A Summary of the International Stormwater BMP Database

Tuesday, February 12, 2013, 1:00PM

Presented by:
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PHRC
www.engr.psu.edu/phrc

Objective

The objective of this webinar is to summarize two PHRC Land Development Briefs on the International Stormwater BMP Database.

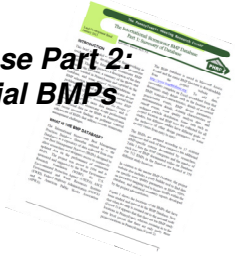
This webinar will introduce viewers to the Database, provide an overview of the data available, and summarize findings that can be incorporated into stormwater management design.

Outline

- Introduce the International BMP Stormwater Database
- Present the BMPs in PA that are in the Database
- Summarize percent removal for sediment, nitrogen and phosphorus for various BMPs
- Present volume reduction data currently available in the Database
- Limitations of % removal
- New beta tool available on the Database webpage
- Summarize design recommendations based on the findings

Summary of Briefs

- PHRC conducted a review of the International Stormwater Database to summarize data applicable to residential projects in Pennsylvania
- The study resulted in two Land Development Briefs available on the PHRC website at www.engr.psu.edu/phrc
  - *The International Stormwater BMP Database Part 1: Summary of Database*
  - *The International Stormwater BMP Database Part 2: Data Summary for the Design of Residential BMPs*



International Stormwater Best Management Practices Database

- **Centralized repository of stormwater BMP data**
- **Supported by:**
  - Water Environment Research Foundation (WERF)
  - U.S. Environmental Protection Agency (USEPA)
  - ASCE Environmental and Water Resources Institute (EWRI)
  - Federal Highway Administration (FHWA)
  - American Public Works Association (APWA)
- **Over 500 BMPs around the country**
- **Designed to allow researchers and designers access to continually updated data on the performance of stormwater BMPs**

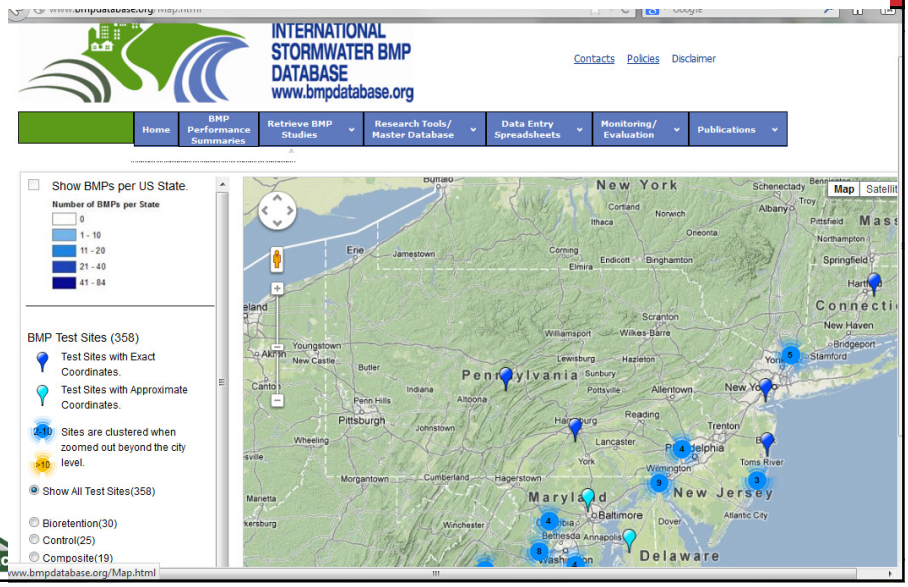
International Stormwater BMP Database

- **Microsoft Access database, free for download**
  - http://www.bmpdatabase.org/
- **Data entered in Excel spreadsheet form**
  - the location of the BMP
  - watershed characteristics
  - details of monitored precipitation events
  - BMP design parameters
  - instrumentation details
  - defining characteristics of runoff events
  - water quality analysis data
  - sediment particle distribution

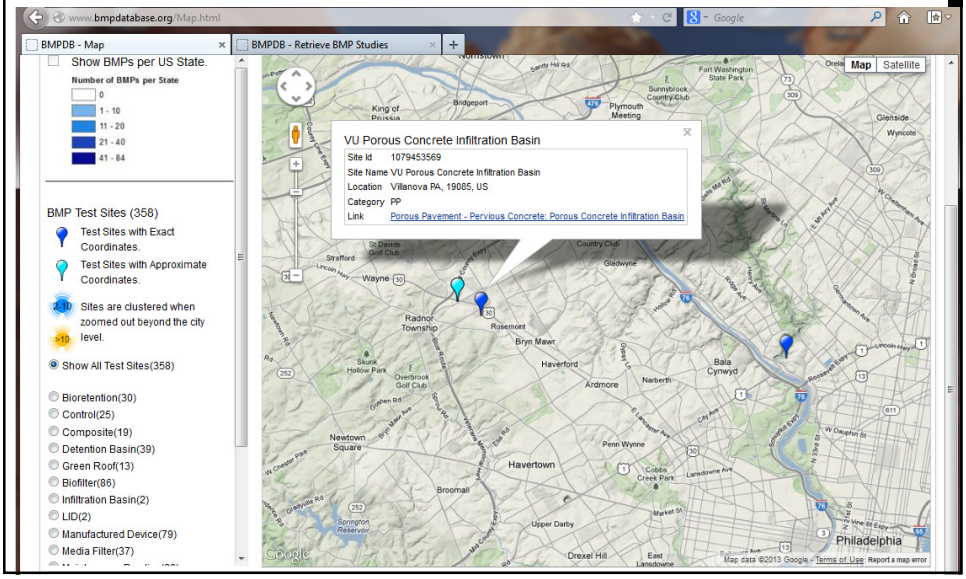
International Stormwater BMP Database

- Search capabilities to find data on specific water quality parameters or BMPs types
- Interactive mapping tool to locate BMPs
- Statistical summary reports developed by the project team

