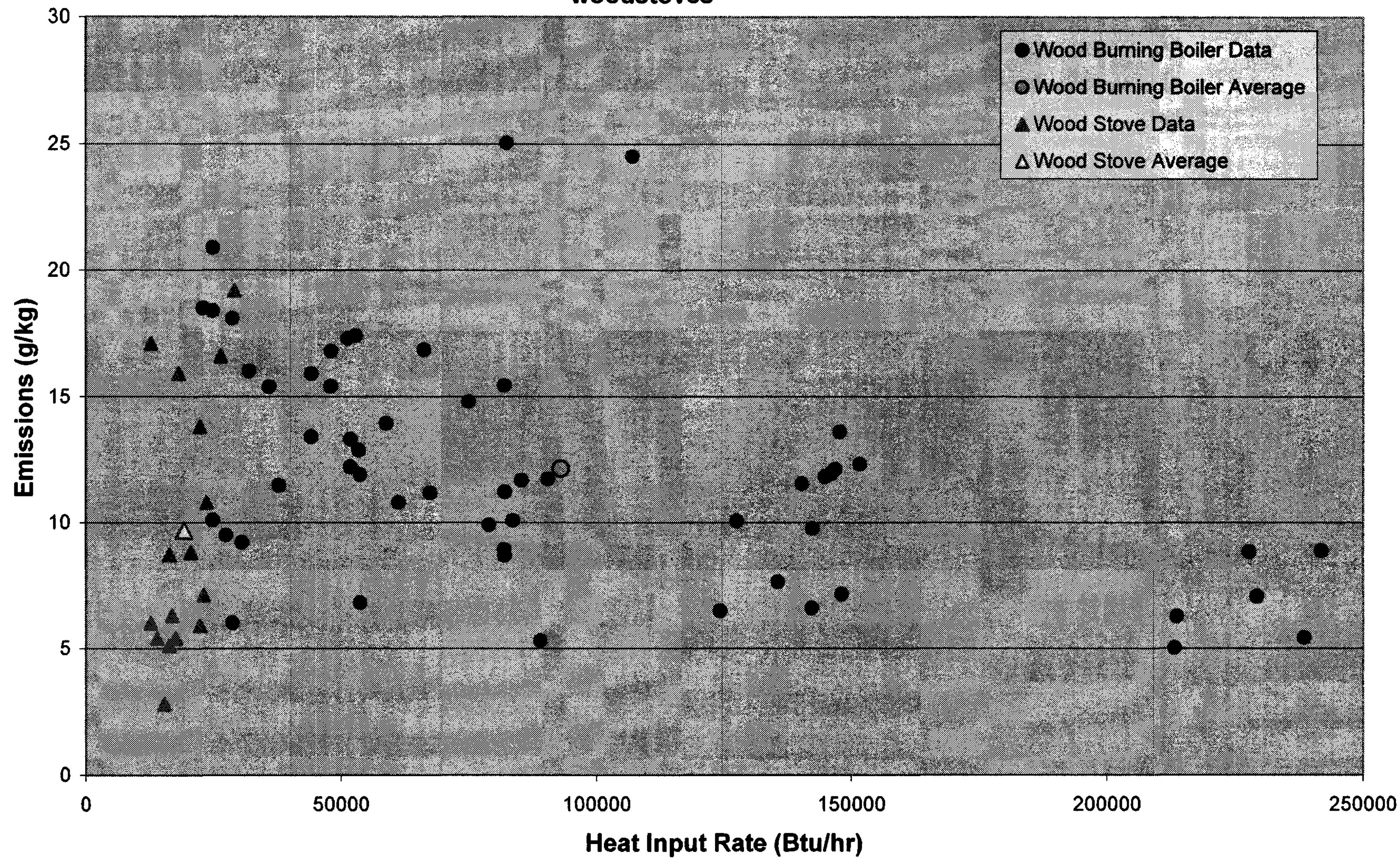


Figure 5. PM emissions (lb/MMBtu) vs heat input rate of outdoor wood boilers vs. certified woodstoves

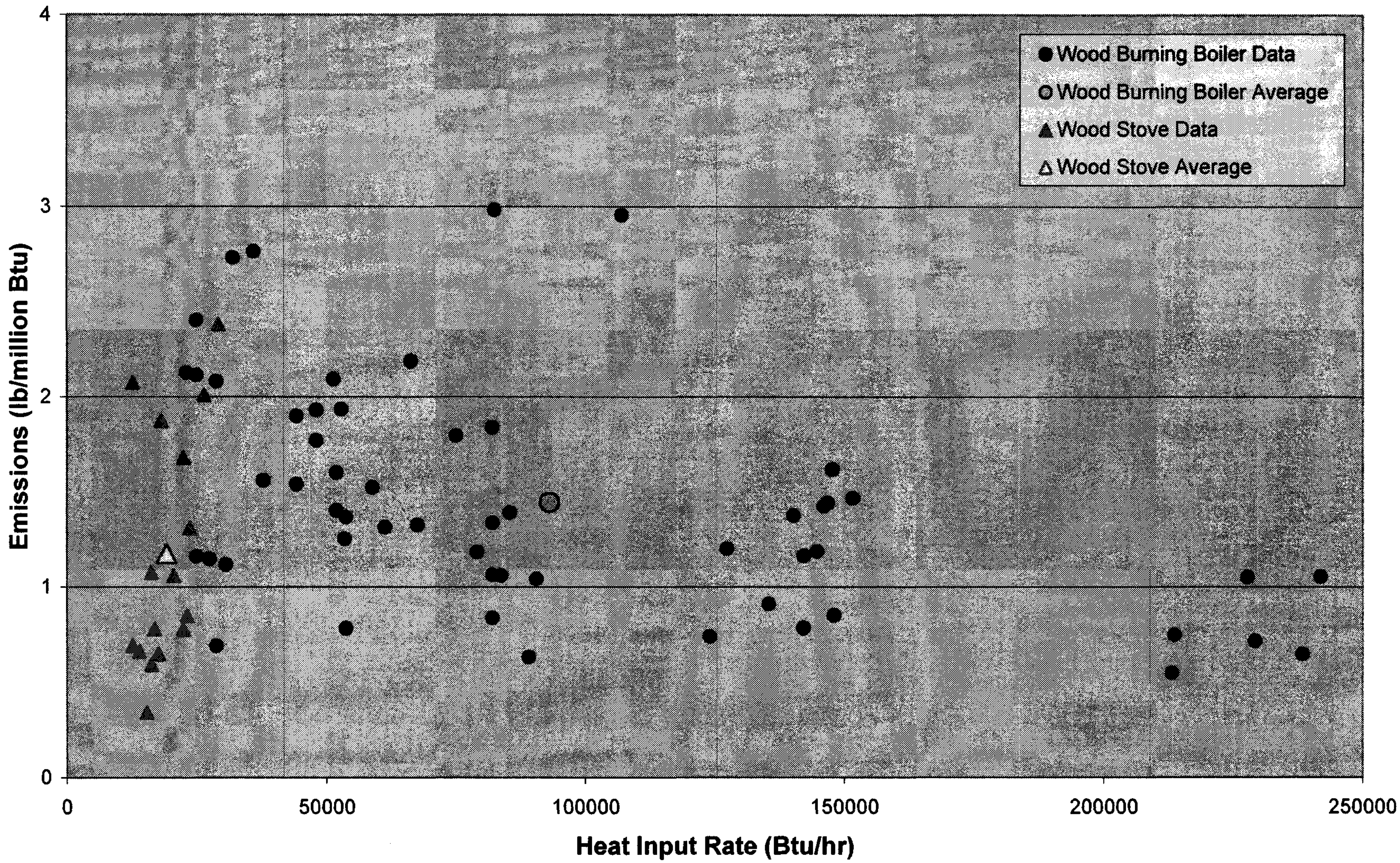


Figure 6. PM emissions (g/kg) vs emissions (g/hr) of outdoor wood boilers vs. wood stoves

