AERMOD Issues for Design Concentrations due to Penetrated Plume

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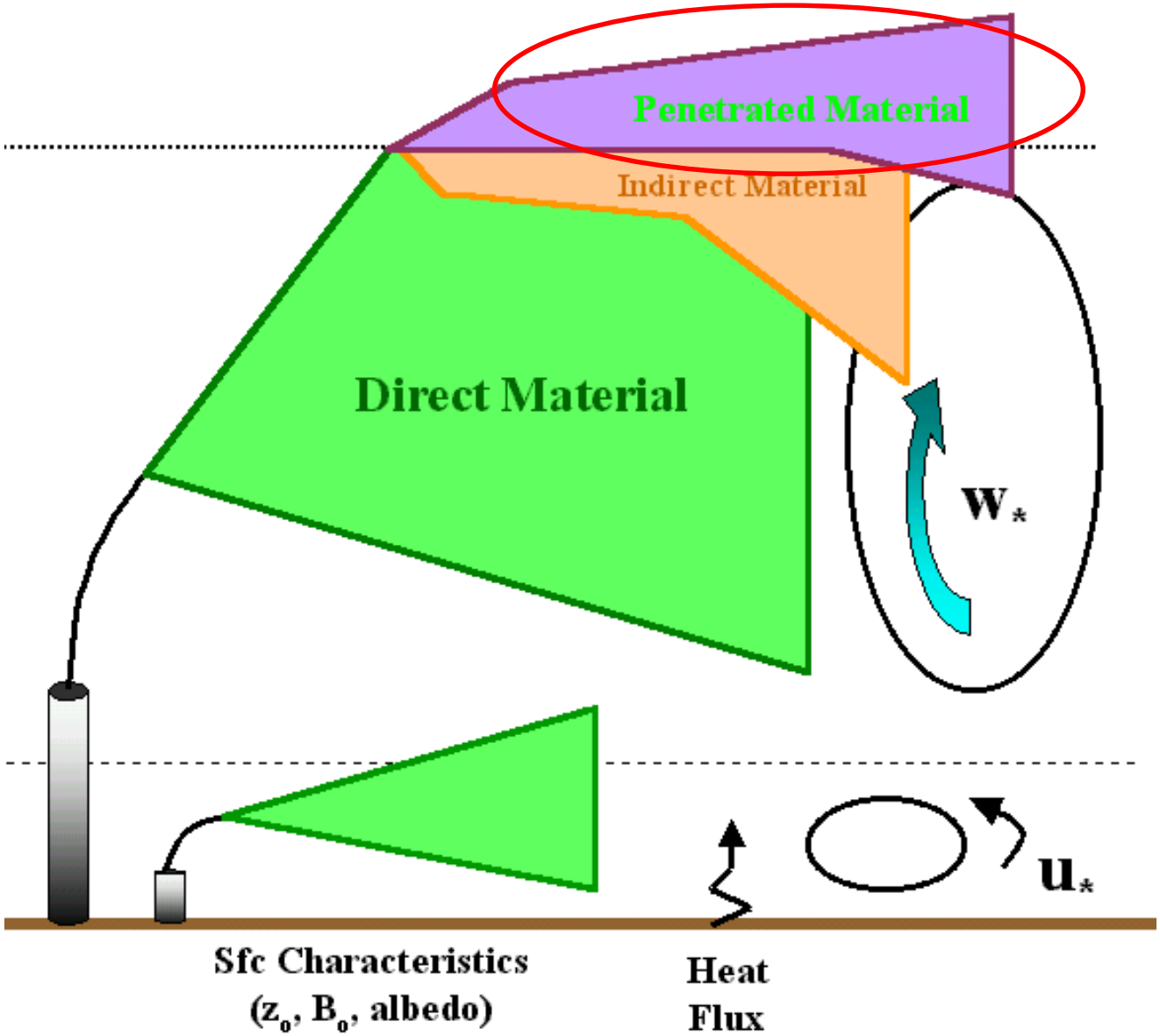
Outline of Presentation

- Overview of Issues
- Available diagnostic tools
- Available model evaluations
- Evaluation results
- Conclusions

