PM Sampling Issues

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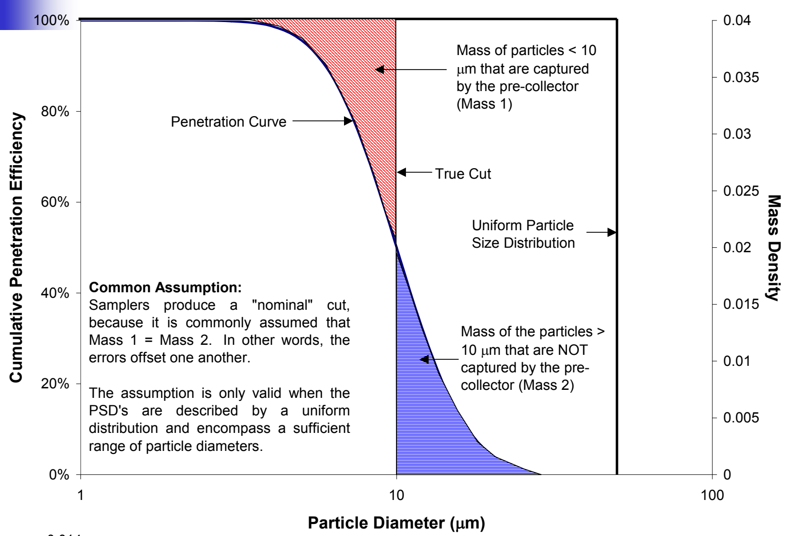
Perspective

Size Selective Ambient Samplers

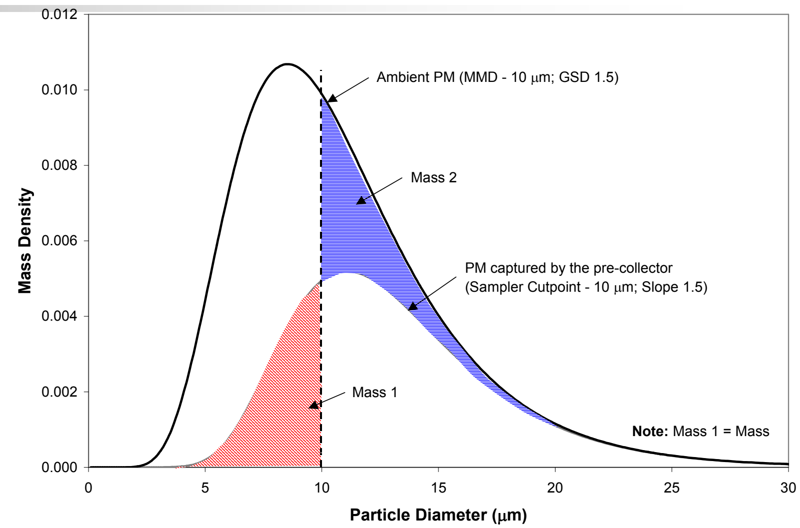
Size Selective Stack Samplers

PM_{10} Samplers – Theoretical Errors

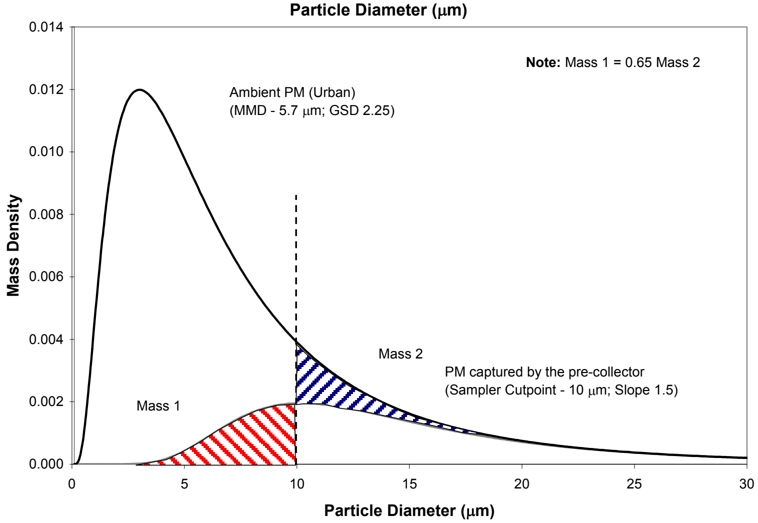
EPA Performance Criteria Guidelines



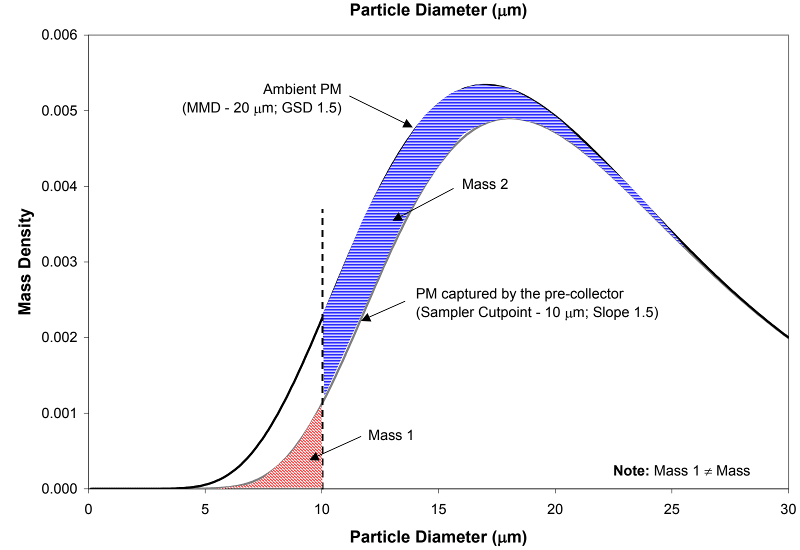
Ideal Environment



Urban Environment



Rural Environment

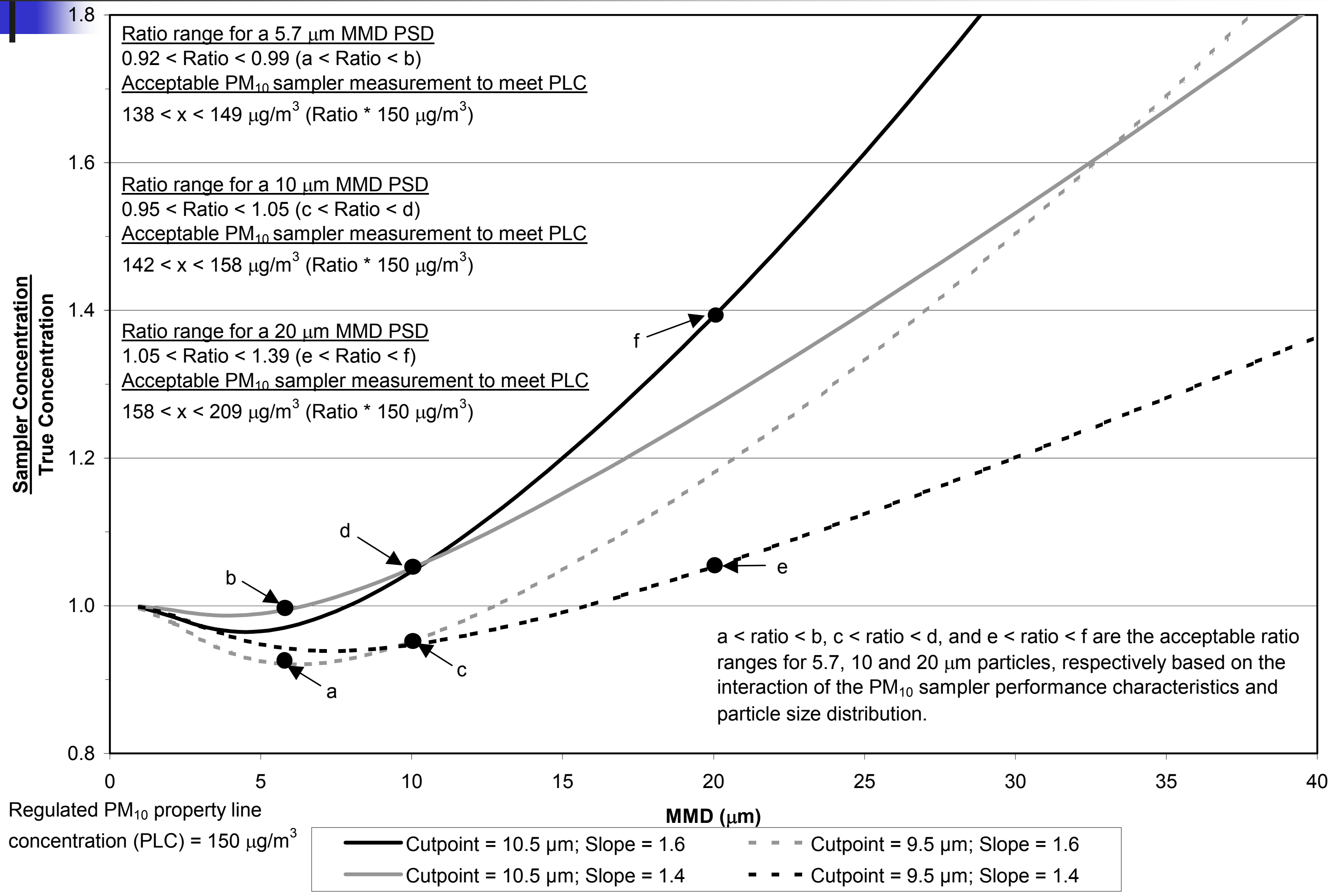


Characteristics of Various Types of Particulate Matter

Source	MMD (μm)	GSD	Particle Density (g/cm^3)	Reference
Urban				
Urban Dust	5.7	2.25	NR	USEPA (1996a)
Agricultural				
Rice	21.75	NR	NR	Plemons (1981)
Rice	12.10	2.24	1.46	Parnell et al. (1986)
Corn	19.57	NR	NR	Plemons (1981)
Corn	13.70	NR	NR	Wade (1979)
Corn	13.60	1.80	1.50	Parnell et al. (1986)
Soybeans	25.17	NR	NR	Plemons (1981)
Soybeans	30.00	NR	NR	Martin (1981)
Soybeans	15.50	NR	NR	Wade (1979)
Soybeans	14.80	1.87	1.69	Parnell et al. (1986)
Wheat	32.97	NR	NR	Plemons (1981)
Wheat	14.70	2.08	1.48	Parnell et al. (1986)
Sorghum	36.92	NR	NR	Plemons (1981)
Sorghum	15.70	2.16	1.43	Parnell et al. (1986)
Cotton Gin (Combined Streams)	20 - 23	1.82 – 2.00	1.8 - 2.0	Wang (2000)
Cotton Lint Fibers	12.94	2.25	NR	Parnell and Adams (1979)
Cattle Feedlot (Downwind)	14.2	2.25	1.71	Sweeten et al. (1989)
Swine Finishing House (Aerial)	14.3	2.02	NR	Barber et al. (1991)
Swine Finishing House (Settled)	18.4	1.99	NR	Barber et al. (1991)
Swine Production Facility	17.97	NR	NR	Barber et al. (1991)
Poultry Production Facility	24.0 – 26.7	1.6	NR	Redwine and Lacey (2001)
Typical Soil	25	2.0	2.5	Pargmann et al. (2000)

