BIOCHAR/IRON SAND FILTERS TO REMOVE BACTERIA & NUTRIENTS IN AN URBAN WATERSHED

IECA 2018 ANNUAL CONFERENCE

Presented by

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WENCK

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ACKNOWLEDGEMENTS

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Review assistance/collaboration:

- Dr. Andy Erickson, University of Minnesota
- Dr. John Gulliver, University of Minnesota
- Dr. Beth Fisher, University of Minnesota
- Dr. Sanjay Mohanty, University of California Los Angeles

MINNESOTA POLLUTION CONTROL AGENCY

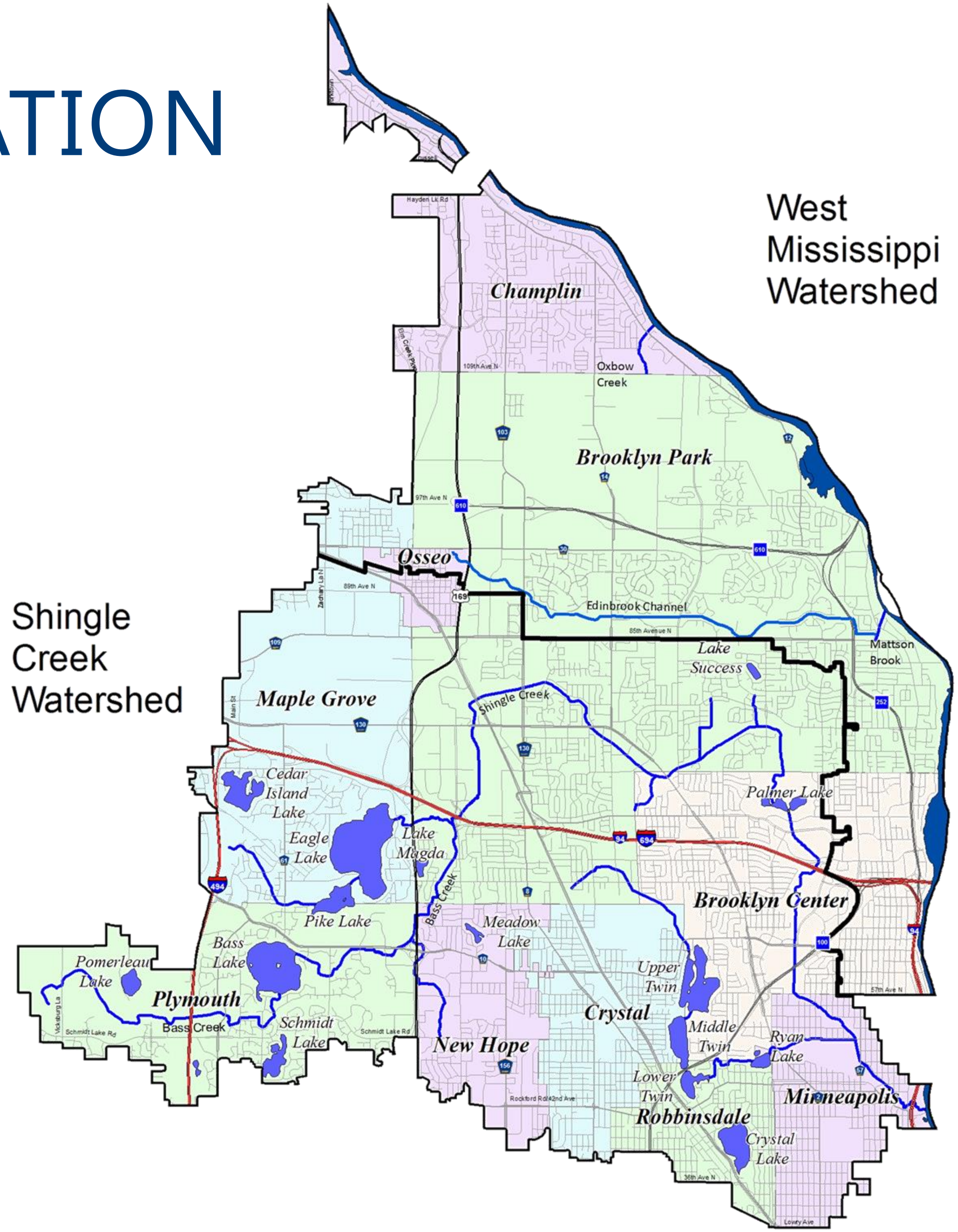
Shingle Creek

West Mississippi Watershed Management Commission

OUTLINE

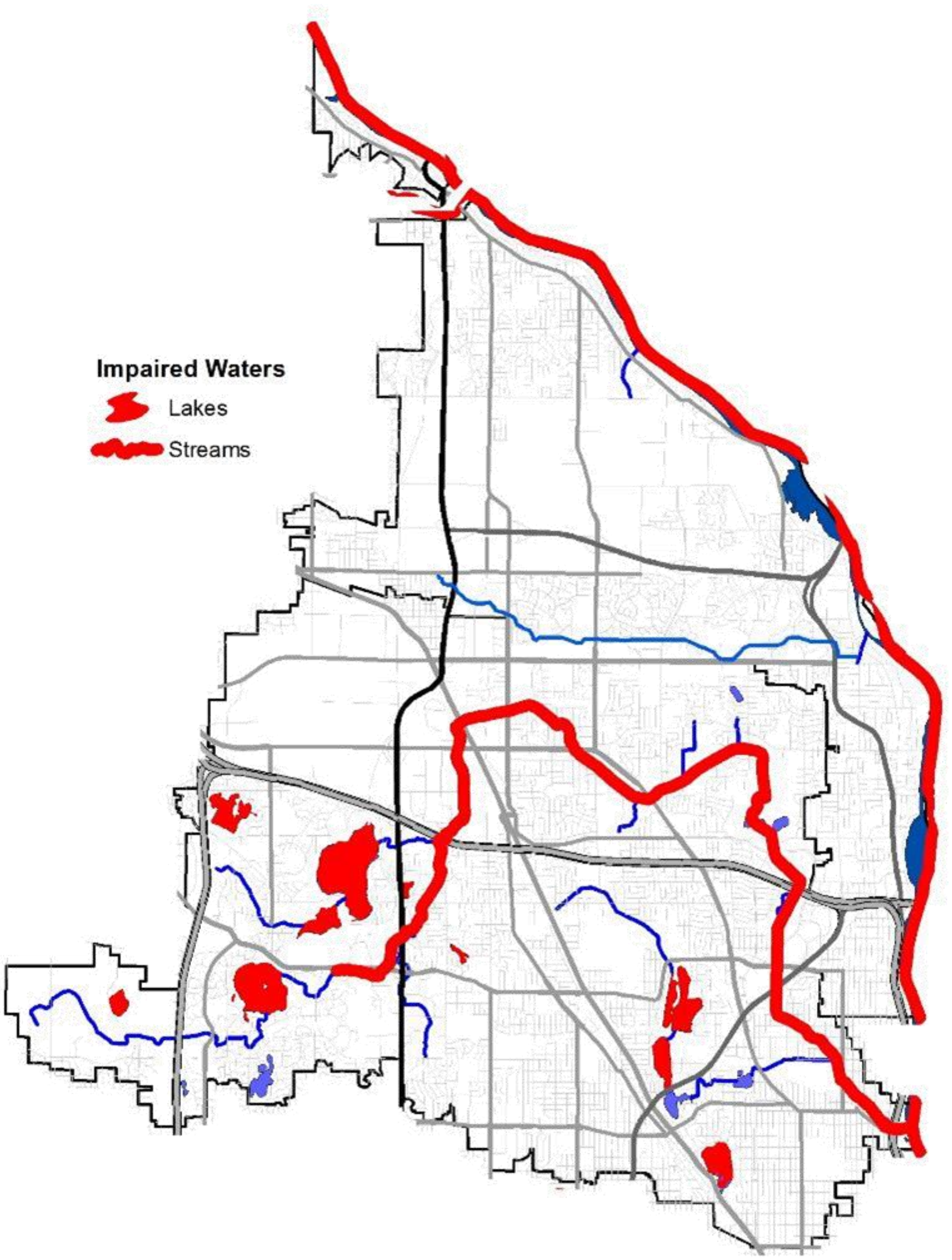
- Project purpose and background
- Bacteria reduction need and sources
- Phosphorus reduction need and sources
- Bacteria reduction using biochar
- Phosphorus reduction using iron/sand
- Implementation and field study

PROJECT LOCATION



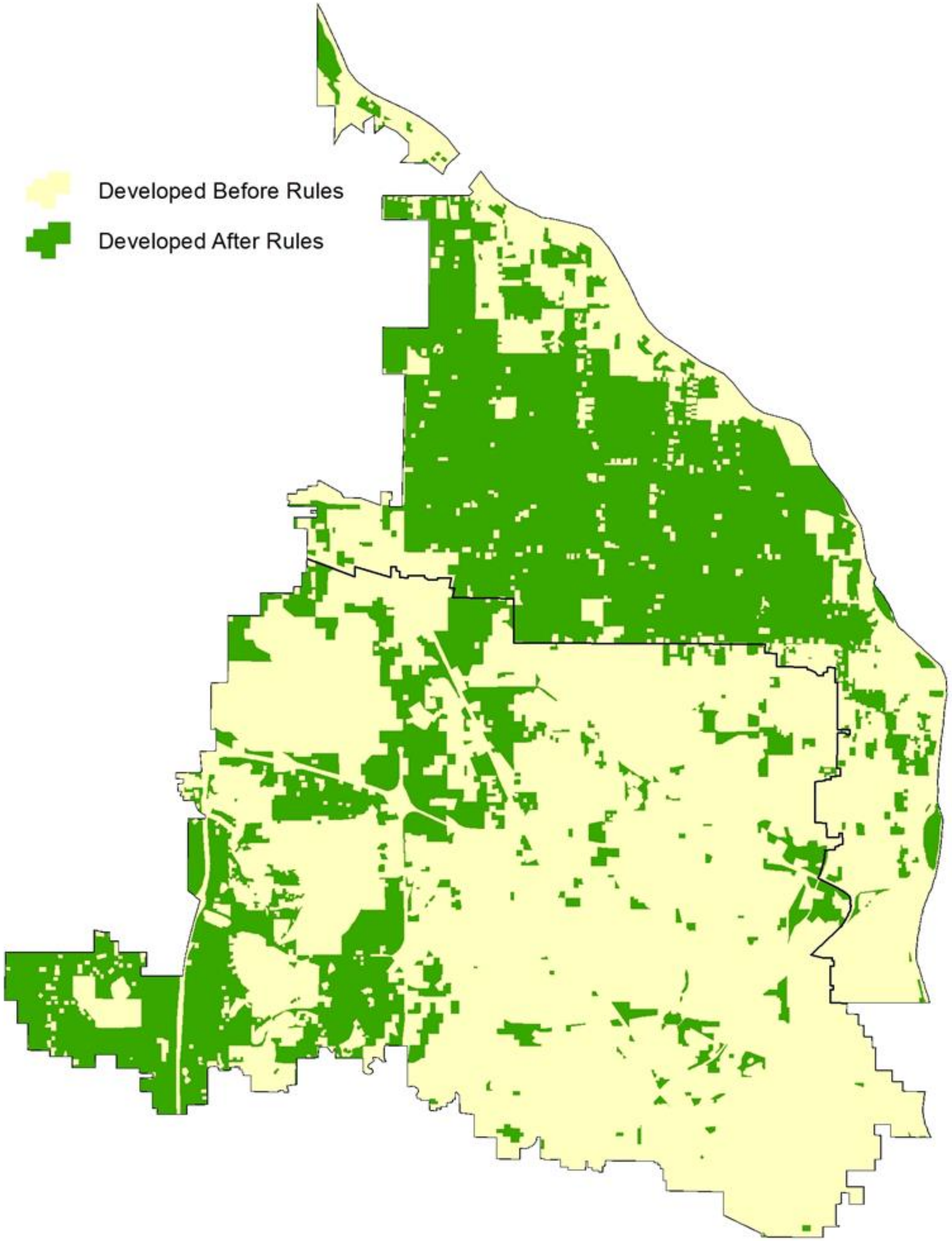
THE PROBLEM

- *Impaired Waters*
  - 10 lakes: nutrients
  - Shingle/Bass Creeks: bacteria, chloride, DO, biota
  - Mississippi River: bacteria, turbidity



THE PROBLEM

- Fully developed
  - *67 square miles*
- Untreated stormwater
  - *>50% watershed*
- Non-point source



PROJECT PURPOSE

Develop a passive and economical method to remove bacteria and phosphorus from storm water runoff and document its effectiveness

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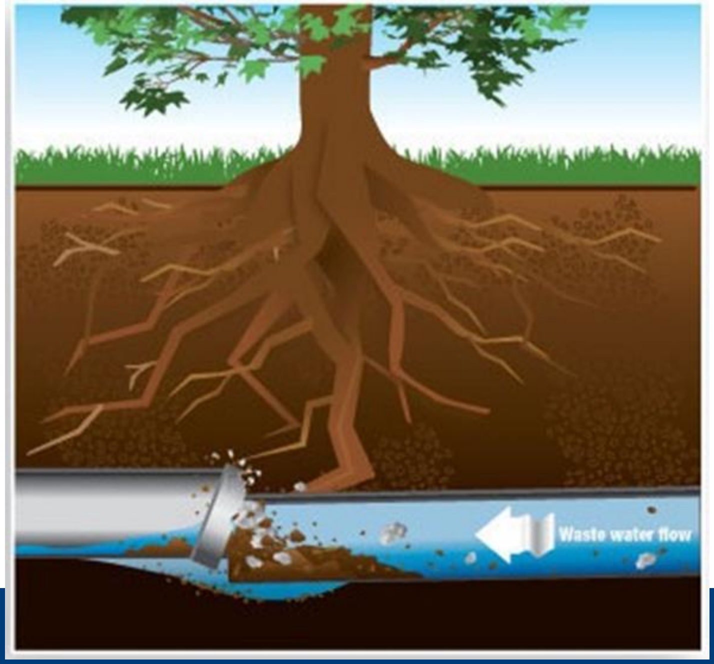
BACTERIA BACKGROUND

- Bacteria exist naturally in lakes and streams, but some bacteria can cause disease– like E. coli

- Shingle Creek and parts of the Mississippi River have more E. coli than the standard allows
  - MN standard: E. coli shouldn't exceed 126 organisms/mL

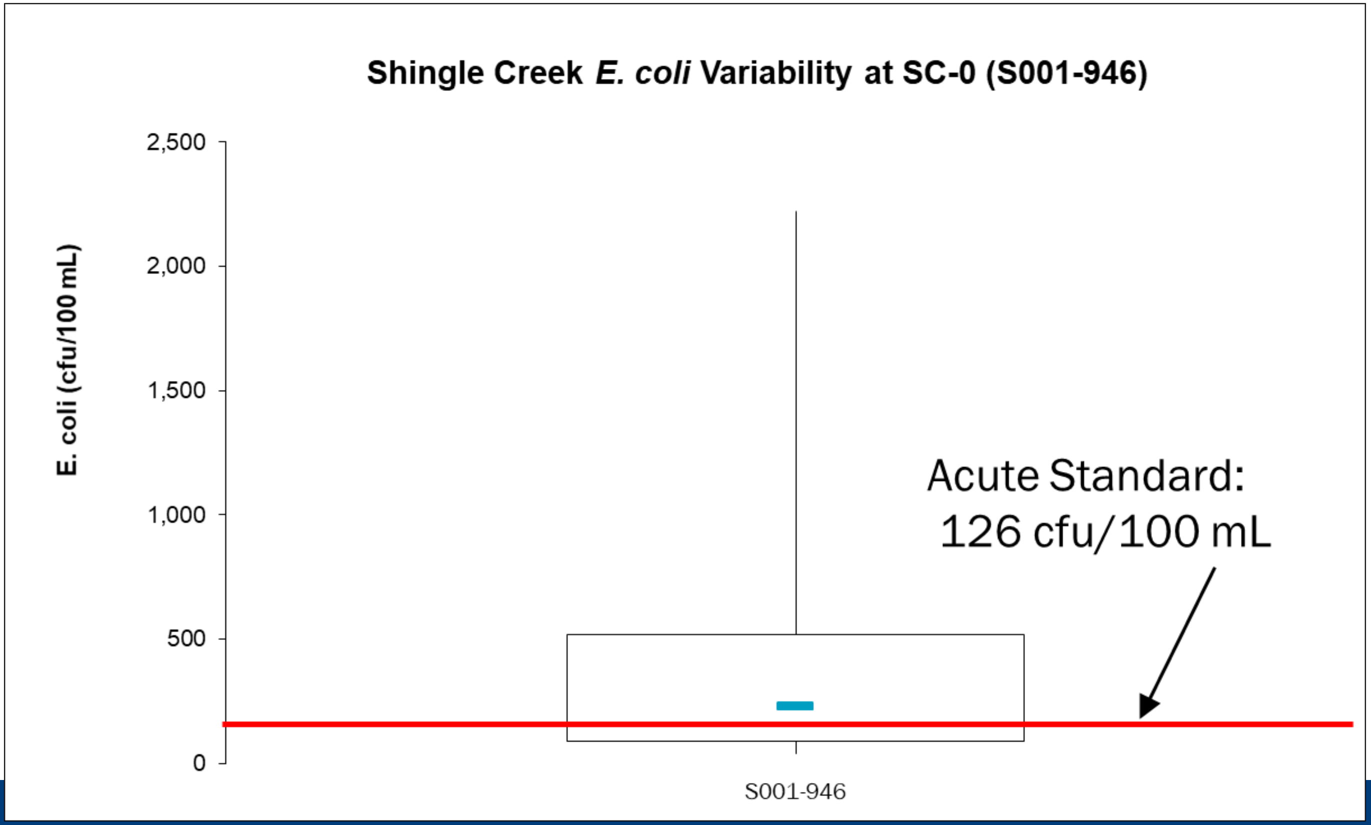
WHERE DOES *E. COLI* COME FROM?

