A Paired Watershed Approach to Evaluate Low Impact Development Practices on Stormwater Quality and Quantity

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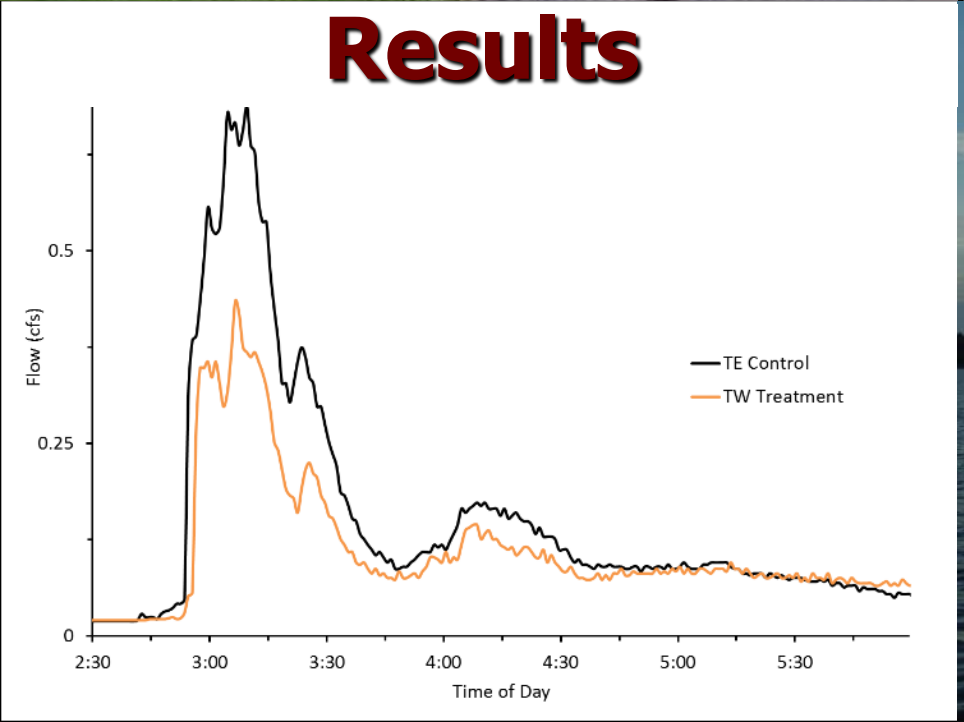
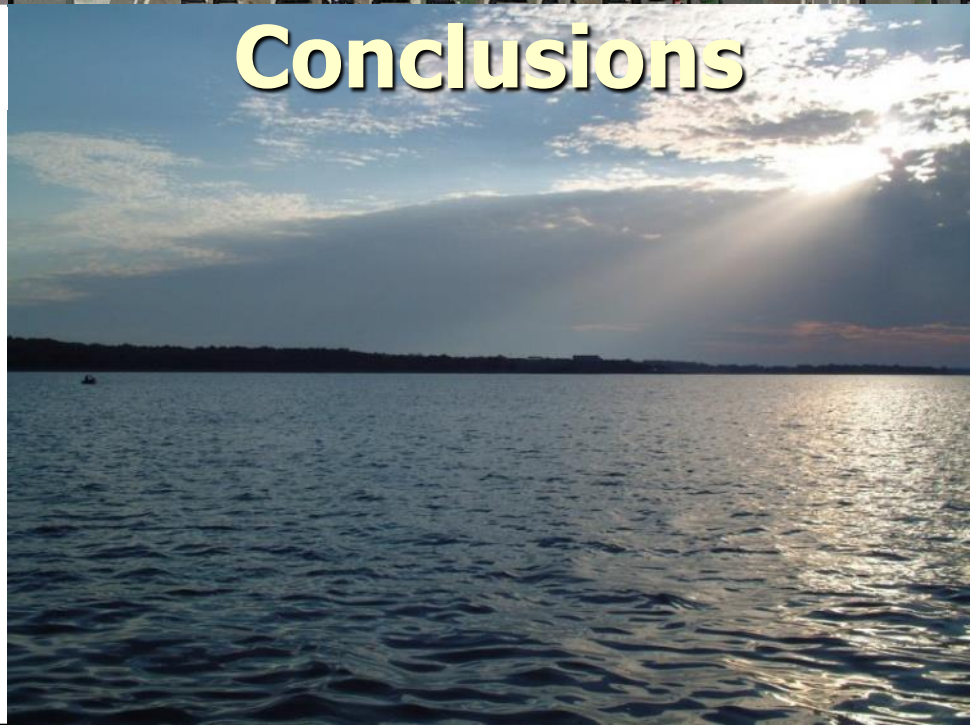
Introduction

