Evaluation of Stormwater Control Measure Performance Uncertainty

Presentation to:

Chesapeake Bay Scientific and Technical Advisory Committee (STAC)

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3/14/2017

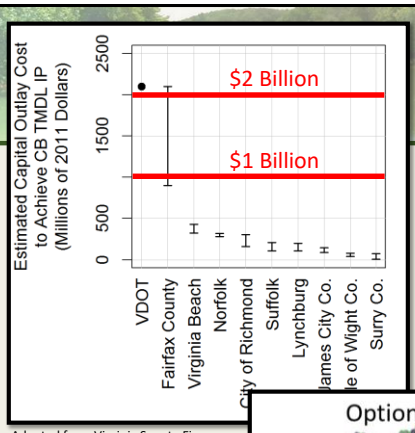
BACKGROUND

Motivated by:

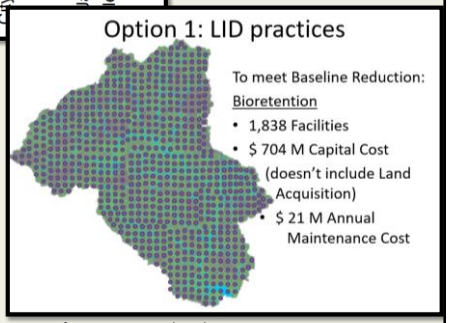
- Number and cost of urban stormwater control measures (SCMs)
- How cost effective are they?

$$\frac{Life\ Cycle\ Cost}{Lbs.\ Removed}$$

- This study focuses on uncertainty in the denominator: **pollutant removal performance**



Adapted from Virginia Senate Finance Committee (2011) and AMEC (2012)

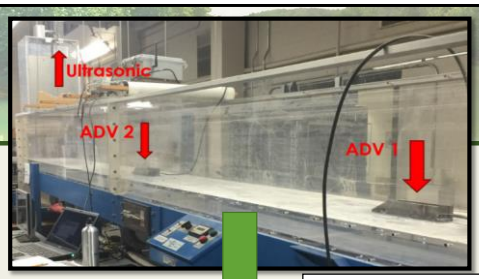


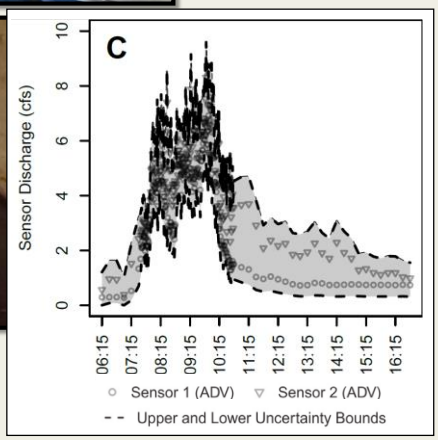
From Fairfax County DPWES (2015)

BACKGROUND

Motivated by:

- Number and cost of urban stormwater control measures (SCMs)
- SCM Cost-effectiveness???
- **Previous study on uncertainty in storm sewer flow measurements**

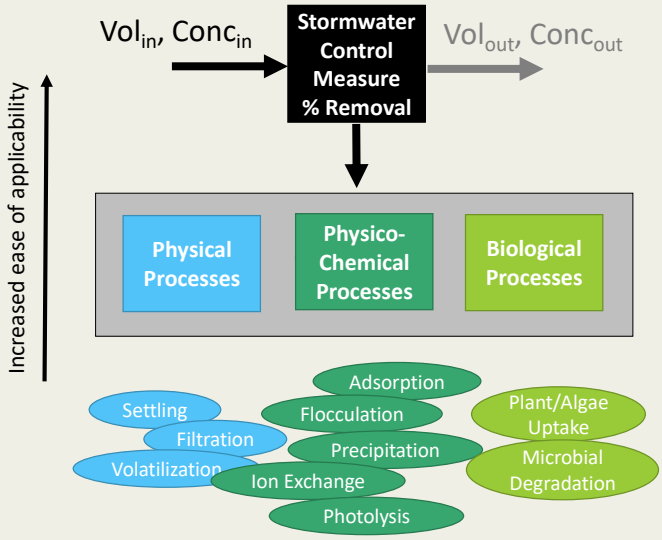




From Aguilar et al. (2016)

BACKGROUND

- Stormwater Treatment Processes
- **Study Approach:** Start with existing regulations, work towards greater scientific validity
- **Methodology:** use literature meta-analysis to evaluate percent removal uncertainty



Taxonomy of processes from Scholes et al. (2008)

