AERMIC Update

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Outline

- History of AERMIC
- Reconstituted AERMIC
- Summary of AERMIC Activities
- Future plans for AERMOD – Overview
- Issues with BPIPPRM Building Processor

History of AERMIC

- AMS/EPA Regulatory Model Improvement Committee initially formed in 1991; charged to develop replacement for ISCST based on state-of-the-science
  - AERMOD promulgated Dec. 2006
  - Membership of “new” AERMIC committee:
    - Roger Brode, EPA/OAQPS, Co-chair
    - Jeff Weil, CIRES-NCAR, Co-chair
    - Akula Venkatram, UC-Riverside
    - Al Cimorelli, EPA Region 3
    - Steve Perry, EPA/ORD/AMD
    - Vlad Isakov, EPA/ORD/AMD

Summary of AERMIC Activities

- AERMIC has held several meetings in RTP since being reconstituted in 2008
- Key focus for AERMIC has been Urban formulation
- AERMIC recognized significant overlap among issues, including Urban, Surface Characteristics and Met Data
- AERMIC also recognized opportunities to address many implementation issues by utilizing newly available data:
  - NLCD land cover data
  - Use of SRTM-NED elevation data to determine height of obstacles
  - Detailed urban morphology data for several cities

Summary of AERMIC Activities

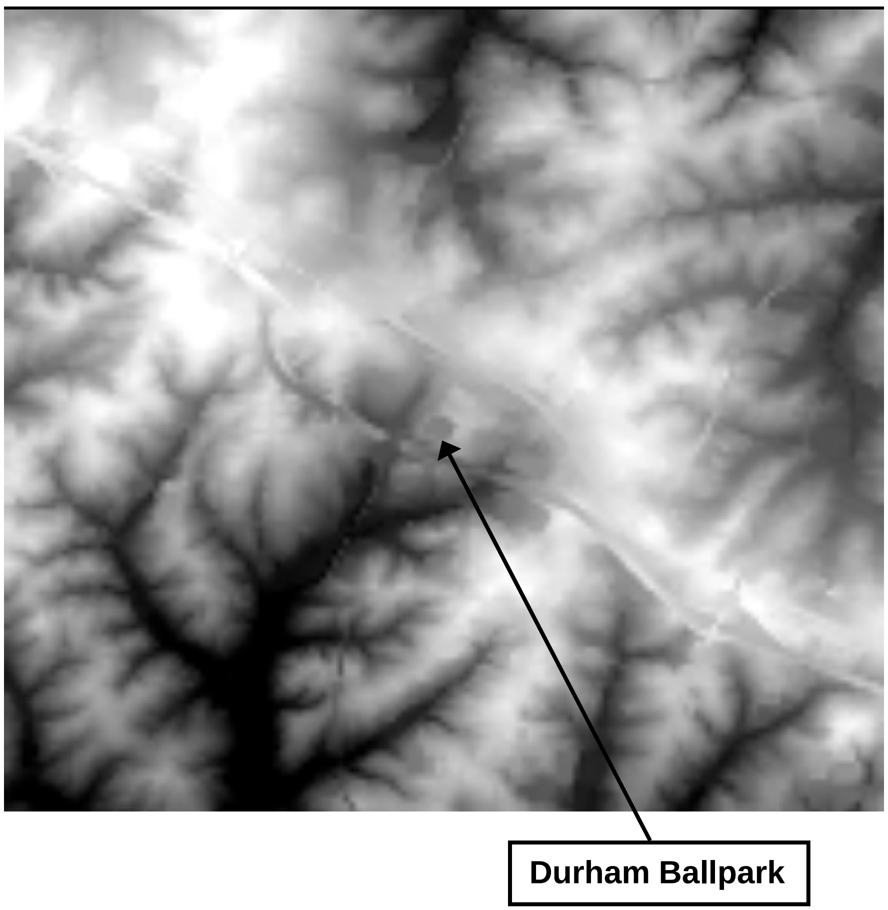
- In addition to developing broad plans for enhancements to the AERMOD modeling system, AERMIC has also addressed several specific issues that have arisen:
  - Assess issues and develop appropriate approaches to address concerns about AERMOD model performance for low wind conditions
  - Address “line” source modeling capabilities, especially inconsistency in AERMOD where POINT and VOLUME sources incorporate horizontal meander algorithm, but AREA sources do not
  - Development of method for estimating effective surface roughness, a key input to AERMET meteorological processor, discussed earlier
  - Review building downwash issues and develop recommendations for alternative building parameters for PRIME algorithm in AERMOD
  - Provide recommendations related to urban morning transition “formulation bug” fix incorporated in version 11059 of AERMOD

Future Plans for AERSURFACE

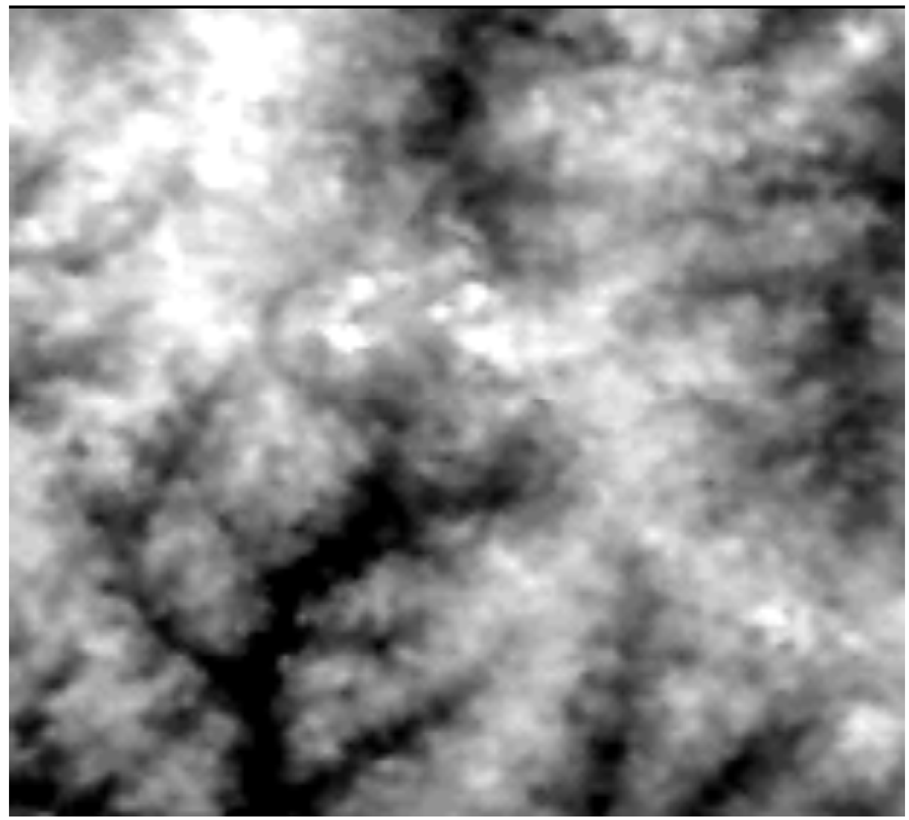
- NED and SRTM elevation data are both available at 1-sec (~30m) horizontal resolution for most of U.S. (no SRTM in northern AK)
  - Same resolution as NLCD data
  - NED represents ground elevations
  - SRTM represents elevations of obstacles:
    - "The elevation data are with respect to the reflective surface, which may be vegetation, man-made features or bare earth." (USGS Product Description)
- Coupling estimates of average height of obstacles with NLCD data should facilitate better estimates of surface roughness
  - Allows for distinguishing between "highly developed" grid cells (based on impervious land cover fraction) that are runways vs. buildings