Design/Methods

Results

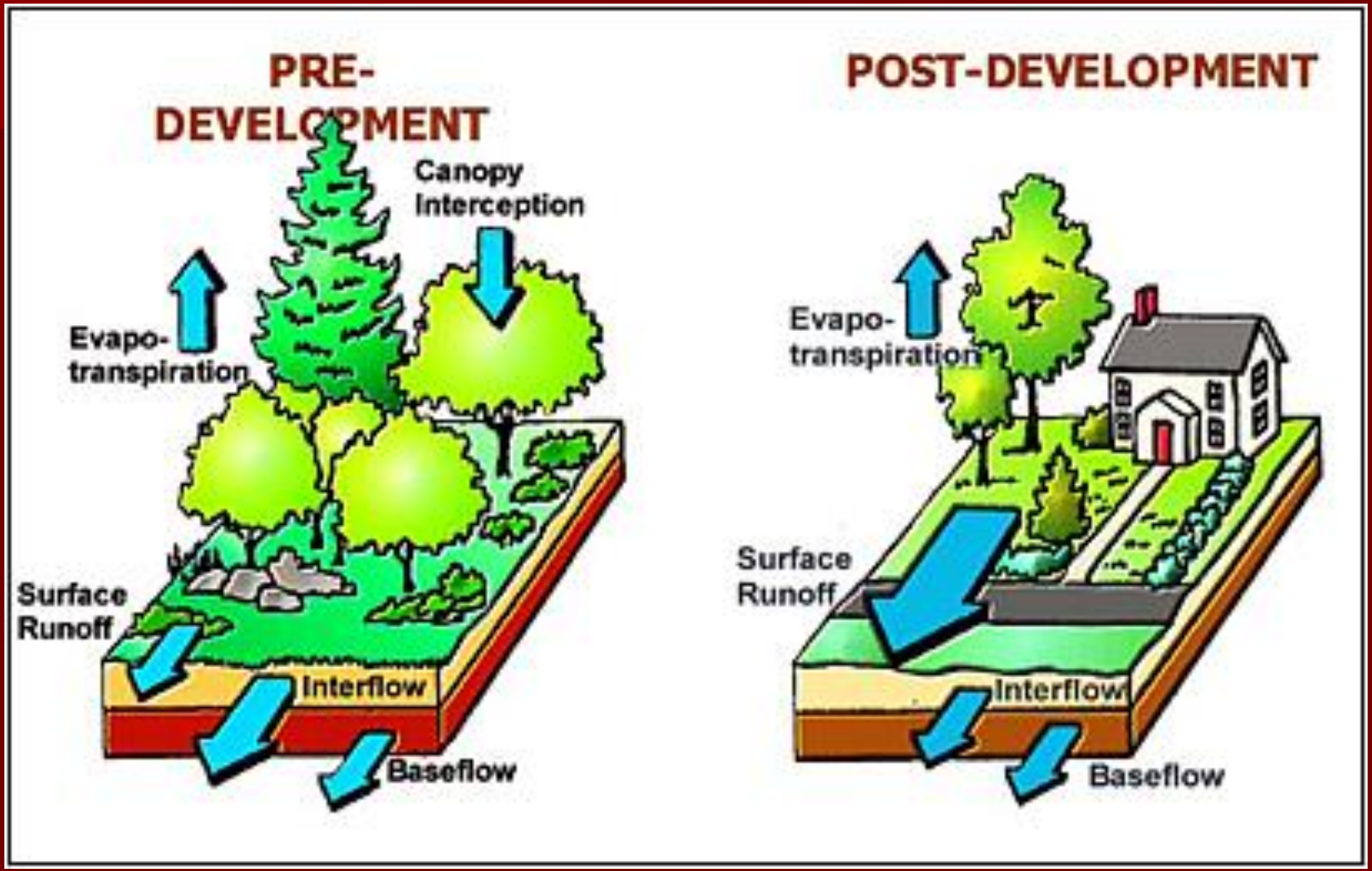


Conclusions

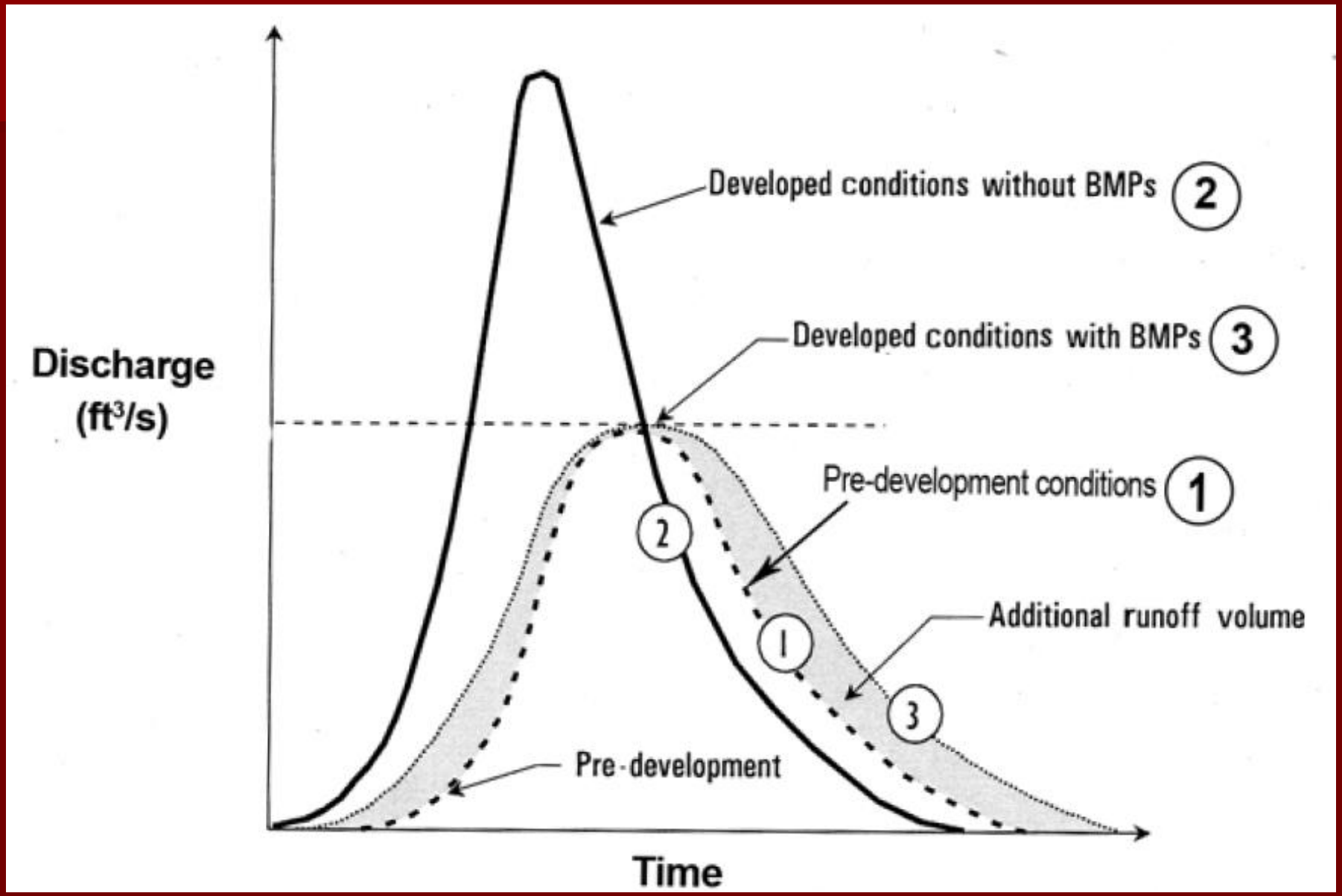


Introduction

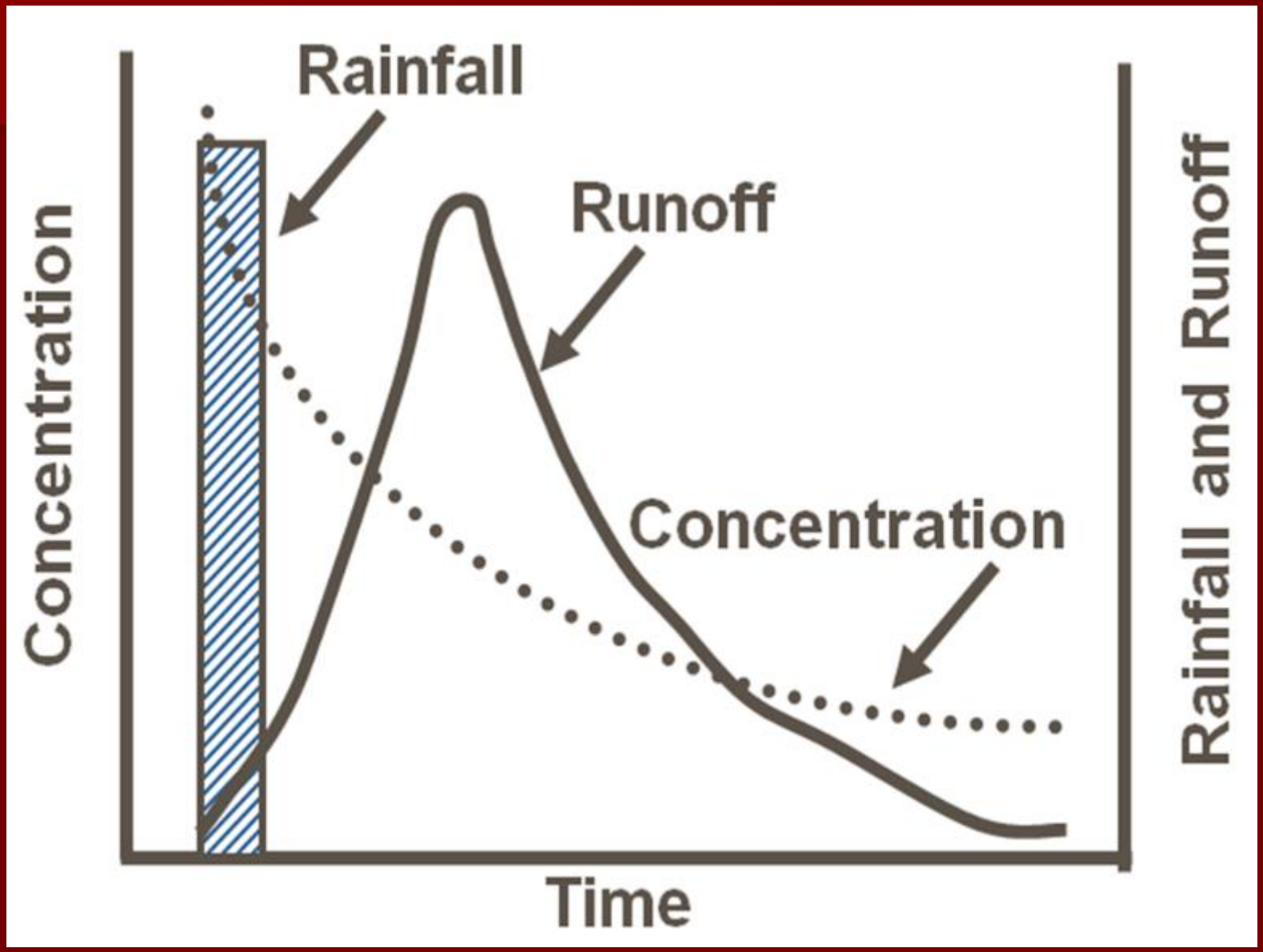
Urban Stormwater



Urban Stormwater Quantity



Urban Stormwater Quality



Best Management Practices

- Traditional approaches
  - Detention/retention
  - Address *quantity*
- Green infrastructure
  - Low impact development BMPs
  - Address *quantity and quality*
  - Manage at source
  - Distributed, decentralized
  - Mimic pre-development hydrology
  - Infiltrate, filter, store, evaporate, detain

-Downspout disconnection

-Rain gardens/ bioswales

-Green roofs

-Green alleys and streets

-Land conservation

-Rainwater harvesting

-Permeable pavement

-Planter boxes

-Green parking

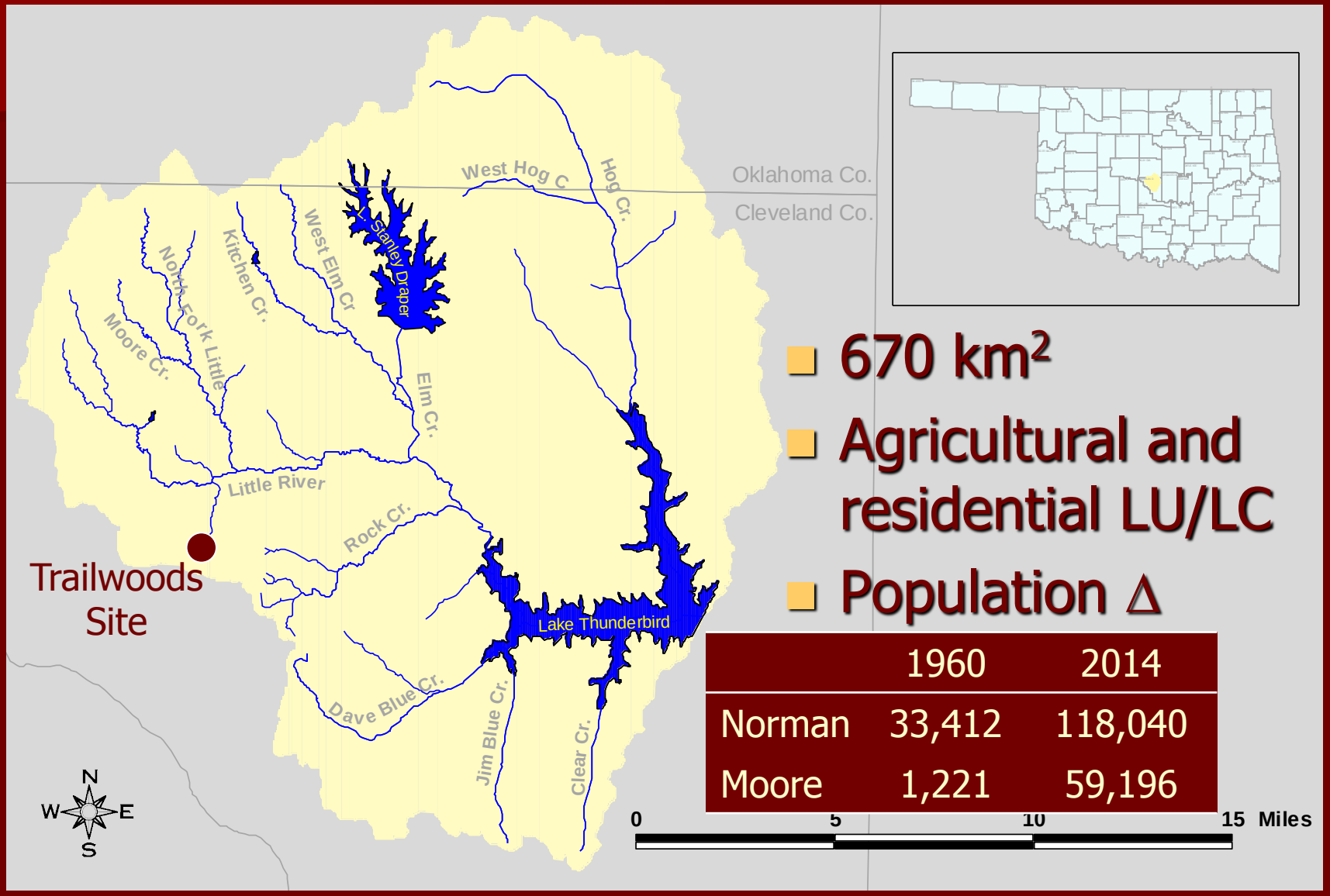
-Urban tree canopy

Project Objectives

- Compare performance of a suite LID BMPs to traditional curb and gutter management on small watershed scale
- Evaluate both hydrologic and physical/biogeochemical effectiveness
- Help build green infrastructure capacity

