ATTACHMENT B

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

This attachment summarizes results of AERMOD modeling conducted to support the Model Clearinghouse assessment of the Alcoa Davenport Works equivalent building dimension (EBD) study. The wind tunnel study for Alcoa Davenport Works was conducted due to concerns regarding the limitations of PRIME downwash algorithms to account for downwash influences associated with buildings with large aspect ratios of building width (W) and/or length (L) divided by building height (H), such as the Alcoa facility, which are well beyond the range of aspect ratios used in the development and evaluation of the PRIME algorithms. EPA Region 7 requested Model Clearinghouse review and concurrence regarding the adequacy of the EBD study for purposes of determining alternative building parameters for input to the AERMOD model.

The modeling summarized here examines the potential impact of the inclusion of additional roughness elements in the wind tunnel study for the EBD tests to account for the roughness of the Alcoa facility, which was identified as one of the key concerns regarding the design of the wind tunnel study conducted for Alcoa. The modeling also examines the viability of an alternative approach to determining appropriate building parameters for the Alcoa facility for input to AERMOD. As noted in the accompanying Model Clearinghouse response memo, there are a number of issues and challenges associated with defining appropriate source and meteorological inputs for the AERMOD dispersion model that would replicate the conditions simulated in the wind tunnel, and therefore the modeling results presented should only be viewed in a very general sense.

The following two cases were examined in detail: 1) source S349 with winds from 240 degrees, a fetch straddling the river bank, simulated in the wind tunnel with a low approach surface roughness length (z_0) of 0.084m; and 2) source S289 with winds from 150 degrees, an overwater fetch also simulated in the wind tunnel with z_0=0.084m. The 240-degree fetch is parallel to the long axis of the plant orientation from SW to NE, and the 150-degree fetch is perpendicular to the long axis. Meteorological parameters were selected for input to AERMOD to approximate the conditions simulated in the wind tunnel.

The location of sources S349 and S289 are shown below in Figures 1 and 2, which are based on Figure 5, parts a and b, from the wind tunnel report for Alcoa Davenport (CPP, 2009). Figure 3 shows a building cross-section relative to source S349 for the 240 degree fetch case, and Figure 4 shows a building cross-section relative to source S289 for the 150 degree fetch case. These cross sections are based on the building heights along transects through the stack locations perpendicular to the wind directions in each case. Both of these cross-sections show a complex series of building tiers of varying heights both upwind and downwind of the stack locations.

One of the main concerns cited in the accompanying Model Clearinghouse memo regarding the CPP wind tunnel study is that the actual facility was replaced with roughness elements intended to simulate the roughness of the actual facility when the equivalence of the EBD was being tested. In some cases, the roughness elements appear to be larger than the EBD structure. To assess the potential impact of this approach, modeling analyses were conducted for the two cases described above, source S349 with a 240-degree wind direction and source S289 with a 150-degree wind direction, in order to assess the potential influence of the additional roughness elements. Figure 5 shows a comparison of normalized modeled concentration results (Concentration/Emissions) based on explicitly modeling the equivalent building selected by CPP for the case of S349 with the 240-degree fetch (designated as 'EBD3' and labeled as 'EBD3-Mod') and modeling results based on BPIPPRM-derived inputs (labeled as 'BPIPPRM'), using meteorological inputs intended to approximate the conditions simulated in the wind tunnel, <u>without</u> the additional roughness elements intended to simulate the roughness of the actual facility. For comparison, Figure 5 also includes results from the CPP wind tunnel study for this case with the "actual" building in place (labeled as 'Actual') and wind tunnel results for EBD3 determined by CPP as "equivalent" for this case (labeled as 'CPP-EBD3'). Table 1 shows the building parameters input to AERMOD for source S349 and 240-degree wind direction based on EBD3 derived from the wind tunnel study and BPIPPRM.

Table 1. Building Parameters for Source S349 and 240-degree Wind Direction

	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

It should be noted that the data included in Figure 5 for the 'Actual' and 'CPP-EBD3' cases (and similar figures presented below) are estimated based on figures provided with the CPP wind tunnel report (CPP, 2009) that included results for only 5 downwind distances. Furthermore, the distances plotted for the 'Actual' case (labeled as 'Alcoa' in the CPP report) differed from the distances plotted for the 'CPP-EBD3' case. An example is provided below in Figure 6 for the S349 case, from Appendix I of the CPP report. The curves presented in this attachment for the 'Actual' and 'CPP-EBD3' results are based on linearly interpolating between the data points included in the CPP report.

The modeled results for 'EBD3-Mod' shown in Figure 5 do not match well with the EBD3 results reported in the CPP report ('CPP-EBD3'), showing significantly lower concentrations than wind tunnel results reported for the 'Actual' building or 'CPP-EBD3' out to about 800 meters. The modeled results based on BPIPPRM inputs in Figure 5 show somewhat higher concentrations than the wind tunnel results, by about 20 percent. Figure 7 shows results for the same scenario as Figure 5, but with the meteorology adjusted to reflect a higher surface roughness (z_0=0.74m), based on the roughness of the actual facility, for consistency with the CPP study. Although the modeled concentrations for 'EBD3-Mod' are still lower than the 'Actual' or 'CPP-EBD3' results, there is much better agreement than shown in Figure 5, illustrating the potential complications introduced by replacing the actual building with "equivalent" roughness elements to account for the roughness of the actual building for the EBD wind tunnel tests.

The modeled results based on BPIPPRM inputs with the higher surface roughness shown in Figure 7 show very good agreement with both the 'Actual' result and 'CPP–EBD3' results from the wind tunnel.

Figures 8 and 9 show comparisons of modeled concentrations for source S349, based on the same meteorological inputs as used above, with and without the additional roughness, for the case with no building (labeled as 'NO-EBD'). The 'NO-EBD' results for these cases are identical to the corresponding modeled results based on 'EBD3-Mod' shown in Figures 5 and 7, indicating that the wind tunnel derived 'EBD3' does not contribute any downwash influence on this source when modeled explicitly in AERMOD based on these tests. This does not necessarily imply that 'EBD3' would not contribute any downwash influences across all meteorological conditions, but it does underscore the main concern cited in the accompanying memo regarding the appropriateness of this wind tunnel study for determining EBDs.

Figures 10 and 11 include results of explicitly modeling the equivalent building selected by CPP for the case of source S289 with the 150-degree fetch (labeled again as 'EBD3-Mod'), and modeling results based on BPIPPRM-derived inputs (labeled again as 'BPIPPRM'), compared with results for the actual building (labeled again as 'Actual') and "equivalent" EBD3 results (labeled again as 'CPP-EBD3') provided in the CPP report, based on the same meteorological inputs as used above with and without the additional roughness. Table 2 shows the building parameters input to AERMOD based on EBD3 and BPIPPRM for source S289 and 150-degree wind direction.

Table 2. Building Parameters for Source S289 and 150-degree Wind Direction

	Height (m)	Width (m)	Length (m)	Xbadj (m)	Ybadj (m)
EBD3	12.0	24.0	12.0	-12.0	0.0
BPIPPRM	16.7	498.4	336.1	-164.6	0.0

Similar to the results based on explicitly modeling the wind tunnel derived EBD for source S349, shown above in Figures 5 and 7, modeled results based on 'EBD3-Mod' for source S289 show significant underprediction compared to the 'Actual' results without the additional roughness elements and much less underprediction when the additional roughness is included. Results based on BPIPPRM-derived building parameters for the case without the additional surface roughness for the Alcoa facility (Figure 10) converge with the 'Actual' and 'CPP EBD' results beyond about 600 meters, but show somewhat lower concentrations closer to the source. The BPIPPRM results with the additional surface roughness (Figure 11) show somewhat lower concentrations and poorer agreement with the 'Actual' and 'CPP–EBD3' results at all distances. Although not shown here, as noted above for source S349, additional modeling based on 'NO-EBD' for source S289 indicates that 'EBD3' does not cause any downwash influence for source S289 when modeled explicitly in AERMOD based on these tests.

