Quantifying Uncertainty of Urban BMPs from Empirical Literature

Chesapeake Bay STAC

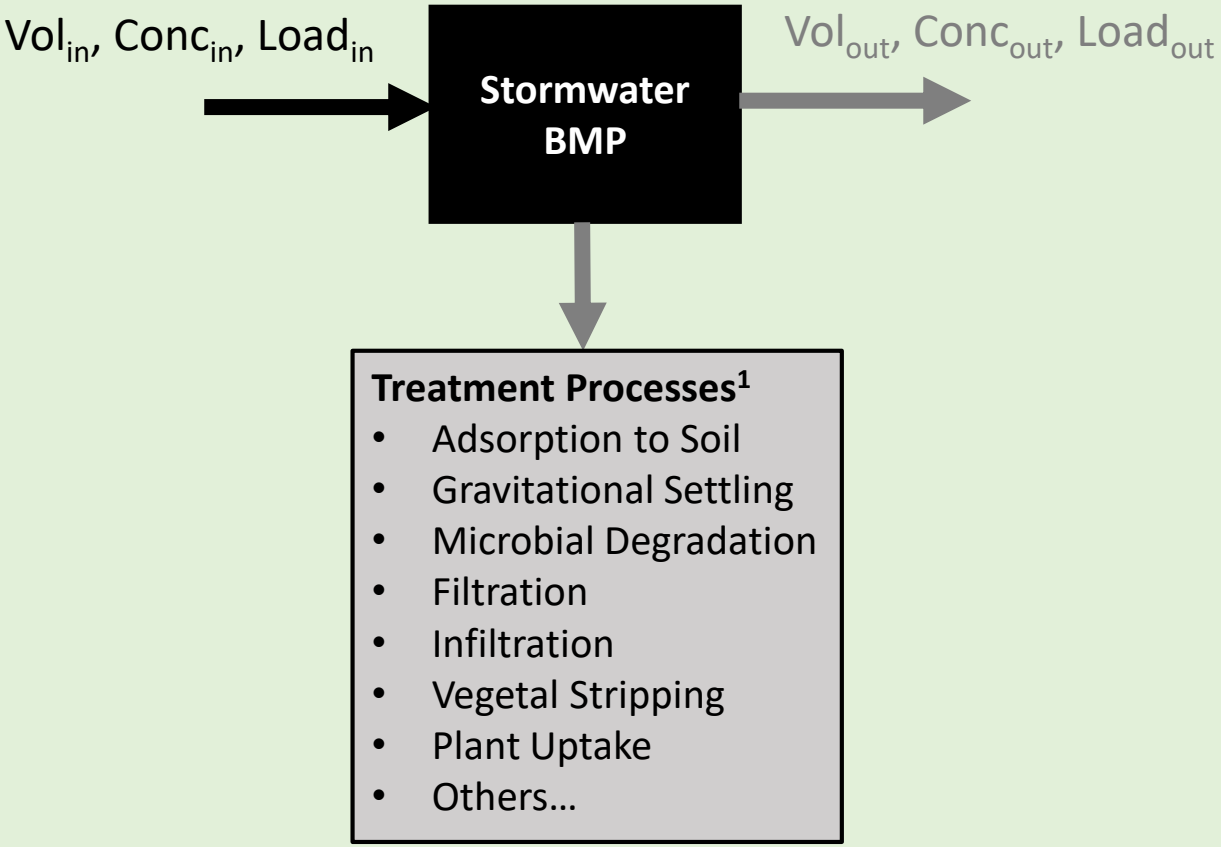
November 15th, 2017

Marcus F. Aguilar, Ph.D.

Research Scientist

Virginia Tech Department of Civil and Environmental Engineering

Background



Center for Watershed Protection – 2008
"Runoff Reduction Method"[2]

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

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

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

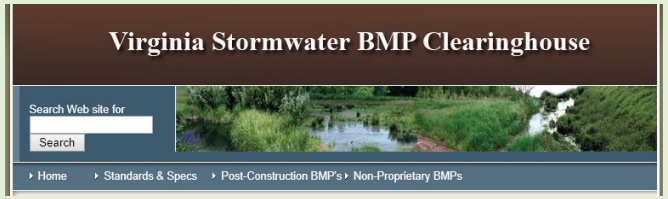
[1]Scholes et al. (2008)
[2] 9VAC25-870-65

Purpose Statement:

What is the empirically defined distribution of TR values around the regulator-defined BMP credit value?

Purpose Statement:

What is the empirically defined distribution of TR values around the **regulator-defined** BMP credit value?