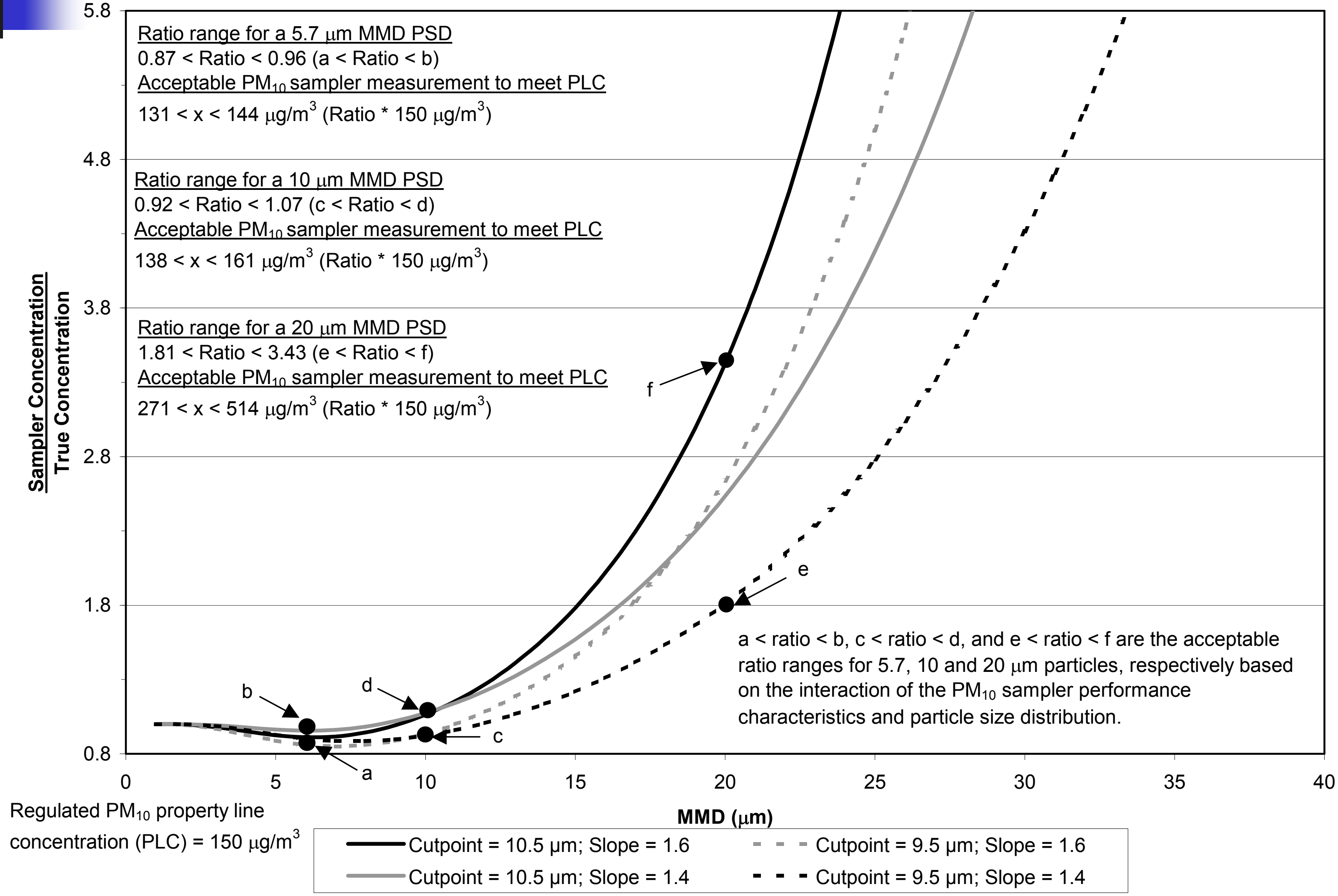
NR – Data not reported in the reference.

Theoretical Ratios of Ambient PM_{10} Sampler to True Concentrations (PSD – GSD = 2.0)

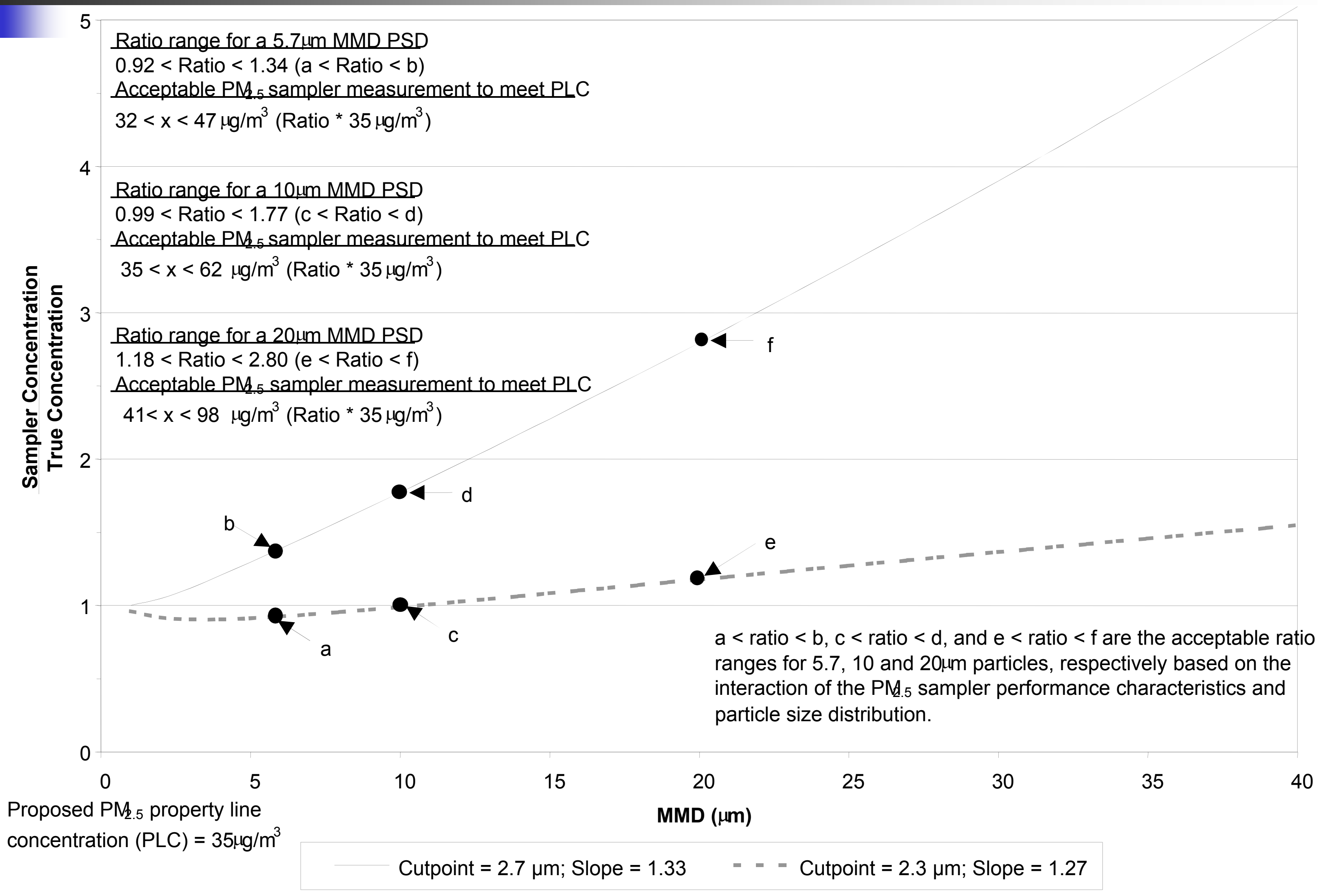


Regulated PM_{10} property line concentration (PLC) = 150 µg/m^3

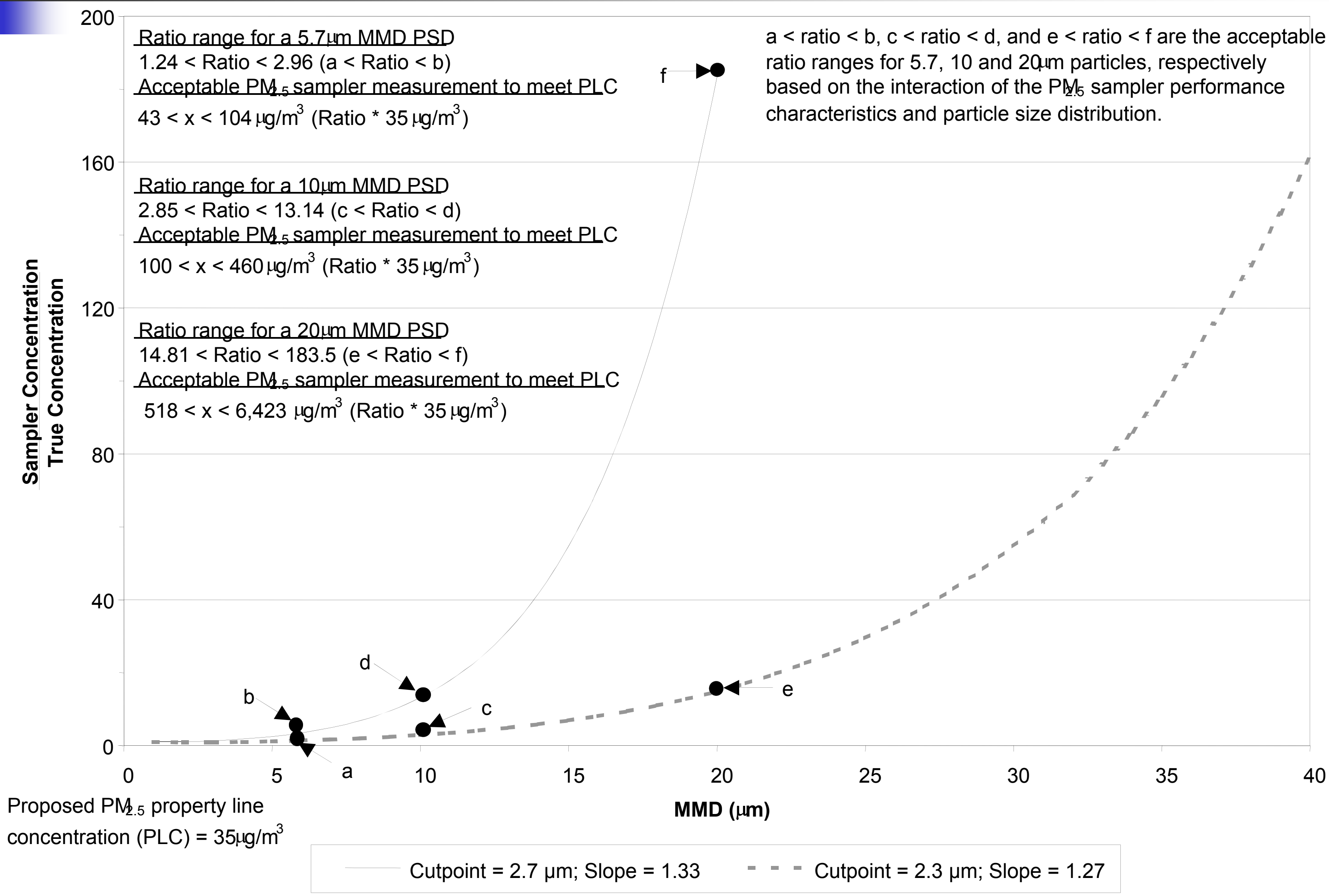
Theoretical Ratios of Ambient PM_{10} Sampler to True Concentrations (PSD – GSD = 1.5)