NED vs. SRTM Elevations for Durham

NED Data



SRTM Data



Aerial Photo for Durham

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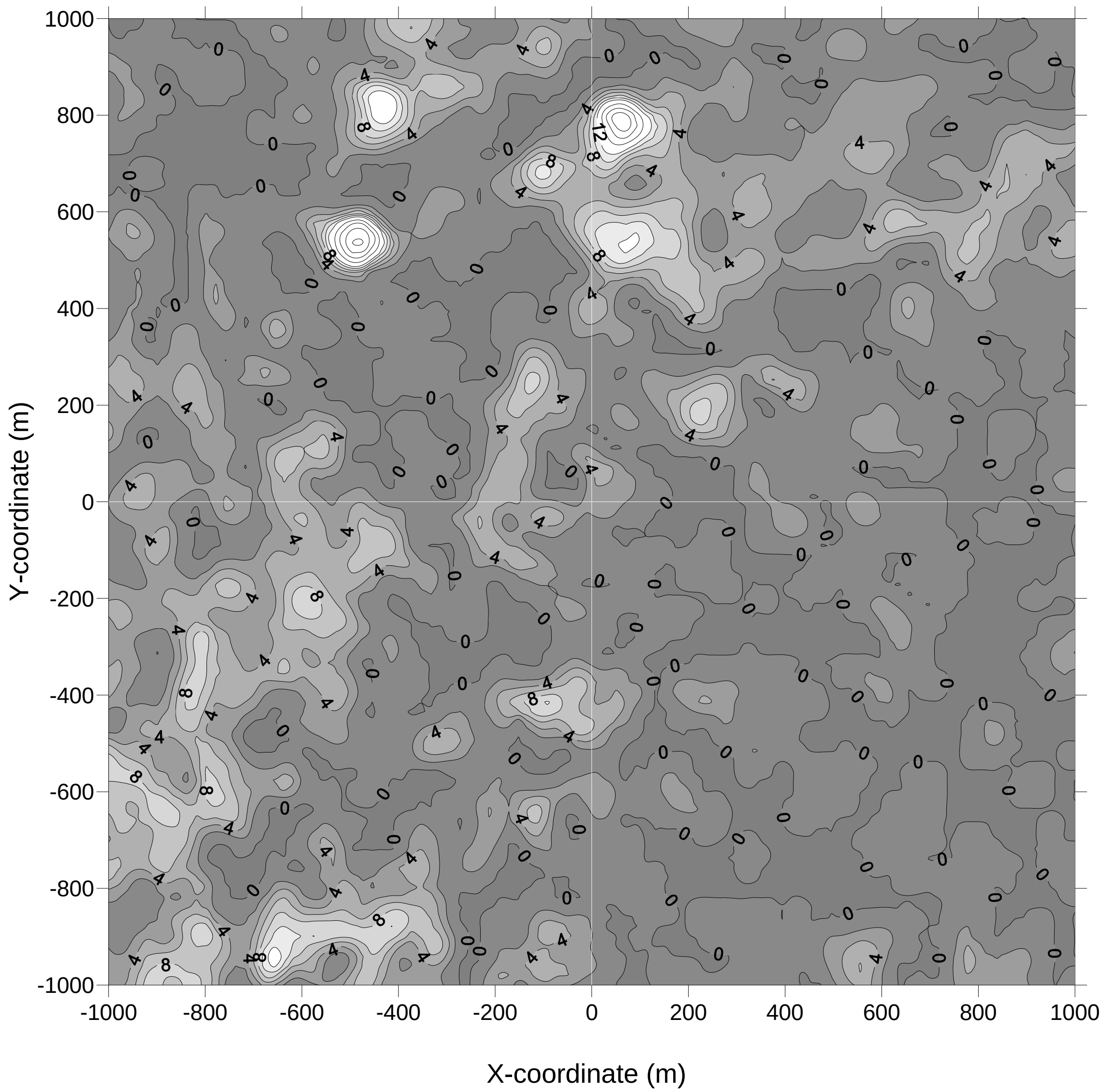
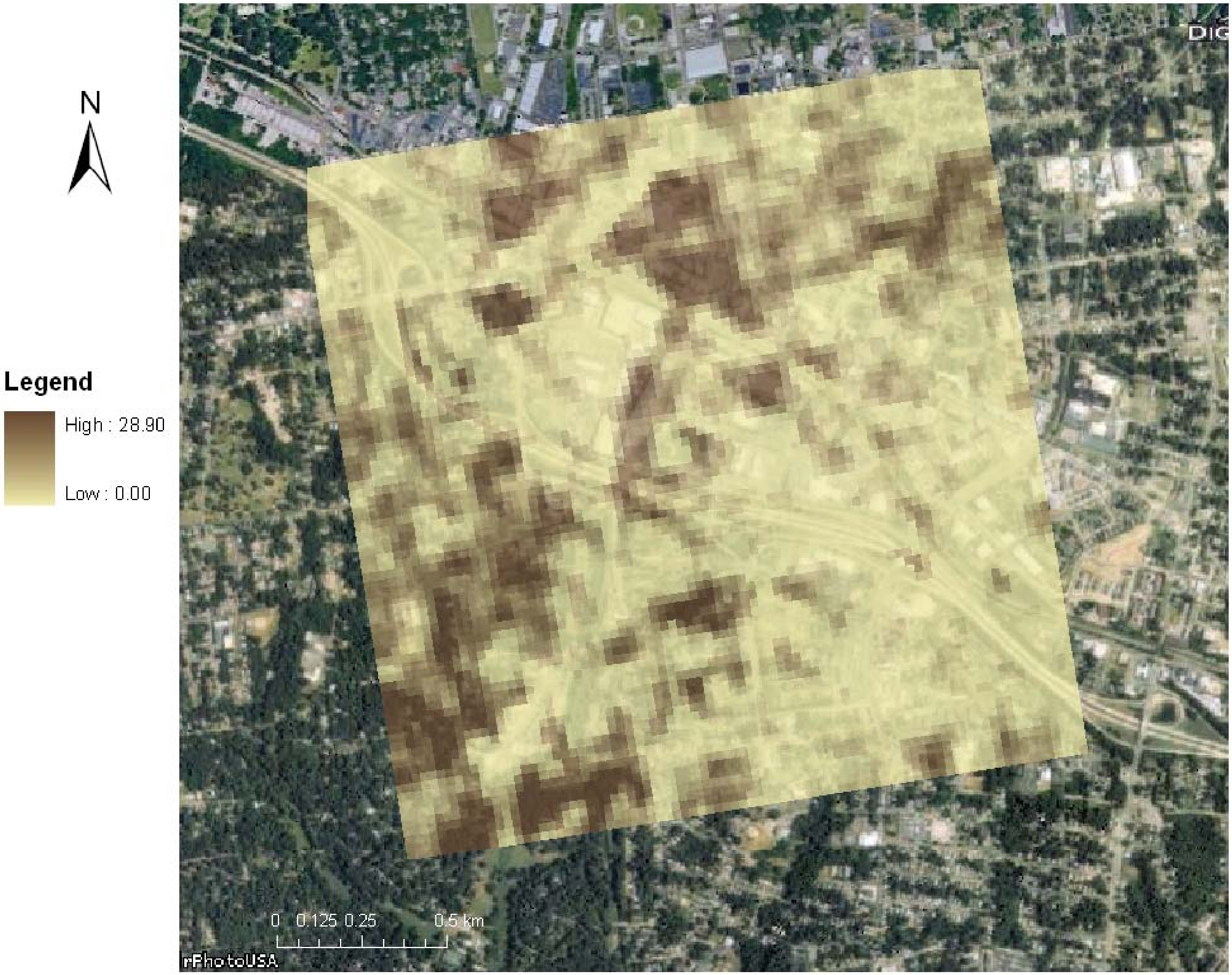
Legend

SRTM-NED Elevations for Durham

Contour Plot of Elevation Differences (m) from SRTM - NED Data for
Downtown Durham; (0,0) = Durham Ballpark - Corner of 1st Baseline



SRTM-NED Elevations for Durham



AERMIC - Future Plans for AERMOD

- Building on plans to enhance AERSURFACE by combining land cover and elevation data, AERMIC is developing an approach to address a wide range of issues by utilizing this data directly in the model
- Land cover and elevation data (SRTM-NED) could be fed directly to AERMOD to develop source-specific meteorology accounting for land cover and obstacle heights around source and met tower
- Meteorology adjustments would also account for effect of urban canopy on wind profiles

Future Plans for AERMOD (cont.)

- This approach could eliminate many implementation issues, especially related to urban applications
  - No distinction between “rural” and “urban” sources
  - No requirement to estimate “effective” population as surrogate for urban influences
  - Spatial and temporal variability of urban heat island influence could be accounted for
  - Representativeness of met data will always be an issue, but influence of surface characteristic variability on that determination should be mitigated
- Considerable work will be required to implement this plan, including performance evaluations

Future Plans for AERMOD (cont.)

- Incorporating fuller range of data directly into AERMOD could eliminate need for preprocessors, including AERMAP, AERMET, and AERSURFACE
- Access to “raw” input data in AERMOD may allow other enhancements, such as direction-specific “hill height scales” for terrain influences
- New AERMOD structure will better accommodate future enhancements as new data sources emerge
- Downside is that this plan is not likely to speed up AERMOD!

Other AERMIC Recommendations

- AERMIC discussed issues associated with building downwash in AERMOD
  - Recommended incorporating building processing function within AERMOD, which eliminates need for separate BPIPPRM processor, may allow more refined methods for determining controlling structure
  - Facilitates assessment of additional options for processing building information for PRIME, including alternative criteria for determining controlling structure; possibility of combining influences from multiple structures; and option for looping through all influencing structures to determine worst-case
  - AERMIC also suggested an approach based on a revised method for "blending" AERMOD and PRIME that could mitigate many of the issues with BPIP and PRIME. This also includes a modified approach to estimating direction-specific building dimensions for input to AERMOD that may address issues with long narrow buildings

Other AERMIC Recommendations

- AERMIC has been involved in efforts to assess and enhance AERMOD's capabilities to estimate impacts from mobile sources
  - Several field studies and wind tunnel studies have been conducted, are underway, or planned to address near-roadway exposure issues
  - Inconsistency in AERMOD's treatment of horizontal meander for volume sources (does) vs. area sources (doesn't) is a factor in these applications
  - Important to understand the complexity of evaluating the modeling system performance for such applications
    - Uncertainties in quantifying temporally and spatially varying non-stationary emissions from sources
    - Uncertainties in characterizing "release" parameters for those emissions
    - Complex influences from roadway design and local land cover characteristics
    - Many important generic issues, such as low wind speeds and surface characteristics variability, play significant role in these applications
  - Practical issue of model runtime for large-scale application of AERMOD for this purpose is also recognized

Other AERMIC Recommendations

- AERMIC has also discussed the use of gridded prognostic meteorological with AERMOD and will provide science support for the development and evaluation of options related to this effort
  - Recommends implementing and testing approach of processing gridded met data as pseudo-observations through AERMET, in addition to approach implemented in MM5-AERMOD Tool
  - Consideration of options to incorporate some non-steady-state characteristics in AERMOD modeling system, possibly driven by gridded meteorological model inputs

BPIPPRM Building Processor Issues

- Several potential issues and concerns regarding BPIPPRM were presented at the 9th Modeling Conference:
  - Original criterion in BPIP for selecting dominant tier for previous algorithms (tier with highest GEP height) may not always be applicable for PRIME, since downwash influence in PRIME also depends on location of stack relative to the building:

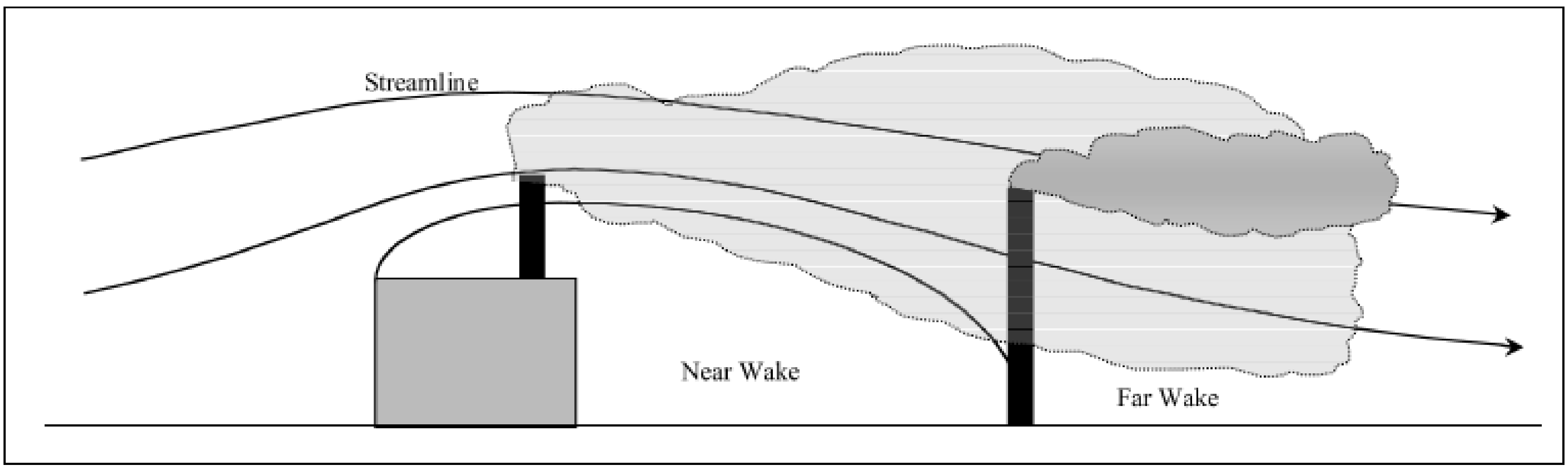


Figure 2. Schematic of building downwash for two identical plumes emitted at different locations. The plume released from the rooftop stack has a larger rate of growth and more descent than the plume released farther downwind.