- Pet waste
- Wildlife waste
- Failing septic systems
- Sanitary sewer overflows/leakages



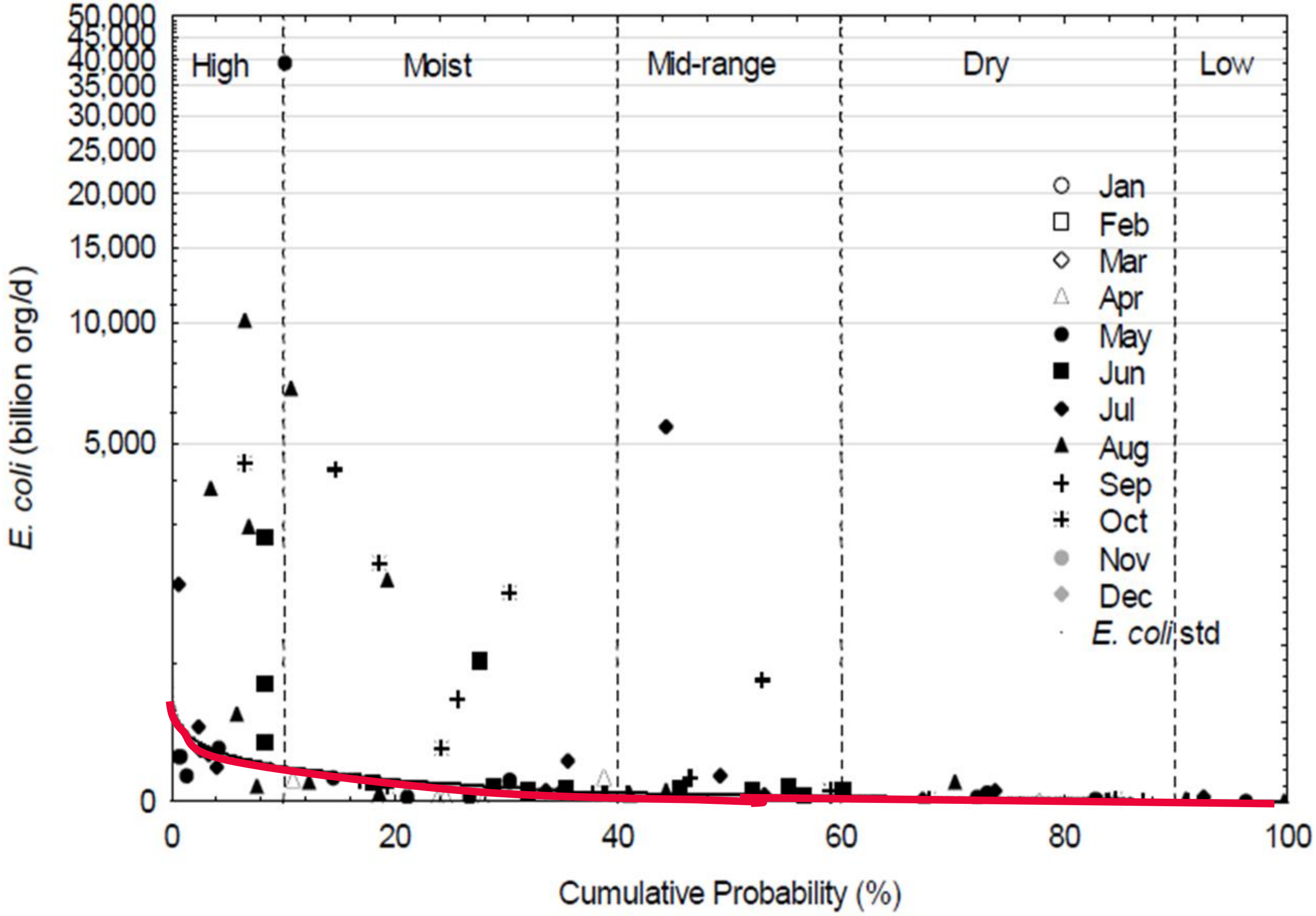
E. COLI CURRENT CONDITIONS

E. Coli concentrations at the outlet range from 10 to 27,000 coliform units/100 mL



E. COLI TMDL LOAD REDUCTION

Shingle Creek TMDL Load Reduction Curve



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PHOSPHORUS BACKGROUND

- Phosphorus exists naturally in lakes/streams, but in excess, can cause algae blooms and low oxygen
  - Bad for recreation and aquatic organisms
- Many water bodies in the watershed exceed the phosphorus standard

Upper Twin Lake, 9/21/17

Algae bloom

WHERE DOES PHOSPHORUS COME FROM?

- Plant/leaf litter
- Soil particles
- Pet waste
- Fertilizers

http://www.columbian.com/news/2011/nov/16/story-for-web-leaves-rain-combine-to-clog-storm-dr/

PHOSPHORUS LOAD REDUCTIONS

- Lakes: 10-83% TP load reduction required
- Shingle Creek: not yet listed impaired, but will be

IN SUMMARY

- Need big reductions in nutrients, sediment, and bacteria
- No handy point sources – diffuse non-point sources
- Fully developed, highly impervious
- Few opportunities for significant new structural BMPs

What should we do?

A MODERN TWIST ON AN OLD TECHNOLOGY…

- Start with sand filters – used to filter drinking water in ancient Sanskrit medical writings …

- …and enhance with **biochar** and **iron filings**

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BIOCHAR BACKGROUND

Research by Dr. Sanjay Mohanty, UCLA

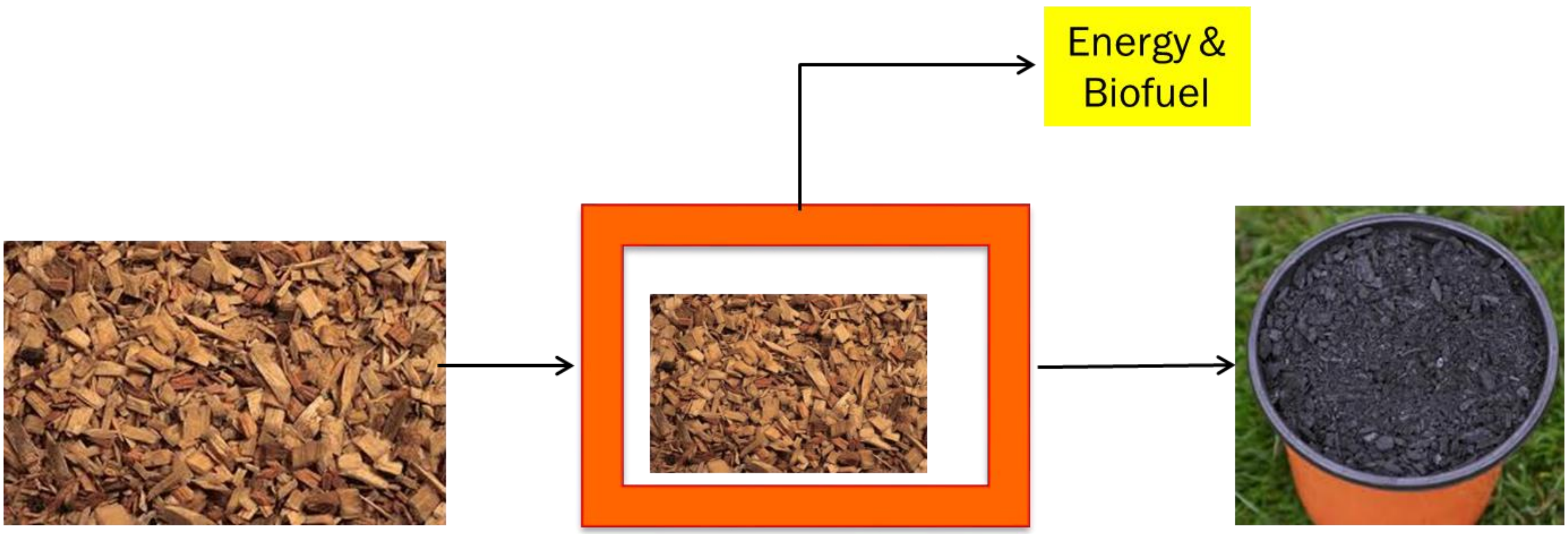
Column study showed biochar could remove up to 99% E. coli from stormwater, compared to 62% with just sand

SK Mohanty, AB Boehm. 2014. Escherichia coli removal in biochar-augmented biofilter: Effect of infiltration rate, initial bacterial concentration, biochar particle size, and presence of compost.

Environmental Science & Technology. 48 (19), 11535-11542.

BIOCHAR

Biochar is essentially a charcoal created by burning organic waste in oxygen-free chamber.



BIOCHAR BACTERIA CAPTURE THEORY

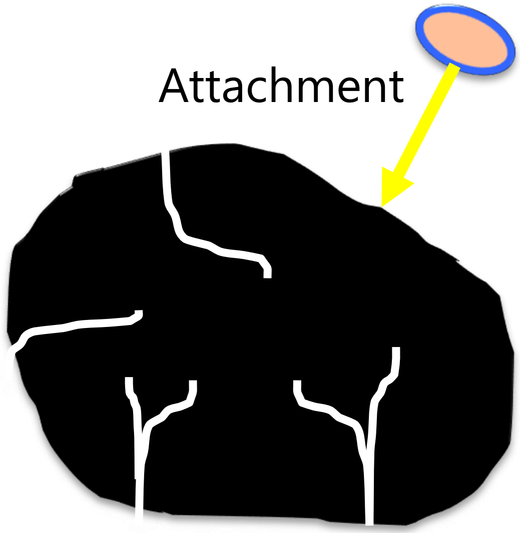
Biochar acts similar to activated carbon in adsorption of organic pollutants.

Production steps:

- Organic material + heat with no oxygen = char
- Char + chemical and physical process = activated carbon (immense surface area)
- Each particle/granule provides a large surface area/pore structure, maximumizing possible exposure to the active sites within the filter media

BIOCHAR'S MAIN USE IS AS A SOIL AMENDMENT FOR RETENTION OF NUTRIENTS AND AGROCHEMICALS FOR PLANT GROWTH

WHY BIOCHAR?



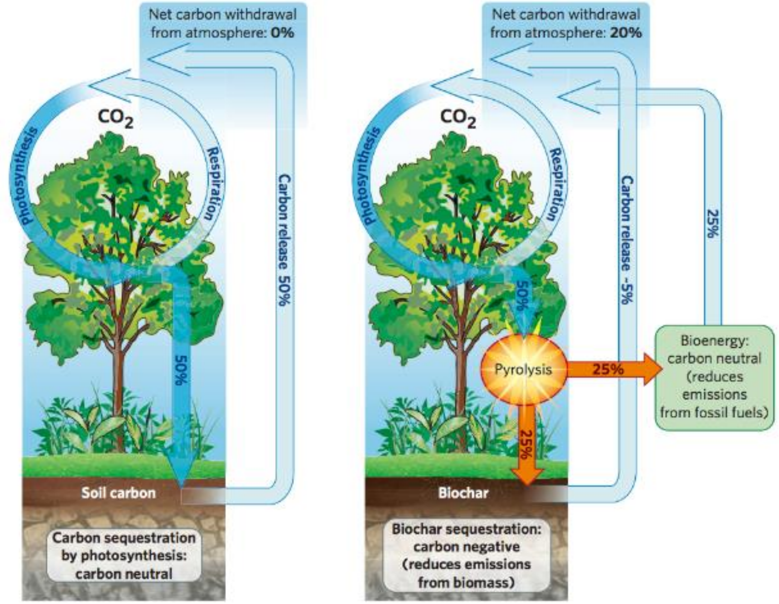
Remove Contaminants

Metals

Poly Aromatic Hydrocarbon

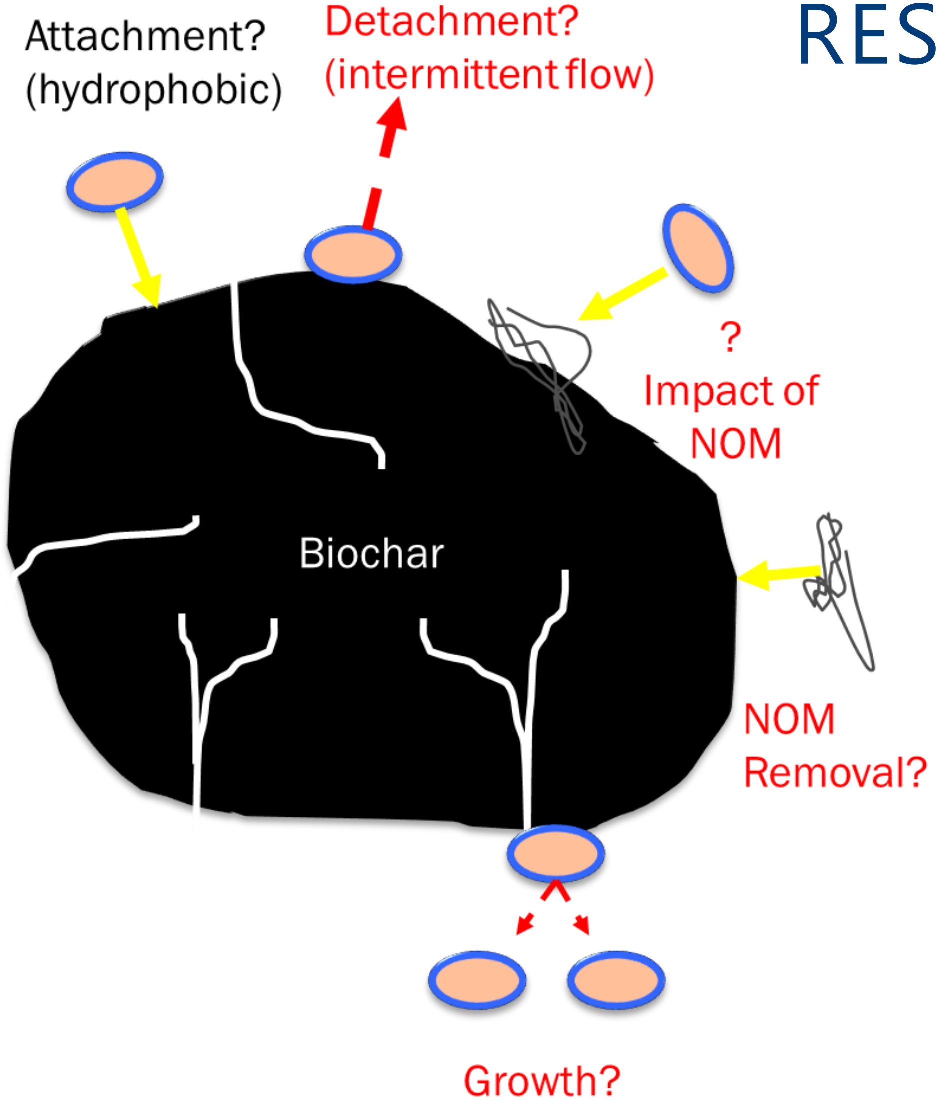
Phosphate (Yao 2011)