Acknowledging some concern regarding the appropriateness of building parameters derived from BPIPPRM for this facility, we also examined an alternative approach for determining appropriate building parameters based on a qualitative assessment of the potential influence of facility structures on dispersion from these two sources, S349 and S289. Given the generally low building heights for the majority of the Alcoa Davenport facility, on the order of 15 meters, with long fetches across the building upwind of the sources, we believe that for many cases the approach flow will be disturbed as it encounters the upwind edge of the building, but will tend to readjust at some point before influencing the stacks such that the top of the building is effectively the new "ground surface." In simple terms, the wind profile of the approach flow will essentially be displaced in response to the long flat building. This very simplistic physical analysis of the possible interaction of the approach flow with the building suggests that an alternative approach to simulate this scenario within the model could be to redefine the "ground elevation" based on the mean building height upwind of the stack, identify any building tiers that are close enough and extend above the displaced surface enough to potentially influence the stack, and treat receptors downwind of the building as "below grade" receptors relative to the top of the building as the redefined "ground elevation." The stack heights and building heights would also be referenced to the redefined "ground elevation" in order to preserve the relative height differences between the sources, building tiers, and downwind ground-level receptors.

For the case of S349 with a 240-degree wind direction, based on the building cross-section presented in Figure 3, it seems reasonable to assign 12.5 meters as the redefined "ground surface" based on the fetch of almost 1,500 meters upwind of the source along the "main building." To assess what effect this alternative approach for defining inputs to AERMOD might have, the stack height relative to the new "ground surface" was set at 8.8 meters, the height of the downwind "building" extending above the new "ground surface" was set at 9.8 meters, the building width at 200 meters, the building length at 300 meters, and the stack location was set at 100 meters upwind of the new "building." Note that these are approximate values that also take into account the variation in tier heights laterally in relation to the stack location for the 240-degree approach flow. The "building" height of 9.8 meters is approximately the average height (above the refined "ground surface" of the building tiers labeled as '830' and '836.' The downwind receptors were placed at 12.5 meters "below grade" to preserve the stack height to receptor height relationship.

Based on the building cross section and other available information for source S289 (see Figure 4), the displaced "ground surface" was set at 11 meters, roughly the average height of the fetch upwind of the building tier labeled '814,' and the stack height relative to the new "ground" was set at 15.6 meters. A building height of 5.6 meters relative to the new "ground" was defined, with a building width of 200 meters, a building length of 260 meters, and the stack was located 60 meters downwind of the upwind edge of the new "building" (beginning with tier '814'). Table 3 shows the "effective" stack and building parameters used for these alternative tests.

Table 3. Alternative Stack and Building Parameters for Source S349 with 240-degree WD, and Source S289 with 150-degree WD

	Stack Height (m)	Building Height (m)	Width (m)	Length (m)	Xbadj (m)
S349/240-deg	8.8	9.8	200.0	300.0	100.0
S289/150-deg	15.6	5.6	200.0	260.0	-60.0

The effective building, stack, and receptor parameters described above for these two cases were input to AERMOD, and comparisons were made to results reported from the wind tunnel study. Figure 12 shows a comparison of normalized modeled concentrations (Concentration/Emission) for source S349 based on the alternative “effective” building parameters described above (labeled as ‘Alt-EBD’) to results from the CPP wind tunnel study with the “actual” building in place (labeled as ‘Actual’) and based on wind tunnel results for EBD3 determined by CPP as “equivalent” for this case (labeled as ‘CPP-EBD3’). Figure 12 shows generally good agreement between the ‘Alt-EBD’ approach and the ’Actual’ results, especially for the higher concentrations within about 500 meters of the source.

Figure 13 shows concentrations for source S289 based on the alternative “effective” building parameters described above (labeled again as ‘Alt-EBD’) to results from the CPP wind tunnel study with the “actual” building in place (labeled again as ‘Actual’) and based on wind tunnel results for EBD3 determined by CPP as “equivalent” for this case (labeled again as ‘CPP-EBD3’). In this case the ‘Alt-EBD’ shows very good agreement with results for the actual facility at and beyond 400 meters, with some overprediction relative to the ‘Actual’ building case closer to the source. The ‘Alt-EBD’, ‘Actual’, and ‘CPP-EBD3’ results all converge beyond 500 meters.

Although the results presented in this attachment should not be interpreted too literally due to a number of issues associated with developing inputs for AERMOD that would emulate the conditions simulated in the wind tunnel, these comparisons of modeled concentrations for the Alcoa Davenport Works facility appear to confirm our concern regarding the potential importance of including additional roughness elements to represent the actual facility in the wind tunnel simulations conducted to determine EBDs, and therefore corroborate our assessment that the approach taken in the wind tunnel study of including additional roughness elements to represent the roughness associated with the actual facility invalidates the results of the study for those tests intended to demonstrate equivalence of the proposed EBD structure.

The results from these limited tests show some modest overprediction (by about 20%) based on modeled concentrations using BPIPPRM-derived building parameters as compared to “Actual” results from the wind tunnel for source S349, but also show a comparable underprediction by about 20% for BPIPPRM-derived parameters vs. “Actual” results for source S289. Although we recognize the limited nature of these comparisons and the uncertainties associated with interpretation of the results, the lack of significant bias in the results based on BPIPPRM inputs is somewhat encouraging. The results also show encouraging agreement between modeled concentrations and wind tunnel results for the actual facility when effective building parameters are derived based on an alternative approach that uses a displaced “ground surface” to represent the effect that the large sprawling Alcoa structure is likely to have on wind flow affecting the sources of concern. However, we further caution that development of such an alternative approach for determining appropriate building input parameters for the PRIME downwash algorithm within AERMOD would entail several complex issues and challenges and involve numerous case-specific considerations. Therefore, consultation and coordination with the appropriate Region Office would be required before pursuing such an approach.