From Schulman, L.L., D.G. Strimaitis and J.S. Scire, 2000. Development and evaluation of the PRIME plume rise and building downwash model. *Journal of the Air and Waste Management Association*, **50**: 378-390.

BPIPPRM Building Processor Issues

- Several potential issues and concerns regarding BPIPPRM were presented at the 9th Modeling Conference:
  - "Split-building" phenomenon – model produces lower estimates when a building is entered as two adjacent tiers of equal height – BPIPPRM selects the structure with the minimum width if two structures have the same GEP height, which will generally cause less downwash and lower concentrations than a wider structure
  - Also, if building is “split” into two equal halves, the results will depend on the order in which the two halves are input since BPIPPRM uses the first tier if GEP height and width are the same
  - Long narrow buildings - projected length is much longer than actual along-wind fetch for some wind angles; cavity is rotated based on the wind angle and positioned relative to projected building rather than the actual building
  - 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 – procedures developed for use with previous downwash algorithms may not be appropriate for PRIME downwash due to cavity algorithm and more refined treatment of stack/building geometry (the issue was also addressed in Oct. 2011 Model Clearinghouse memorandum)

BPIPPRM Building Processor Issues

- Several potential issues and concerns regarding BPIPPRM were presented at the 9th Modeling Conference (cont.):
  - Horizontal meander algorithm currently not incorporated in PRIME component of AERMOD
  - AERMOD-PRIME does not account for upwind dispersion for plume released within the cavity due to recirculation
  - PRIME includes partial plume entrainment into the cavity, but the wake effects switch is "all-or-nothing" - a formulation change to allow partial entrainment into the wake may reduce some discontinuities in model results, especially for CBL conditions where near field updraft/downdraft influences could be important
  - Draft BETA-test options for capped/horizontal stacks subject to downwash incorporated in AERMOD, but some verification or validation is needed
  - Is there a minimum wind speed needed for downwash?

BPIPPRM Building Processor Issues

- AERMIC developed several recommendations related to these BPIPPRM issues, including:
  - Use actual projected building width (W), but redefine effective building length as L = Ap/W, where Ap is area of the building footprint, i.e., conserving the building volume.
  - Consistent with the ideas for projected (horizontal) building dimensions, it was suggested to use an effective building height, heff = Av/W, where Av is the vertical projected area of the building. This would allow for combining multiple tiers on a structure in a manner that should mitigate the issue associated with the current criterion for selecting the controlling structure based on highest GEP height in some cases (such as a small penthouse on a large building being selected, but ignoring the building itself).

BPIPPRM Building Processor Issues

- Additional BPIPPRM issues have recently emerged:
  - Use of 5L limit on structure influence zone (SIZ) has been reassessed (see Clarification Memorandum presentation):
    - 5L limit is incorporated in GEP stack height regulations in the definition of “nearby” related to which structures can be considered in determining GEP stack height, but technical evidence is clear that significant building downwash influences can extend beyond 5L
  - BPIPPRM is apparently using the minimum actual distance between two structures to determine whether nearby structures should be combined based on a distance of less than L, rather than the projected gap
  - If two structures are close enough to be combined in terms of their downwash influence, then it may not make physical sense to also consider the influence of the individual structures – since BPIPPRM currently selects the structure with the smallest projected width if the GEP heights are the same, BPIPPRM will generally not select the combined structure in these cases, even though it may be likely to have greater influence

Current Plans for BPIPPRM

- Given the range and number of issues identified with BPIPPRM, it will take some time to fully address them:
  - Focus will initially be on the simplest issues, with the most clear-cut fixes, such as:
    - Correct BPIPPRM to use the projected gap between the projected buildings in determination of which tiers to combine;
    - Modify BPIPPRM to ignore individual tiers when multiple tiers are combined;
    - Incorporate internal checks in BPPPRM to flag building tiers with slight differences in tier height, which results in BPIPPRM selecting the tier with the higher GEP height even though the differences in height are negligible – also develop guidance for users on how to define building tiers for input to BPIPPRM to avoid such problems;
  - Develop options for adjusting the structure influence zone (SIZ) currently implemented in BPIPPRM, based on 2L upwind, 5L downwind, and 0.5 L on either side of a structure, to address reassessment of the inappropriateness of the 5L limit in BPIPPRM
  - Evaluate options to redefine effective building parameters for input to AERMOD, beginning with the projected length parameter (preliminary results of recent tests are presented below)

Preliminary Results – Effective Length

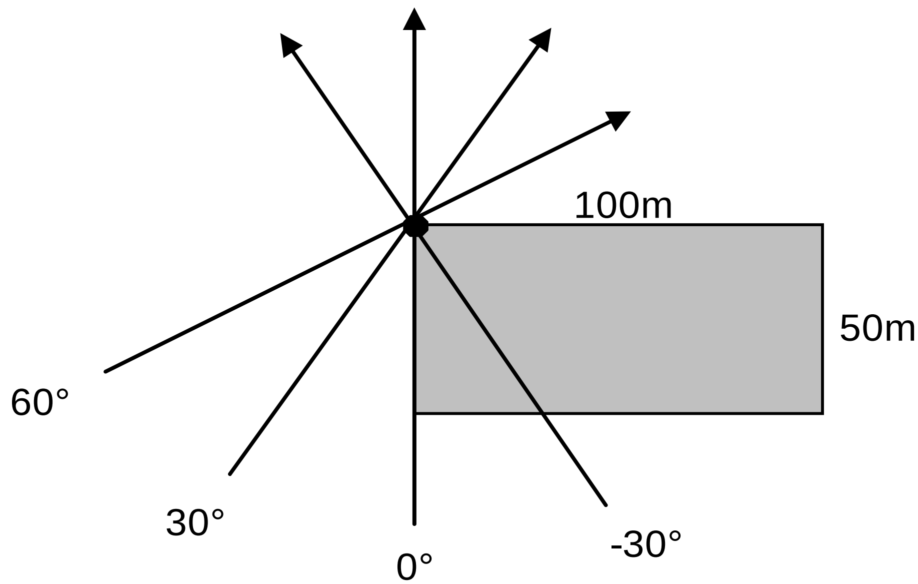
- An alternative "effective" building length parameter has been compared to the current BPIPPRM approach based on the projected building length, using wind tunnel data derived from Alan Huber's 1989 ***Atmospheric Environment*** paper titled "*The Influence of Building Width and Orientation on Plume Dispersion in the Wake of a Building*" (**Vol. 23**, No. 10, pp. 2109-2116);
- This preliminary Effective Length approach takes into account the actual alongwind fetch across the building, with some adjustments for stacks located at the corner of the building for orientations with no alongwind fetch;
- The Effective Length approach is still under development and more details regarding the approach will be provided at a later time;
- Huber's wind tunnel study examined the effects of building width for buildings having width-to-height ratios ranging from 2 to 22, and also examined the effects of oblique orientations of buildings relative to the wind flow for angles ranging from -30 to +60 degrees. Several configurations of stack height and placement relative to the building were examined, but the evaluation results summarized below focus on those scenarios that are most relevant to the issue of effective building lengths for elongated buildings at a angle to the wind.

Preliminary Results – Effective Length

- The comparisons presented below include two configurations of building/stack geometry, as follows:
  - stack located at the downwind corner of a building with a width/height ratio (W/Hb) of 2;
  - stack located at the downwind center of a building with a width/height ratio of 2;
- Modeled results have been normalized to match the wind tunnel results for the 0° orientation where the effective length and projected length are equal
- These cases are illustrated in next slides

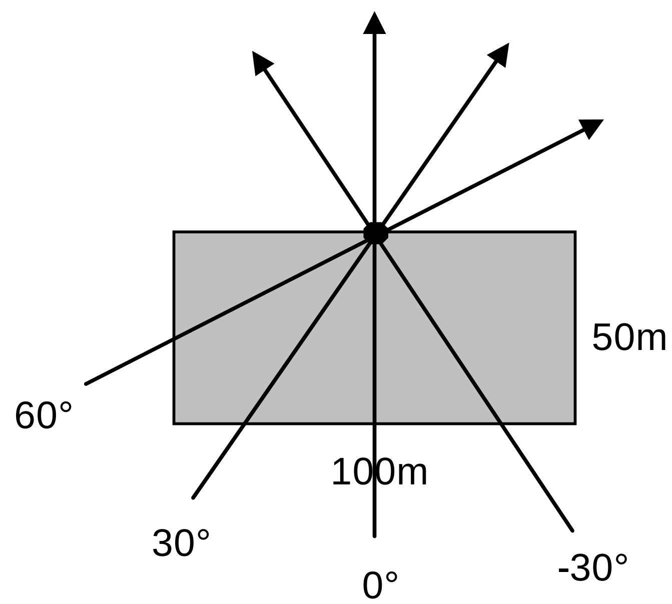
Preliminary Results – Effective Length

Fig. 1. Huber Wind Tunnel Study - Case S2 - Source at Downwind Corner of Building (W=2Hb)