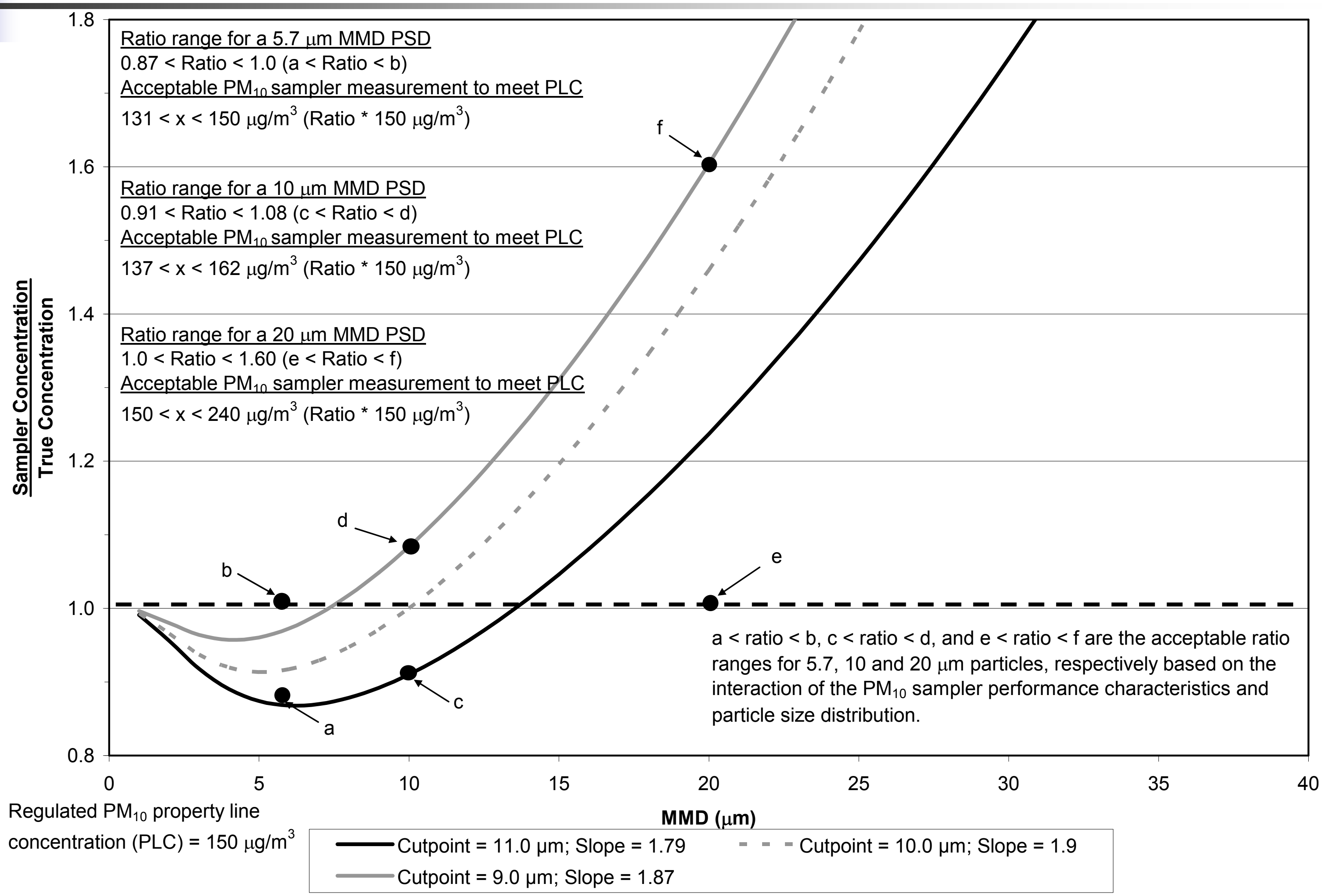
Theoretical Ratios of Ambient $PM_{2.5}$ Sampler to True Concentrations (PSD – GSD = 2.0)



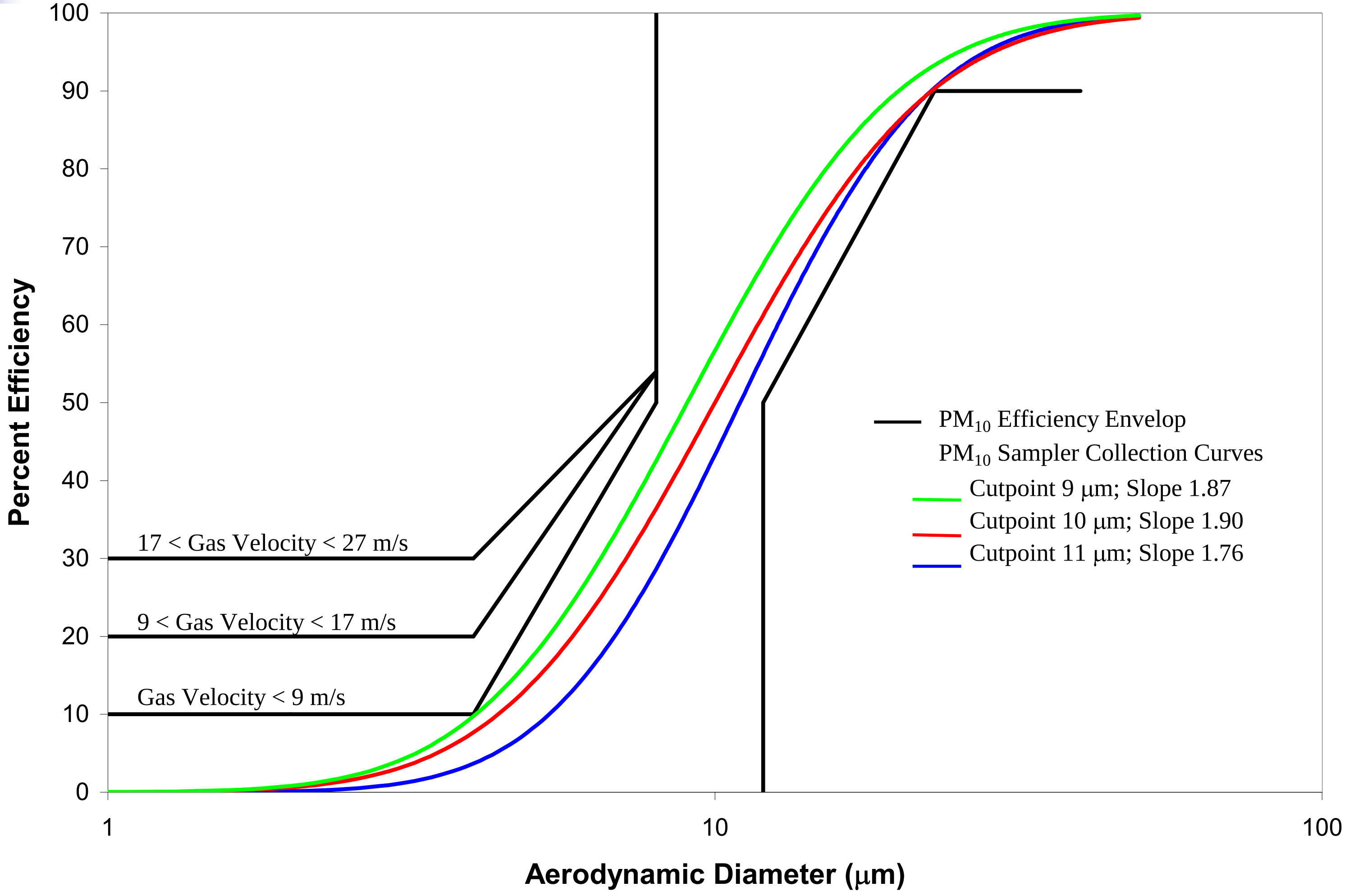
Theoretical Ratios of Ambient $PM_{2.5}$ Sampler to True Concentrations (PSD – GSD = 1.5)



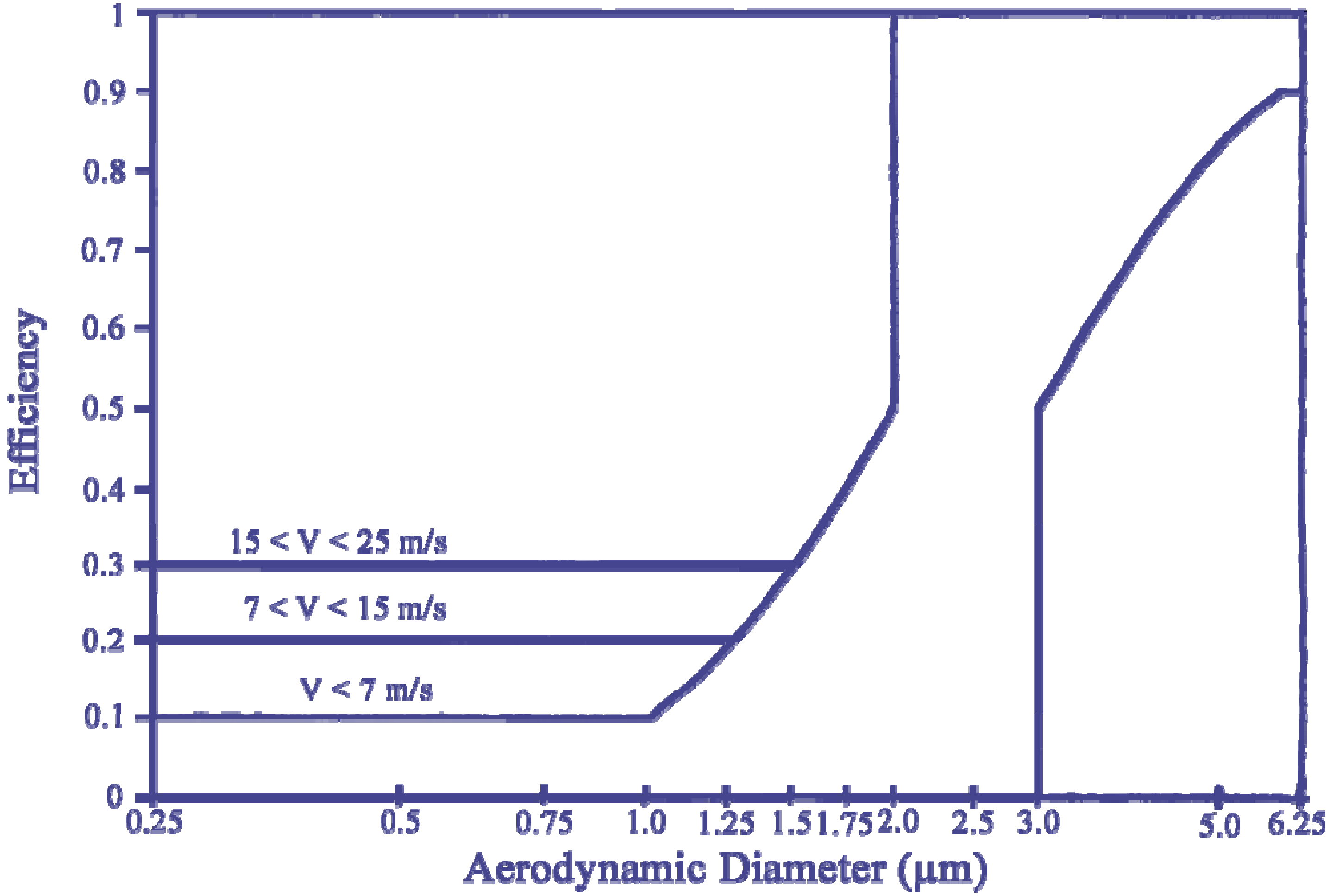
Theoretical Ratios of Stack PM_{10} Sampler to True Concentrations (PSD – GSD = 2.0)