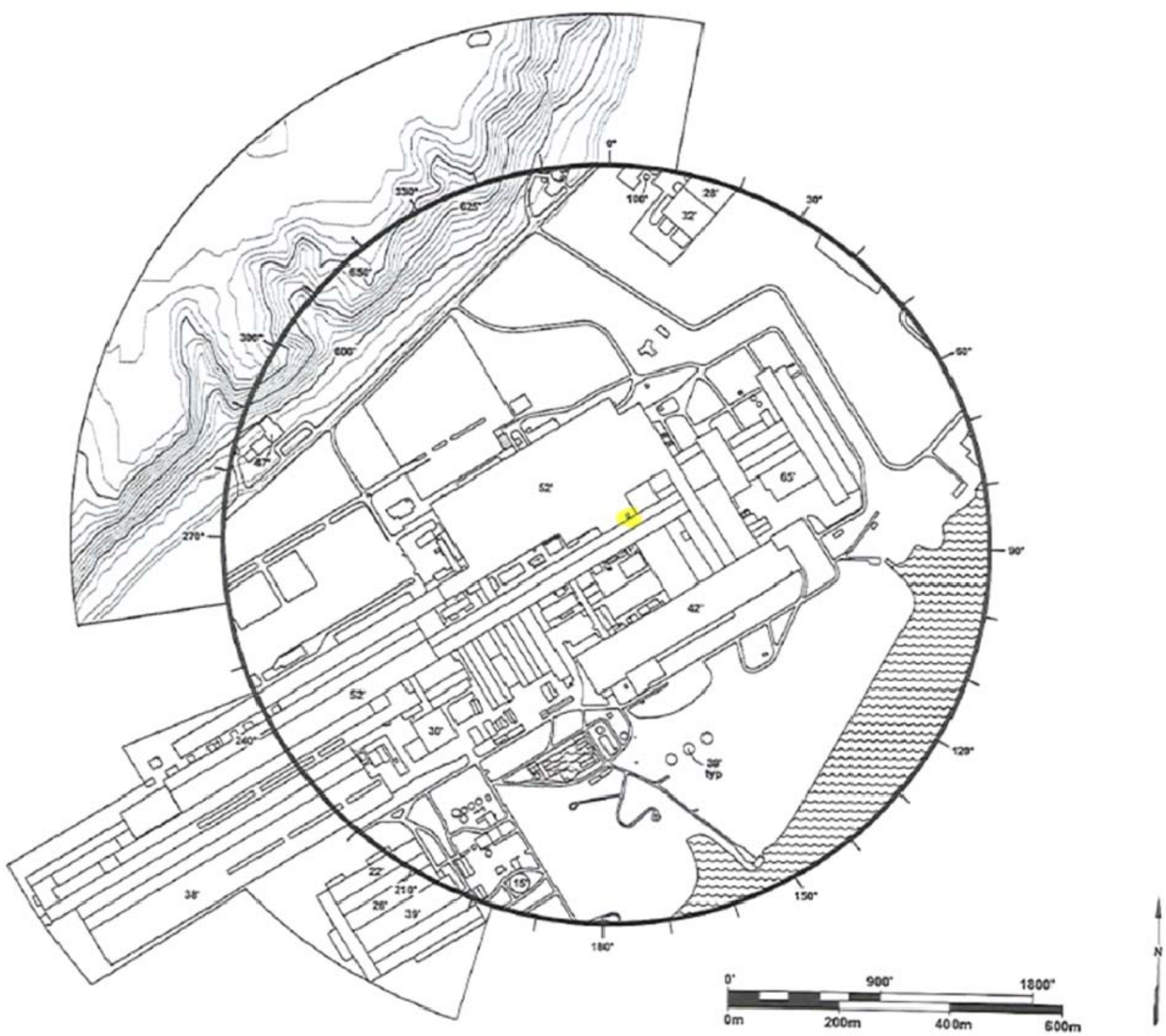

Figure 1. Alcoa Davenport Plant Layout (Figure 5, Part a, of CPP (2009))

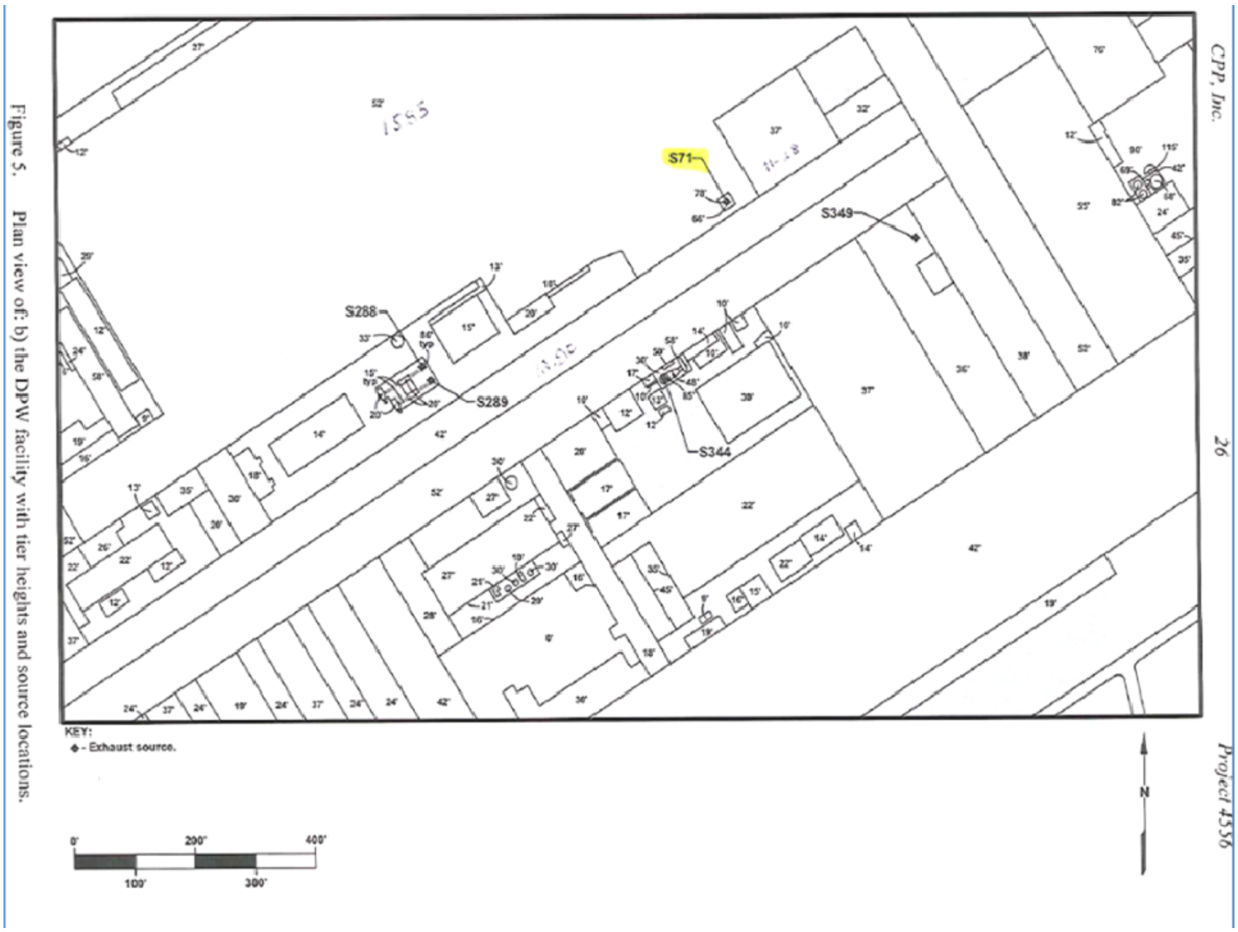

Figure 2. Alcoa Davenport Plant Layout (Figure 5, Part a, of CPP (2009))

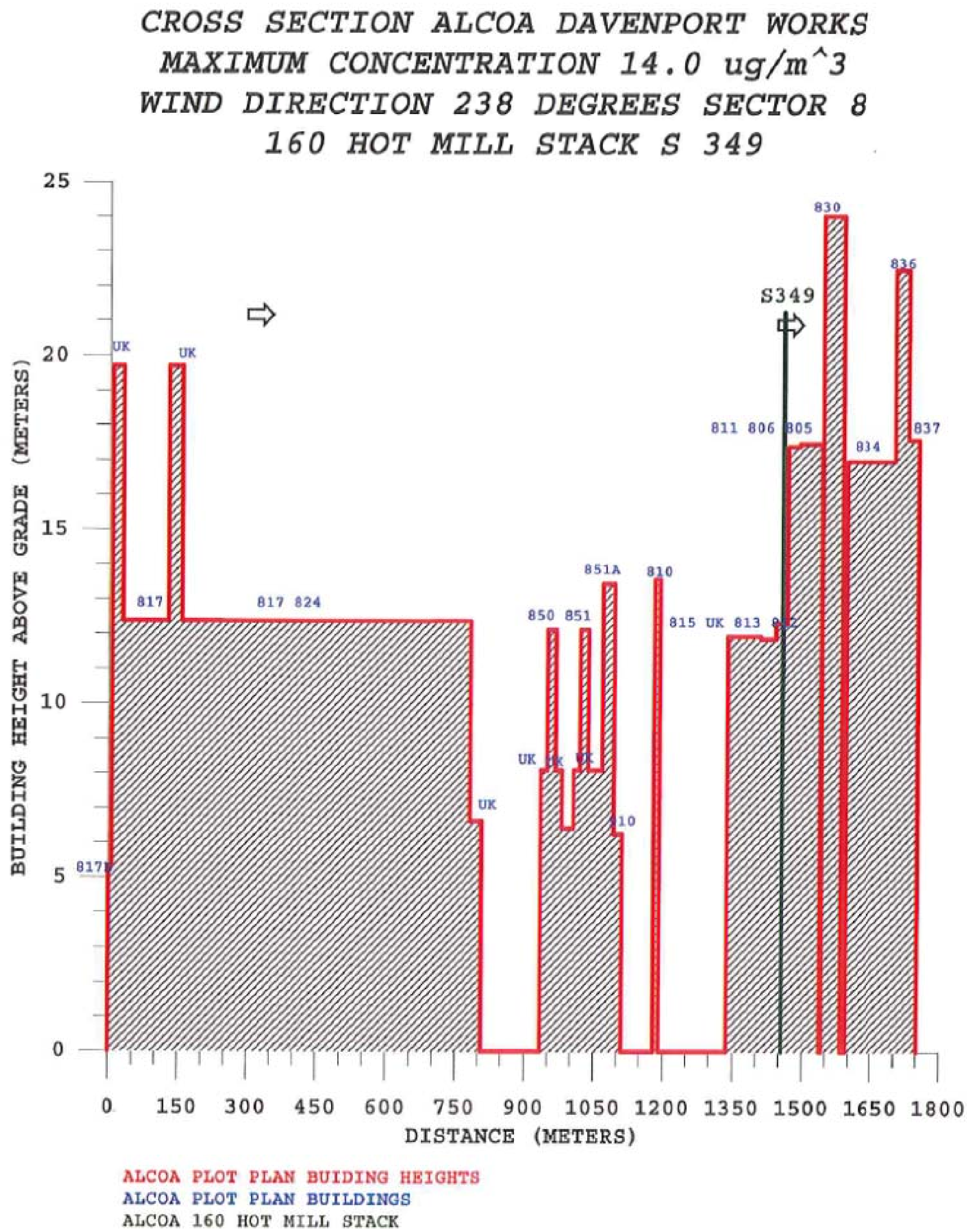

Figure 3. Building Cross-section for Source S349 and 240-degree Wind Direction for Alcoa Davenport Works.