Design/Methods

Lake Thunderbird Watershed



- 670 km²
- Agricultural and residential LU/LC
- Population Δ

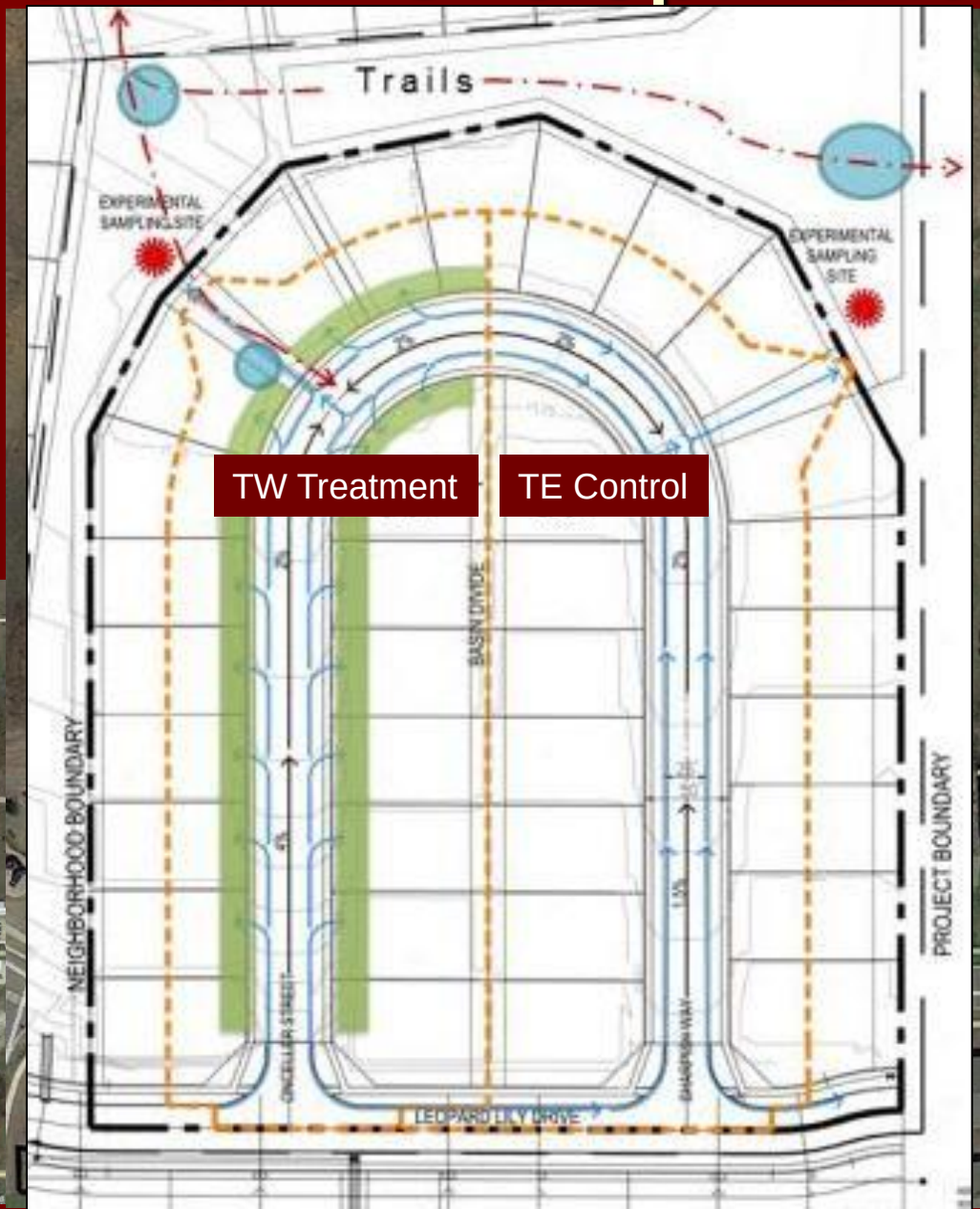
	1960	2014
Norman	33,412	118,040
Moore	1,221	59,196

Lake Thunderbird

- Sensitive Water Supply
  - Norman
  - Midwest City
  - Del City
- 303(d) listed
  - Elevated turbidity
  - Low DO
  - Excessive [chlorophyll-*a*]
- Urban runoff major driver (Vieux et al 2007, OCC 2013)

Trailwoods Residential Development

- Little River drainage
- Construction 2009
- Paired watershed
- Trailwoods East
  - Control - traditional curb and gutter
  - 2.28 acres
- Trailwoods West
  - Treatment - LID BMPs
  - 2.31 acres



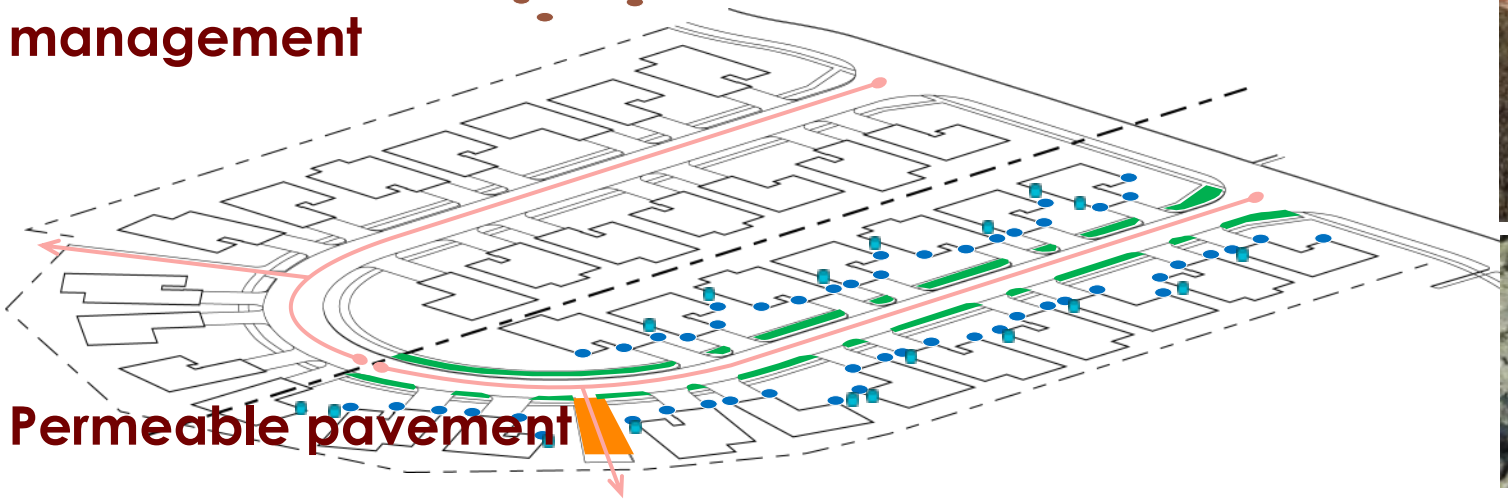
Trailwoods LID BMPs

Rain gardens

Rain Barrels

Runoff management

Permeable pavement



Data Collection

- Pre-fab FRP 18”x45° trapezoidal flumes
  - Accommodate Q_2 to Q_{100} storm events
- Automatic flow-activated samplers (Isco 6712 w/730 bubbler modules)
- Tipping bucket rain gauges

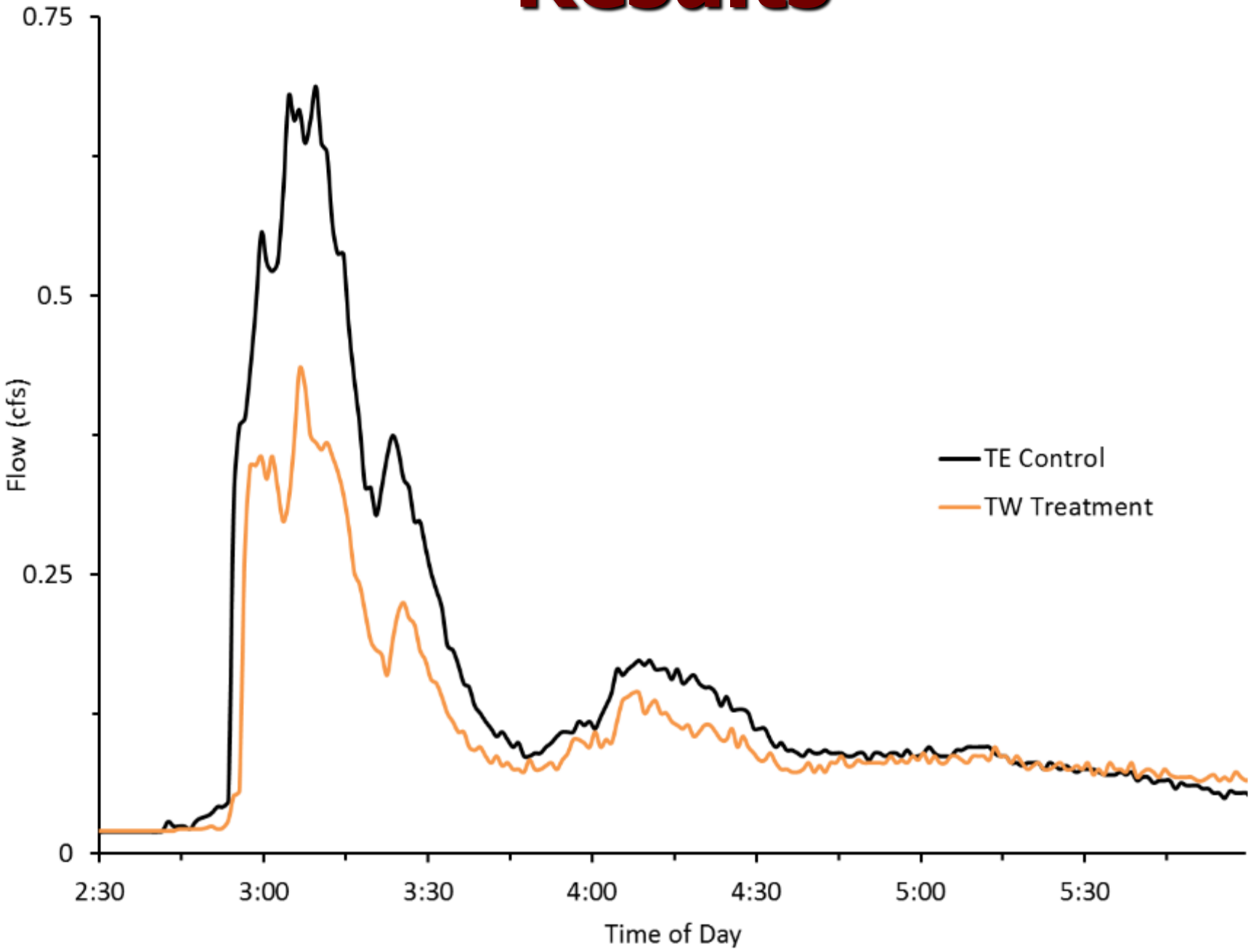
Data Collection

- Continuous Q measurement
- Sampling triggered at given depth
- Two sampling regimes
  - First flush
  - Composite storm

Data Collection

- Physical parameters: pH, DO, T, SC, TDS
- Total suspended solids
- Carbonaceous biochemical oxygen demand
- Total N, NH_3-N, NO_3-N
- Total P, Dissolved reactive P
- Trace metals: Al, As, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, and Zn