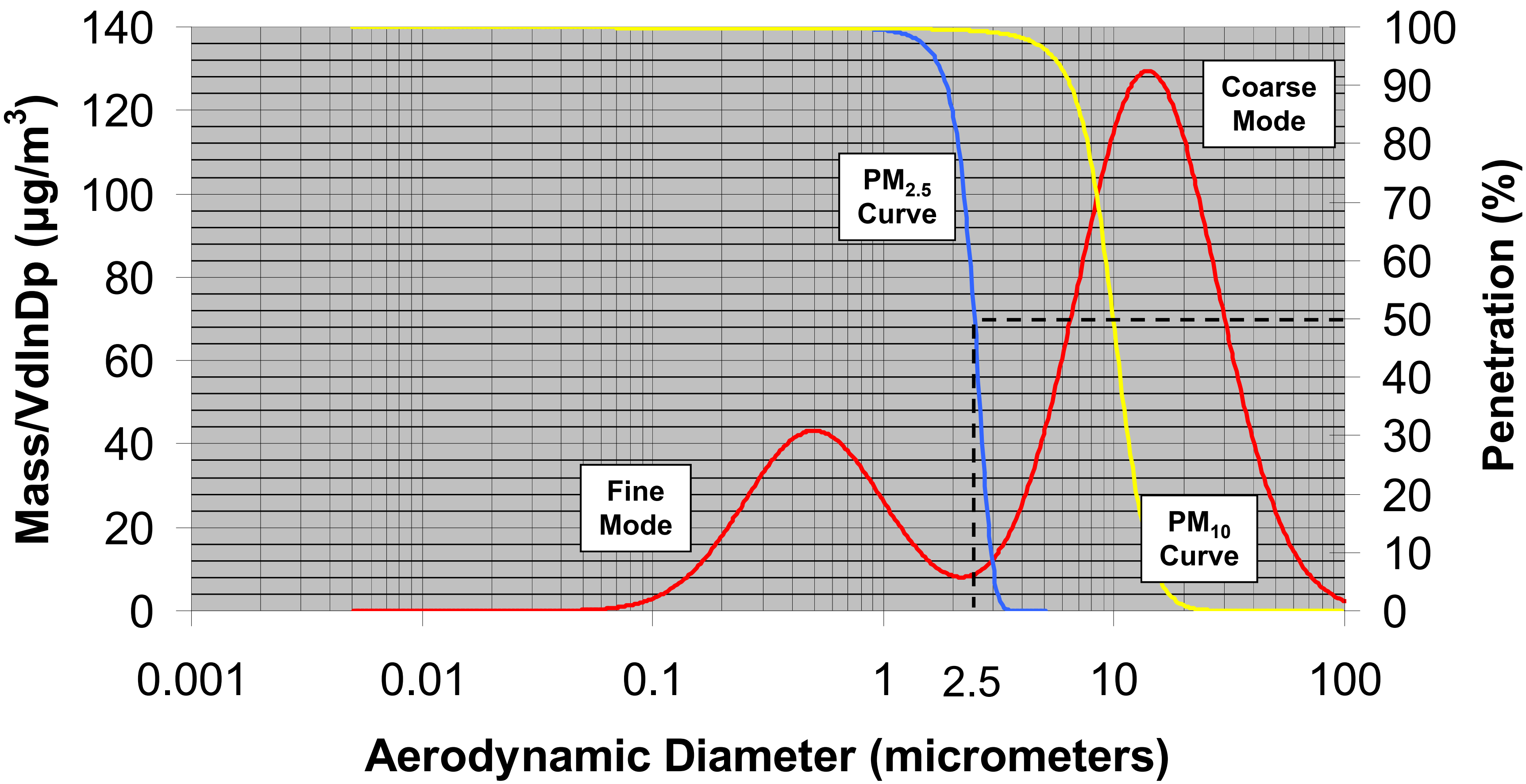
PM_{10} Stack Sampler Performance Criteria



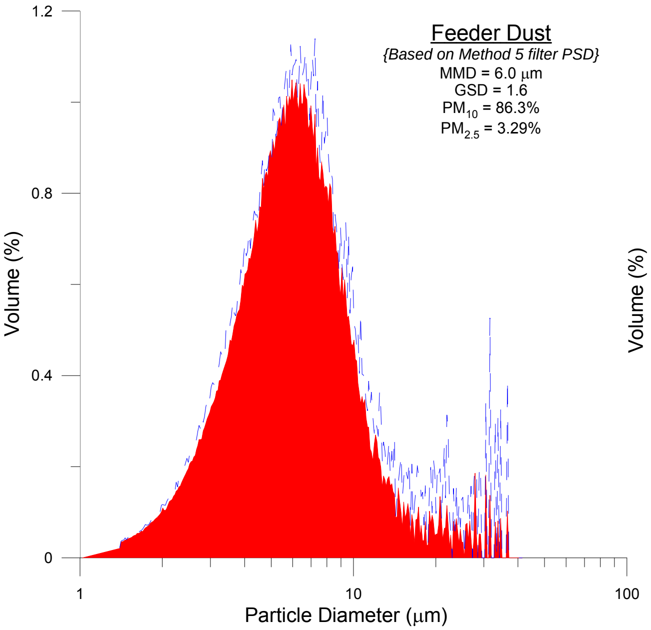
PM$_{2.5}$ Stack Sampler Performance Criteria

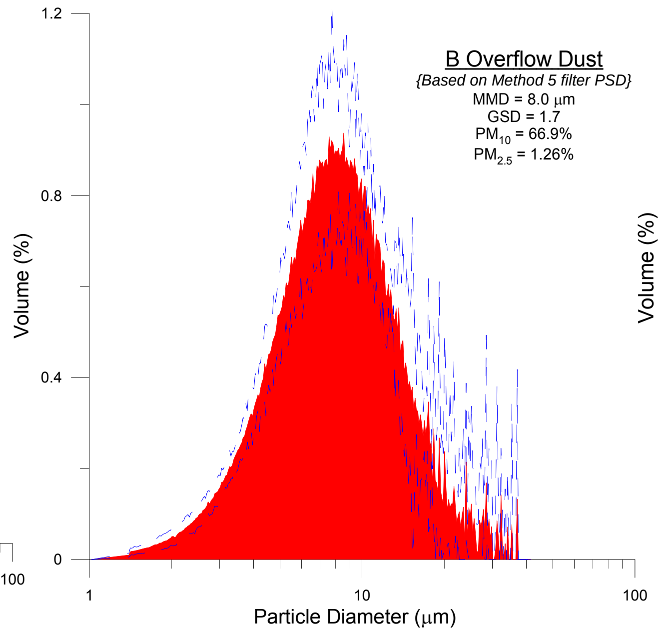


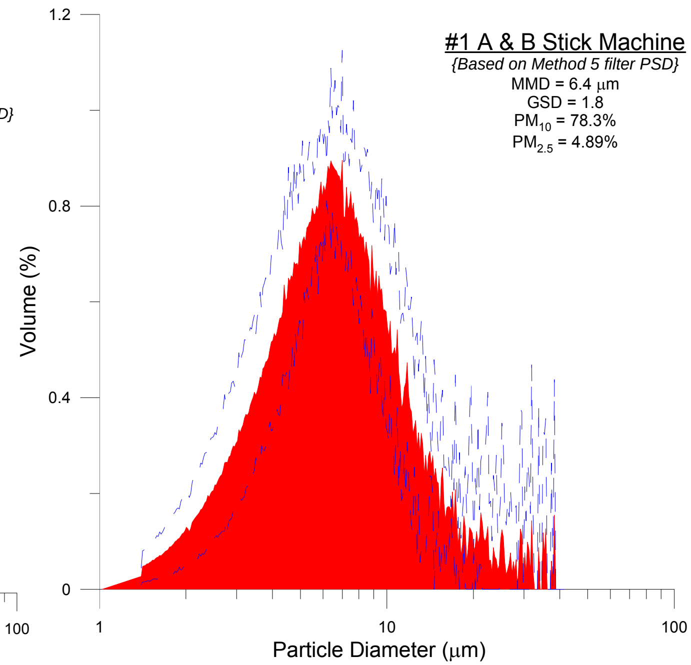
Theoretical Ambient Particle Size Distribution (Vanderpool, 2010)



Stack Sampling - Field Evaluation Results







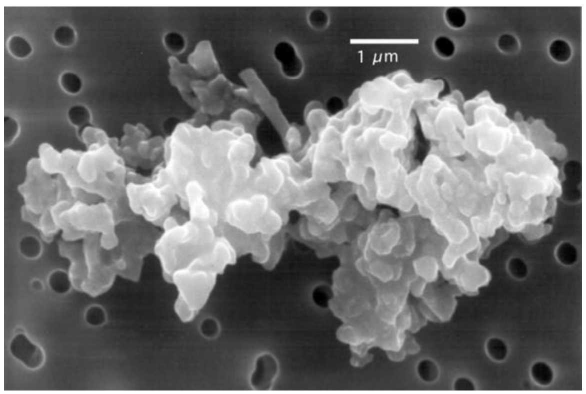
	CTM-039 Results		PSD Analysis of Method 5 Filter		Sampler/True	
Exhaust	% < 10µm	% < 2.5µm	% < 10µm	% < 2.5µm	% < 10µm	% < 2.5µm
Stick Machine	73%	28.3%	78%	4.90%	93%	579%
Overflow	67%	16.8%	67%	1.30%	100%	1335%
Feeder	81%	36.0%	86%	3.30%	93%	1095%

Note: PSDs are in terms of ESD not AED (conservative estimates)

AERODYNAMIC DIAMETER: describes a particle's inertial behavior

(Vanderpool, 2010)

D_p = 4.0 μm (equiv. physical diameter)
ρ_p = 2 g/cc (particle density)
Κ = 1.3 (dynamic shape factor)