Overview of Issue

- Many AERMOD modeling applications with tall stack emissions in simple terrain indicate controlling concentrations in daytime convective conditions with low mixing heights
- However, observations tend to indicate peak observations throughout the daytime period, not necessarily tied to low mixing heights
- Debugging output from AERMOD indicates that the cause of the high predictions is due to plumes that are emitted into the stable layer aloft, but still reach the ground within about a short distance (within 5 km)
- This condition is associated with the “penetrated plume”
- In previous model (ISC), this plume’s impact was set to zero because it is generally thought to take a long time to mix to the ground

AERMOD's Three Plume Treatment of the CBL



Critical Periods are for Plume Mostly in Stable Layer Aloft (P close to1)

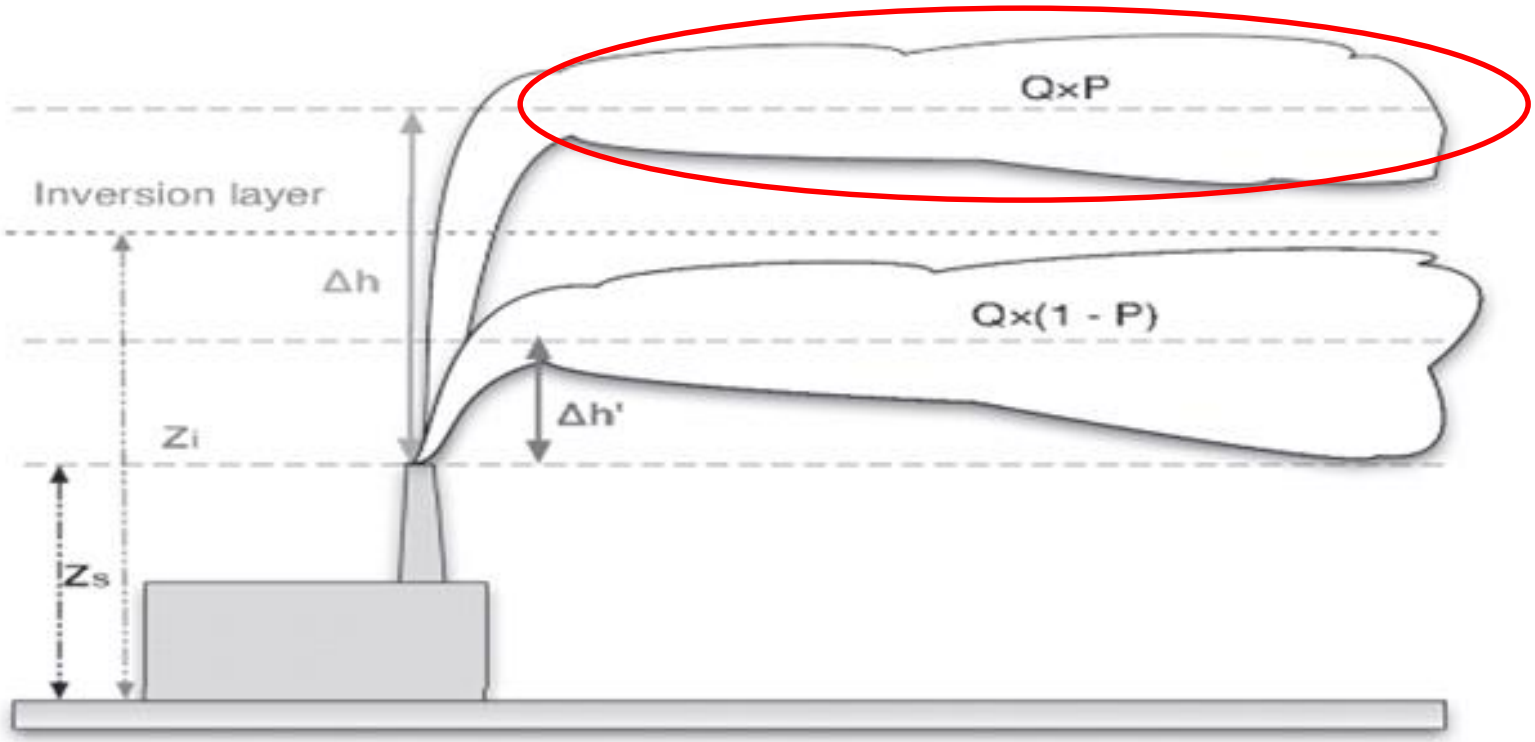


FIG. 2. Partial penetration in the inversion layer: z_s is the source height and z_i is the inversion layer source height. The penetration factor is P. The initial plume rise is Δh and the plume rise of the remnant part of the plume within the boundary layer is $\Delta h'$. Also, Q is the total emission rate.

