Urban Runoff and Colorado's Proposed Nutrient Criteria

Presented by

Jane Clary, CPESC

Wright Water Engineers, Inc.

For

Mountain States Chapter, IECA Dec. 2011

Brief Background on Proposed CO Nutrient Criteria

- November 21, 2011 Water Quality Control Division Released Proposed Nutrient Criteria for Colorado

1. Basic Standards and Methodologies for Surface Water, Regulation #31 (5 CCR 1002-31) (revisions)
2. Nutrients Management Control Regulation, Regulation #85 (to be codified at 5 CCR 1002-85) (new)

- Rulemaking Hearing scheduled for March 12, 2012

http://www.cdphe.state.co.us/op/wqcc/Hearings/Rulemaking/Nutrients/Nutrients.html

Three Major Components

1. Establish interim numeric criteria for TP, TN and Chl-a for streams/lakes.
2. Establish numerical effluent limitations for domestic WWTPs and other wastewater dischargers that use active treatment and are likely to have significant levels of nutrients in their discharges. It also describes steps to be taken by other point source dischargers and nonpoint sources to address nutrients.
3. Establish monitoring requirements for point source dischargers and a program aimed at monitoring surface waters for nutrients and related parameters. This effort is geared towards better characterizing nutrient sources, and current nutrient conditions, to help inform future regulatory decisions regarding nutrients.

Requirements Subject to Change Based on Outcome of March 2012 Rulemaking

Minimum Proposed MS4 Permit Requirements Related to Nutrients

- Public education and outreach on stormwater impacts associated with nutrients
- Pollution Prevention/Good Housekeeping for Municipal Operations associated with nutrients

Plus "Monitoring Requirement":

- To identify information that exists, and the need for additional monitoring to be conducted in the future, to determine the approximate nitrogen and phosphorus contribution to state waters due to discharges from MS4.
- Collaboration with other MS4's regionally, watershed-specific or statewide allowed.

Requirements Subject to Change Based on Outcome of March 2012 Rulemaking

Discharge Assessment Data Report

- Discharge Assessment Data Report by **October 31, 2014**, that:
  - Documents the availability of existing data, and
  - Provides a "Gap Analysis" that identifies the need for additional information (e.g., monitoring data or studies).
  - Data do not have to be collected from each MS4, provided that the data are representative of the quality of the stormwater being discharged.
  - Data must be representative of land uses, imperviousness, watershed hydrology, precipitation, and irrigation practices within the area which the data are intended to represent.
  - Data quality requirements are also specified.

General Overview of National Runoff Data

- Runoff Quality (Pitt)
  - General
  - "Source Areas"
- BMP Influent and Effluent Quality (BMP Database)
- Stormwater Monitoring
  - Common Problems
  - How Much is Enough?
  - What questions are we trying to answer in Colorado?

Denver Data (from Volume 3)

Table 1-2. Event Mean Concentrations (mg/L) of Constituents in Denver Metropolitan Area Runoff
(per DRURP and Phase I Stormwater CDPS Permit Application for Denver, Lakewood and Aurora)
(Source: Aurora et al. 1992. *Stormwater NPDES Part 2 Permit Application Joint Appendix*
and DRCOG 1983. *Urban Runoff Quality in the Denver Region.*

Constituent	Units	Natural Grassland	Commercial	Residential	Industrial
Total Phosphorus (TP)	mg/L	0.40	0.42	0.65	0.43
Dissolved or Orthophosphorus (PO_4)	mg/L	0.10	0.15	0.22	0.2
Total Nitrogen (TN)	mg/L	3.4	3.3	3.4	2.7
Total Kjeldahl Nitrogen (TKN)	mg/L	2.9	2.3	2.7	1.8
Ammonia Nitrogen (NH_3)	mg/L	0.1	1.5	0.7	1.2
Nitrate + Nitrite Nitrogen (NO_3/NO_2)	mg/L	0.50	0.96	0.65	0.91

INTERNATIONAL STORMWATER BMP DATABASE
www.bmpdatabase.org

Shop Creek Wetland-Pond System (95-97)

Composite—Overall Site BMP

Phosphorus as P, Total (mg/L)

BASIC STATISTICS

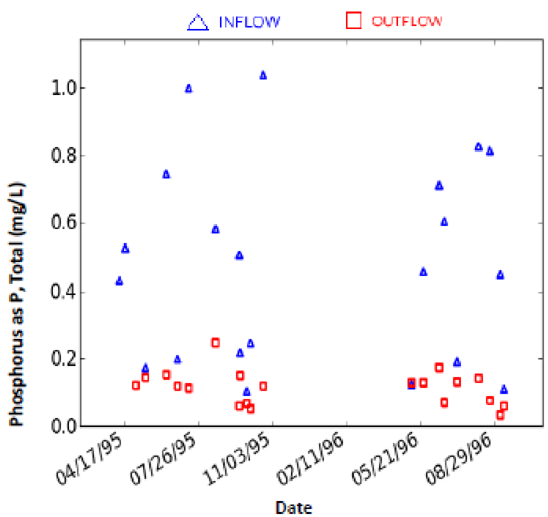
PERFORMANCE METRIC	INFLOW	OUTFLOW	COMPARISON
Number of EMCs:	21	20	--
Percent Non-Detects:	0%	0%	--
Median:	0.46	0.12	Decreased*
Mean:	0.48	0.12	Decreased
Standard Deviation:	0.29	0.05	--
25th Percentile:	0.2	0.07	Decreased
75th Percentile:	0.71	0.14	Decreased
Well-fit to normal distribution?	Yes	Yes	--
Well-fit to lognormal distribution?	Yes	Yes	--

*Statistically Significant Difference in Median?	YES

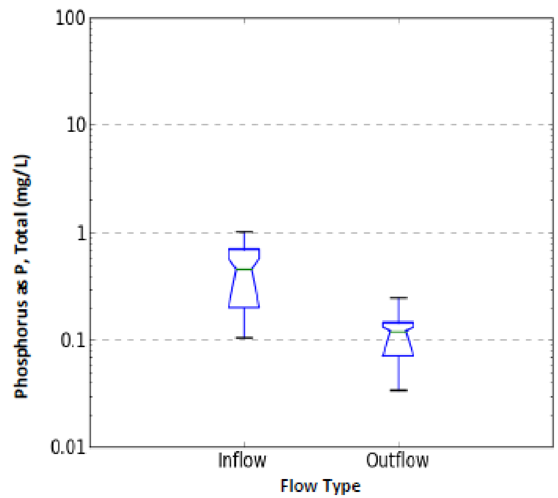
HYPOTHESIS TESTING:

STATISTICAL TEST	DATA	NULL HYPOTHESIS	p-value	Reject Null Hypothesis?	
				α=0.05	α=0.10
Mann-Whitney:	Raw	The inflow and outflow median EMCs are equal.	0	YES	YES
t-Test: (Assume Equal Variance)	Raw	The inflow and outflow mean EMCs are equal.	0	YES	YES
	Log	The inflow and outflow mean EMCs are equal.	0	YES	YES
t-Test: (Assume Unequal Variance)	Raw	The inflow and outflow mean EMCs are equal.	0	YES	YES
	Log	The inflow and outflow mean EMCs are equal.	0	YES	YES
Levene (Raw Data):	Raw	The two variances are equal.	0	YES	YES
	Log	The two variances are equal.	0.059	NO	YES

