Quantifying Pollutant Loads w/ Sediment Collected by Source Control and Maintenance Practices

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Maintenance Matters !!

- Not only does maintenance matter, it reduces pollutant loads to receiving waters; and it also pays for a MS4 to quantify their maintenance
- This project creates a "yardstick" by which pounds of residual sludge and particulate matter recovered from MS4 drainage appurtenances and BMPs is equated to pounds of pollutants for which an MS4 can utilize in the BMAP process

Project Background

1. A very significant inventory of urban residual material is deposited (albeit temporarily) in the infrastructure components of the urban drainage network on a wet and dry weather basis

2. The most significant component of this drainage network is the urban pavement surface (> 15% of a Florida MS4 area)

3. The most numerous component of this drainage network are catch basins (curb/gutter inlets)

4. Catch basin inserts and “BMP” are becoming a more common and maintenance-intensive component of the drainage network

Project Hypothesis

- Based on results for recovery of urban residuals from BMPs and urban snow inventories, results demonstrated a set of relationships between dry pounds of residuals (sludge, debris, particulate matter …) and metals (Cd, Cu, Pb, Zn …)
- Therefore it is hypothesized that there is a set of relationships between dry pounds of residuals and nutrients (N and P)
- Knowledge of this set of relationships can allow a MS4 to convert dry pounds of residuals recovered to pounds of nutrients recovered without requiring N and P analysis for each maintenance operation undertaken by an MS4

Project Objective and Outcome

The project objective is to develop a quantitative “yardstick “by which a Florida MS4 can quantify the load of a nutrient (N and P) recovered through cleaning and recovery of residuals from :

1. Street sweeping,
2. Catch basins,
3. Common BMP (preferentially catch basin or baffle box insert)

The outcome will be a “yardstick” combined with documentation allowing an MS4 to equate pounds of dry residuals recovered during a maintenance operation, to pounds of N and P recovered

Previous results from 2007 FSA study

- Examine particulate matter inventories as a function of:
  - Control strategy that collects particulate matter (PM)
    1. *Recovery of PM from street sweeping*
    2. *Catch basins*
    3. *BMPs*
  - Each control represents loadings from range of cover conditions, activities, and unknown operational and maintenance plans (*plans rarely utilized for BMPs*)
  - Street sweeping represent source area loadings and can represent dry deposition if captured before a rainfall.

Catch Basin Particulate Matter Pollutant Inventory

- All constituents values on a dry weight basis
- Particulate matter (PM) cleaned out from catch basins
- Data from previous studies obtained from the literature
  - Particle size gradation (PSD) generally unknown (2 exceptions:)
    - *Sansalone and Lin (2003) provided PSD and metals for catch basins*
    - *Townsend's FSA study provided metals, but no nutrients or PSDs*
  - While PSDs are generally unknown; gradations are coarse (> 75 μm)
- Data fit a statistical distribution - there is statistical set of values associated with a given land use: <u>Goal – minimize variability</u>

Previous results from 2007 FSA study

- 100^{+} national and international databases
- Disparate variety of methods and results
  - Resulting high variability in results
- Statistical analysis of results

GOAL: *Demonstrate how much pollutant is collected for each dry pound of dry sludge collected*

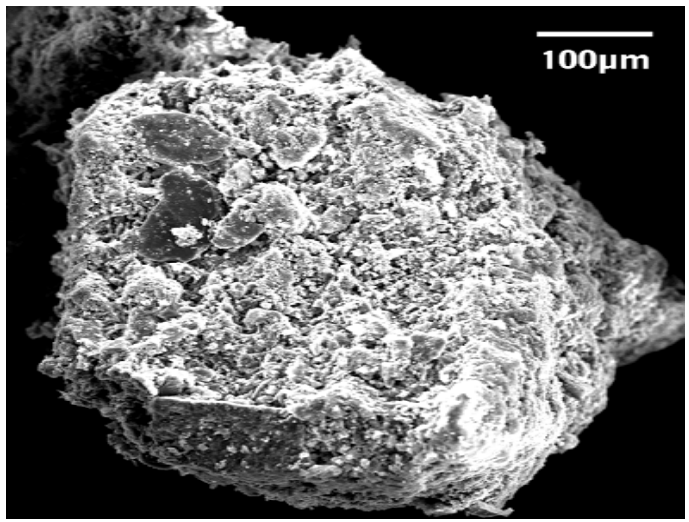
RESULT: *Despite the disparate methods, results indicate there is a relationship between pollutant and sludge recovered, albeit with high variability*

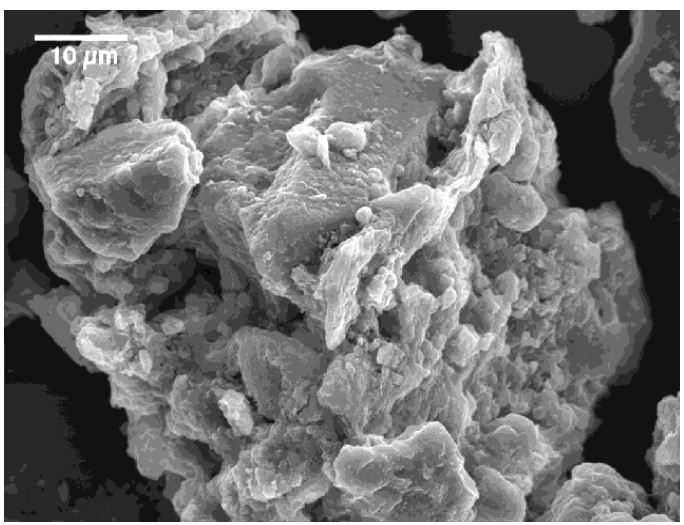
Background: MS4 Deposition-Runoff-Sludge

What is Urban MS4 Particulate Matter (PM) ?

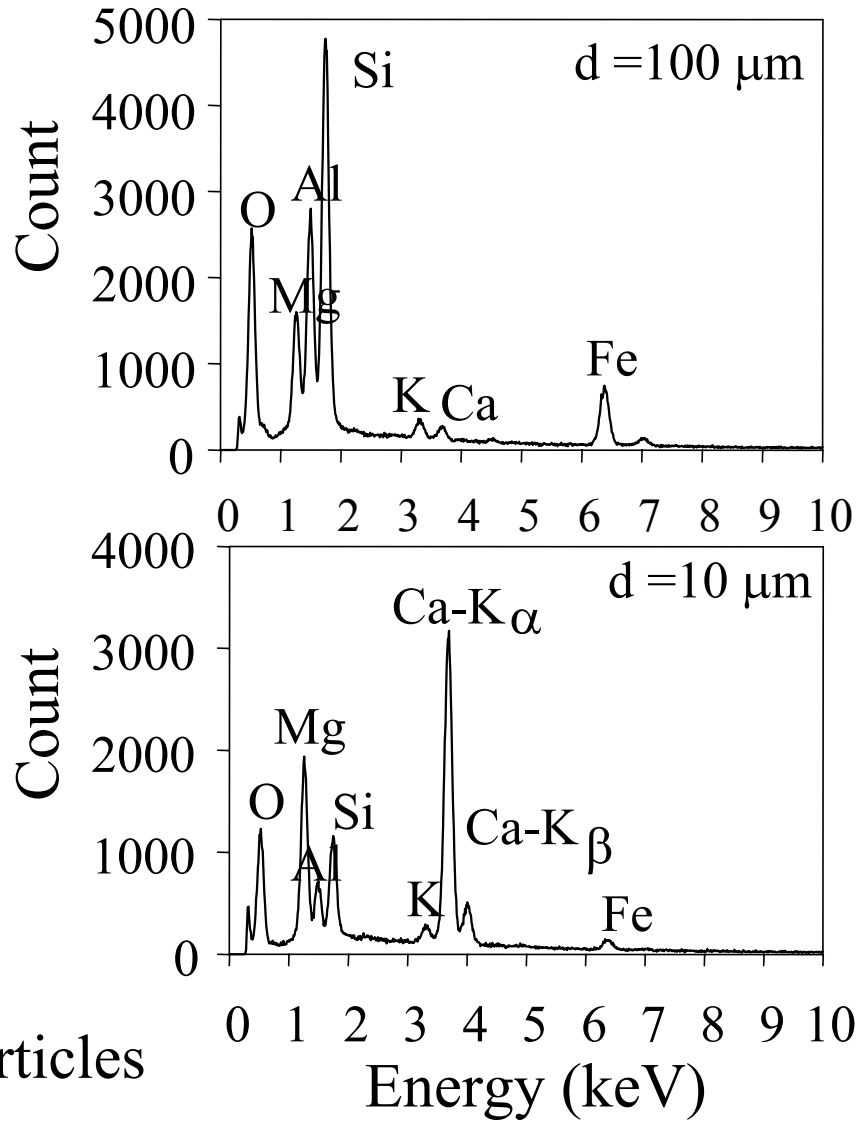
- Heterogeneous mixture of particulate-type materials from a variety of biogenic and anthropogenic sources
- Very hetero-disperse (wide particle size distribution)
- Variable density, ρ_s
- Coarser “sediment” fraction separated at #200 sieve
- Generated by anthropogenic sources (i.e. traffic) and biogenic sources
- Transported by wind and runoff intensity