Penetrated Plume Example

Credit: Sue Ann Bowling, https://homecomingbook.wordpress.com/2012/01/28/inversions-and-smokestacks-ian1/

AERMOD Debug Output Clearly Identifies these Cases

OBSERVED MET CONDITIONS FOR: YYMMDDHH: 14030510	USTAR (m/s)	WSTAR (m/s)	OBULEN (m)	URB_OBULEN (m)	ZIMECH (m)	ZICONV (m)	ZI_URB (m)	SFCZ0 (m)	THSTAR (K)
	0.14	0.45	-17.20	N.A.	119.00	256.00	N.A.	0.0500	-9.990

POINT SOURCES:

SOURCE ID	RCPT NO.	FINAL PLUME HT. (m)	DIST. FINAL PL.HT (m)	WDIR FINAL HT. (deg)	Effect. WSPD (m/s)	<------ DISTANCE 3600* ueff (m/s)	TO RECEPT (m)	-----> PLUME TYPE	MEAND. FRAC.	PART. PEN. FRAC.	EFFECT. SIGMA_V (m/s)	EFFECT. SIGMA_W (m/s)	HOURLY CONC. (µg/m3)
P 50	6833	353.6	1284.7	84.	1.918	6905.4	3441.5	PEN	0.181	0.889	0.500	0.213	105.954
P 51	6866	355.9	1284.7	84.	1.918	6906.1	3655.7	PEN	0.184	0.898	0.500	0.211	120.389

This output comes from the “DISTANCE DEBUG” output available from AERMOD v. 14134 available for download at the EPRI web site: http://sourceforge.net/projects/epri-dispersion/