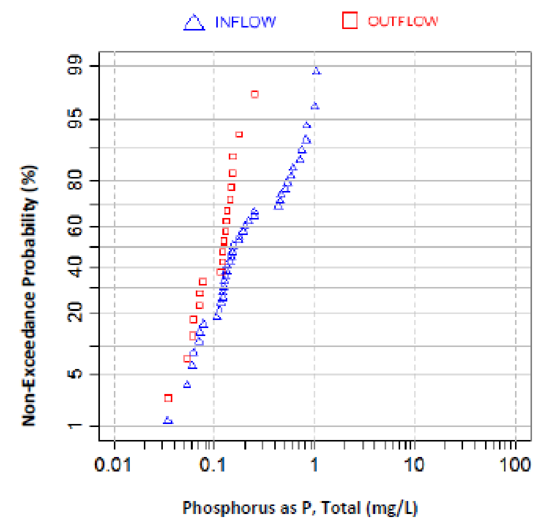
TIME SERIES PLOT



NOTCHED BOX-AND-WHISKER PLOT



LOGNORMAL PROBABILITY PLOT



INTERNATIONAL STORMWATER BMP DATABASE
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Shop Creek Wetland-Pond System (95-97)

Composite—Overall Site BMP

Kjeldahl nitrogen (TKN) (mg/L)

BASIC STATISTICS

PERFORMANCE METRIC	INFLOW	OUTFLOW	COMPARISON
Number of EMCs:	21	20	--
Percent Non-Detects:	0%	10%	--
Median:	3.2	0.9	Decreased*
Mean:	4.32	0.87	Decreased
Standard Deviation:	3.36	0.47	--
25th Percentile:	1.8	0.48	Decreased
75th Percentile:	5.7	1.2	Decreased
Well-fit to normal distribution?	No	Yes	--
Well-fit to lognormal distribution?	Yes	No	--

*Statistically Significant Difference in Median?	YES

HYPOTHESIS TESTING:

STATISTICAL TEST	DATA	NULL HYPOTHESIS	p-value	Reject Null Hypothesis?	
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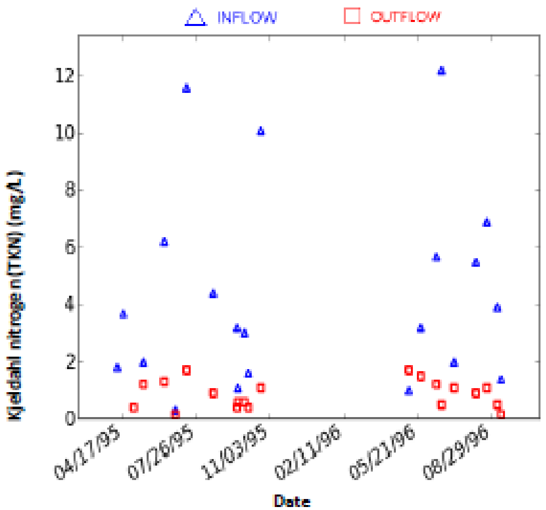
t-Test: (Assume Equal Variance)	Raw	The inflow and outflow mean EMCs are equal.	0	YES	YES
	Log	The inflow and outflow mean EMCs are equal.	0	YES	YES
t-Test: (Assume Unequal Variance)	Raw	The inflow and outflow mean EMCs are equal.	0	YES	YES
	Log	The inflow and outflow mean EMCs are equal.	0	YES	YES
Levene (Raw Data):	Raw	The two variances are equal.	0.001	YES	YES
	Log	The two variances are equal.	0.425	NO	NO

TIME SERIES PLOT



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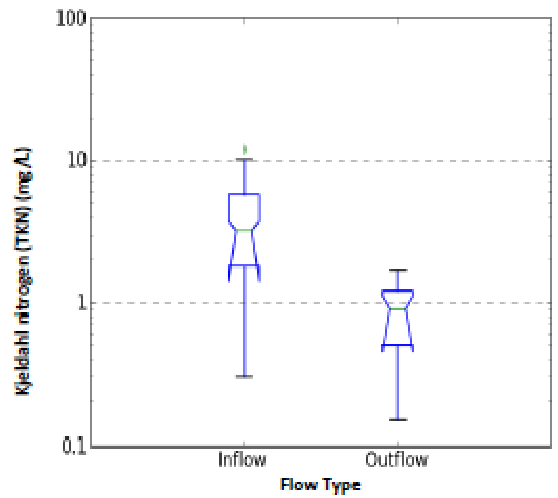
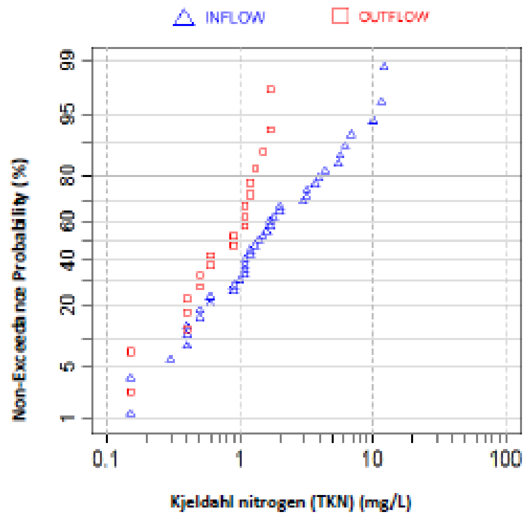


LOGNORMAL PROBABILITY PLOT



Land Uses Associated with CO Data

Test Site Name	Land Use	% of Land Use in Watershed
Denver Wastewater Building ICBP (to 2010)	Office Commercial	100
Denver Wastewater Building PAP (to 2010)		
EPA Denver Green Roof	Office Commercial	100
Grant Ranch	Low Density Residential	100
Lakewood RP - MF Vault (96)	Light Industrial	100
Lakewood RP Vault (97-98)		
Lakewood RP SF Vault (95)		
Lakewood Shops (to 2010)	Office Commercial	100
Shop Creek Wetland-Pond (1990-94)	Multi-Family Residential Low Density Residential	1 99
Shop Creek Wetland-Pond (1995-97)		
UDFCD Modular Porous Pavement 05 to 06	Office Commercial	100
UDFCD Modular Porous Pavement 94 to 04		

