AERMOD PREDICTION CHALLENGES FOR CYLINDRICAL STRUCTURES AND OTHER UNUSUAL BUILDINGS IN LIGHT OF THE 2011 EPA MEMORANDUM

Control Number: 16

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INTRODUCTION

Previous studies[1,2,3,4,5] have shown various building configurations where the Building Profile Input Program (BPIPPRM)[6] determined inputs into AERMOD[7] result in inaccurate concentration estimates. Petersen and Beyer-Lout[8] discussed the following problem building configurations in some detail: 1) very complicated building geometries, porous or lattice type structures and cylindrical structures; 2) building aspects ratios significantly different than those for which the model was developed and tested; 3) wind directions where the stack and upwind building corners are in alignment (enhanced downwash due to corner vortex); or 4) when terrain wake effects are important. This paper will discuss in more detail BPIPPRM problems for single and multiple cylindrical structures[8]. AERMOD treats cylindrical structures as if they are rectangular solids; hence, one would expect that AERMOD may tend to overestimate the downwash and resulting predicted ground-level concentrations due to the streamlined nature of the tank. It is possible that AERMOD could underpredict because the lateral dispersion would be less, which could increase concentrations. Second, BPIPPRM may merge multiple cylindrical structures into one very long and/or wide structure depending upon structure spacing. The large building dimension inputs (generated by BPIPPRM merging the structures together) may tend to result in unrealistically high ground-level concentration estimates. To determine appropriate building dimension inputs for AERMOD for these situations, wind tunnel modeling can be conducted to determine the Equivalent Building Dimensions (EBD) to use in place of the BPIPPRM calculated dimensions.

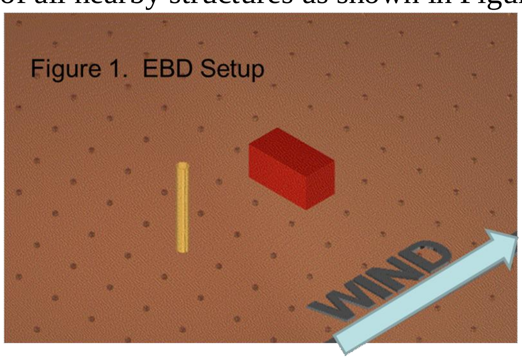
A challenging aspect to using the more accurate EBD inputs for this situation (and other similar situations) is the October 24, 2011 Model Clearinghouse Memorandum regarding the use of EBD in AERMOD. The 2011 EPA Memo[9] states that "all past EPA ***guidance*** related to determining EBDs through wind tunnel modeling is hereby suspended until further notice." Even though the 2011 Memo states that future studies will not be summarily rejected, the outcome of future EBD studies is not clear to industry and the time-line for the approval process is uncertain. The likelihood of using the EBD approach to obtain improved building dimension inputs is therefore reduced. This paper will discuss a regulatory process that could be followed to encourage the use of more accurate EBD building dimension inputs for situations when BPIPPRM dimensions are obviously not appropriate. As these cases are evaluated, a data base is being generated that can be used to improve BPIPPRM for these problem situations (i.e., cylindrical structures, lattice structures, very wide building, etc.).

The paper also presents the results of a research EBD study conducted for a couple of the problem building configurations. For this EBD research study, new procedures were utilized based on comments provided in the 2011 EPA Memorandum. These new procedures included: 1) utilizing short roughness elements during the EBD testing; 2) positioning the EBD at the approximate location of the actual buildings of concern relative to the stack; and 3) utilizing a neutrally buoyant plume. Two building configurations were evaluated where BPIPPRM will have obvious problems: 1) a single cylindrical structure (49 m high and 80 m wide) positioned 100 m downwind of a 64 m exhaust stack; and 2) three cylindrical structures positioned 100 m downwind of the exhaust stack with a 39 m spacing between the tanks. When the three cylindrical structures are input into BPIPPRM, they may or may not be combined into one very wide structure when the structures are downwind depending upon the stack location and cylinder spacing.

The paper will outline the new methods used for conducting the EBD study, compare the BPIPPRM and EBD determined building dimensions, and compare concentration estimates with BPIPPRM and EBD inputs used in AERMOD.

DISCUSSION ON METHOD FOR DETERMINING EBD

In the past, the basic modeling approach for determining equivalent building dimensions is to first document, in the wind tunnel, the dispersion characteristics as a function of wind direction at the site with all significant nearby structure wake effects included. No modification to this step is suggested. Next, the dispersion is characterized, in the wind tunnel, with an equivalent building that is usually positioned (for use in PRIME model within AERMOD) at or near the site of the actual building in place of all nearby structures as shown in Figure 1. This testing is conducted for various candidate equivalent building sizes until an equivalent building is found that provides a profile of maximum ground level concentration versus downwind distance that is similar (within the constraints defined below) to that with all site structures in place. Testing with an EBD building may or may not be the best approach. It is possible that AERMOD could be run in an iterative fashion to determine the EBD value that would best match the wind tunnel observations. Both approaches are evaluated in this paper.



In the past, the criteria for defining whether or not two concentration profiles are similar is to determine the smallest building which: 1) produces an overall maximum concentration exceeding 90 percent of the overall maximum concentration observed with all site structures in place; and 2) at all other longitudinal distances, produces ground-level concentrations which exceed the ground-level concentration observed with all site structures in place less 20 percent of the overall maximum ground-level concentration with all site structures in place. For future studies a slightly more restrictive criterion is recommended as follows. The smallest EBD is chosen that:

- produces an overall maximum concentration exceeding 95 percent of the overall maximum concentration observed with all site structures in place; and
- at all other longitudinal distances, produces ground-level concentrations which exceed the ground-level concentration observed with all site structures in place less 10 percent of the overall maximum ground-level concentration with all site structures in place.

