10th Conference on Air Quality Modeling
A&WMA AB-3 Committee
Use of Equivalent Building Dimensions (EBDs) in AERMOD

Presented by
Ron Petersen, Ph.D., CCM
CPP Inc.
1415 Blue Spruce Drive
Fort Collins CO 80524
970 221 3371
rpetersen@cppwind.com

Air & Waste Management Association
Air Pollution Meteorology (AB-3) Committee

Outline

- Background
- Current Status – EPA Clearinghouse Memo
- Cases where BPIP Input will not Work
- Review of EPA Evaluation of Past EBD Study
- Path Forward

Background

- Equivalent Building Dimensions” (EBDs) are the dimensions (height, width, length and location) that are input into AERMOD (or ISC) in place of BPIP dimensions to more accurately predict building wake effects
- Guidance originally developed when ISC was the preferred model –
  – EPA, 1994. Wind Tunnel Modeling Demonstration to Determine Equivalent Building Dimensions for the Cape Industries Facility, Wilmington, North Carolina. **Joseph A. Tikvart Memorandum, dated July 25, 1994.** U.S. Environmental Protection Agency, Research Triangle Park, NC
- Original guidance developed collaboratively

Background (Continued)

- Several studies conducted and approved using original guidance for ISC applications
  - **Amoco Whiting Refinery**
  - **Public Service Electric & Gas**
  - **Cape Industries**
  - **Cambridge Electric Plant**
  - **District Energy**
  - **Celco Plant**
- Some studies conducted using original guidance for AERMOD/PRIME applications (some approved and some not)
  - Mirant Power Station (Approved)
  - Hawaiian Electric
  - Sunlaw Energy
  - Alcoa (Not Approved)

Current Status

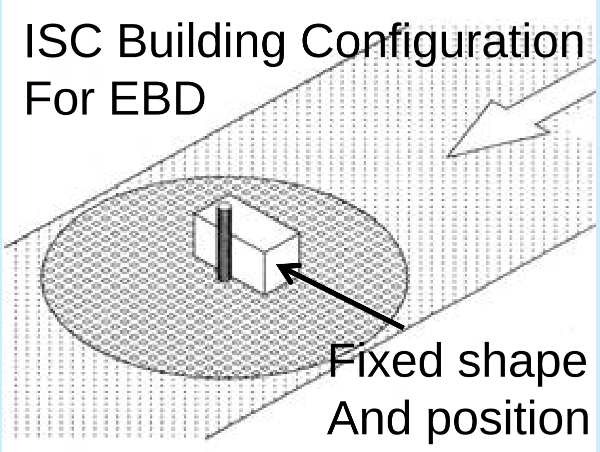
October 24, 2011 Model Clearinghouse Review of EBD for AERMOD

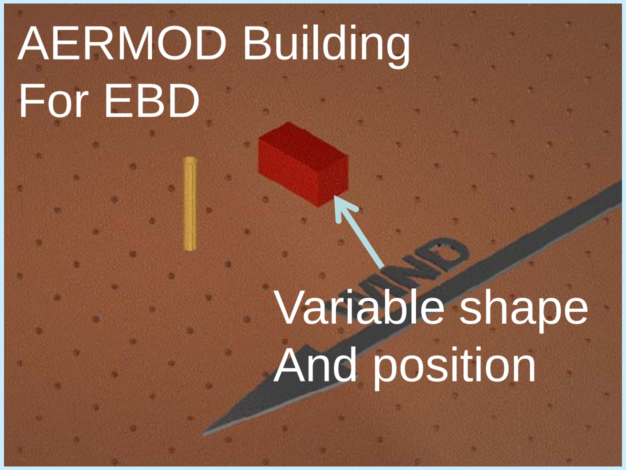
- “All past EPA guidance related to determined EBDs through wind tunnel modeling is hereby suspended until further notice” – Alcoa study disapproved.
- Many in industry have interpreted this to mean that EBD can not be used – they did not read on.
- “this should not be taken to imply that all such studies will be summarily rejected…”
- “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.”
- Original 1994 memo acknowledged the evolving nature of the guidance
- Does not change the assessment of these wind tunnel EBD studies as source characterization studies