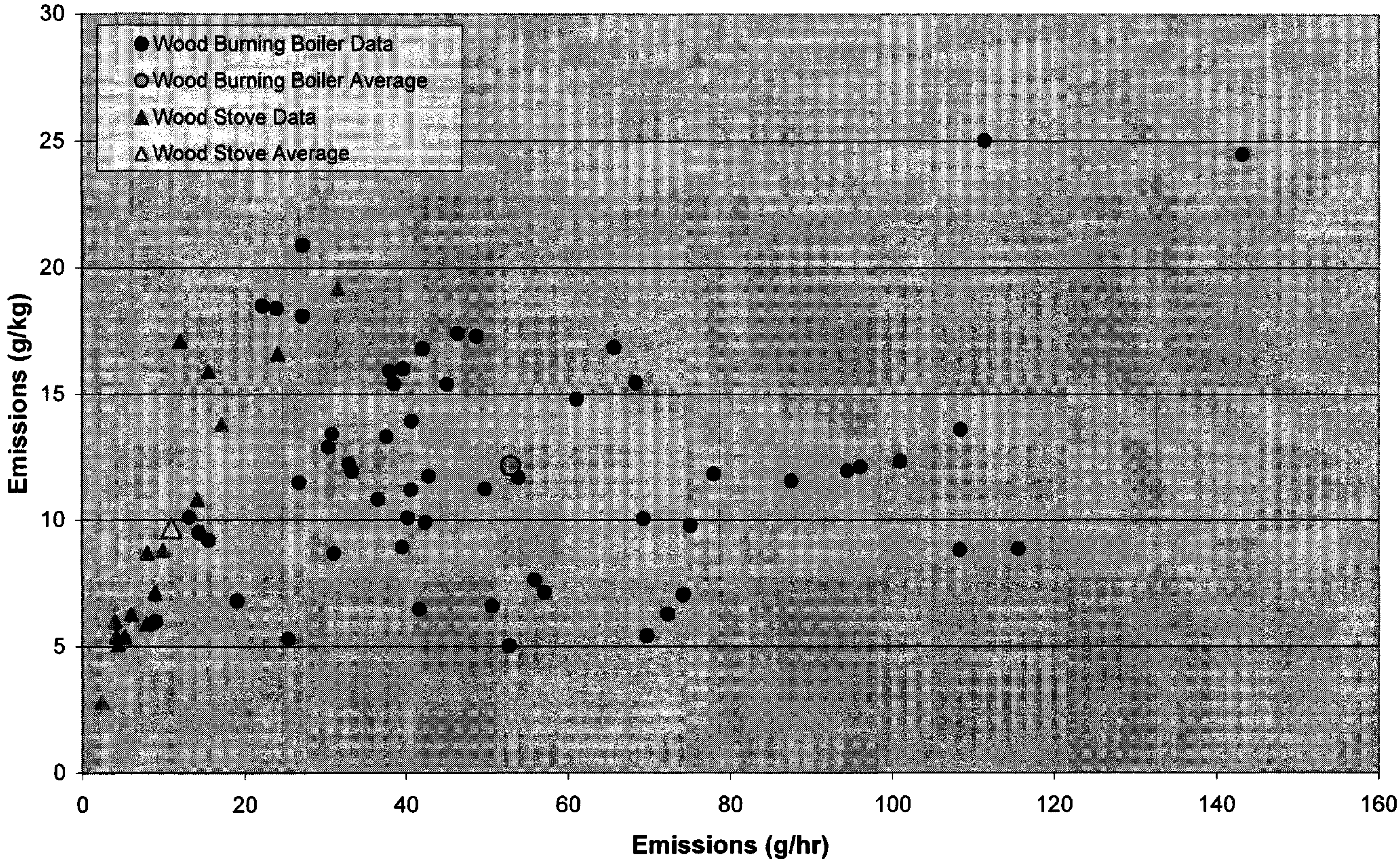


Figure 7. Five-year Average 24-Hour H8H $PM_{2.5}$ Concentrations (ug/m^3) For An OWB With A 20-Foot Stack Emitting 60 g/hr

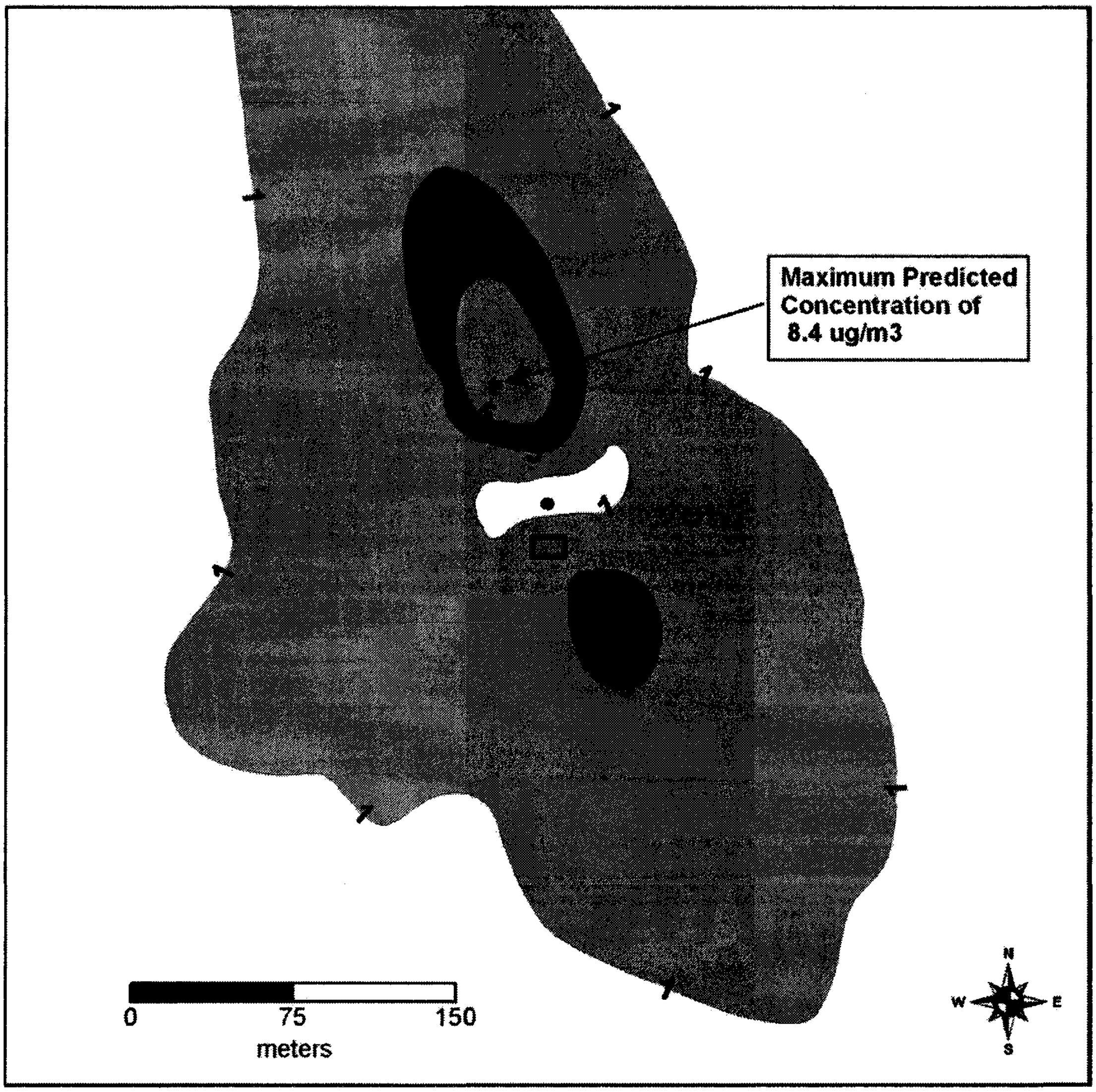
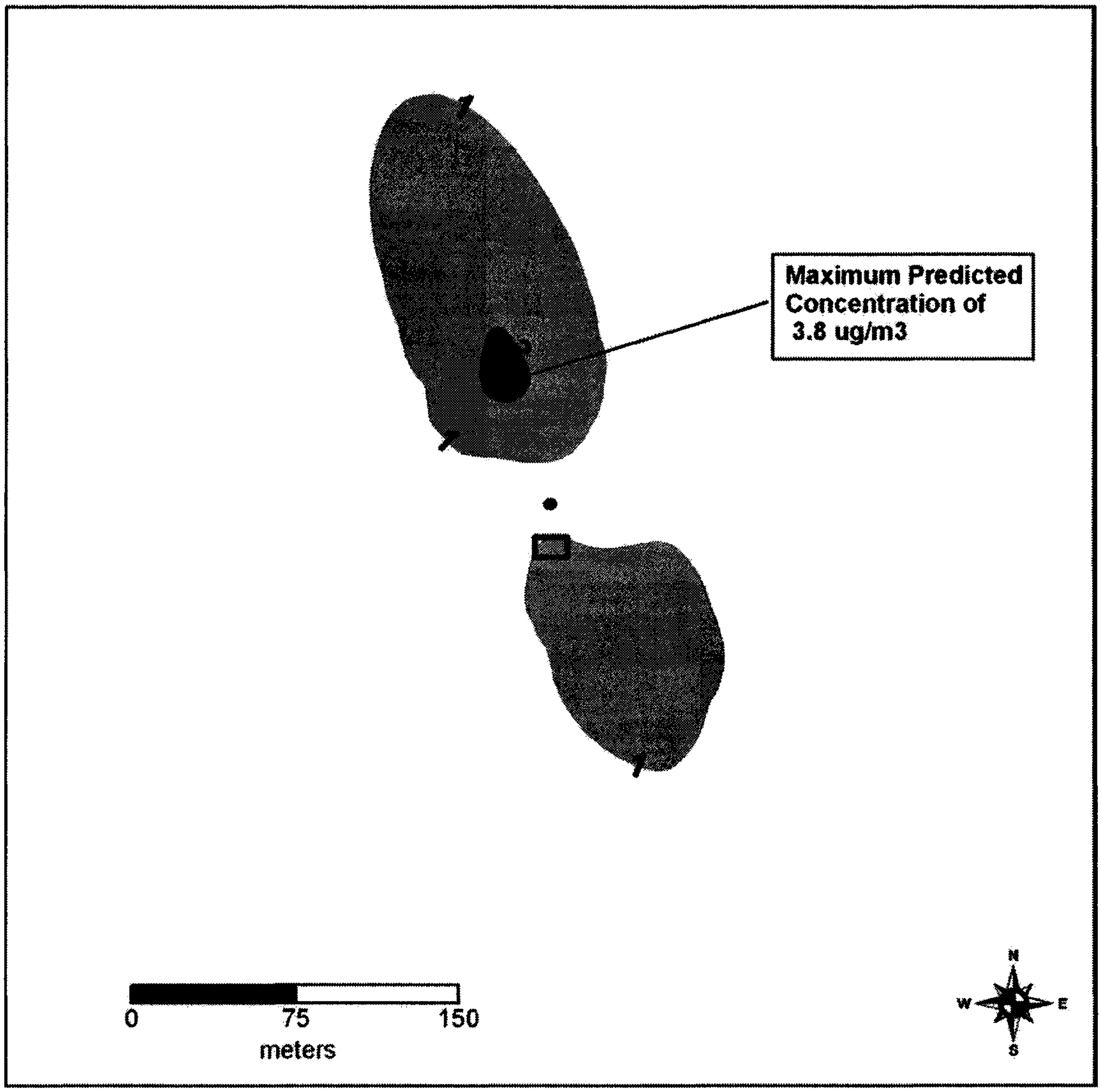