METHODS

- Current Virginia regulatory paradigm for pollutant removal performance:

Runoff Reduction Method – CWP (2008)

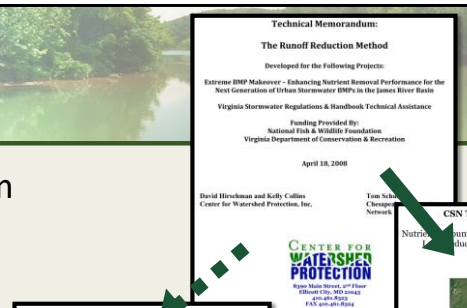
$$Runoff\ Reduction\ (RR) = \frac{Vol_{in} - Vol_{out}}{Vol_{in}}$$

$$Pollutant\ Removal\ (PR) = \frac{Conc_{in} - Conc_{out}}{Conc_{in}}$$

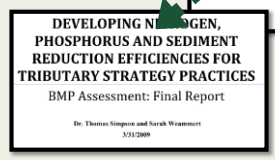
$$\boldsymbol{Total\ Removal\ (TR) = RR + [PR \times (1 - PR)]}$$

→ TR values used directly

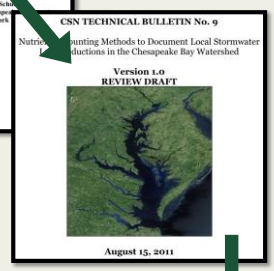
⇢ TR values used but modified


Technical Memorandum:
The Runoff Reduction Method
Developed for the Following Projects:
Extreme BMP Makeover – Enhancing Nutrient Removal Performance for the Next Generation of Urban Stormwater BMPs in the James River Basin
Virginia Stormwater Regulations & Handbook Technical Assistance
Funding Provided By:
National Fish & Wildlife Foundation
Virginia Department of Conservation & Recreation
April 18, 2008
David Hirschman and Kelly Collins
Center for Watershed Protection, Inc.
CENTER FOR WATERSHED PROTECTION

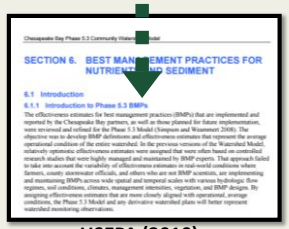
CWP (2008)


DEVELOPING NITROGEN, PHOSPHORUS AND SEDIMENT REDUCTION EFFICIENCIES FOR TRIBUTARY STRATEGY PRACTICES
BMP Assessment: Final Report
Dr. Thomas Simpson and Sarah Weammert
3/31/2009

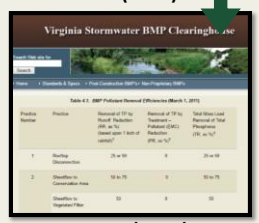
Simpson and Weammert (2009)


CSN TECHNICAL BULLETIN No. 9
Nutrient Accounting Methods to Document Local Stormwater Reductions in the Chesapeake Bay Watershed
Version 1.0
REVIEW DRAFT
August 15, 2011

CSN (2011)


SECTION 6. BEST MANAGEMENT PRACTICES FOR NUTRIENT AND SEDIMENT
6.1 Introduction
6.1.1 Introduction to Phase 5.3 BMPs

USEPA (2010)


Virginia Stormwater BMP Clearinghouse

VDEQ (2014)

METHODS

- 15 SCM Categories (from VDEQ)
- 4 Pollutants of Concern:
  - Runoff Volume
  - TP, TN, TSS
- 163 Studies, 308 unique SCMs from:
  - Peer-reviewed + Conference literature
  - Int'l Stormwater BMP Database
  - USGS and other Technical Reports
- ~6,700 individual percent removal values
- 2 Sources of Uncertainty
  - Observation Uncertainty
  - Environmental Uncertainty


The Effects of Flow-Path Modification on Water-Quality Constituent Retention in an Urban Stormwater Detention Pond and Wetland System, Orlando, Florida
By W. Scott Gain
U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95-4297
Prepared in cooperation with the FLORIDA DEPARTMENT OF TRANSPORTATION