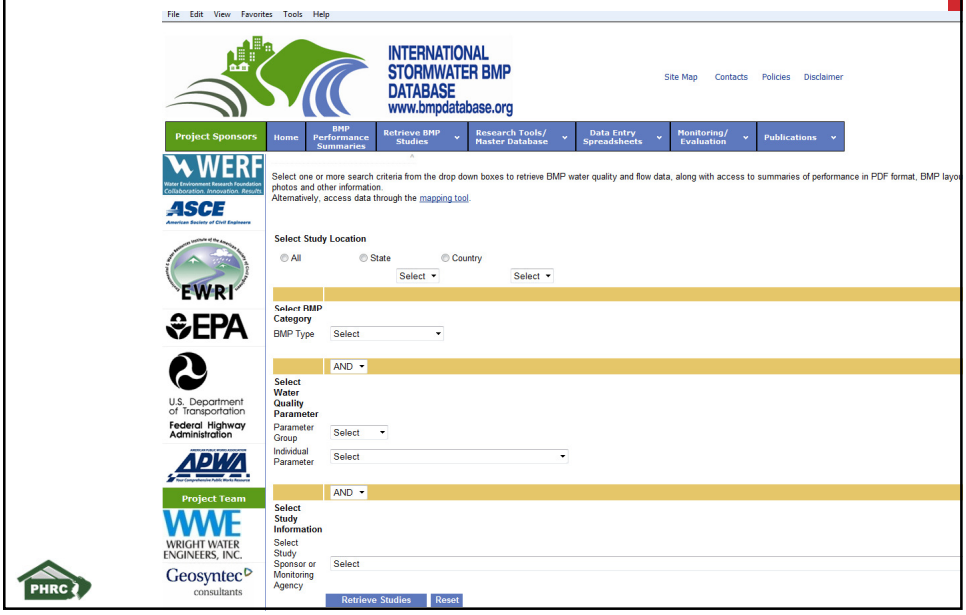
Interactive Mapping Tool



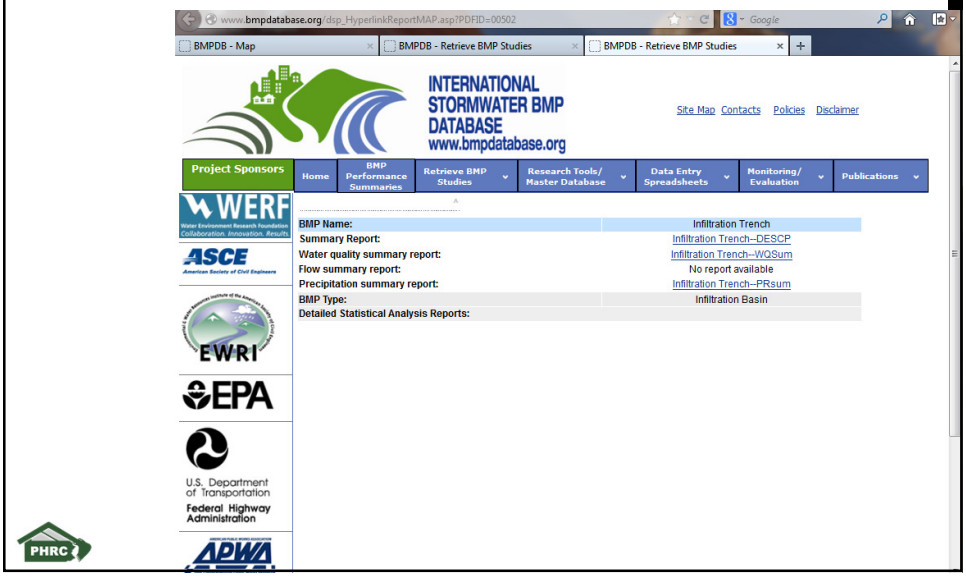
Interactive Mapping Tool



Search Tool



Summary Reports:
Result of Mapping Tool and Query Builder



Summary Categories

BMP Category	# of BMPs Studied
Bioretention	30
Detention basin	39
Green roof	13
Biofilter – Grass strip	45
Biofilter – Grass swale	41
Infiltration basin	2
LID (site scale)	2
Manufactured device	79
Media filter	37
Percolation trench/well	12
Porous pavement	35
Retention pond	68
Wetland basin	31
Wetland channel	19
Composite (treatment train)	25
Maintenance practice	28
Other	6
Total	512

Projects in PA

- **Harrisburg Public Works Yard**
  - Manufactured device - two-chamber sediment trap
- **Penn State University (University Park)**
  - Green room
- **Villanova University**
  - Infiltration trench
  - Porous concrete infiltration basin
  - Additional data at Villanova Urban Stormwater Partnership http://www3.villanova.edu/vusp/