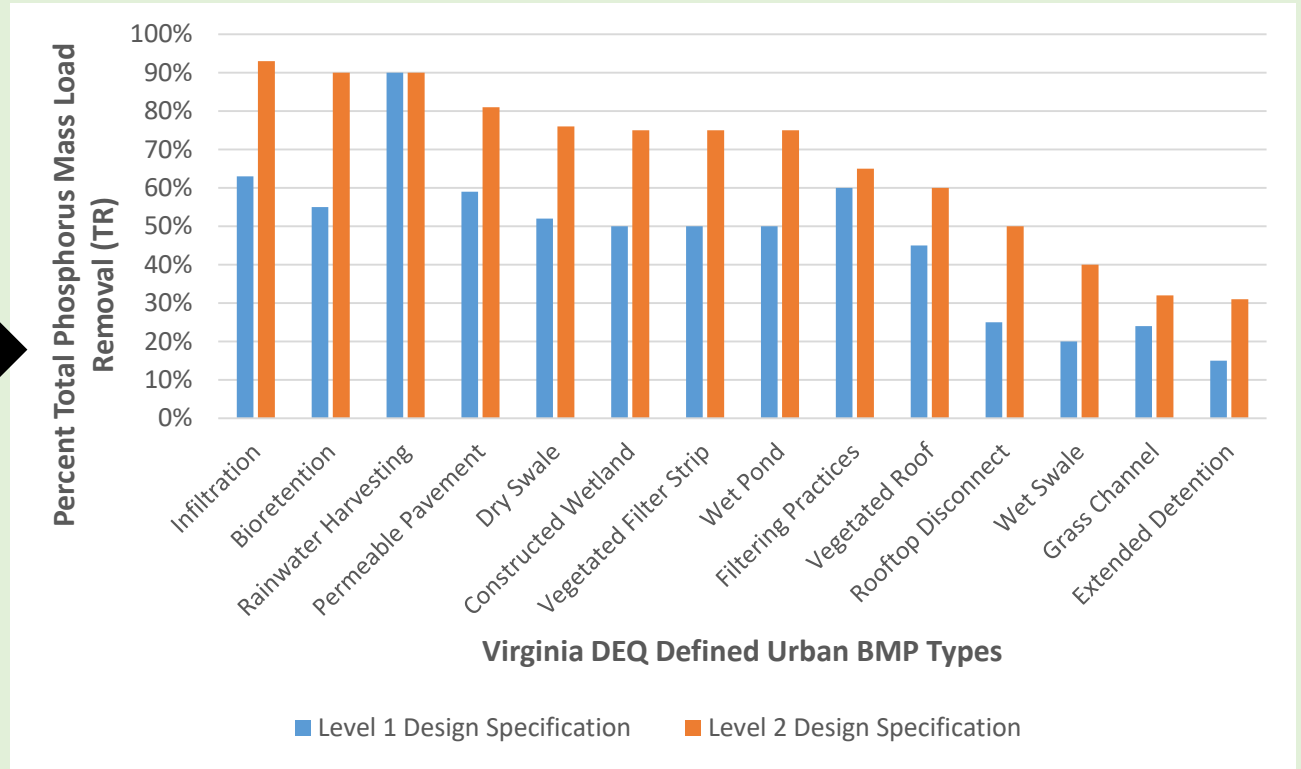

Virginia Stormwater BMP Clearinghouse

Search Web site for
Search

Home · Standards & Specs · Post-Construction BMP's · Non-Proprietary BMPs

Table 4.1. BMP Pollutant Removal Efficiencies (March 1, 2011)

Practice Number	Practice	Removal of TP by Runoff Reduction (RR, as %) (based upon 1 inch of rainfall)[1]	Removal of TP by Treatment – Pollutant (EMC) Reduction (PR, as %)[1]	Total Mass Load Removal of Total Phosphorus (TR, as %)[1]
1	Rooftop Disconnection	25 or 50	0	25 or 50
2	Sheetflow to Conservation Area	50 to 75	0	50 to 75
	Sheetflow to Vegetated Filter	50	0	50
3	Grass Channel	10 to 30	15	24 to 41
4	Soil Amendments	Used to decrease runoff coefficient for turf cover at the site. See the design specs for Roof Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channels		



Purpose Statement:

What is the **empirically defined** distribution of TR values around the **regulator-defined** BMP credit value?

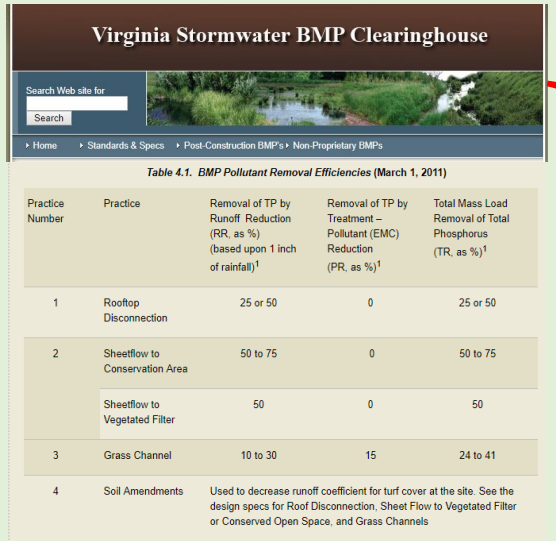
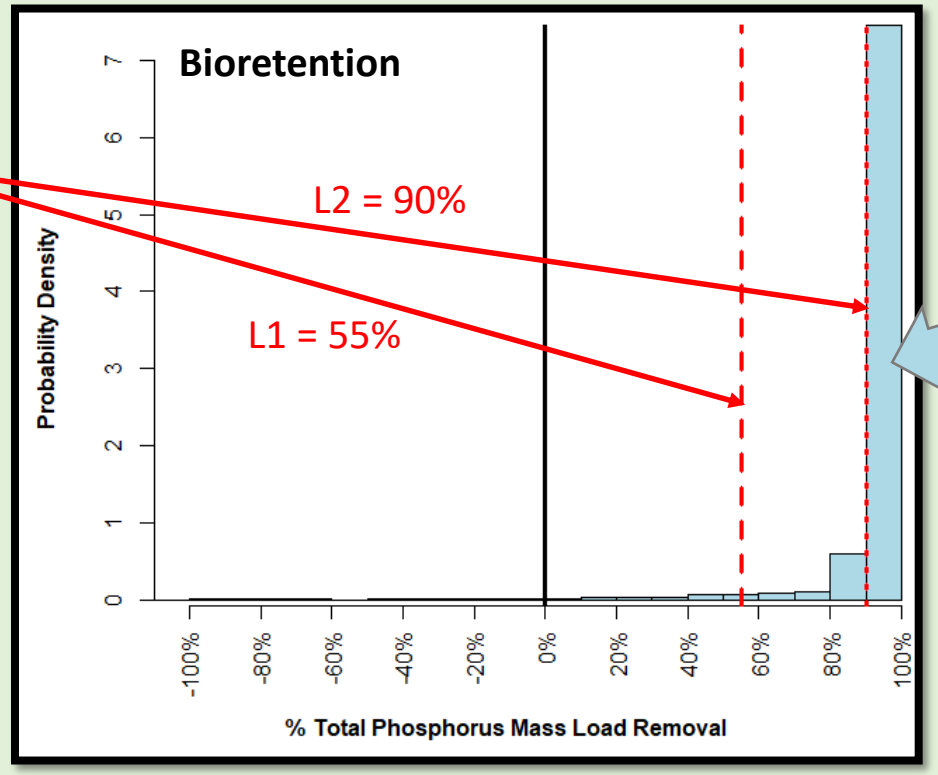