Bacteria (Bolster 2012)



Carbon sequestration
(climate change)

Nutrient capture and release
(Increase soil fertility)



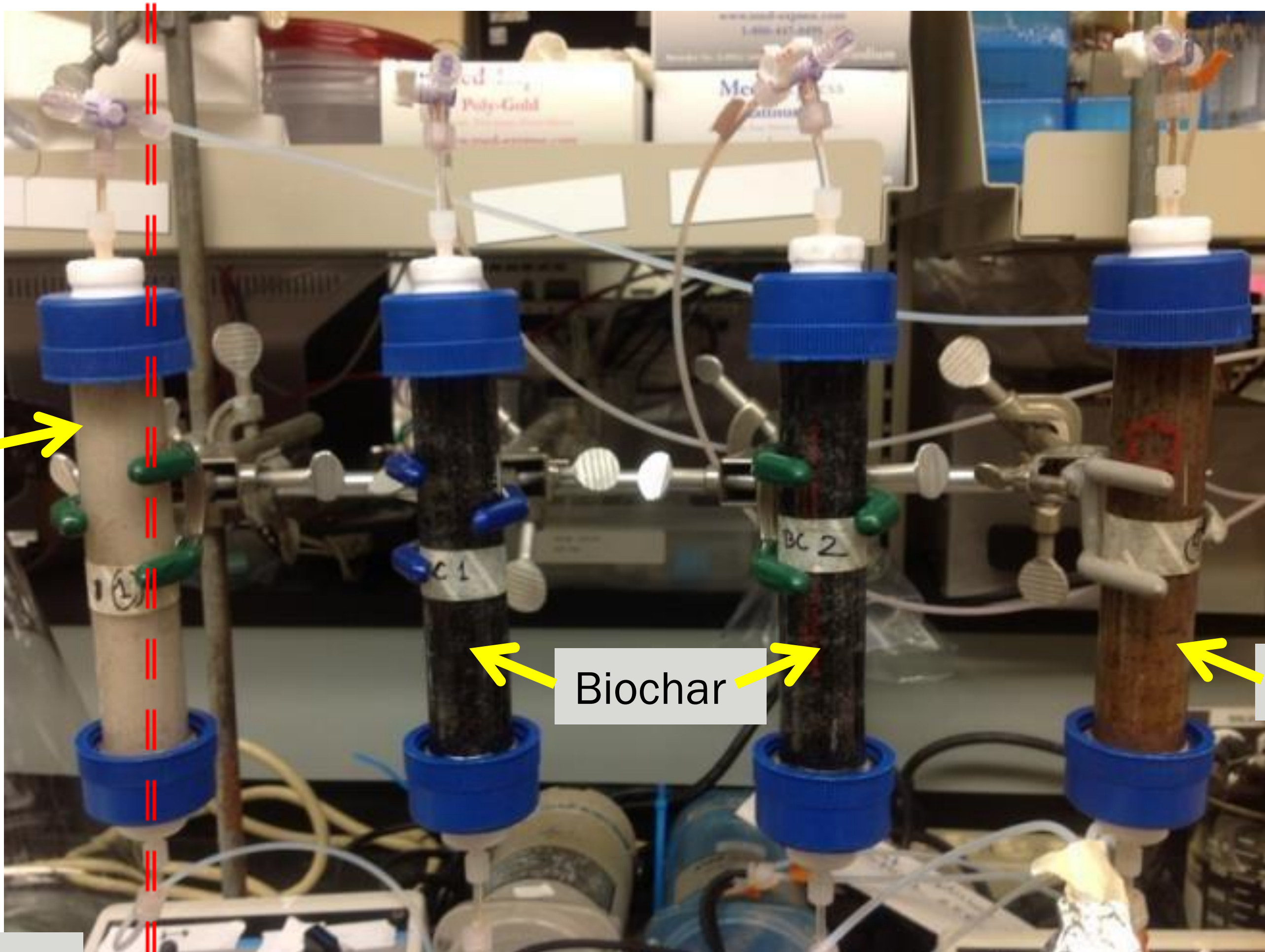
RESEARCH QUESTIONS

1. Does biochar remove E. coli?
2. Does intermittent flow mobilize E. coli attached to biochar?
3. Does NOM affect the removal of E. coli?
4. Does biochar remove NOM?
5. Does biochar provide ideal environment to support the growth of E. coli?

NOM = Natural Organic Matter

LAB-SCALE EXPERIMENTAL SETUP

Stormwater with bacteria



Sand

Biochar

Iron filings

Stormwater OUT

Slide: Dr. Sanjay Mohanty

BIOCHAR LAB SCALE SUMMARY

<u>Potential</u>

- Biochar could remove *E. coli* from stormwater (99% removal v. 62% with just sand)
- NOM decreased removal and increased mobilization, but less severely compared to other geomedia (e.g. IOCS)
- Intermittent flow mobilized small fraction of attached *E. coli*

<u>Pitfalls</u>

- Biochar could raise the pH of stormwater.

IOCS = Iron Oxide-Coated Sand

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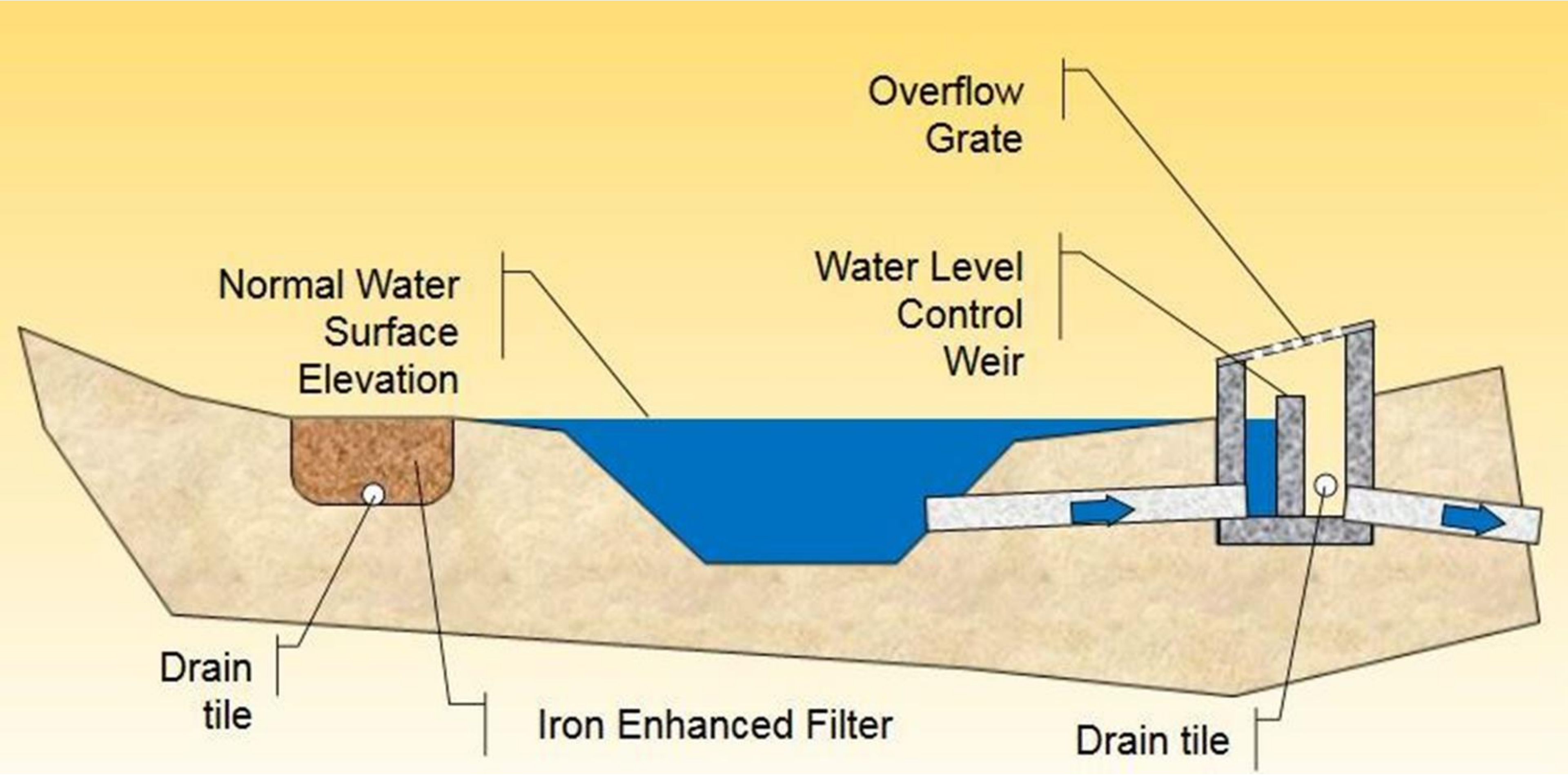
IRON/SAND FILTER BACKGROUND

Research by Dr. Andy Erickson and Dr. John Gulliver of the University of Minnesota St. Anthony Falls Lab

Steel-enhanced, sand-filter columns retained between 25 and 99% of dissolved phosphorus in synthetic stormwater

Erickson, A.J., J.S. Gulliver and P.T. Weiss. 2007. Enhanced Sand Filtration for Storm Water Phosphorus Removal. *Journal of Environmental Engineering*. 133(5), 485-497, 2007.

MINNESOTA FILTER



Graphic: Andy Erickson, SAFL

PHOSPHORUS REDUCTION

Fe^{+3} + $HnPO_3$-n = Fe(OH)s

Ferric iron + Phosphorus > metal hydroxide

(surface bond)

OK, so it works in the lab….

Does it work in the field?

And does it help us solve our problems?

Time for some field tests!

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IRON/SAND BIOCHAR MEDIA

Iron/sand 5% by weight purchased premixed from Plaisted Companies.

Biochar produced by Char Energy, LLC. Made from hard wood at 500°C. Optimally installed at 30% by volume.

FIELD DEMONSTRATION

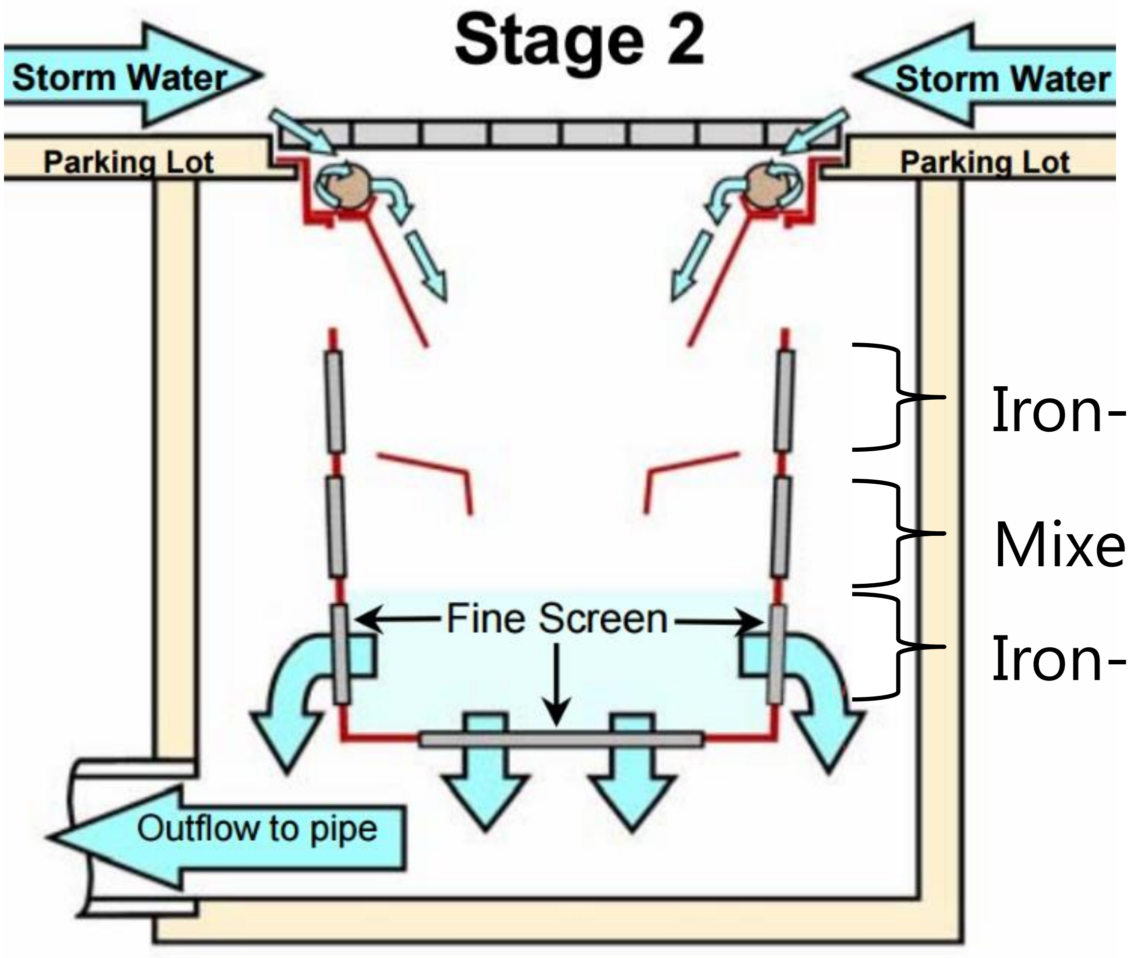
Three field applications:

- Catch basin media inserts
- Utility box filter
- Pond filter bench

CATCH BASIN INSERTS

Gutter line flow in two locations using standard grate inlet skimmer box

CATCH BASIN INSERT FILTER DESIGN



Iron-enhanced sand

Mixed hardwood biochar

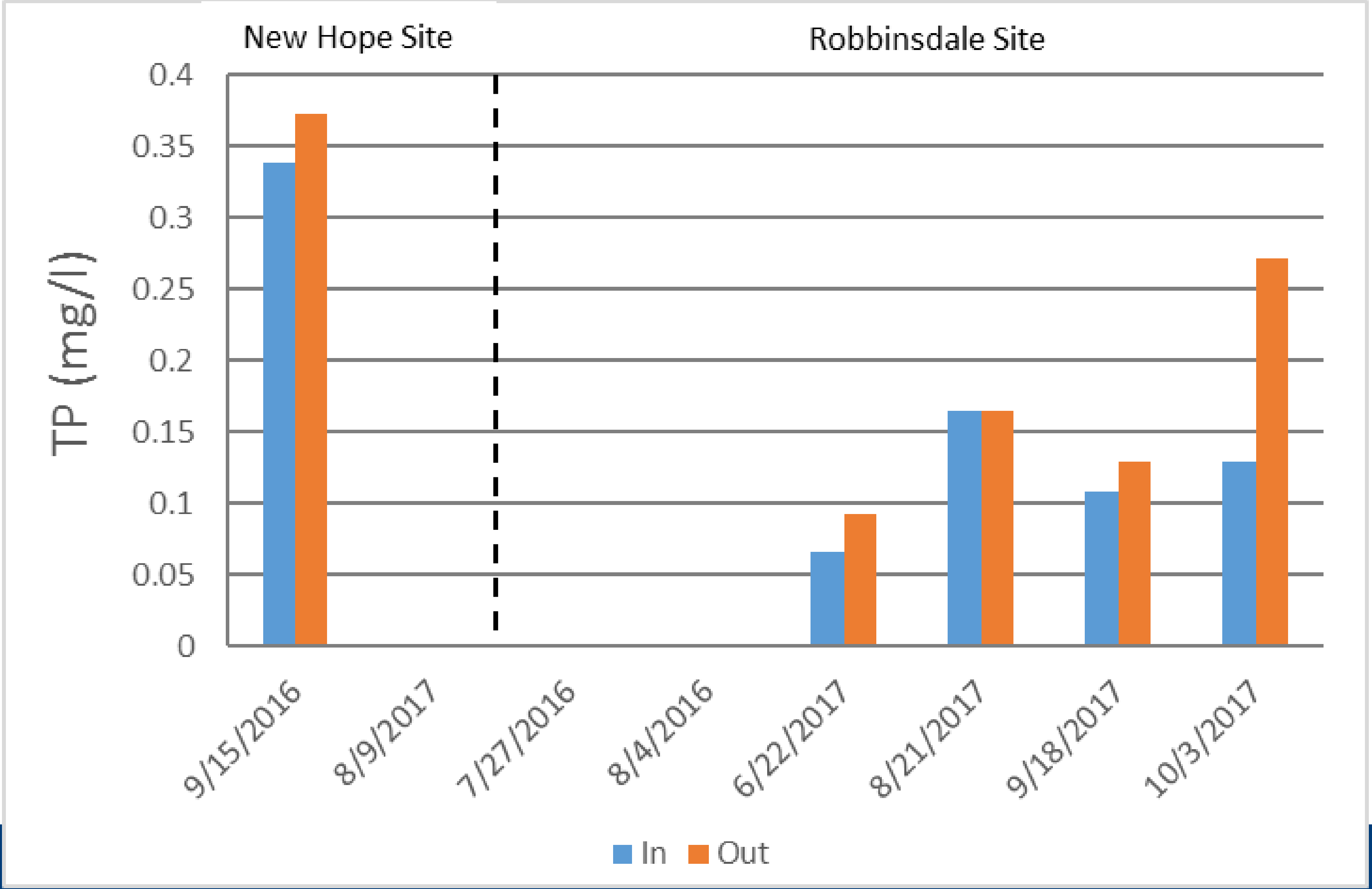
Iron-enhanced sand

CATCH BASIN INSERT WITH MEDIA

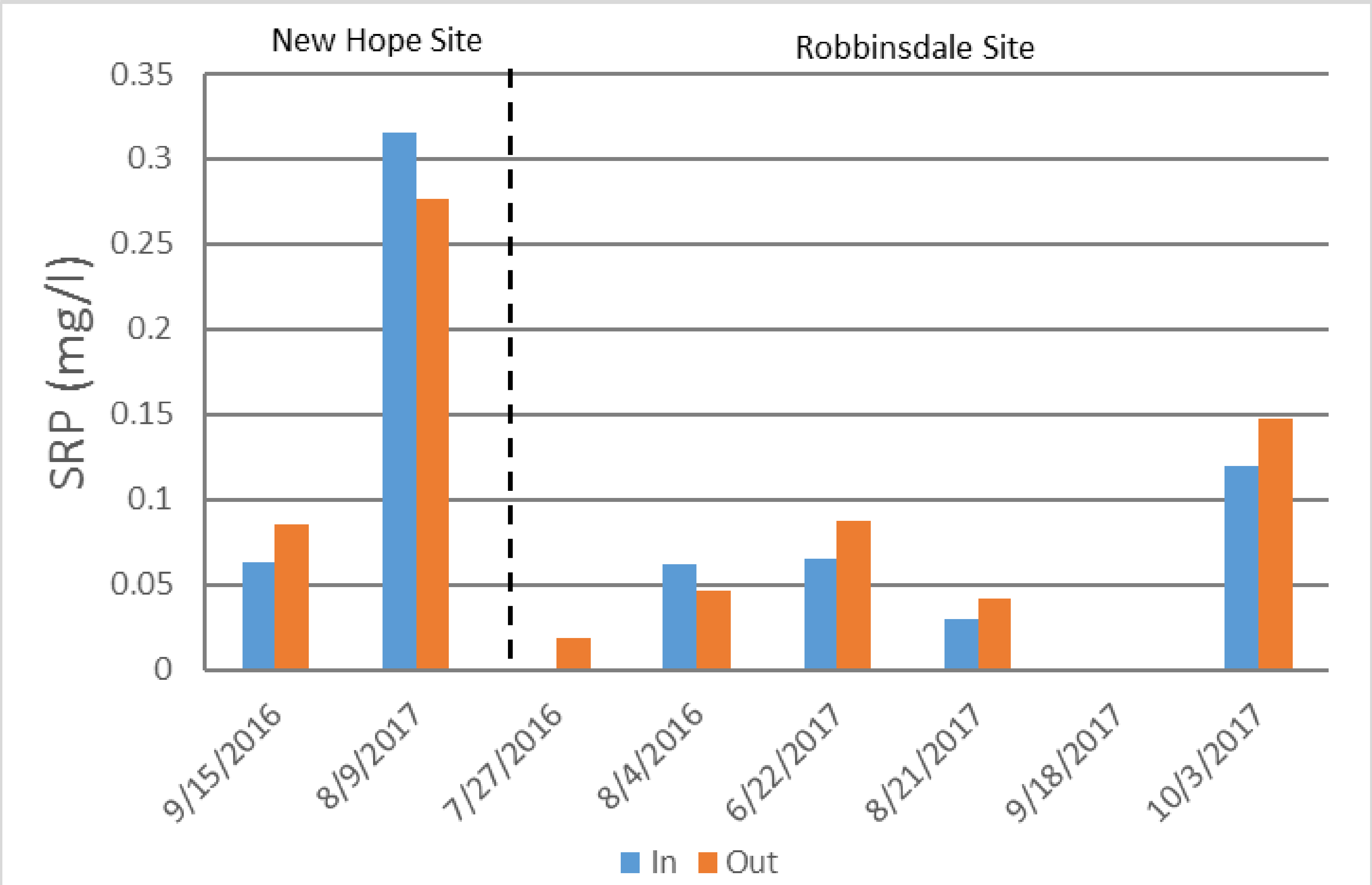
CATCH BASIN INSERT IN PLACE

CATCH BASIN INSERT SAMPLING

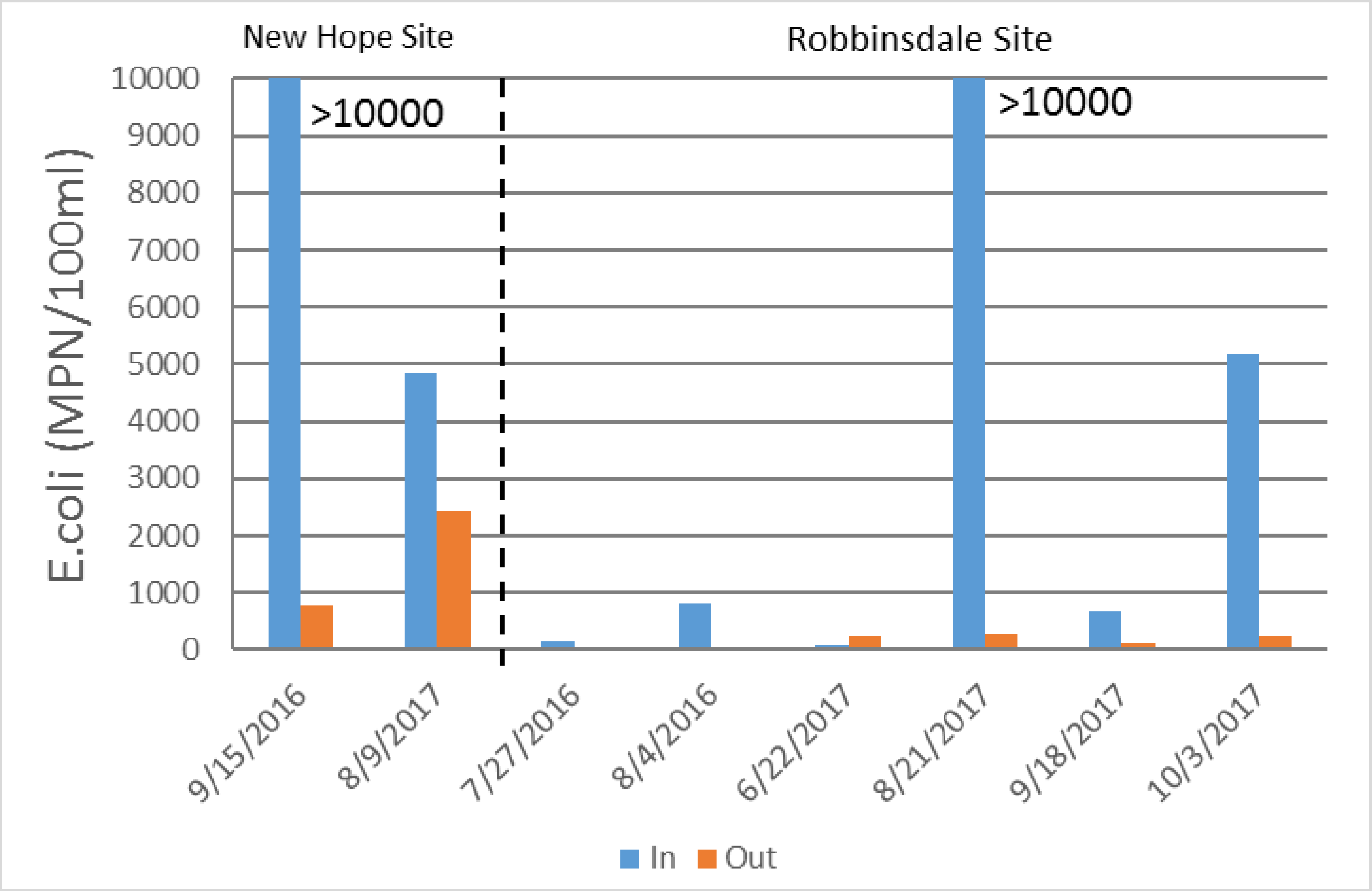
CATCH BASIN INSERTS TP REMOVALS



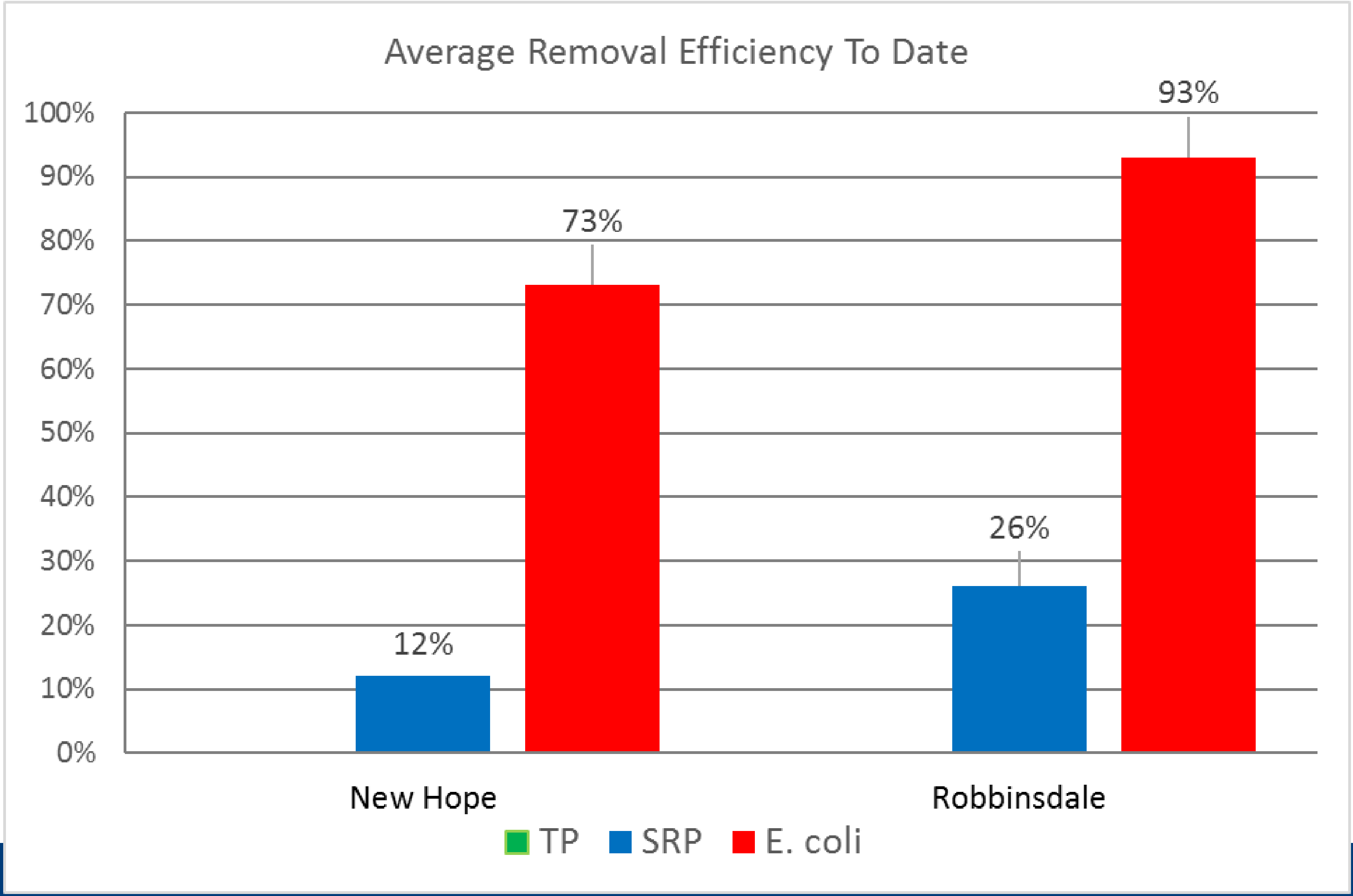