Water Quality Data

- **Over 3,000 different water quality constitutes reported**
- **Sediment, nitrogen & phosphorous**
  - Chesapeake Bay TMDL Plan
  - PA DEP NPDES Permit for Stormwater Discharges Associated with Construction Activities
- **Median influent and effluent values reported project team in technical reports**

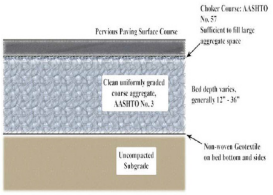
Percent Removal

$$\text{percent removal} = \frac{(\text{influent conc.} - \text{effluent conc.})}{\text{influent conc.}} * 100$$

- PA DEP NPDES Permits for Stormwater Discharges Associated with Construction Activities
- TMDL Strategy Plan as part of the NPDES Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) (PAG-13)

BMP Manual Ch 6

BMP 6.4.1: Pervious Pavement with Infiltration Bed



Pervious pavement consists of a permeable surface course underlain by a uniformly-graded stone bed which provides temporary storage for peak rate control and promotes infiltration. The surface course may consist of porous asphalt, porous concrete, or various porous structural pavers laid on uncompacted soil.

Key Design Elements

- Almost entirely for peak rate control
- Water quality and quantity are not addressed
- Short duration storage; rapid restoration of primary uses
- Minimize safety risks, potential property damage, and user inconvenience
- Emergency overflows
- Maximum ponding depths
- Flow control structures
- Adequate surface slope to outlet

Potential Applications

Residential: Limited
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Limited

Stormwater Functions

Volume Reduction: Medium
Recharge: Medium
Peak Rate Control: Medium
Water Quality: Medium

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

BMP Manual Appendix A

COMPREHENSIVE BMP LIST

		Pollutant Removal Efficiency %		
		TSS	TP	NO3
Non-Structural BMP				
5.4.1	Protect Sensitive / Special Value Features	SC	SC	SC
5.4.2	Protect / Conserve / Enhance Riparian Areas	SC	SC	SC
5.4.3	Protect / Utilize Natural Flow Pathways in Overall Stormwater Planning and Design	30	20	0
5.5.1	Cluster Uses at Each Site; Build on the Smallest Area Possible	SC	SC	SC
5.5.2	Concentrate Uses Areawide through Smart Growth Practices	SC	SC	SC
5.6.1	Minimize Total Disturbed Area - Grading	40	0	0
5.6.2	Minimize Soil Compaction in Disturbed Areas	30	0	0
5.6.3	Re-vegetate and Re-forest Disturbed Areas using Native Species	85	85	50
5.7.1	Reduce Street Imperviousness	SC	SC	SC
5.7.2	Reduce Parking ImperviousnesS	SC	SC	SC
5.8.1	Rooftop Disconnection	30	0	0
5.8.2	Disconnection from Storm Sewers	30	0	0
5.9.1	Streetsweeping	85	85	50
Structural BMP				
6.4.1	Porous Pavement with Infiltration Bed	85	85	30
6.4.2	Infiltration Basin	85	85	30
6.4.3	Subsurface Infiltration Bed	85	85	30
6.4.4	Infiltration Trench	85	85	30
6.4.5	Rain Garden / Bioretention	85	85	30
6.4.6	Dry Well / Seepage Pit	85	85	30
6.4.7	Constructed Filter	85	85	30
6.4.8	Vegetated Swale	50	50	20
6.4.9	Vegetated Filter Strip	30	20	10
6.4.10	Infiltration Berm and Retentive Grading	60	50	40
6.5.1	Vegetated Roof	85	85	30
6.5.2	Rooftop Runoff - Capture and Reuse	100	100	100
6.6.1	Constructed Wetland	85	85	30
6.6.2	Wet Pond / Retention Basin	70	60	30
6.6.3	Dry Extended Detention Basin	60	40	20
6.6.4	Water Quality Filter	60	50	20
6.7.1	Riparian Buffer Restoration	65	50	50
6.7.2	Landscape Restoration	85	85	50
6.7.3	Soils Amendment and Restoration	85	85	50

Sediment

- **Sediment parameters**
  - Total suspended sediment (TSS)
  - Total dissolved sediment (TDS
  - Turbidity

Sediment Removal

- **TSS removal**
  - Media filters
  - Porous pavement
  - Composite BMPs
- **TDS removal**
  - Not statistically significant
- **Turbidity removal**
  - Similar to TSS, limited data

Data Tables

- **Number of studies and Number of EMCs**
- **Median concentrations, mg/L (from Database)**
  - Influent
  - Effluent
- **Percent reduction (calculated)**
  - Influent
  - Effluent
- **Shaded, bold values indicate statistically significant decrease or increase in calculated percent removal**

Sediment, TSS

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Media Filter	**28, 442**	**29, 409**	**52.7**	**8.7**	**83%**
Porous Pavement	**14, 246**	**23, 406**	**65.3**	**13.2**	**80%**
Composite	**10, 201**	**10, 163**	**94**	**17.4**	**81%**
Retention Pond	**47, 725**	**48, 723**	**70.7**	**13.5**	**81%**
Bioretention	**14, 202**	**14, 193**	**37.5**	**8.3**	**78%**
Detention Basin	**20, 287**	**21, 299**	**66.8**	**24.2**	**64%**
Grass Strip	**19, 350**	**20, 286**	**43.1**	**19.1**	**56%**
Wetland Basin	**15, 301**	**17, 305**	**20.4**	**9.06**	**56%**
Manufactured Device	**55, 923**	**63, 904**	**34.5**	**18.4**	**47%**
Bioswale	**21, 338**	**23, 354**	**21.7**	**13.6**	**37%**
Wetland Channel	**8, 189**	**8, 154**	**20**	**14.3**	**29%**
Green Roof	2, 20	4, 51	10.5	2.9	72%