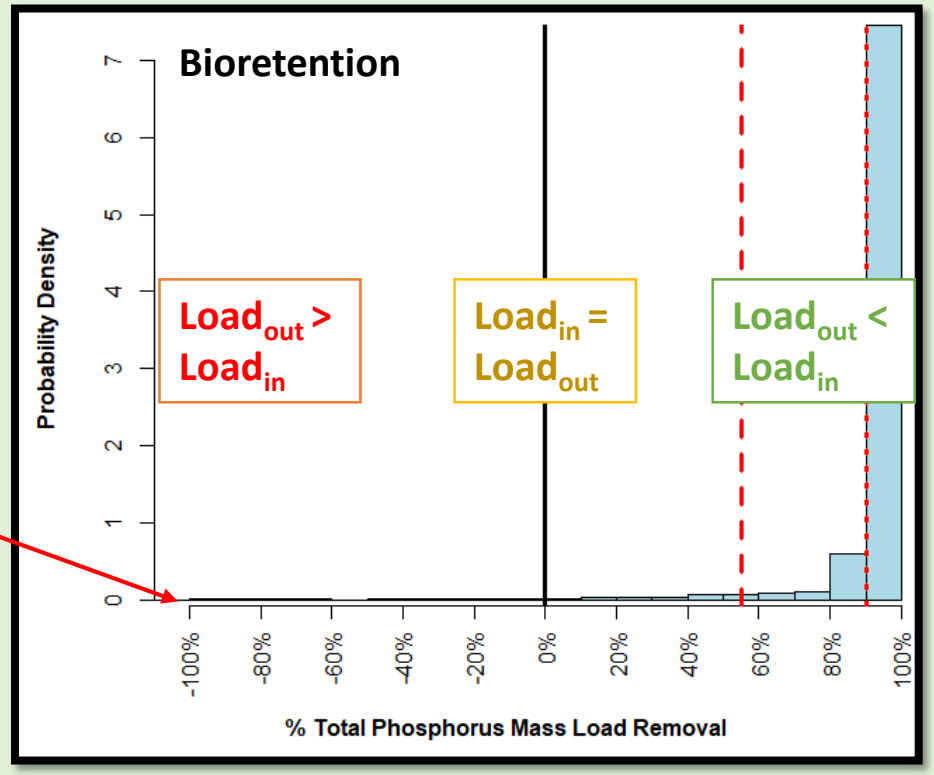
Table 4.1. BMP Pollutant Removal Efficiencies (March 1, 2011)

Practice Number	Practice	Removal of TP by Runoff Reduction (RR, as %) (based upon 1 inch of rainfall)[1]	Removal of TP by Treatment – Pollutant (EMC) Reduction (PR, as %)[1]	Total Mass Load Removal of Total Phosphorus (TR, as %)[1]
1	Rooftop Disconnection	25 or 50	0	25 or 50
2	Sheetflow to Conservation Area	50 to 75	0	50 to 75
	Sheetflow to Vegetated Filter	50	0	50
3	Grass Channel	10 to 30	15	24 to 41
4	Soil Amendments	Used to decrease runoff coefficient for turf cover at the site. See the design specs for Roof Disconnection, Sheet Flow to Vegetated Filter or Conserved Open Space, and Grass Channels		



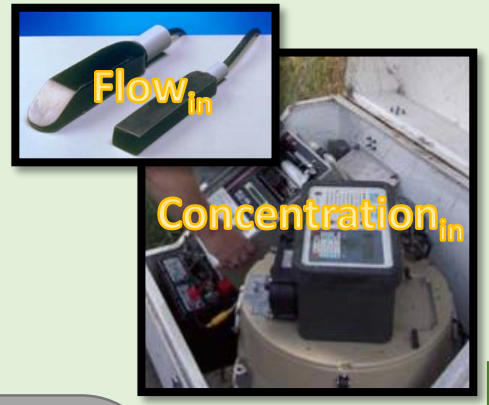
Purpose Statement:

What is the **empirically defined** distribution of TR values around the **regulator-defined** BMP credit value?



Note: all values < -100% binned into 1 group (none visible)

A Typical Urban BMP Study



Developed Site

Stormwater BMP

Photographs from *Urban Stormwater BMP Performance Monitoring* by Geosyntec Consultants et al. (2009)

Methods

For each **empirical study reviewed**, two types of uncertainty w.r.t. defining a single %TR value[1]:

Environmental Uncertainty

- Rainfall Event:
  - Depth
  - Intensity
  - Duration
  - Inter-event time (antecedent moisture)
- Pollutant build-up in the drainage area

Observation Uncertainty

- Field Measurements
  - Precipitation
  - Depth and discharge
  - Sampling methods
- Sample Preservation/Storage
- Laboratory Methods
- What data were reported?