Urban Anthropogenic Particles
(Examination with SEM, energy dispersive X-ray spectra)

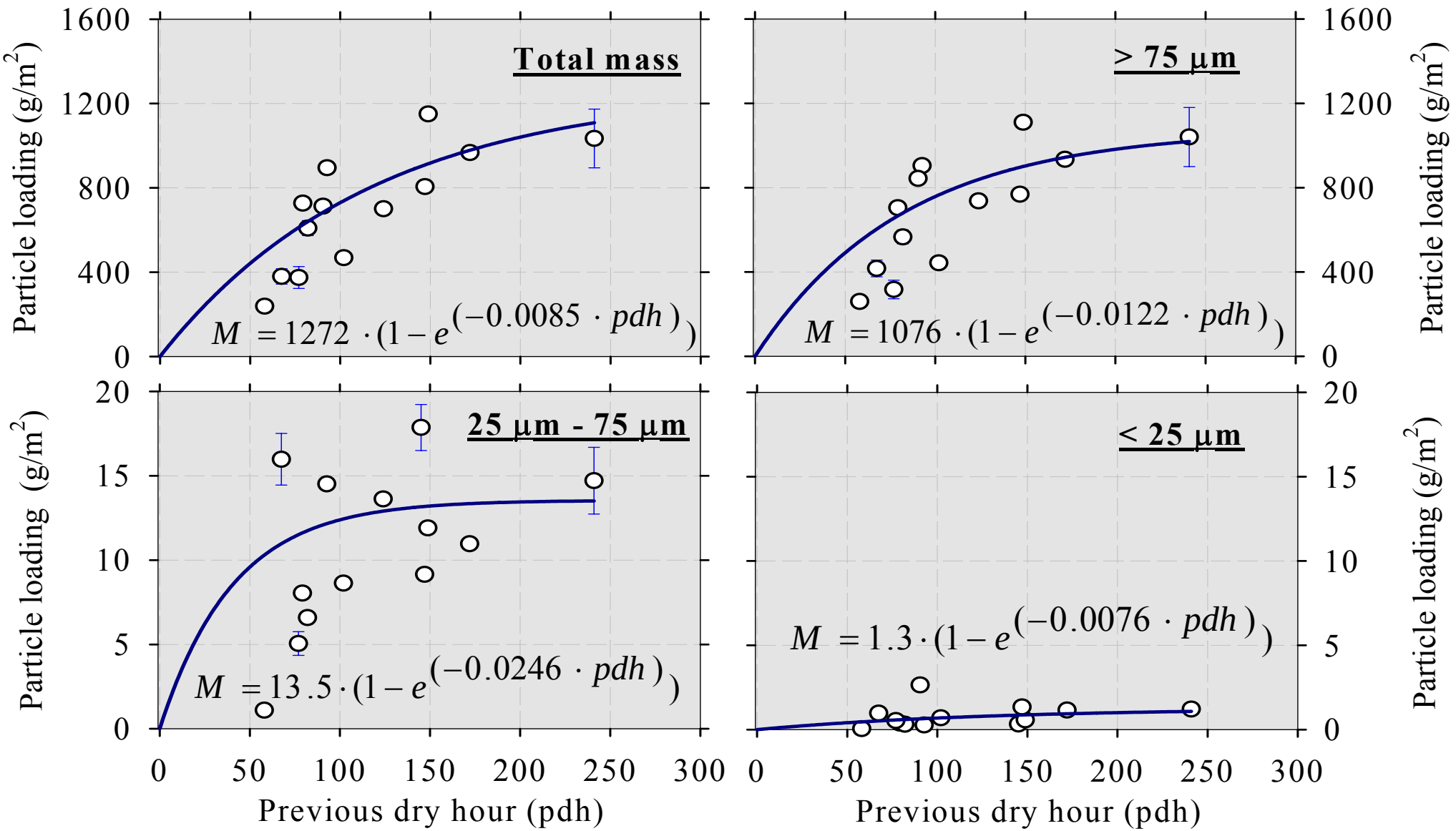




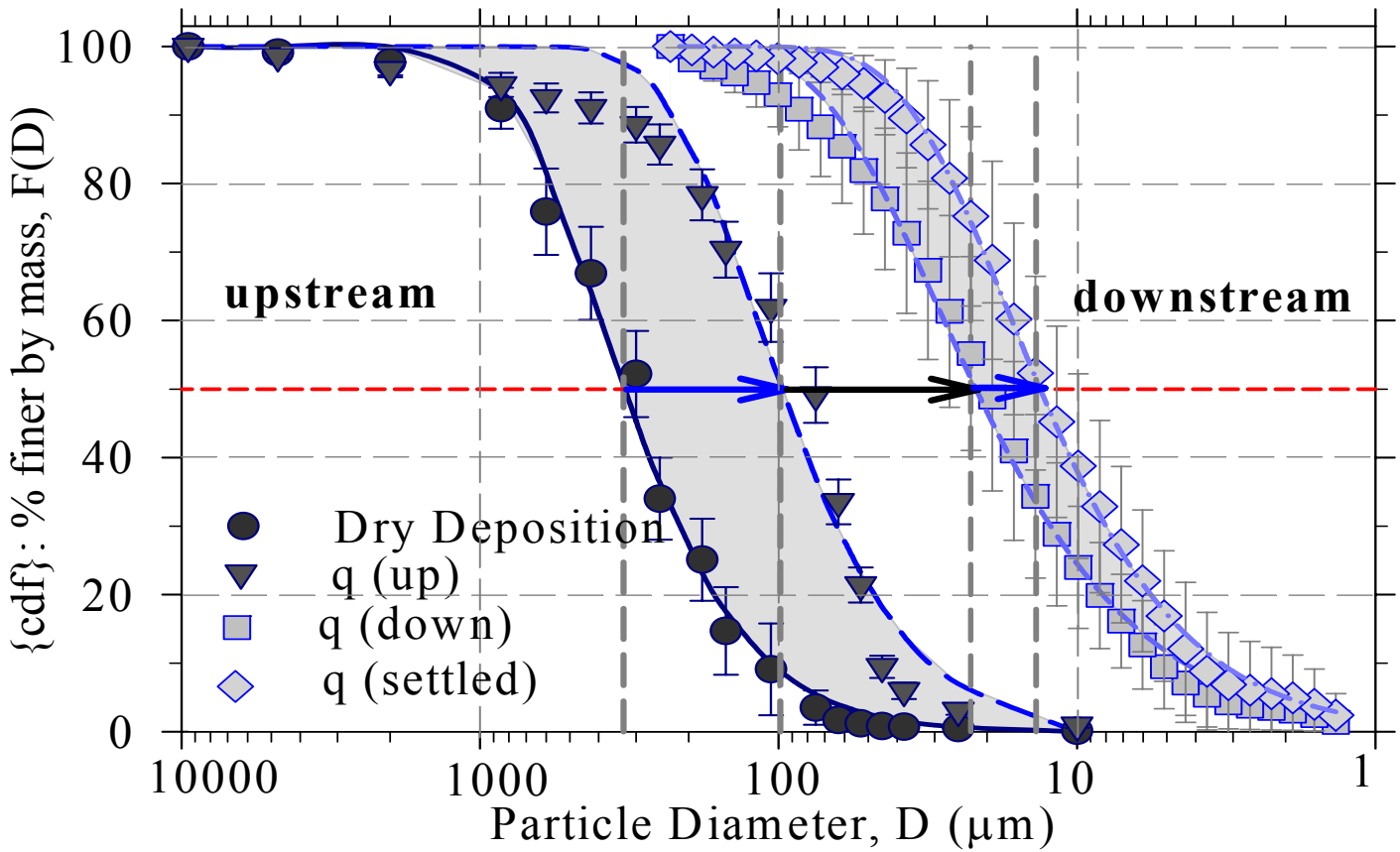
SEM images for stormwater particles



Relationship of Previous Dry Hour and Particle Mass



Particle Size Modification by Urban Conveyance System: Choice and location of a unit operation will influence treatment behavior