Sediment Removal Techniques

- **Increase hydraulic residence time**
  - Lengthen flow paths in ponds or wetlands
  - Increase bed thickness
  - Create evenly distributed flows
  - Increase density of vegetation
- **Conduct regular maintenance to prevent clogging in filtration and infiltration BMPs**

Nitrogen

- **Total nitrogen (TN),**
  - Sum of TNK plus nitrate (NO_3^-) and nitrite (NO_2^-)
- **Total Kjeldahl nitrogen (TKN),**
  - Sum of organic nitrogen, ammonia (NH_3), and ammonium (NH_4^+)
- **NO_x**
  - Sum of NO_3^- and NO_2^-

Total Nitrogen (TN)

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Retention Pond	**19, 259**	**19, 272**	**1.83**	**1.28**	**30%**
Bioretention	**12, 218**	**12, 200**	**1.25**	**0.9**	**28%**
Composite	**3, 53**	**4, 64**	**2.37**	**1.71**	**28%**
Media Filter	**5, 100**	**5, 87**	**1.06**	**0.82**	**23%**
Grass Strip	8, 138	8, 122	1.34	1.13	16%
Wetland Channel	5, 83	6, 88	1.59	1.33	16%
Bioswale	6, 181	8, 238	0.75	0.71	5%
Manufactured Device	8, 133	8, 117	2.27	2.22	2%
Green Roof	NA	NA	NA	NA	NA
Wetland Basin	6, 222	6, 223	1.14	1.19	-4%
Porous Pavement	1, 14	9, 136	1.26	1.49	-18%
Detention Basin	**3, 52**	**3, 64**	**1.4**	**2.34**	**-67%**

Total Kjeldahl Nitrogen (TKN)

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Porous Pavement	**12, 224**	**23, 396**	**1.66**	**0.8**	**52%**
Media Filter	**26, 411**	**25, 374**	**0.96**	**0.57**	**41%**
Composite	**7, 130**	**9, 145**	**1.64**	**1.02**	**38%**
Bioretention	**14, 214**	**14, 201**	**0.94**	**0.6**	**36%**
Retention Pond	**36, 482**	**39, 496**	**1.28**	**1.05**	**18%**
Wetland Channel	**6, 122**	**7, 139**	**1.45**	**1.23**	**15%**
Grass Strip	19, 350	19, 272	1.29	1.09	16%
Bioswale	17, 288	19, 324	0.72	0.62	14%
Manufactured Device	24, 390	31, 433	1.59	1.48	7%
Wetland Basin	6, 72	8, 184	0.95	1.01	-6%
Detention Basin	11, 175	12, 185	1.49	1.61	-8%
Green Roof	1, 15	3, 32	1.51	1.75	-16%

Nitrate + Nitrite (NO_x)

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Wetland Basin	**11, 245**	**11, 246**	**0.24**	**0.08**	**67%**
Retention Pond	**43, 639**	**43, 626**	**0.43**	**0.18**	**58%**
Wetland Channel	**8, 149**	**8, 132**	**0.34**	**0.19**	**44%**
Detention Basin	**13, 201**	**14, 213**	**0.55**	**0.36**	**35%**
Composite	**9, 157**	**10, 142**	**0.57**	**0.4**	**30%**
Grass Strip	**20, 360**	**20, 287**	**0.41**	**0.27**	**34%**
Bioretention	**17, 278**	**17, 259**	**0.26**	**0.22**	**15%**
Green Roof	2, 21	4, 55	0.39	0.31	21%
Bioswale	20, 335	22, 372	0.3	0.25	17%
Manufactured Device	33, 504	40, 546	0.41	0.41	0%
Media Filter	**27, 434**	**26, 391**	**0.33**	**0.51**	**-55%**
Porous Pavement	**13, 229**	**23, 401**	**0.42**	**0.71**	**-69%**

Nitrogen Removal Techniques

- **Overall, vegetated BMPs with permanent pools such as wetland basins and channels, bioretention and retention ponds are the most effective BMPs for reducing forms of N**

Phosphorus

- **Total phosphorus (TP)**
  - Includes all forms of phosphorus, both the particulate form that is frequently adsorbed to soil particles and the phosphorus that is dissolved in the runoff
- **Orthophosphate (OP)**
  - Phosphate ion (PO_4^{3-}) and is often referred to as reactive phosphorus
- **Dissolved phosphorus (DP)**
  - Portion of phosphorus that is dissolved in the runoff and found by passing the sample through a 0.45 micron membrane to remove any sediment from the sample

Total Phosphorus (TP)