DETERMINING WIND TUNNEL OPERATING CONDITIONS

An accurate simulation of the boundary-layer winds and stack gas flow is an essential prerequisite to any wind tunnel study of diffusion when *accurate* concentration estimates (i.e., ones that will compare with the real-world) are needed. The similarity requirements can be obtained from dimensional arguments derived from the equations governing fluid motion. A detailed discussion on these requirements is given in the EPA fluid modeling guideline[10]. For EBD type studies, the recommended criteria used for simulating plume trajectories and the ambient air flow are summarized below. These criteria maximize the accuracy of the building wake simulation and apply a conservative approach for simulating plume rise. The below criteria are updated from what has been used on past EPA approved EBD type studies[1,2,3,4] to improve the simulation method for aid in comparing AERMOD and wind tunnel predictions as carried out in the 2011 EPA Memo.

Modeling Plume Trajectories

To model plume trajectories for the cylindrical tank research study, the velocity ratio, *R*, was set equal to 1.5 and the density ratio, λ, was set equal to 1.0. Hence, the full-scale exhaust temperature has been assumed to be equal to the ambient temperature. These quantities are defined as follows:

$$R = \frac{V_e}{U_h} \qquad (1)$$

$$\lambda = \frac{\rho_s}{\rho_a} \qquad (2)$$

U_h = wind velocity at stack top (m/s),
V_e = stack gas exit velocity (m/s),
ρ_s = stack gas density (kg/m^3),
ρ_a = ambient air density (kg/m^3).

A velocity ratio of 1.5 was used to ensure that stack tip downwash effects do not occur. When the velocity ratio is less than 1.5, stack-tip downwash can occur in which case the stack wake can complicate the EBD determination process. A density ratio of 1.0 was used to ensure that a non-buoyant plume is simulated. This method is consistent with the method recommended be EPA[11] and is conservative in that the plume rise will be negligible. Another advantage of this approach is that it will simplify AERMOD and wind tunnel concentration prediction comparisons (i.e., plume rise prediction differences between AERMOD and the wind tunnel will be small).

Also, the stack gas flow in the model was set to be fully turbulent upon exit as it is in the full scale. This criteria is met if the stack Reynolds number ($Re_s = dV_e / v_s$), where d is exhaust diameter and v_s is the exhaust gas viscosity, is greater than 2,000 for a non-buoyant plume[12].

Modeling the Airflow and Dispersion

To simulate the airflow and dispersion around the tanks, the following criteria were met[10]:

- all significant structures within a 620 m (2000 ft) radius of the stack were modeled at a 1:360 scale reduction. Upwind of this area, roughness elements were installed to represent the approach roughness within 5 km of the stack.
- The mean velocity profile through the depth of the boundary layer was represented by a log law

$$\frac{U}{U^*} = \frac{1}{k} \ln\left(\frac{z}{z_0}\right) \qquad (3)$$

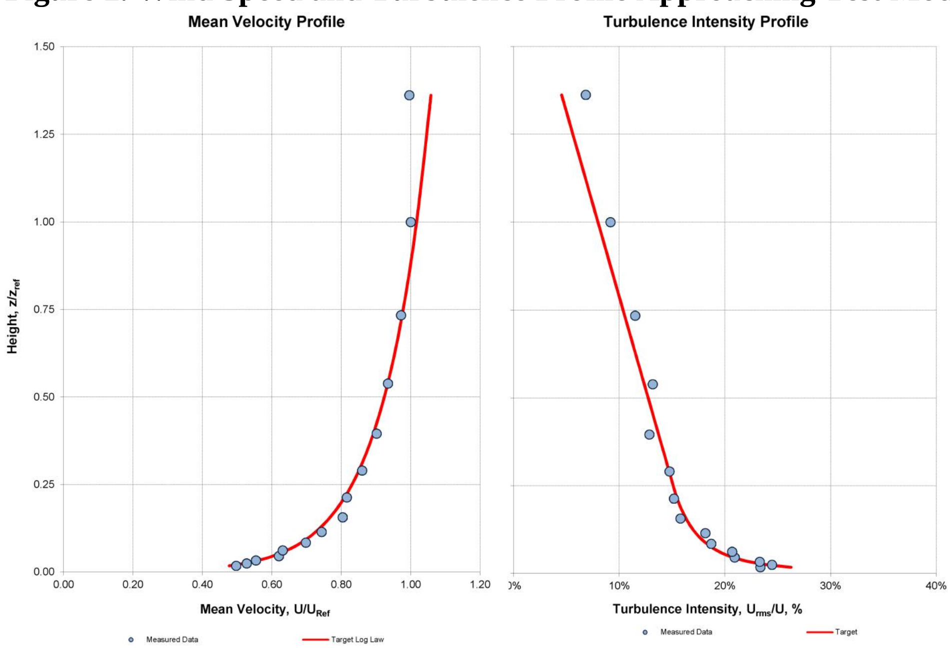
where U is the wind speed at height z, U_* is the friction velocity, k is the van Karman constant and z_o is the surface roughness length.