PSD gamma model

$$f(D) = \frac{(D/\beta)^{\gamma-1} e^{(-D/\beta)}}{\beta \cdot \Gamma(\gamma)}$$

$$F(D) = \Gamma_D(\gamma) / \Gamma(\gamma)$$

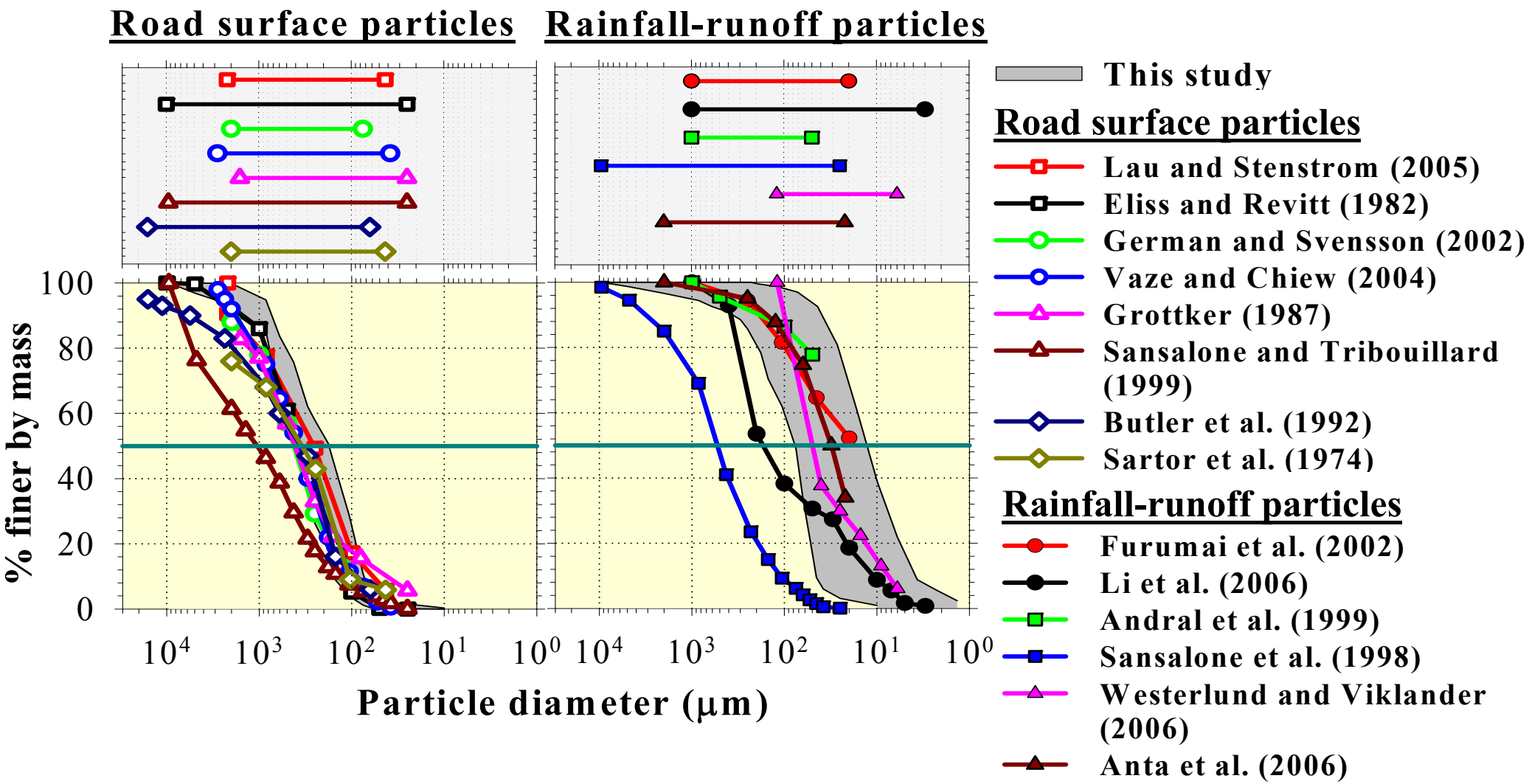
$$\Gamma(\gamma) = \int_0^{\infty} x^{\gamma-1} e^{(-x)} dx$$

$$\Gamma_D(\gamma) = \int_0^{D} x^{\gamma-1} e^{(-x)} dx$$

Location	(γ, β)
DD	(2.06, 187.7)
q (up)	(1.90, 61.9)
q (down)	(1.23, 23.6)
q (settled)	(1.51, 11.1)

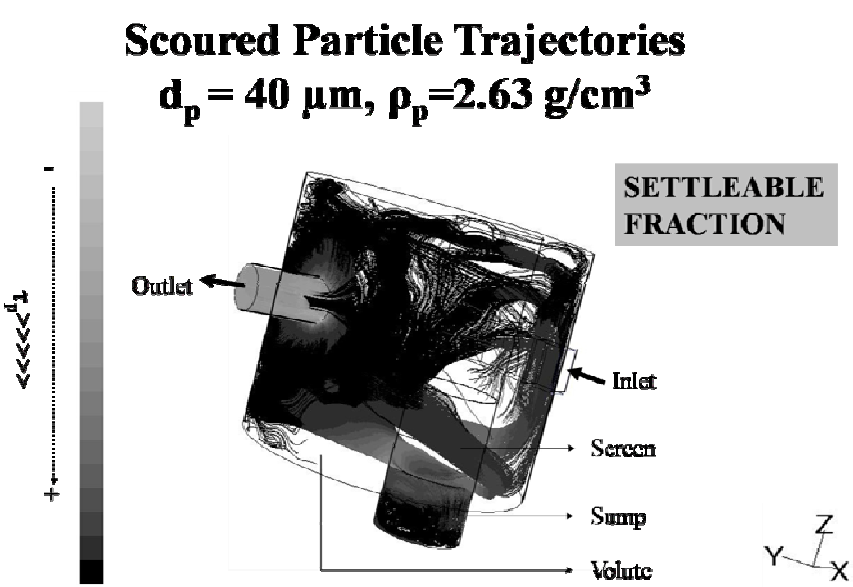
	DD Dry Deposition	q (up) Upstream Runoff	q (down) Downstream Runoff	q (settled) Settled (1 hour) Runoff
D_{50m}, µ m	330.7	98.6	22.6	13.7

Comparison of PSDs and measured particle size ranges on road surfaces and in urban rainfall-runoff



Maintenance and pollutant inventories: The “Achilles Heel” of manufactured BMPs and stormwater conveyance components

- The photo is a clogged stormwater catch basin inlet grate on steep slope of NW 22nd Street
- The challenge of microbiological vectors, long-term contaminant legacy, leaching, scour and clogging. How does MS4 monitor viability and maintenance of hundreds of such BMPs in an MS4 or County ?

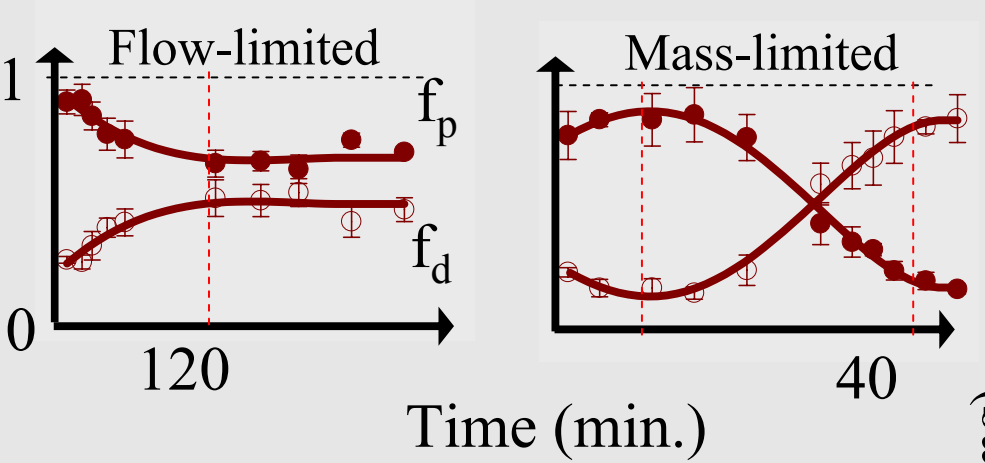


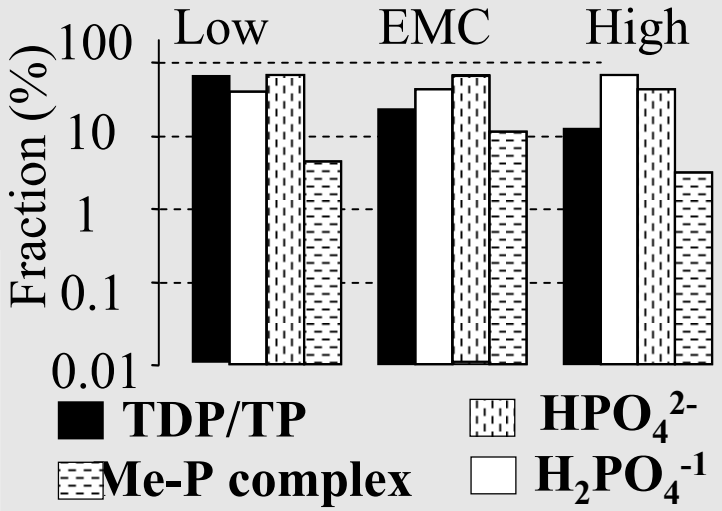
Partitioning/distribution mass loads (example – P)