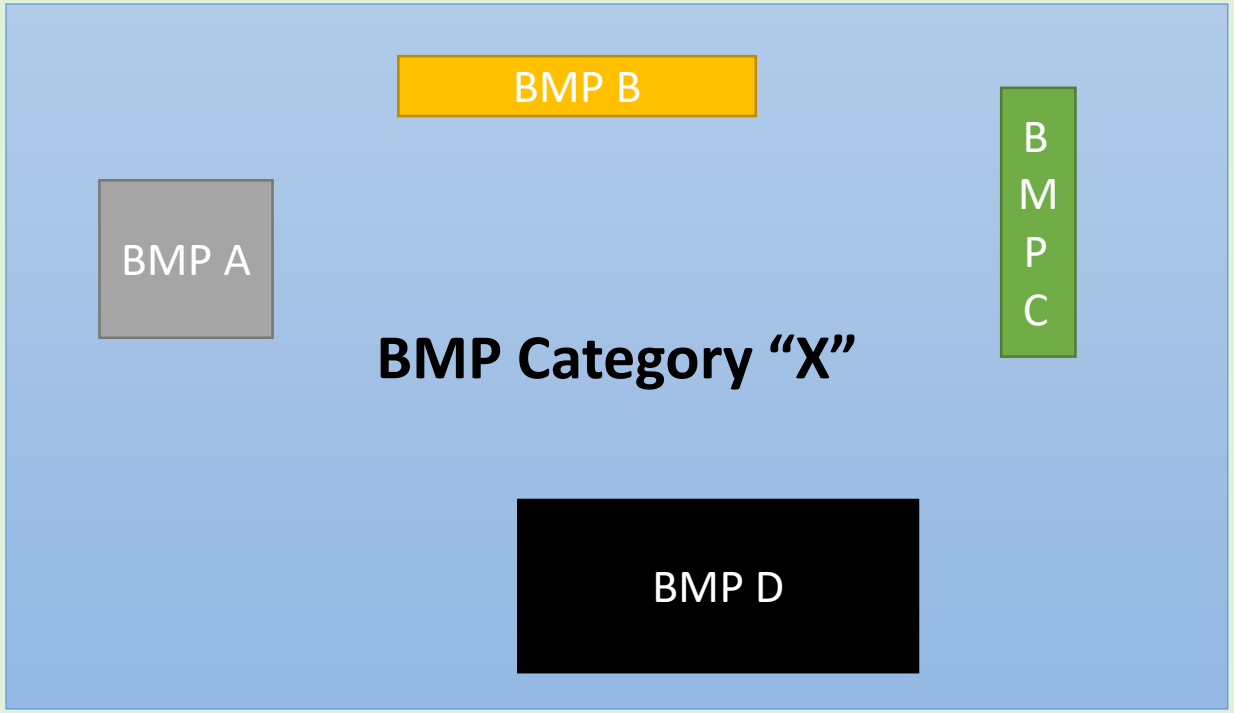
[1]Uncertainty framework from Merz and Theiken (2005)

Methods

For each **BMP category**, uncertainty w.r.t. defining a single %TR value[1]:

BMP "Category" Uncertainty

- Design specifications
- Construction quality
- BMP age
- Maintenance



[1]Uncertainty framework from Merz and Theiken (2005)