CATCH BASIN INSERTS SRP REMOVALS



CATCH BASIN INSERTS *E.COLI* REMOVALS

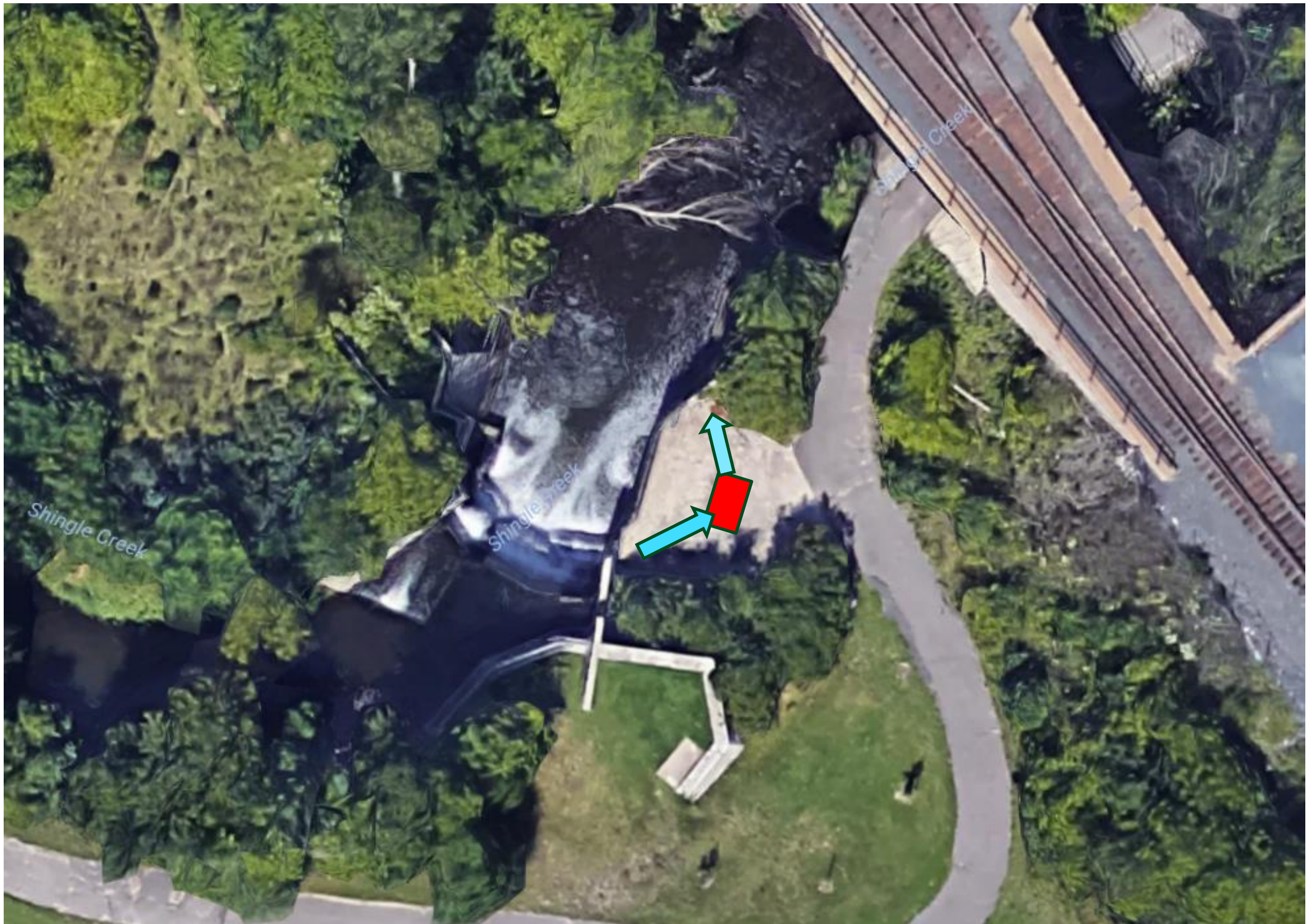


CATCH BASIN INSERTS REMOVAL EFFICIENCY



SHINGLE CREEK FALLS IN WEBBER PARK, MINNEAPOLIS

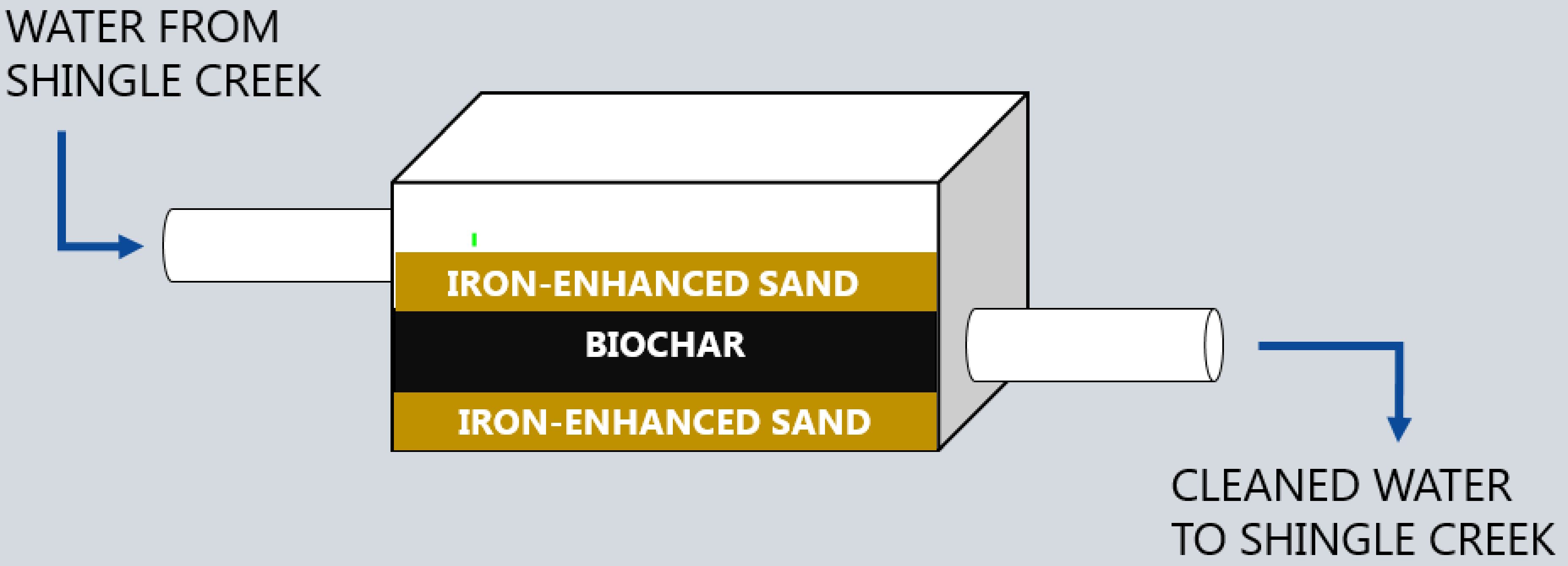
UTILITY BOX FILTER



Utility box location

Flow direction

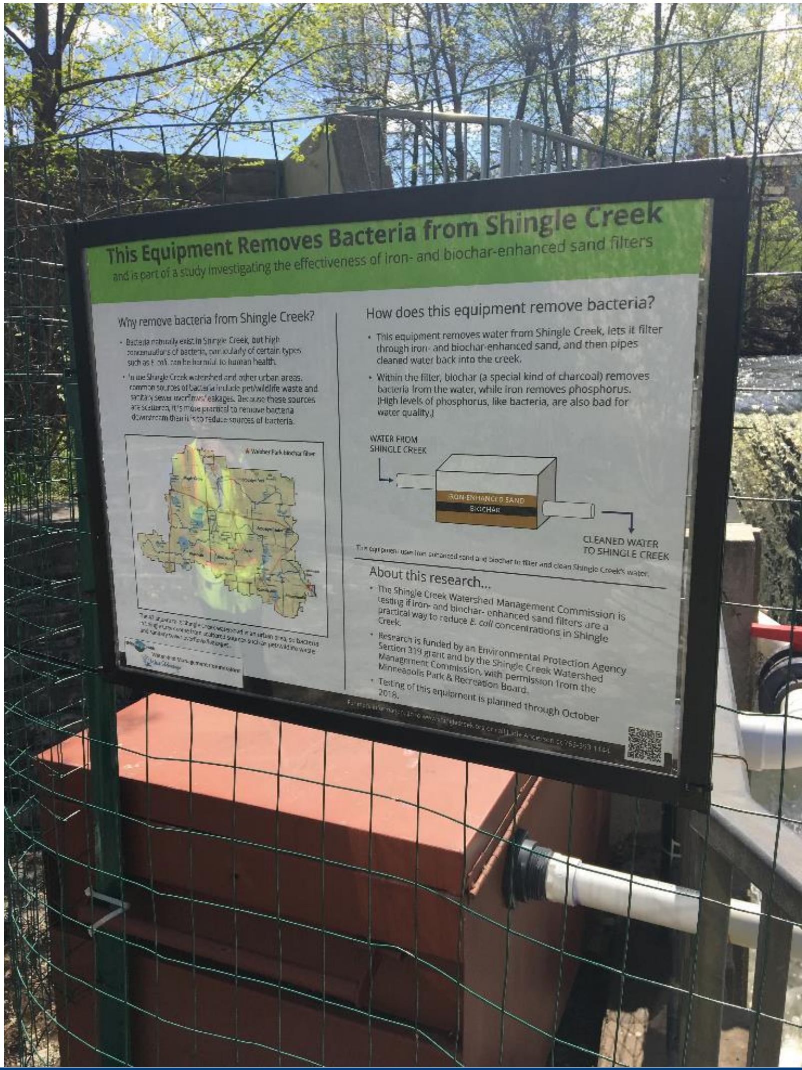
DESIGN SCHEMATIC



FILTER BOX ASSEMBLY

PUBLIC OUTREACH

Interpretive sign explains how the filter works and its purpose



SURFACE MEDIA CLOGGING

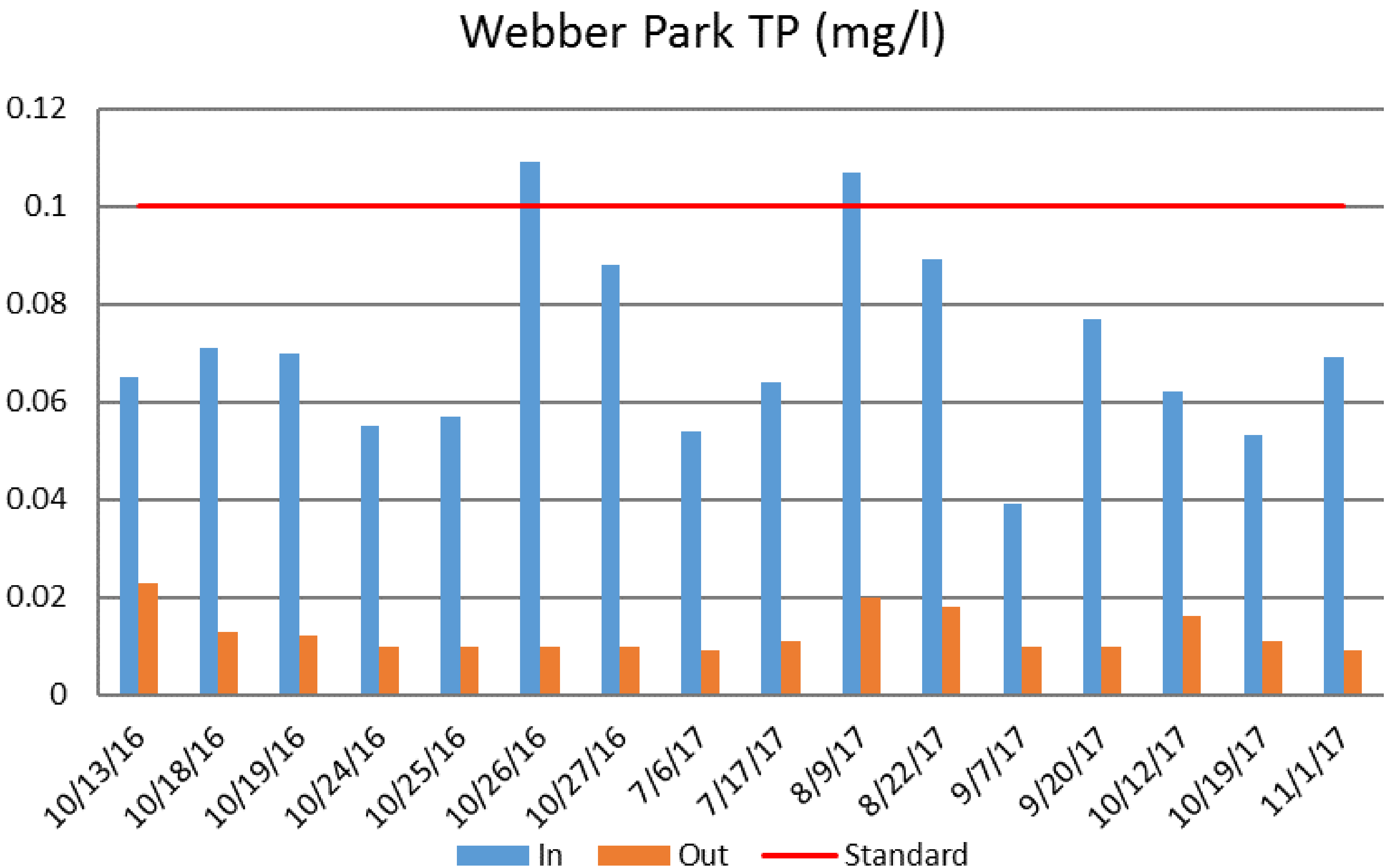
UTILITY BOX INLET

REVISED INLET