Ken Rayner Investigations

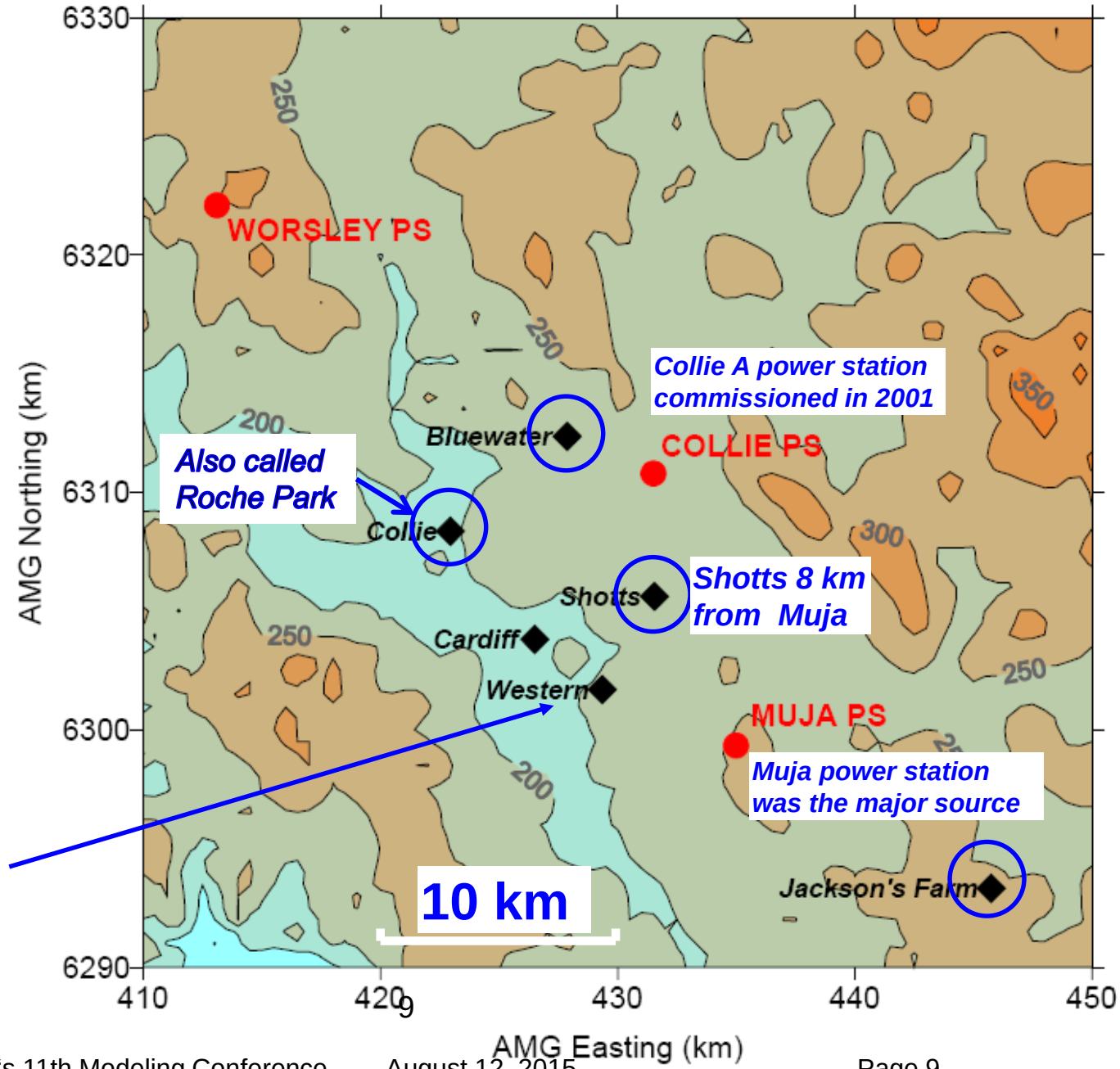
- Dr. Ken Rayner, recently retired from the Western Australia Department of Environmental Conservation, “drilled into” the AERMOD code to better understand the high predictions due to penetrated plumes
- He reviewed modeling data vs. observations for tall-stack coal-fired power plants in simple terrain in Western Australia
- He also provided model comparisons to a monitor called “Shotts” with and without the contributions from the penetrated plume
- His presentation is available at http://www.casanz.org.au/sigs/ModSIG%20Workshop%20Sydney%20Conference%20%208%20September%20201/Rayner_2013ModSIG_Workshop.pdf