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Composite	**9, 176**	**10, 153**	**0.36**	**0.13**	**64%**
Retention Pond	**46, 657**	**48, 654**	**0.3**	**0.13**	**57%**
Media Filter	**28, 433**	**28, 403**	**0.18**	**0.09**	**50%**
Porous Pavement	**13, 231**	**22, 389**	**0.15**	**0.09**	**40%**
Wetland Basin	**13, 282**	**13, 278**	**0.13**	**0.08**	**38%**
Manufactured Device	**45, 602**	**52, 641**	**0.19**	**0.12**	**37%**
Detention Basin	**18, 250**	**19, 275**	**0.28**	**0.22**	**21%**
Bioretention	18, 271	18, 249	0.11	0.09	18%
Wetland Channel	8, 167	8, 147	0.15	0.14	7%
Grass Strip	**20, 358**	**20, 280**	**0.14**	**0.18**	**-29%**
Bioswale	**20, 331**	**22, 364**	**0.11**	**0.19**	**-73%**
Green Roof	**2, 22**	**5, 60**	**0.09**	**0.5**	**-456%**

Orthophosphate

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Retention Pond	**27, 361**	**28, 357**	**0.1**	**0.04**	**60%**
Manufactured Device	**14, 201**	**14, 185**	**0.21**	**0.1**	**52%**
Media Filter	**9, 170**	**9, 157**	**0.05**	**0.03**	**40%**
Wetland Basin	**5, 166**	**5, 161**	**0.03**	**0.02**	**33%**
Detention Basin	2, 31	2, 31	0.53	0.39	26%
Composite	4, 56	4, 47	0.09	0.07	22%
Porous Pavement	7, 87	9, 112	0.05	0.05	0%
Grass Strip	**14, 274**	**14, 223**	**0.03**	**0.06**	**-100%**
Wetland Channel	**3, 84**	**3, 63**	**0.03**	**0.06**	**-100%**
Bioretention	**13, 164**	**13, 164**	**0.01**	**0.04**	**-300%**
Bioswale	**5, 140**	**7, 197**	**0.03**	**0.12**	**-300%**
Green Roof	**2, 21**	**4, 55**	**0.02**	**0.46**	**-2200%**

Dissolved Phosphorus (DP)

	# of studies, # of EMCs		Median concentrations (mg/L)		Percent reduction
	Inf.	Eff.	Inf.	Eff.	
Retention Pond	**19, 379**	**20, 371**	**0.13**	**0.06**	**54%**
Wetland Basin	**5, 114**	**5, 113**	**0.08**	**0.05**	**38%**
Composite	7, 143	8, 142	0.16	0.08	50%
Bioretention	1, 10	1, 10	0.25	0.13	48%
Manufactured Device	16, 239	23, 265	0.08	0.06	25%
Media Filter	13, 103	13, 96	0.08	0.08	0%
Green Roof			NA	NA	NA
Detention Basin	8, 91	9, 94	0.1	0.11	-10%
Wetland Channel	5, 92	5, 89	0.08	0.09	-13%
Porous Pavement	4, 114	5, 125	0.04	0.05	-25%
Grass Strip	3, 21	3, 17	0.08	0.25	-213%
Bioswale	**6, 66**	**6, 52**	**0.06**	**0.07**	**-17%**

Phosphorus Removal Techniques

- **Phosphorus generally transported through the adsorption to sediment rather than dissolved in water**
  - Remove sediment → remove phosphorus
  - Sedimentation and filtration

Addressing P Increases

- **BMP media with high P concentrations can export P in the effluent**
- **Especially important in BMPs where water is stored in soil or media with an under-drained system**
- **Specify soil or media, test P concentration if using site soils**

Volume Reduction

- **Early data collection focused on WQ**
- **Volume data not included until more recently**
- **BMPs with normally dry conditions are best for long-term volume reduction**
  - Largest volume reduction for smaller storms which occur more frequently than larger storms

Volume Reduction

	# of Study Locations	Median % Reduction
Bioretention (w/underdrain)	7	57%
Biofilter – grass swales	13	42%
Biofilter – grass strips	16	34%
Detention basins – surface, grass lined	11	33%

Volume Reduction

- **Very sensitive to local soil conditions**
  - Soil textural class
  - Compaction
  - Depth to groundwater, bedrock or impermeable layer

Limitations of Percent Removal

- **Can be function of influent water quality rather than BMP effectiveness**
  - Dirtier water has a higher percent removal than cleaner water
- **Hides large variability in data**
- **Doesn't account for volume reduction**

Concentration vs. Load

Bioswale

Median influent concentration is 0.11 mg/L
Median effluent concentration is 0.19 mg/L
73% increase in phosphorus concentration

Concentration vs. Load

Influent
Concentration = 0.11 mg/L
Volume = 10,000 L

Effluent
Concentration = 0.19 mg/L

42% volume reduction

Concentration vs. Load

Influent Load Calculation

$$(0.11\ mg/L) \times (10{,}000\ L) \times \left(\frac{1\ g}{1{,}000\ mg}\right) = 11.0\ g$$