- Reynolds number independence was ensured: the building Reynolds number ($Re_b = U_b H_b / v_a$; the product of the wind speed, U_b, at the building height, H_b, times the building height divided by the viscosity of air, v_a) was greater than 11,000 as recommended[10] for rectangular structures. Since this study evaluated cylindrical structures, the 11,000 minimum requirement may not have been adequate; hence, tests were conducted to confirm Reynolds number independence.
- a neutral atmospheric boundary layer was established (Pasquill–Gifford C/D stability) by setting the bulk Richardson number (R_{ib}) equal to zero in model and full scale.

To simulate full scale wind profiles in the wind tunnel, it is necessary to match the surface roughness length used in the model to that of the actual site. The surface roughness lengths for the site were specified using AERSURFACE[13] with a radius of 5 km around the site.

Using the above criteria and the source characteristics shown in Table 1, the model test conditions for this generic site were computed for the stack under evaluation. The model test conditions were computed for D stability at the simulated wind speed. The simulated wind profile is provided in Figure 2.

Figure 2. Wind Speed and Turbulence Profile Approaching Test Model



SUGGESTED EBD APPROACH

The following outlines the recommended approach for conducting an EBD study. The approach is written based on a generic study of cylindrical tanks.

Test Protocol Development and Approval

During this phase of the project, a test protocol should be developed and submitted to the Regional EPA office and the Model Clearinghouse. The protocol should define the methods used to conduct the study, the area and sources to be modeled, the wind directions and wind speeds to be simulated and the results that will be provided. After EPA review and approval, the study should proceed.

Past experience with the process has been that EPA does not officially approve a protocol. EPA usually says that they need to see the study results before approval can be given. This non-approval upfront can create problems for any source considering an EBD study. One source did submit a protocol upfront with general agreement that the approach looked acceptable[14]. Once the report was submitted, the review process took an extended amount of time and at the end of that review the study was disapproved. Had there been some feedback during the protocol phase or even right after the report had been submitted, the problems mentioned could have solved very quickly and the wind tunnel testing plan adjusted accordingly.

For EBD studies to be a viable alternative when more accurate concentration estimates are needed, the protocol approval process needs to be streamlined and official approval needs to be provided up-front. Initial feedback based on preliminary results also needs to be provided in case additional wind tunnel testing is needed.

Model Construction and Setup

Once the protocol is approved, model construction can start. For this example EBD evaluation 1:360 scale models of one and three cylindrical tanks were constructed and placed on a turntable. The turntable model included all significant structures within a 620 m (2000 ft) radius of the stack. Beyond that radius roughness elements were installed to represent the approach roughness within a 5 km radius of the stack. Figures 3 and 4 shows the drawings of the two configurations modeled for this generic EBD evaluation.