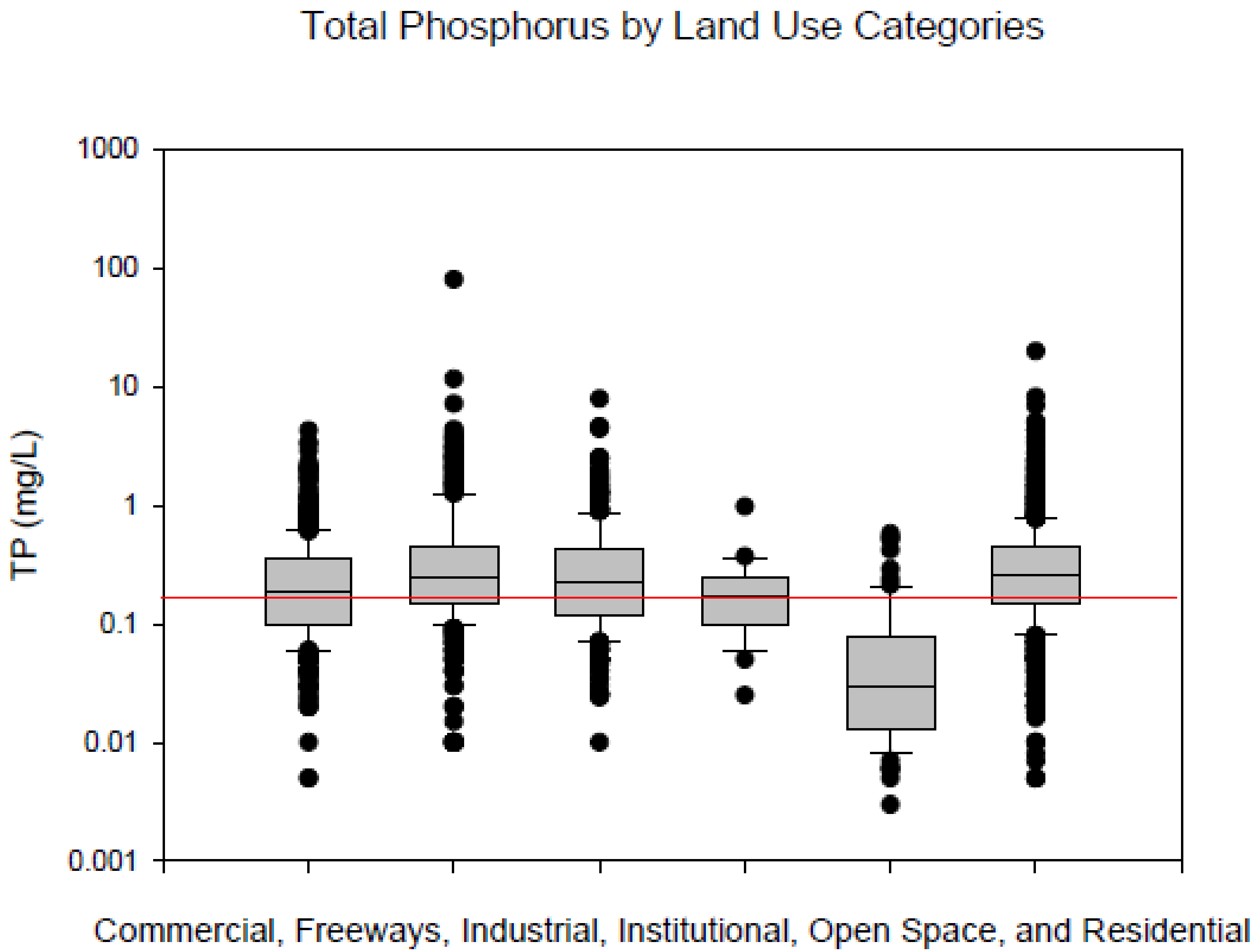
NSQD Research by Bob Pitt

TABLE 3-4 Summary of Selected Stormwater Quality Data Included in NSQD, Version 3.0

	TSS (mg/L)	COD (mg/L)	Fecal Colif. (mpn/100 mL)	Nitrogen, Total Kjeldahl (mg/L)	Phosphorus, Total (mg/L)	Cu, Total (µg/L)	Pb, Total (µg/L)	Zn, Total (µg/L)
All Areas Combined (8,139)								
Coefficient of variation (COV)	2.2	1.1	5.0	1.2	2.8	2.1	2.0	3.3
Median	62.0	53.0	4300	1.3	0.2	15.0	14.0	90.0
Number of samples	6780	5070	2154	6156	7425	5165	4694	6184
% samples above detection	99	99	91	97	97	88	78	98
All Residential Areas Combined (2,586)								
COV	2.0	1.0	5.7	1.2	1.6	1.9	2.1	3.3
Median	59.0	50.0	4200	1.2	0.3	12.0	6.0	70.0
Number of samples	2167	1473	505	2026	2286	1640	1279	1912
% samples above detection	99	99	89	98	98	88	77	97
All Commercial Areas Combined (916)								
COV	1.7	1.0	3.0	0.9	1.2	1.4	1.7	1.4
Median	55.0	63.0	3000	1.3	0.2	17.9	15.0	110.0
Number of samples	843	640	270	726	920	753	605	839
% samples above detection	97	98	89	98	95	85	79	99
All Industrial Areas Combined (719)								
COV	1.7	1.3	6.1	1.1	1.4	2.1	2.0	1.7
Median	73.0	59.0	2850	1.4	0.2	19.0	20.0	156.2
Number of samples	594	474	317	560	605	536	550	596
% samples above detection	98	98	94	97	95	86	76	99
All Freeway Areas Combined (680)								
COV	2.6	1.0	2.7	1.2	5.2	2.2	1.1	1.4
Median	53.0	64.0	2000	1.7	0.3	17.8	49.0	100.0
Number of samples	360	439	67	430	585	340	355	587
% samples above detection	100	100	100	99	99	99	99	99
All Institutional Areas Combined (24)								
COV	1.1	1.0	0.4	0.6	0.9	0.6	1.0	0.9
Median	18.0	37.5	3400	1.1	0.2	21.5	8.6	198.0
Number of samples	23	22	3	22	23	21	21	22
% samples above detection	96	91	100	91	96	57	86	100
All Open-Space Areas Combined (79)								
COV	1.8	0.6	1.2	1.2	1.5	0.4	0.9	0.8
Median	10.5	21.3	2300	0.4	0.0	9.0	48.0	57.0
Number of samples	72	12	7	50	77	15	10	16
% samples above detection	97	83	100	96	97	47	20	50

NOTE: The complete database is located at: http://unix.eng.ua.edu/~rpitt/Research/ms/mainms4.shtml. SOURCE: National Stormwater Quality Database.

Phosphorus in Urban Runoff



Source: Maestre and Pitt (2005), as provided in Urban Stormwater Management in the United States (NRC 2008)

More Pitt Source Characterization

TABLE 3-6 Roof Runoff Analysis—A Literature Summary

Roof Type	Location	Water Quality Parameter								Reference
		Cu (µg/L)	Zn (µg/L)	Pb (µg/L)	Cd (µg/L)	As (µg/L)	pH	NH_4^+ (mg/L)	NO_3^- (mg/L)	
Polyester	Duebendorf, Switzerland	6817	2076	510	3.1					Boller (1997)
Tile		1905	360	172	2.1					
Flat gravel		140	36	22	0.2					
Plywood w/ roof paper/tar	Washington	$166^{T}/128^{D}$	$877^{T}/909^{D}$	$11^{T}/<5^{D}$			4.3			Good (1993)
Rusty galvanized metal		$20^{T}/2^{D}$	$12200^{T}/11900^{D}$	$302^{T}/35^{D}$			5.9			
Old metal w/Al paint		$11^{T}/7^{D}$	$1980^{T}/1610^{D}$	$10^{T}/<5^{D}$			4.8			
Flat tar surface w/fibrous reflective Al paint		$25^{T}/14^{D}$	$297^{T}/257^{D}$	$10^{T}/5^{D}$			4.1			
New anodized Al		$16^{T}/7^{D}$	$101^{T}/82^{D}$	$15^{T}/<5^{D}$			5.9			
Zinc-galvanized Fe	Dunedin City, New Zealand	560 µg/g	5901 µg/g	670 µg/g						Brown & Peake (2006)
Fe-Zn sheets	Ile-Ife, Nigeria						6.77	0.06	1.52	Adeniyi and Olabanji (2005)
Concrete slate tiles							7.45	0.05	3.34	
Asbestos cement sheets							7.09	0.06	2.26	
Aluminum sheets							6.68	0.05	6.18	
Cu panels	Munich, Germany	200–11100					6.7–7.0			Athanasiadis et al. (2006)
Galvanized metals (primarily Galvalume®)	Seattle, WA	10–1400	420–14700	ND						Tobiason (2004)
CCA wood	Florida					1200–1800				Khan et al. (2006)
Untreated wood						2–3				

Note: D, dissolved; T, total; ND, not detected.

