The Use of Local Stormwater Monitoring in Conjunction with the National Stormwater Quality Database (NSQD, ver. 3)

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Monitoring for the Next Decade
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Robert Pitt, Ph.D., P.E., BCEE, D.WRE
and Many Graduate Students and Colleagues
Department of Civil, Construction, and Environmental Engineering
The University of Alabama
Tuscaloosa, AL 35487

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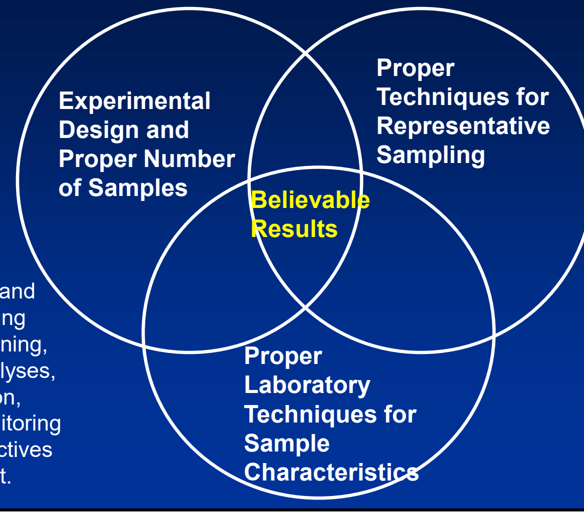
Many Facets Needed for a Successful Monitoring Program



An over-simplification, perhaps, but without these components, and other supporting elements (training, statistical analyses, communication, etc.), the monitoring program objectives cannot be met.

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Much can be Learned from Prior Efforts

- Existing data from the National Stormwater Quality Database (NSQD) can be used to estimate expected characteristics (especially variability) and influencing factors.
- Historically assumed characteristics about stormwater not always valid.
- Can use this information to help design local monitoring programs.

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Stormwater NPDES Data Collection and Evaluation Project

- The University of Alabama and the Center for Watershed Protection were awarded an EPA 104(b)3 grant in 2001 to collect, review, and analyze selected Phase 1 NPDES stormwater permit data.
- We received an extension of the project in 2005 to expand the database to include under-represented areas. We have completed version 3.1 of the database which is available on the Internet at: http://unix.eng.ua.edu/~rpitt/Research/ms4/mainms4.shtml

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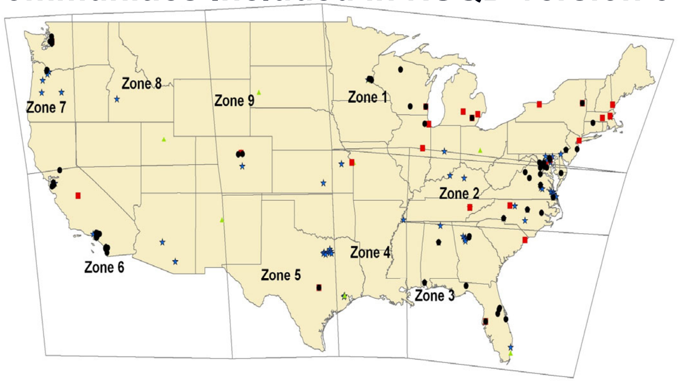
Communities Included in NSQD version 3



Version 3 incorporates MS4 data, along with selected data from the International BMP Database, the USGS, and NURP.

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Number of Events and Geographical Coverage in NSQD ver. 3

RAIN ZONE	TOTAL EVENTS	PERCENTAGE
Zone 1- Great Lakes and Northeast	1,271	15
Zone 2- Mid Atlantic	3,984	46
Zone 3- Southeast	744	9
Zone 4- Lower Mississippi Valley	301	4
Zone 5- Texas	799	9
Zone 6- Southwest	417	5
Zone 7- Northwest	865	10
Zone 8- Rocky Mountains	24	0.3
Zone 9- Midwest	197	2
TOTAL	8,602	100

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Number of Events and Land Use Coverage in NSQD ver. 3

LAND USE	TOTAL EVENTS	PERCENTAGE
Residential	2,979	35
Mixed Residential	1,245	15
Commercial	1,288	15
Mixed Commercial	525	6
Institutional	115	1
Industrial	887	10
Mixed Industrial	269	3
Freeway	763	9
Open Space	404	5
TOTAL	8,602	100