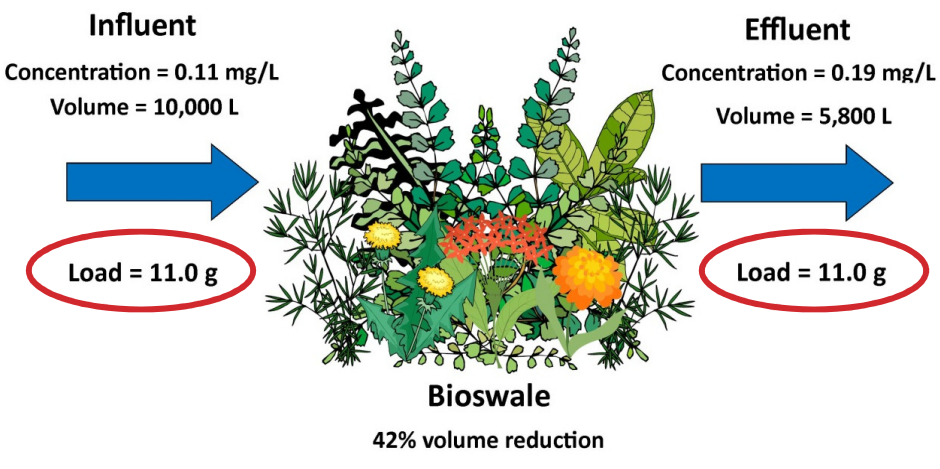
Effluent Volume Calculation

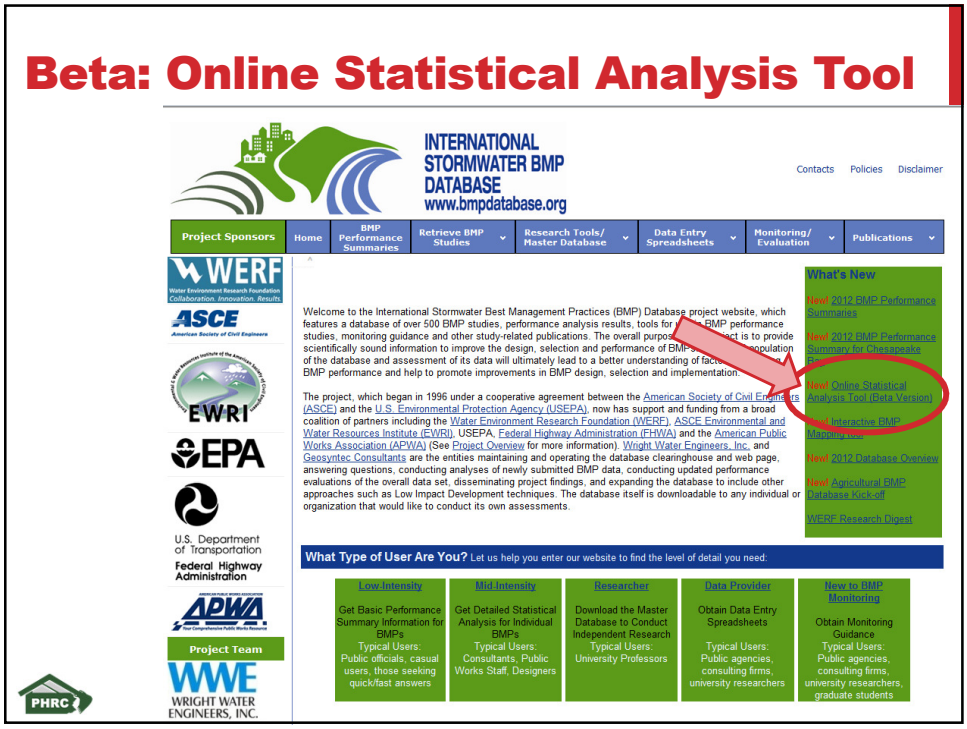
$$(10{,}000\ L) \times (1 - 0.42) = 5{,}800\ L$$

Effluent Load Calculation

$$(0.19\ mg/L) \times (5{,}800\ L) \times \left(\frac{1\ g}{1{,}000\ mg}\right) = 11.0\ g$$