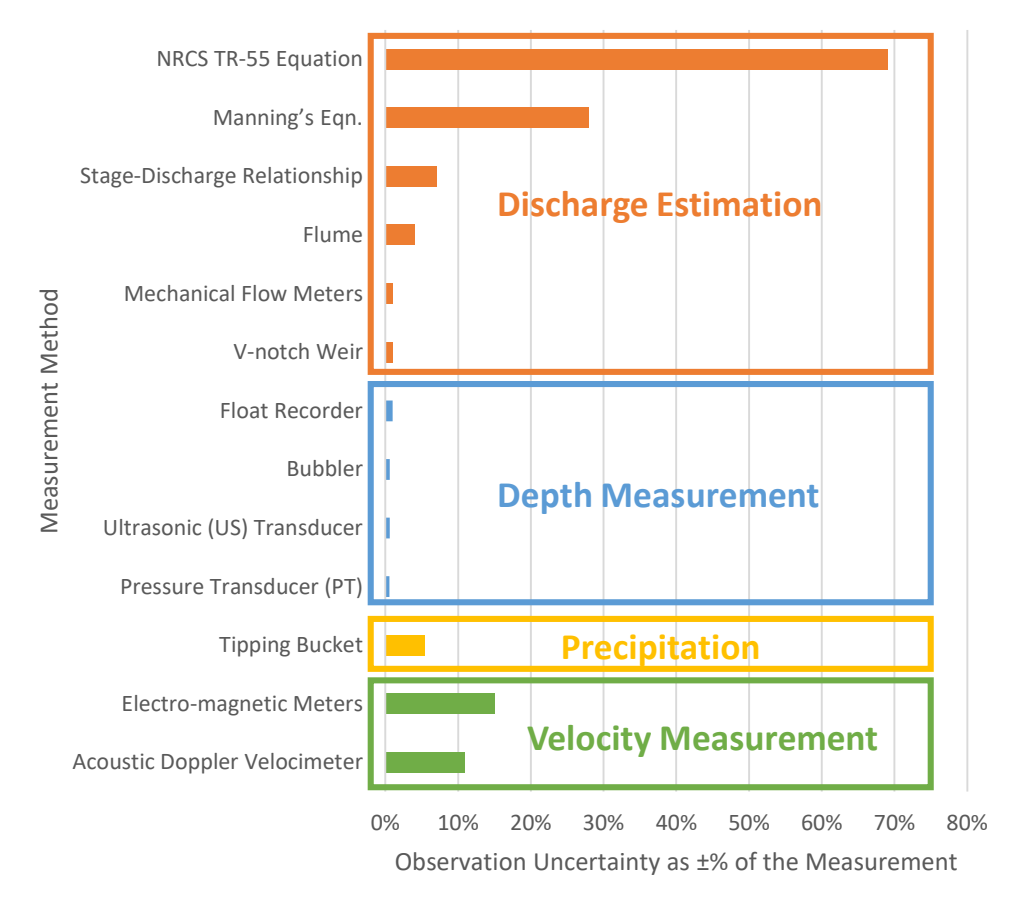
Methods

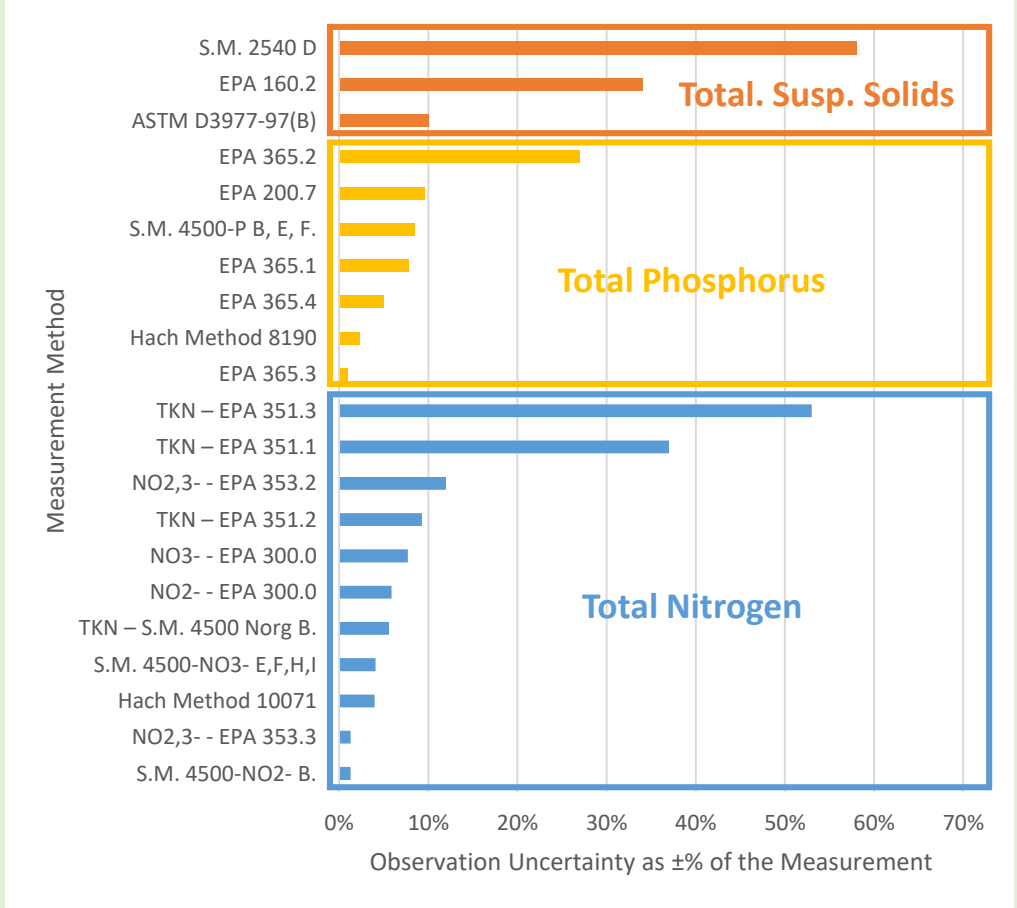
Weight Study Results Based on Types of Data Reported

Type of Data Reported	Handling of Data	Data Weight (w_{data})	Count of Individual Data Points
Study, annual, or monthly water balance	Use original data	1	127
Individual Storm Event	Use original data	1	7,329
Individual Lab Trial	Use original data	0.1	153
Event Mean and Standard Deviation	Generate random normal dist'n w/given statistics	0.1	12
Event Mean, Geo. Mean or Median, no measure of dispersion	Use original data (single data point)	1	167
Lab Trial Mean and Stand. Dev.	Generate random normal dist'n with given statistics	0.05	5
Lab Trial Mean or Water Balance, no measure of dispersion	Use original data (single data point)	0.05	10
Event Range, Range of monthly water balances	Generate random uniform dist'n with given statistics	0.05	35