SOURCE: Reprinted, with permission, from Clark et al. (2008). Copyright 2008 by American Society of Civil Engineers.

INTERNATIONAL STORMWATER BMP DATABASE
www.bmpdatabase.org

WERF Water Environment Research Foundation

ASCE American Society of Civil Engineers

Environmental & Water Resources Institute of the American Society of Civil Engineers EWRI

EPA

U.S. Department of Transportation Federal Highway Administration

American Public Works Association APWA Your Comprehensive Public Works Resource

Welcome to the International Stormwater Best Management Practices (BMP) Database project website, which features a database of over 300 BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance and other study-related publications. The overall purpose of the project is to provide scientifically sound information to improve the design, selection and performance of BMPs. Continued population of the database and assessment of its data will ultimately lead to a better understanding of factors influencing BMP performance and help to promote improvements in BMP design, selection and implementation.

The project, which began in 1996 under a cooperative agreement between the American Society of Civil Engineers (ASCE) and the U.S. Environmental Protection Agency (USEPA), now has support and funding from a broad coalition of partners including the Water Environment Research Foundation (WERF), ASCE Environmental and Water Resources Institute (EWRI), USEPA, Federal Highway Administration (FHWA) and the American Public Works Association (APWA). Wright Water Engineers, Inc. and Geosyntec Consultants are the entities maintaining and operating the database clearinghouse and web page, answering questions, conducting analyses of newly submitted BMP data, conducting updated performance evaluations of the overall data set, disseminating project findings, and expanding the database to include other approaches such as Low Impact Development techniques. The database itself is downloadable to any individual or organization that would like to conduct its own assessments.

What's New

2007 Data Analysis Report released in October 2007

Website revised with new, ease-to-use performance summary information

Master Database exceeds 300 BMP studies with access to a new bibliography

Florida Department of Environmental Protection BMP Database Integrated into International Stormwater BMP Database--searchable online

What Type of User Are You?
Let us help you enter our website to find the level of detail you need:

Low-Intensity
Get Basic Performance Summary Information for BMPs
Typical Users: Public officials, casual users, those seeking quick/fast answers

Mid-Intensity
Get Detailed Statistical Analysis for Individual BMPs
Typical Users: Consultants, Public Works Staff, Designers

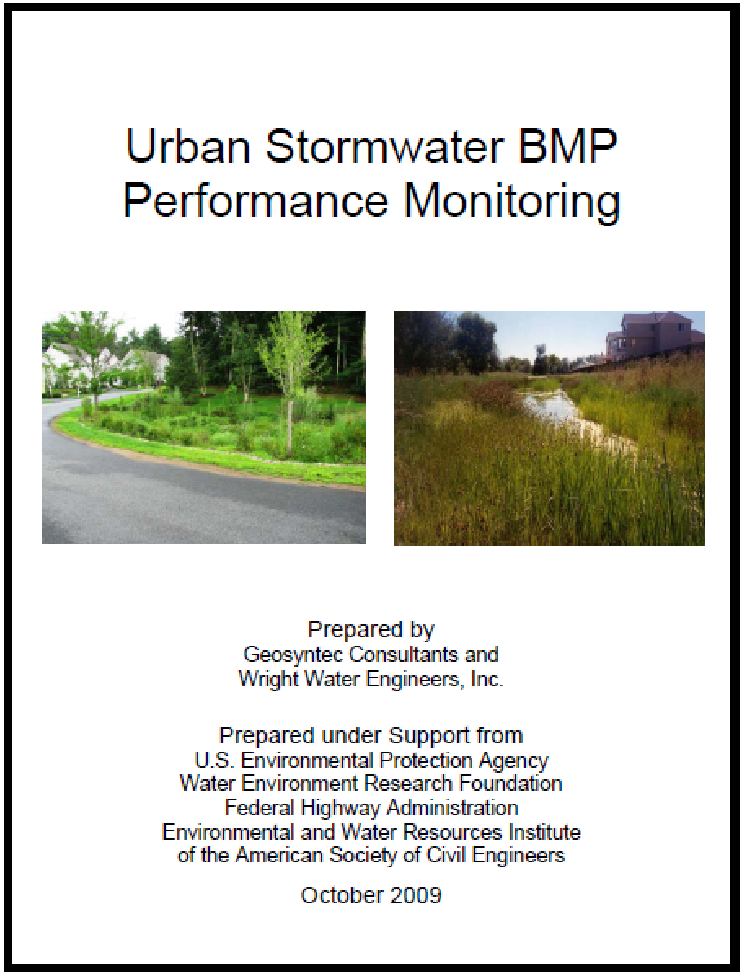
Researcher
Download the Master Database to Conduct Independent Research
Typical Users: University Professors

Data Provider
Obtain Data Entry Spreadsheets
Typical Users: Public agencies, consulting firms, university researchers

New to BMP Monitoring
Obtain Monitoring Guidance
Typical Users: Public agencies, consulting firms, university researchers

BMP Database Overview (1996-present)

- BMP Database includes over ~~470~~ **500!** BMP monitoring studies, including green infrastructure
- From 2008-2010, a key focus has been to better integrate green infrastructure through:
  - Monitoring Guidance
  - Reporting Protocols
  - Analysis Protocols
  - Data Acquisition


Urban Stormwater BMP
Performance Monitoring

Prepared by
Geosyntec Consultants and
Wright Water Engineers, Inc.

Prepared under Support from
U.S. Environmental Protection Agency
Water Environment Research Foundation
Federal Highway Administration
Environmental and Water Resources Institute
of the American Society of Civil Engineers