Stack height: 64m

Tank height: 50m

Tank diameter: 82m

Distance between stack and tank wall: 100m

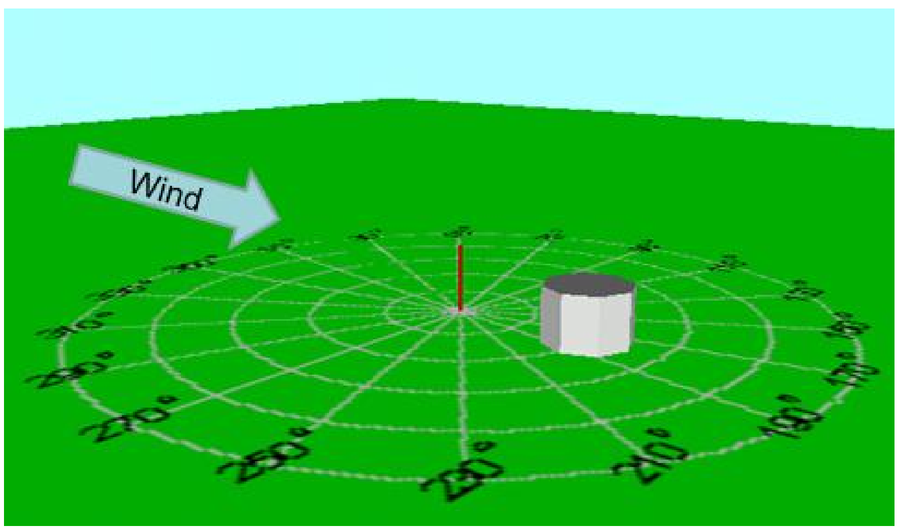


Figure 3. Schematic of single tank downwind of stack

Stack height: 64m

Tank heights: 50m

Tank diameters: 82m

Closest distance between stack and tank wall: 100m

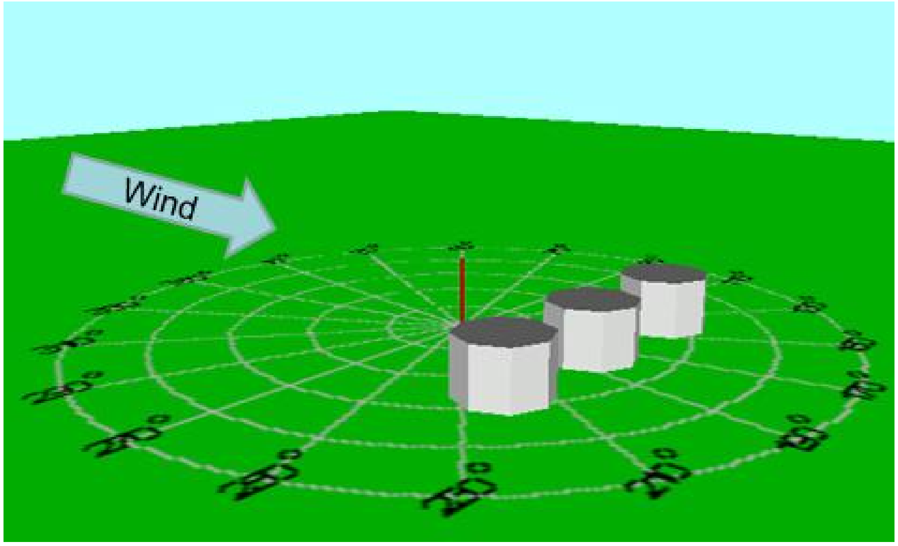


Figure 4. Schematic of three tanks downwind of stack

The tank models were constructed utilizing 3D drawing files of typical storage tanks. These files were used to generate a 3D model print file that is used directly to construct the scale model using either a Stereolithography (SLA) or 3D printing process. Both Stereolithography and 3D printing processes use the same file output type to create the models. Also, both processes typically build the models in layers of 0.004" per layer. For this project both process were used to construct various structural elements depending upon the needed durability.

The stack was constructed of a brass tube and was supplied with an air–hydrocarbon mixture of neutral density. Measures were taken to ensure that the flow was fully turbulent upon exit. Precision gas flow meters were used to monitor and regulate the discharge velocity.

A set of solid structures, all with height to width ratios similar to those determined using BPIPRM were fabricated for placement at the approximate locations specified by BPIPRM. These structures were used to determine the equivalent building dimensions. The stack in Table 1 and idealized buildings were tested with the site structures in Figures 3 and 4 removed from the wind tunnel and an EBD installed in its place.

All testing was carried out in a closed-circuit wind tunnel. Spires and a trip at the leading edge of the test section begin the development of the atmospheric boundary layer. The long boundary layer development region between the spires and the site model was filled with roughness elements. The roughness patterns are experimentally set to develop the appropriate approach boundary layer wind profile and approach surface roughness length. Testing was conducted with the target approach surface roughness length of 0.18 m.

For all testing, concentration measurements were obtained at various locations on the surface of the wind tunnel so that approximately 45 locations were sampled for each simulation. A typical sampling grid consists of 6 to 9 measurement points located in each of 5 or 6 rows that are spaced perpendicular to the wind direction. The lateral and longitudinal spacing of measurement points is designed so that the maximum concentrations are defined in the lateral and longitudinal directions.

Wind Tunnel Testing – Documentation Tests

Before conducting the detailed wind tunnel testing, a limited series of documentation tests was conducted. CPP has previously conducted atmospheric dispersion comparability (ADC) tests at a similar model scale and these tests were not repeated for this study. However, Reynolds number independence tests were conducted.

For the Reynolds number tests, a scale model of the tanks and vicinity was installed in the wind tunnel. A tracer gas was emitted from the stack and ground-level concentration measurements were taken downwind of the tanks for three different Reynolds numbers. If Reynolds number effects are negligible, the normalized concentration results should be equivalent (within 10 percent). The minimum test speed for the remaining tests was chosen such that Reynolds number effects are negligible. The results of this testing showed Reynolds number independence at wind tunnel speeds at and above 6 m/s. All testing was conducted at 6 m/s.

Initial Meeting at the Wind Tunnel

Before detailed testing in the wind tunnel is carried out it is recommended that representatives from the source and appropriate government agency be present to inspect the model for accuracy and review the test plan. Visualizations of exhaust behavior can then be conducted. The visualization will provide those present with a qualitative understanding of the effect of the structures on the dispersion and will provide information that can be used to finalize the test plan.

Wind Tunnel Testing – Equivalent Building Dimensions

The purpose of this testing is to define the Equivalent Building Dimensions (EBD) that can be input into AERMOD for the exhaust stack listed in Table 1.

Table 1. Full-Scale Stack Source Parameters

Parameter	Value
Stack Height above grade, h (m)	63.95
Stack Inside Diameter, d (m)	3.01
Exit Velocity, V_e (m/s)	27.07
Stack Temperature (K)	294.65
Emission Rate (g/s)	1

Table 2 summarizes the cases that were evaluated in the wind tunnel and Table 3 provides the cases that were run in AERMOD.

Table 2. Cases Evaluated in the Wind Tunnel					
Description	Hb BUILDHGT (m)	W BUILDWID (m)	L BUILDLEN (m)	XBADJ (m)	YBADJ (m)
Single tank	50	Cylindrical tank with diameter = 81 m		100	0
Three tanks	50	Cylindrical tanks with diameter = 81 m spaced 39 m apart		100	0
EBD 2	32.1	81	40.5	100	0
EBD 5	50	81	81	11	0
EBD 6	50	81	81	14	0
EBD 9	50	81	81	100	0

Table 3. Cases Evaluated in AERMOD					
Description	Hb BUILDHGT (m)	W BUILDWID (m)	L BUILDLEN (m)	XBADJ (m)	YBADJ (m)
Single tank – treated as rectangular by AERMOD	50	81	81	100	0
Three tanks, not merged - treated as rectangular	50	81	81	100	0
Three tanks, merged – treated as rectangular	50	320	81	100	0
EBD 5	50	81	81	11	0
EBD 6	50	81	81	14	0
EBD 7	60	81	81	11	0
EBD 20	58	58	58	0	0

The building positions in Tables 2 and 3 are defined as follows[6]:

- BUILDHGT: Height of building (m);
- BUILDWID: Width of building perpendicular to the flow (m);
- BUILDLEN: Projected length of the building along the flow (m);
- XBADJ: Along-flow distance from the stack to the center of the upwind face of the projected building (m);
- YBADJ: Across-flow distance from the stack to the center of the upwind face of the projected building (m);

For the cases in Table 2, a tracer gas was released from the indicated stack and the maximum ground-level concentrations versus downwind distance were determined. After the site structure tests were completed, tests were conducted to determine the Equivalent Building Dimensions. For these tests, all site structures were removed from the wind tunnel and the EBD were installed at the positions specified in Table 2. The EBD building that produces similar concentrations as with the site structures (single and three tanks) in place is the equivalent building. These dimensions can be used in AERMOD to assess maximum ground-level impact for the wind directions evaluated.