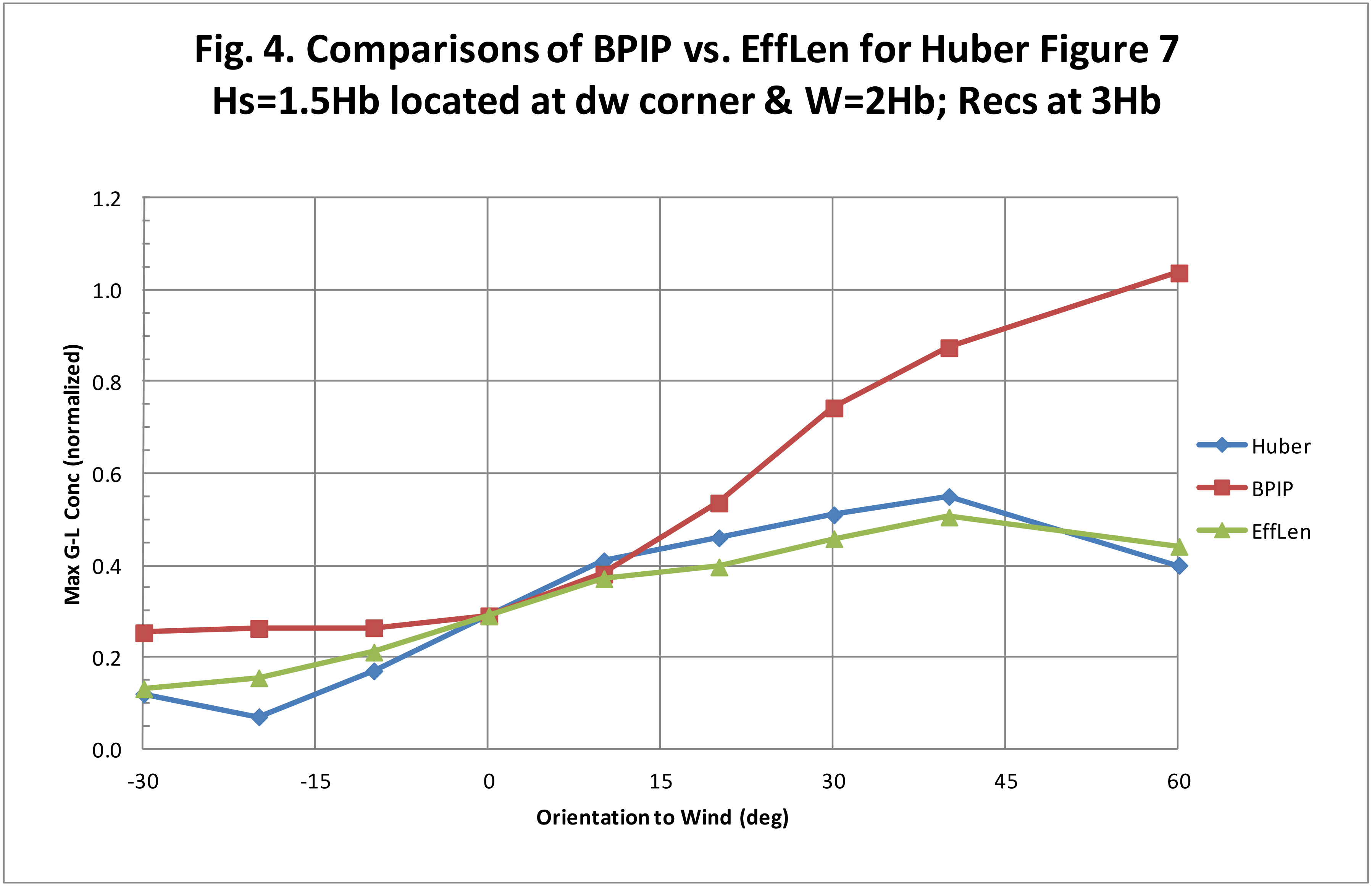


Preliminary Results – Effective Length

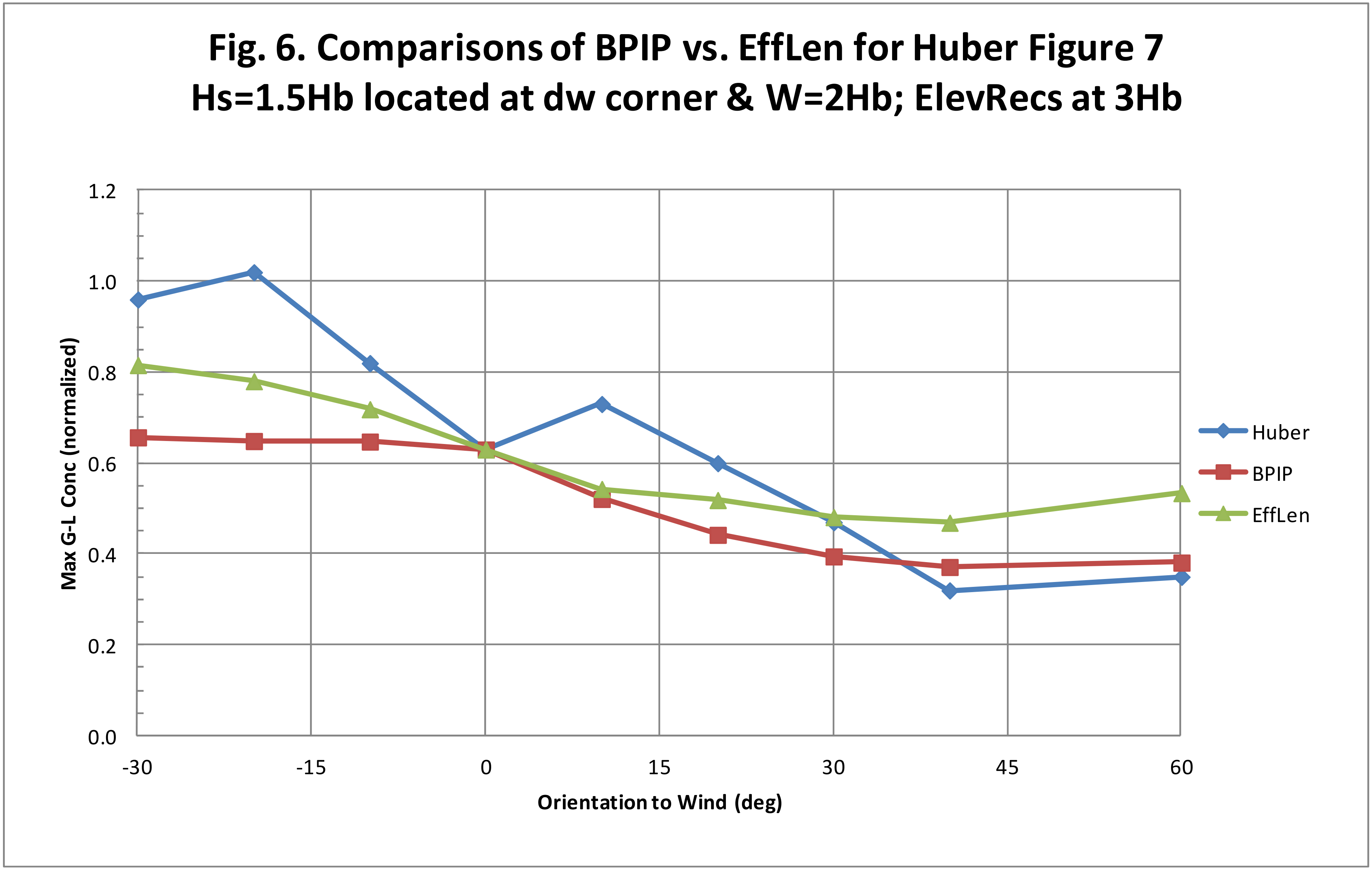
Fig. 2. Huber Wind Tunnel Study - Case S1 - Source at Downwind Center of Building (W=2Hb)