Figure 8. Five-year Average 24-Hour H8H $PM_{2.5}$ Concentrations (ug/m^3) For An OWB With A 20-Foot Stack Emitting 27 g/hr



AIR QUALITY DISPERSION MODELING OF OUTDOOR WOOD HYDRONIC HEATERS

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April 10, 2007

1.0 EXECUTIVE SUMMARY

Air dispersion modeling was performed with the U.S. AERMOD model and following EPA guidance to determine the effect of a Central Boiler Outdoor Wood Hydronic Heater (OWHH) on air quality. Air dispersion modeling assumed the OWHH was located a typical distance of 50 feet from either a one-story or a two-story house and had a stack top two feet above the roof peak of the nearest structure, following the chimney height installation instructions supplied by Central Boiler with every new unit. Five years of hourly meteorological data for Burlington, Vermont were utilized in the modeling.

The principal air pollutant emitted by OWHHs is particulate matter (PM). The Central Boiler Model 6048 was first assumed to emit 60 g/hr of PM using the average of U.S. EPA test data[1] for emissions from Central Boiler furnaces of 10.7 g/kg-dry and a firing rate of 5.6 kg-dry/hour,[2] corresponding to a heat input rate of approximately 99,600 Btu/hour. The emission rate is thus 1.33 lb/MMBtu heat input. With 55% efficiency, the heat output rate is 54,300 Btu/hour and satisfies the peak heating-load for January in a northern State for a larger-than-average 2,800 sf home. Second, the new EPA Phase 1 guideline of 0.60 lb/MMBtu was assumed in the dispersion modeling, which translates to a mass emission rate of 27 g/hr.

The modeling results demonstrate that maximum predicted air concentrations from operation of a Central Boiler OWHH with an emission rate of either 60 g/hour or 27 g/hour are safely in compliance with the new 24-hour National Ambient Air Quality Standards (NAAQS) for fine particulate matter ($PM_{2.5}$) of 35 $\mu g/m^3$. The NAAQS have been established by EPA to protect the most sensitive groups in the population (for PM, these are people with asthma and respiratory disease) from any adverse effects, with a margin of safety. Full compliance with the NAAQS is demonstrated both on the homeowner's property and off-site for both stack heights.

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[1] U.S. EPA, "Emissions From Outdoor Wood-Burning Residential Hot Water Furnaces," EPA-600/R-98-017, February 1998, p. 22, Table 4-1a, average of Furnace B/B-1 through B-4 test results for a Central Boiler unit.

[2] Wood firing rate of 16 lb/hr (24% moisture) = 7.4 kg/hour = 5.6 kg-dry/hour.

2.0 AIR QUALITY STANDARDS

The principal air pollutant emitted by OWHHs is particulate matter (PM). EPA has established National Ambient Air Quality Standards (NAAQS) for both coarse (PM_{10}) and fine ($PM_{2.5}$) particulate matter. The PM_{10} standard applies to particles with a mass-mean diameter of 10 microns or less, while the $PM_{2.5}$ standard is keyed to particles 2.5 microns in diameter or less. While both long-term (annual) and short-term (24-hour) standards have been established, the 24-hour standards are the controlling set because of their more stringent limits. Also, the $PM_{2.5}$ standard is more stringent than the PM_{10} standard. Thus, only the 24-hour $PM_{2.5}$ levels are examined in this study.

The 24-hour $PM_{2.5}$ standard is 35 $\mu g/m^3$, measured as a 3-year average of 98^{th}-percentile concentrations. In a one-year period, the 8th-highest 24-hour value represents the 98^{th}-percentile concentration. For compliance purposes, the $PM_{2.5}$ design concentration is the 3-year average of the highest, 8^{th}-highest (H8H) values in each year at any receptor location. The US EPA added special processing for $PM_{2.5}$ in the latest versions of AERMOD (versions 06341 and 07026) to predict the design concentrations for each receptor. AERMOD now calculates the N-year average H8H 24-hour average $PM_{2.5}$ concentration at each receptor over the N years of meteorological data provided. The U.S. EPA considers the five-year average of the H8H 24-hour $PM_{2.5}$ values at each receptor to be unbiased estimates of the 3-year average H8H values, since US EPA guidance requires the use of five years of meteorological data when the data are from an off-site National Weather Service meteorological station.[3] Thus, the five-year average H8H values from the AERMOD model are the design values used to establish compliance with the NAAQS.

[3] US EPA, "Addendum User's Guide for the AMS/EPA Regulatory Model – AERMOD (EPA-454/B-03-001, September 2004)", pp. 5 – 7, December 2006.

3.0 OWHH EMISSIONS AND STACK PARAMETERS

Particulate matter from a fuel combustion process contains a wide distribution of particle sizes. For wood combustion, these range from relatively larger carbon particles (soot) down to sub-micron organic compound aerosols. Research studies of OWHH emissions have used sampling methods that capture the full size distribution of PM, solid particles and condensible organics. EPA particle size distribution data for wood boilers reveal that typically 90% of the total PM mass has a diameter of 10 microns or less, and 76% has a diameter of 2.5 microns or less.[4] As a conservative assumption in this study, all PM emissions were assumed to be $PM_{2.5}$.

Air dispersion modeling assumed the OWHH was located a typical distance of 50 feet from a house having a 30-foot by 50-foot footprint. The OWHH building had dimensions of 5.4 feet by 5.8 feet and stood 6 feet high (a Central Boiler Model 6048). Four modeling cases were examined:

- Case 1: One-story house, 18-foot roof peak, 20-foot stack, PM = 60 g/hr
- Case 2: Two-story house, 33-foot roof peak, 35-foot stack, PM = 60 g/hr
- Case 3: One-story house, 18-foot roof peak, 20-foot stack, PM = 27 g/hr
- Case 4: Two-story house, 33-foot roof peak, 35-foot stack, PM = 27 g/hr

Central Boiler has recommended since 1996 that OWHH stacks be installed to a height two feet above the roof-line of the nearest structure. These chimney height installation instructions accompany every new Central Boiler OWB that is sold and are contained in the industry's Best Burn Practices guideline attached to this report.