Analysis and Reporting

The data were analyzed shortly after collection and put in a form ready for report. The analyses include:

- conversion of wind tunnel concentrations to full-scale hourly average normalized concentrations using the equation recommended by Snyder (1981)[10]; and
- tabulation of equivalent building dimensions for the wind directions of concern.

The tabulated equivalent building dimensions can then be input directly into AERMOD. BPIPRM determined building dimensions can be used for the wind directions where EBD are not determined. Upon completion of all analyses, a concise, comprehensive report is prepared and submitted to the client for review and comment. After comments on the report are received, final bound copies are provided for agency submittal, review and approval.

COMPARING THE WIND TUNNEL WITH AERMOD

To evaluate whether AERMOD could be used directly to determine EBD values, a method had to be developed to run AERMOD in manner that would replicate the wind tunnel simulation. First, the wind and turbulence profiles measured in the wind tunnel were converted to full scale conditions and input into AERMOD using the values and assumptions listed in Table 4.

Table 4. Meteorological data input for AERMOD to replicate wind tunnel experiment

Height (m)	Wind Speed (m/s)	Temperature (deg. C)	STD of Wind Direction Fluctuations (deg.)[1]	STD of Vertical Wind Speed Fluctuations (m/s)[2]
8.5	13.4	21.5	8.5	1.636
21.5	16.0	21.5	7.1	1.655
54.2	20.4	21.5	5.4	1.610
100.5	21.8	21.5	5.1	1.608
254.2	24.7	21.5	4.0	1.418

1) Computed from the wind tunnel longitudinal turbulence intensity by assuming the lateral turbulence is 0.6 times the longitudinal intensity
2) Computed from the wind tunnel longitudinal turbulence intensity by assuming the vertical turbulence intensity is 0.5 times the longitudinal.

These factors were determined by running AERMOD with different factors until good agreement with the wind tunnel was achieved. Ideally, these values should be measured directly during the wind tunnel experiment.

Table 5 summarizes the values assumed for various other inputs. It should be noted that the wind tunnel is neutrally stratified, which is the same as an infinite Monin-Obukhov length (L). Theoretically it should not matter if L is positive or negative infinity but this evaluation showed that AERMOD provided different results for the two conditions. Best agreement with the wind tunnel observations was found with L= 8888 m (stable stratification).

Table 5. Other AERMOD Inputs Used to Replicate the Wind Tunnel (Shaded values are different for Stable and Neutral conditions)		
Parameter	**Neutral/Stable**	**Neutral/Unstable**
Sensible Heat Flux (W/m^2)	-0.1	0.0
Surface Roughness Length (m)	0.18	0.18
Surface Friction Velocity (m/s)	1.333	1.333
Convective Velocity Scale (m/s)	-9.000	0.001
Vertical Potential Temperature Gradient above PBL	-9.000	0.005
Height of Convectively Generated Boundary Layer (m)	-999	0
Height of Mechanically Generated Boundary Layer (m)	600	600
Monin-Obukhov Length (m)	8888	-8888
Wind Speed (m/s)	20.56	20.56
Reference Height for Wind Speed and Direction (m)	64.0	64.0
Ambient Temperature (K)	294.7	294.7
Reference Height for Temperature (m)	64.0	64.0

Figure 5 below shows the results of the AERMOD runs and wind tunnel observations for the case with the shortest EBD that was evaluated in the wind tunnel. This case was used, since building wake effects would be the smallest. For future evaluations, it is recommended that a no building case also be used for the initial validation of AERMOD when using AERMOD to determine EBD's.