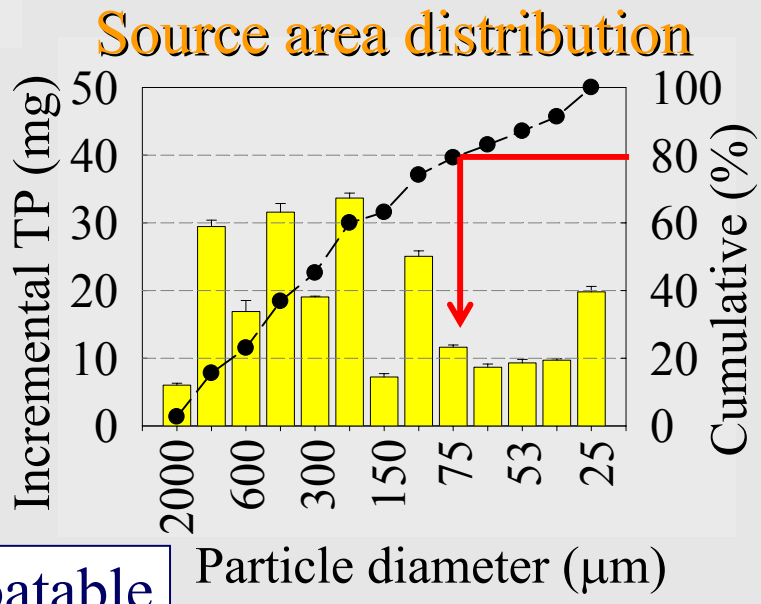
Inorganic or organic mass

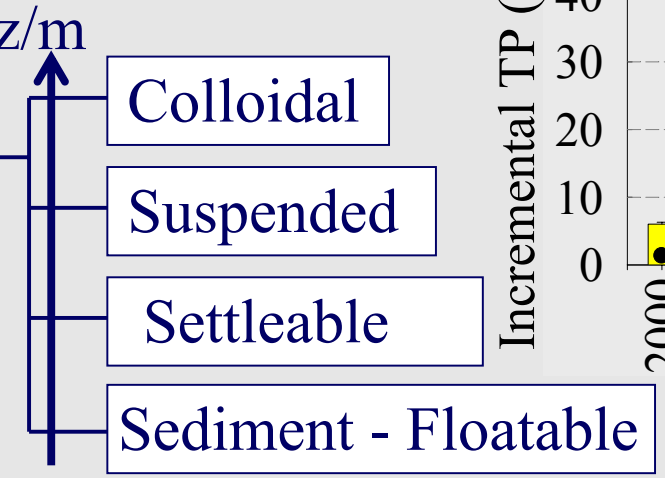
- Dissolved (aqueous) f_d
  - Ionic
  - Complexed
- Adsorbed (Particulate-Bound) f_p
  - Colloidal
  - Suspended
  - Settleable
  - Sediment - Floatable

Poorly sampled and often ignored









Fate of Pollutants in MS4s

By design, our impervious pavement systems are collectors, concentrators and generators of runoff and pollutants.

- For example as a collector, common design practice is to drain the front yard to the pavement curb and into the gutter
- For example as a concentrator, aerially-distributed rainfall becomes concentrated curb/gutter flow on a pavement thereby allowing for effective pollutant transport
- For example as a generator, traffic generates pollution load equal or greater for many pollutants than untreated MS4 wastewater from the same MS4

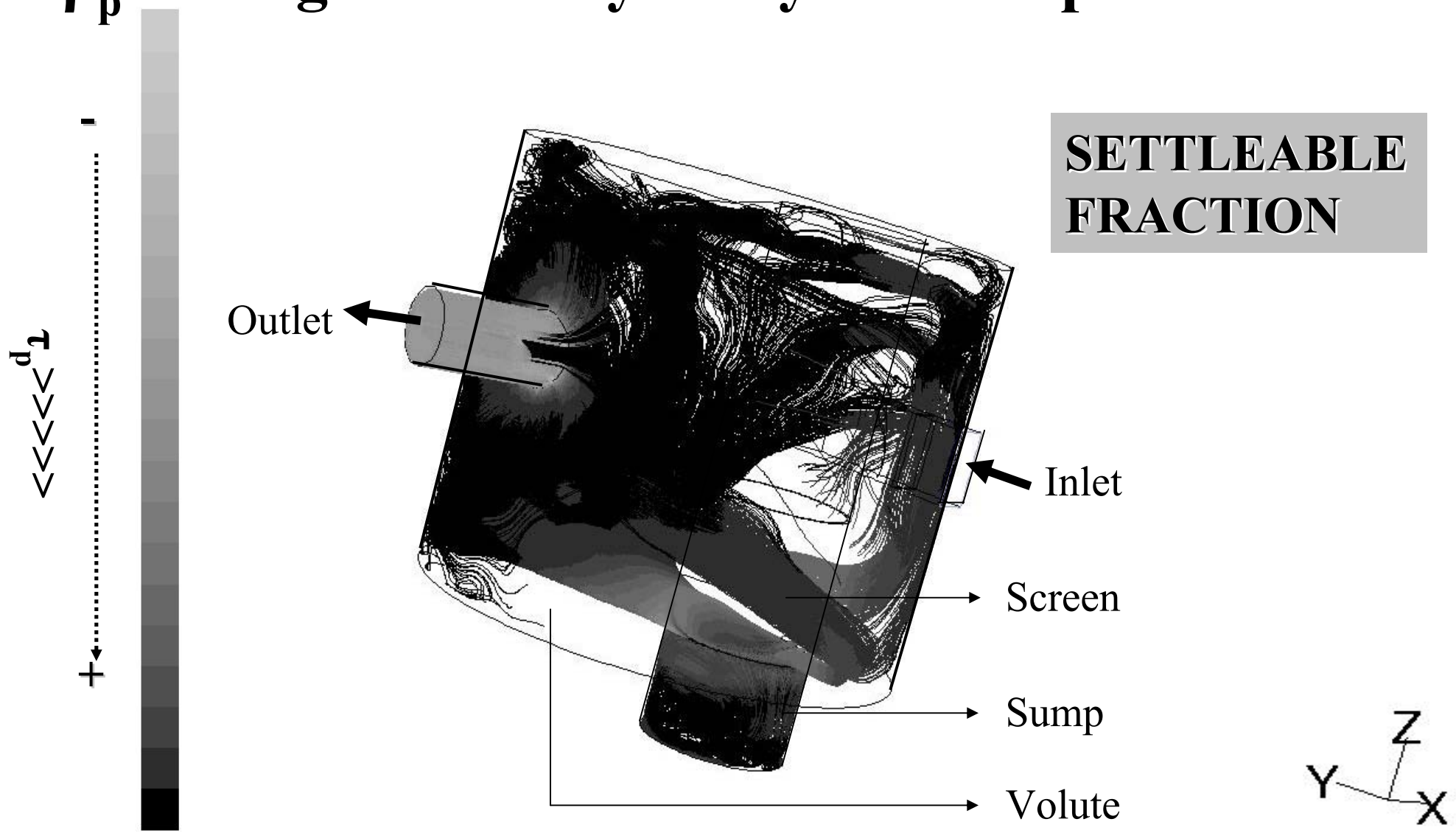
This runoff and pollutant load is either deposited on the pavement, or temporarily in our drainage appurtenances and BMPs

