AERMOD BEYOND THE BOX

HOW BETTER INPUTS CAN GIVE YOU BETTER RESULTS

INTRODUCTION

AERMOD is known to calculate exhaust concentrations, in certain situations, that are less accurate and worse than they really are. Because AERMOD's underlying equations were developed for solid rectangular buildings having certain sizes and shapes, the model can overestimate pollutant concentrations by a factor of 4 or more when user inputs don't fall within the ranges for which the equations were optimized.

An Equivalent Building Dimension (EBD) approach models a real building, or groups of buildings and structures, as an equivalent building that has the same airflow and dispersion patterns as the real thing, but with dimensions that fall within AERMOD's optimal input ranges. A wind tunnel study offers a fast and convenient way to determine the equivalent building dimensions and lets users justify more accurate and frequently lower concentration levels than AERMOD might otherwise indicate.

BACKGROUND INFORMATION

AERMOD is a software tool developed by the American Meteorological Society (AMS)/Environmental Protection Agency (EPA) Regulatory Model Improvement Committee (AERMIC). It is the EPA's preferred regulatory tool for modeling pollutant dispersion. The software package includes three components of relevance to this discussion.

1. The AERMOD modeling system itself includes the underlying mathematical models, a meteorological pre-processor, and a terrain pre-processor.
2. The Plume Rise Model Enhancements (PRIME) package models downwash effects that occur when a plume flows over nearby buildings and structures.
3. The Building Profile Input Program (BPIP) aids users in transforming site plans and building heights into the input formats required by AERMOD.

AERMOD's internal equations were developed and tested using only a specific range of building dimensions. If we refer to a building's length, width, and height as L, W, and H, respectively, then AERMOD's range of applicability based on Schulman, Strimatis and Scire (2000) is generally limited to box-shaped buildings having the following dimensions:

$W = L \text{ and } 0.33 \leq \frac{W}{H} \leq 1$	$W = H \text{ and } 0 < \frac{L}{H} \leq 4$
A building that is taller than it is wide, but no more than three times as tall as it is wide	A building that is up to four times as long as it is tall

AERMOD is frequently used for buildings and structures that fall outside this range, but the further one strays from these bounds, the more likely it is that AERMOD will produce inaccurate results.

BPIP PROBLEMS

Building dimension inputs for AERMOD are developed using the Building Profile Input Program (BPIP). Building plan dimensions and building tier heights are input into BPIP and the program uses various logical assumptions from past research to specify a single *L*-*W*-*H* and building location for each of 36 wind directions. In these calculations, BPIP assumes lattice/porous and streamlined structures are rectangular solids. In addition, BPIP will often merge separate buildings into one larger building, and may overestimate the effective building height by using the tallest tier. The net result is that in some situations BPIP will generate building dimension inputs that do not fit the theory in AERMOD.

RESULTING AERMOD SHORTCOMINGS

AERMOD is known to calculate pollutant concentration results that are less accurate and often worse than is seen in reality for certain kinds of buildings and structures. Situations that are likely to cause such problems include the following.

- Complicated site configurations
- A short building that is very wide and/or long (warehouses and distributions centers, for example)
- Porous structures like lattices
- Cylindrical or streamlined structures
- Nearby terrain features (Note: AERMOD concentration estimates will likely be higher for this case)

THE EQUIVALENT BUILDING DIMENSION APPROACH

A simple and highly effective way to improve AERMOD's performance for these kinds of situations is by finding Equivalent Building Dimensions (EBDs). While we expect that numerical methods may one day present attractive alternatives to determine these dimensions, wind tunnel modeling currently offers the best available science.

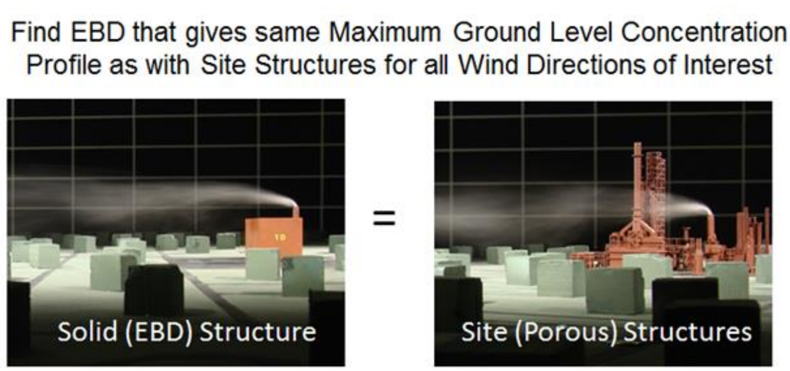

Figure 1: EBD approach for a porous lattice structure

Determining these EBDs using a wind tunnel approach involves the following sequence.

1. Using a scale model of the real buildings, surroundings, and terrain, we quantify and characterize dispersion behavior for wind approaching from all directions.

2. The scale models are replaced by a simple rectangular building, matching AERMOD theory, that is moved to various locations near the pollution source (stack).
3. The building geometry and position are adjusted until the dispersion behavior at ground level matches that observed for the scale model of the actual site.