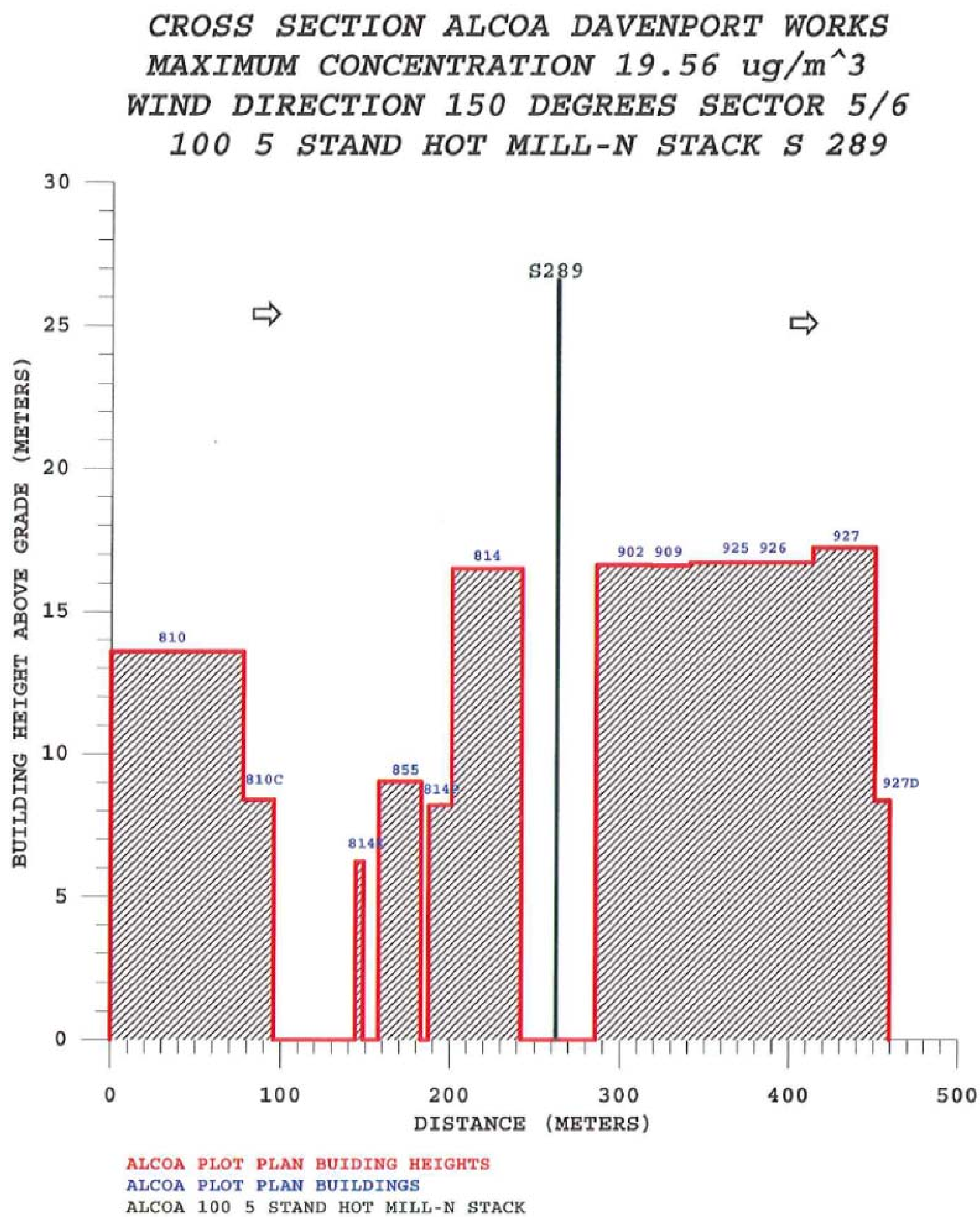

Figure 4. Building Cross-section for Source S289 and 150-degree Wind Direction for Alcoa Davenport Works.

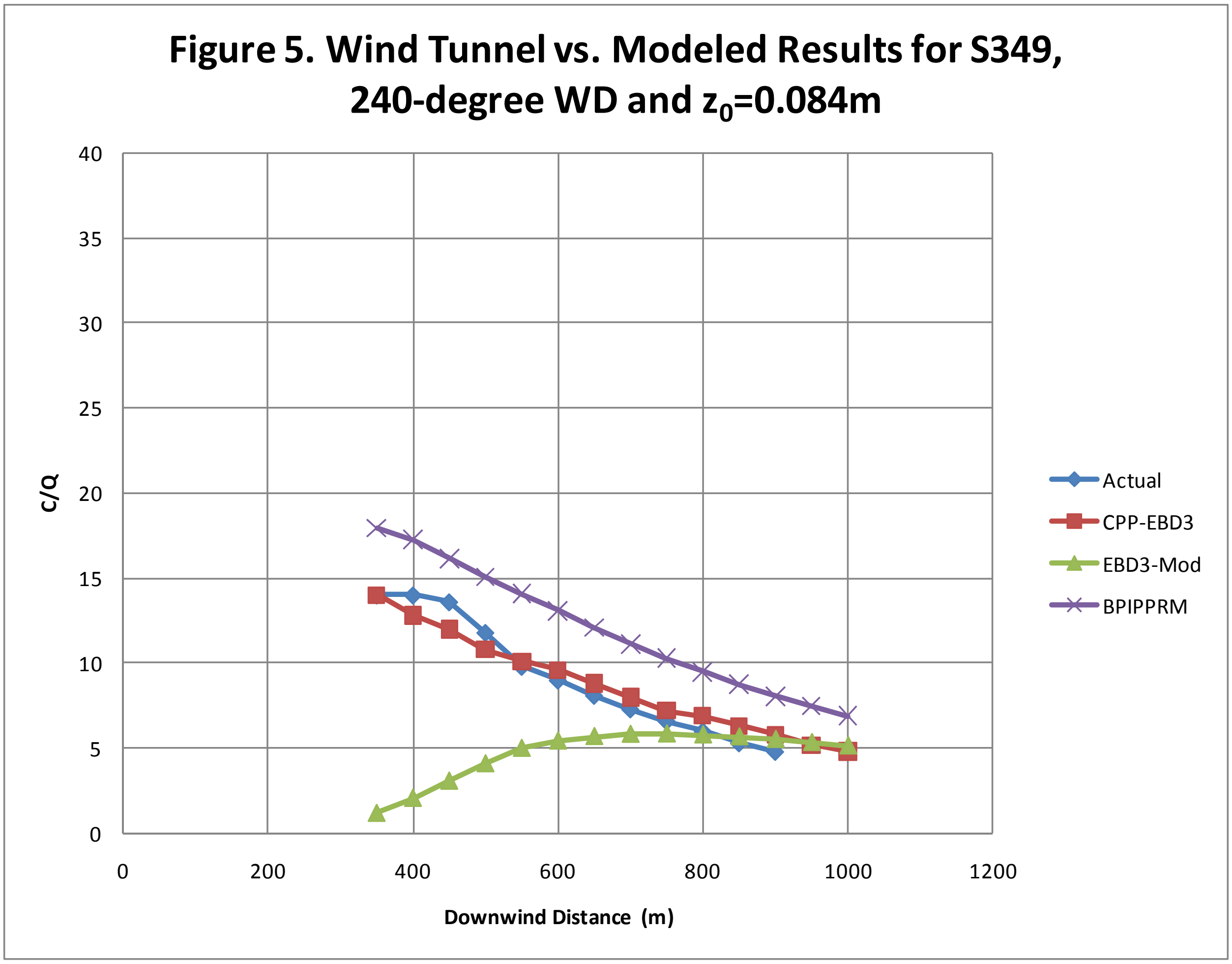

Figure 5. Wind Tunnel vs. Modeled Results for S349,
240-degree WD and z0=0.084m
40
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c/Q
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400
600
800
1000
1200
Downwind Distance (m)
Actual
CPP-EBD3
EBD3-Mod
BPIPPRM