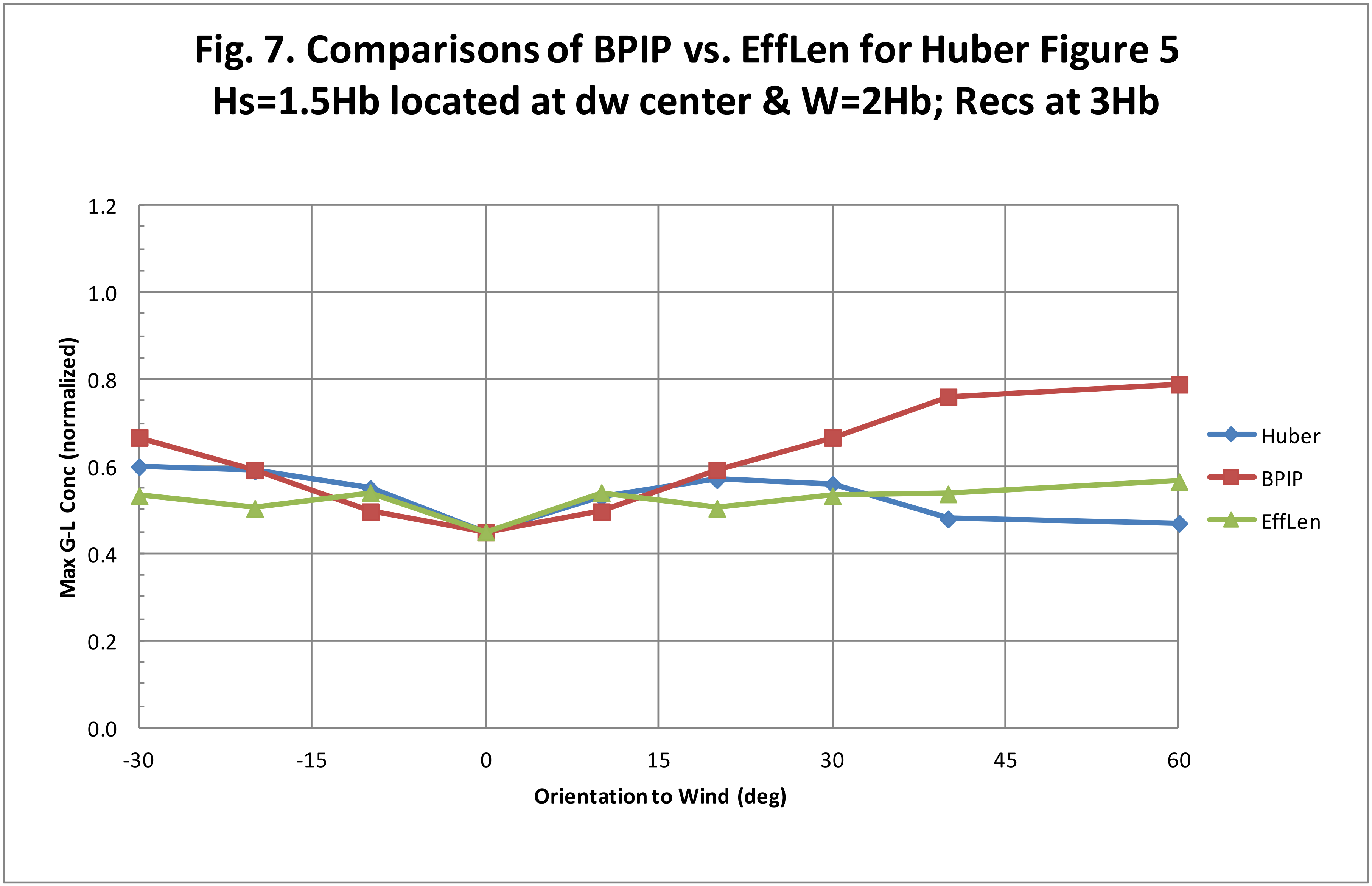
Preliminary Results – Effective Length



Preliminary Results – Effective Length



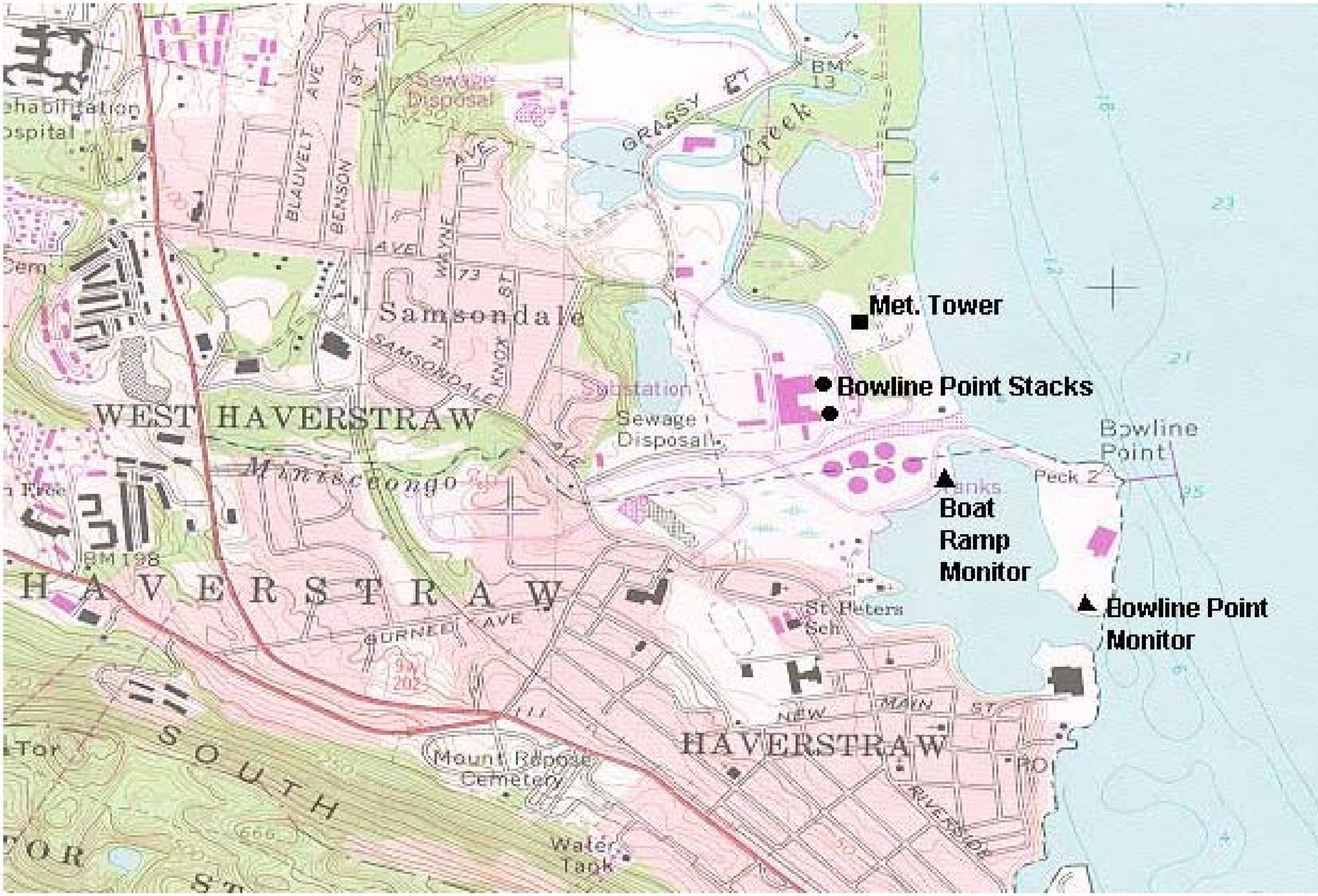
Preliminary Results – Effective Length



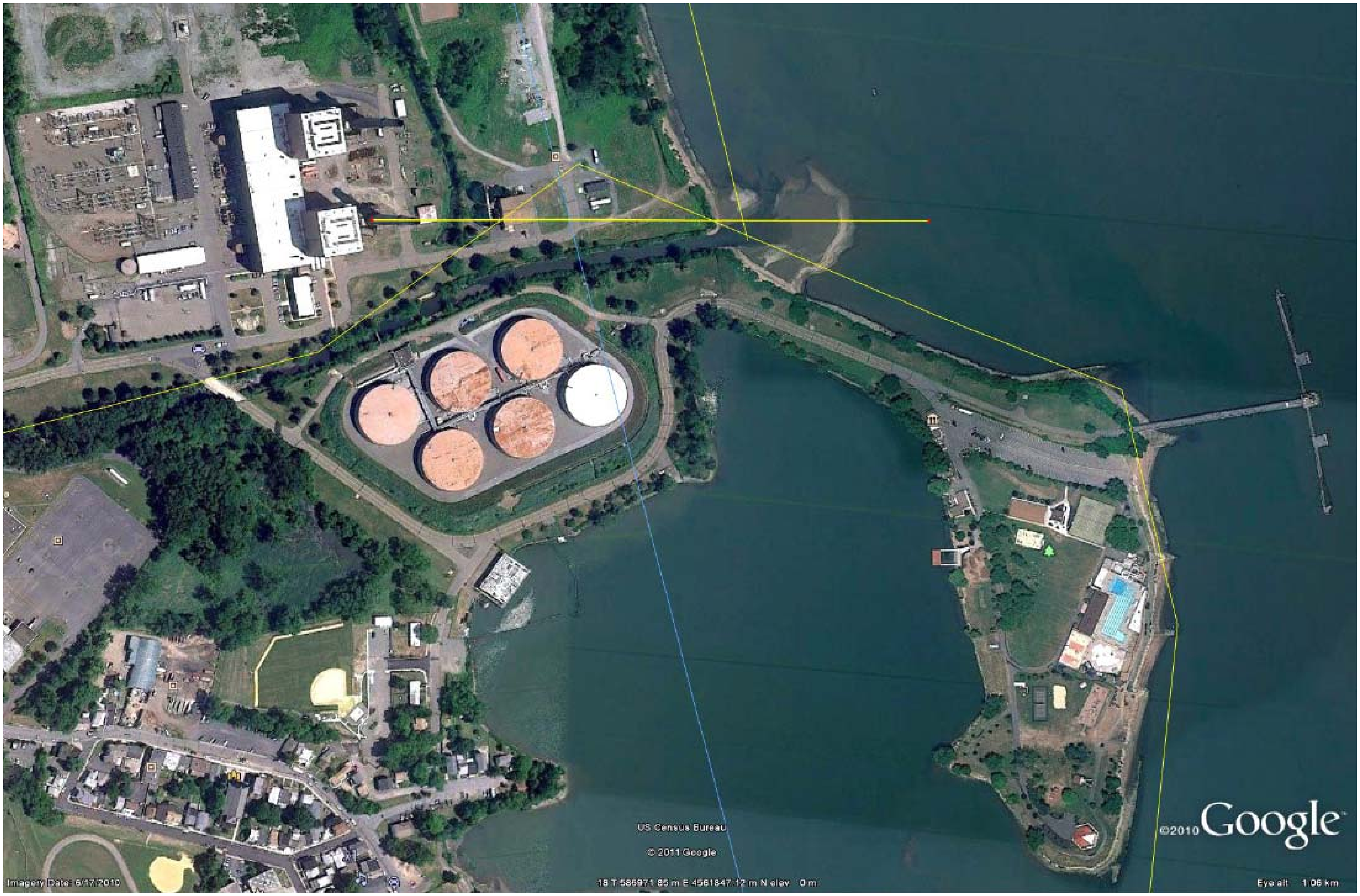
Preliminary Results – Effective Length

- An alternative “effective” building length parameter has also been compared to the current BPIPPRM approach based on the projected building length, using the Bowline field study database used in the evaluation of ISC-PRIME and AERMOD
- Effective Length results look generally similar to original results based on results for both ambient monitors combined, but EffLen approach performs better than projected length for the Boat Ramp (closer) monitor

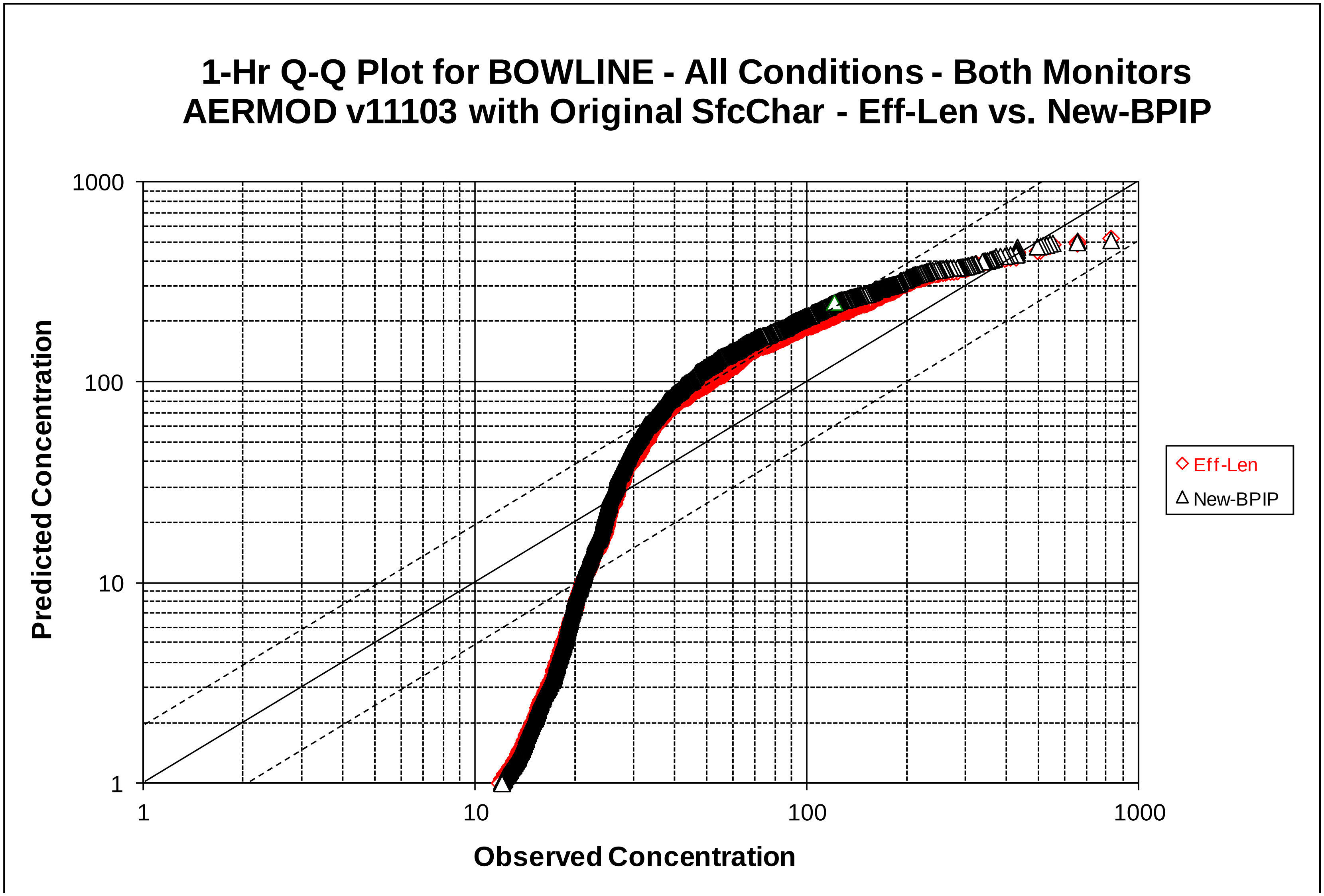
Preliminary Results – Effective Length Bowline Point, Haverstraw, NY