The stack gas exit temperature and exit velocity used in this analysis represent typical values measured in Central Boiler's emissions test laboratory in Greenbush, Minnesota for the OWHHs. All stack and emission values used in this study are summarized in Table 1.

[4] EPA publication AP-42, Section 1.6.

TABLE 1

STACK PARAMETERS AND EMISSIONS FOR AIR DISPERSION MODELING

Parameter	English Units	Metric Units
Stack Height Case 1 Case 2	 20 feet 35 feet	 6.1 m 10.7 m
Stack Exit Diameter	8 inches	0.2 m
Stack Exit Velocity	7.2 feet/sec.	2.2 m/s
Stack Exit Temperature	350^{o} F	449.9^{o} K
$PM_{2.5}$ Emission Rate Existing OWHH Models Model Meeting EPA Phase 1 Limit	 0.13 lb/hr 0.06 lb/hr	 60.0 g/hr 27.1 g/hr

4.0 MODELING RESULTS

The air dispersion modeling results are summarized in Tables 3 and 4, and the model output is appended to this report. $PM_{2.5}$ contour maps are presented in four figures at the end of this section. All maximum predicted $PM_{2.5}$ concentrations are in compliance with the National Ambient Air Quality Standards (NAAQS) for all stack heights and emission rates.

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The modeling results are presented without background levels or an assumption as to where the OWHH is located. In general, if the OWHH is located in a rural area and has emissions of 60 g/hour, compliance with the $PM_{2.5}$ NAAQS will be achieved under Cases 1 and 2 where the homeowner installs a properly tall stack.

TABLE 3

24-HOUR $PM_{2.5}$ AIR MODELING RESULTS FOR CENTRAL BOILER MODEL 6048 WITH PM EMISSIONS OF 60 G/HR ($\mu g/m^3$)

	Case 1	Case 2
Roof Height (ft)	18	33
Stack Height (ft)	20	35
Assume All PM is $PM_{2.5}$		
5-Year Average of H8H	8.4	4.5
NAAQS	35.0	35.0

TABLE 4

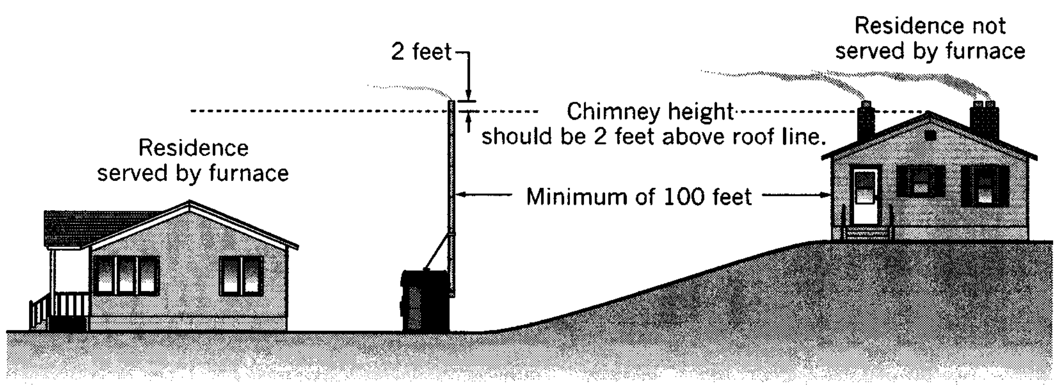
24-HOUR $PM_{2.5}$ AIR MODELING RESULTS FOR CENTRAL BOILER MODEL 6048 WITH PM EMISSIONS OF 27 G/HR ($\mu g/m^3$)

	Case 3	Case 4
Roof Height (ft)	18	33
Stack Height (ft)	20	35
Assume All PM is $PM_{2.5}$		
5-Year Average of H8H	3.8	2.0
NAAQS	35.0	35.0

OUTDOOR WOOD FURNACE BEST BURN PRACTICES

1. Read and follow all operating instructions supplied by the manufacturer.
2. FUEL USED: Only those listed fuels recommended by the manufacturer of your unit. Never use the following: trash, plastics, gasoline, rubber, naphtha, household garbage, material treated with petroleum products (particle board, railroad ties and pressure treated wood), leaves, paper products, and cardboard.
3. LOADING FUEL: For a more efficient burn, pay careful attention to loading times and amounts. Follow the manufacturer's written instructions for recommended loading times and amounts.
4. STARTERS: Do not use lighter fluids, gasoline, or chemicals.
5. LOCATION: It is recommended that the unit be located with due consideration to the prevailing wind direction.
   - Furnace should be located no less than 100 feet from any residence not served by the furnace.
   - If located within 100 feet to 300 feet to any residence not served by the furnace, it is recommended that the stack be at least 2 feet higher than the peak of that residence.