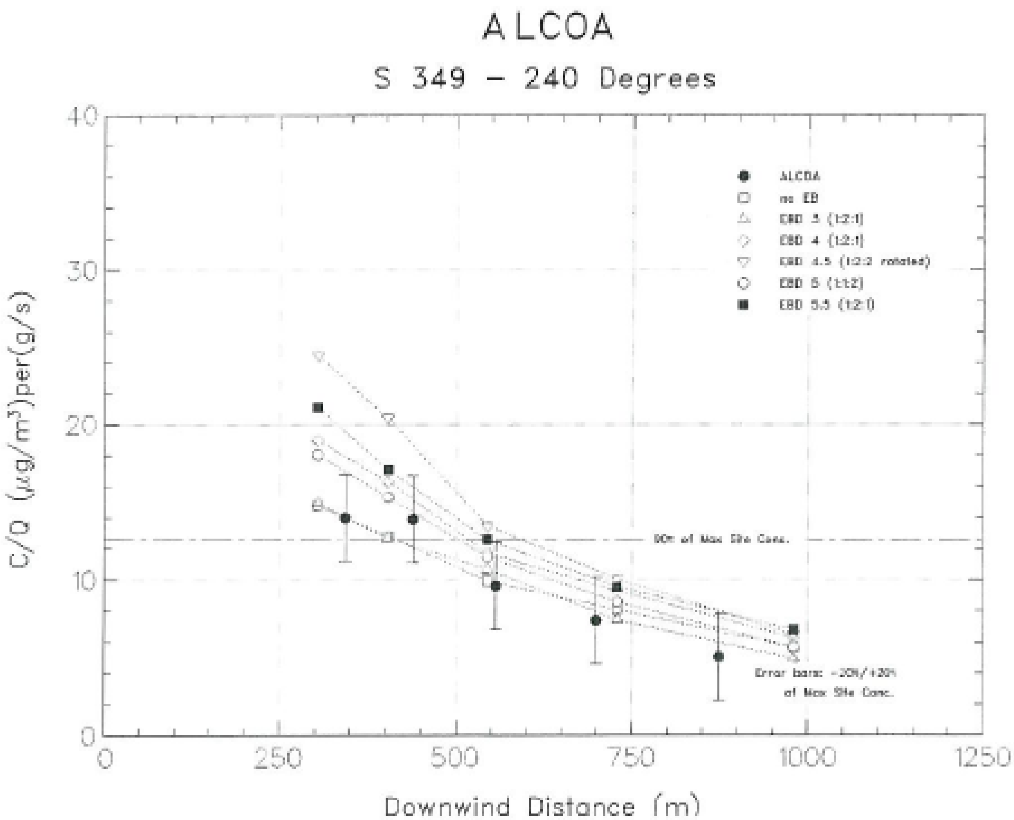

Figure 6. Example of C/Q Plot from CPP Report for S349 with 240-degree Wind Direction

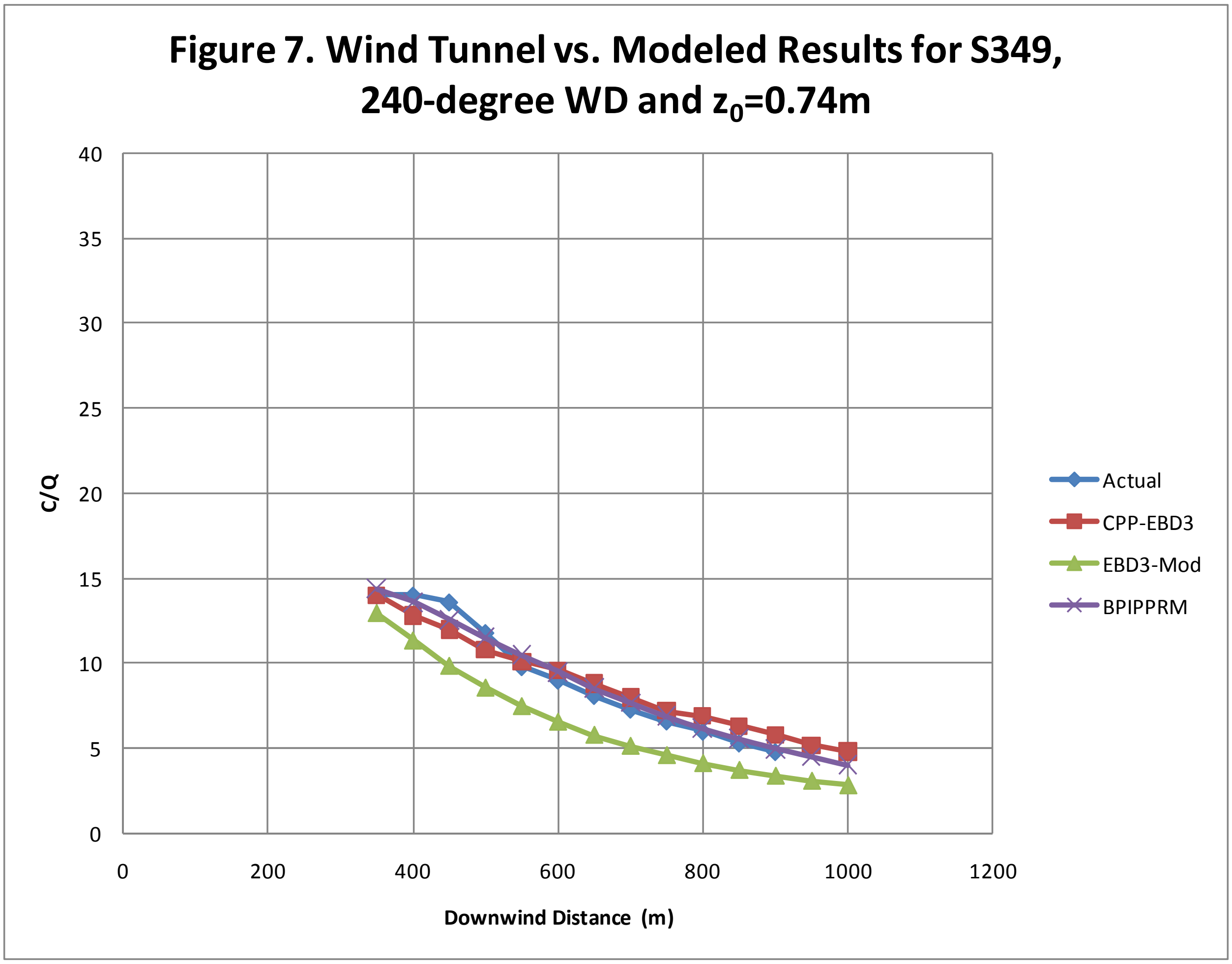
Figure 7. Wind Tunnel vs. Modeled Results for S349, 240-degree WD and z_0=0.74m
40
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c/Q
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1200
Downwind Distance (m)
Actual
CPP-EBD3
EBD3-Mod
BPIPPRM