Sampling of Street Sweeping Residuals

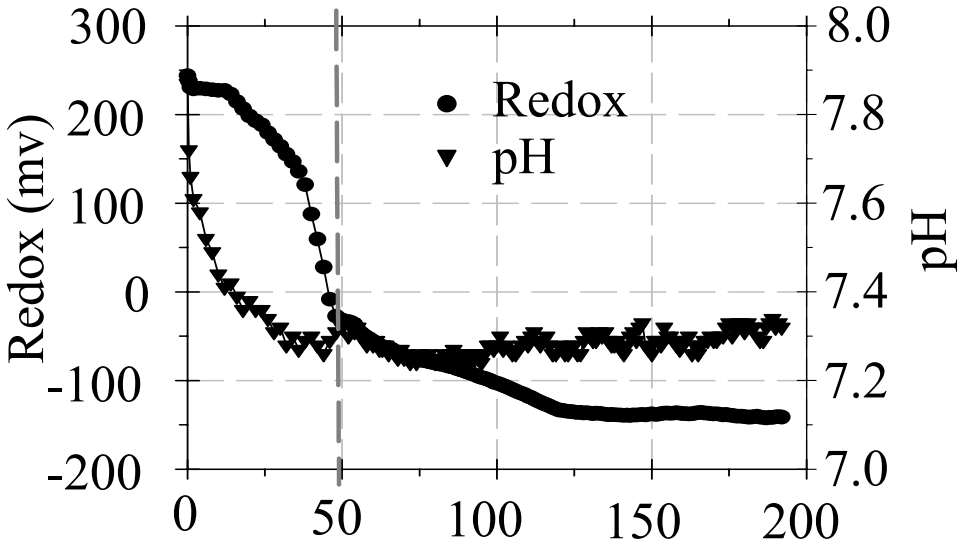
It is always more economical to recover street sweeping residuals in the dry phase instead of separation of such residuals and pollutants in runoff by structural "BMPs"

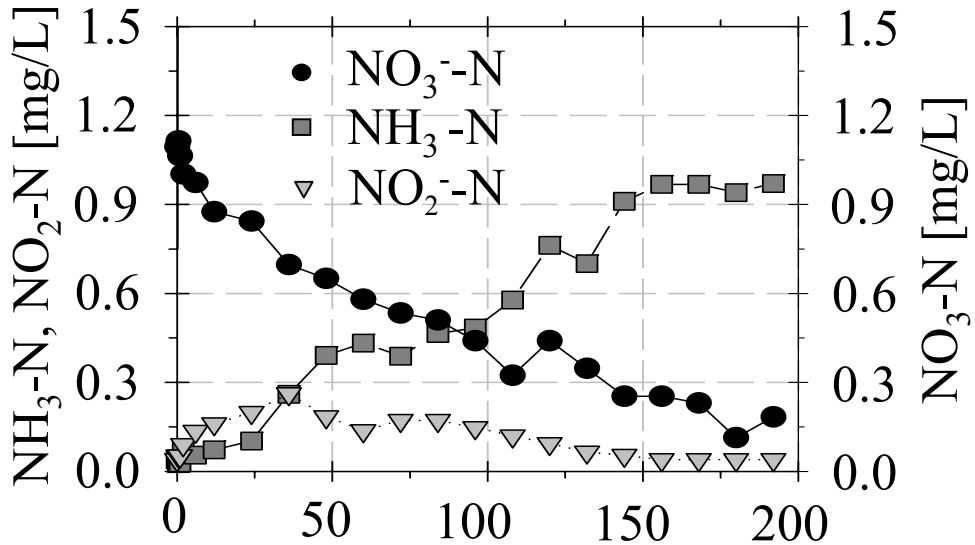
- **Arguably, the most logical and cost-effective pollutant load recovery tool of a Florida MS4**
- HOWEVER, not all pavement cleaners or street sweepers are created equal
- This is significant mis-application of street sweeper types for given conditions
- How (speed, frequency …) a street sweeper is operated is also important
- New generation, high efficiency street sweeper are significantly more effective than older systems

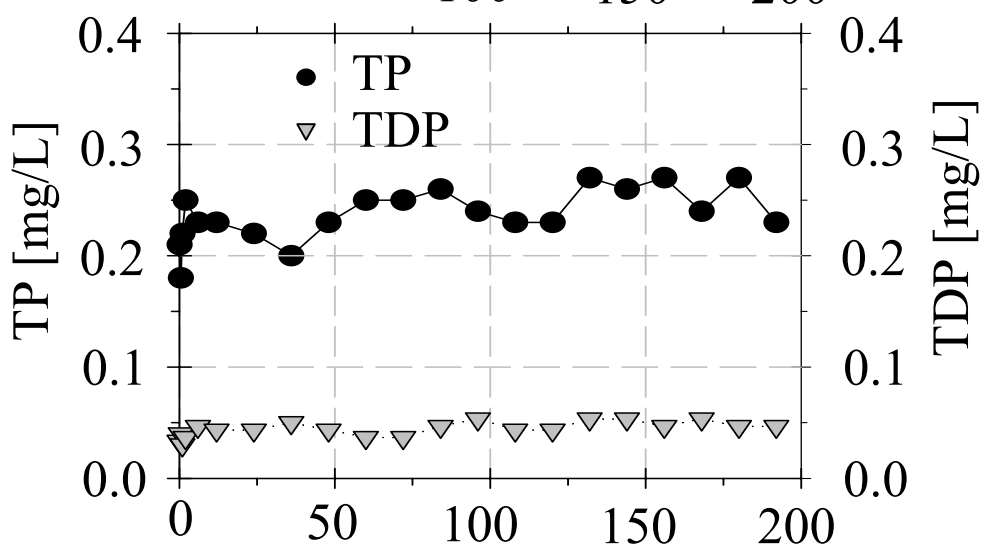
Scoured Particle Trajectories, $d_p = 40\ \mu m$, $\rho_p = 2.63\ g/cm^3$ for hydrodynamic separator