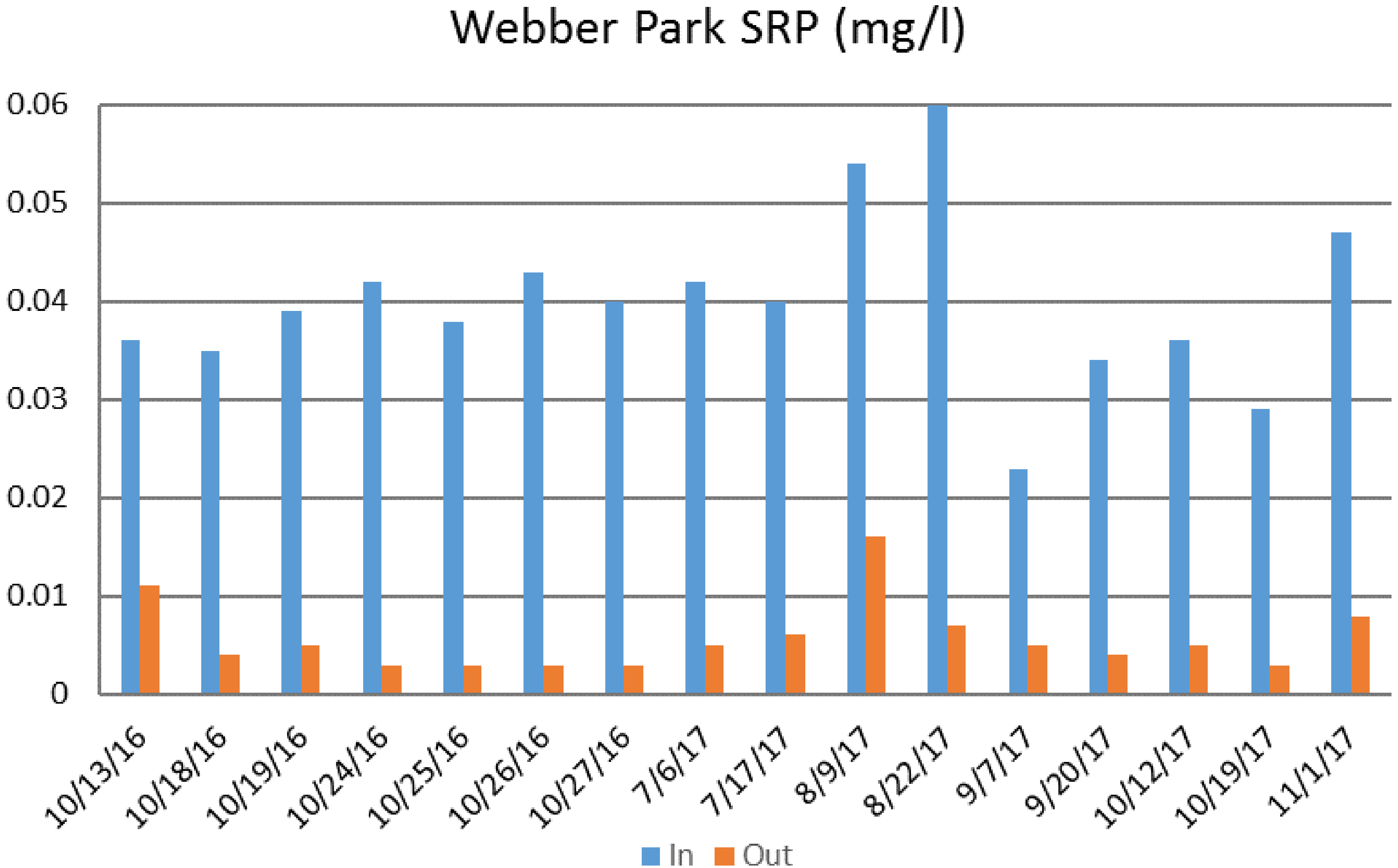
LOWERED AND LENGTHENED INLET PIPE WITH SOCK SOLVED CLOGGING

SAMPLING RESULTS

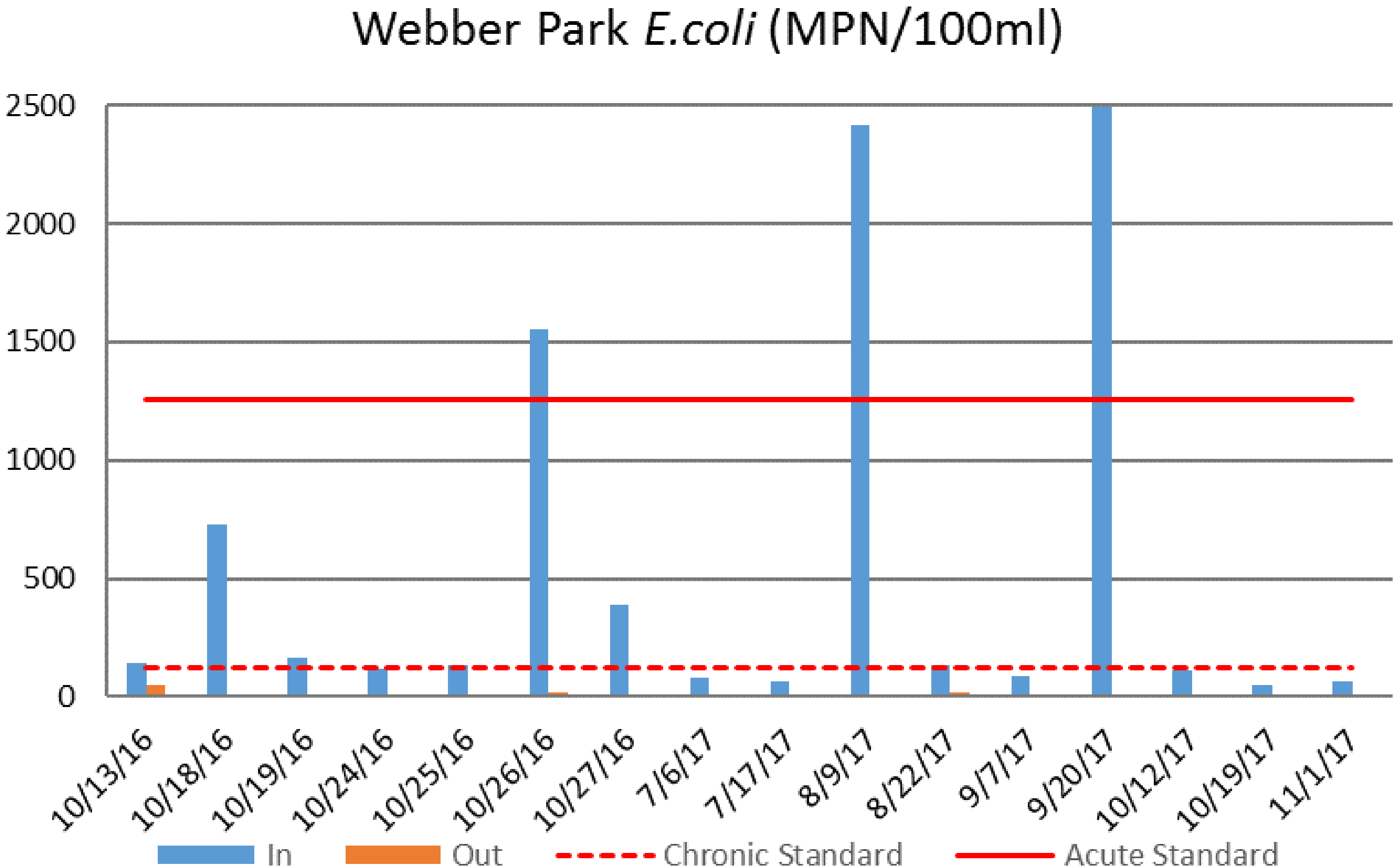
UTILITY BOX TP REMOVAL



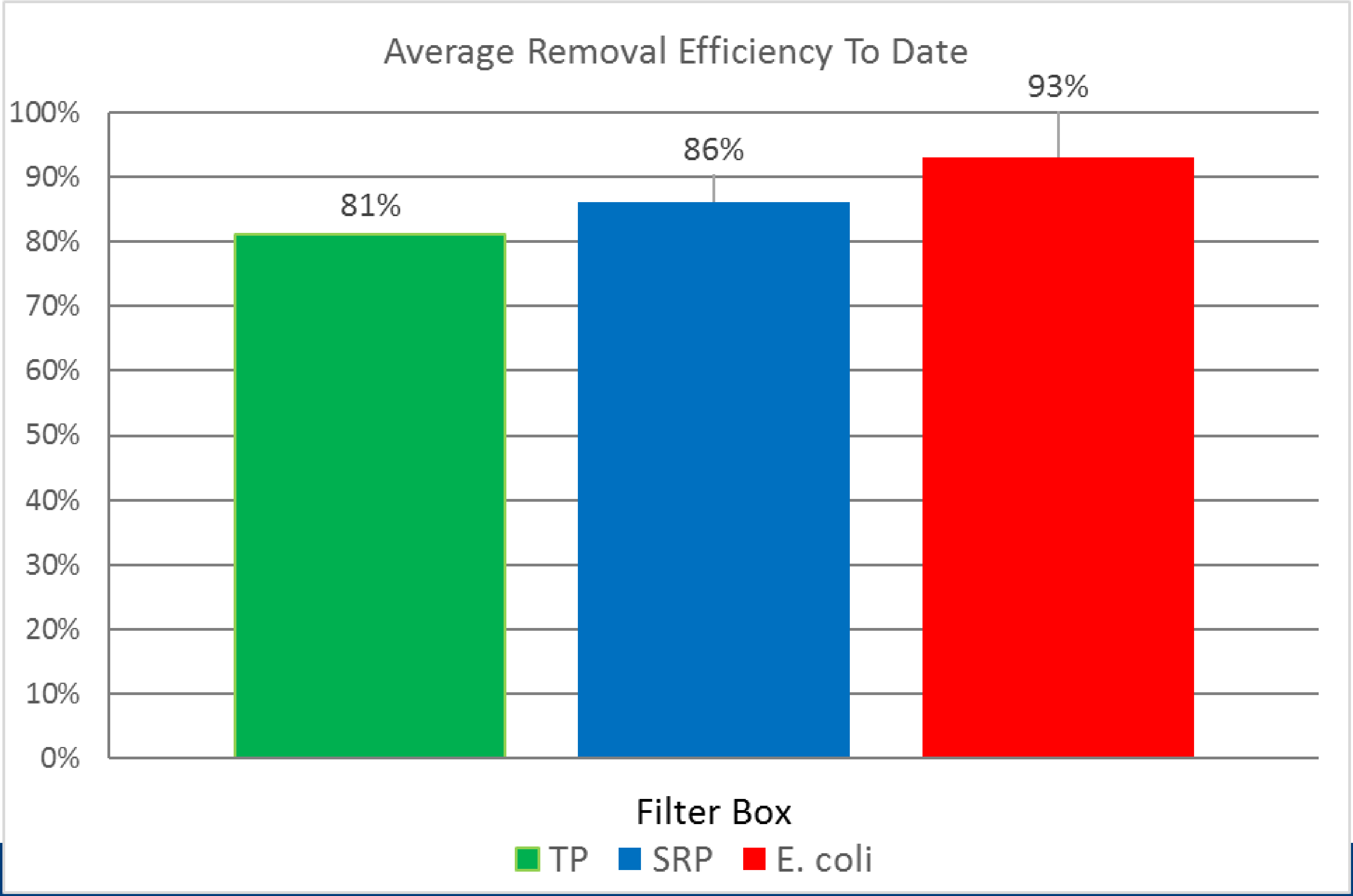
UTILITY BOX SRP REMOVAL



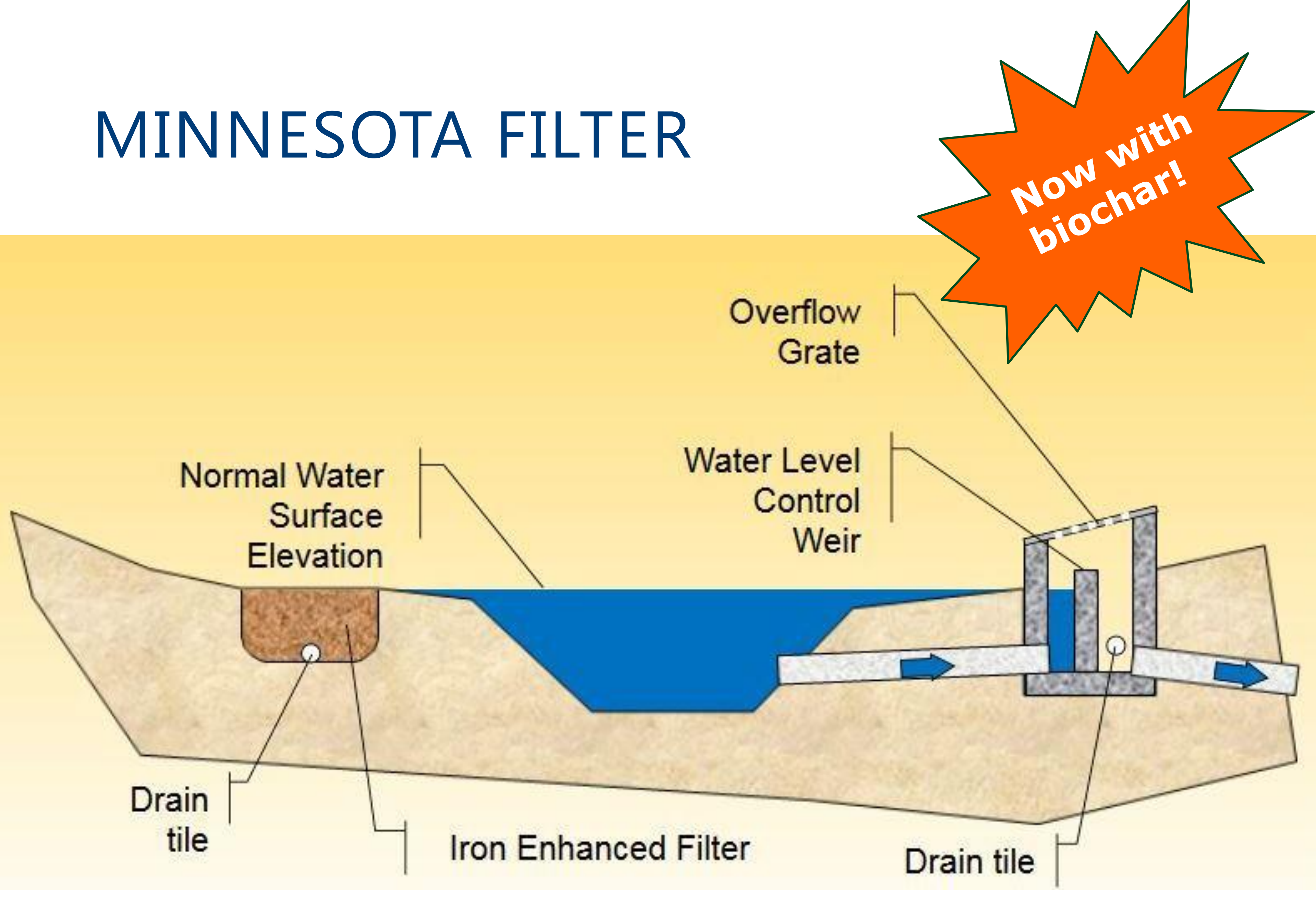
UTILITY BOX *E. COLI* REMOVAL



UTILITY BOX REMOVAL EFFICIENCY

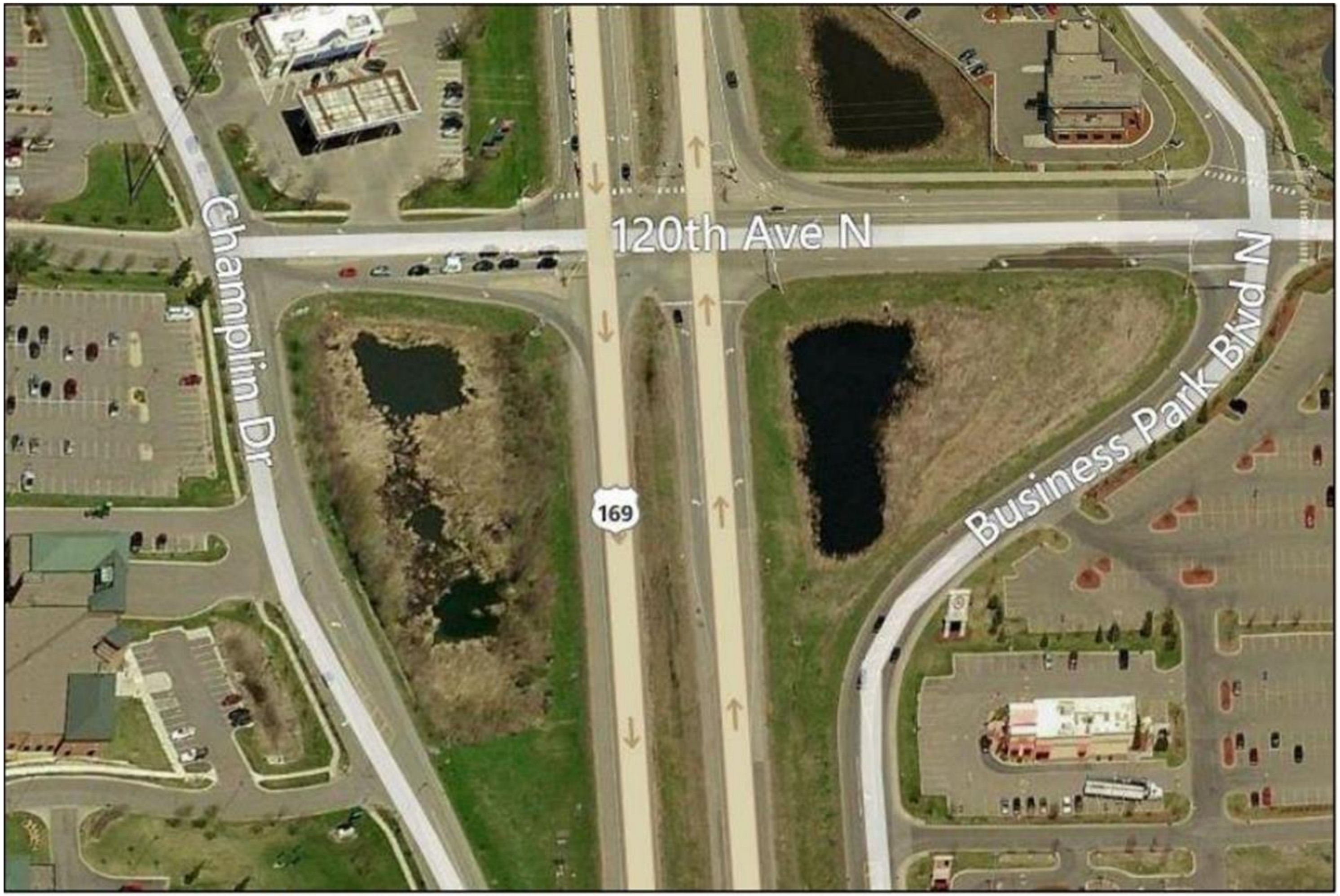


MINNESOTA FILTER



Graphic: Dr. Andy Erickson, SAFL

POND 1: CHAMPLIN CITY HALL



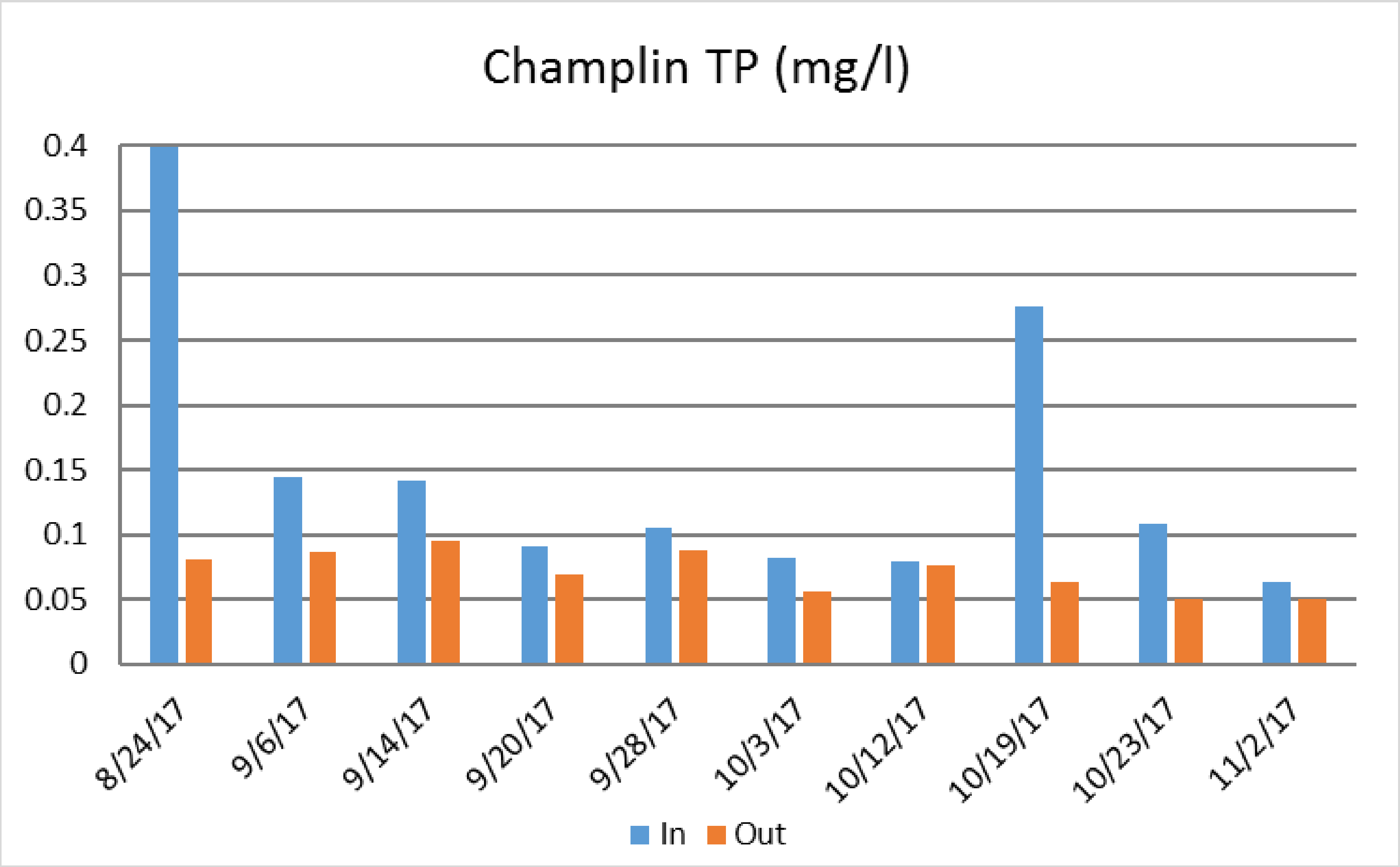
120th Avenue N/Champlin Dr Pond, Champlin