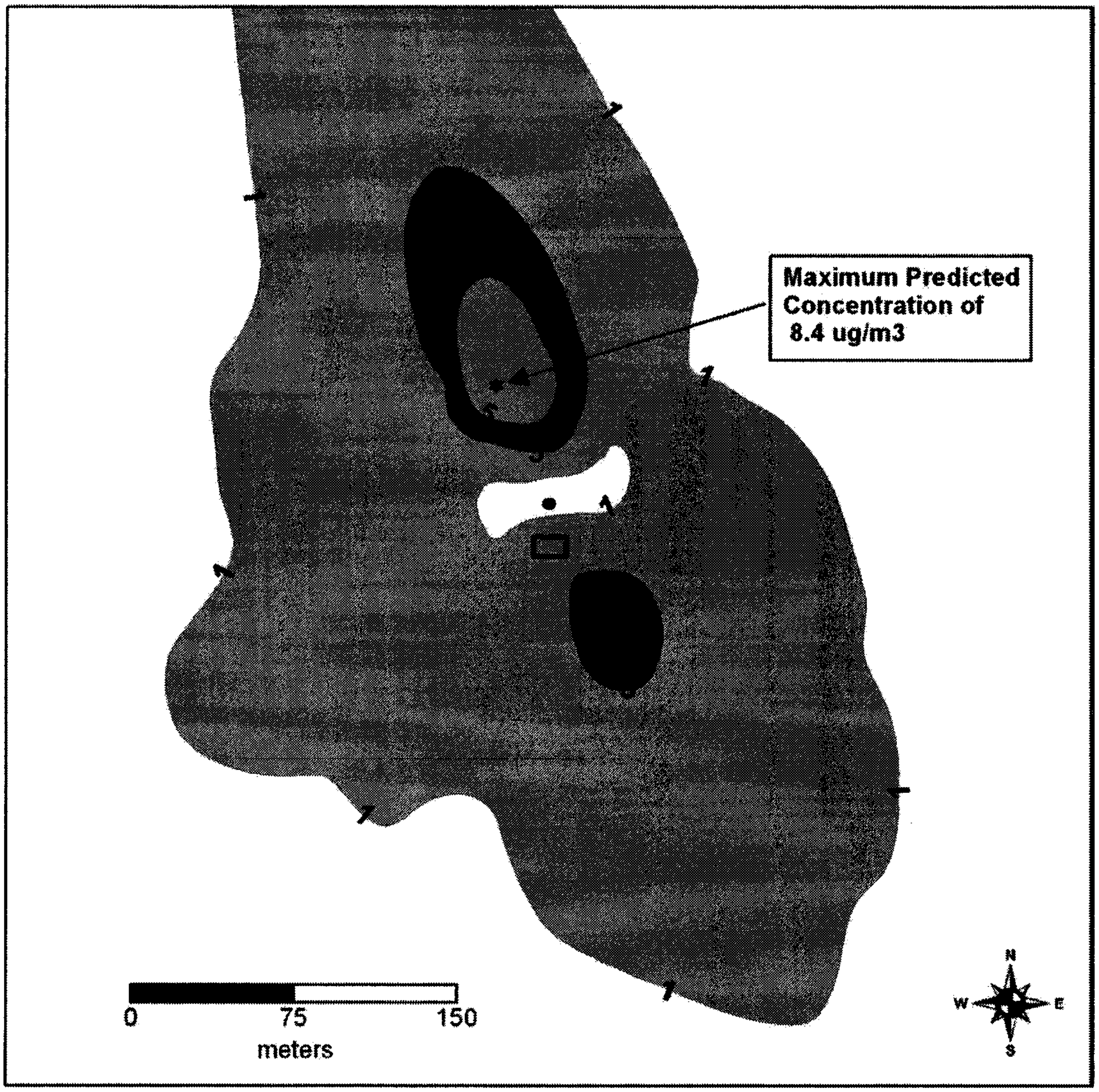
Chimney Height Installation Scenario



6. Always remember to comply with all applicable state and local codes.

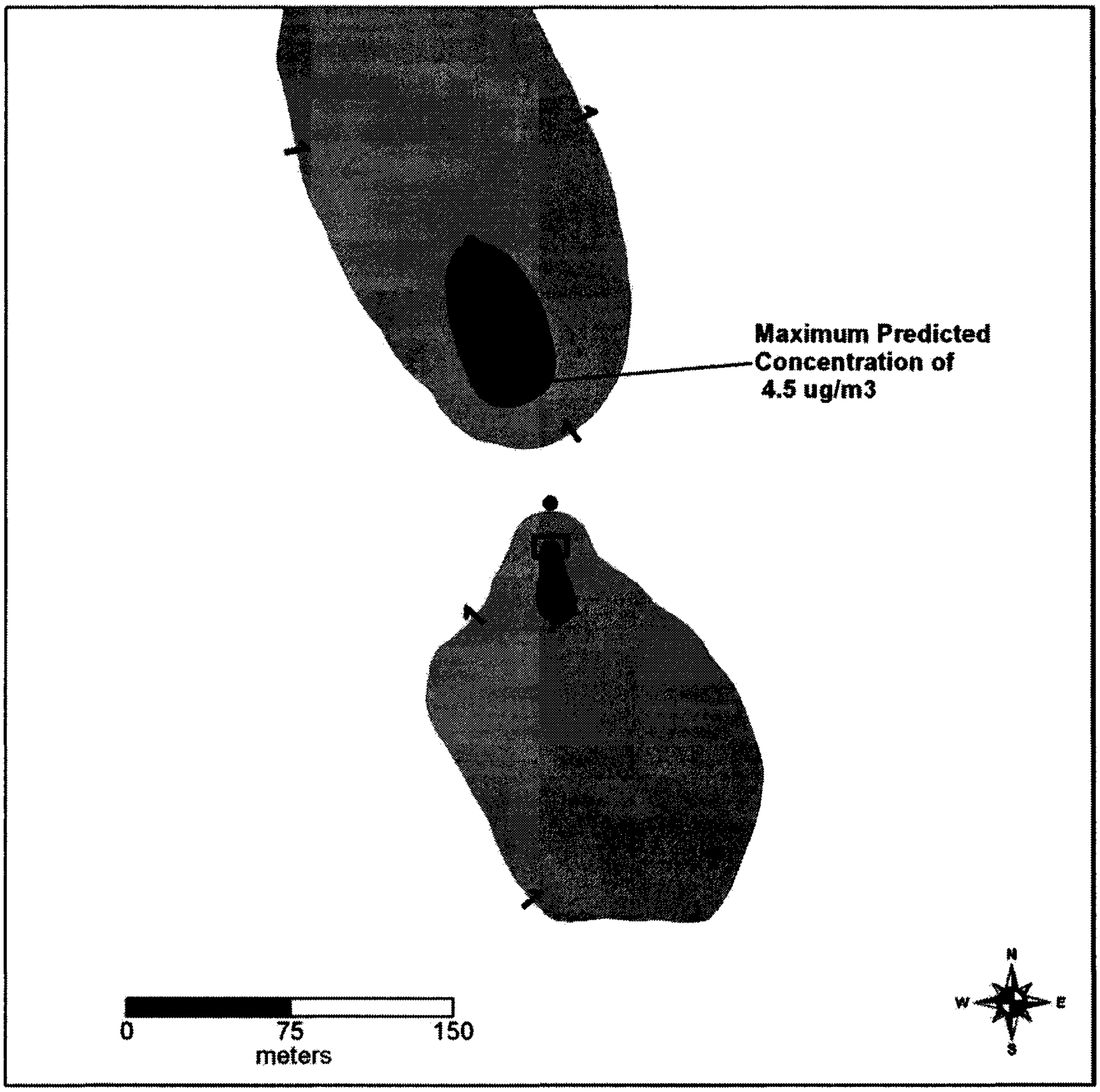
HPBA
Hearth, Patio & Barbecue Association

OUTDOOR FURNACE MANUFACTURERS CAUCUS



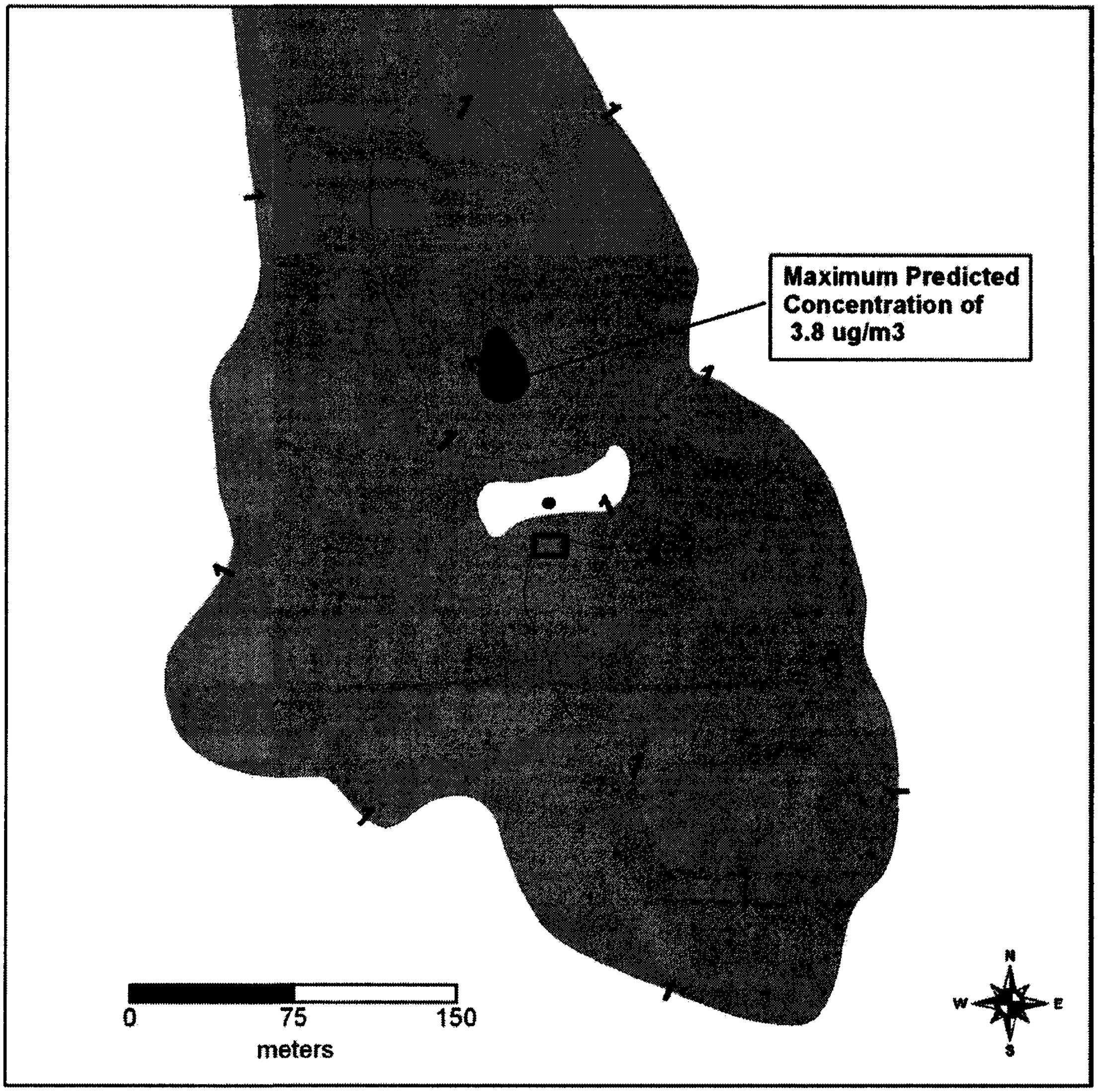
20-FOOT WOOD BOILER STACK (CASE 1)

Five-Year Average 24-Hour H8H Concentations for 60 grams/hour (ug/m3)