Current Status (Continued)

October 24, 2011 Model Clearinghouse Review of EBD for AERMOD

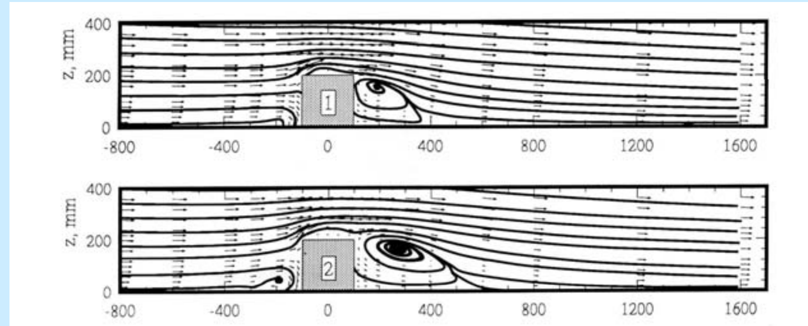
- Problem areas identified
  - High roughness used during the EBD testing to simulate roughness of facility.
  - Different downwash algorithm in PRIME versus ISC, can now account for building position.

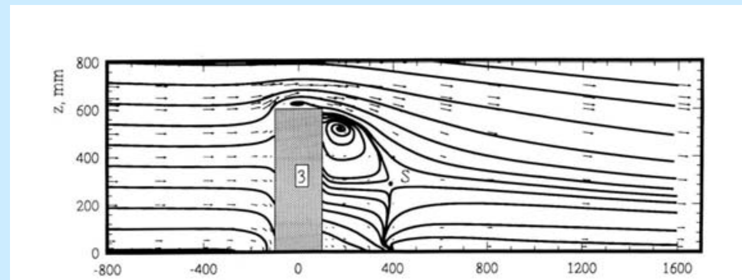


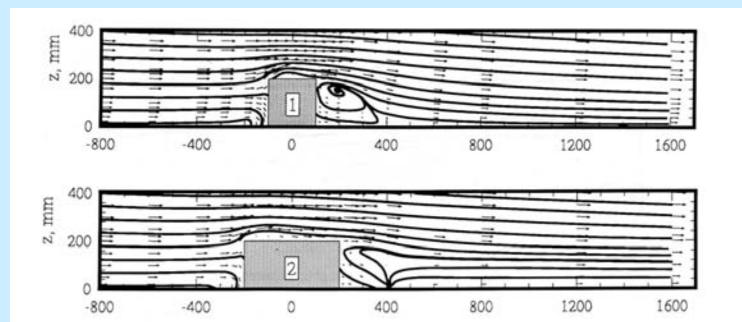


Sampling of Snyder Data Base

Ultimately, AERMOD/PRIME needs the Building Shape and Position that Places the Stack in the Correct Snyder/Lawson Data Base Flow Region (i.e., Data Base Used to Develop Downwash Algorithms)







Streamline figures from: Snyder, W.H. and R.E. Lawson, Jr.: Wind Tunnel Measurements of Flow Fields in the Vicinity of Buildings; 8th Joint Conference on Appl. of Air Poll. Met. With A&WMA; AMS, Boston, MA, 1994; pp. 244-250

Examples where BPIP Inputs have a problem

Complicated urban environment
- Background turbulence may dominate the dispersion versus the building wake

Porous/Lattice structures
- Air flow different than theory

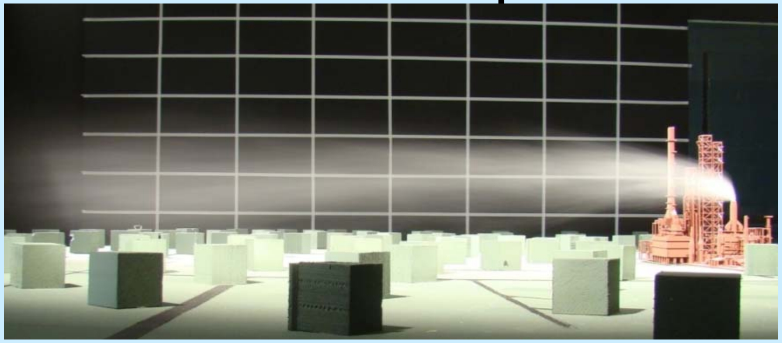
AMOCO Whiting Refinery – 1st Study in Early 1991
EBD Used for Lattice Type Structure