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Total Suspended Solids by Land Use and Geographical Area (mg/L)

		1	2	3	5	7	All
Commercial	Mean	135	86	60	67	81	110
	Count	237	454	50	40	42	934
	COV	1.2	1.8	2.0	1.6	1.1	1.8
Industrial	Mean	177	78	96	244	182	160
	Count	100	304	82	43	24	683
	COV	1.4	1.0	1.3	1.6	1.2	1.6
Residential	Mean	140	85	107	109	100	114
	Count	332	1,388	122	107	170	2,346
	COV	1.2	1.7	1.6	1.0	0.9	2.0
ALL	Mean	155	97	95	138	126	136
	Count	1,132	3,466	420	488	443	6,747
	COV	1.6	1.7	1.5	1.5	1.7	2.2

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Factors Potentially Affecting Data

- We have conducted numerous statistical tests of the data to identify important factors that may affect stormwater characteristics. We examined the data for such effects as:
  - Sampling method effects (manual or automated sample collection, time or flow-weighted composite sampling, discrete or composite sampling, etc.)
  - Land use and geographical location effects
  - Seasonal effects
  - Long-term trends
  - Effects due to storm size (and “first-flush” effects)

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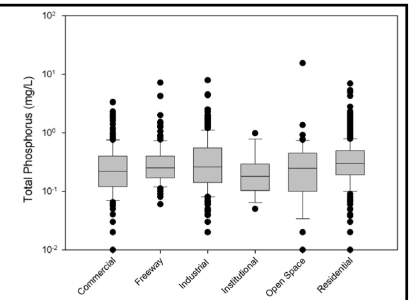
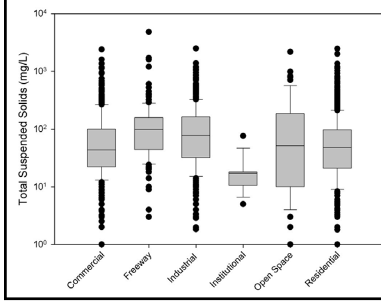
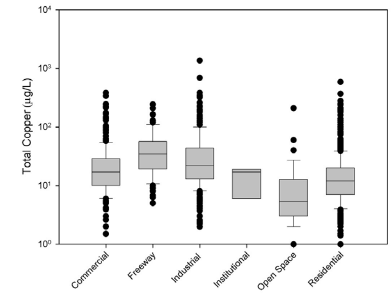
These grouped box-whisker plots sort all of the data by land use. Kruskal-Wallis analyses indicate that all constituents have at least one significantly different category from the others. Heavy metal differences are most obvious.







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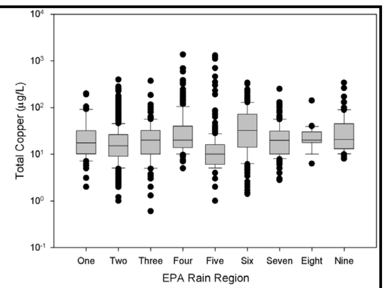
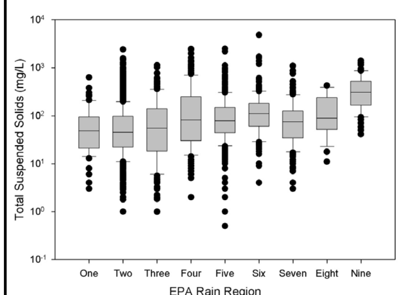
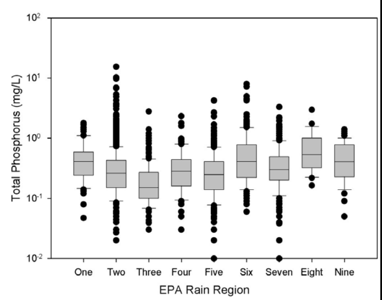
Residential area concentrations grouped by EPA rain zones. Zones 1-4 are east half of country, zones 5-9 are western half of country. Zones 3 and 7 are the wettest zones.