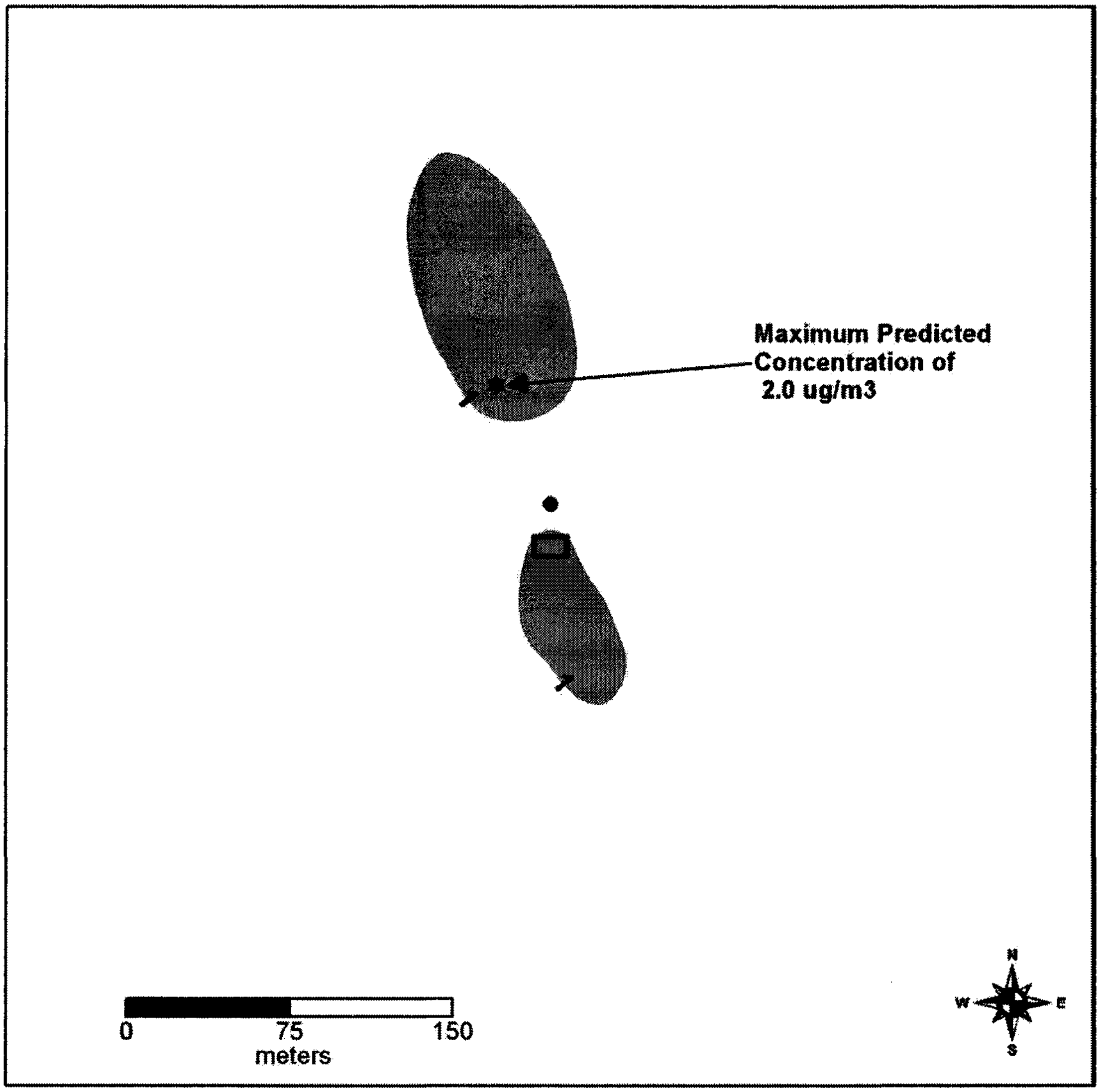
35-FOOT WOOD BOILER STACK (CASE 2)

Five-Year Average 24-Hour H8H Concentations for 60 grams/hour (ug/m3)



20-FOOT WOOD BOILER STACK (CASE 3)

Five-Year Average 24-Hour H8H Concentations for 27.1 grams/hour (ug/m3)



35-FOOT WOOD BOILER STACK (CASE 4)

Five-Year Average 24-Hour H8H Concentations for 27.1 grams/hour (ug/m3)

20-FOOT STACK WITH 18-FOOT BUILDING (CASE 1)
(60 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
*** RESIDENTIAL WOOD BOILER PM -  CASE 1                          ***
*** Model Executed on 04/10/07 at 12:54:50 ***
 Input File - W:\Apps\aermod\2618\April 2007\Case1_86_PM25.DTA

Output File - W:\Apps\aermod\2618\April 2007\Case1_86_PM25.LST

   Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

      Number of sources -          1
Number of source groups -          1
    Number of receptors -        441
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.16700E-01	0.0	19.8	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC		RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	8.42747	AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	6.90871	AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	5.44383	AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	5.00462	AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	4.31651	AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	4.26745	AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	4.16853	AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	4.15689	AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	4.09860	AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	3.81323	AT (	-50.00,	150.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH 33-FOOT BUILDING (CASE 2)
(60 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
 *** RESIDENTIAL WOOD BOILER PM -  CASE 2                          ***
 *** Model Executed on 04/10/07 at 12:51:43 ***
  Input File - W:\Apps\aermod\2618\April 2007\Case2_86_PM25.DTA

 Output File - W:\Apps\aermod\2618\April 2007\Case2_86_PM25.LST

   Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

      Number of sources -         1
 Number of source groups -         1
    Number of receptors -       441
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.16700E-01	0.0	19.8	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	4.48828 AT	(-25.00, 75.00, 0.00, 0.00, 0.00)	DC	
	2ND HIGHEST VALUE IS	4.39258 AT	(-25.00, 100.00, 0.00, 0.00, 0.00)	DC	
	3RD HIGHEST VALUE IS	3.61820 AT	(0.00, -25.00, 0.00, 0.00, 0.00)	DC	
	4TH HIGHEST VALUE IS	3.61481 AT	(0.00, 0.00, 0.00, 0.00, 0.00)	DC	
	5TH HIGHEST VALUE IS	3.48059 AT	(-25.00, 125.00, 0.00, 0.00, 0.00)	DC	
	6TH HIGHEST VALUE IS	3.04284 AT	(0.00, 75.00, 0.00, 0.00, 0.00)	DC	
	7TH HIGHEST VALUE IS	2.95700 AT	(-50.00, 125.00, 0.00, 0.00, 0.00)	DC	
	8TH HIGHEST VALUE IS	2.94544 AT	(0.00, 100.00, 0.00, 0.00, 0.00)	DC	
	9TH HIGHEST VALUE IS	2.76617 AT	(-50.00, 150.00, 0.00, 0.00, 0.00)	DC	
	10TH HIGHEST VALUE IS	2.70425 AT	(-25.00, 150.00, 0.00, 0.00, 0.00)	DC	

20-FOOT STACK WITH 18-FOOT BUILDING (CASE 3)
(27.1 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
*** RESIDENTIAL WOOD BOILER PM -  CASE 3                                    ***
*** Model Executed on 04/10/07 at 12:48:13 ***
 Input File - W:\Apps\aermod\2618\April 2007\Case3_86_PM25.DTA

Output File - W:\Apps\aermod\2618\April 2007\Case3_86_PM25.LST

   Met File - W:\Apps\aermod\2618\metdata\Burl86-90.sfc

      Number of sources -          1
Number of source groups -          1
    Number of receptors -        441
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.75300E-02	0.0	19.8	0.0	6.10	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER   5 YEARS ***

** CONC OF PM25   IN MICROGRAMS/M**3   **

GROUP ID		AVERAGE CONC		RECEPTOR (XR,	YR,	ZELEV,	ZHILL,	ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	3.79993	AT (	-25.00,	75.00,	0.00,	0.00,	0.00)	DC	
	2ND HIGHEST VALUE IS	3.11512	AT (	-25.00,	100.00,	0.00,	0.00,	0.00)	DC	
	3RD HIGHEST VALUE IS	2.45461	AT (	0.00,	75.00,	0.00,	0.00,	0.00)	DC	
	4TH HIGHEST VALUE IS	2.25657	AT (	-25.00,	125.00,	0.00,	0.00,	0.00)	DC	
	5TH HIGHEST VALUE IS	1.94631	AT (	-50.00,	125.00,	0.00,	0.00,	0.00)	DC	
	6TH HIGHEST VALUE IS	1.92419	AT (	0.00,	50.00,	0.00,	0.00,	0.00)	DC	
	7TH HIGHEST VALUE IS	1.87958	AT (	0.00,	100.00,	0.00,	0.00,	0.00)	DC	
	8TH HIGHEST VALUE IS	1.87434	AT (	-50.00,	100.00,	0.00,	0.00,	0.00)	DC	
	9TH HIGHEST VALUE IS	1.84805	AT (	25.00,	-25.00,	0.00,	0.00,	0.00)	DC	
	10TH HIGHEST VALUE IS	1.71938	AT (	-50.00,	150.00,	0.00,	0.00,	0.00)	DC	