EBD generated plume profile:

BPIP generated plume profile:

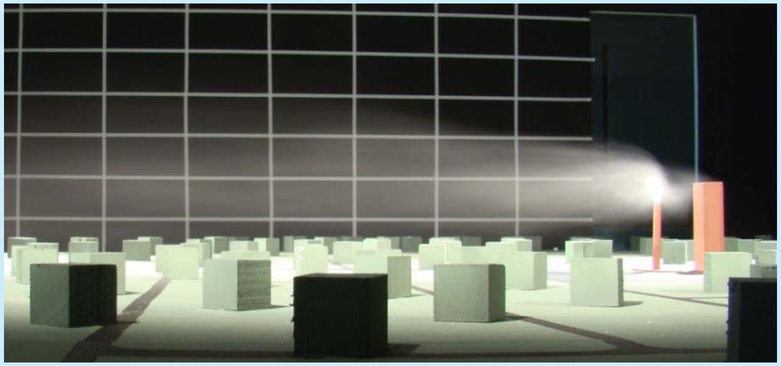
Recent example

Lattice Structure Downwind



Lattice Structure Upwind

Solid Building Upwind



Air & Waste Management Association

Air Pollution Meteorology (AB-3) Committee

Examples where BPIP Inputs have a problem

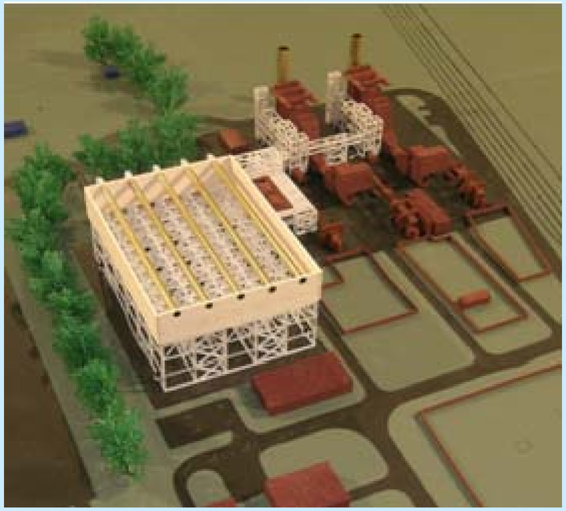
Hyperbolic cooling towers
-- streamlined

Short building with a large foot print
-- outside PRIME theory

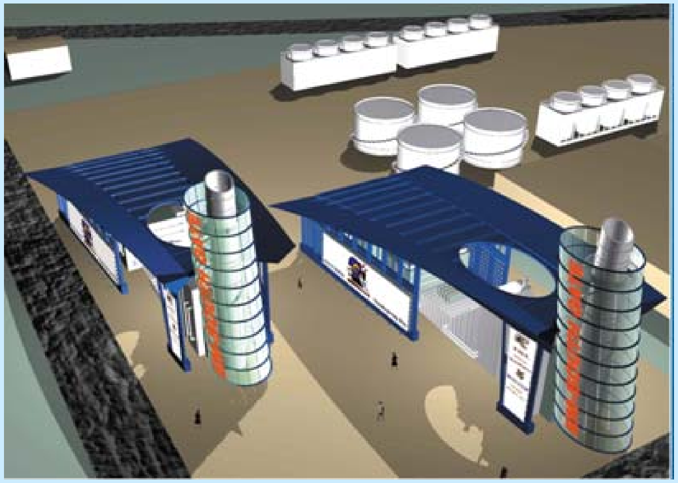
AIR & WASTE MANAGEMENT ASSOCIATION

Air Pollution Meteorology (AB-3) Committee

Examples where BPIP Inputs have a problem



Air cooled condenser units
-- lattice/solid combination



Multi-tiered sloped and
porous structures

Review of Attachment B to Memo:

Summary of AERMOD Modeling Conducted to Support the Assessment of Alcoa Davenport Works EBD Study

- Compared wind tunnel observations with AERMOD predictions.
- Results used to provide additional justification regarding concerns about large roughness.