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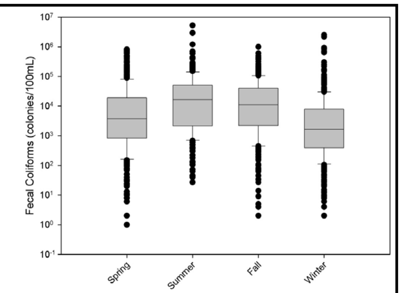
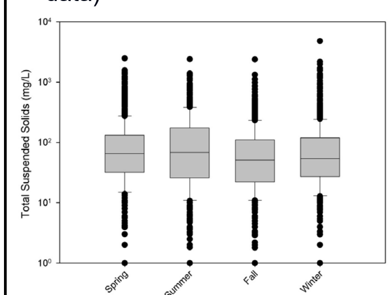
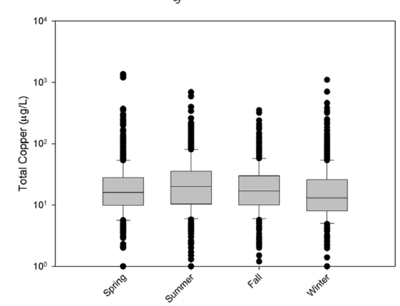
These grouped box-whisker plots sort residential data by sampling season. The most obvious difference is shown for fecal coliforms (a similar conclusion was found during NURP, EPA 1983). (These plots are only for residential data)







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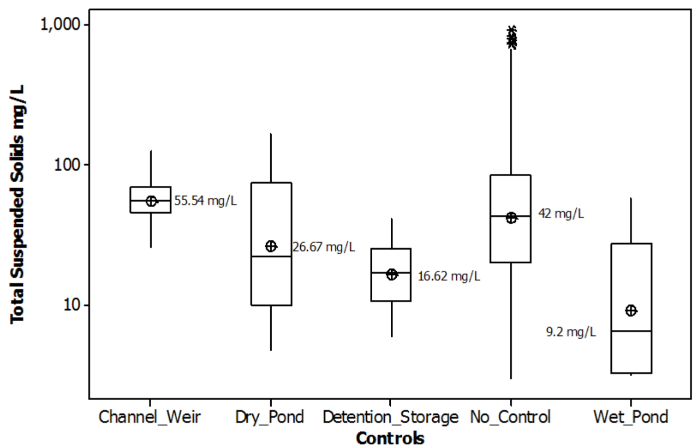
Comparison of Control Practices (Residential Land Uses EPA Rain Zone 2)



Why Monitor as Part of MS4 Permits?

- "Characterization" monitoring may not be necessary unless in under-represented areas or land uses. Iowa is not currently represented in the NSQD, but other regional data are available.
- Monitoring at small scales (having homogeneous characteristics) more useful than for large multi-land use locations.
- More efficient to require monitoring to learn about processes (sources, transport, control, and effects) and for program assessment/validation.
- A coordinated monitoring program for an area would be much more efficient than a standardized "one-size-fits-all" approach.

Recommendations for Improved Future Regulatory Monitoring Activities

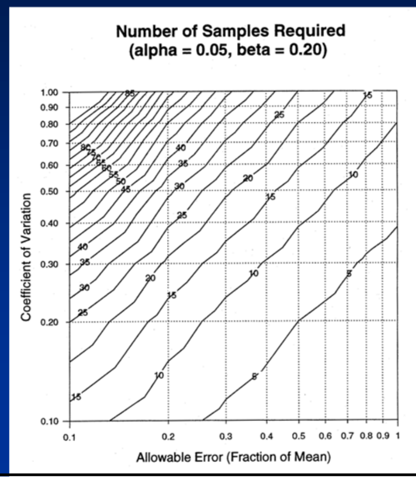
- Better site descriptions (drainage area delineation, effective percentage impervious area, transient and adjacent activities that may affect water quality) are always needed.
- Adequate on-site rain gauges and flow monitoring critical.
- Monitor for the complete event duration (not just "first flush," or only for 3 hours)

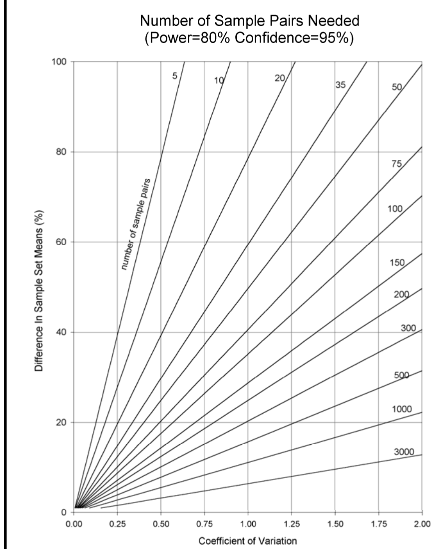
Recommendations for Improved Future Regulatory Monitoring Activities (cont).