Western Australia Setting

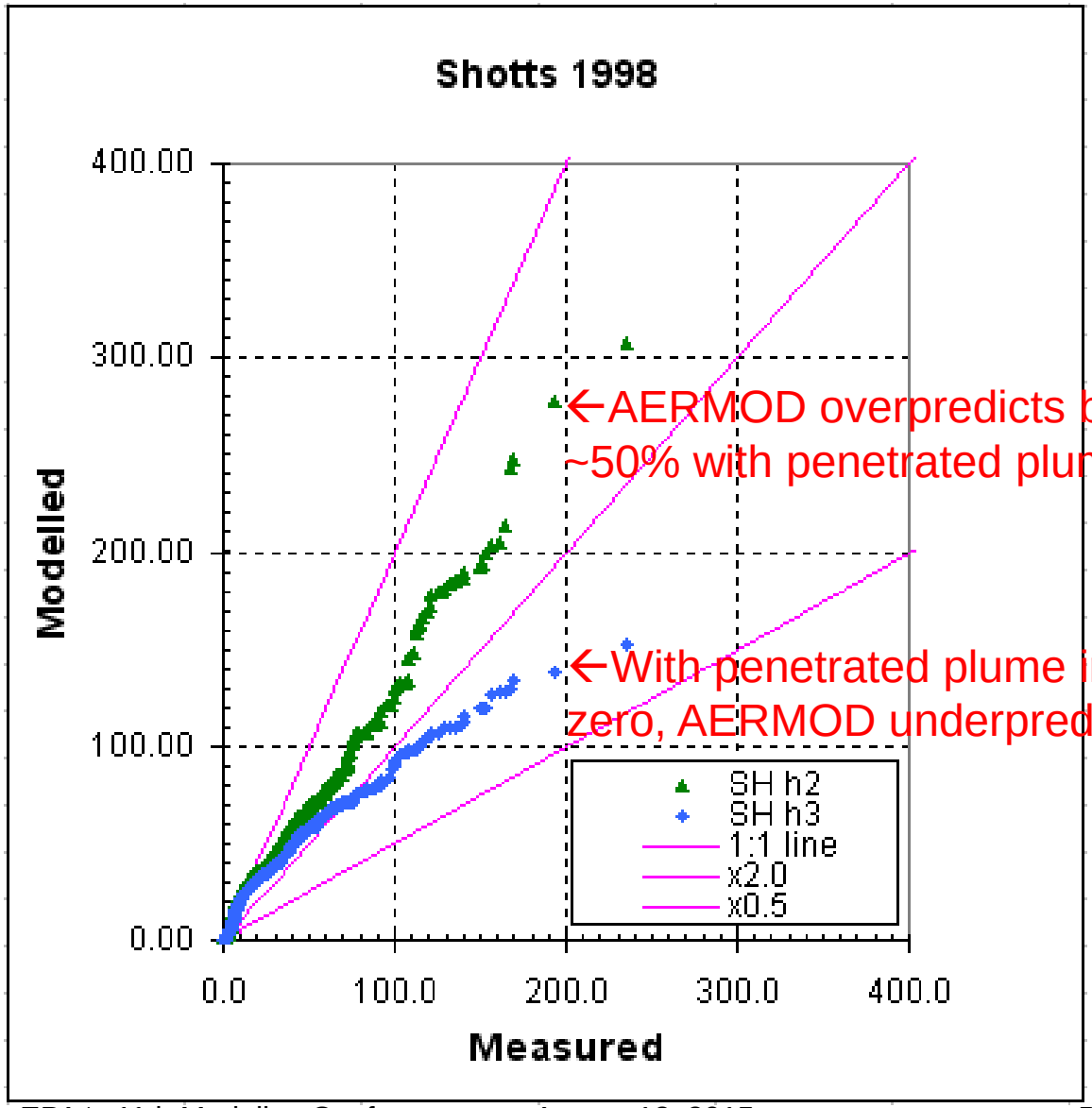
Western Power monitoring program 1996 - 2001