Concentration vs. Load




Beta: Online Statistical Analysis Tool
INTERNATIONAL STORMWATER BMP DATABASE
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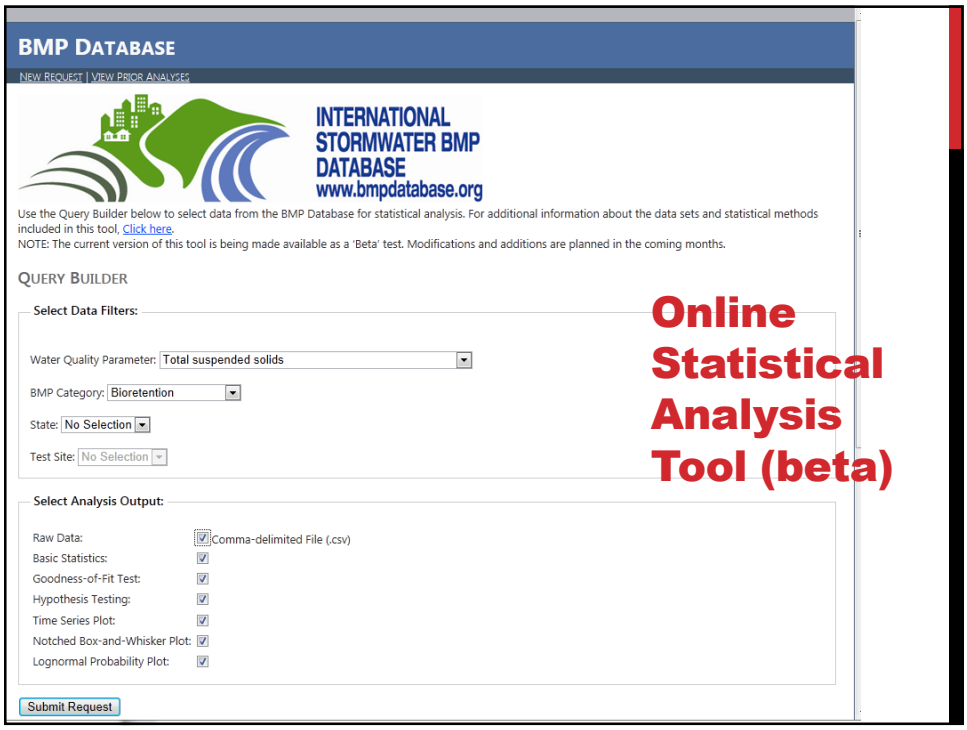
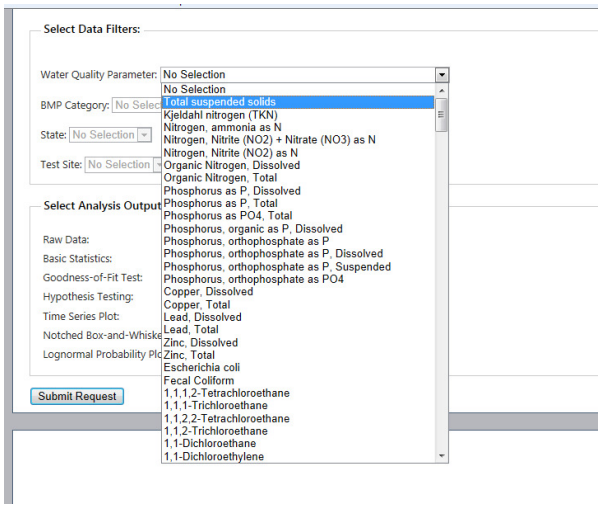
What's New
New! 2012 BMP Performance Summaries
New! 2012 BMP Performance Summary for Chesapeake
New! Online Statistical Analysis Tool (Beta Version)
New! Interactive BMP Mapping Tool
New! 2012 Database Overview
New! Agricultural BMP Database Kick-off
WERF Research Digest
What Type of User Are You? Let 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, graduate students
Project Team
WRIGHT WATER ENGINEERS, INC.

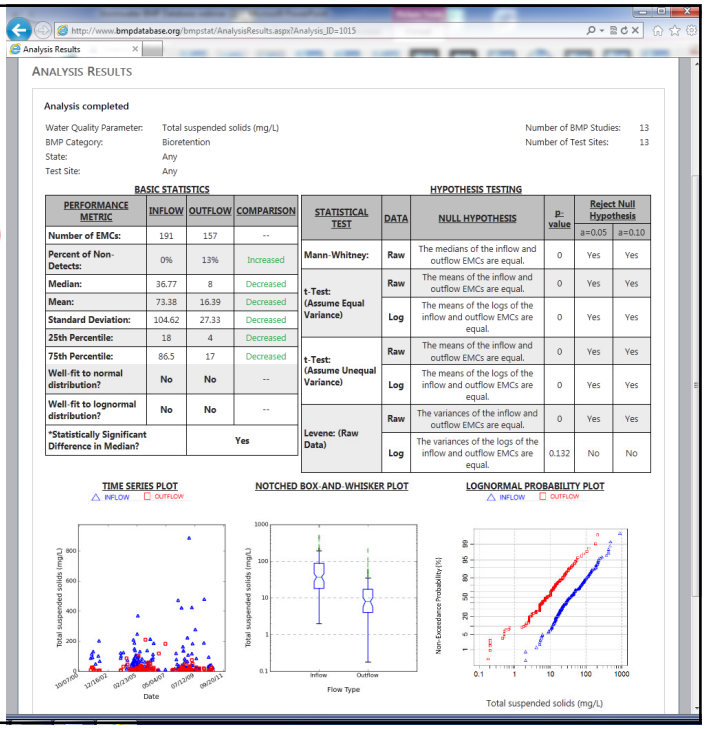

BMP DATABASE
NEW REQUEST | VIEW PRIOR ANALYSES
INTERNATIONAL STORMWATER BMP DATABASE
www.bmpdatabase.org
Use the Query Builder below to select data from the BMP Database for statistical analysis. For additional information about the data sets and statistical methods included in this tool, Click here.
NOTE: The current version of this tool is being made available as a 'Beta' test. Modifications and additions are planned in the coming months.
QUERY BUILDER
Select Data Filters:
Water Quality Parameter: Total suspended solids
BMP Category: Bioretention
State: No Selection
Test Site: No Selection
Select Analysis Output:
Raw Data: Comma-delimited File (.csv)
Basic Statistics:
Goodness-of-Fit Test:
Hypothesis Testing:
Time Series Plot:
Notched Box-and-Whisker Plot:
Lognormal Probability Plot:
Submit Request
Online Statistical Analysis Tool (beta)

Online Statistical Analysis Tool (beta)

- **Water Quality Parameters**



Online Statistical Analysis Tool (beta)



ANALYSIS RESULTS

Analysis completed

Water Quality Parameter: Total suspended solids (mg/L)
BMP Category: Bioretention
State: Any
Test Site: Any

Number of BMP Studies: 13
Number of Test Sites: 13

BASIC STATISTICS

PERFORMANCE METRIC	INFLOW	OUTFLOW	COMPARISON
Number of EMCs:	191	157	--
Percent of Non-Detects:	0%	13%	Increased
Median:	36.77	8	Decreased
Mean:	73.38	16.39	Decreased
Standard Deviation:	104.62	27.33	Decreased
25th Percentile:	18	4	Decreased
75th Percentile:	86.5	17	Decreased
Well-fit to normal distribution?	No	No	--
Well-fit to lognormal distribution?	No	No	--
*Statistically Significant Difference in Median?		Yes	