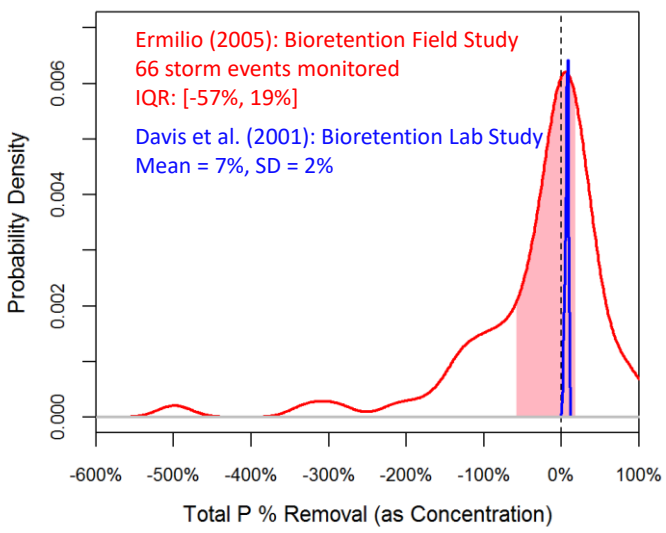
Evaluating Bioretention Hydrology at Three Field Sites in N

Caltrans
Final Report
Roadside Vegetated Treatment Sites (RVTS) Study
CTSW-RT-03- 028
CALTRANS DIVISION OF ENVIRONMENTAL ANALYSIS
NOVEMBER 2003

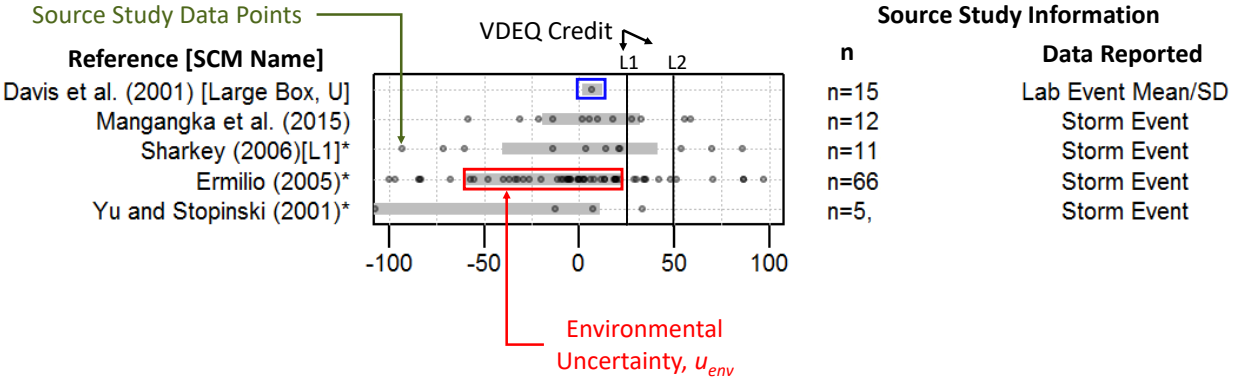
METHODS

"Environmental Uncertainty", u_{env}

- Environmental Variability
  - Precipitation
  - Random catchment events
- Estimated as the variability in % removal values for a single SCM monitoring study
- u_{env} varies widely across studies:
  - Field vs. lab studies
  - Data reported



METHODS

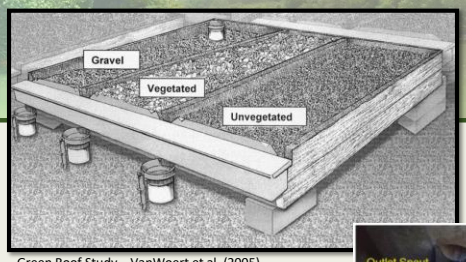


Bioretention - Total Phosphorus % EMC Reduction

METHODS

"Observation Uncertainty", u_{obs}

- Measurement Error
  - Precipitation (sometimes)
  - Depth and Discharge
  - Autosampling, Manual Sampling
  - Sample Storage and Preservation
  - Laboratory Characterization
- Estimated as ± % from error studies in the literature



Green Roof Study – VanWoert et al. (2005)

Fig. 4. Automatic water sampling setup for bioretention basin testing.

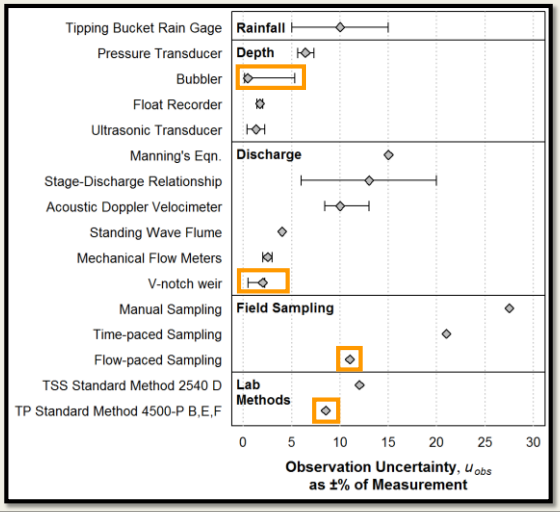
Bioretention Study - Lucke and Nichols (2015)