- Statistical analyses indicated differences between automatic and manual sampling.
- Automatic flow-weighted composite sampling in complete mixed sites (cascading flows) preferred in most cases, supplemented with bed load and floatables sampling.
- Larger errors can be associated with insufficient sample efforts though!

Experimental Design - Number of Samples Needed

The number of samples needed to characterize stormwater conditions for a specific site is dependent on the COV and allowable error. For most constituents and conditions, about 20 to 30 samples may be sufficient for most objectives. Most Phase 1 sites only have about 10 events, but each stratification category usually has much more.





Experimental Design - Number of Samples Needed can be Large

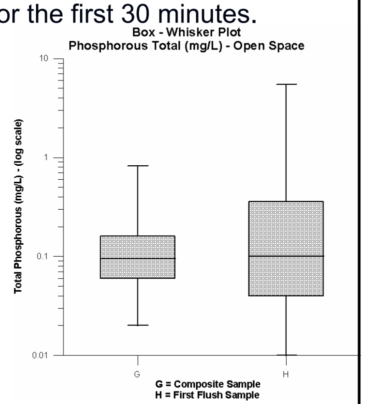
Obviously, easier to confirm removals when the differences between influent and effluent are greatest. Data sets having few samples cannot detect small and moderate differences. A power analysis before the monitoring program needs to be conducted to determine the level of control that can be detected with significance and to ensure that value meets the data quality objectives for the project.

Burton and Pitt 2002

Comparison of First-Flush and Composite Samples

More than 400 paired samples were available for comparison. The first-flush samples are for the first 30 minutes.

The Fligner-Policello (symmetrical about the medians) and the Mann-Whitney (symmetrical and same variance) non-parametric comparison tests were used to compare the paired first-flush concentrations with the whole storm composite concentrations. The Anderson-Darling test was used to test for normality.



Common for concentrations to be similar, but first-flush variance larger

Flow Sources Vary for Different Rain Depths

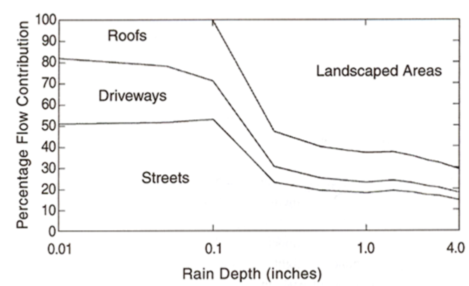


FIGURE 4.13 Flow sources for example medium density residential area having clayey soils. (From Pitt, R. and Voorhees, J., EPA/625/R-95/003, 1995.)

First-Flush Observations

- COD, BOD_5, TDS, TKN, and Zn all had significant first-flushes for all land uses (except for open space).
- The ratio of the first-flush to composite concentrations ranged from 1.3 to 1.7 for these constituents.
- Turbidity, pH, fecal coliforms, fecal strep., total N, dissolved P, and orthophosphate did not have significant first-flushes for most of the separate land uses.
- No open space, and only a few institutional data sets had significant first-flushes.
- First-flushes most obvious in areas having significant amounts of directly connected impervious surfaces.