HYPOTHESIS TESTING

STATISTICAL TEST	DATA	NULL HYPOTHESIS	p-value	Reject Null Hypothesis a=0.05	Reject Null Hypothesis a=0.10
Mann-Whitney:	Raw	The medians of the inflow and outflow EMCs are equal.	0	Yes	Yes
t-Test: (Assume Equal Variance)	Raw	The means of the inflow and outflow EMCs are equal.	0	Yes	Yes
	Log	The means of the logs of the inflow and outflow EMCs are equal.	0	Yes	Yes
t-Test: (Assume Unequal Variance)	Raw	The means of the inflow and outflow EMCs are equal.	0	Yes	Yes
	Log	The means of the logs of the inflow and outflow EMCs are equal.	0	Yes	Yes
Levene: (Raw Data)	Raw	The variances of the inflow and outflow EMCs are equal.	0	Yes	Yes
	Log	The variances of the logs of the inflow and outflow EMCs are equal.	0.132	No	No

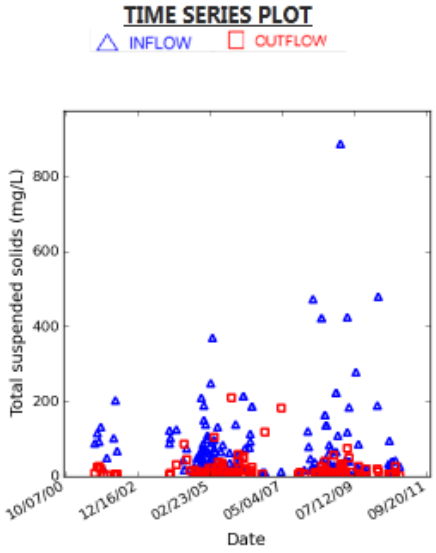
TIME SERIES PLOT

NOTCHED BOX-AND-WHISKER PLOT

LOGNORMAL PROBABILITY PLOT

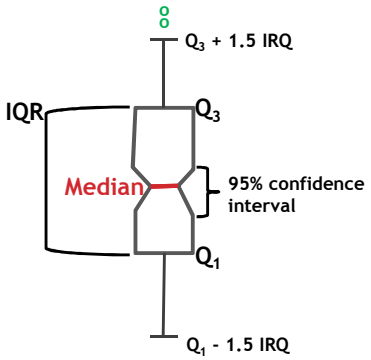
Online Statistical Analysis Tool (beta)

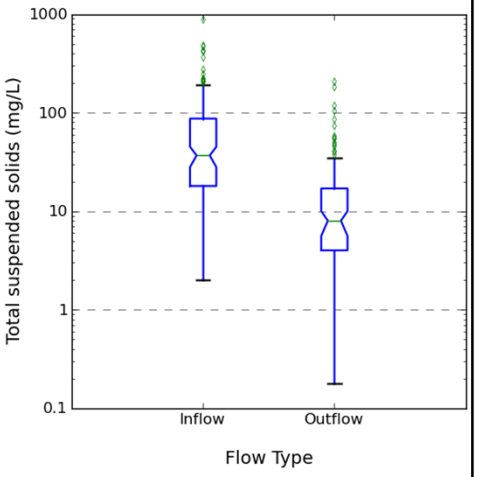
- Time Series Plot



Online Statistical Analysis Tool (beta)

- Notched box & whisker plot





Interquartile range (IQR) = Q_3 - Q_1

° outliner (> 1.5 IQR from Q_3)

Recommended BMPs Based on % Removal Calculated from the Database

TSS	Media filters Porous pavement Retention ponds Bioretention Detention basins	Grass strips Wetland basins Bioswales Manufactured devices Wetland channels
Total N	Retention ponds Bioretention ponds Media filter	
TKN	Porous pavement Media filters Bioretention	Retention pond Wetland channel
NO_x	Wetland basins Retention ponds Wetland channels	Detention basin Grass strip Bioretention

Based on percent removals calculated from median influent and effluent from the Database

Recommended BMPs Based on % Removal Calculated from the Database

Total P	Retention pond Media filters Porous pavement	Wetland basins Manufactured devices Detention basin
Orthophosphate	Retention ponds Manufactured devices	Media filters Wetland basins
Dissolved P	Retention ponds Wetland basins	
Volume	Filter strips Vegetated swales	Bioretention basins Detention basins (grass lined)

Based on percent removals calculated from median influent and effluent from the Database

BMPs that Tend Increase Pollutant Concentrations

Total N	Detention basin
NOx	Porous pavement Media filters
TP	Grass strips Bioswales Green roofs
Orthophosphate	Grass strips Bioretention Bioswales Green roofs Wetland channels
Dissolved P	Bioswales

Based on percent removals calculated from median influent and effluent from the Database

Thank you!

Questions?

PA Housing and Land Development Conference

February 20-21, 2013

Day 1 – Housing Conference

Day 2 – Land Development Conference & Training (Housing-Related)

www.engr.psu.edu/phrc

Next month's webinar:

Attic and Roof Ventilation – Facts and Fiction

Tuesday, March 12, 1:00 PM

Register at: www.engr.psu.edu/phrc/Training/Webinars.htm