Results


0.75
0.5
0.25
0
Flow (cfs)
2:30
3:00
3:30
4:00
4:30
5:00
5:30
Time of Day
TE Control
TW Treatment

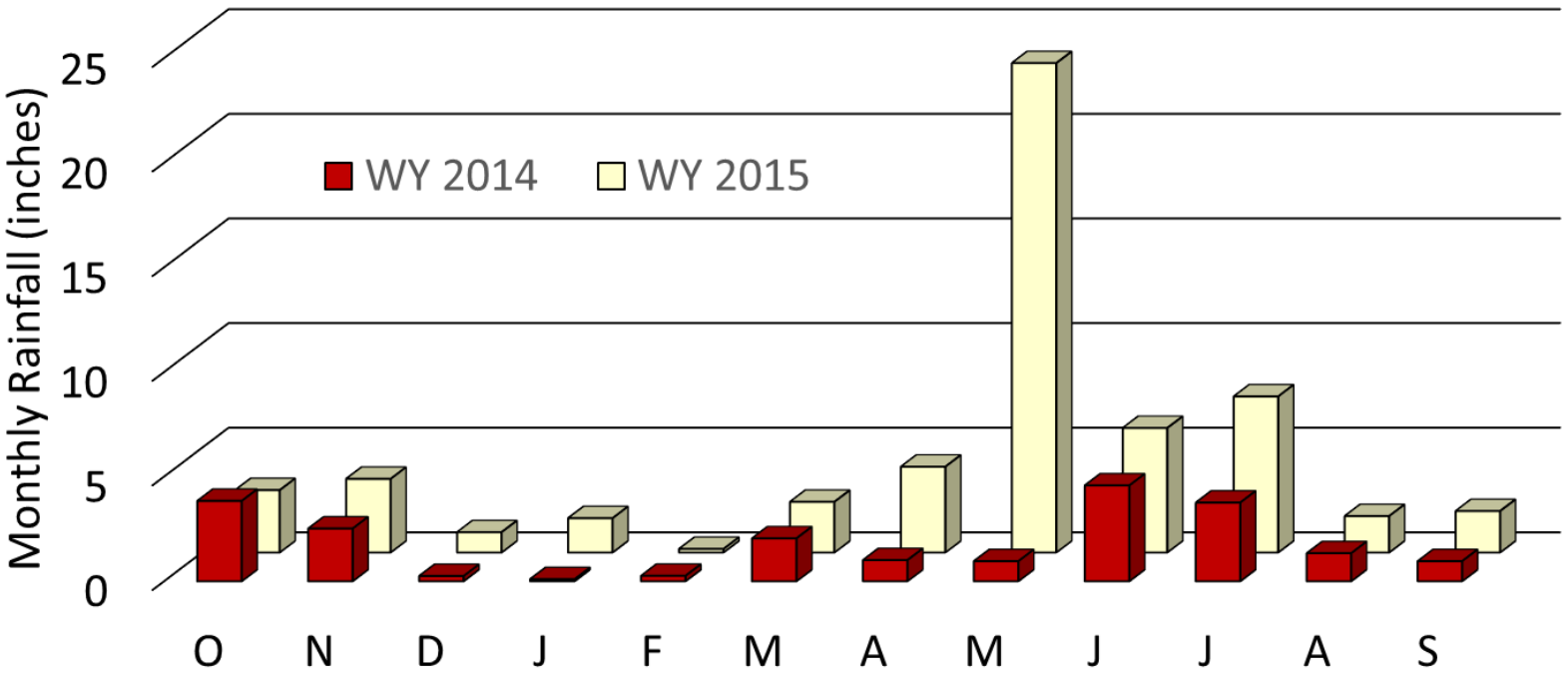
A few notes…

- Site selection/planning began - 2009
- Site master plan - 2010
- Grading, utilities, roads - late 2010
- Home construction - early 2011
- Last home completed - October 2013
- Final project
  - 35 lots
  - 18 rain gardens (366 m^2)
  - 17 rain barrels
  - small section (11 m^2) porous concrete

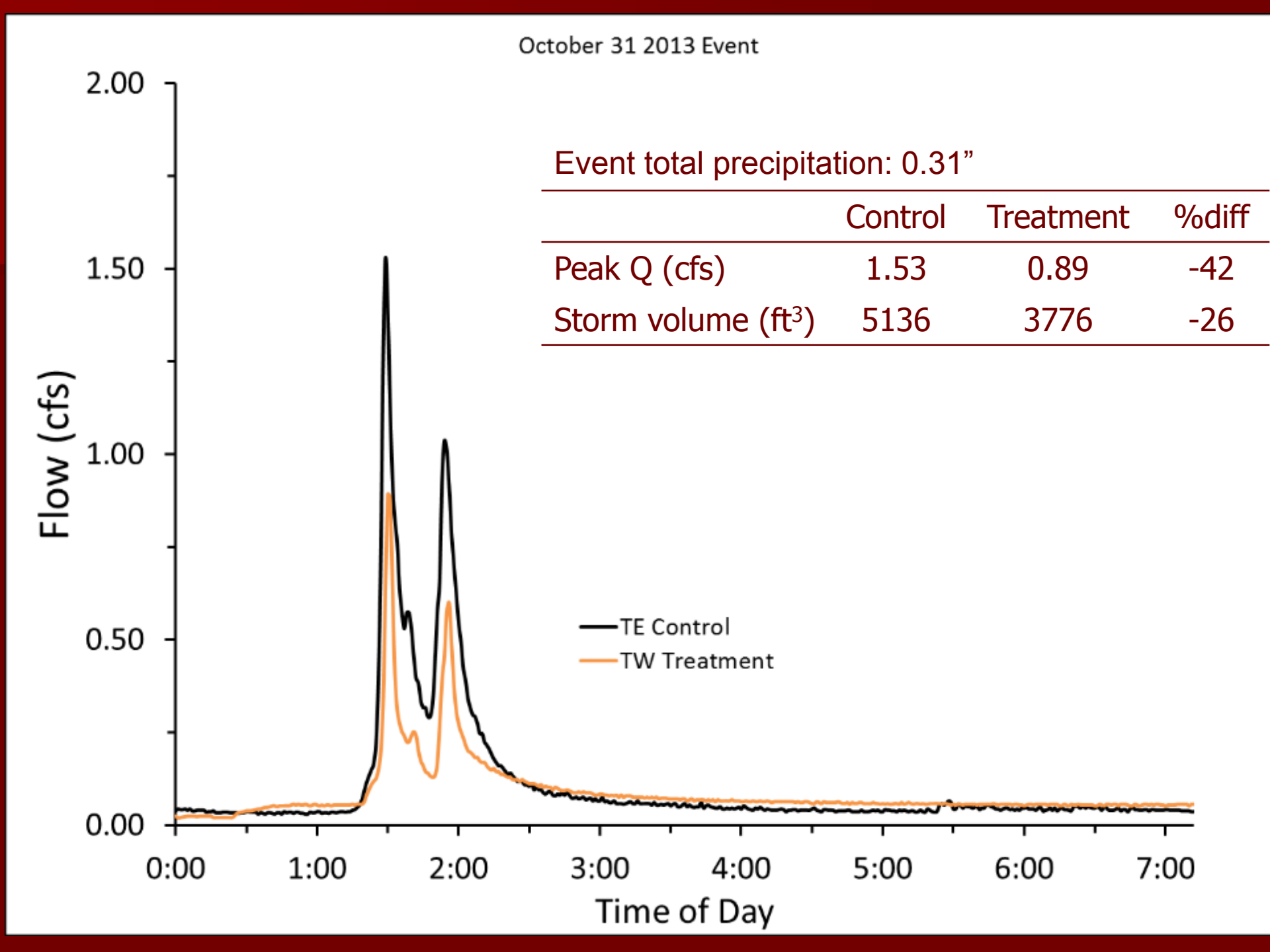
Storm Events

- 35 events captured
  - 25 first flush (10/2013 - 4/2015)
  - 10 storm composite (5/2015 - 9/2015)
- Event total precipitation
  - 0.66 ± 0.17 inches
  - Range 0.04 – 3.99 inches
- Maximum daily 5-min precipitation intensity
  - 0.96 ± 0.13 in/hr
  - Range 0.12 – 2.75 in/hr