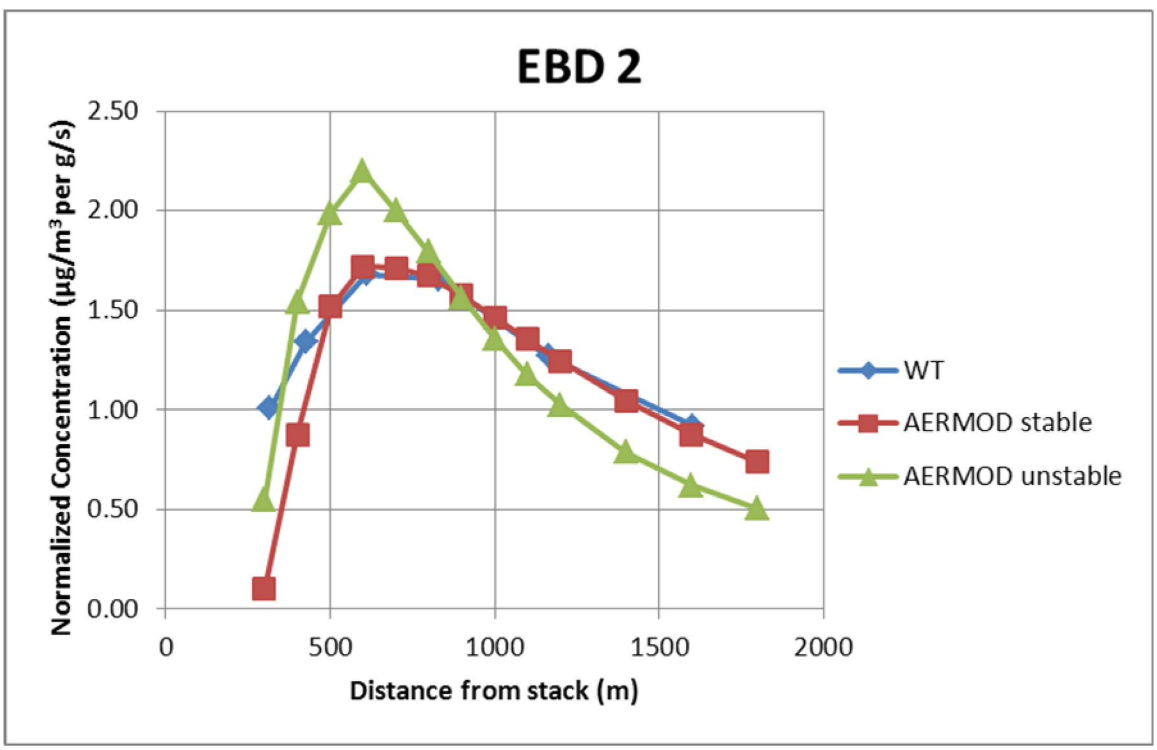


Figure 5. AERMOD versus Wind Tunnel Observations for EBD2.

Figure 5 shows that the AERMOD stable case agrees well with the wind tunnel observations and based on this comparison the stable Table 5 inputs were used for AERMOD runs to determine EBD. It should be noted that the AERMOD unstable has case shows different results even though the Monin-Obukhov length was large enough for both cases to be classified as neutral. This is a theoretical AERMOD inconsistency problem that should be resolved at some time in the future.

EDB RESULTS

Figure 6 shows the conventional (or standard) graph used to determine EBD based on wind tunnel testing. The line 'WT EBD5 x=11' is the EBD testing case that would be selected as the AERMOD input to replicate the downwash due the single tank. The EBD dimensions are provided in Table 2. It is interesting to note that the EBD has the same height and width as the cylindrical tank but has to be positioned closer to the stack to match the concentration profile. Based on these results, the concentrations due a cylindrical storage tank are greater than those due to a rectangular structure at the same downwind location (i.e., WT EBD9 x=100). Expectation was that the EBD would be shorter and not as large since the wake of a cylinder should be smaller than the wake due to a rectangle. This suggests that the lateral dispersion is smaller for the tank than a similar rectangular structure, thus causing an increase in ground-level concentrations.

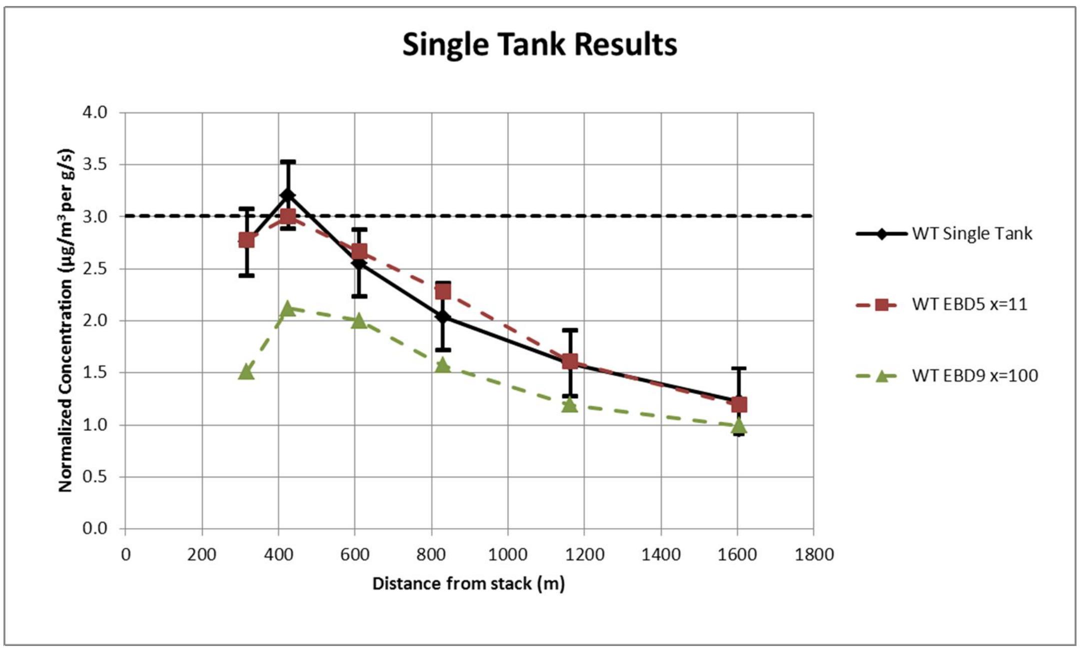


Figure 6. Wind tunnel maximum normalized concentrations versus downwind distance for the single tank case and two EBD cases.