Methods -> Results

Weight Study Results Based on Observation Uncertainty





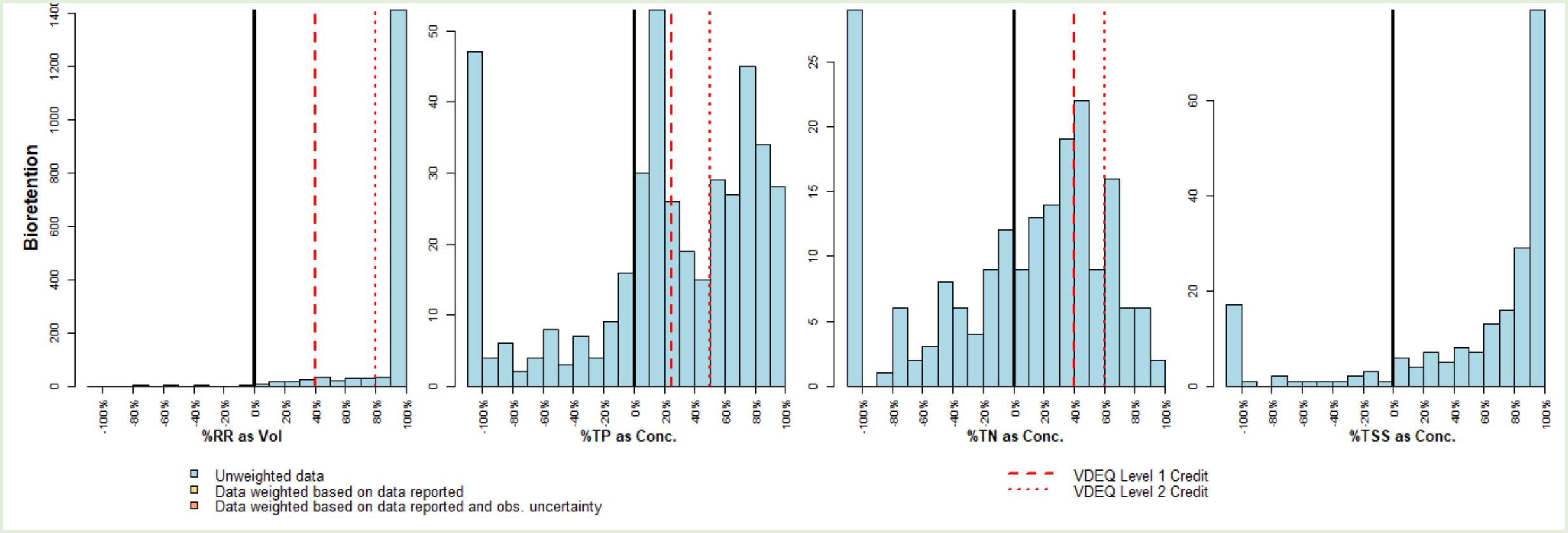
Results

RR: 28 BMPs monitored
1,617 data points

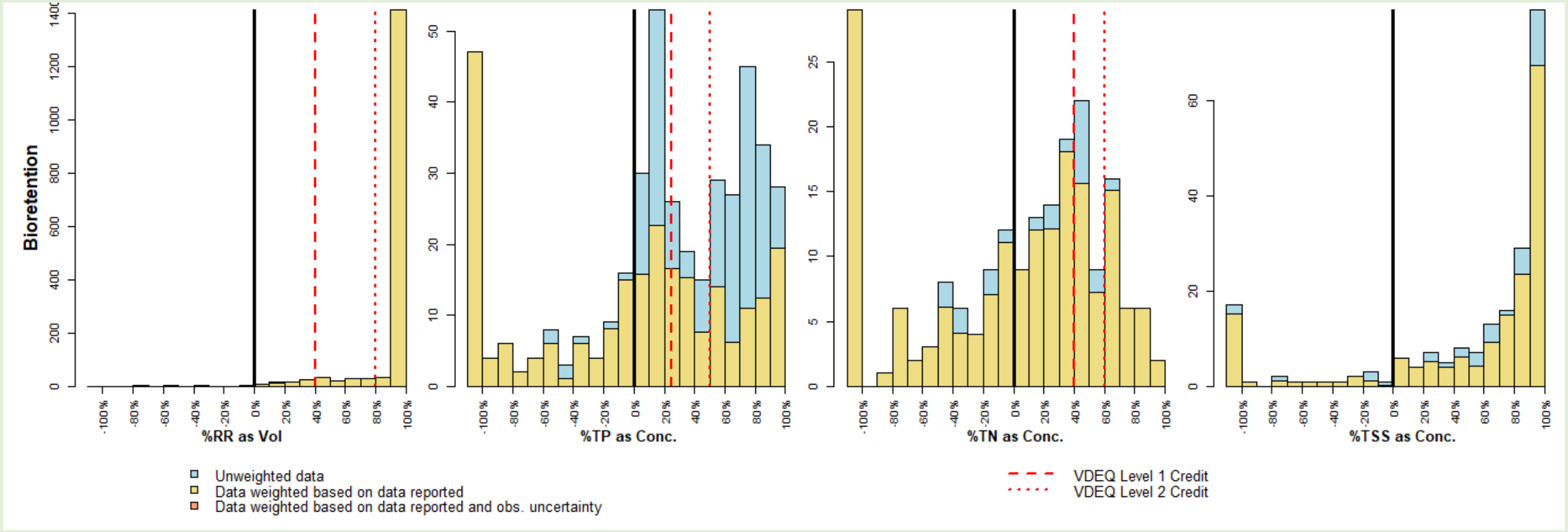
TP: 25 BMPs
260 data points

TN: 14 BMPs
178 data points

TSS: 14 BMPs
193 data points



Results


Bioretention
%RR as Vol
%TP as Conc.
%TN as Conc.
%TSS as Conc.
Unweighted data
Data weighted based on data reported
Data weighted based on data reported and obs. uncertainty
VDEQ Level 1 Credit
VDEQ Level 2 Credit