Review of EPA Attachment B: Continued

- Problems with analysis
  - Appears EPA used model speed at reference height – should use simulated full scale speeds versus height.
  - EPA used roughness length input for dispersion calculations: should use measured turbulence profiles in wind tunnel.
  - Assumed stable conditions: neutral simulated
  - Used combination of model and full scale inputs – should use model values appropriately scaled to full scale.
  - Not enough data collected during wind tunnel testing to do a valid comparison
- Attachment B conclusions flawed – here is where collaboration would have been useful.

EPA AERMOD/Wind Tunnel Comparison for S349, Zo=0.084m

Comparison of key model inputs:

	EPA[1]	Estimated Correct Inputs: Petersen Beyer-Lout
Stack Height (m)	21.3	21.3
Stack Inside Diameter (m)	2.47	2.54
Stack Exit Temperature (K)	310.9	295.97
Stack Exit Velocity (m/s)	17.8	16.9
Surface Roughness Length (m)	0.084	0.084
Wind Direction (degrees)	240	240
Monin-Obukhov Length (m)	400	-8888
Wind Speed (m/s)	4.6	10.23
Reference Height for Wind Speed and Direction (m)	10	21.3 (stack top)
Reference Height for Temperature (m)	2	21.3 (stack top)
Profiles, temperature, turbulence and wind	Default	as simulated in the wind tunnel

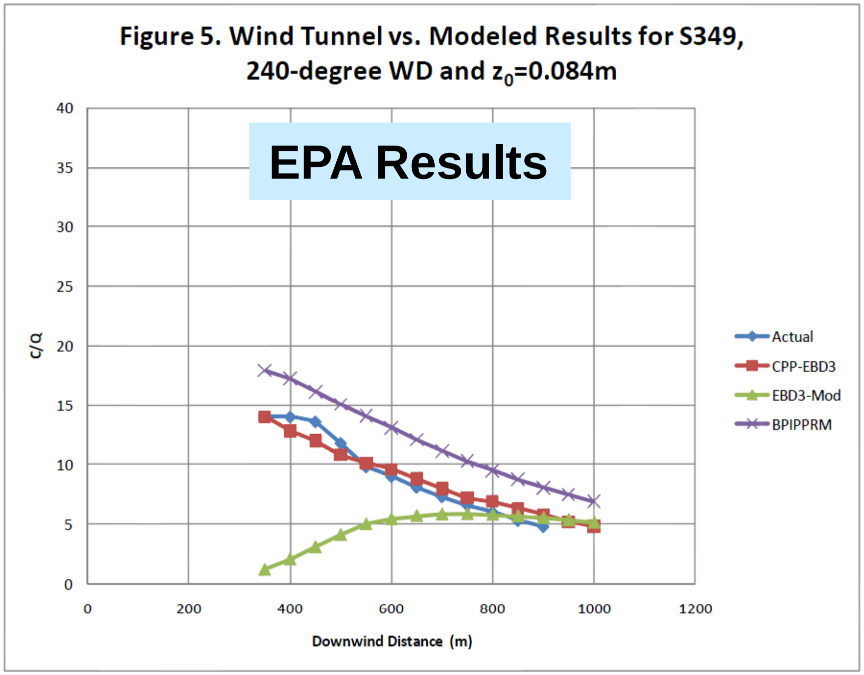
1) Actual inputs not provided by EPA. These are the inputs that Petersen and Beyer-Lout found agreed with EPA predictions