Figure 7 shows the alternate method for determining EBD based on AERMOD runs. The figure shows the WT single tank results and the results for different AERMOD simulations. The AERMOD run with EBD5 x=11 is lower than the wind tunnel observations and would be the AERMOD prediction using the EBD input based on the wind tunnel EBD determined value. The AERMOD run with the original tank dimensions gives a much lower value than the wind tunnel observations. AERMOD run with dimensions listed in Table 3 for EBD20 placed directly downwind of the stack agrees best with the wind tunnel simulations. The EBD building is taller than the tank but narrower.

Figure 8 shows the standard graph used to determine EBD based on wind tunnel testing for three tanks. The single tank results are shown for comparison. The maximum ground-level concentrations are lower for three tanks than for the single tank, indicating enhanced horizontal dispersion. WT EBD9 agrees best with the three tank results but a different configuration could be found with additional testing that would agree better.

Figure 9 shows the alternate method for determining EBD for three tanks using AERMOD. The figure shows the WT three tank results and the results for different AERMOD simulations. The AERMOD runs with EBD5, 6 and 7 all agree fairly well with the wind tunnel observations and would be the AERMOD predictions using these EBD inputs. AERMOD run with the original single tank dimensions gives slightly lower values than the wind tunnel observations with three tanks.

BPIPPRM may merge multiple cylindrical structures into one very long and/or wide structure depending upon structure spacing. The large building dimension inputs generated by merging the structures are listed in Table 3. The resulting ground-level concentrations for the merged case are shown in Figure 9. AERMOD significantly overpredicts at the distance closest to the stack, however, concentrations drop off quickly with distance and AERMOD underpredicts for all other locations.

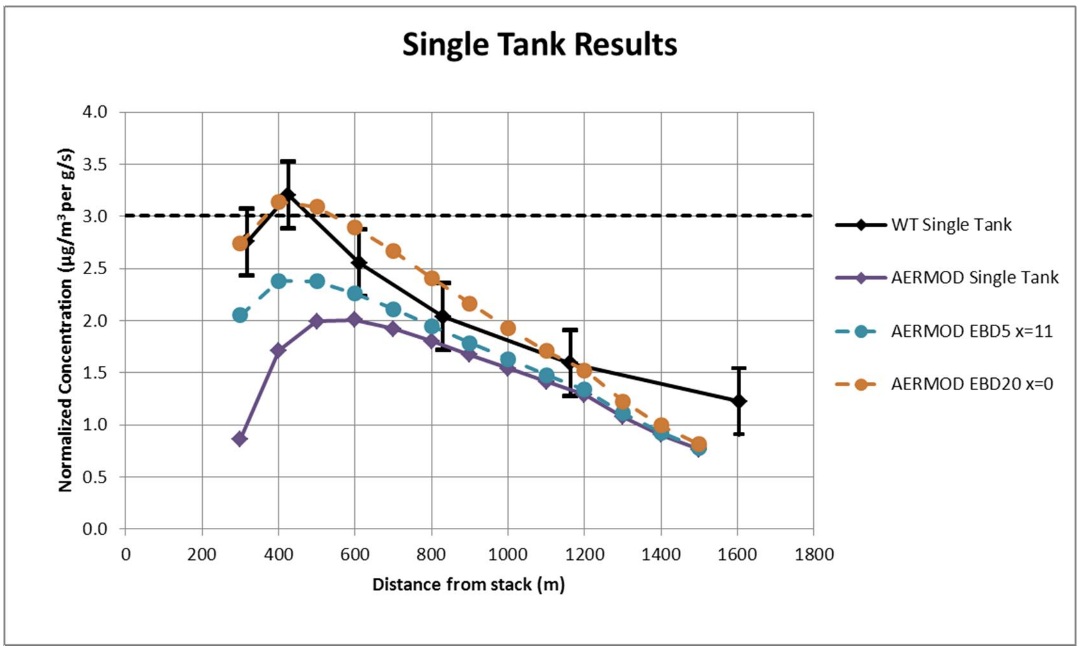


Figure 7. AERMOD and wind tunnel maximum normalized concentrations versus downwind distance for the site structures case and AERMOD two EBD cases.