V_s = 2.8 m/hr

Aerodynamic Diameter

D_a = 5.0 μm
ρ_a = 1 g/cc

V_s = 2.8 m/hr

$$\boxed{D_a = D_p\,(\rho_p / Κ\,\rho_a)^{0.5}}$$

2004 NRI Grant – Errors Associated with PM Stack Samplers

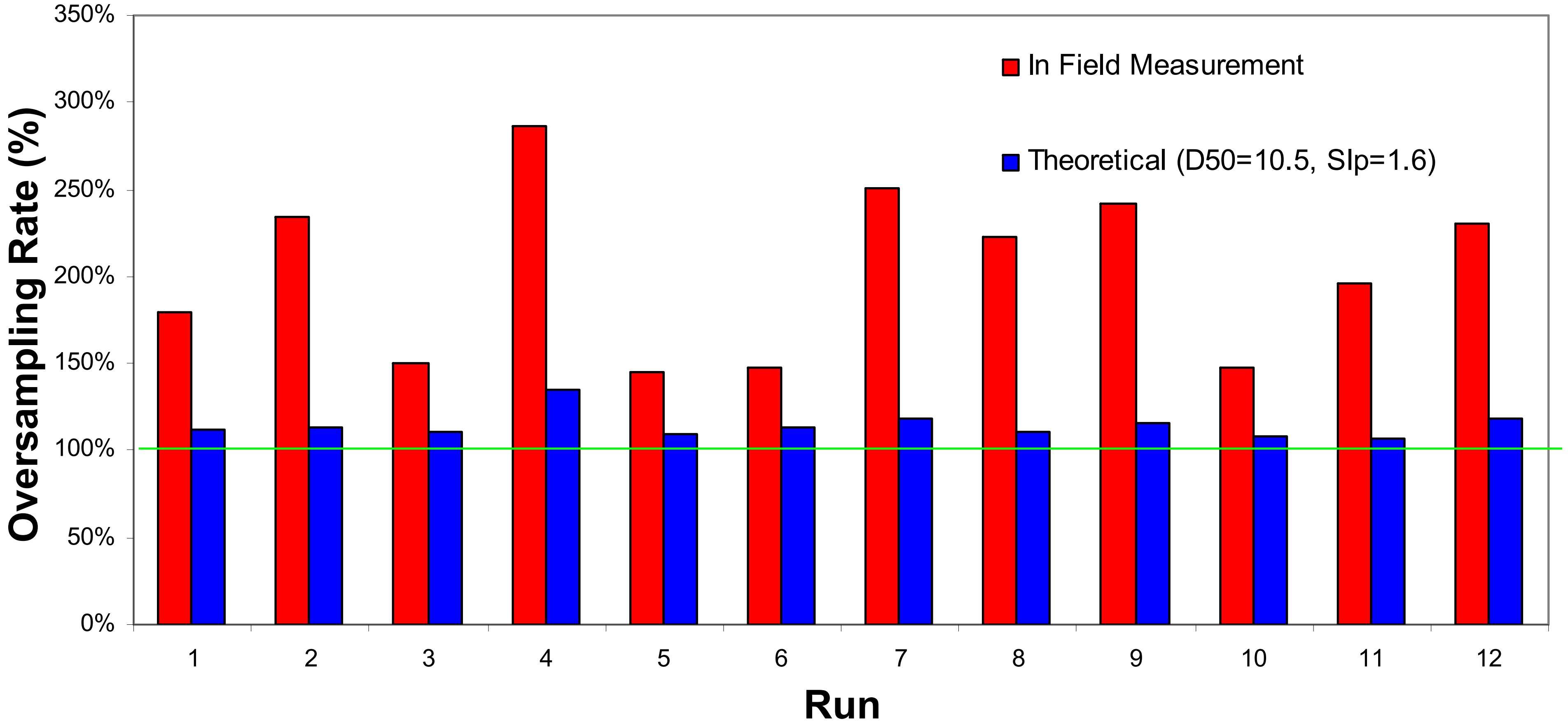
Study Results

Limestone	PM_{10} Over-Sampling	$PM_{2.5}$ Over-Sampling
Rate = 32 g/m^3	123%	700%
Rate = 148 g/m^3	133%	606%
Starch		
Rate = 32 g/m^3	477%	30000%
Rate = 148 g/m^3	444%	25316%

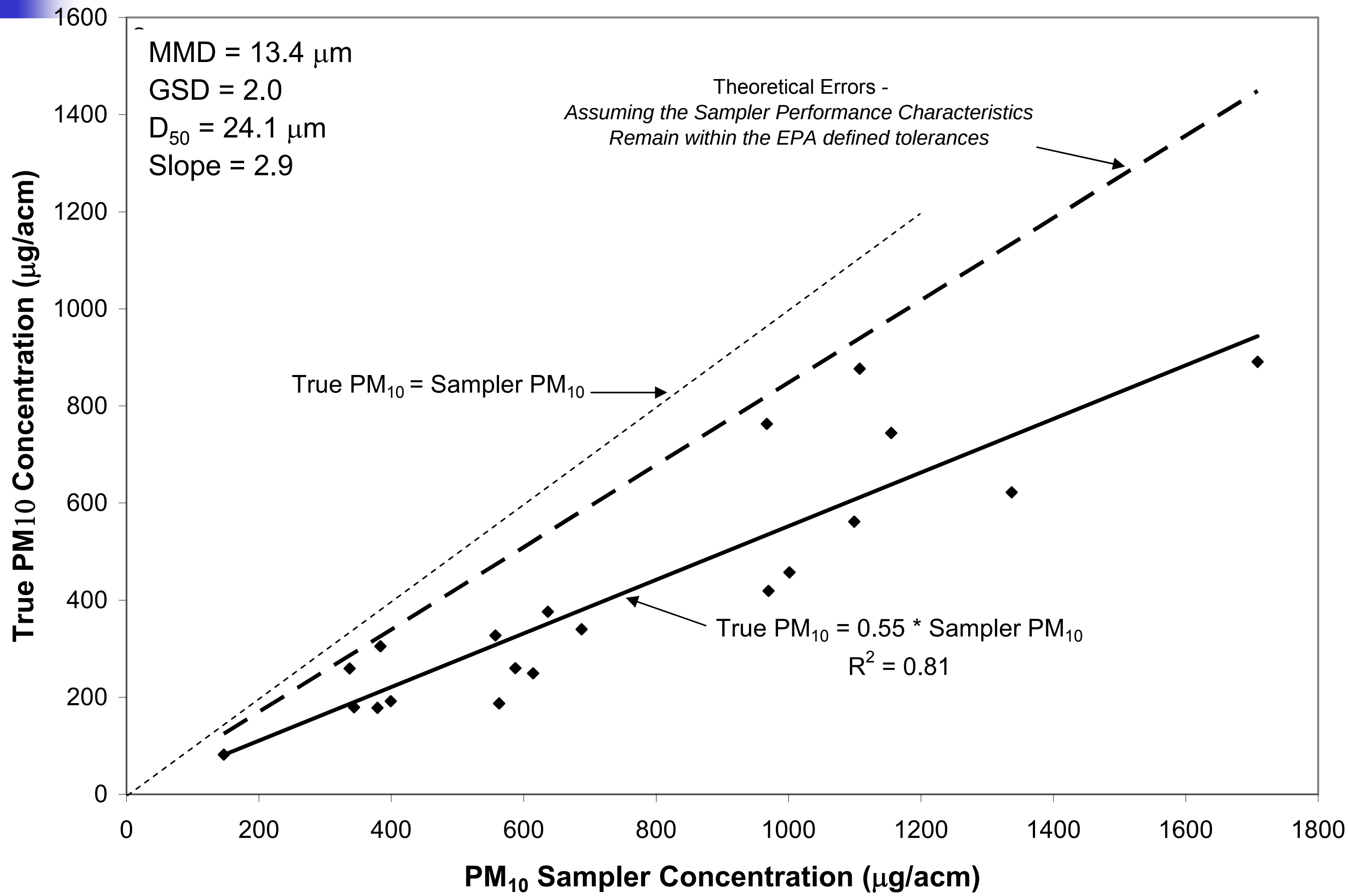
Limestone - MMD = 7.0 μm ESD; GSD = 1.71; ρ = 2.62 g/cm^3