SO_2 monitoring
Western Power
1998, 2001

Western 2 (W2) meteorological station



Dr. Rayner's Review of AERMOD Penetrated Plume



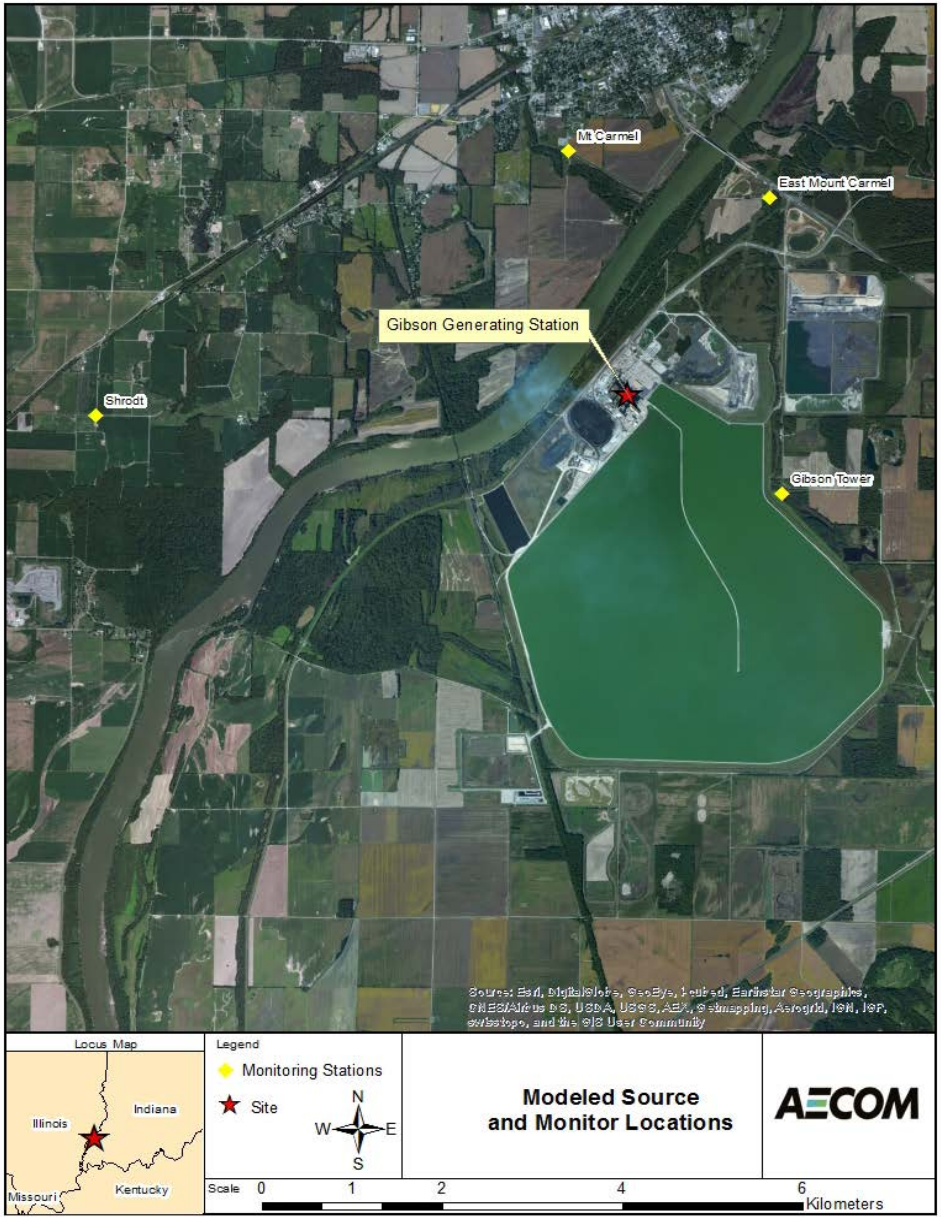
←AERMOD overpredicts by ~50% with penetrated plume