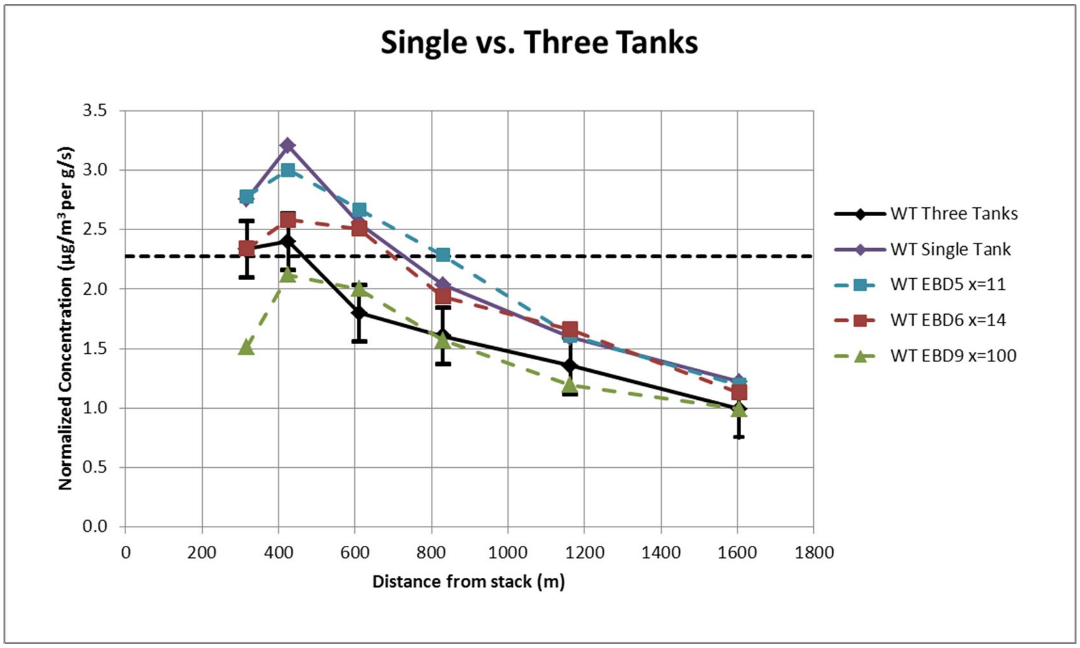


Figure 8. Wind tunnel maximum normalized concentrations versus downwind distance for the site structures cases and three EBD cases.

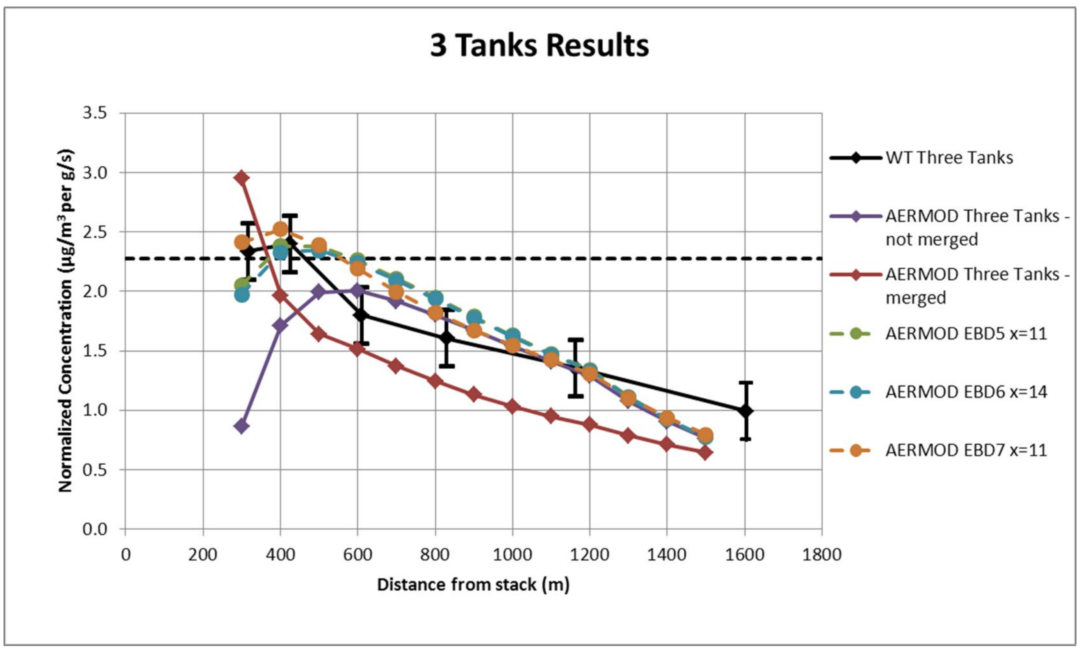


Figure 9. AERMOD and wind tunnel maximum normalized concentrations versus downwind distance for the site structures case and AERMOD three EBD cases.

CONCLUSIONS

The following conclusions can be drawn from this study for one or three 50 m high cylindrical tanks with an 81 m diameter positioned 100 m downwind of a 64 m high stack with insignificant plume rise.

Wind Tunnel Testing

- Maximum ground-level concentrations downwind of single cylindrical tank are greater than those for a rectangular structure at the same position with the same height and width W=L = 81 m = tank diameter.
- The wind tunnel determined EBD for the single tank has the following dimensions: H_b= 50 m; W = L = 81 m; XBADJ=11m; YBADJ = 0.
- Maximum ground-level concentrations downwind of three cylindrical tanks were less than those for the single tank.
- The wind tunnel determined EBD for the three tanks has the following approximate dimensions: H_b= 50 m; W = L = 81 m; XBADJ=100m; YBADJ = 0.

AERMOD

- AERMOD can be run in manner to match the wind tunnel simulations for a simple rectangular building. On this basis, AERMOD can also be used directly to determine EBD by matching AERMOD EBD simulations to wind tunnel simulations with site structures present (one or three tanks for this study).
- The AERMOD determined EBD for the single tank has the following dimensions: H_b= 58 m; W = L = 58 m; XBADJ=0 m; YBADJ = 0. This does not agree well with the wind tunnel determined EBD. The use of BPIPRM inputs for the single tank would significantly underestimate maximum ground-level concentrations.
- The AERMOD EBD for three tanks has the following approximate dimensions: Hb= 50 m; W = L = 81 m; XBadj=between 14 and 100m; YBadj = 0. This results agrees fairly well with the wind tunnel determined EBD.

Based on the results of this study it appears that an alternate approach for determining EBD could be utilized. This approach would include the use of wind tunnel modeling to determine the maximum concentrations versus downwind distance with site structures (i.e., tanks, lattice, complicated sites, etc.) present. Next AERMOD runs would be carried out in an iterative fashion to determine the appropriate building dimension inputs (EBD) that would match the wind tunnel results for every wind direction of concern. The AERMOD EBD runs would be carried out after AERMOD is shown to match the wind tunnel for several different simple building configurations which match the theory in AERMOD.

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