Redox, pH, N and P changes in a manufactured BMP

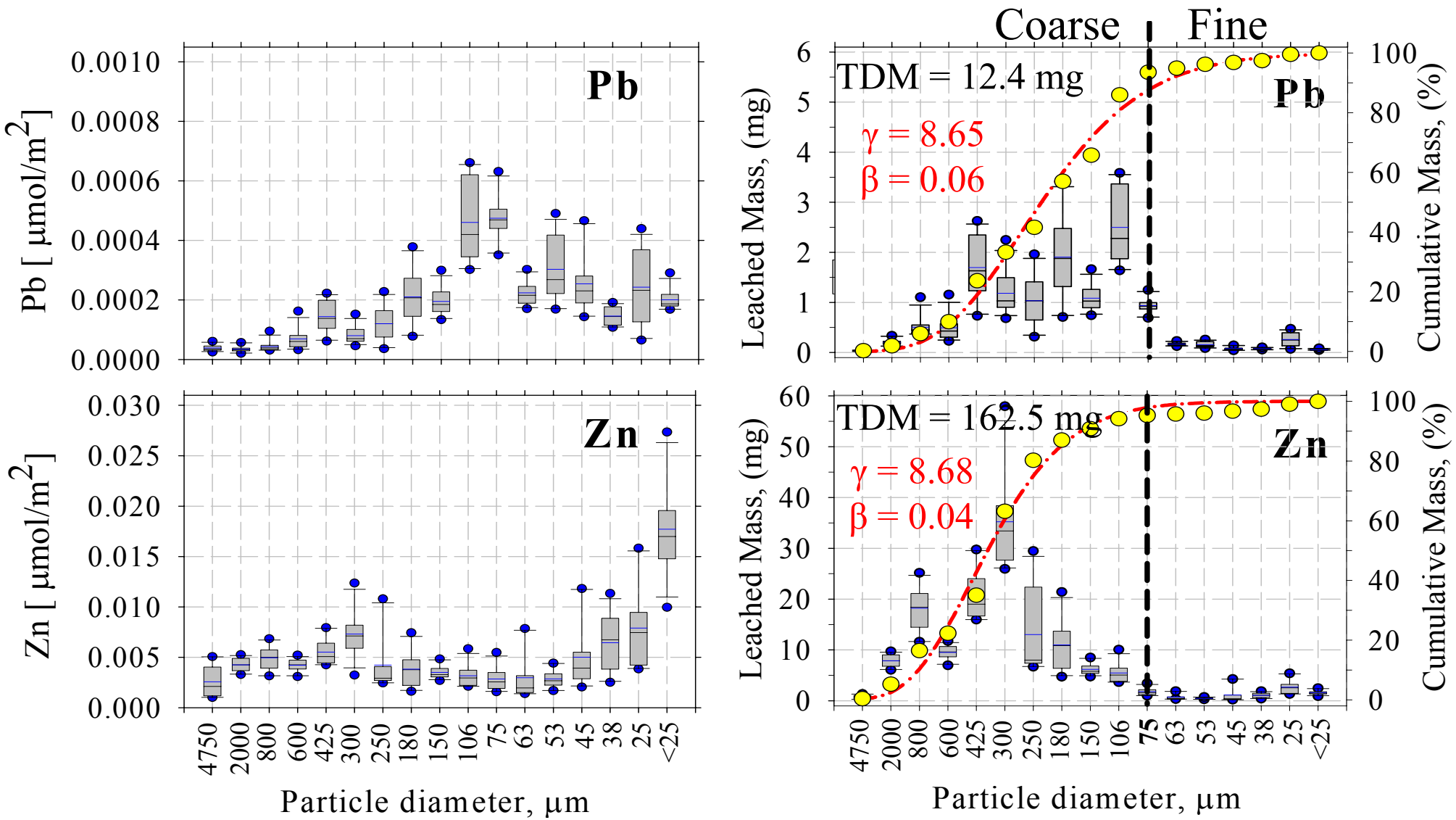






- Time 0 represents the cessation of runoff from the 09 August 2006 event
- Redox significantly drop in 48 hrs residence time after 15 hrs acclimation
- Transformation to anoxic/anaerobic condition for BMPs with extended periods of residence time
- Nitrogen species that are more toxic are ammonia and nitrite; ammonia significantly increases over time

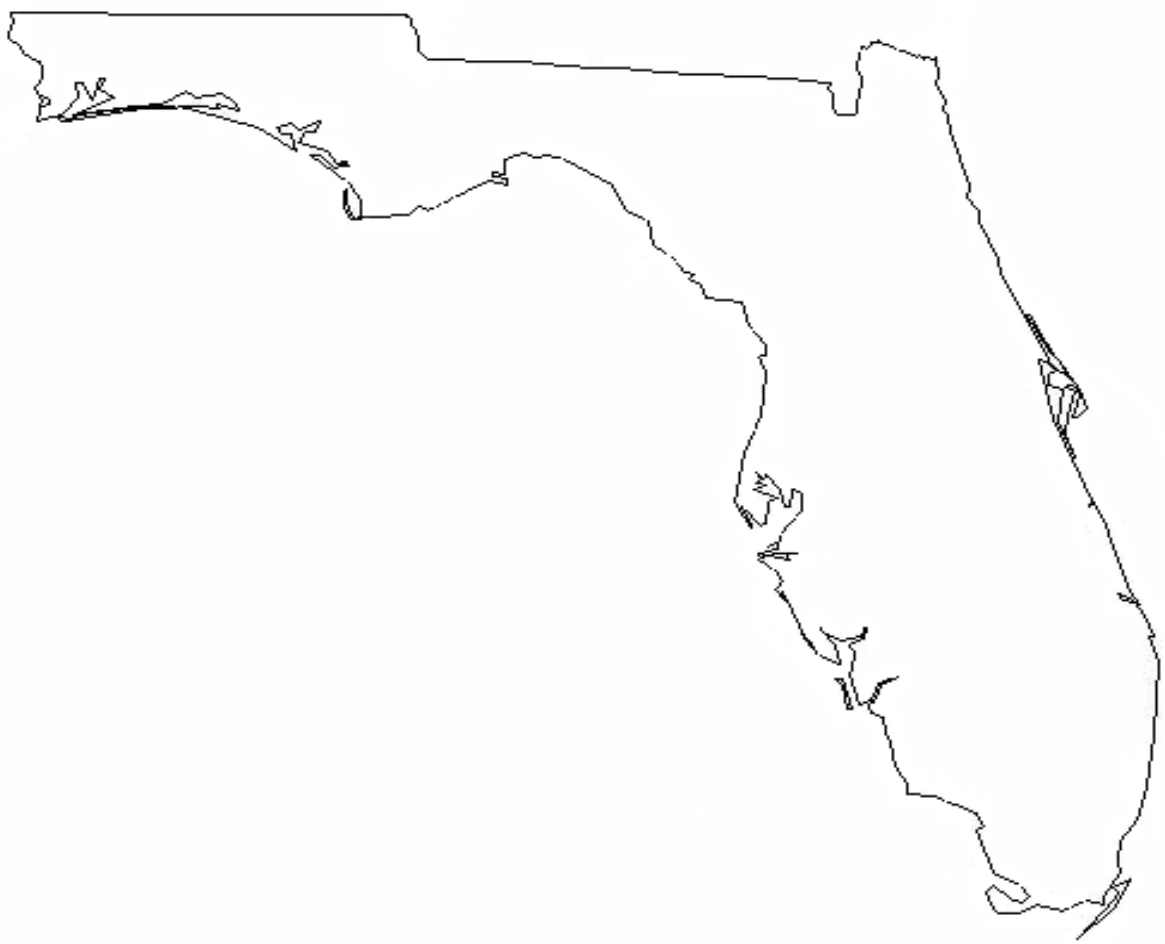
Distribution of Pb and Zn Leached from Urban Particulate Matter Subject to Rainfall: *(redox > +300 mV) with an Initial pH Range from 3 to 7*



What is proposed ?

Current proposed MS4s locations in Florida

(3 locations include inside and outside reclaimed wastewater areas)



- Orlando
- Tallahassee
- Jacksonville
- Gainesville ***(in and out)***
- Orange County
- Tampa ***(in and out)***
- Sarasota County ***(in and out)***
- St. Petersburg/Pinellas Co.
- Lee County
- Seminole County
- Miami-Dade County
- Hillsborough County
- City of Stuart

What is the proposed *sampling* plan ?

1. Representative sampling of "urban residual inventories"
2. 12 MS4s across geographic/climatic regions of Florida
   a. 3 of the MS4s have urban areas irrigating with reclaimed wastewater
   b. Sampling/analysis both inside and outside irrigated areas
3. There are 3 land uses examined per MS4
   a. Roadway (major or minor arterial)
   b. Residential
   c. Commercial/Retail
4. There are 3 BMPs, practices, HFUs examined per MS4
   a. Street sweeping (source control)
   b. Catch basins
   c. A BMP common to each MS4 that captures residuals

Sampling of Urban MS4 Residuals

1. A very significant inventory of urban residual material is deposited (albeit temporarily) in the infrastructure components of the urban drainage network on a wet and dry weather basis

2. The most significant component of this drainage network is the urban pavement surface (> 15% of a Florida MS4 area)

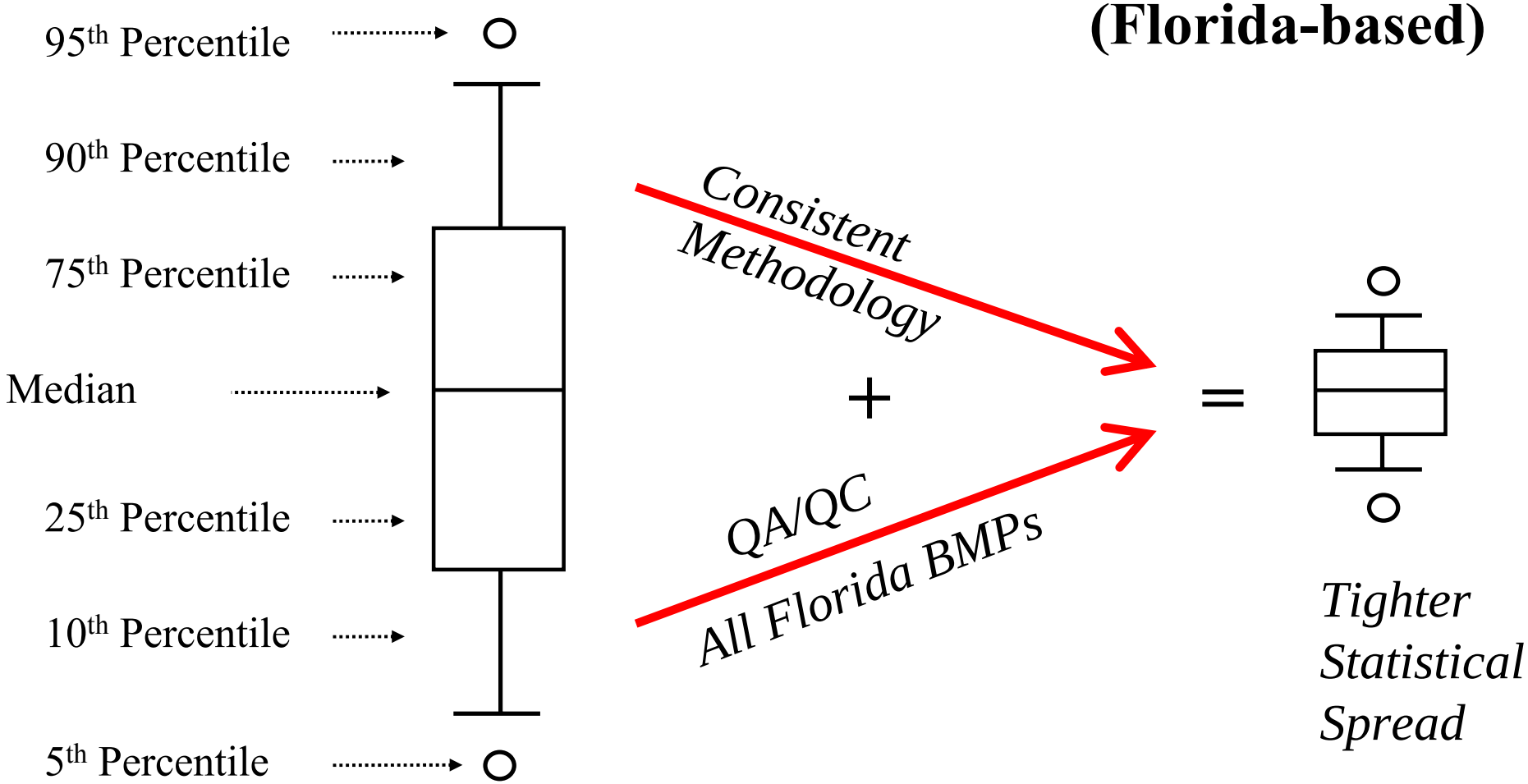
3. The most numerous component of this drainage network are catch basins (curb/gutter inlets)