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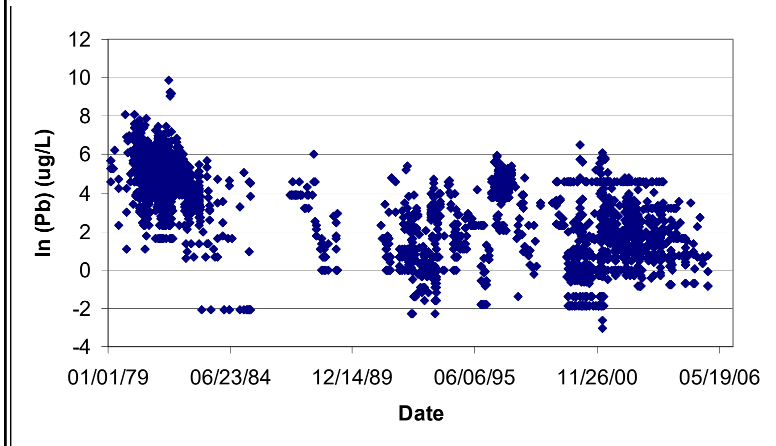
Trends in Lead Concentrations with Time



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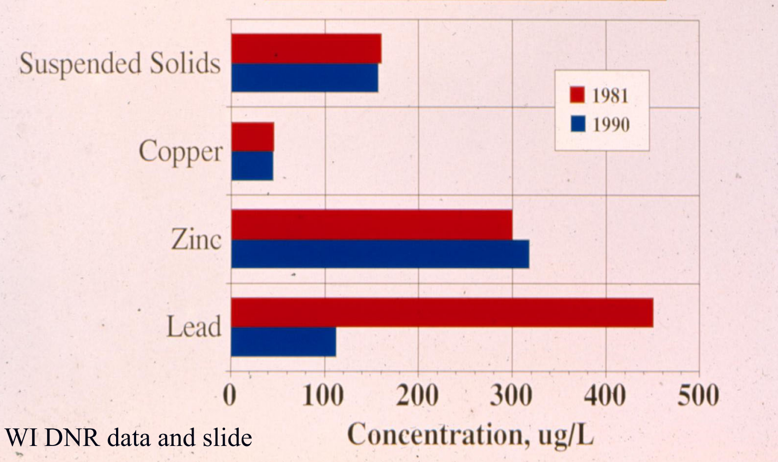
Trends in Metal EMC at Wood Center



WI DNR data and slide

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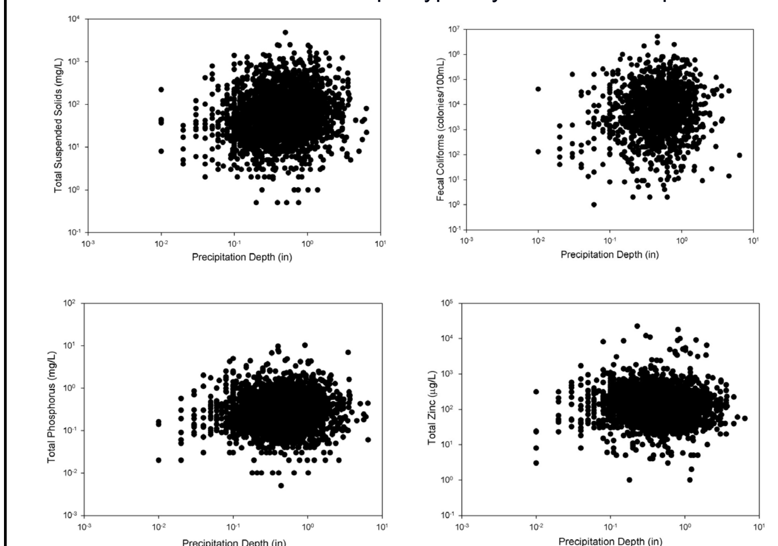
Plots of concentrations vs. rain depth typically show random patterns.



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Special Sampling and Handling Needs – solids processing

- A wide range of sample characteristics need to be considered in a sampling program
- Automatic samplers are not effective in collecting large particles; recovery of particles >250 µm is usually <50%, while they can be close to 100% effective for particles <100 µm.
- In most cases, the actual errors in annual mass discharges are <10%. However, complete mass balances need to be done as part of control practice monitoring to quantify the errors and to identify the large particle fraction.

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Special Sampling and Handling Needs – solids processing (cont.)

- Particle size information is one of the most important stormwater characteristics affecting treatability, transport, and fate.
- Cone splitters need to be used to divide samples for analyses and SSC (suspended sediment concentration) should be used instead of TSS for the most repeatable results.
- Discrete particle size pollutant analyses on different particle sizes can also be important for treatability and fate analyses.