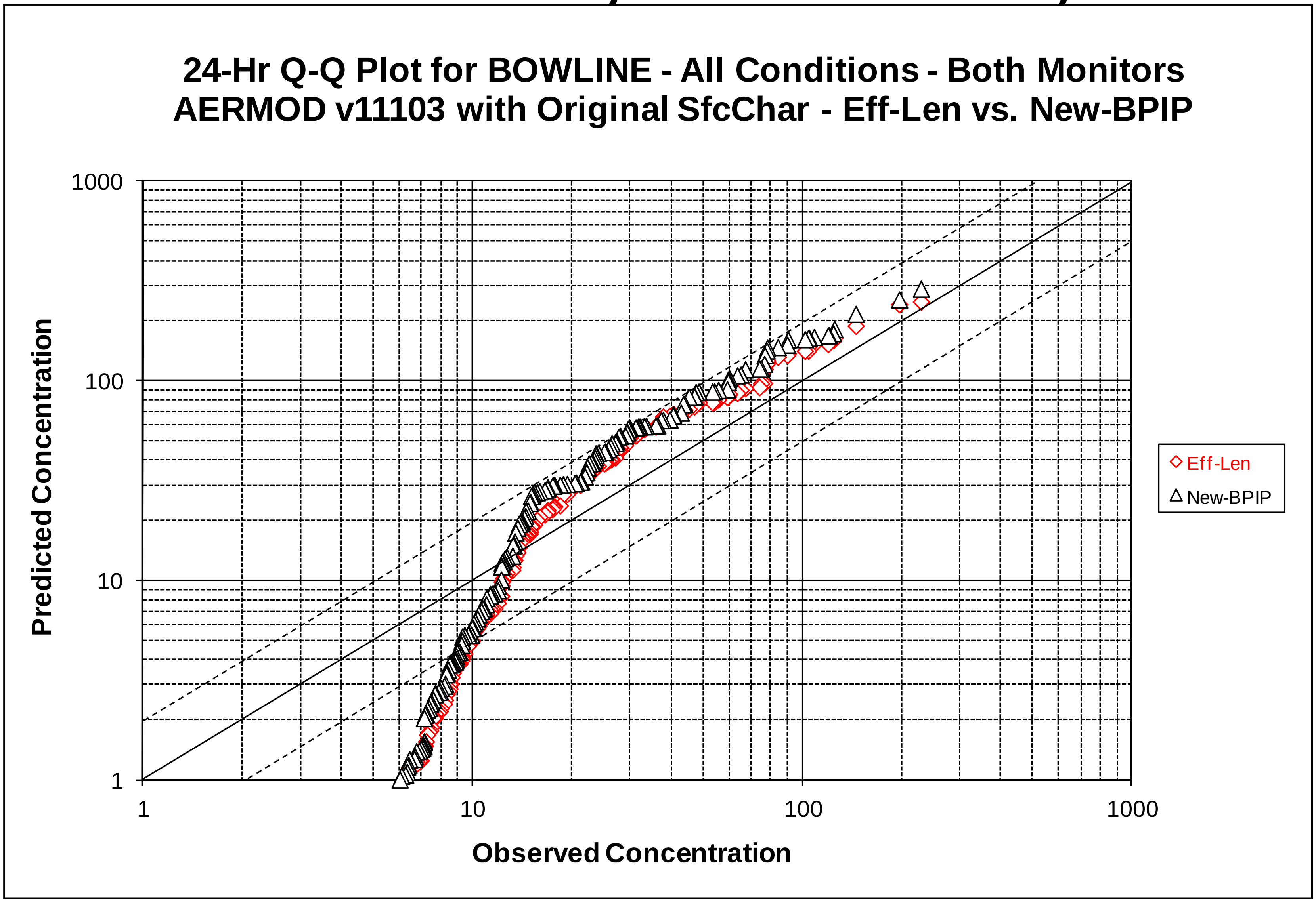
Preliminary Results – Effective Length
Bowline Plant, Haverstraw, NY



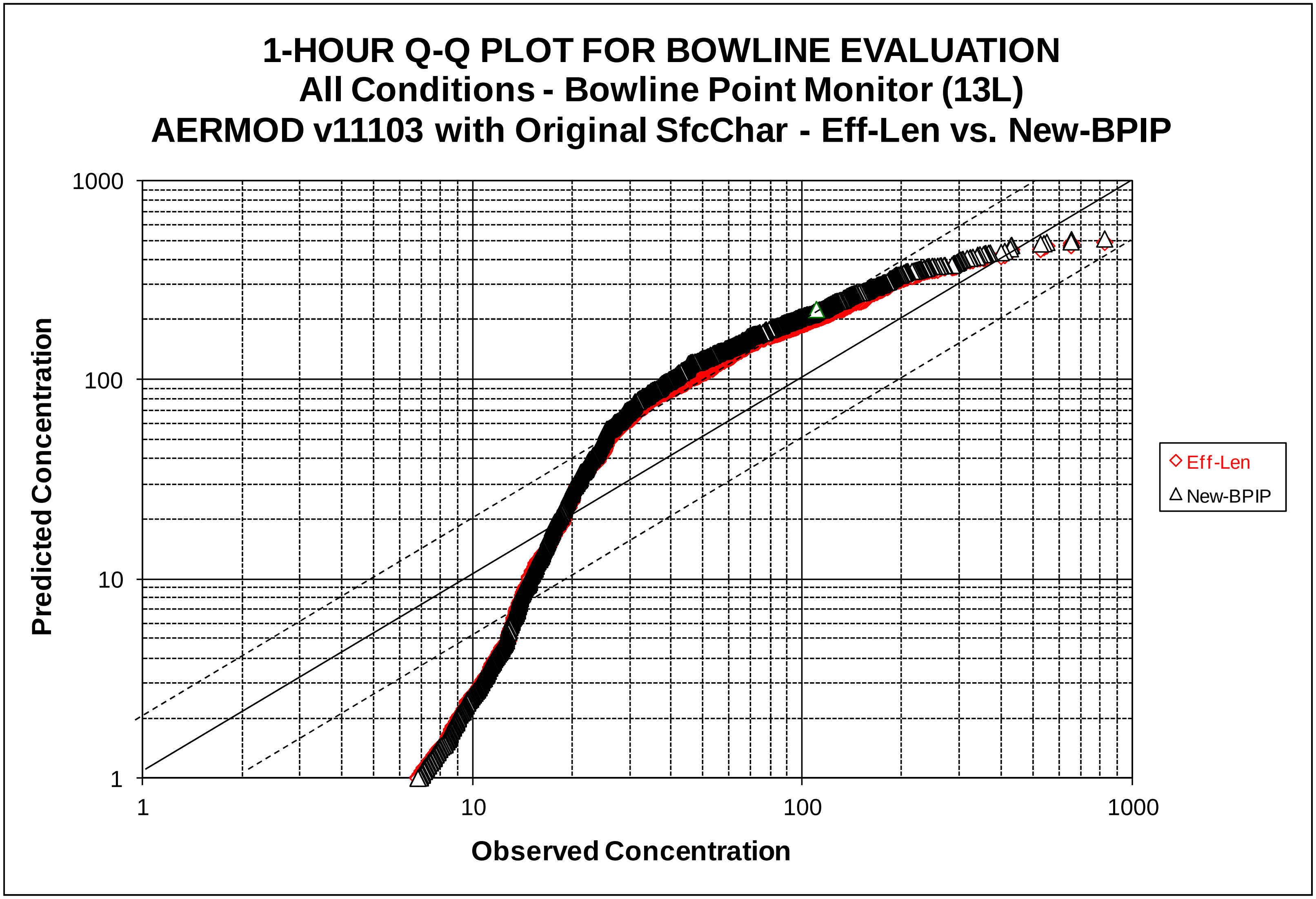
Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