Monthly Precipitation

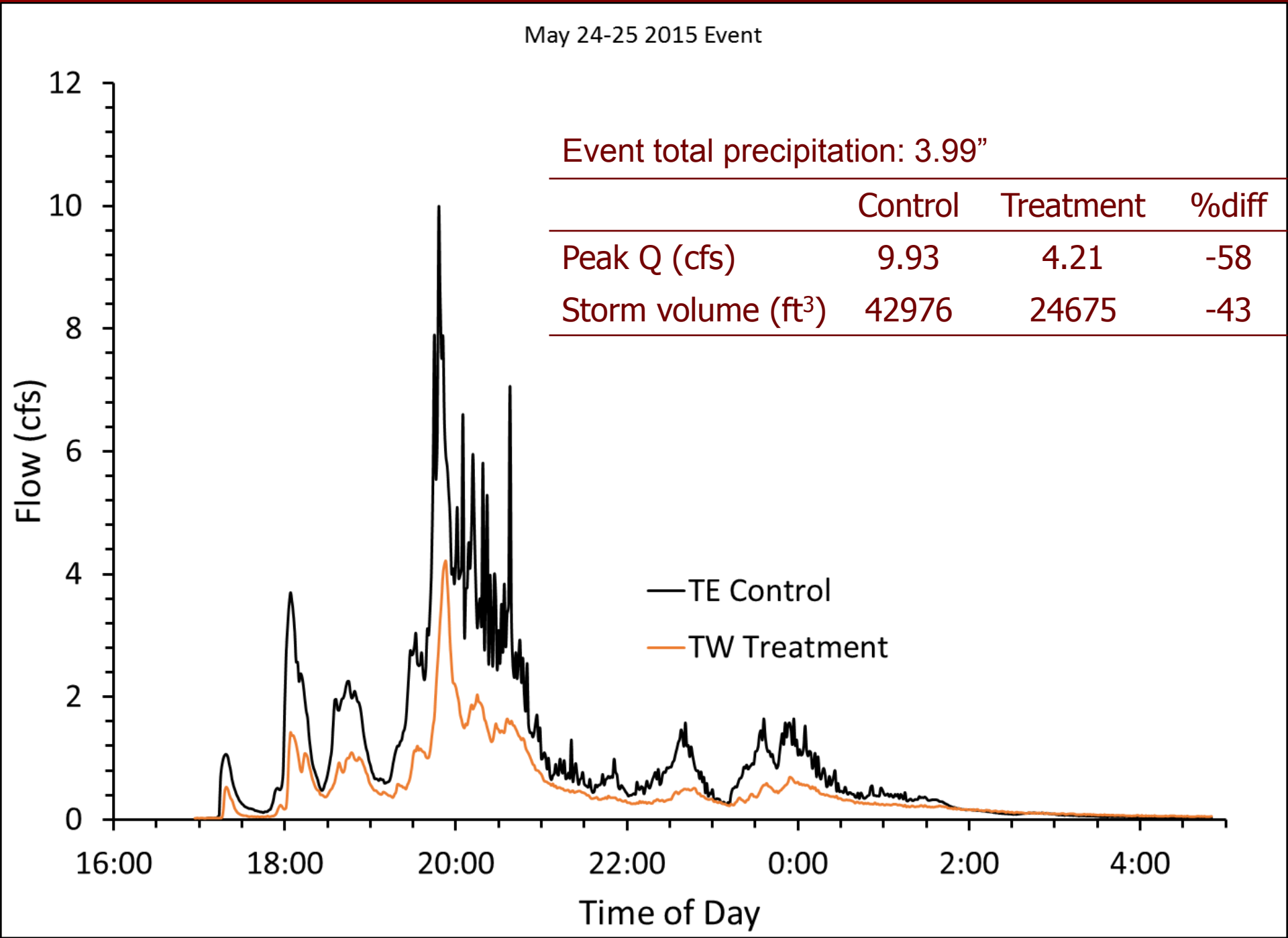


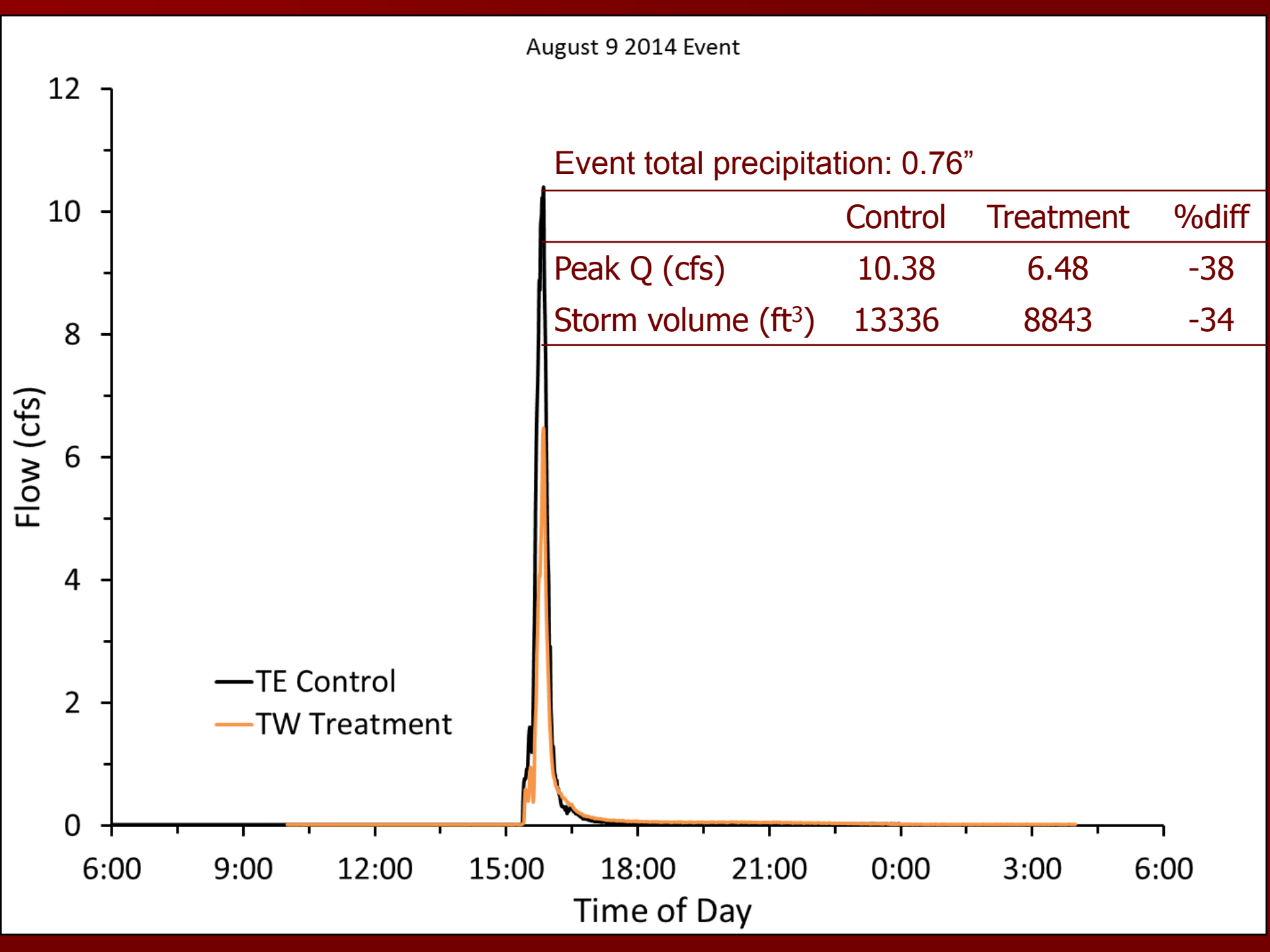
2014: 21.63”
2015: 56.32” (May: 23.39”)
Long-term annual mean: 34.67”



Event total precipitation: 0.31”

	Control	Treatment	%diff
Peak Q (cfs)	1.53	0.89	-42
Storm volume (ft^3)	5136	3776	-26


May 24-25 2015 Event
Event total precipitation: 3.99”
Control
Treatment
%diff
Peak Q (cfs)
9.93
4.21
-58
Storm volume (ft3)
42976
24675
-43
TE Control
TW Treatment
Flow (cfs)
0
2
4
6
8
10
12
16:00
18:00
20:00
22:00
0:00
2:00
4:00
Time of Day

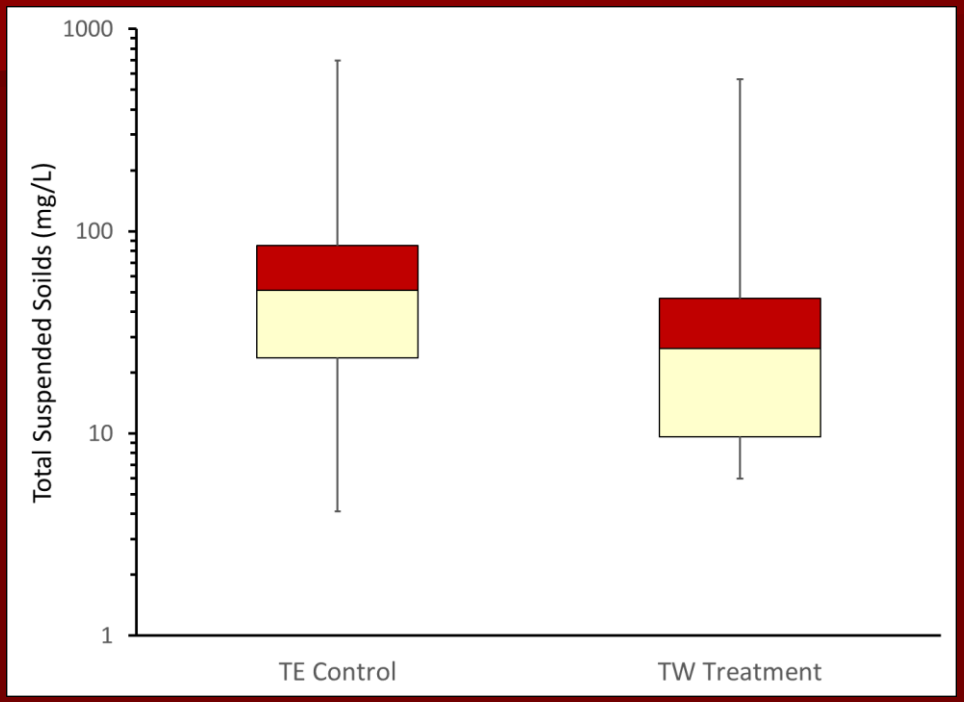

August 9 2014 Event
Event total precipitation: 0.76”
Control
Treatment
%diff
Peak Q (cfs)
10.38
6.48
-38
Storm volume (ft3)
13336
8843
-34
Flow (cfs)
0
2
4
6
8
10
12
TE Control
TW Treatment
6:00
9:00
12:00
15:00
18:00
21:00
0:00
3:00
6:00
Time of Day

Hydrology Summary

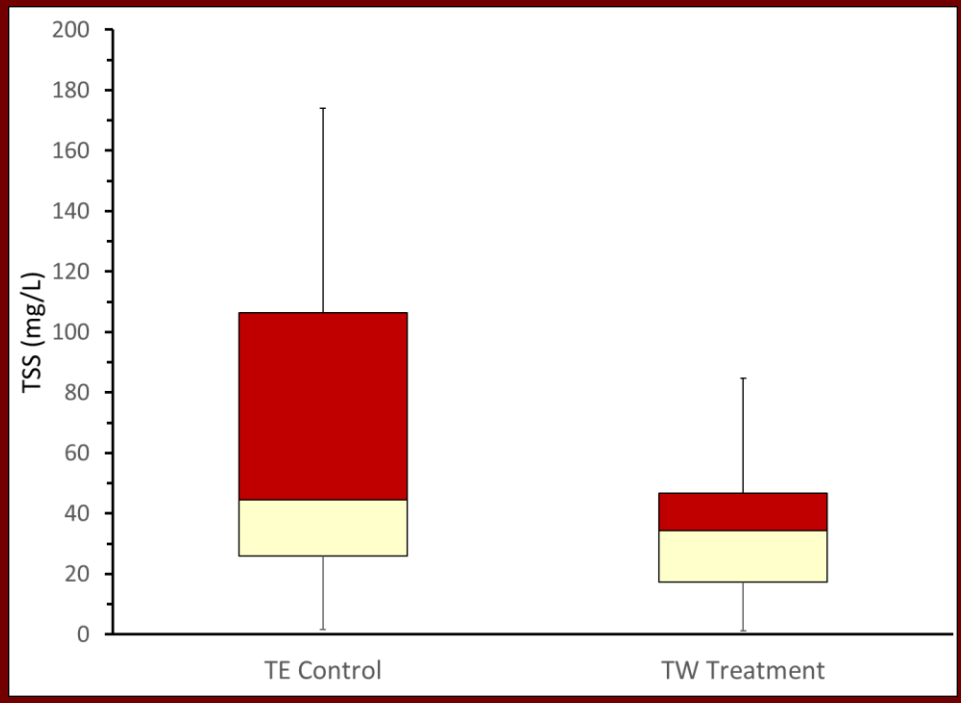
- Wide range of storms of differing magnitude and duration captured
- Overall differences in peak discharge and storm volumes ($p < 0.10$)
- Runoff depths, runoff ratios, and lag times did not show differences
- LID BMPs "knock the top off" storm hydrographs and release less water downstream