35-FOOT STACK WITH 33-FOOT BUILDING (CASE 4)
(27.1 GRAMS/HOUR)

```
*** AERMOD - VERSION 07026 ***
*** RESIDENTIAL WOOD BOILER PM -  CASE 4                              ***
*** Model Executed on 04/10/07 at 12:39:31 ***
 Input File - W:\Apps\aermod\2618\April 2007\Case4_86_PM25.DTA

Output File - W:\Apps\aermod\2618\April 2007\Case4_86_PM25.LST

   Met File - W:\Apps\aermod\2618\metdata\Bur186-90.sfc

      Number of sources -          1
Number of source groups -          1
    Number of receptors -        441
```

*** POINT SOURCE DATA ***

SOURCE ID	NUMBER PART. CATS.	EMISSION RATE (GRAMS/SEC)	X (METERS)	Y (METERS)	BASE ELEV. (METERS)	STACK HEIGHT (METERS)	STACK TEMP. (DEG.K)	STACK EXIT VEL. (M/SEC)	STACK DIAMETER (METERS)	BLDG EXISTS	URBAN SOURCE	CAP/ HOR	EMIS RATE SCALAR VARY BY
BOILER	0	0.75300E-02	0.0	19.8	0.0	10.67	449.90	2.20	0.20	YES	NO	NO	

*** SOURCE IDs DEFINING SOURCE GROUPS ***

GROUP ID	SOURCE IDs
ALL	BOILER ,

*** THE SUMMARY OF MAXIMUM 8TH-HIGHEST 24-HR RESULTS AVERAGED OVER 5 YEARS ***

** CONC OF PM25 IN MICROGRAMS/M**3 **

GROUP ID		AVERAGE CONC	RECEPTOR (XR, YR, ZELEV, ZHILL, ZFLAG)	OF TYPE	NETWORK GRID-ID
ALL	1ST HIGHEST VALUE IS	2.02376 AT (	-25.00, 75.00, 0.00, 0.00, 0.00)	DC	
	2ND HIGHEST VALUE IS	1.98060 AT (	-25.00, 100.00, 0.00, 0.00, 0.00)	DC	
	3RD HIGHEST VALUE IS	1.63144 AT (	0.00, -25.00, 0.00, 0.00, 0.00)	DC	
	4TH HIGHEST VALUE IS	1.62991 AT (	0.00, 0.00, 0.00, 0.00, 0.00)	DC	
	5TH HIGHEST VALUE IS	1.56939 AT (	-25.00, 125.00, 0.00, 0.00, 0.00)	DC	
	6TH HIGHEST VALUE IS	1.37201 AT (	0.00, 75.00, 0.00, 0.00, 0.00)	DC	
	7TH HIGHEST VALUE IS	1.33330 AT (	-50.00, 125.00, 0.00, 0.00, 0.00)	DC	
	8TH HIGHEST VALUE IS	1.32809 AT (	0.00, 100.00, 0.00, 0.00, 0.00)	DC	
	9TH HIGHEST VALUE IS	1.24726 AT (	-50.00, 150.00, 0.00, 0.00, 0.00)	DC	
	10TH HIGHEST VALUE IS	1.21934 AT (	-25.00, 150.00, 0.00, 0.00, 0.00)	DC	

RTP ENVIRONMENTAL ASSOCIATES, INC.®

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Memorandum

To: Jack Goldman and Allan Cagnoli, Hearth Patio & Barbecue Association

From: David Keen, RTP Environmental

Date: January 4, 2008

Subject: Response to EPA's Letter of December 14, 2007

A. BACKGROUND

RTP Environmental has reviewed the December 14, 2007 letter from Greg Green of EPA to Jack Goldman of the Hearth, Patio & Barbecue Association (HPBA). This letter was written in response to our review of the January 26, 2007 NYSDEC modeling study supporting the NESCAUM model rule for outdoor wood-fired hydronic heaters (OWHH). We address three issues raised in EPA's December 14th letter: 1) that our modeling failed to address adjustments to stack gas exit temperature and velocity at taller stack heights, 2) the assertion that EPA dispersion modeling guidance dictates use of potential hourly emissions when estimating short-term impacts, and 3) EPA's concern about impacts in complex terrain.

B. OWHH MODELED VELOCITY AND TEMPERATURE

The stack gas temperature, exit velocity, and diameter employed in the modeling were identical to as those used by the NYSDEC in their modeling study. As stated in our review of the NESCAUM modeling, the stack gas exit temperature and flow rate modeled by the NYSDEC are not typical of the majority of OWBs. A more typical stack gas exit temperature is 350F, while a more typical gas exit velocity is 6.5 ft/sec with an 8" diameter stack. However, since we determined that the NYSDEC modeled parameters did little to influence concentrations when compared to more typical values and that building downwash has a much greater influence on maximum modeled concentrations, we intentionally did not alter these parameters in efforts to mimic the NYSDEC study (see the August 21, 2007 letter, page 5 footnote). The maximum difference in modeled concentrations between a typical Phase I compliant OWHH (like the one modeled by RTP Environmental) and an OWHH modeled with the NYSDEC gas release parameters was determined to be 1.8 $\mu g/m^3$. Therefore, only the stack height and modeled emissions were changed from what was modeled by the NYSDEC. It should be noted that the modeled concentrations could be less for units that need not comply with the Phase I model rule which have gas exit temperatures and velocities greater than those modeled by either RTP or the NYSDEC.

In our modeling study of OWHH PM2.5 impacts, we evaluated two stack heights: 1) a 22 foot stack adjacent to a 20 foot structure, and 2) a 35 foot stack adjacent to a 33 foot structure. The modeled scenarios were designed to represent typical stack/structure relationships that would exist with an OWHH stack built according to manufacturer recommendations. NYSDEC's model also employed two different stack heights (a 10 foot stack and an 18 foot stack). The NYSDEC also did not adjust gas temperature or velocity based upon stack height. We find the lack of adjustment appropriate as the overwhelming majority of Phase I OWHHs are expected to be forced draft units and the velocity would not decrease at increased stack heights. Moreover, the stack gas flow rate of an OWHH (whether it be an induced draft or natural draft unit) would increase with any increase in stack height because the taller stack would decrease backpressure and increase the firebox vacuum. Increase in stack height would therefore result in an increase, not decrease in velocity. In addition, the stack temperature modeled (294F) is less than the temperature anticipated from a typical OWHH, even one with a 40 foot stack. The OWHH stack temperature would therefore not be less than the temperature modeled even at a stack height nearly doubled that modeled.

For these reasons, we therefore disagree with EPA's contention that there was an oversight in our modeling, that the temperature or velocity will change at taller stack heights, or - assuming they would change - that the change would significantly influence the results.

C. MODELED EMISSION RATES

C.1. Emission Rates Modeled by NYSDEC and RTP Environmental

In calculating the Model Rule Phase 1 mass emission rates input to the model, the NYSDEC used the NESCAUM Model Rule Phase 1 emission standard of 0.44 lb PM/MMBtu heat input. This emission standard was converted to a maximum lb $PM_{2.5}$/hr emission rate and an average lb/hr emission rate using heater heat input rates of 350,000 and 215,000 Btu/hr, respectively. The resultant mass emission rates of 70 and 43 g/hr were input to the model and used to assess ambient impacts.

In our review, we questioned the validity of these hourly emission rates for assessing compliance with the 24-hour PM2.5 National Ambient Air Quality Standard (NAAQS). We stated that the modeled emission rates were not appropriate for assessing compliance with the 24-hour PM2.5 NAAQS for two reasons. Primarily, the NYSDEC modeled emission rates were in excess of the potential to emit of an OWHH in a 24-hour period because they did not adequately account for the fact that these units cycle based upon heat demand and, with a resultant inherent variability in potential emissions over the course of a 24-hour period. Secondly, the NYSDEC employed a heat input value in calculating its hourly emission rates that was in excess of even the largest residential OWHH.