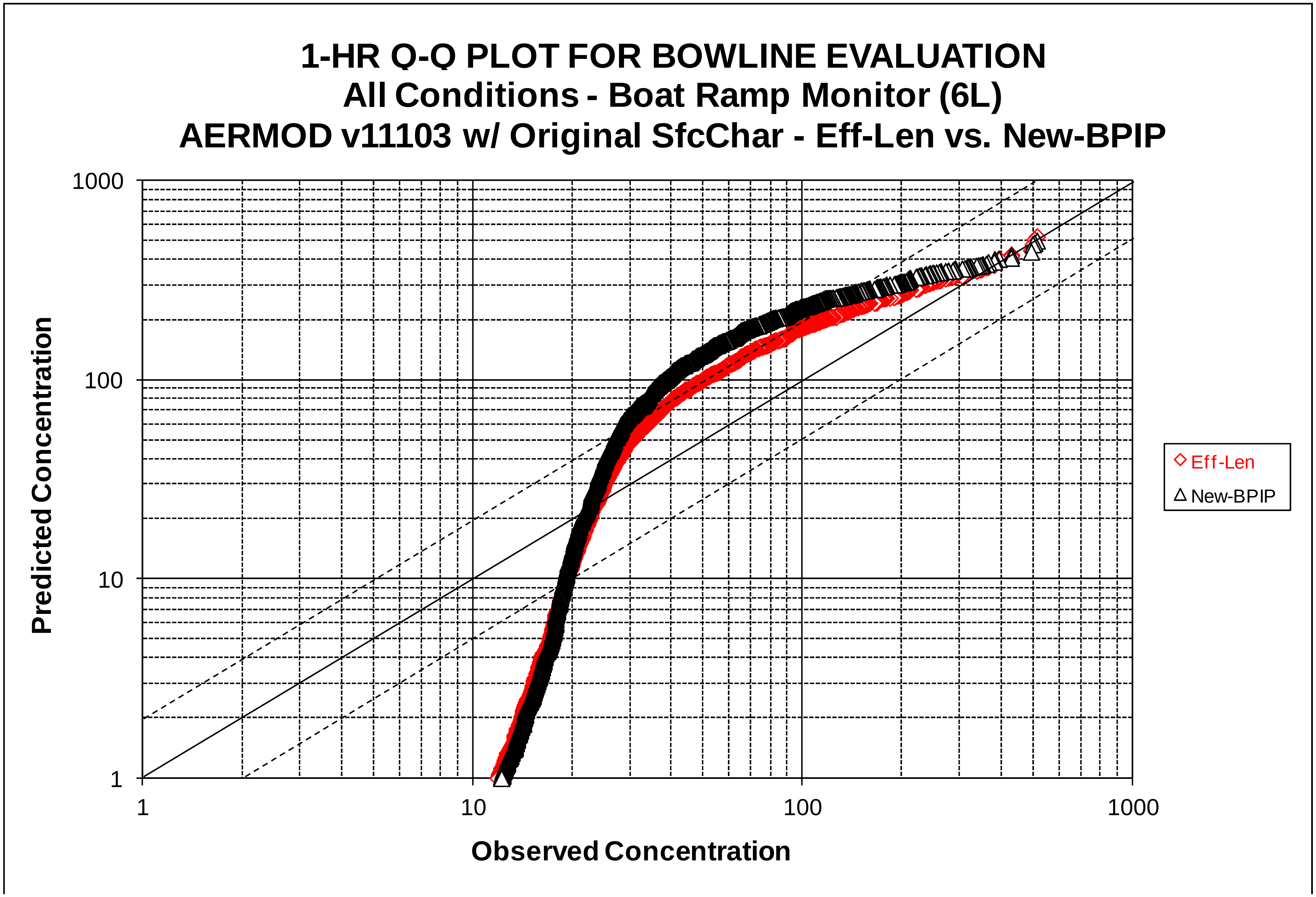
Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



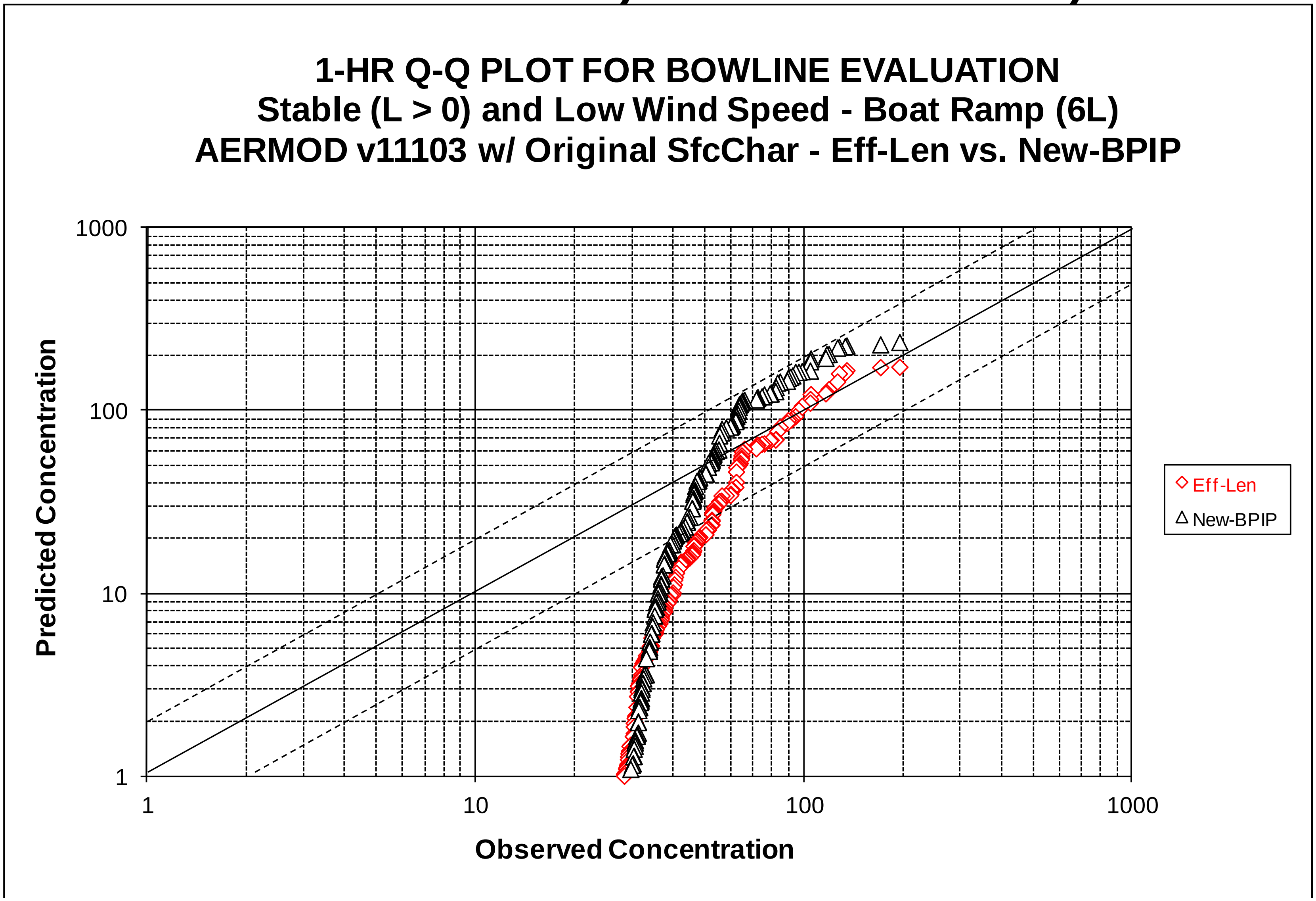
Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



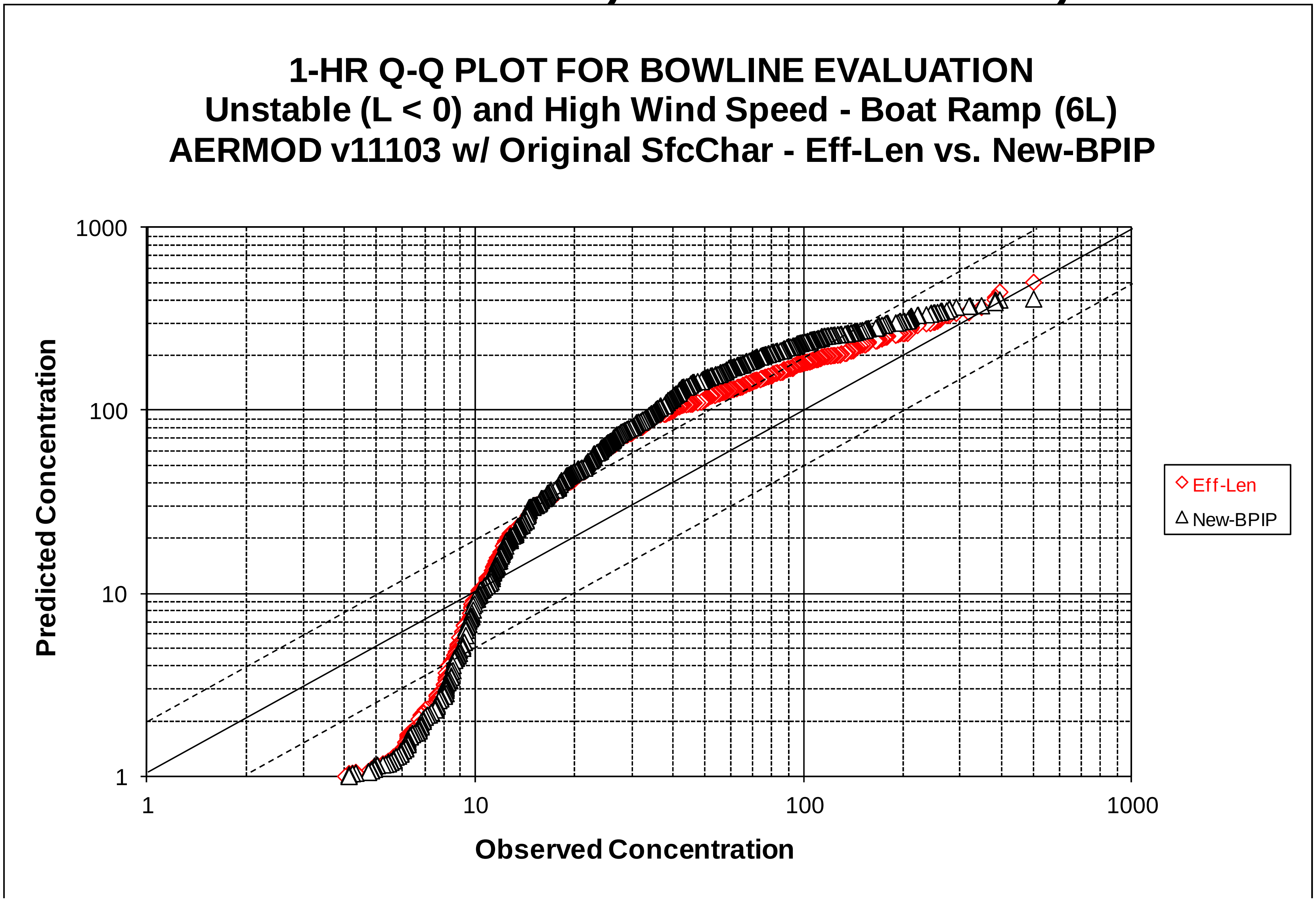
Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