←With penetrated plume impact set to zero, AERMOD underpredicts by ~30%

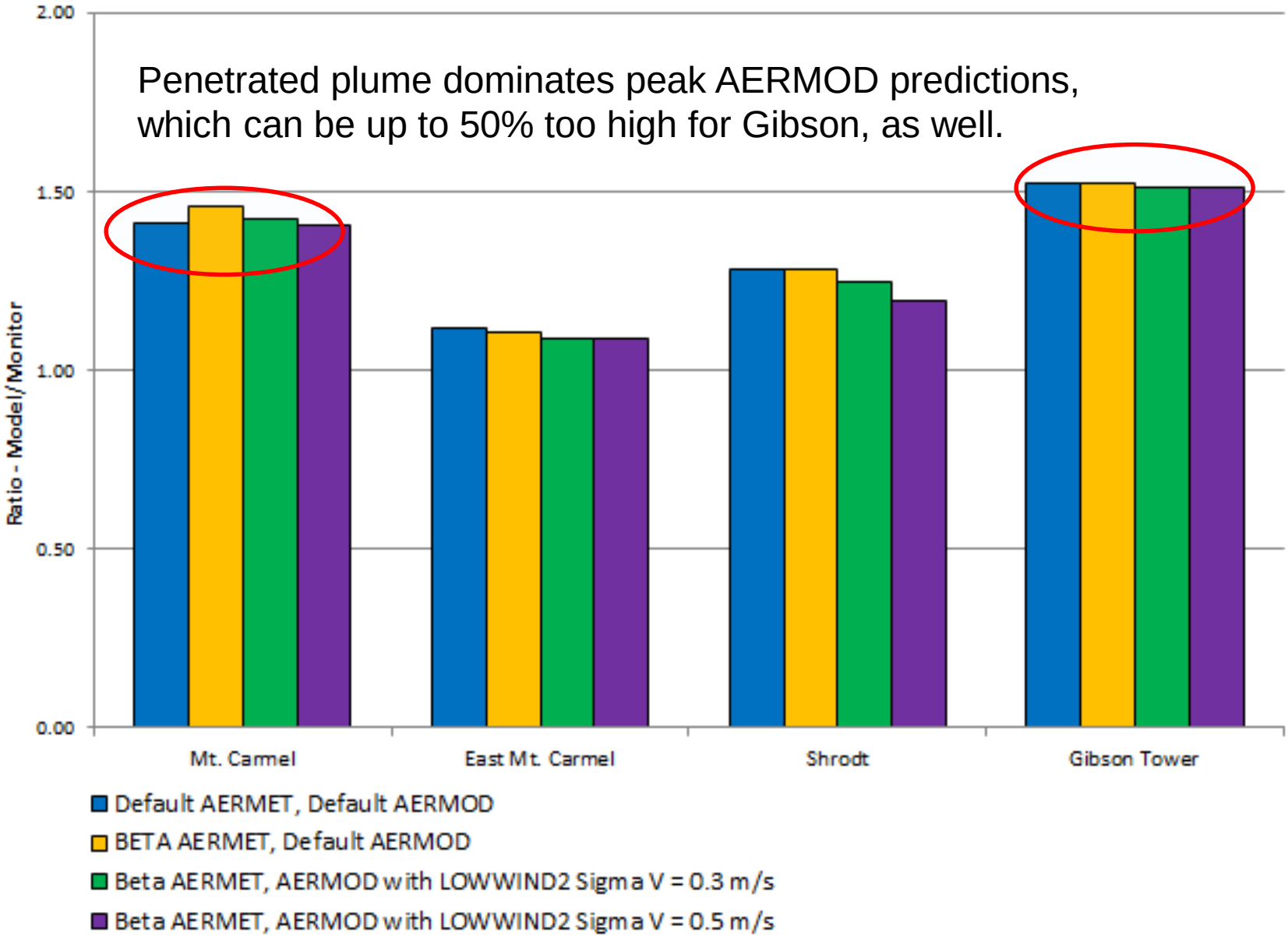
Rayner's Summary of AERMOD Penetrated Plume Issue

- Ken Rayner found a ~50% overprediction due to the penetrated plume at the Shotts monitor
- He believes that AERMOD mixes the plume to the ground too fast (constrained to do so in the same hour of emission in a steady-state model like AERMOD) and in a form that is too concentrated
- Other issues of concern are the dependence of the predictions on a calculated parameter (mixing height, which is not directly observed) that could be changing during the hour, but is held fixed by AERMOD for the whole hour
- Bottom line: AERMOD (v. 14134) could over-predict by 50% for the critical conditions involved modeling tall stacks with buoyant plumes in simple terrain

Gibson Generating Station Monitoring Network



Design Concentration Results for Gibson



Conclusions

- A consistent pattern for AERMOD peak predictions for tall stacks in simple terrain has emerged
- Peak concentrations are often due to penetrated plume in daytime convective conditions
- The modeled plume may be reaching the ground too fast
- AECOM and Dr. Rayner's review of previous AERMOD versions indicates that the sigma-z values used for the plume reflection height and the plume dispersion to the ground warrant additional EPA review

Conclusions, continued

- EPA (Appendix W) indicates that AERMOD model uncertainty is on the order of 10-40%; this feature may extend this uncertainty to 50% on the over-prediction side
- Although a 50% over-prediction bias is still “relatively good”, it is critical for consideration in SO_2 NAAQS compliance assessments, such that AERMOD modeled values up to 150% of the NAAQS cannot reliably indicate a NAAQS violation, especially if due to controlling concentrated caused by the penetrated plume issue
- Review of AERMOD v. 15181 is ongoing to determine if this issue is still present in the new version with recommended low wind options deployed