EPA AERMOD/Wind Tunnel Comparison

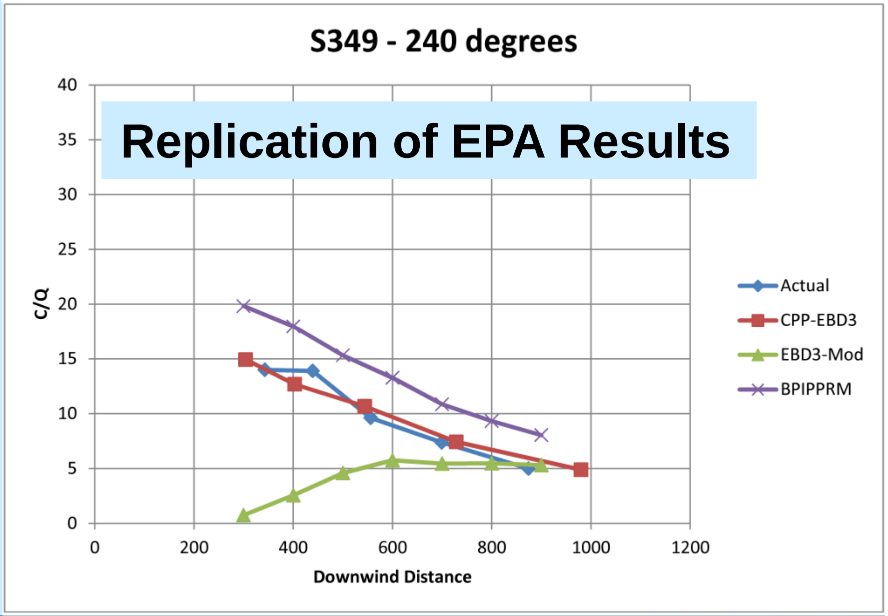
Key model inputs:

	Height (m)	Width (m)	Length (m)	Xbadj (m)	Ybadj (m)
EBD3	12.0	24.0	12.0	-12.0	0.0
BPIPPRM	17.4	299.4	35.1	31.4	0.0

Stack Height (m)	21.3
Stack Inside Diameter (m)	2.5
Stack Exit Temperature (K)	310.9
Stack Exit Velocity (m/s)	17.8
Surface Roughness Length (m)	0.084
Wind Direction (degrees)	240



Petersen/Beyer-Lout Best Replication of EPA



Additional estimated model inputs:

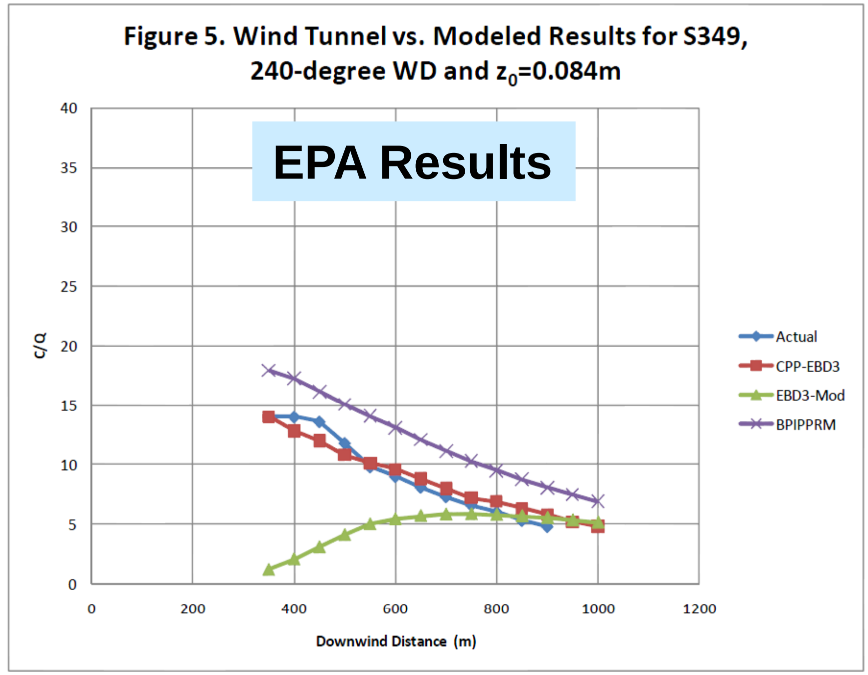
Sensible Heat Flux (W/m^2)	-10.0
Surface Friction Velocity (m/s)	0.385
Convective Velocity Scale (m/s)	-9.000
Vertical Potential Temperature Gradient above PBL	-9.000
Height of Convectively Generated Boundary Layer (m)	-999
Height of Mechanically Generated Boundary Layer (m)	600
Monin-Obukhov Length (m)	400
Wind Speed (m/s)	4.6
Reference Height for Wind Speed and Direction (m)	10
Ambient Temperature (K)	295.8
Reference Height for Temperature (m)	2