Starch - MMD = 15.1 μm ESD; GSD = 1.33; ρ = 1.26 g/cm^3

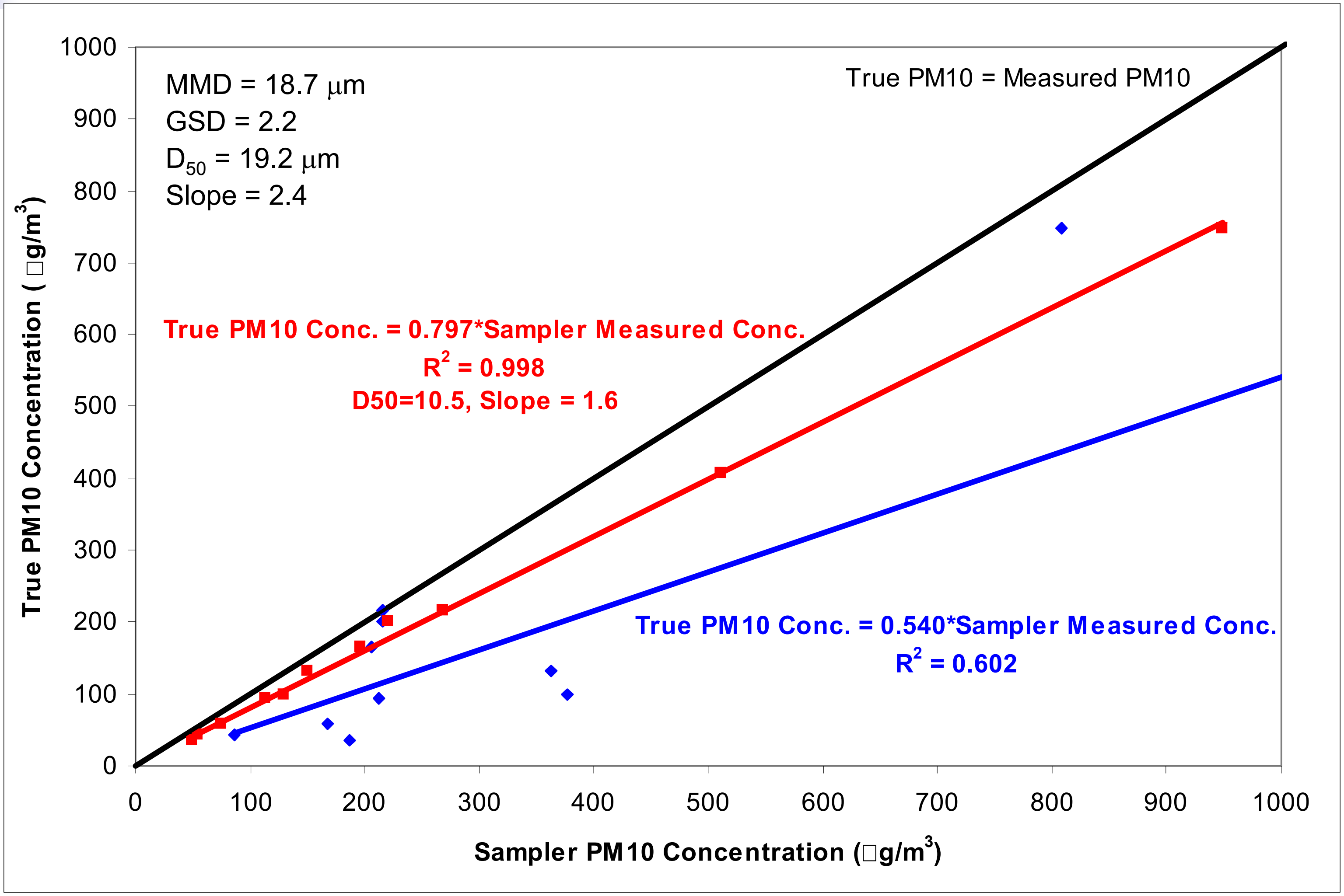
Ambient Sampler Errors – Field Studies



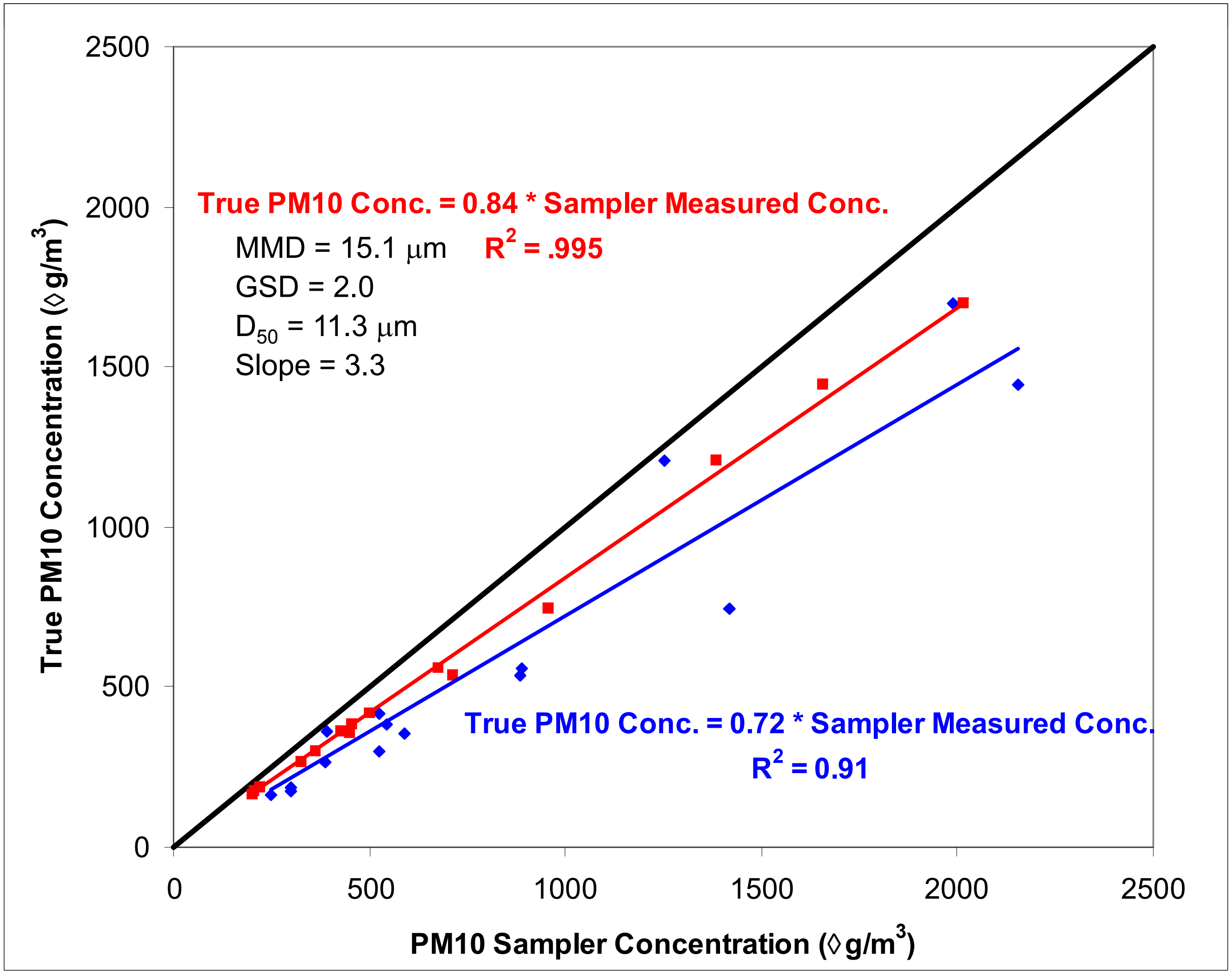
Ambient PM_{10} Sampler – Actual Errors {Cotton Gin}



Ambient PM_{10} Sampler – Actual Errors {Cattle Feed Yard}



Ambient PM_{10} Sampler – Actual Errors {Almond Orchard – Harvesting}

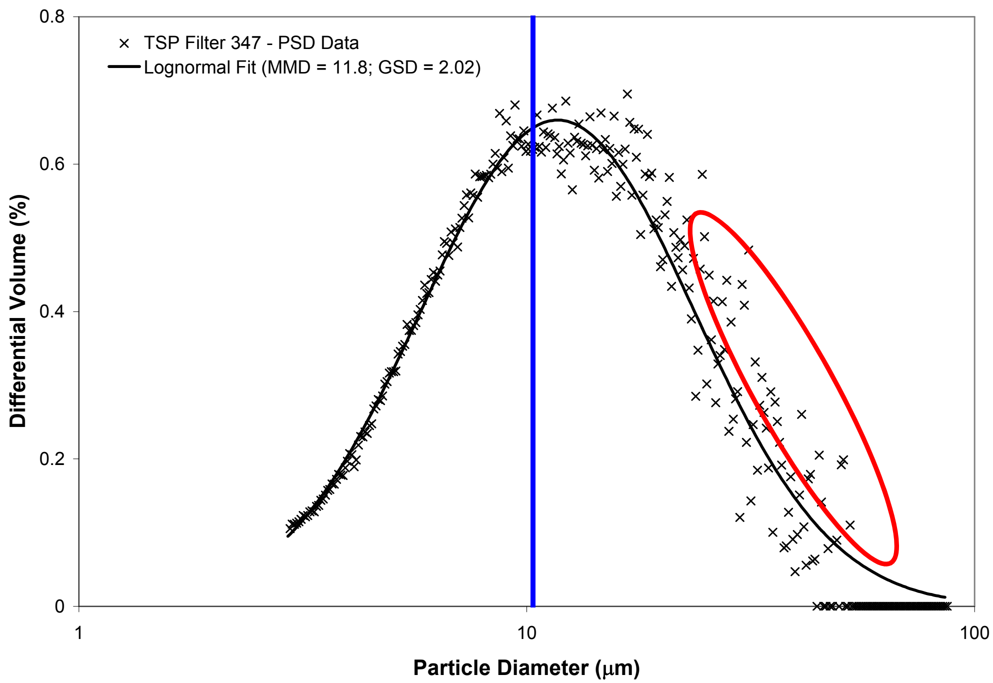


So why are the actual differences larger than the theoretical differences?

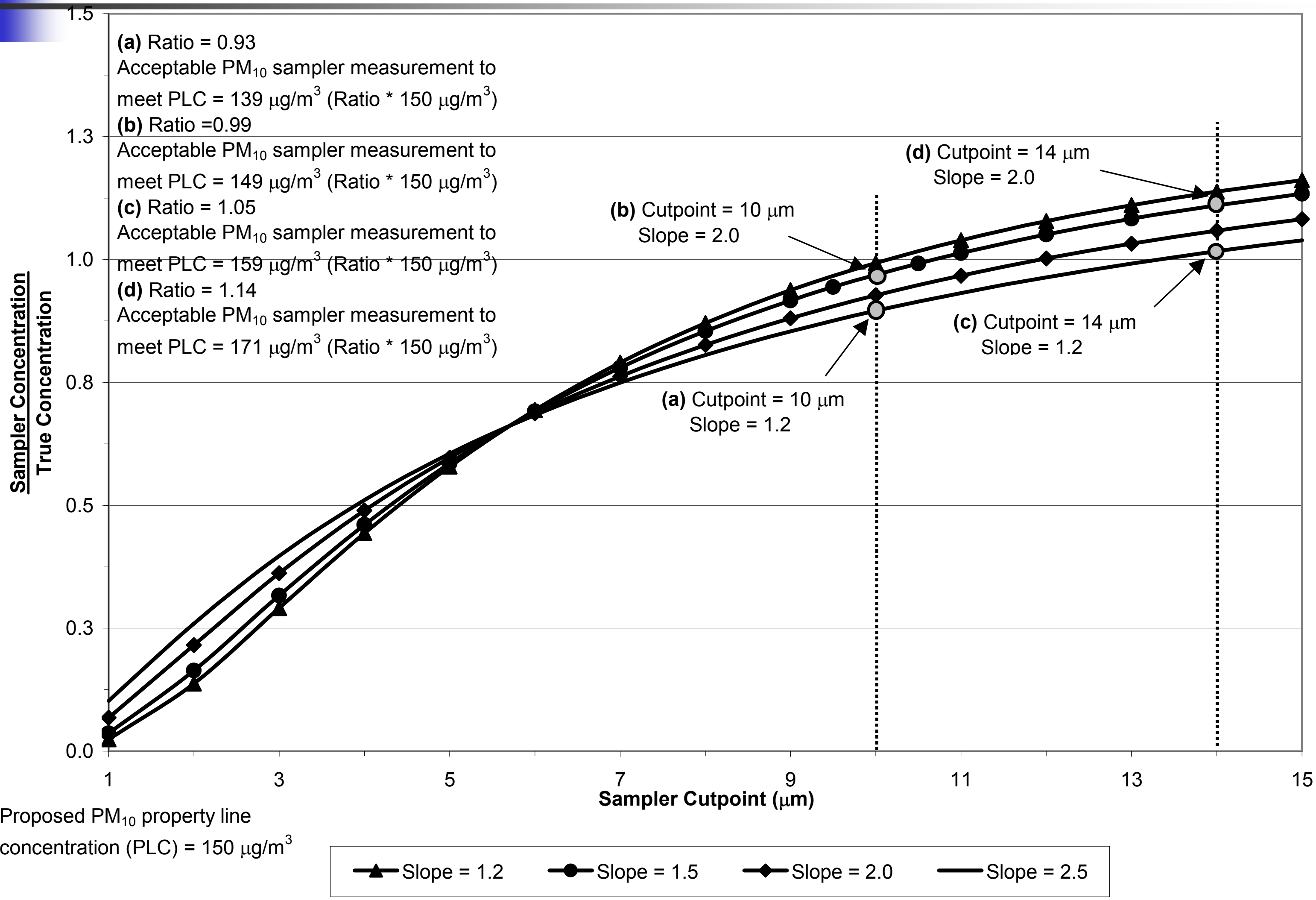
	Concentration ($\mu g/m^3$)	MMD (μm)	GSD
TSP	1,207	13.4	2
PM_{10}	812	11.3	1.8

- Bottom Line!
  - Cutpoint = 24.1 μm {compared to 10 μm}
  - Slope = 2.9

    {compared to 1.5}
- Causes
  - High Concentrations
  - PSD Characteristics
  - Poor sampler placement