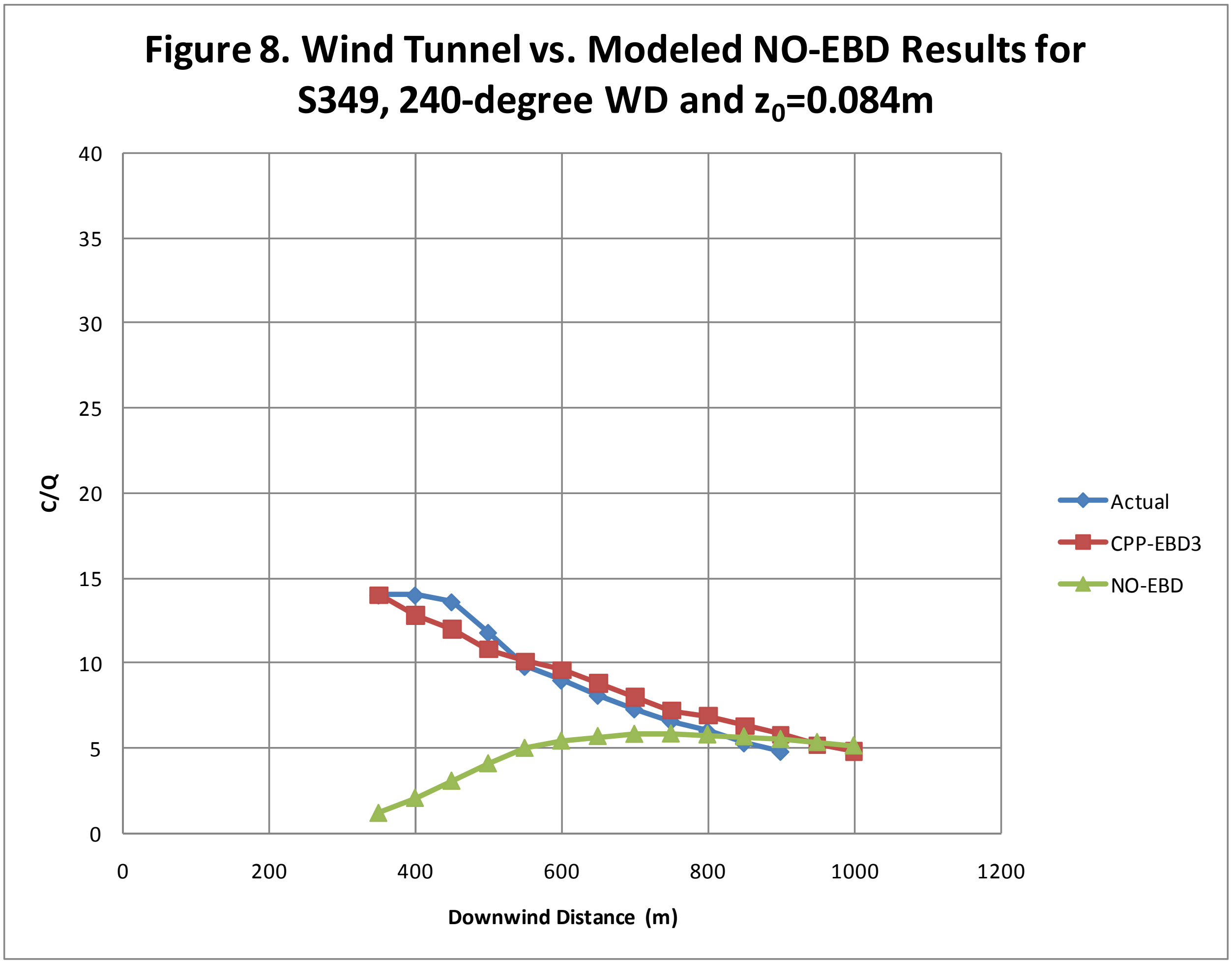
Figure 8. Wind Tunnel vs. Modeled NO-EBD Results for S349, 240-degree WD and z0=0.084m
c/Q
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1000
1200
Downwind Distance (m)
Actual
CPP-EBD3
NO-EBD

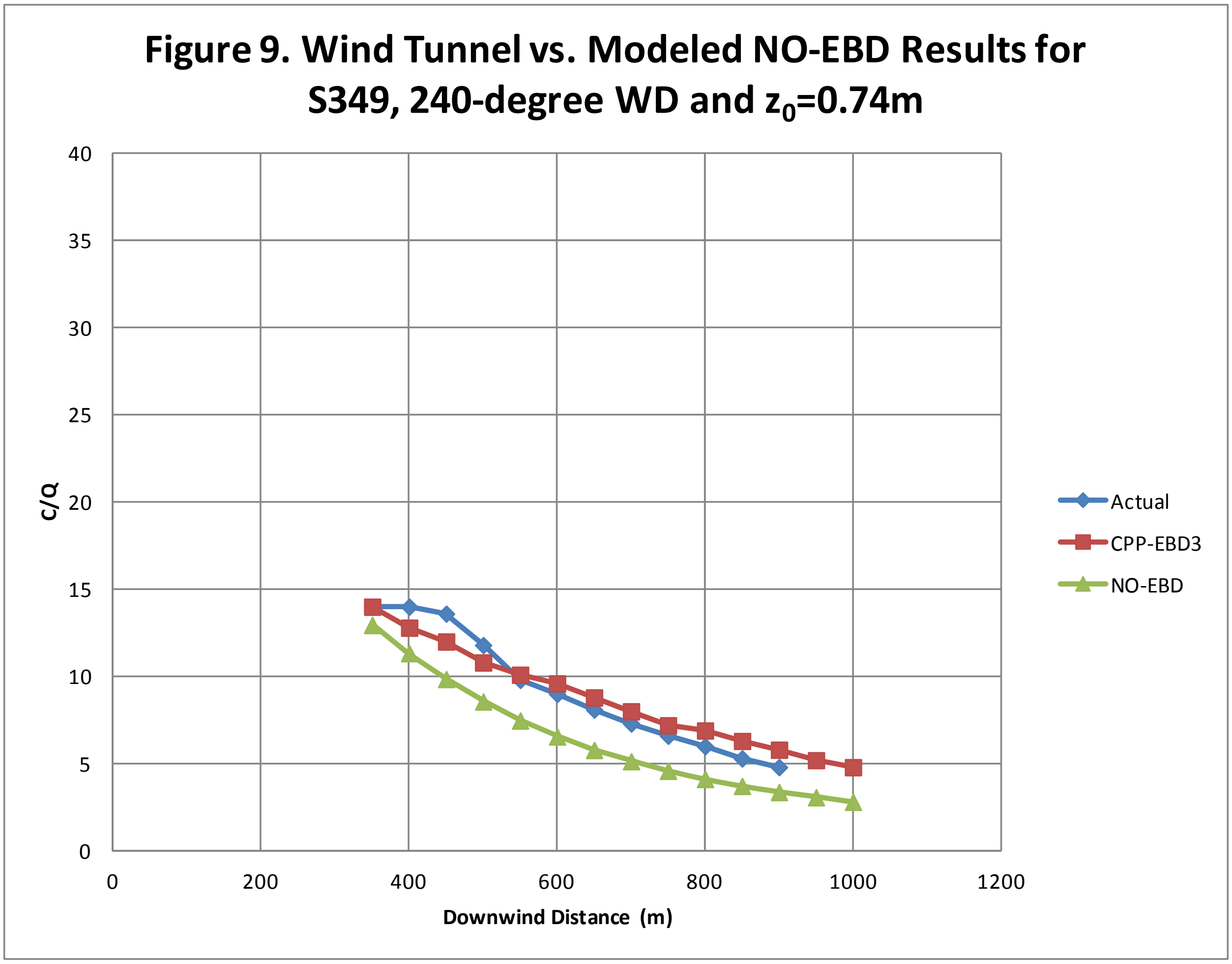
Figure 9. Wind Tunnel vs. Modeled NO-EBD Results for S349, 240-degree WD and z_0=0.74m
40
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c/Q
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200
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600
800
1000
1200
Downwind Distance (m)
Actual
CPP-EBD3
NO-EBD