We recommended the use of the weighted average approach used in EPA Method 28 OWHH to reflect the potential to emit over a 24-hour period. Our approach is consistent with the averaging time of the underlying standard (i.e., the 24-hour NAAQS), and appropriately uses the weighting scheme in Method 28 OWHH (that, ironically, was developed by NYSDEC) to characterize the average emission rate of the appliance during its operating cycle. Since actual data on EPA Phase I units was not available, we used an algorithm developed by the HPBA to derive our modeled emissions. The range of emissions derived from the algorithm was 21 to 39 g/hr. Our high end modeled emission rate of 39 g/hr is therefore consistent with the low end emission rate of 43 g/hr modeled by the NYSDEC. However, the high end of the estimated NYSDEC emission range is not representative of the true potential to emit of an EPA Phase I unit over the course of a 24-hour period.

C.2. Averaging Time for Modeled Emission Rates

In the December 14, 2007 letter, EPA states, "EPA dispersion modeling guidance dictates that modelers should use the maximum potential hourly emission rates when estimating short-term air quality impacts." RTP Environmental has reviewed EPA modeling guidance, policy, and practice and does not agree with this statement in the December 14, 2007 letter.

EPA Modeling Guidance

EPA modeling guidance does not support the claim in the December 14, 2007 letter. While we are not certain what guidance EPA is referring in its letter, the most widely used modeling guidance is contained in the Draft 1990 New Source Review Workshop Manual.

Page C.45 of the Workshop Manual discusses the recommended method for calculating short term emissions for modeling input. The methodology follows that specified in EPA regulations (please see Table 8-1 of Appendix W to 40 CFR Part 51, EPA's "Guideline on Air Quality Models"). The guidance is to multiply the source emission limit (expressed in terms of lb/MMBtu), the operating level (MMBtu/hr), and the operating factor (e.g., hr/day) to derive the modeled emission rate via the following formula:

(lb/MMBtu) x (MMBtu/hr) x (hr/day) = lb/day

Nothing in the Workshop Manual or Appendix W stipulates that a maximum potential hourly emission rate must be employed when assessing compliance with a longer term (i.e., 24-hr) standard. Instead, the Workshop Manual states that the modeled emission rate must "reflect the maximum allowable operating conditions as expressed by the federally enforceable emission limit, operating level, and operating factor for each applicable pollutant and averaging time" (Please see page C.45 of the 1990 Draft New Source Review Workshop Manual). Furthermore, the Guidance states that an adjustment to the modeled emission rate may be made if the operation does not occur for all hours of the time period of consideration (e.g., 3 or 24 hours) and if the source operation is constrained by a federally enforceable permit condition (as is evident from the equation above which contains the hr/day multiplier). Therefore, as evident from both Appendix W and the NSR Workshop Manual, EPA clearly intends for emissions to be expressed over periods of greater than 1-hour when a source does not have the capability to emit continuously at a particular rate over the time period modeled (as is the case with an OWHH).

Even the NYSDEC in their modeling attempted to model an emission rate other than the maximum hourly emission rate anticipated from an OWHH. The NYSDEC used the NESCAUM Model Rule Phase I weighted **average** limit of 0.44 lb/MMBtu in development of emission rates input to its model. However, this average emission limit was used in conjunction with the maximum hourly heat input of the unit which fails to consider that the maximum heat input is not attainable for the full 24-hour period due to the inherent limitations discussed above. In addition, it is clear from NYSDEC's study that they were modeling what they believed to be an average mode of OWHH operation in evaluating compliance with the 24-hour PM2.5 NAAQS,

> "It was found that the units generally spend about 25% of the time in burn mode with the dampers open, and about 75% of the time in standby mode, with the dampers closed. ...These values were then weighed averaged for use in the modeling..."

Other EPA guidance also clearly states that the averaging time of the modeled emissions and resultant emission limitation be consistent with the averaging time of the underlying NAAQS or increment. See, for example, the December 12, 1998 EPA letter from Richard Long, Director of the Air and Radiation Program, to Dave Ouimette, Colorado Air Pollution Control Division, which states,

> "In EPA's view, the target source must be modeled at its maximum potential to emit over the short-term averaging time(s) associated with the NAAQS and increments."

The potential to emit of an OWHH is limited over the course of a 24-hour period due to the inherent operation of the process. The PM2.5 NAAQS in question is expressed on a 24-hour average. Based upon EPA policy and practice, the source must be modeled at its potential to emit over the averaging time associated with the NAAQS. It is therefore not appropriate for EPA to require that an OWHH be modeled at a rate in excess of its potential to emit over the course of a 24-hour period in demonstrating compliance with the 24-hour NAAQS.

EPA Modeling Practice

In reviewing ambient air quality impact analyses submitted in support of PSD permit applications for major stationary sources, EPA's practice is to model short-term emission rates that are numerically equivalent to enforceable emission limits, provided that the emission limit has an averaging time equal to or shorter than the ambient standard.

As one example, EPA Region 8 recently issued the PSD permit for the Bonanza power plant in Utah. The modeled SO_2 and PM-10 emission rates used to demonstrate compliance with the short-term NAAQS were as follows:

- 110 g/s (equal to 872 lbs/hr) for the 3-hr SO_2 NAAQS
- 25.46 g/s (equal to 201.9 lbs/hr) for the 24-hr SO_2 NAAQS
- 9.47 g/s (equal to 75.4 lbs/hr) for the 24-hr PM10 NAAQS

Not coincidentally, the enforceable emission limits in the permit are as follows:

1. 872 pounds per hour of sulfur dioxide, averaged over a 3-hour block period.
2. 202 pounds per hour of sulfur dioxide, averaged over a 24-hour block period.
3. 75.4 pounds per hour of total PM10 (filterable plus condensible), averaged over a 24-hour block period.

Clearly, the PSD permit issued by EPA Region 8 would allow the Bonanza plant emit at a rate much higher than 75.4 lbs PM10/hr for one hour, provided that its emission rate was sufficiently less than 75.4 lbs/hr for the remaining 23 hours in the day, such that its daily emissions are no more than 1,810 pounds per 24-hour block period. As is clearly shown in the administrative record for the Bonanza PSD permit, those higher rates are not reflected in EPA's ambient air quality impacts analysis. Instead, EPA appropriately modeled the maximum potential 24-hour average PM10 emission rate when determining compliance with the 24-hour PM10 NAAQS. Likewise, EPA modeled the maximum potential 3-hr average SO_2 emission rate when determining compliance with the 3-hr SO_2 NAAQS and the maximum potential 24-hr average SO_2 emission rate when determining compliance with the 24-hr SO_2 NAAQS. In our experience performing PSD permitting and associated air quality impacts analyses, EPA's procedures in the Bonanza permitting action are consistent with EPA's long-standing practice.

C.3. Demonstration of Ambient Impacts from Higher Emission Rates
As has been demonstrated by both the RTP and NYSDEC modeling, ground level impacts from OWHHs are most sensitive to stack height relative to adjacent structure height. Therefore, even if the unrealistic NYSDEC emissions were modeled, NAAQS compliance can be demonstrated by increasing stack height.

RTP conducted additional modeling which demonstrates NAAQS compliance at the upper range of the NYSDEC modeled emissions (70 g/hr) with a stack constructed at least two feet above roofline (per manufacturer recommendations). The gas release parameters modeled by the NYSDEC were assumed as was the stack placement relative to the structure. The most recent 3-year Syracuse dataset was modeled (1990-1992) with the receptor grid employed by the NYSDEC. Two stack/structure heights were evaluated: 1) a 22 foot stack adjacent to a 20 foot single story house, and 2) a 35 foot stack adjacent to a 33 foot two story house (or barn). The 3-year average of the highest 8^{th} high values were determined to be 25.6 and 11.3 $\mu g/m^3$ for the 22 and 35 foot stacks, respectively.

D. COMPLEX TERRAIN IMPACTS

In its December 14, 2007 letter, EPA presents an additional element of concern that it states was not fully addressed by either NYSDEC or RTP Environmental. The concern pertains to impacts in complex terrain during periods of valley channeling or stagnation, each of which could lead to higher concentrations. EPA indicates that a non-steady-state puff model may be a more appropriate model for evaluating impacts under such conditions.

The NYSDEC conducted limited modeling in complex terrain and concluded that impacts in complex terrain are comparable to those with structure downwash effects. NYSDEC also concluded that valley stagnation effects could lead to accumulation of concentration, but that scenario could not be simulated with AERMOD. Based upon its modeling, NYSDEC concluded that the downwash results were a good representation of worst-case 24-hour impacts in complex terrain for single source simulations.

RTP agrees with NYSDEC's conclusions. The maximum concentrations from the single source simulations were found to be controlled by downwash. The elevated downwash impacts are a good representation of impacts likely expected at more distant complex terrain locations. Therefore, emission limitations based upon the downwash controlled impacts should generally be protective of impacts in complex terrain.