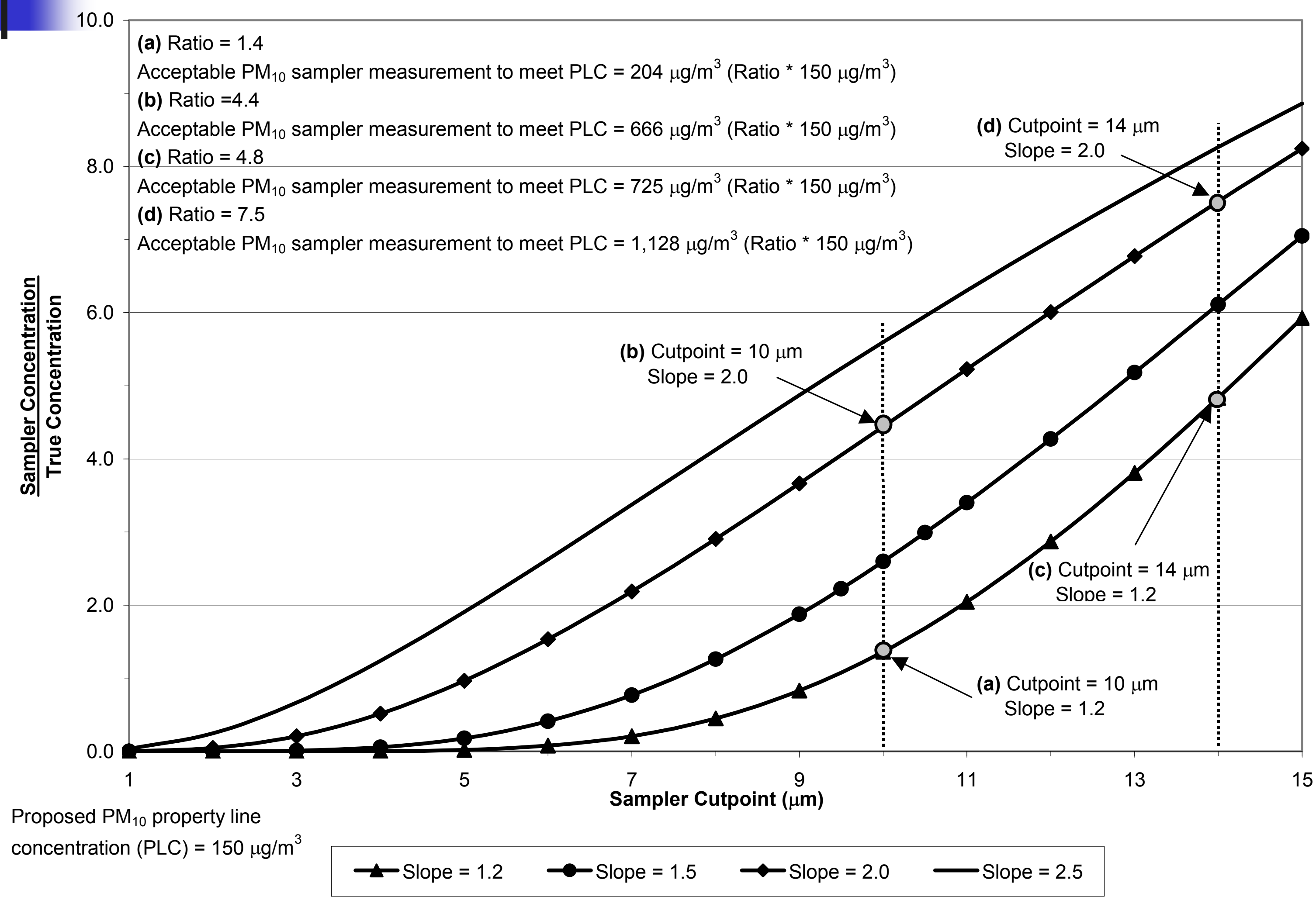


Effects of Varying PM_{10} SPC (PSD: MMD = 5.7 μm; GSD = 2.25)



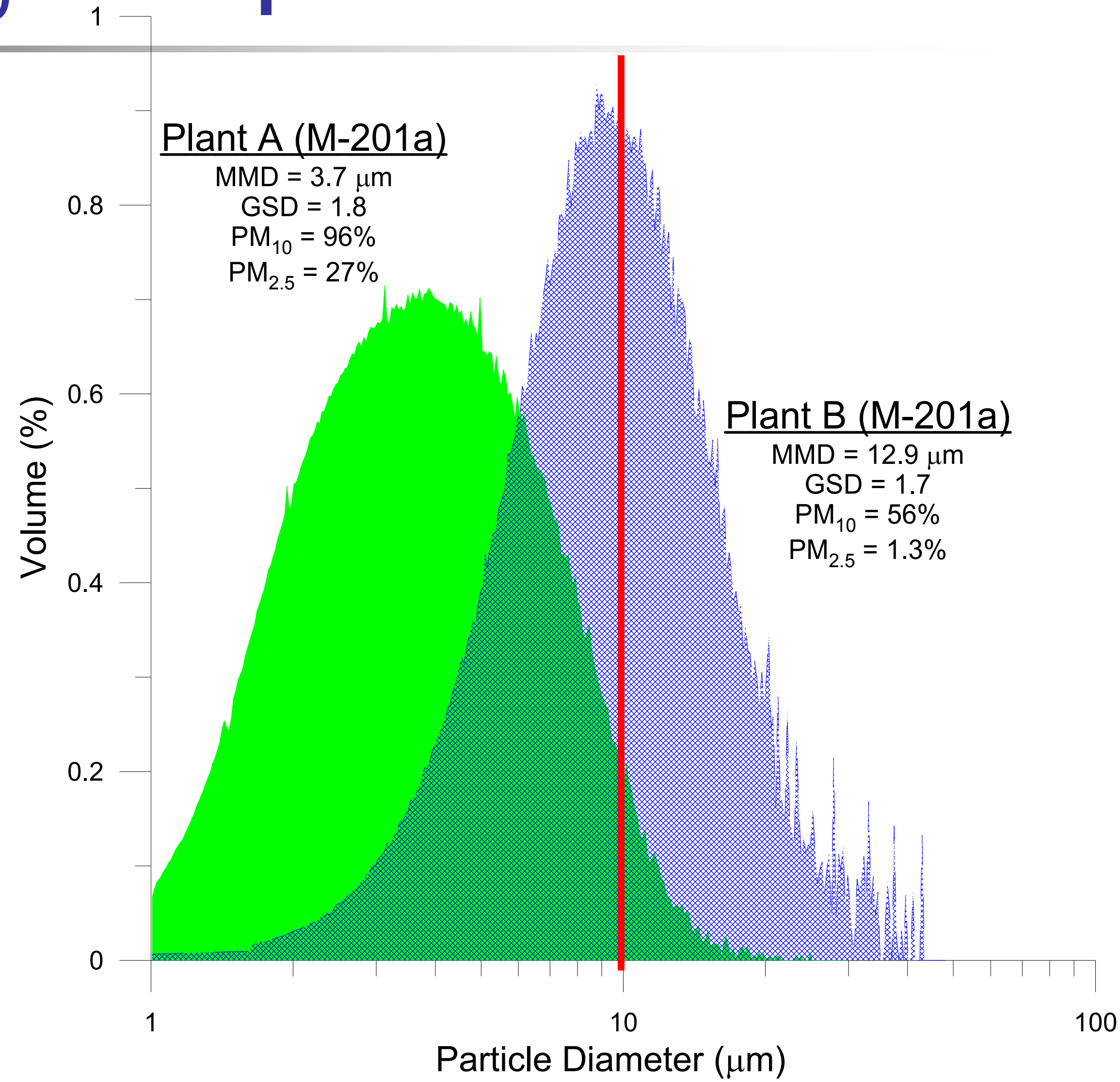
Proposed PM_{10} property line concentration (PLC) = 150 μg/m^3

Effects of Varying PM_{10} SPC (PSD: MMD = 20 µm; GSD =1.5)



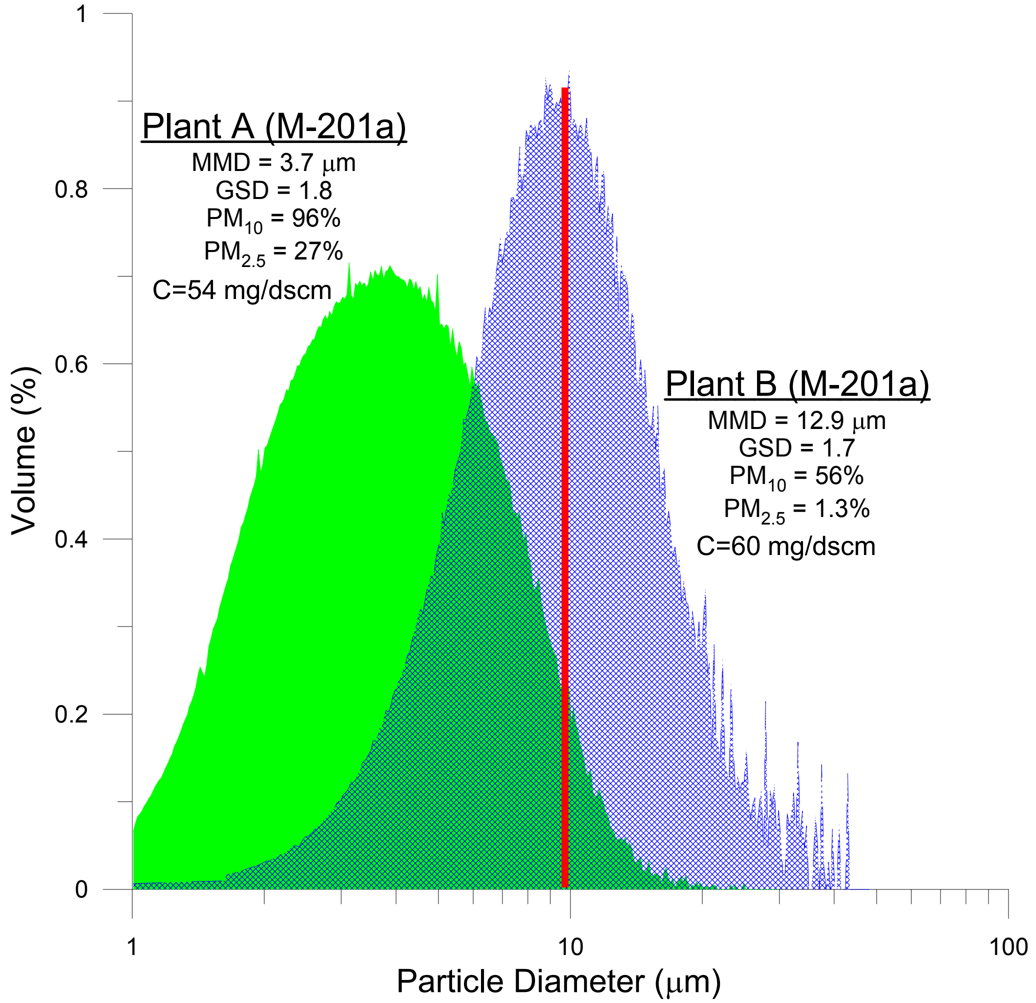
Comparing Material Collected from PM_{10} samplers

- Both samples were collected using Method 201a (PM_{10} sampler)
- Filter comparison only
- Concentration based on filter mass only
  - Plant A – 48 mg/dscm
  - Plant B – 60 mg/dscm
- Concentration < 10 μm
  - Plant A – 46 mg/dscm
    - {48*0.96=46}
  - Plant B – 34 mg/dscm
    - {60*0.56=34}