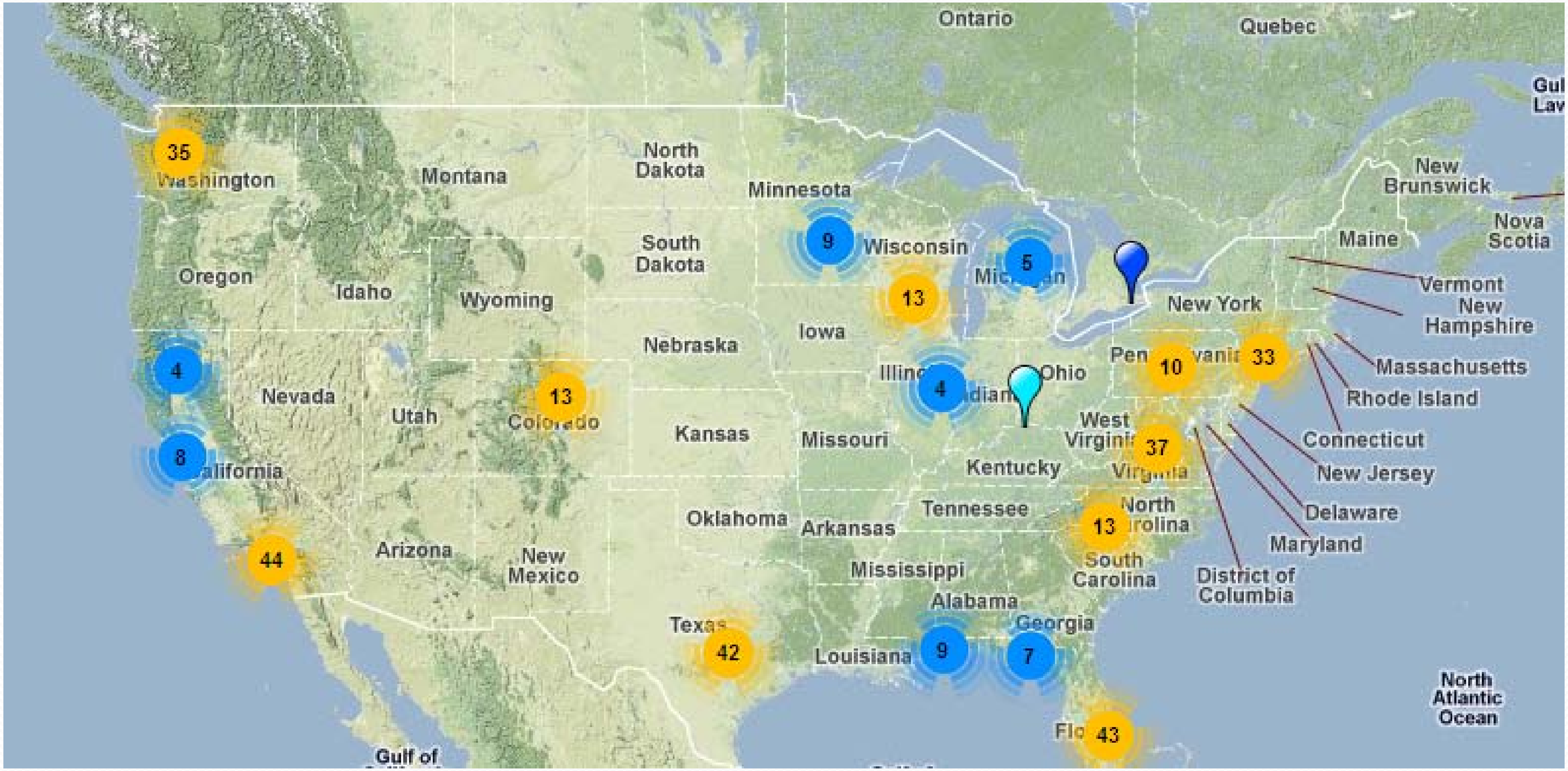
October 2009

INTERNATIONAL STORMWATER BMP DATABASE
www.bmpdatabase.org

- Pollutant Category Summary: Nutrients (Geosyntec and WWE 2010)
- The nutrient analysis for the BMP Database focused on
  - Phosphorus
  - Nitrogen
  - Organ carbon
- >40,000 nutrient records in BMP Database
- Added many more records since analysis

BMP Category	#
Bioretention	24
Detention Basin (dry basin)	39
Green Roof	11
Biofilter (swales & buffer strips)	82
Infiltration Basin	1
Manufactured Device	78
Media Filter	35
Maintenance Practice	28
Porous Pavement	26
Percolation Trench/Well	11
Retention Pond (wet pond)	65
Wetland Basin	29
Wetland Channel	17
LID (site-scale)	1
Composite System (series)	21
Other	2
Total	**470**

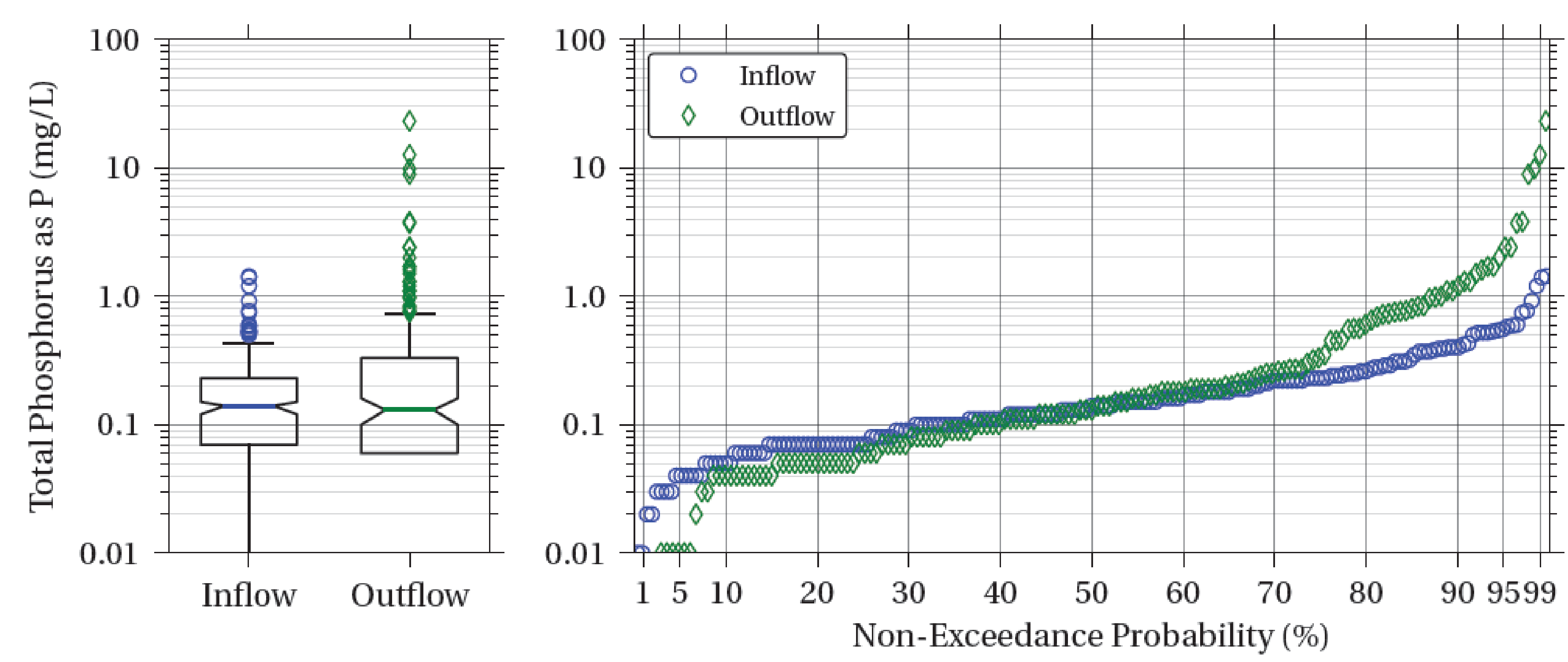
Where are these data sets?