4. Catch basin inserts and “BMP” are becoming a more common and maintenance-intensive component of the drainage network

Benefits of Florida-based MS4 Evaluation

FSA 2007 National Study

Proposed FSA Study (Florida-based)



Calibrated-validated method to predict constituent load
(For example, metals associated with urban particulates in MS4s)

Measured granulometric constituent distribution

Develop model

$$Me_{cf} = \alpha M_{cf}^{\beta}$$

Granulometric mass Distribution (M_T) Sieve analysis

Predict

Granulometric constituent distribution

Total constituent mass (i.e. Me_T)

Calculate

Constituent mass associated with any gradation (mg)

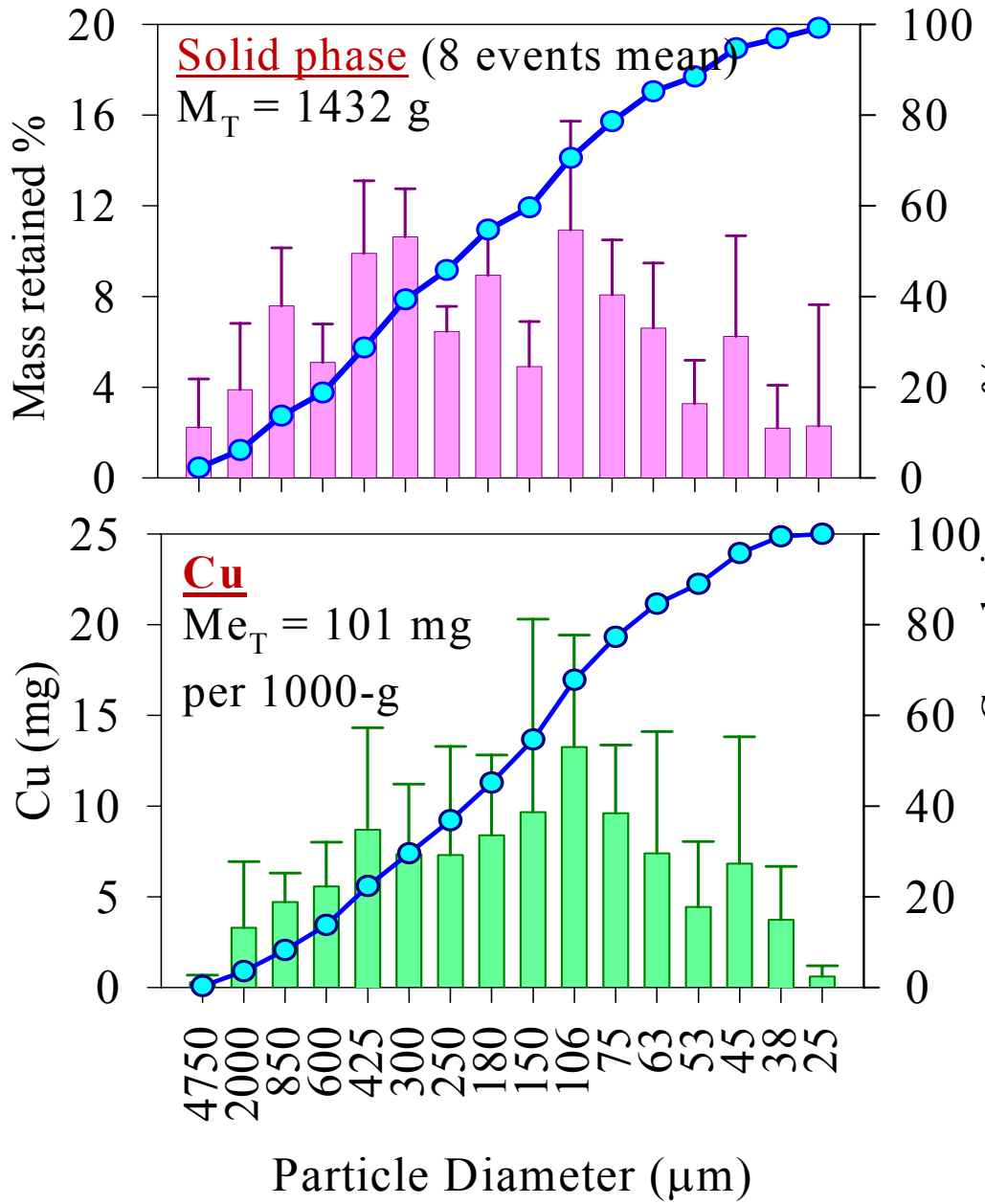
Me_{cf} : Cumulative constituent (metal) mass %
M_{cf} : Cumulative particulate mass %
M_T : Total dry particulate mass (mg)
Me_T : Total constituent (metal) mass (mg)
α : Cumulative metal mass index
β : metal mass-granulometric index
α, β are *f* (constituent, land use, BMP control, time)

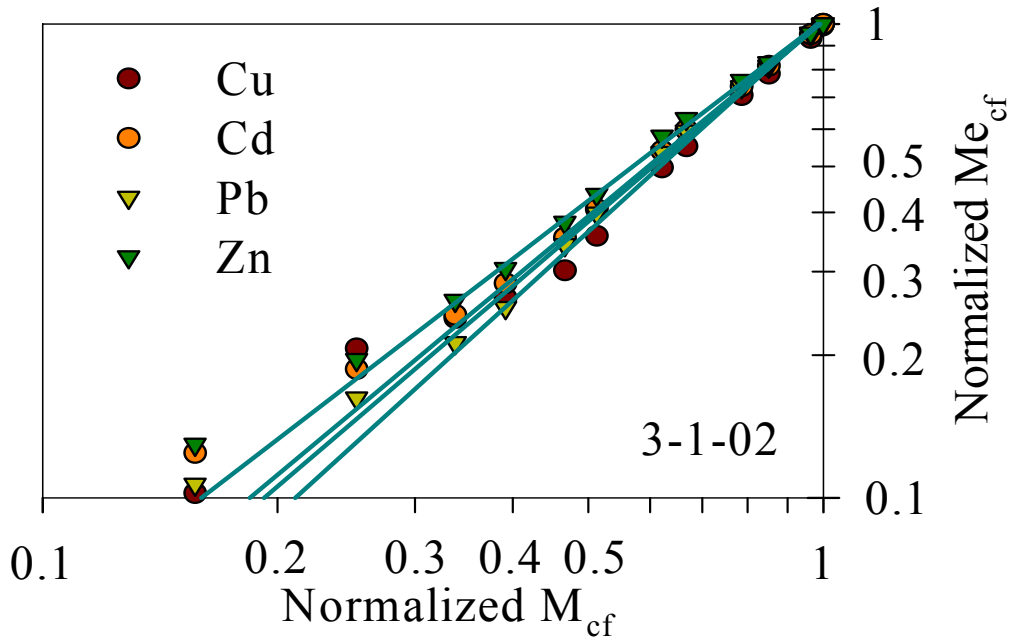
Method Example:

Based on 10 similar land use sites for calibration and 1 site used for validation (all from same MS4)

Reference: Sansalone and Cristina 2005, JEE

Another MS4 Example: Metal – Particulate Distribution Model





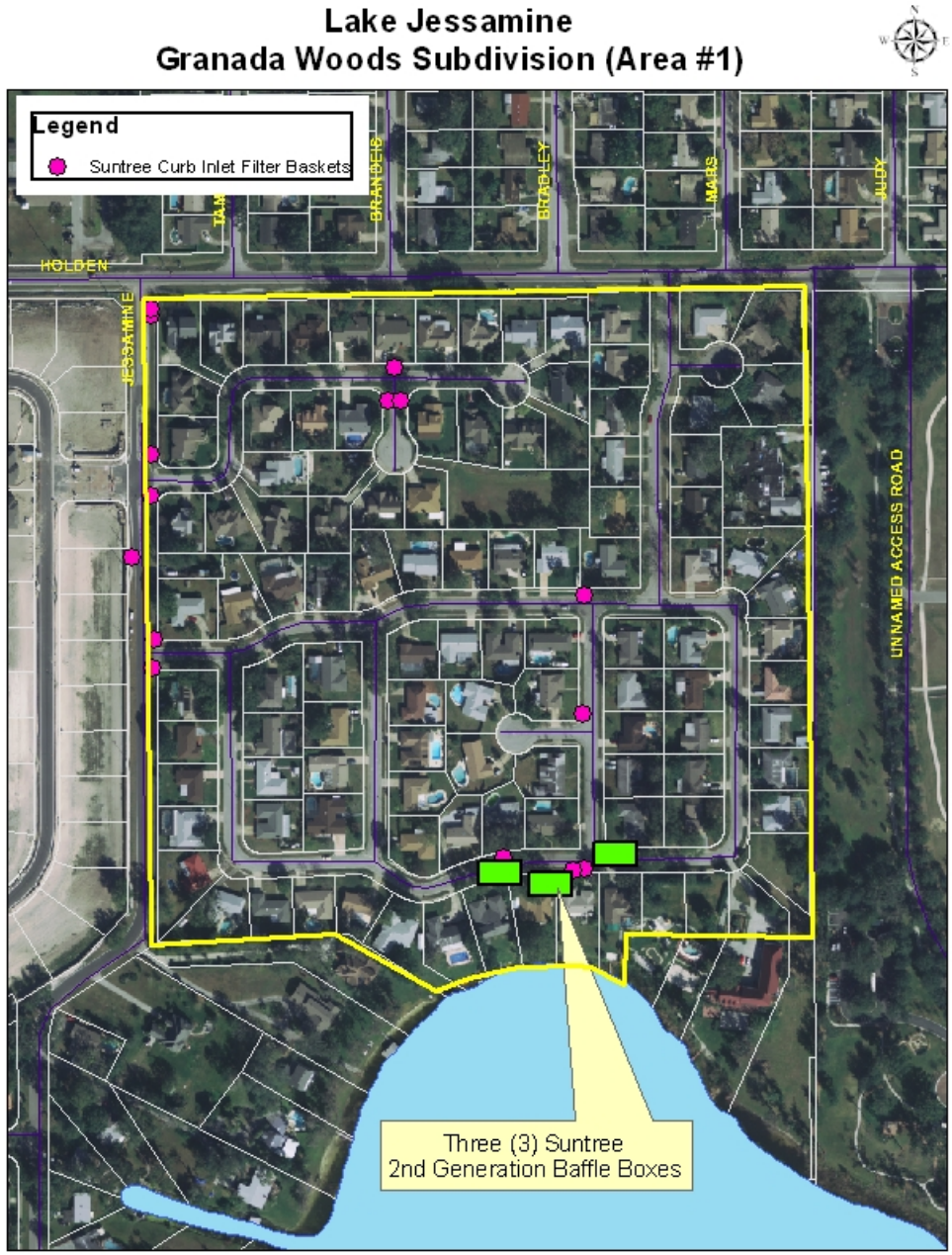
$$Me_{cf} = \alpha M_{cf}^{\ \beta}$$

Metal	α*	β*	SSE**
Cu	1.012	1.404	0.011
Cd	1.015	1.370	0.004
Pb	1.027	1.495	0.008
Zn	1.018	1.265	0.003

* Site mean ** SSE – sum of square error

Example of Proposed Orange County Conditions

- Existing residential land use in mature single family development
- Catch basins and Curb inlet filters (BMP)
- Variety of BMPs available
- Area swept weekly
- Moderate tree canopy
- Downstream discharge directly to receiving water



What is the proposed *testing* plan ?

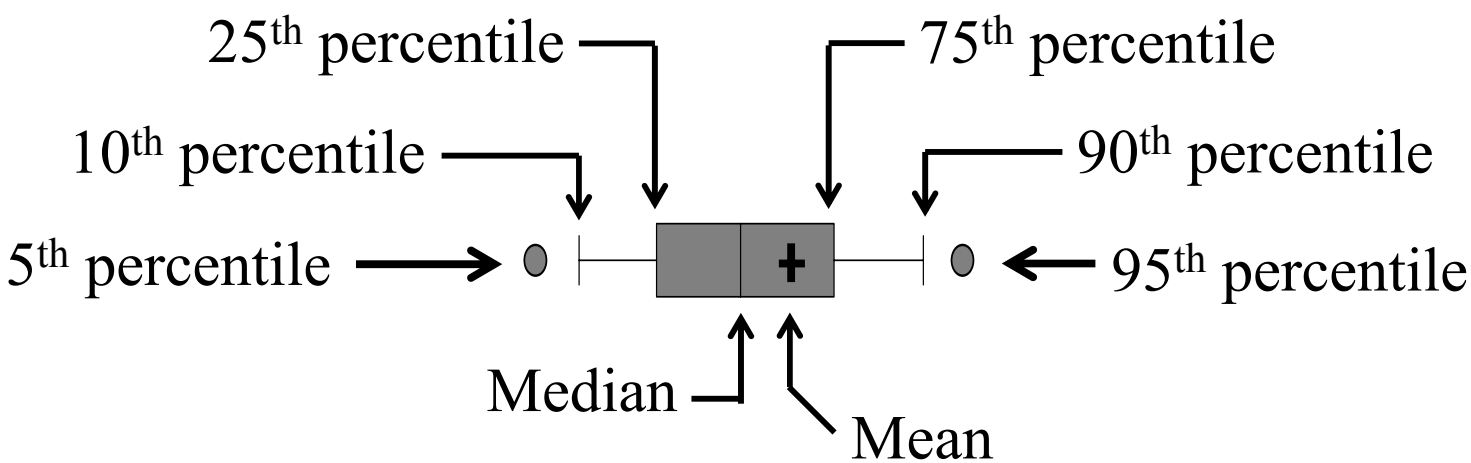
1. Focused on nutrients associated with particulate matter (PM) residuals
2. Phosphorus and Nitrogen analysis
    a. Total (TP and TN) associated with PM
    b. Leachable phosphorus and nitrogen
3. Gravimetric (mass) analysis of PM recovered
    a. Dry mass
    b. Organic/inorganic fractions by ignition
    c. Distribution of TP and TN across particle size for one MS4
4. Statistical and spreadsheet “calibration” yardsticks
    a. Statistical analysis of results and the variability of results
    b. A calibrated relationship between sediment mass and nutrient mass

What is the proposed schedule ?

1. MS4 Education and Sampling Workshop already completed
2. QAPP completed and submitted to FDEP
3. MS4s currently submitting sampling location selections
4. Samples collection in December 2008
5. Analysis of MS4 samples through 2009
6. Draft Report complete in June 2010

Presentation of Key Results of this Study

- Statistical distribution of particulate-bound inventories for specific constituent, land use and "control" in MS4s
- Results presented as "box and whisker" plots if sufficient data were available; if not, as box plots



Questions for proposed study

- Can a relationship between pollutant mass (TP or TN) and particulate matter inventories be obtained ?

  Answer: YES

- Can the inherent variability in such a relationship be reduced through a consistent methodology across Florida MS4s ?

  Answer: YES

Conclusions

- Pollutant inventories in MS4 systems and urban BMPs is immense; and inventories leach or scour pollutant load over time
- Without frequent maintenance, many manufactured BMPs or conveyances function as costly inventory sinks for coarse urban debris; potentially becoming pollutant sources
- This study provides a defensible Florida-based tool that MS4s can utilize to realize value-added for source control and maintenance practices for common land uses
- Study results will allow a Florida MS4 to establish a relationship between pounds of “material” recovered and pounds of TN or TP; and to examine the N and P leaching potential