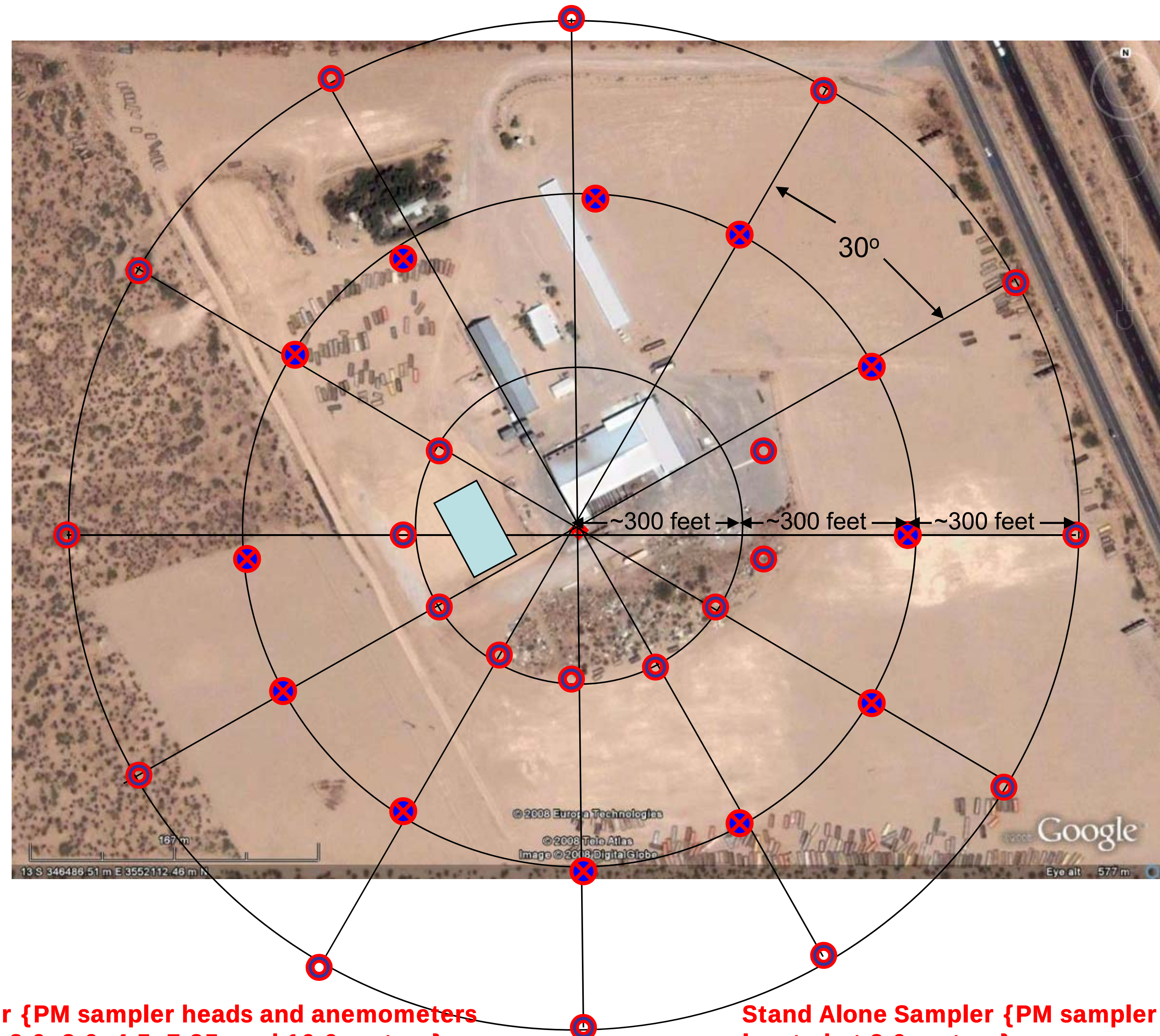


Questions

1) Health based studies – are the PM data used in the studies comparable?
   A. Are we comparing apples to apples?
2) If I stand at the property line that separates Plant A and B will Plant B's (higher PM_{10} sampler based concentration) emissions more negatively impact my health?
3) If I'm evaluating regional PM air quality models using FRM PM sampler concentrations, how good are my modeling results?
   A. Garbage in – garbage out
4) Are these plants being equally regulated?
5) How will you answer the same questions for $PM_{2.5}$?
   1) The PSD differences are greater

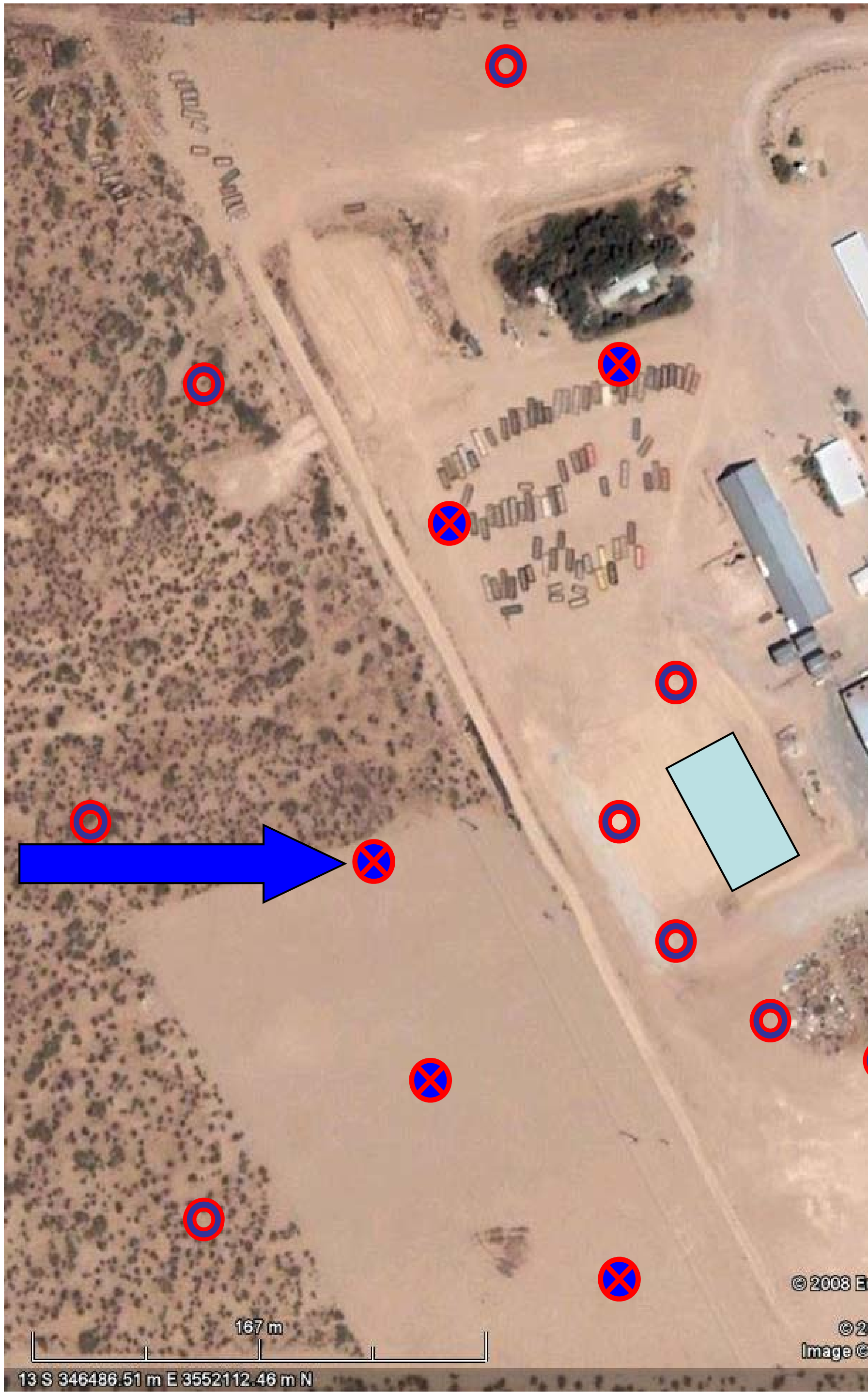


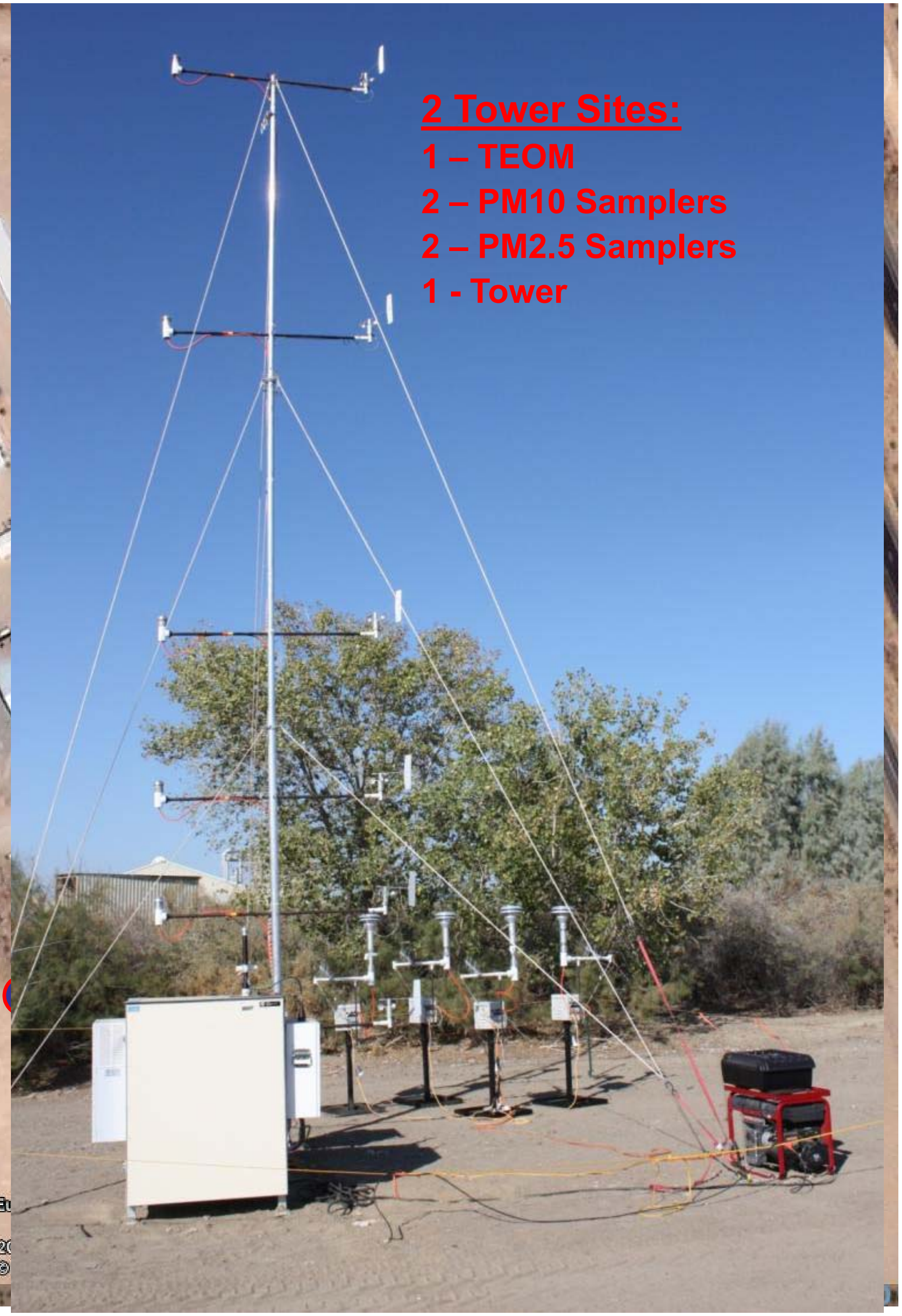
Dispersion Modeling



Tower Sampler {PM sampler heads and anemometers located at 1.0, 2.0, 3.0, 4.5, 7.25, and 10.0 meters}

Stand Alone Sampler {PM sampler head located at 2.0 meters}


167 m
13 S 346486.51 m E 3552112.46 m N


2 Tower Sites:
1 – TEOM
2 – PM10 Samplers
2 – PM2.5 Samplers
1 - Tower

Recommendations

- Development of alternative ambient and stack sampling methodologies
  - TSP or total particulate matter sampling coupled with particle size analysis
- Development of ambient PM_{10} and $PM_{2.5}$ sampler placement guidelines
- Development of dispersion modeling correction factors for low level sources