New Performance Analysis

- Provides a series of interpretive technical summaries (see www.bmpdatabase.org)
- Technical summaries prepared for:
  - Solids (TSS)
  - Bacteria (not much data)
  - Metals
  - Nutrients
  - Volume Reduction
- Important to consider both WQ and volume reduction, particularly for bioretention
- Summaries provide regulatory context, unit treatment process information, data summaries, conclusions, recommendations, statistical summary

Total P (mg/L) for Bioretention



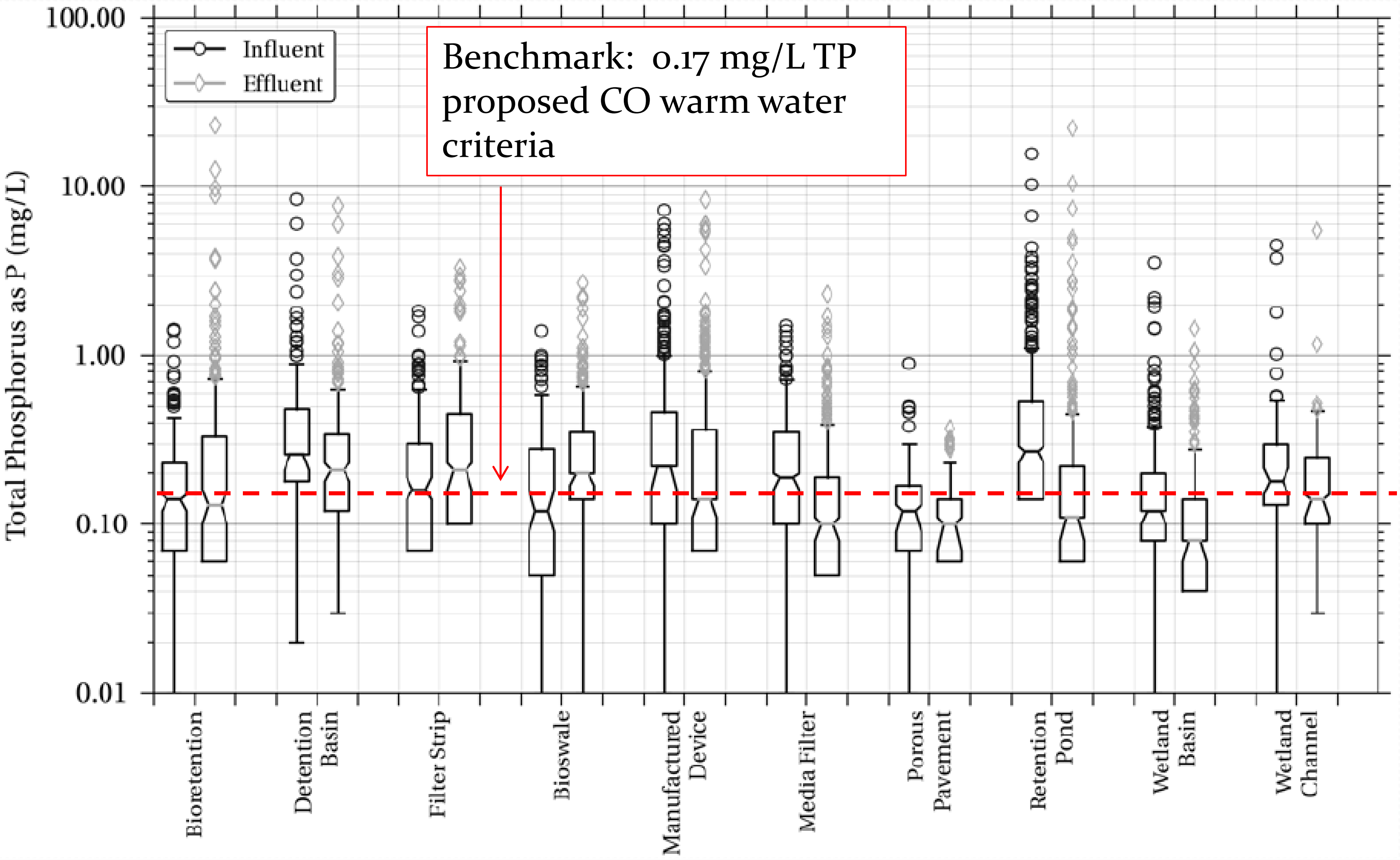
Statistic	Inlet	Outlet
Count	187	157
Number of Studies	12	12
Median (95% conf. interval)	0.14 (0.12, 0.15)	0.13 (0.1, 0.16)

Tabular Summary for TP

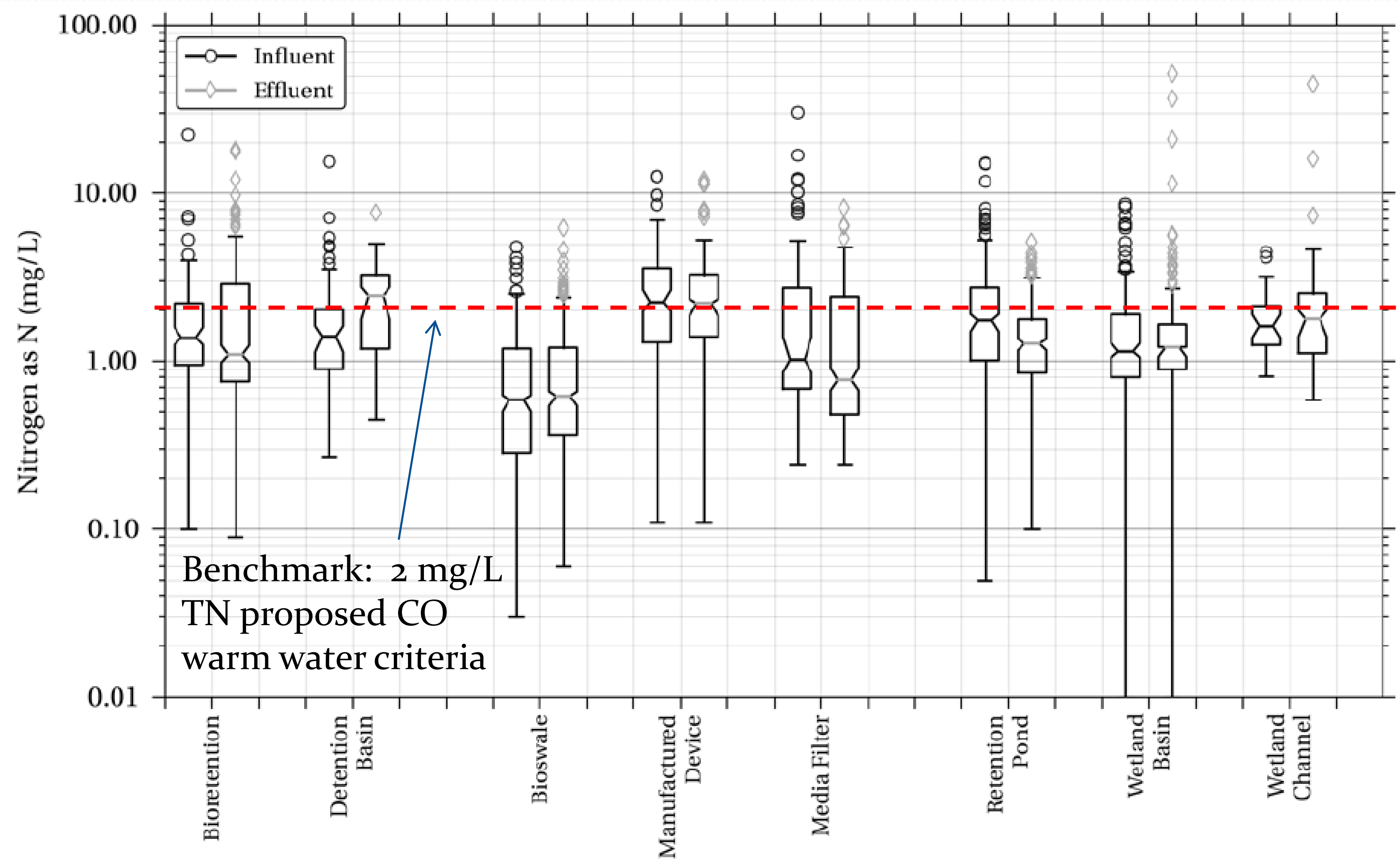
Table 10. Influent/Effluent Summary Statistics for Total Phosphorus.