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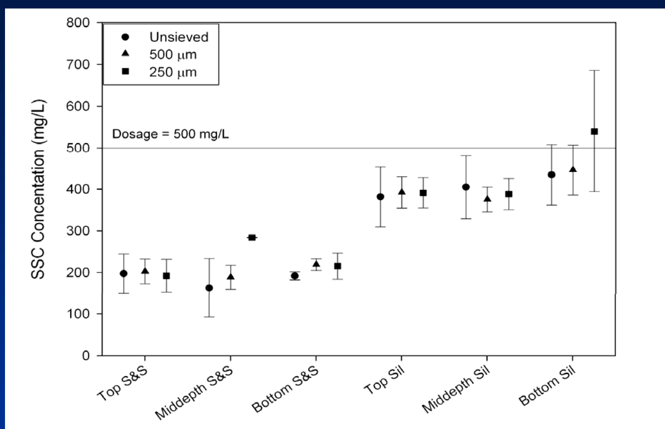
Effect of Intake Location and Solids PSD



• Well-mixed water column required to not see biases in intake location. Smaller particle sizes less subjected to bias because they stay suspended.
• Sand-sized particles much more problematic; sands > 250 µm not highly recovered.

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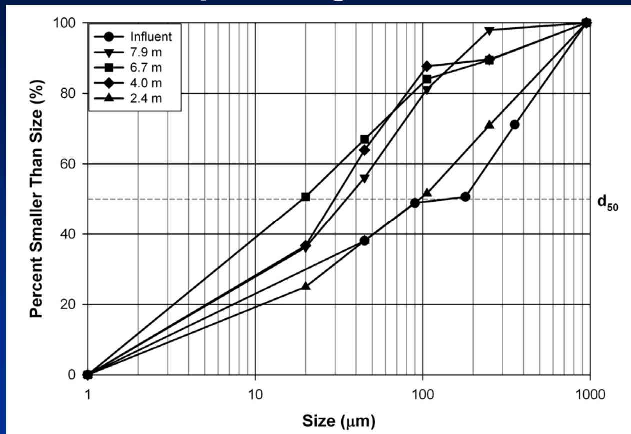
Sampler Height Effects



In this example, sampler heights >2.5 m resulted in fewer larger particles in sampler.

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Comparison of three TSS/SSC analytical methods

	EPA TSS (160.2) ISO 11923	*Standard Methods* TSS (2540D)	USGS SSC (ASTM D3977-97(B))
Filter Nominal Pore Size	Not specified	< 2.0 µm	1.5 µm
Sample Mixing	Shake vigorously	Stir plate	Decant super-natant & flush bottle with DI
Aliquot Size	Not specified (normal 100 mL)	Not specified (normal 100 mL)	Entire sample
Method of Aliquot Collection	Pour aliquot into graduated cylinder	Pipet: mid-depth in bottle & mid-way between wall and vortex	Pour from original bottle

Tested differences between methods using samples from 50 – 500 mg/L particulate matter having two different particle size distributions (PSDs), d_{50} of 90 and 260 µm.

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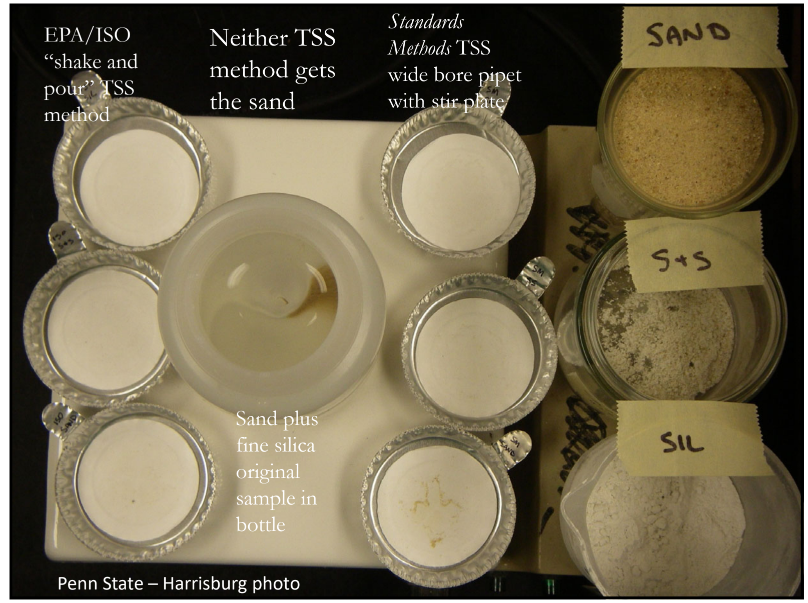