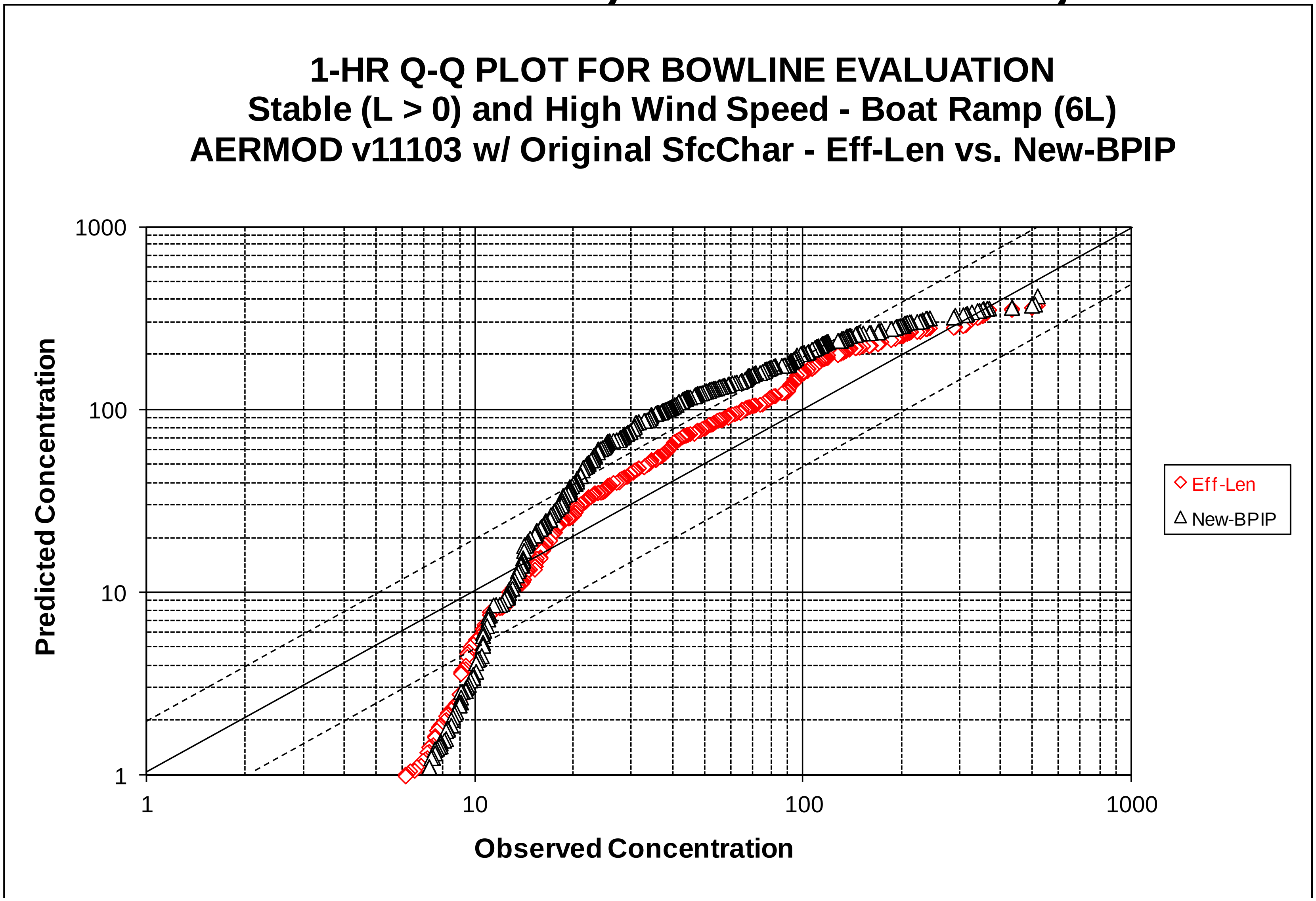
Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



Preliminary Results – Effective Length Bowline Plant, Haverstraw, NY



Effective Length Evaluation Statistics Cox-Tikvart Protocol
Bowline Plant, Haverstraw, NY

	3-hr RHC	3-hr Pred/Obs	24-hr RHC	24-hr Pred/Obs	CPM	MCM	± 90% C.I.
Observed	469.34	- - -	203.57	- - -	- - -	- - -	- - -
Old-BPIP	594.56	1.27	300.79	1.48	0.311	0.0574	0.0672
New-BPIP	535.94	1.14	290.74	1.43	0.304	0.0505	0.0443
Eff-Len	511.47	1.09	262.10	1.29	0.254	- - -	- - -

Old-BPIP = AERMOD results based on current version of BPIPPRM.

New-BPIP = AERMOD results based on "new" version of BPIPPRM that corrects an error related to determining which tiers should be combined.

Eff-Len = AERMOD results based on a proposed alternative approach for determining the "effective" building length instead of the current BPIPPRM approach based on the projected building length. The results for the Eff-Len also reflect corrected parameters based on the "new" version of BPIPPRM. The approach used to determine the Eff-Len parameter is described below in Appendix A.

RHC = Robust Highest Concentration.

CPM = Composite Performance Measure based on a combination of operational (3-hr and 24-hr) and diagnostic (1-hr) results; lower value indicates better performance.

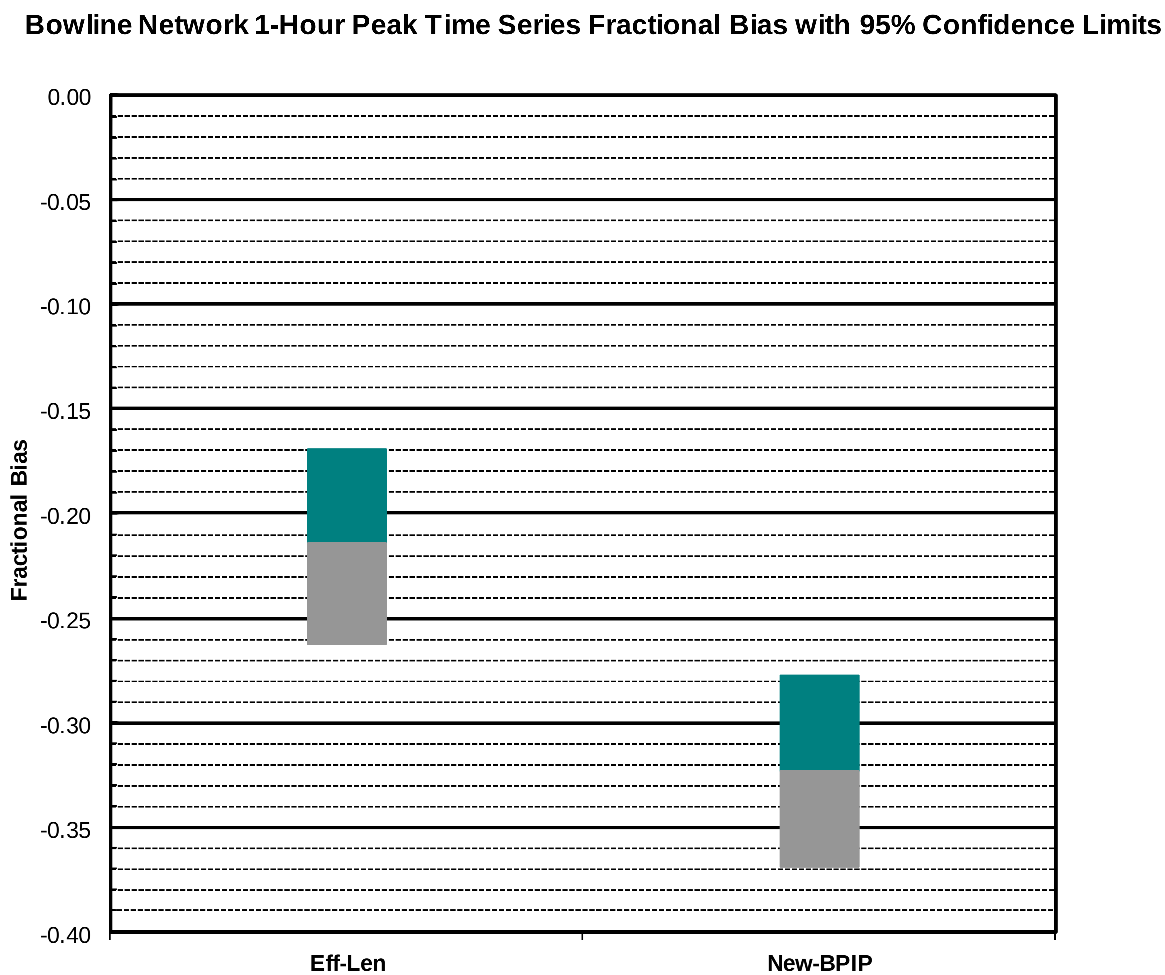
MCM = Model Comparison Measure = difference between CPM values for a pair of models; values reported are based on Old- or New-BPIP vs. Eff-Len results.

90% C.I. = the 90% confidence interval on the MCM values; if the C.I. value is <u>less than</u> the MCM (i.e., the confidence interval does not cross zero), then the difference in performance between a pair of models is statistically significant at the stated confidence level.

Effective Length Evaluation Statistics BOOT Program
Bowline Plant, Haverstraw, NY

	Observed ($\mu g/m^3$)	**AERMOD Eff-Len**	**AERMOD New-BPIP**
Average Conc	16.79	20.83	23.26
Highest 1-hr Conc	823.50	523.90	512.26
2nd Highest 1-hr Conc	652.70	504.80	508.09
Fraction within Fac2	n/a	0.125	0.110
Correlation Coef.	n/a	0.656	0.643
NMSE	n/a	6.27	7.01
FB (< 0 → over pred)	n/a	-0.215	-0.323
FB_{FN}	n/a	0.399	0.372
FB_{FP}	n/a	0.613	0.695

Effective Length Evaluation Statistics BOOT Program
Bowline Plant, Haverstraw, NY



Preliminary Results – Effective Length

- Preliminary evaluations of using an Effective Length parameter instead of projected building length for input to AERMOD have been conducted using wind tunnel data based on Huber (1989) and the Bowline Point field study
- Preliminary evaluation results are encouraging in that the Effective Length approach more accurately captured the pattern of impacts vs. wind orientation angle than the current projected length approach, especially for the case with a stack located at the downwind corner of the building; Effective Length results in that case showed much better agreement than the projected length results, which were about 2.5 times higher than observed.

Preliminary Results – Effective Length

- Preliminary evaluation results of the Effective Length approach for Bowline were also encouraging in that model performance statistics showed a statistically significant improvement as compared to the projected length approach based on the Cox-Tikvart Protocol and the BOOT analysis program
- The improved performance for Bowline was primarily associated with reduced overestimation at the closer Boat Ramp monitor compared to the projected length approach

BPIPPRM Issues – Future Steps

- Complete evaluations of Effective Length parameter for Huber and Bowline and document for independent review
- Identify potential data bases for independent evaluations of Effective Length approach
- Develop Effective Length tool for use in simple applications involving a single or small number of elongated buildings
- Develop design document for modifying BPIPPRM program with Effective Length approach and other modifications
- Since Model Clearinghouse has indicated that building parameterizations for input to AERMOD are "source characterizations" rather than "alternative models" the path forward to implement these improvements in BPIPPRM should not necessitate rulemaking