BMP Type	Count (Studies/Data Pts.)		25th Percentile (mg/L)		Median (95% Conf. Interval) (mg/L)		75th Percentile (mg/L)	
	In	Out	In	Out	In	Out	In	Out
Bioretention	12/187	12/157	0.07	0.06	0.14 (0.12,0.15)	0.13 (0.10,0.16)	0.23	0.33
Detention Basin	17/222	17/241	0.18	0.12	0.26 (0.21,0.26)	0.21 (0.18,0.23)	0.48	0.34
Filter Strip	14/245	14/169	0.07	0.10	0.16 (0.14,0.19)	0.21 (0.16,0.23)	0.30	0.45
Bioswale	17/257	19/293	0.05	0.14	0.12 (0.09,0.16)	***0.20 (0.17,0.20)***	0.28	0.35
Manufactured Device	34/457	41/456	0.10	0.07	0.22 (0.16,0.22)	**0.14 (0.11,0.14)**	0.46	0.36
Media Filter	19/291	20/282	0.10	0.05	0.19 (0.16,0.20)	**0.10 (0.08,0.11)**	0.35	0.19
Porous Pavement	5/65	6/65	0.07	0.06	0.12 (0.09,0.13)	0.10 (0.07,0.11)	0.17	0.14
Retention Pond	38/578	40/561	0.14	0.06	0.27 (0.23,0.29)	**0.11 (0.08,0.11)**	0.53	0.22
Wetland Basin	12/284	13/271	0.08	0.04	0.12 (0.10,0.12)	**0.08 (0.06,0.08)**	0.20	0.14
Wetland Channel	6/88	6/83	0.13	0.10	0.18 (0.15,0.22)	**0.14 (0.11,0.15)**	0.30	0.25

BMP Performance: Total P



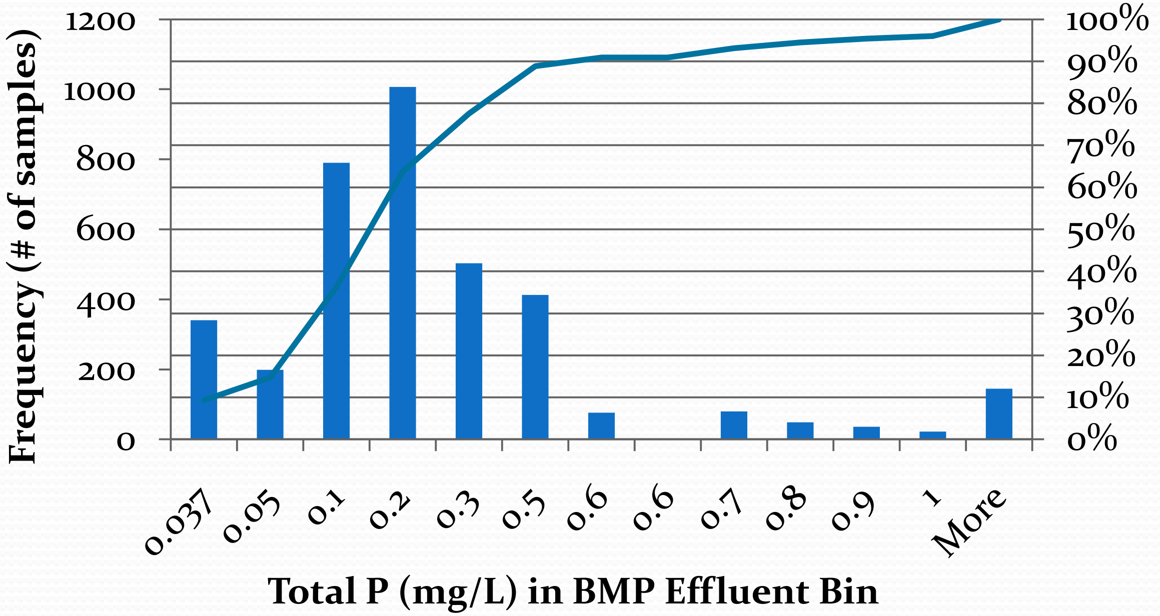
BMP Performance for Total Nitrogen (mg/L)



Additional Cumulative Analysis of July 2011 BMP Database

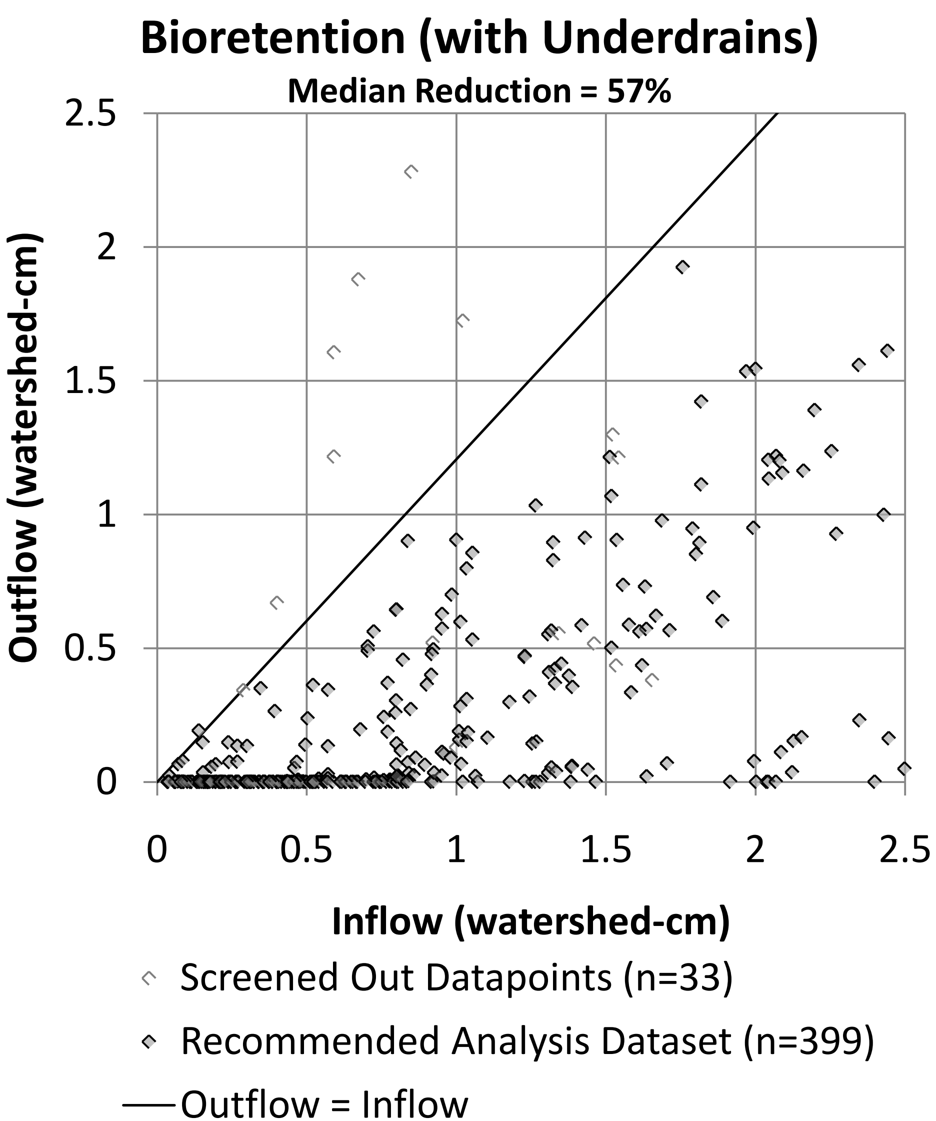
Descriptive Statistic	In-flow	Out-flow
Mean	0.36	0.27
Median	**0.22**	**0.14**
Std. Dev.	0.47	0.64
Minimum	0.002	0.001
Maximum	8.44	23.10
Count	3651	3661