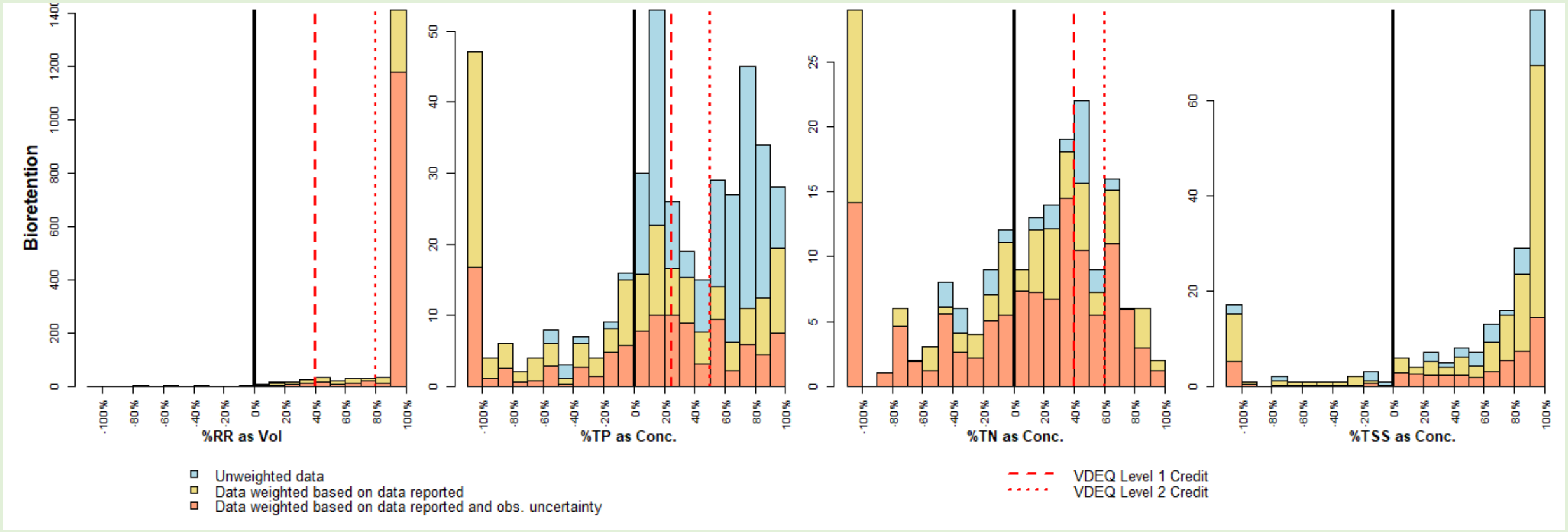
Results

RR: 28 BMPs monitored
1,281 data points

TP: 25 BMPs
109 data points

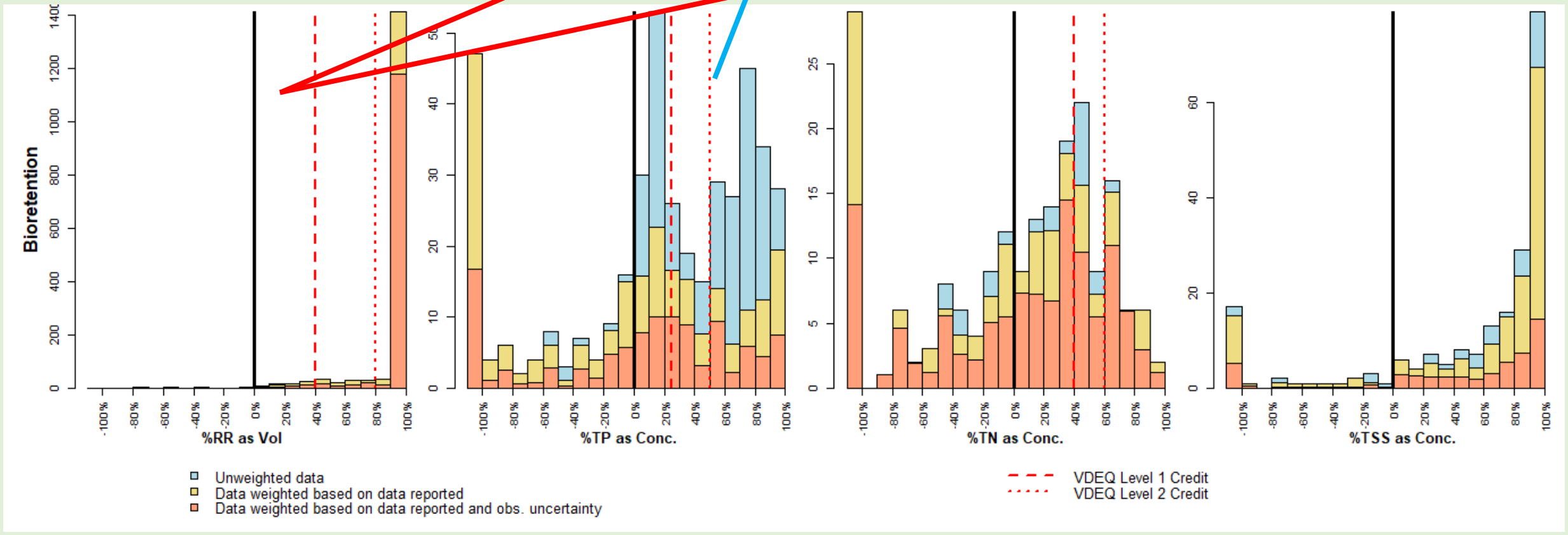
TN: 14 BMPs
116 data points

TSS: 14 BMPs
51 data points



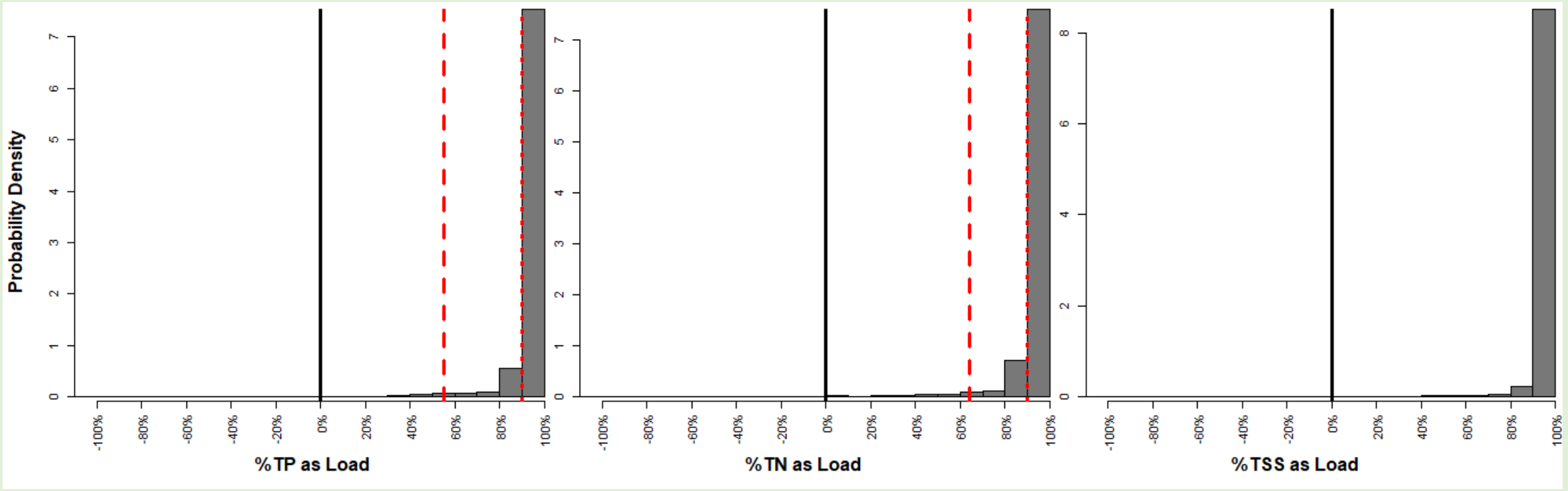
Results

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



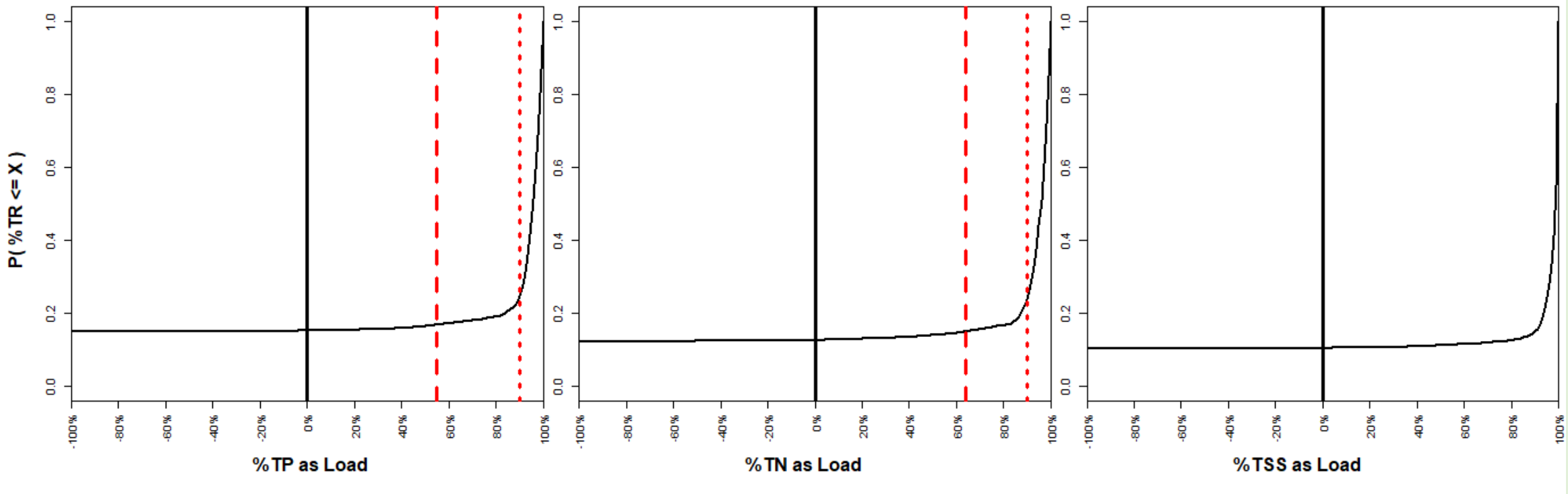
Results

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



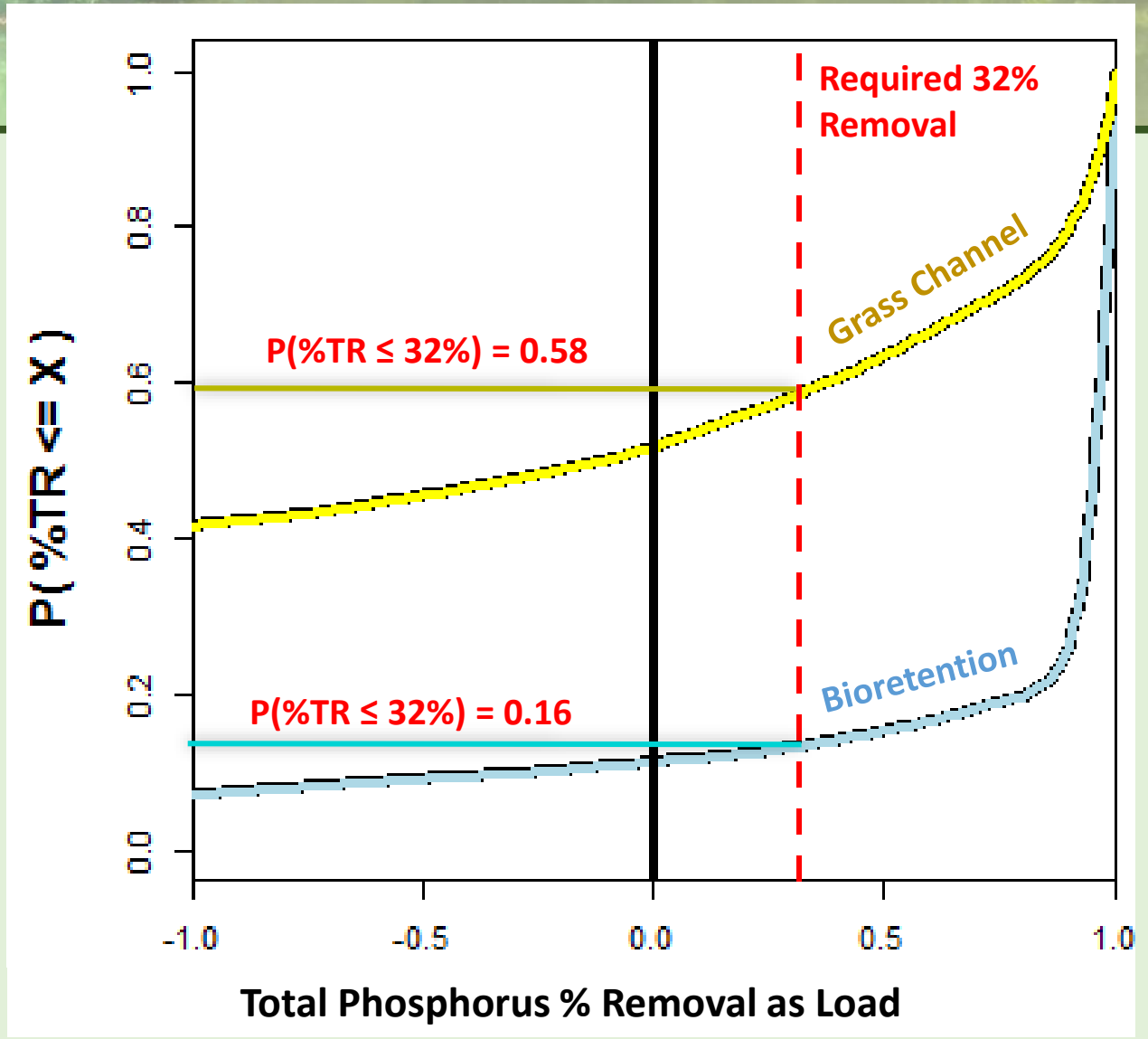
Results

Cumulative Distribution Functions



Discussion

- Lumping empirical studies into VDEQ categories
- Framework does not account for varying amount of data in each category
- Some BMP types are more difficult to perform input-output monitoring
- Relationship between event-based and long-term results
- Selection bias



References

- Aguilar, M. F., and Dymond, R. L. (Under Review). Evaluation of Stormwater Control Measure Performance Uncertainty. *Journal of Environmental Engineering*.
- CWP. (2008). Technical Memorandum: The Runoff Reduction Method. Ellicott City, Maryland: Center for Watershed Protection. Retrieved from http://www.vwrrc.vt.edu/swc/documents/pdf/CWP Technical Memo RRMethod_041808 w_Apps.pdf.
- Geosyntec Consultants, and Wright Water Engineers. (2009). *Urban Stormwater BMP Performance Monitoring*. International Stormwater BMP Database.
- Merz, B., and Thieken, A. H. (2005). Separating natural and epistemic uncertainty in flood frequency analysis. *Journal of Hydrology*, *309*, 114–132. doi:10.1016/j.jhydrol.2004.11.015.
- Scholes, L., Revitt, D. M., and Ellis, J. B. (2008). A systematic approach for the comparative assessment of stormwater pollutant removal potentials. *Journal of Environmental Management*, *88*(3), 467–478. doi:10.1016/j.jenvman.2007.03.003.