Photo by M. Aguilar

METHODS

I. Background
II. Methods
III. Results
IV. Conclusion/ Discussion

"Observation Uncertainty", u_{obs}



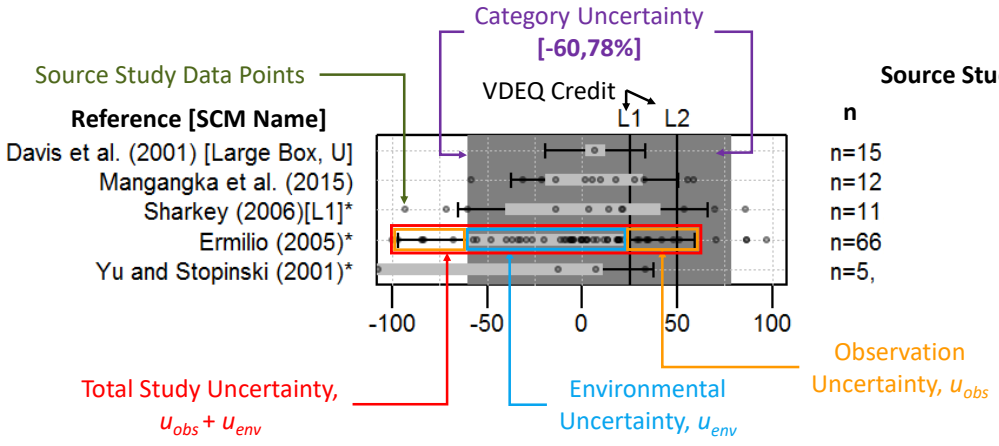
- Propagation of Uncertainty:

$$u_{comb.} = \sqrt{\sum_{i=1}^{N} u_{x_i}^2}$$

- Example: Bioretention monitoring in Passeport et al. (2009)
  - Bubblers and V-notch weirs
  - Flow-paced Autosamplers
  - Standard Laboratory Methods

RESULTS

$$Total\ Mass\ Load\ \%\ Removal\ (TR) = RR + [PR \times (1 - PR)]$$



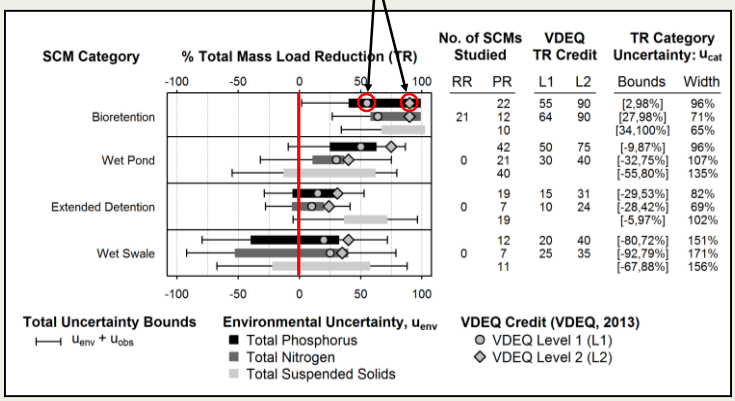
Bioretention - Total Phosphorus % EMC Reduction

RESULTS

- Top 3 – Infiltration, ~~Dry Swale,~~ Rainwater Harvesting → Insufficient data
- More studies ⇏ less uncertainty
- (+) Removal of all three pollutants:
  - Permeable Pavement
  - Bioretention
- (+) Removal of Suspended Solids
  - Filtering Practices
  - Vegetated Filter Strip
  - Constructed Wetland

VDEQ Credit Values

VDEQ Credit Values



15 SCM Categories (only 4 shown)

CONCLUSION AND DISCUSSION

- **Primary Outcomes:**
  - SCM Uncertainty using % Removal confounds effective management decision
  - Insufficiency of the metric
  - Insufficiency of the SCM category paradigm
- **Next Steps:**
  - Build framework for u_{obs} and u_{env} separately in two part paper
    - Further refine the combination of component uncertainties
    - Use probabilistic methods: PDFs, Monte Carlo simulation instead of ± summary statistics?
  - Combine two components in third paper that evaluates effects on SCM selection, TMDL progress, impact of uncertainty on cost/cost-effectiveness

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