Figure 1 illustrates how this approach is used for a porous lattice structure.

AN EXAMPLE

To demonstrate how effectively an EBD approach can increase accuracy while reducing predicted pollutant concentrations, consider the building depicted in Figure 2 below. The building was modeled using three approaches

1. Standard BPIP-generated dimensions
2. Conservative estimates of EBDs based upon our past experience
3. Detailed EBD measurements from wind tunnel modeling

Each of the three approaches yields different values of L, W, and H, and each approach yields different pollutant concentrations due to a 1 gram/second emission rate from the stack indicated in red. As shown in the table, the default BPIP inputs lead to concentrations that are as much as three or more times greater than what is found using dimensions based upon a wind tunnel study.

AERMOD Building Dimension Inputs	AERMOD Maximum predicted concentration (µg/m^3) 1-hour	24-hour	annual
BPIP	15.19	8.20	0.89
Screening EBD Values	9.68	5.05	0.19
EBD values from wind tunnel study	3.99	1.88	0.18

Figure 2: EBD as applied to a large building

REGULATORY STATUS OF THE EBD APPROACH

The EPA has approved the use of the Equivalent Building Dimension approach for many cases, and EBD methods enjoy more than two decades of successful application. A brief history of the regulatory approval status of the approach follows.

1994 MODEL CLEARINGHOUSE MEMORANDUM

A 1994 EPA Model Clearinghouse memorandum, which influenced the EPA's approval of EBD as a useful and reliable method, reached the following conclusions (Tikvart 1994):

- Wind tunnel investigations to determine EBDs are source characterization studies, not replacements for ambient air quality analyses using preferred air quality models. EBD methods therefore do not need to follow alternative model requirements.
- EBD studies can be used to develop appropriate direction-dependent "equivalent building dimensions" for inputs into AERMOD (then ISC2), and a technically sound wind tunnel study is a reasonable approach for deriving those inputs.

This memorandum is generally accepted as having established the precedent for EBD's acceptance.

2011 MODEL CLEARINGHOUSE MEMORANDUM

A 2011 EPA Model Clearinghouse memorandum (Bridgers 2011) concerns the first and only EBD-based study that the EPA has ever disapproved. The study was conducted for the Alcoa Davenport Works facility in Davenport, Iowa, and the memo cites several reasons why approval was not granted, including the positioning of the EBD buildings in the wind tunnel and the sizes of the roughness elements used to simulate atmospheric turbulence effects. These criticisms were concerned with the methods used to carry out the wind tunnel test and not a judgment on the approach itself.

The 2011 memo retroactively suspended all pre-2011 EPA guidance regarding the EBD approach but did *not* retract the endorsement of the method. In fact, the memo reasserts the EPA's position on the EBD method and

- Acknowledges and restates a fundamental conclusion of the 1994 memo, that a wind tunnel-based EBD study amounts to a "source characterization study."
- Implies the EPA's continued support of the EBD approach, noting, "This [suspension of guidelines] *should not be taken to imply that all such studies will be summarily rejected.*" [emphasis added]
- Leaves open the opportunity to continue using the EBD approach, saying, "Any EBD studies being considered should be discussed with the appropriate reviewing authority as early in the process as possible and that the Model Clearinghouse should also be engaged as early as possible."

This memo retracted the EPA's prior *guidance* on how to conduct EBD determination studies in the wind tunnel but retained the agency's general *support* of such methods.

CURRENT STATUS

The EPA is currently investigating how to re-establish its guidelines for conducting EBD studies. However, the agency's support for the method remains strong.

At the 2012 EPA Regional/State/Local Modelers Workshop in Chicago, Roger Brode of the EPA states, "Use of wind tunnel derived 'equivalent building dimensions' (EBDs) needs to be reviewed and perhaps standard procedures and/or guidance developed on their use in regulatory modeling" (Brode 2012).

More recently, Steve Perry of the EPA recommended in a recent email that the Air & Waste Management Association (AWMA) Atmospheric Modeling and Meteorology (formerly AB-3) Committee provide recommendations to the EPA's Office of Air Quality Planning and Standards (OAQPS) on how to perform future EBD studies. Indeed, the AWMA Committee plans to suggest this option at the 2014 EPA Regional/State/Local Modelers Workshop held in Salt Lake City.

CONCLUSION

The Equivalent Building Dimension approach offers an attractive way to more accurately calculate pollutant concentrations in the presence of large or unusual buildings, terrain features, and complex sites. The EBD results are frequently lower than what standard methods would predict, and this improvement in accuracy could easily represent the difference between passing and failing regulatory requirements.

CPP has a proven track record of delivering EBD-based results that meet EPA requirements. To discover how our wind tunnel services can help make your next project a success, please call our office in Fort Collins, Colorado, at +1 970 221 3371, or email us at info@cppwind.com.

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Bridgers, George. *Model Clearinghouse Review of Equivalent Building Dimensions for AERMOD.* Research Triangle Park, NC: United States Environmental Protection Agency, October 24, 2011.

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