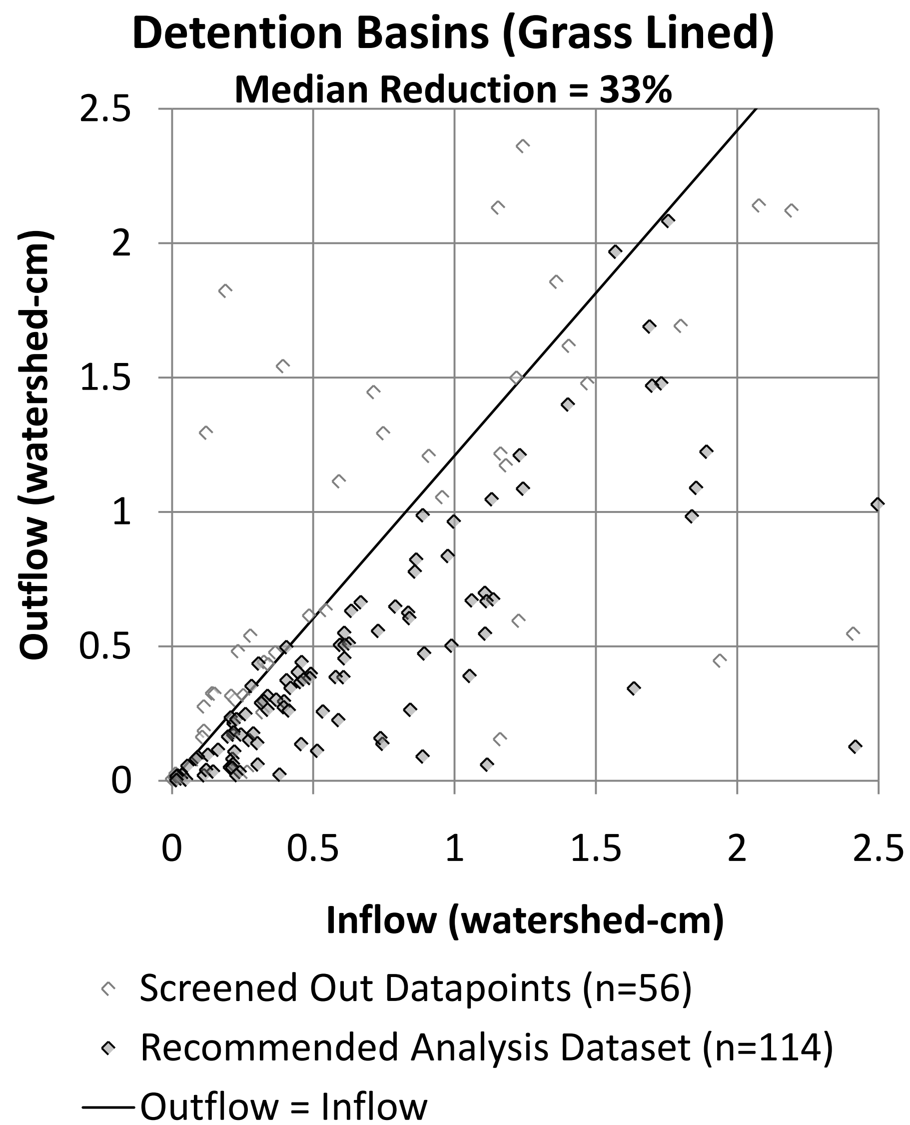
Figure 2-2. Histogram and Cumulative Frequency Distribution for BMP Database Total P Data in Treated Effluent



Volume Reduction Performance Summary

Practice Level





Volume Reduction Performance Summary for "Normally Dry BMPs"

BMP Category	#	25th Percentile	Median	75th Percentile	Avg.
Biofilter – Grass Strips	16	18%	34%	54%	38%
Biofilter – Grass Swales	13	35%	42%	65%	48%
Bioretention (w/underdrains)	7	45%	57%	74%	61%
Detention Basins –Grass Lined	11	26%	33%	43%	33%

Planning-level estimates only. These percentages only tell part of the story.

March-April 2008

You Were Collecting Stormwater Samples and *What* Happened?

By Jonathan E. Jones, T. Andrew Earles, John O'Brien, Michael Claffey, Sally Kribs

Comments

Article Tools

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On all too many occasions when attempting to collect stormwater runoff samples or data, we have failed to successfully complete the task. Sometimes, the circumstances that created the problem were unforeseeable and, in some instances, were almost unbelievable. We have returned to the office and shared our field stories with colleagues only to be met with "You say what happened when you were collecting samples?" The purpose of this article is to summarize representative problems that we have encountered, along with some "lessons learned."

You may also be interested in...

- Post-Restoration Water-Quality Monitoring
- Monitoring Options
- Remote Water-Quality Monitoring
- Water Monitoring and Sampling Tools: Part One
- Supporting Streams

Lessons Learned

Here are the key lessons we have learned:

REAL WORLD LESSONS

- Constant maintenance and calibration required
- Interference from animals
- Interference from the public
- Assumed hydrograph (for programming) does not match actual hydrograph

REAL WORLD LESSONS(Cont.)

- Laboratory and employee scheduling (All storms do not occur on Monday morning at 8 am)
- Battery power difficult to maintain at remote locations
- Trigger conditions too sensitive or not sensitive enough
- Multiple storms occurring before system has had time to drain

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Concluding Remarks

- Proposed Colorado Nutrient Criteria will pose new requirements for MS4 permit holders.
- As part of data gap analysis, it would be worthwhile to review available data from throughout the U.S., compare Colorado data to these findings—then focus on the real data gaps.
- Stormwater BMP performance monitoring in Colorado for UDFCD-based designs is important—we think it's worthwhile.
- It's very important to clearly define sampling plan objectives—put the time in right upfront.
- Systematically manage the data so it's useful for the long-run. (BMP Database!)

Questions?

Jane Clary, CPESC: clary@wrightwater.com

Andrew Earles, Ph.D., P.E., D.WRE, CPESC: aearles@wrightwater.com

Wright Water Engineers, Inc.

303-480-1700

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