Total Suspended Solids

First Flush

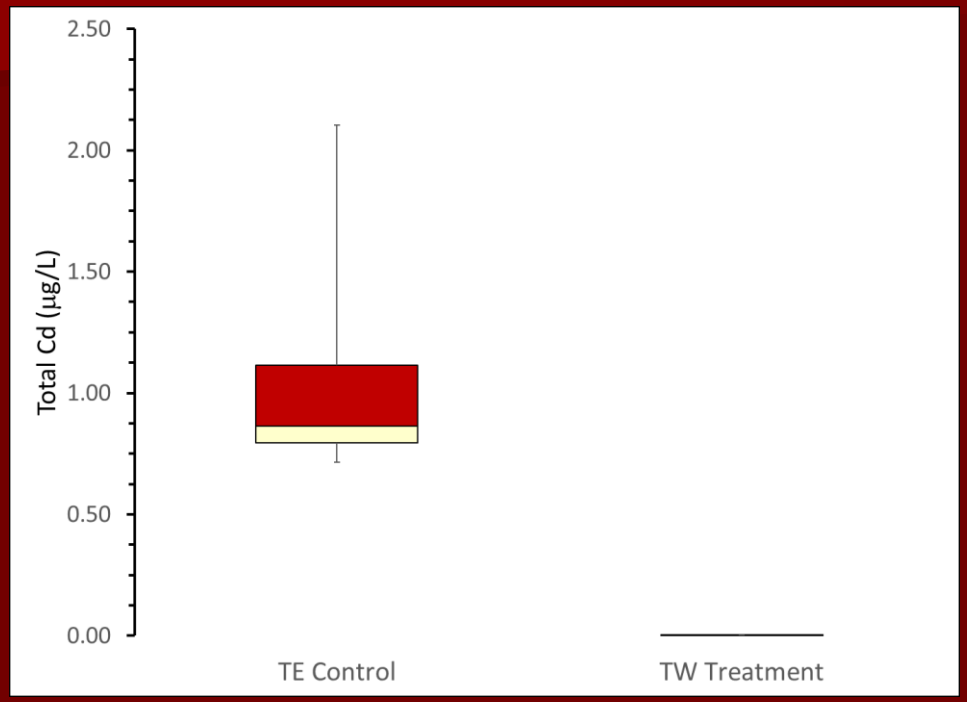


Storm Composite

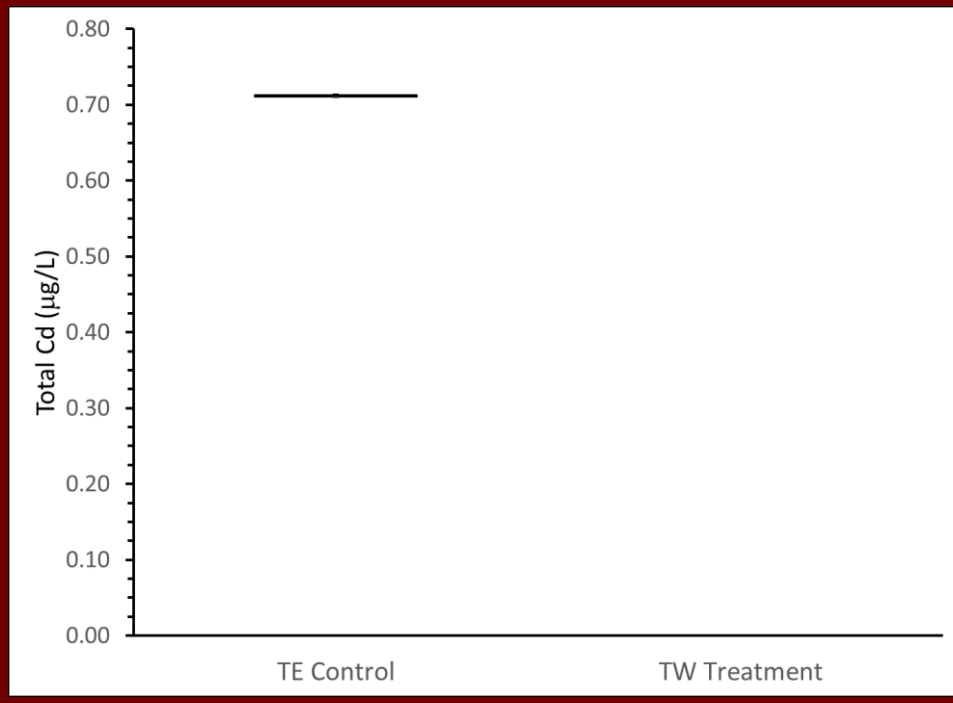


Total Cadmium

First Flush

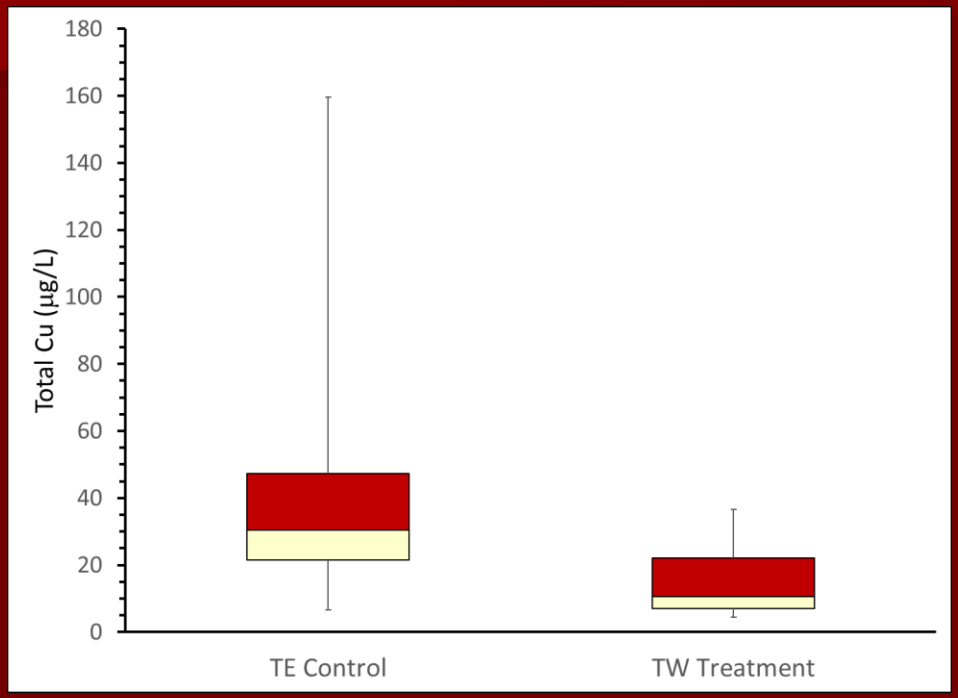


Storm Composite

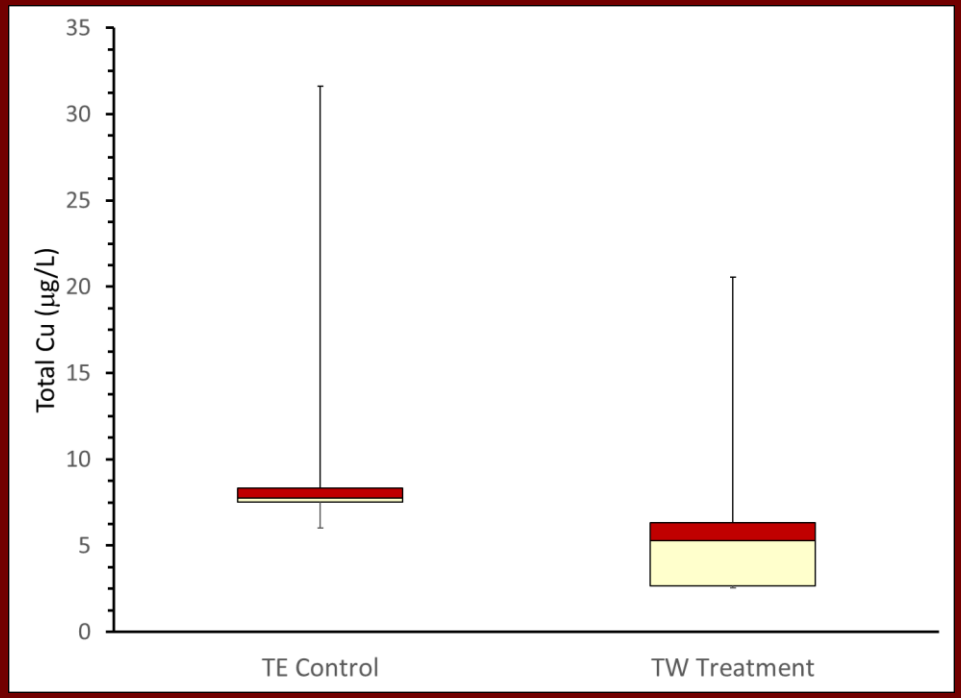


Total Copper

First Flush

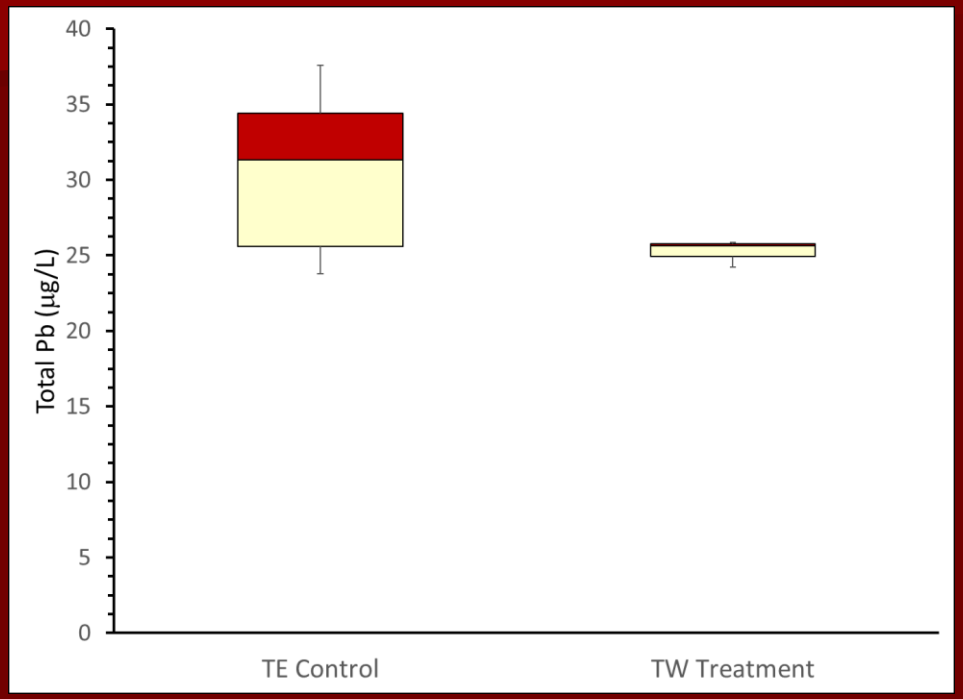


Storm Composite

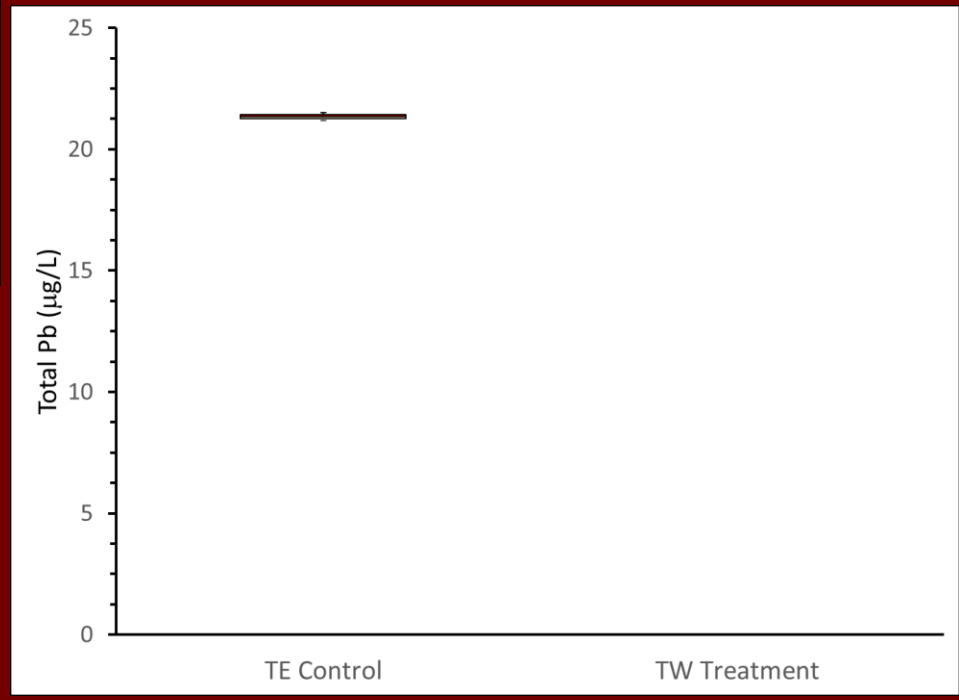


Total Lead

First Flush

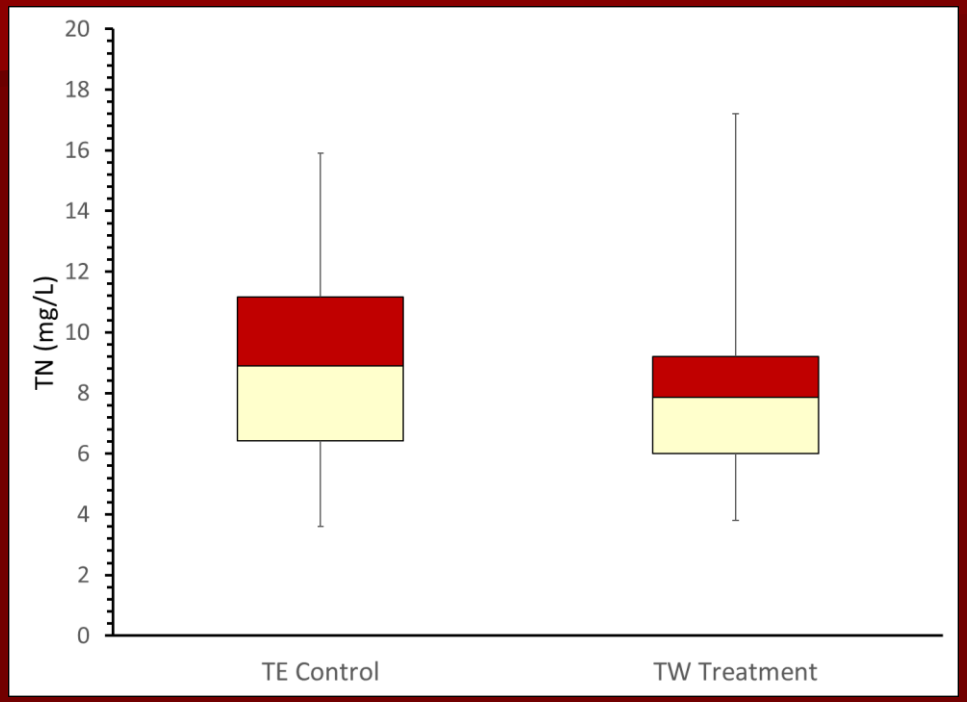


Storm Composite

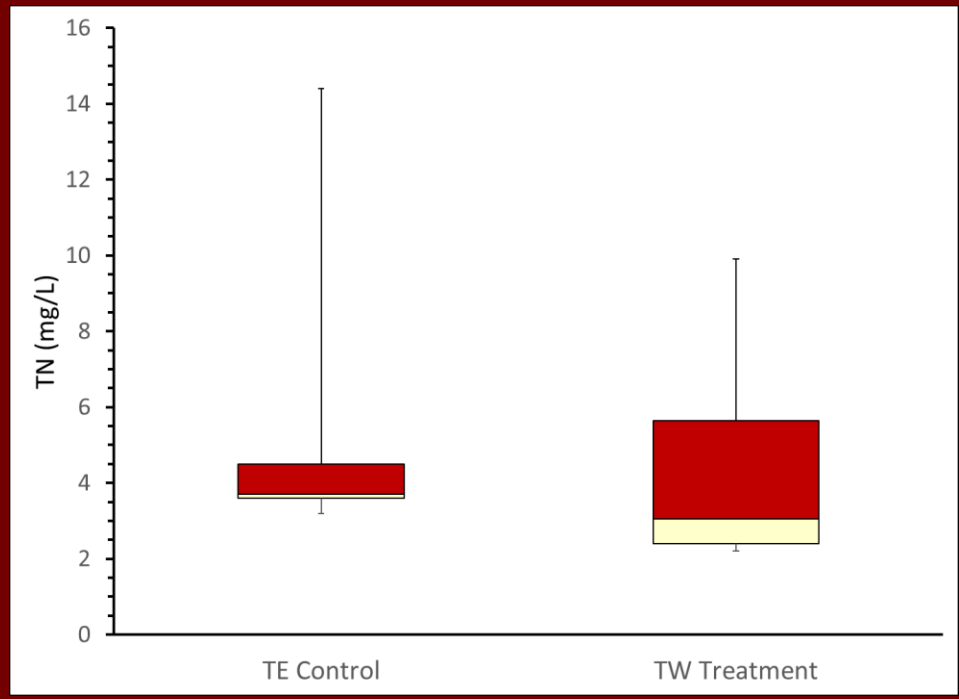


Total Nitrogen

First Flush

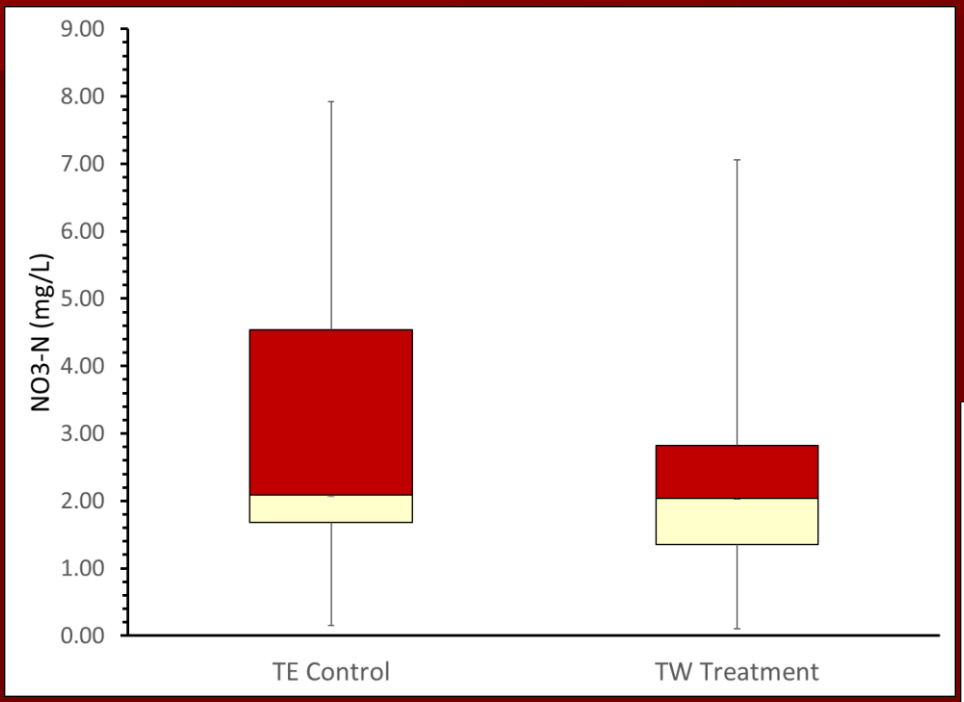


Storm Composite

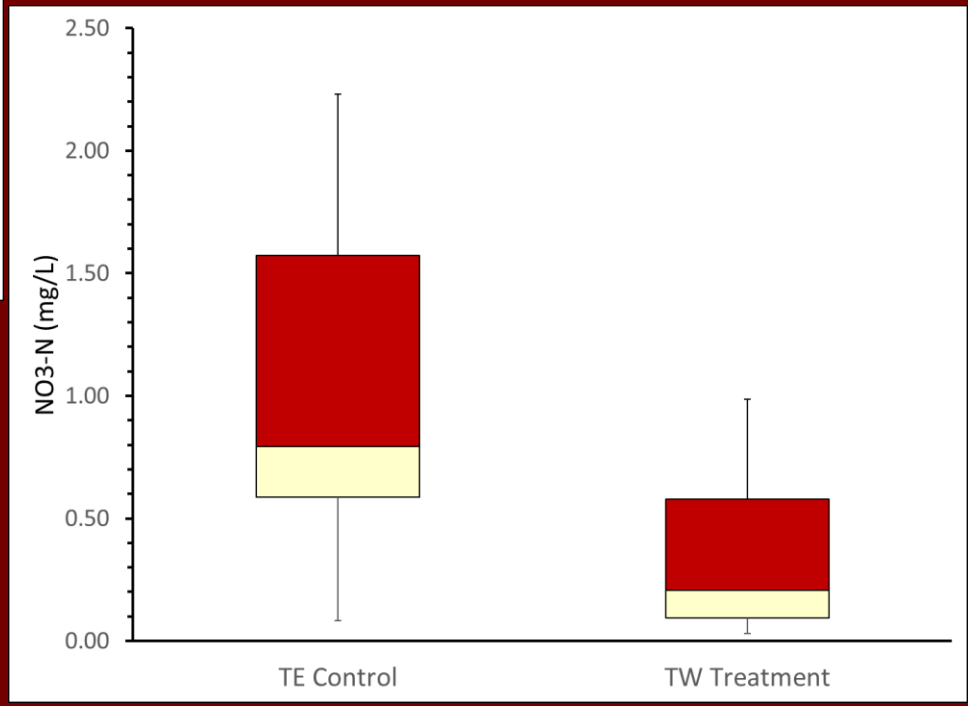


NO_3-N

First Flush

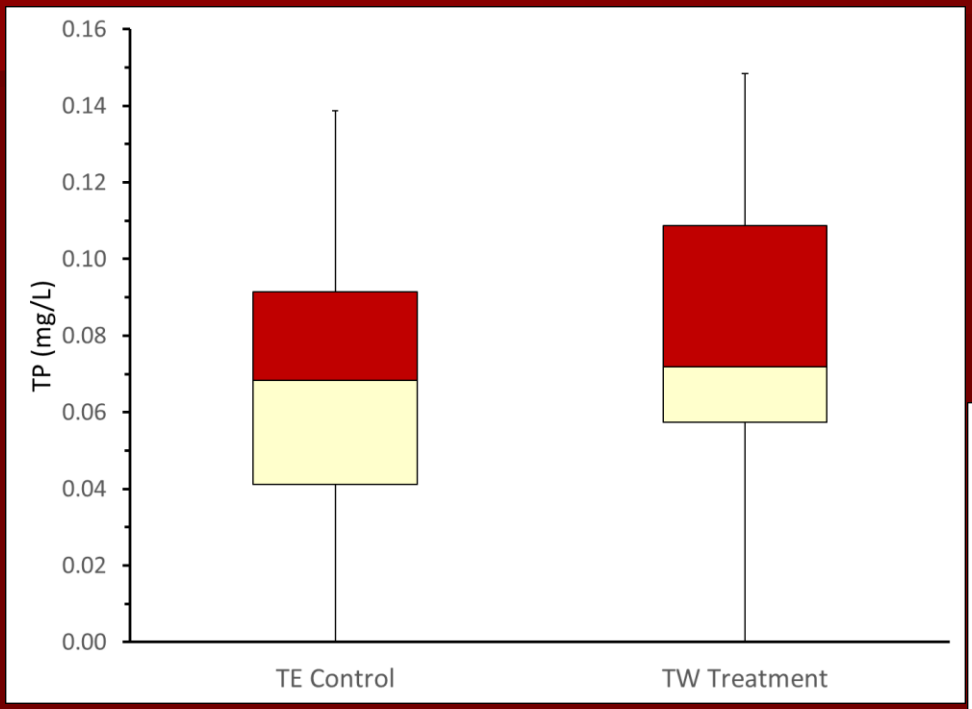


Storm Composite