EPA AERMOD/Wind Tunnel Comparison

Key model inputs:

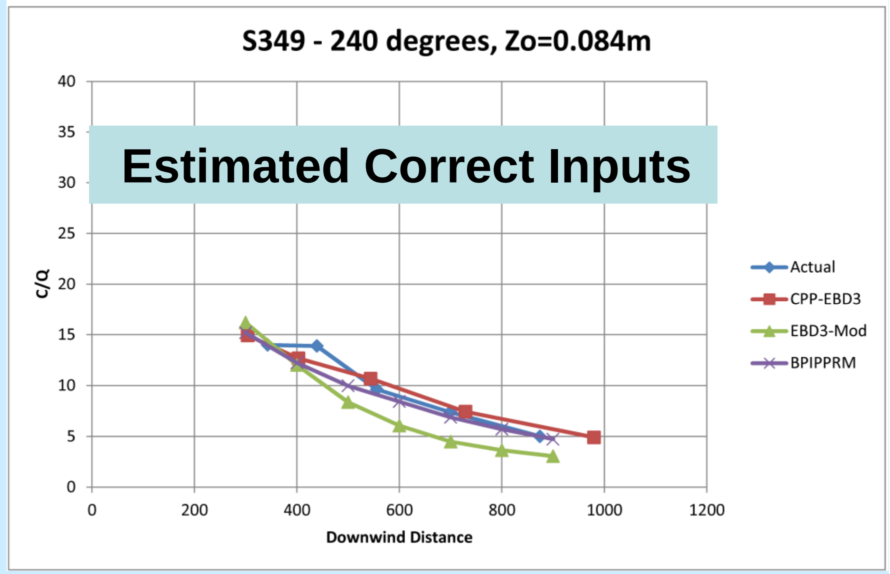
	Height (m)	Width (m)	Length (m)	Xbadj (m)	Ybadj (m)
EBD3	12.0	24.0	12.0	-12.0	0.0
BPIPPRM	17.4	299.4	35.1	31.4	0.0

Stack Height (m)	21.3
Stack Inside Diameter (m)	2.5
Stack Exit Temperature (K)	295.97
Stack Exit Velocity (m/s)	16.9
Surface Roughness Length (m)	0.084
Wind Direction (degrees)	240



***Petersen/Beyer-Lout Estimate of Correct Model Inputs*:**

Sensible Heat Flux (W/m²)	0.0
Surface Friction Velocity (m/s)	0.739
Convective Velocity Scale (m/s)	0.001
Vertical Potential Temperature Gradient above PBL	0.005
Height of Convectively Generated Boundary Layer (m)	0
Height of Mechanically Generated Boundary Layer (m)	600
Monin-Obukhov Length (m)	-8888
Wind Speed (m/s)	10.08*
Reference Height for Wind Speed and Direction (m)	21.3 (stack top)
Ambient Temperature (K)	295.8
Reference Height for Temperature (m)	21.3 (stack top)



*Wind and turbulence profile as simulated in the wind tunnel

Path Forward

- Option 1:
  - Create an Industry/EPA work group to develop a guideline for conducting EBD evaluations
  - Publish guideline much like the EPA Fluid Modeling Guideline
- Option 2:
  - Wait for next EBD protocol submitted to EPA
  - EPA Clearinghouse review and comment on protocol
  - Collaboration as needed during the review process
  - Approve final protocol – not done in that past
  - Conduct the study in a collaborative fashion with near real-time feedback and make adjustments as needed
  - Use final protocol as a template for future studies