EXCAVATING THE SHELF

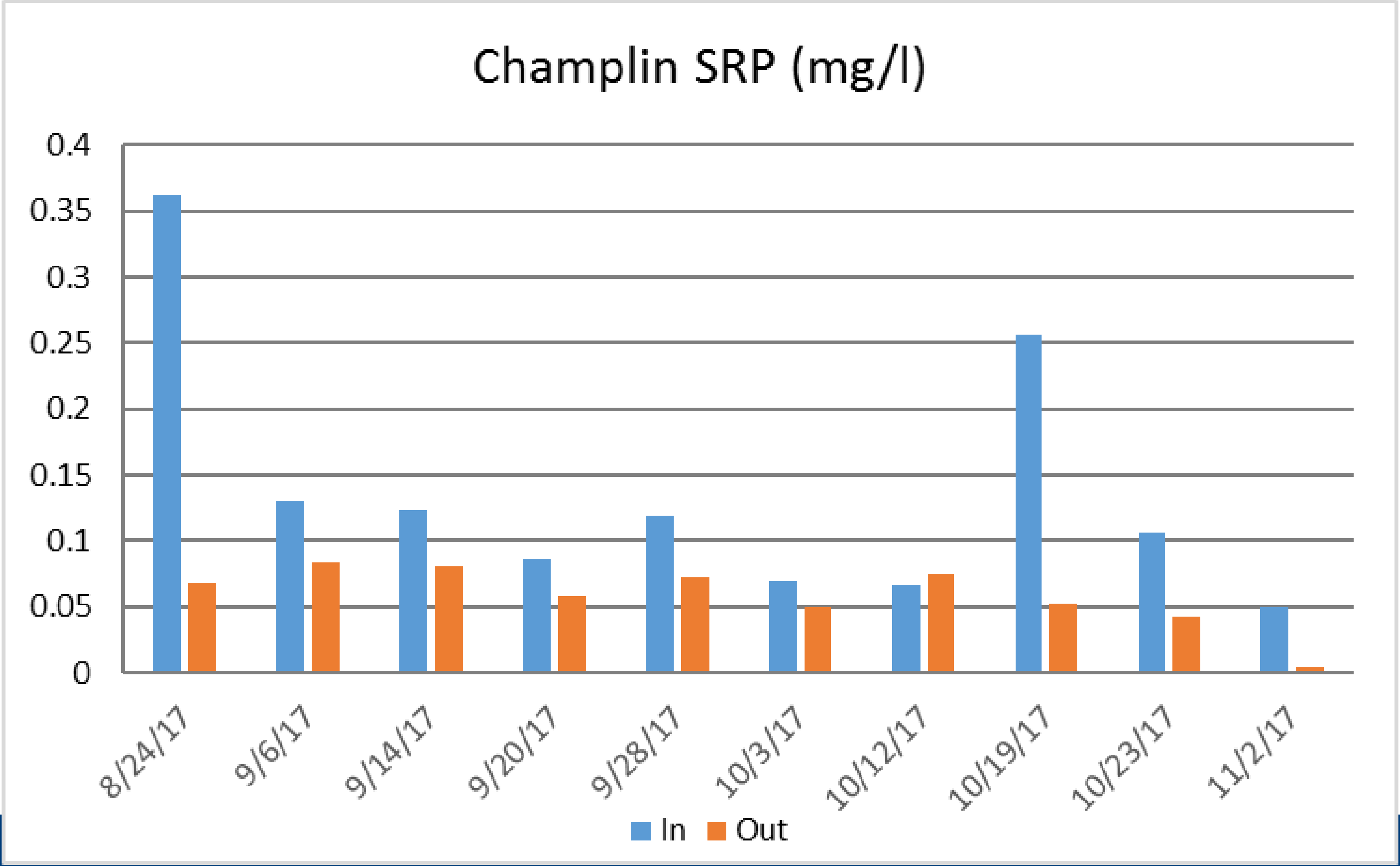
IRON AND BIOCHAR SAND FILTER

CHAMPLIN POND IN OPERATION

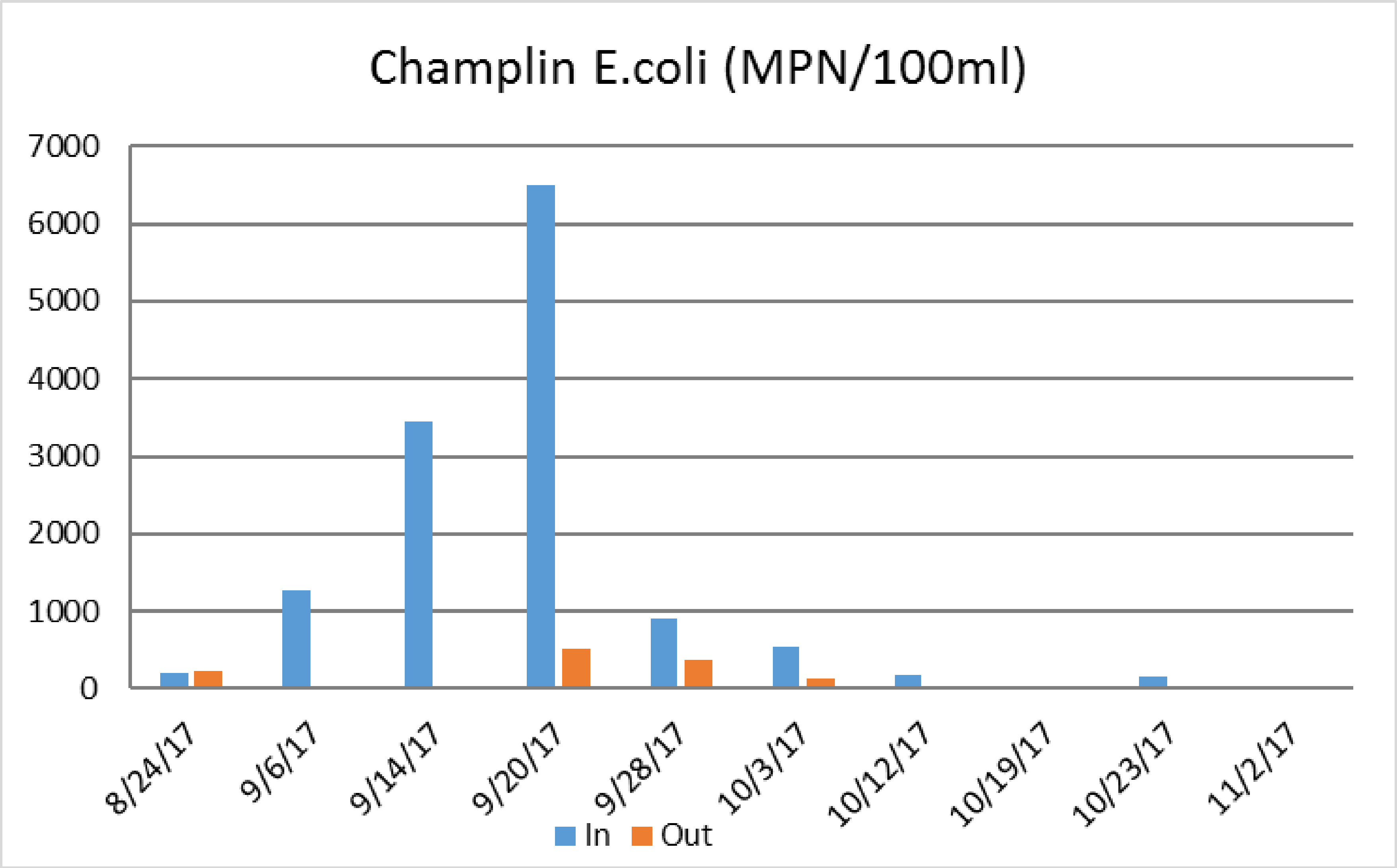
CHAMPLIN TP REMOVAL



CHAMPLIN SRP REMOVAL



CHAMPLIN *E. COLI* REMOVAL



POND 2: CRYSTAL NORTH LIONS PARK IRON/SAND ONLY

Crystal Lions Park Pond, Crystal

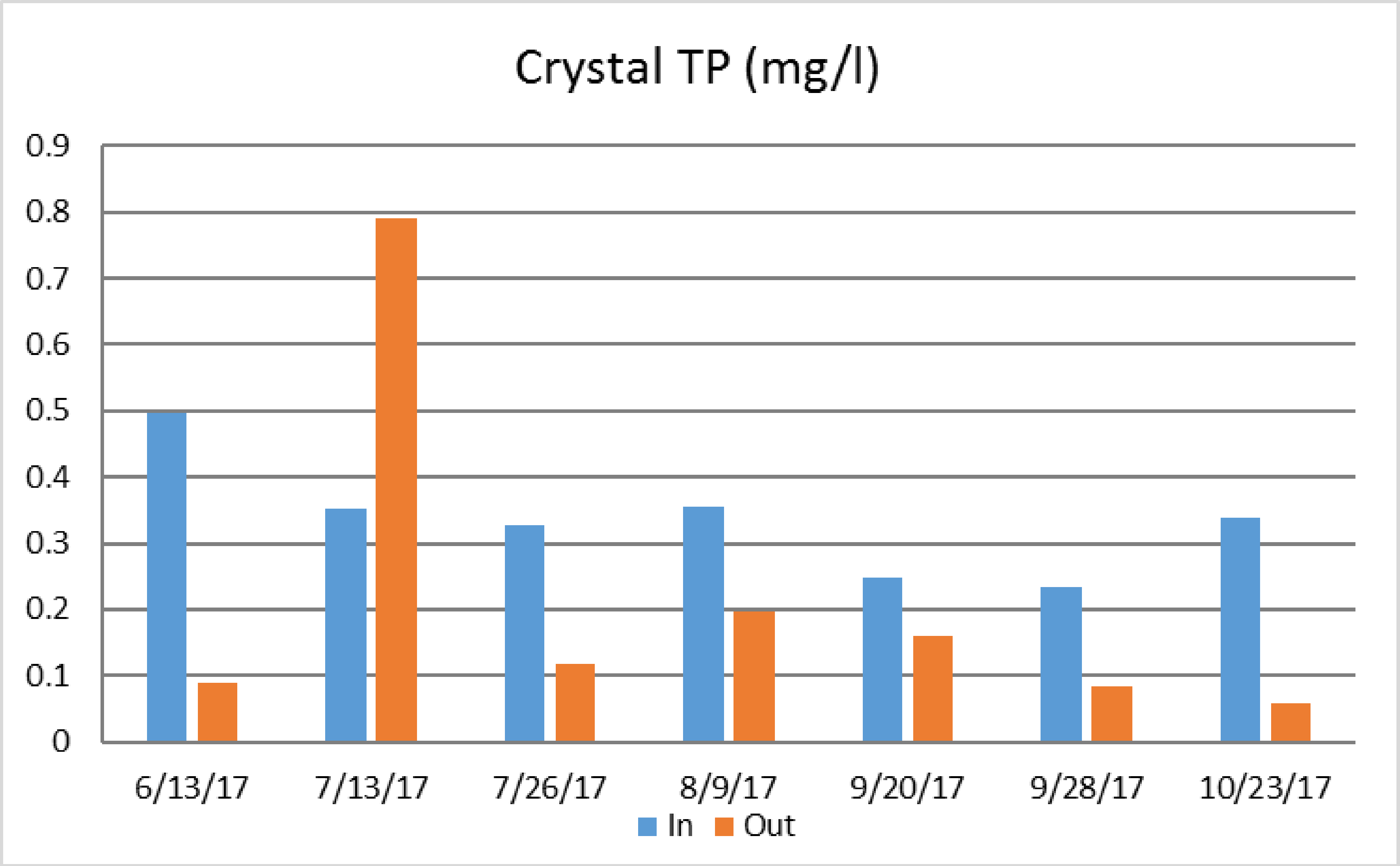
UNDERDRAIN INSTALLATION

CRYSTAL POND IN OPERATION