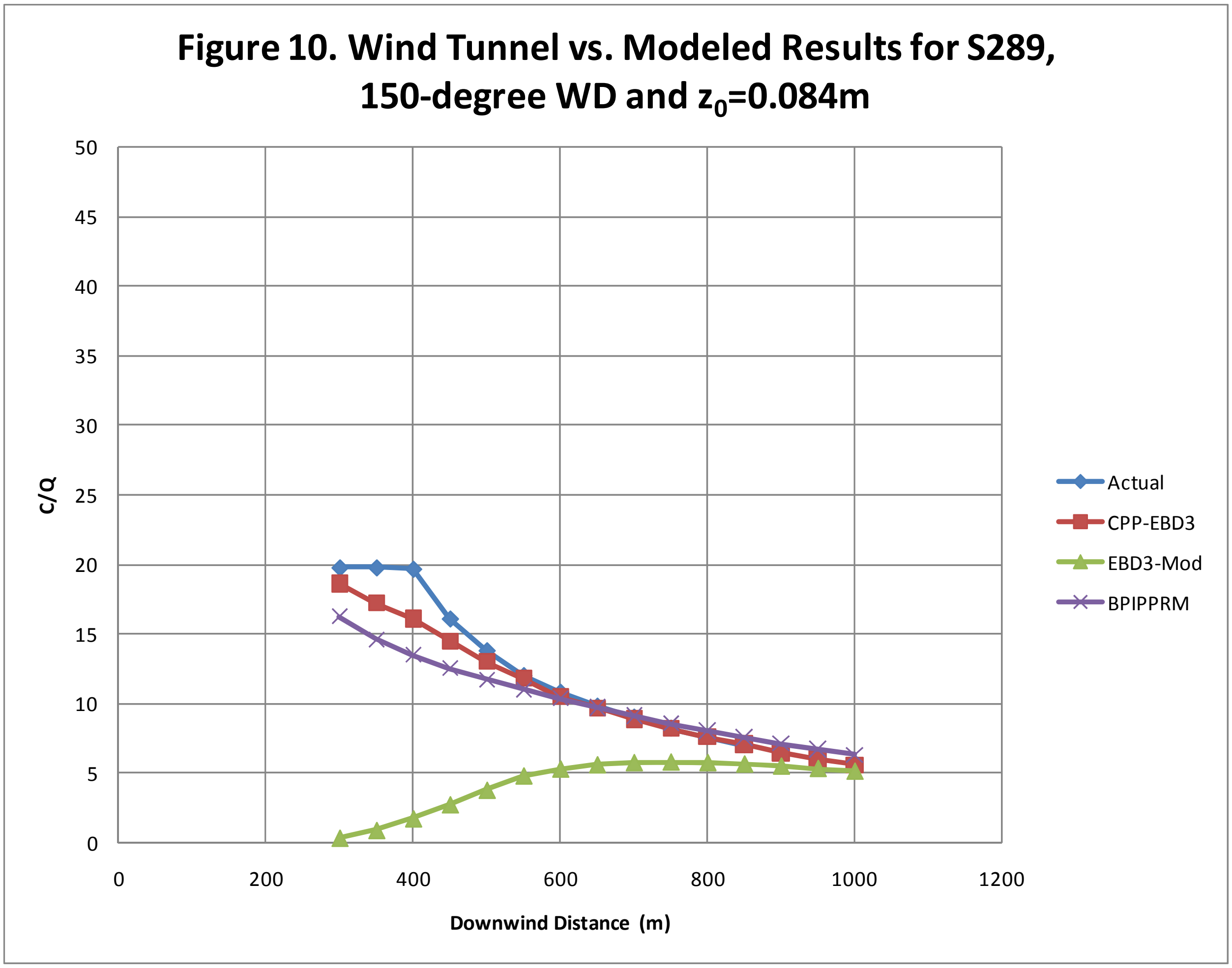
Figure 10. Wind Tunnel vs. Modeled Results for S289,
150-degree WD and z_0=0.084m
c/q
50
45
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1200
Downwind Distance (m)
Actual
CPP-EBD3
EBD3-Mod
BPIPPRM

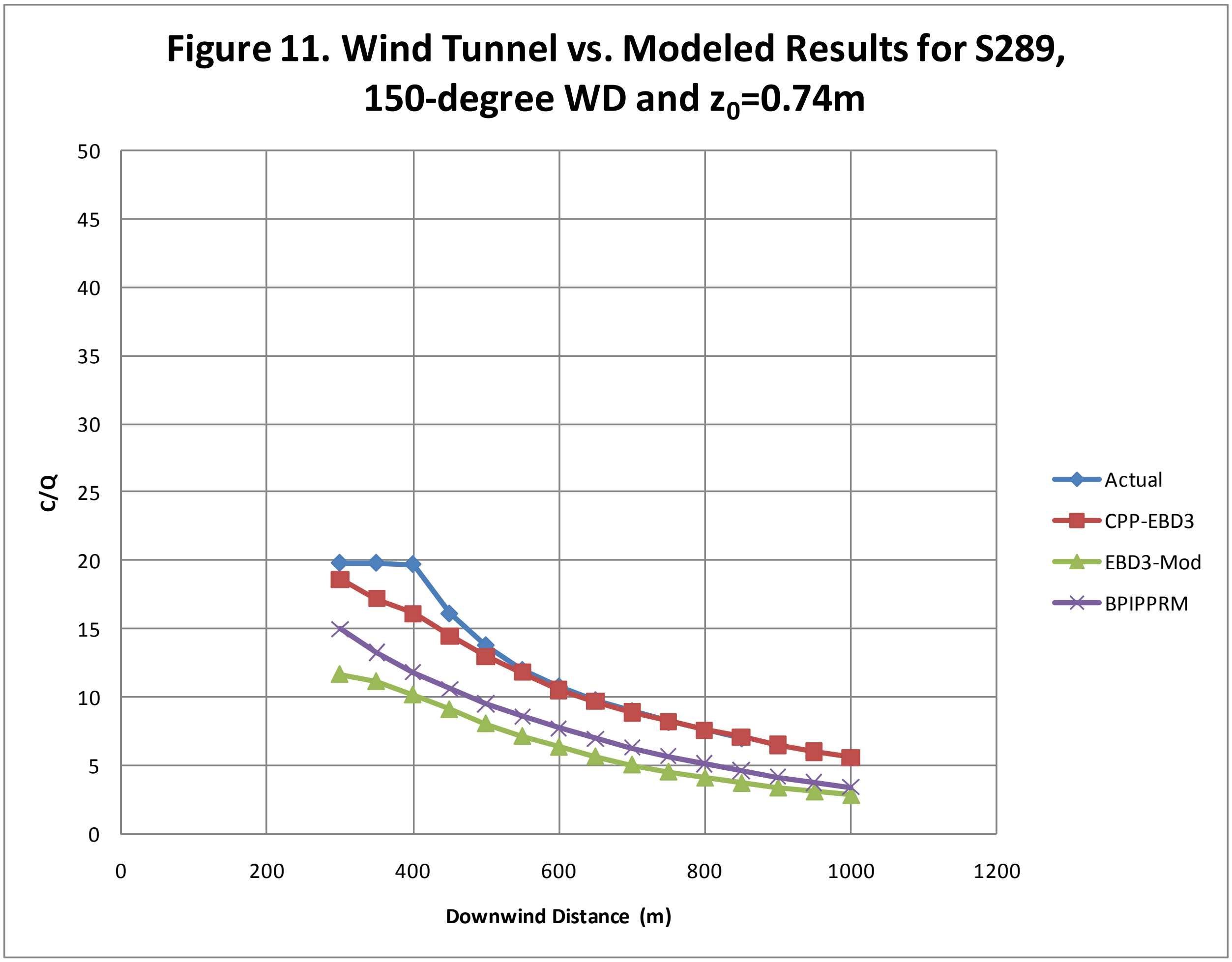
Figure 11. Wind Tunnel vs. Modeled Results for S289,
150-degree WD and z0=0.74m
c/Q
Downwind Distance (m)
0
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10
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1200
Actual
CPP-EBD3
EBD3-Mod
BPIPPRM