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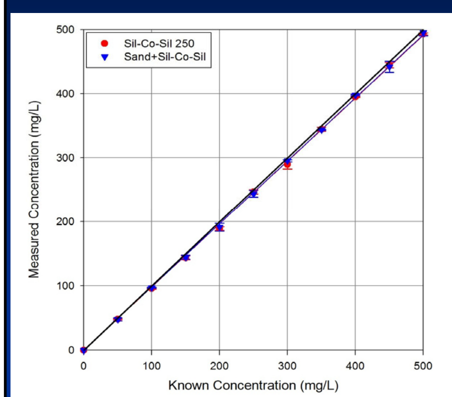
Suspended Sediment Concentrations Compared to Known Laboratory Additions



- SSC methodology closely matches known concentrations, regardless of sample concentrations or PSD.

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Sample Preparation before Particle Size Association Tests

- These tests used to obtain concentration and particle samples associated with different particle sizes.
- Samples first split using a USGS/Dekaport cone splitter, and the individual samples individually separated using a variety of filters and sieves.
- The filtered portion for each separated subsample then individually analyzed and the associations determined by difference. Sediment samples also analyzed by examining the filters, or by removing some of the captured debris from the sieves.

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Large sample volume (about 5 L) separated into subsamples using USGS/Dekaport cone splitter. The sample is first poured through a 1,200 µm screen to remove leaves and grass clippings, and coarse sediment that would clog the splitter. This captured material is also analyzed.

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Sampling Method Critical along with Sample Analysis for Solids Analyses

- Well-mixed flowing sample in pipe or channel almost impossible to obtain (must use depth-integrated sampler or cascading sample location).
- Typical conveyance systems trap most of the large particulates (>250 µm) in the bedload, so large particles normally not present at outfalls; large particles are present at source areas and at inlets
- Complement complete sample using automatic sampler with bed-load sampler. Also do full mass-balance if monitoring control effectiveness.

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Bedload samplers installed at WI DNR/USGS monitoring location. About 5% of annual sediment was in bedload fraction that was not captured by automatic samplers.

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Specific Challenges of QA/QC and Statistical Methods

- Effects of left-censored data (non-detects) on data summaries and statistical tests and what are the best ways of handling these data?
- Critical that suitable detection limits be used for laboratory analyses (do not want more than 15% non-detectable observations for critical constituents)
- Effects of a few incorrect data in large databases (for example, if 1% of the data are off by 1000x (possible for metal reports when concentrations are actually µg/L but are reported as mg/L), can increase the COV by 10x! Fewer bad data actually make this worse, while more have less impact.
- How much can the data be subdivided into interesting groups before we lose the ability to distinguish them?

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Conclusions

- Much concern expressed abut use of MS4 Phase 1 data due to various experimental designs, different sampling and analytical procedures, etc.
- However, the large amount of data, the documentation available (although some hard to locate), and the wide range of conditions included in the monitoring program, allow a great deal of information to be extracted and summarized.

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Conclusions (cont.)

- Phase 1 data shows significant patterns for different land uses and geographical locations for most constituents, but few seasonal variations (no snowmelt info.).
- It is important to examine as many elements of the urban area stormwater pollutant mass balance as possible during monitoring activities to appreciate the component being investigated.

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Conclusions (cont.)

- Proper sampling and handling is needed to obtain the best particulate solids information.
- The study objectives may require a large sampling effort to obtain statistically valid results.
- Basic data analyses are easy to perform, but care must be taken to ensure that the methods used are appropriate.

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Acknowledgements

- Bryan Rittenhouse, the US EPA project officer for the Office of Water, is gratefully acknowledged.
- The many municipalities and firms who worked with us to submit data and information were obviously crucial and the project could not have been conducted without their help.
- A number of graduate students at the University of Alabama and staff at the Center for Watershed Protection were active project participants and supplied critical project assistance.

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