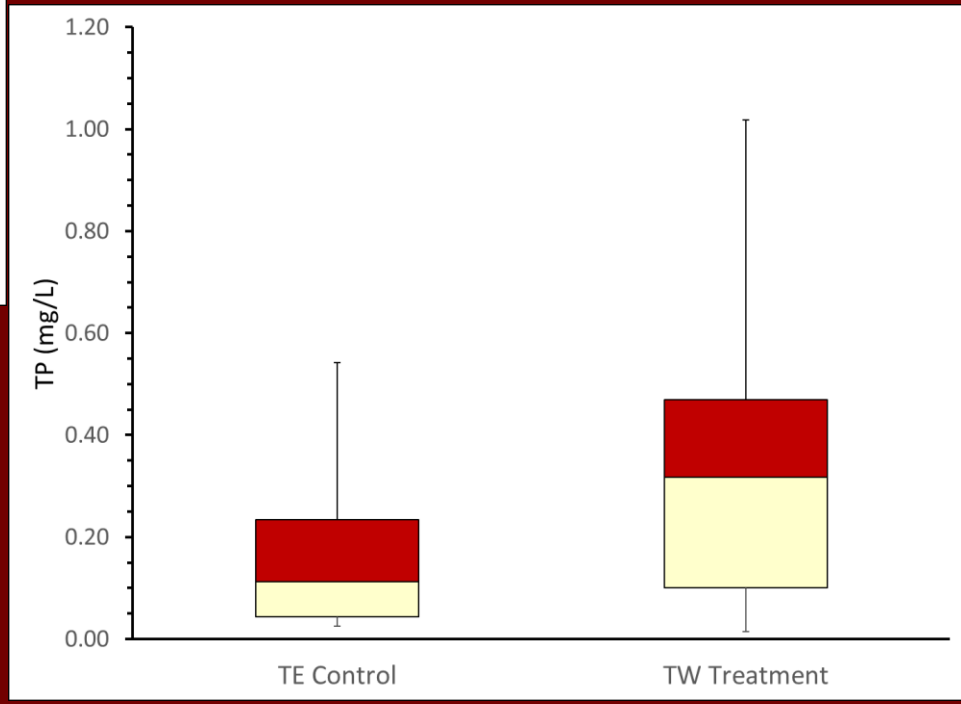


Total Phosphorus

First Flush



Storm Composite



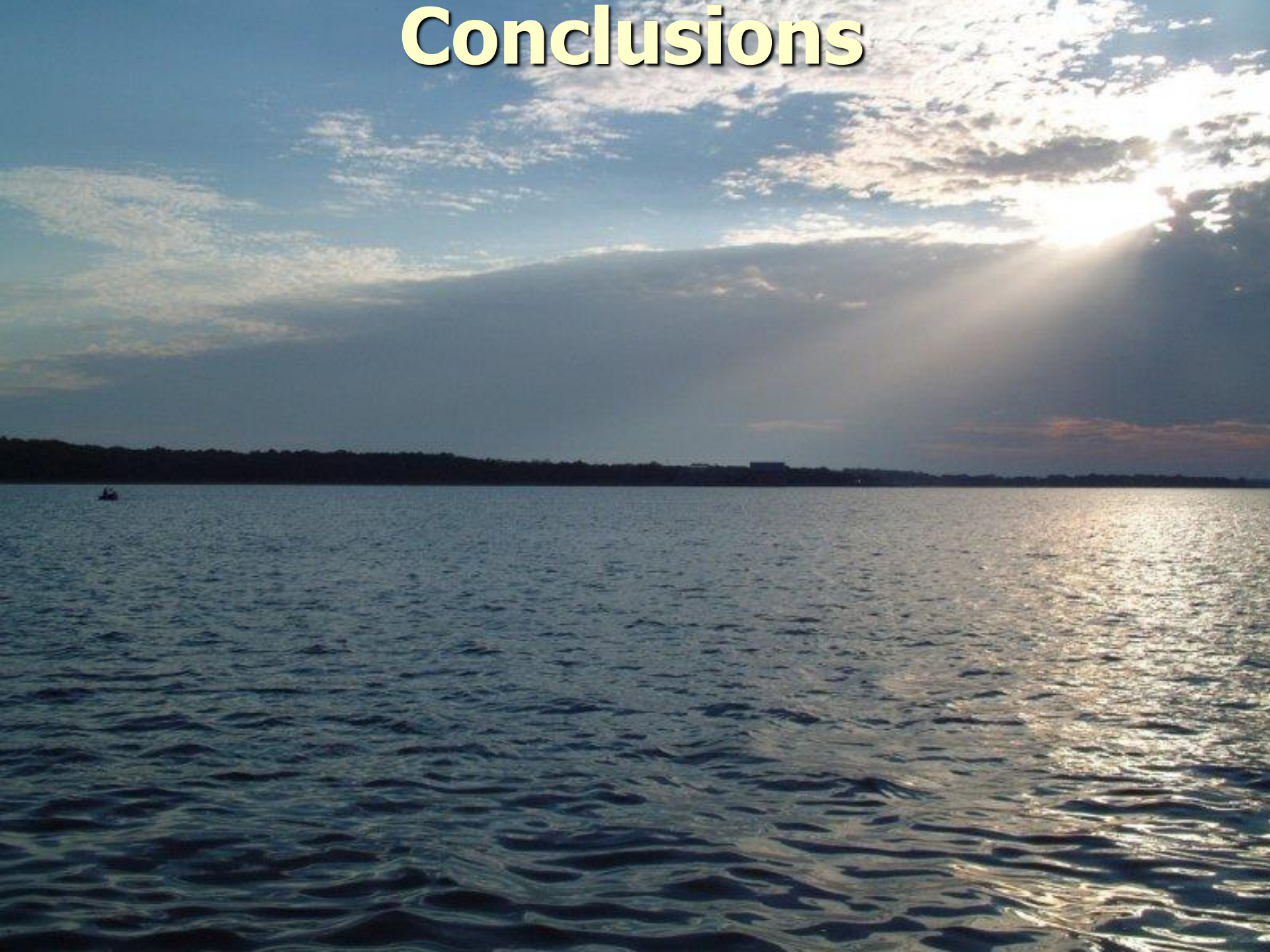
Water Quality Summary

- Concentrations and mass loads (not presented) were generally lower exiting treatment watershed
  - Solids retained ($p < 0.10$) by LID BMPs
  - Increased retention times and redox conditions in rain gardens likely led to denitrification ($p < 0.10$)
  - Selected metals immobilized via sorption processes

Water Quality Summary

- Phosphorus export, however, greater from treatment watershed
  - Lack of homeowner covenants regarding lawn care compromised study design
  - Organic growth media in rain gardens likely contributed to phosphorus export

Conclusions



Conclusions

- Hydrology
  - LID BMPs showed demonstrable influences on stormwater runoff peak discharge rates and total storm volumes
- Water quality
  - Sampling regime influenced assessment
  - LID BMPs exported less TSS, TN, NO_3-N, and metals
  - TP and DRP export is of concern and warrants redesign

Conclusions

- Closer coordination between design, construction and monitoring teams would benefit evaluative processes
- Requiring residential landowners to manage lawns and LID BMPs in a specific manner should be evaluated

Acknowledgements

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- SMC Engineering
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Questions?
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