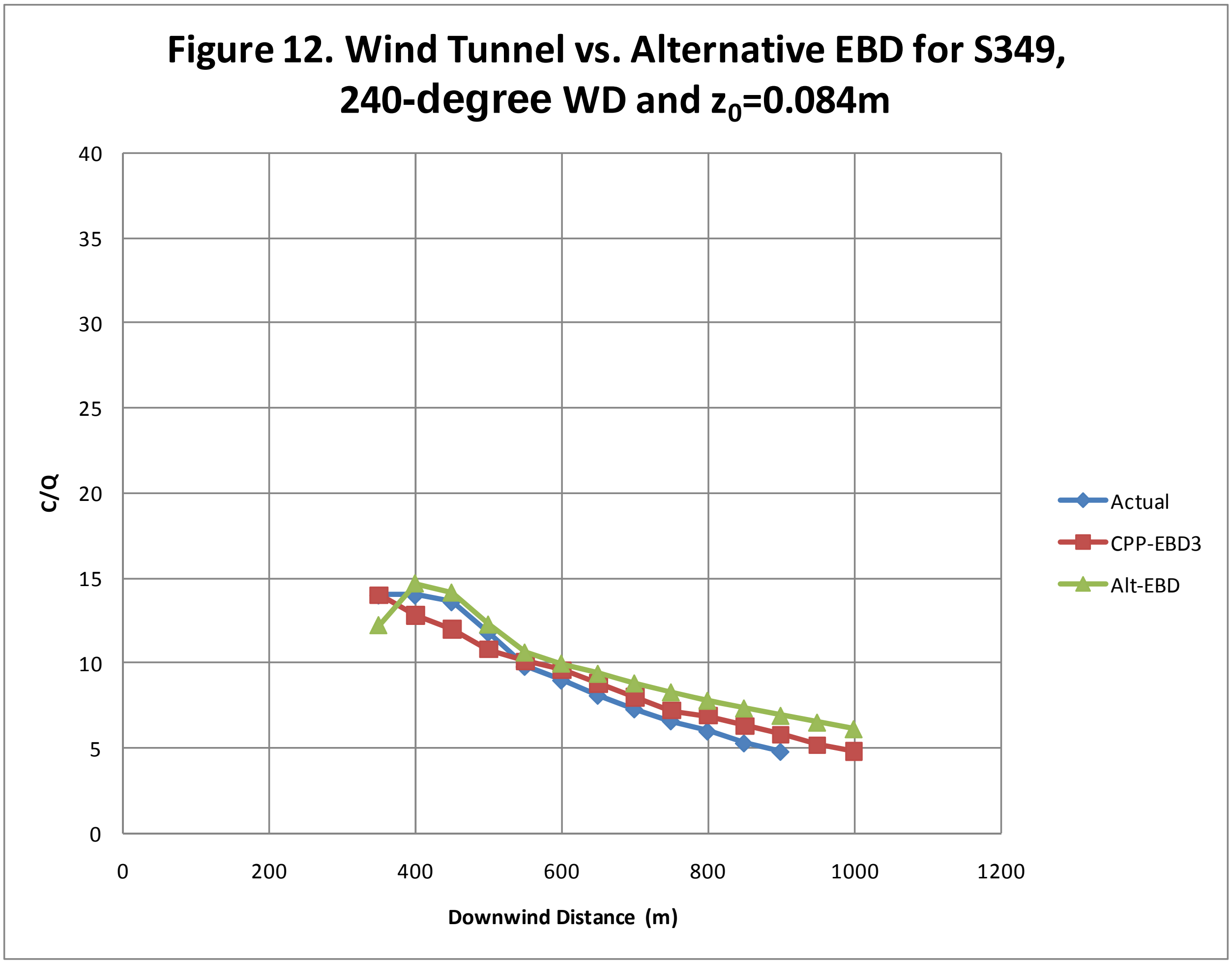
Figure 12. Wind Tunnel vs. Alternative EBD for S349, 240-degree WD and z_0=0.084m
c/Q
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200
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600
800
1000
1200
Downwind Distance (m)
Actual
CPP-EBD3
Alt-EBD

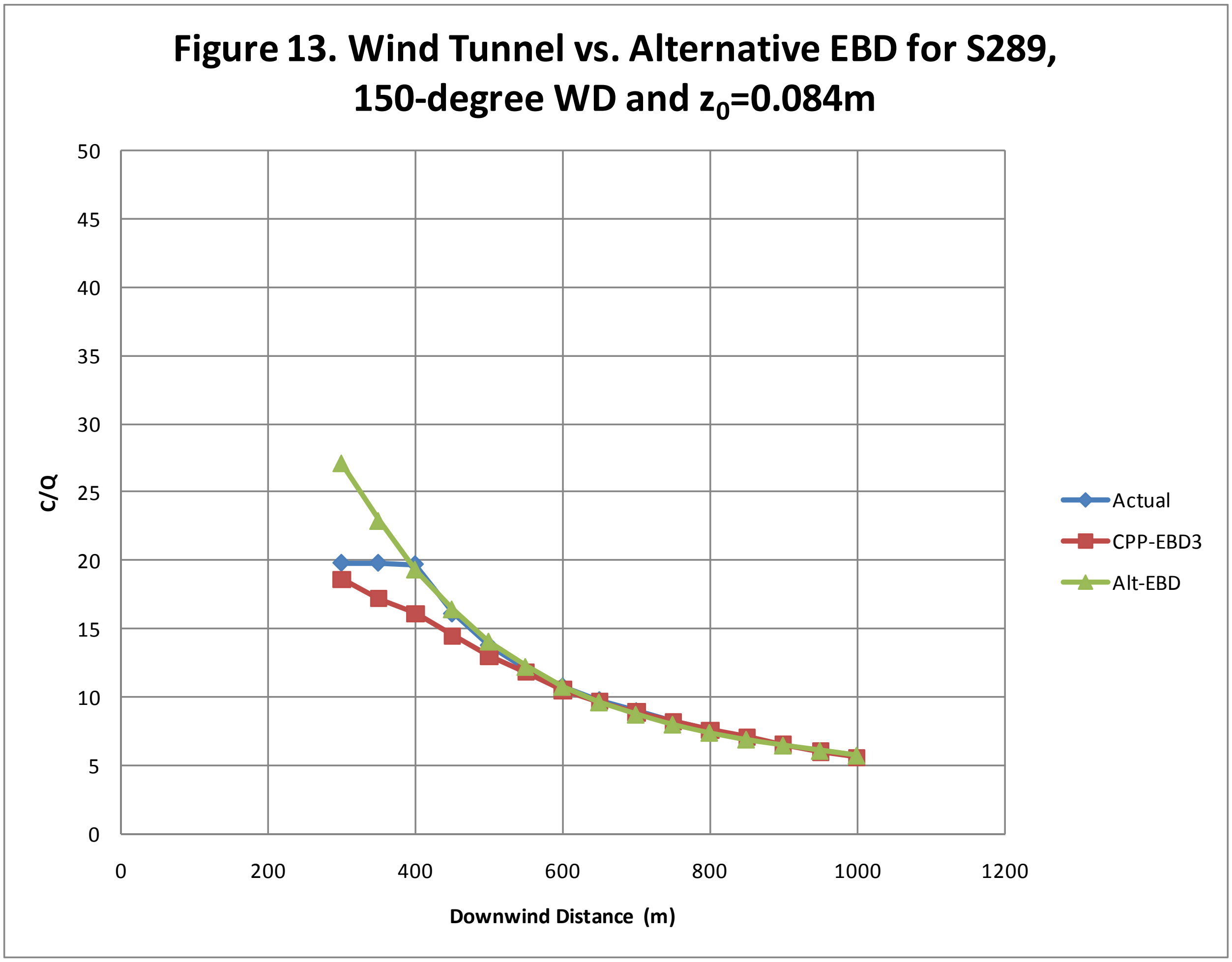
Figure 13. Wind Tunnel vs. Alternative EBD for S289,
150-degree WD and z_0=0.084m
c/Q
50
45
40
35
30
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10
5
0
0
200
400
600
800
1000
1200
Downwind Distance (m)
Actual
CPP-EBD3
Alt-EBD