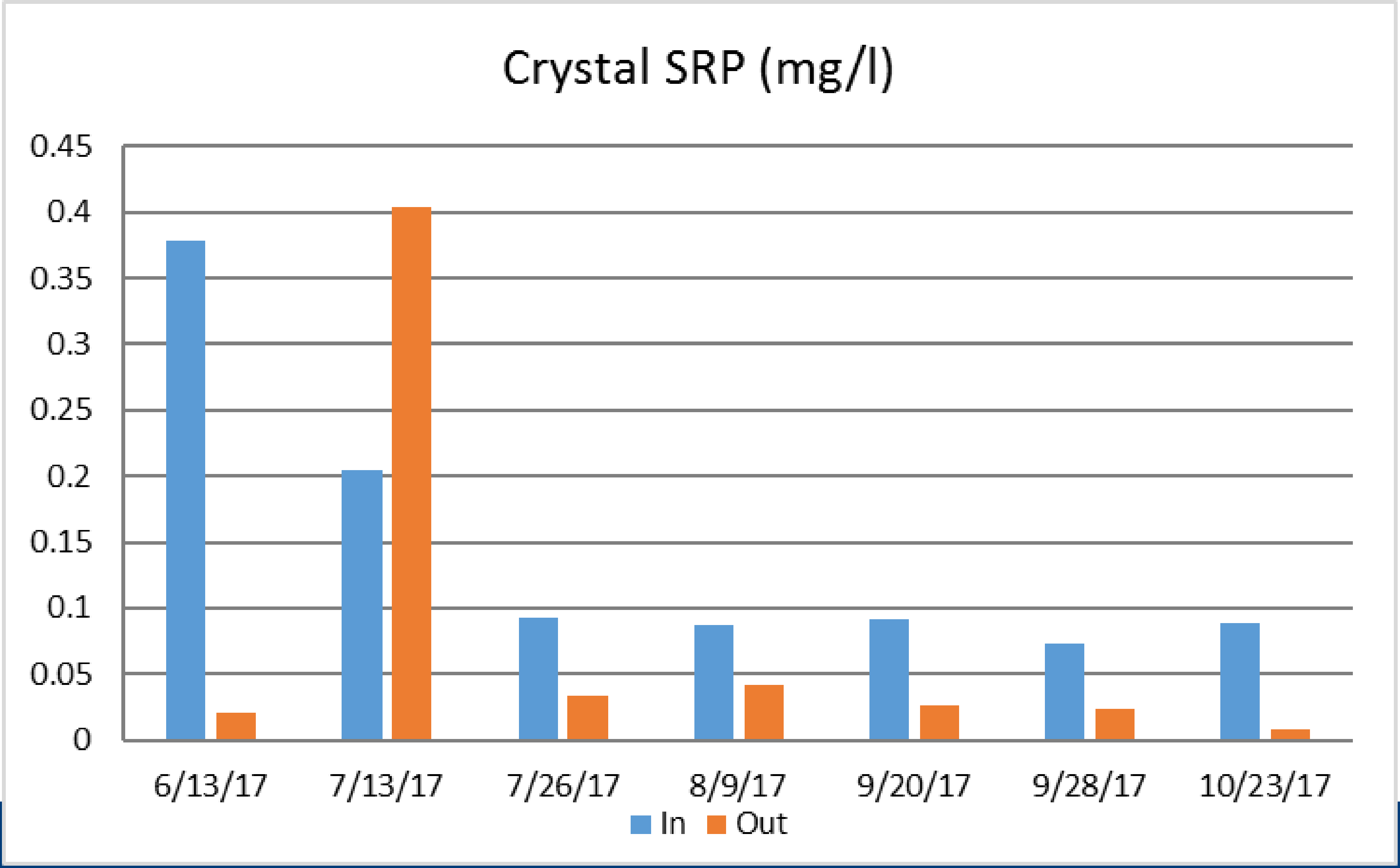
CRYSTAL FILTER OCTOBER 2017

SAMPLING

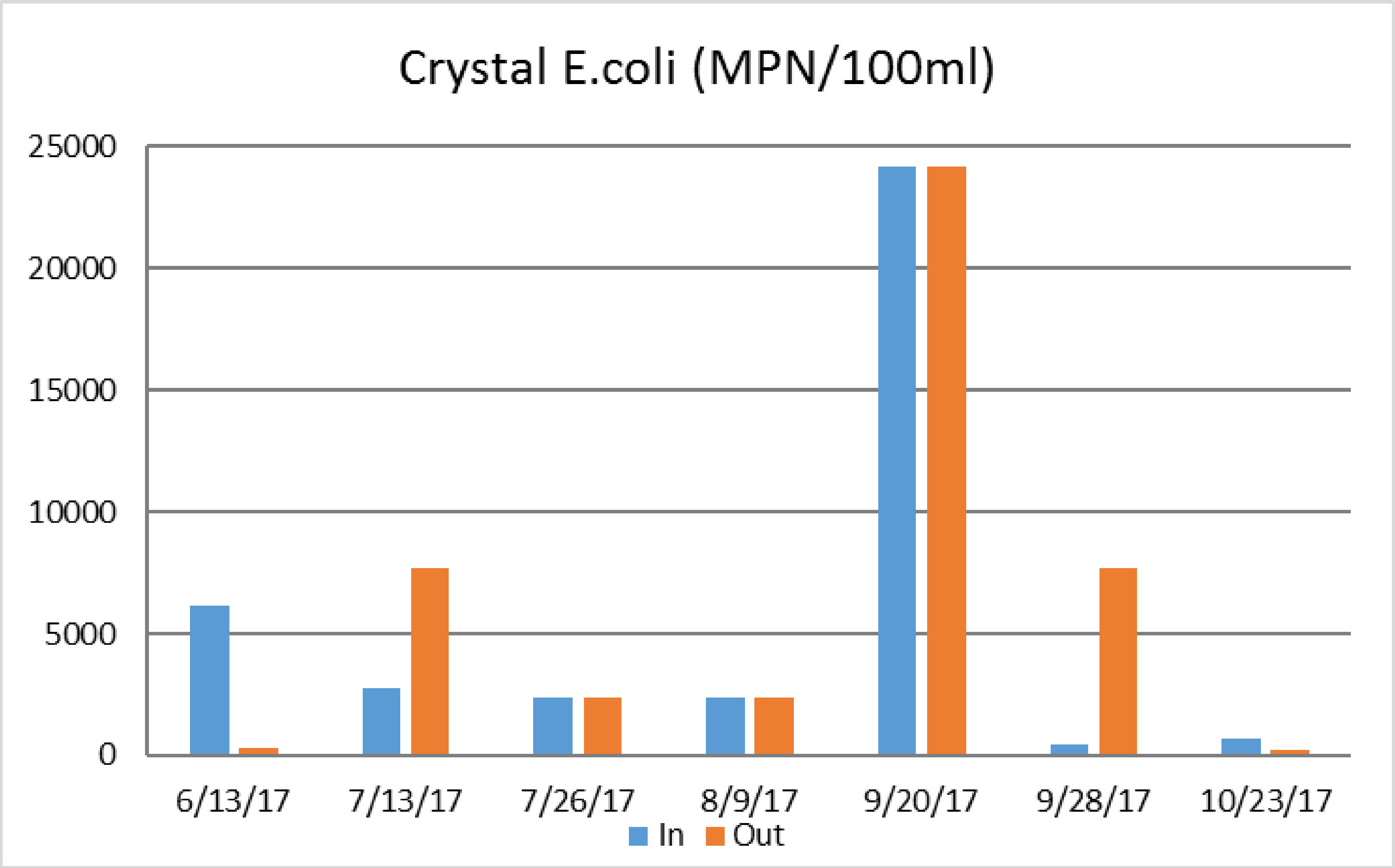
CRYSTAL TP REMOVAL



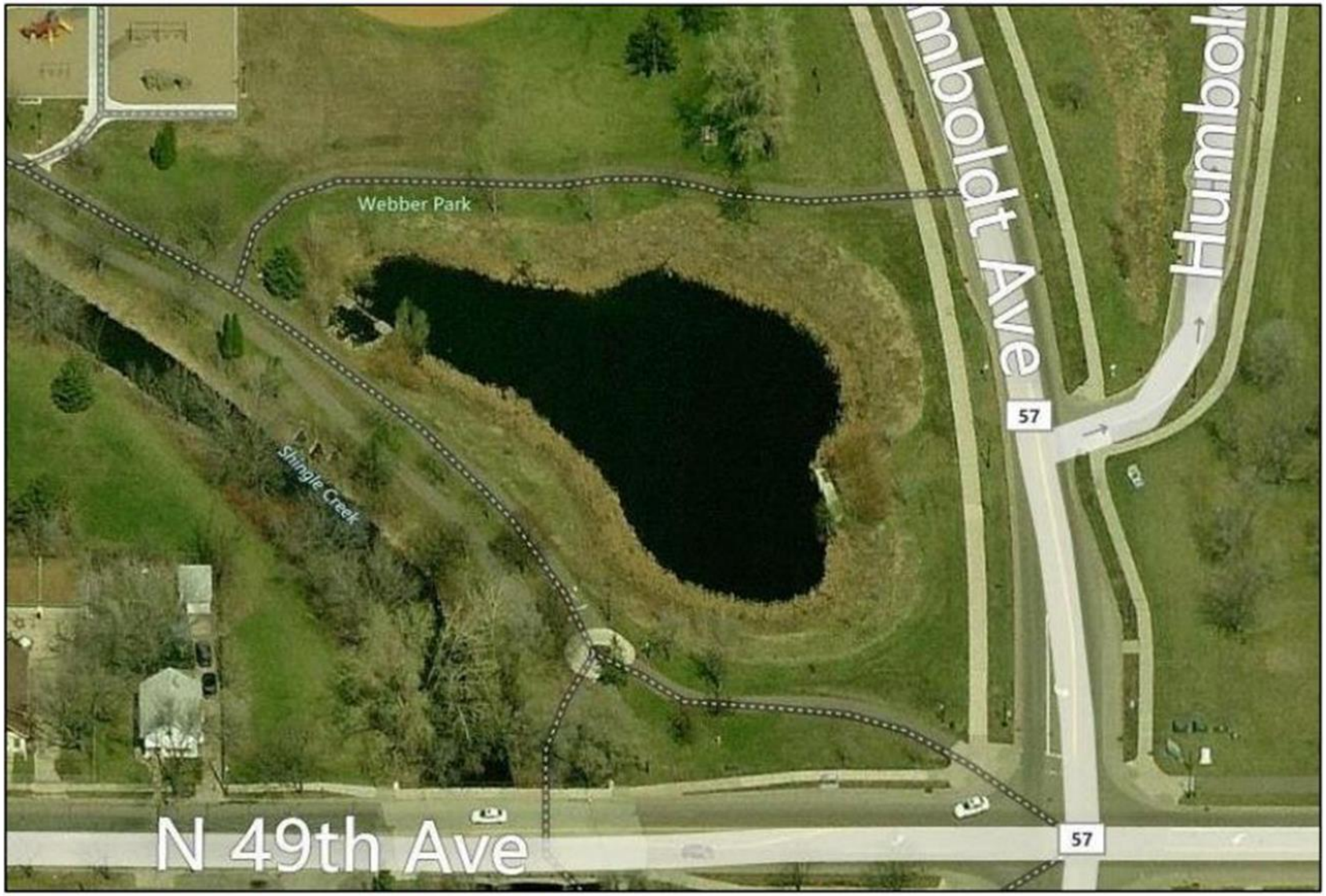
CRYSTAL SRP REMOVAL



CRYSTAL *E. COLI* REMOVAL (NO BIOCHAR, IRON/SAND ONLY)



POND 3: MINNEAPOLIS HUMBOLDT POND



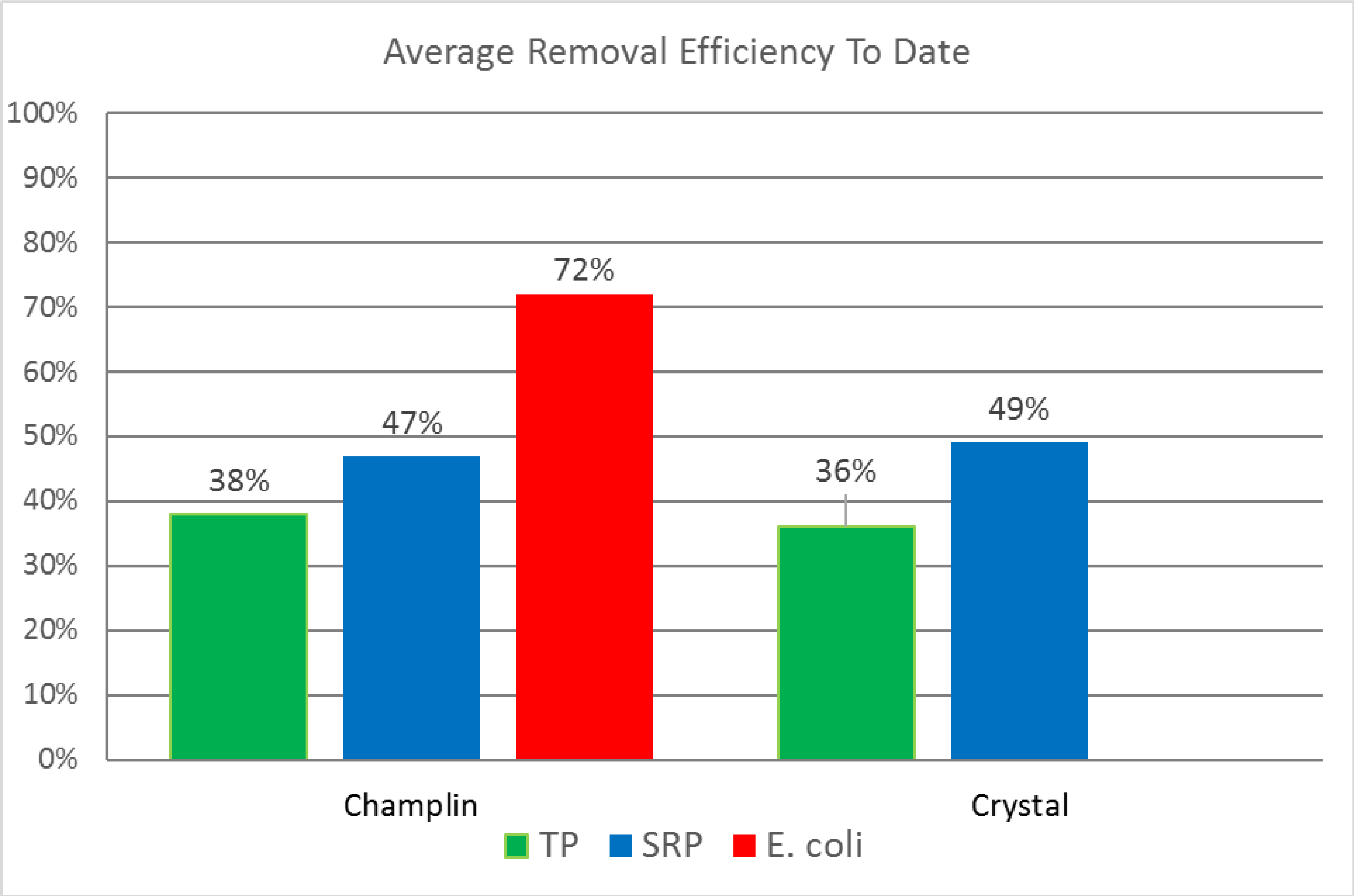
Humboldt Avenue N Pond, Minneapolis

INSTALLED FILTER

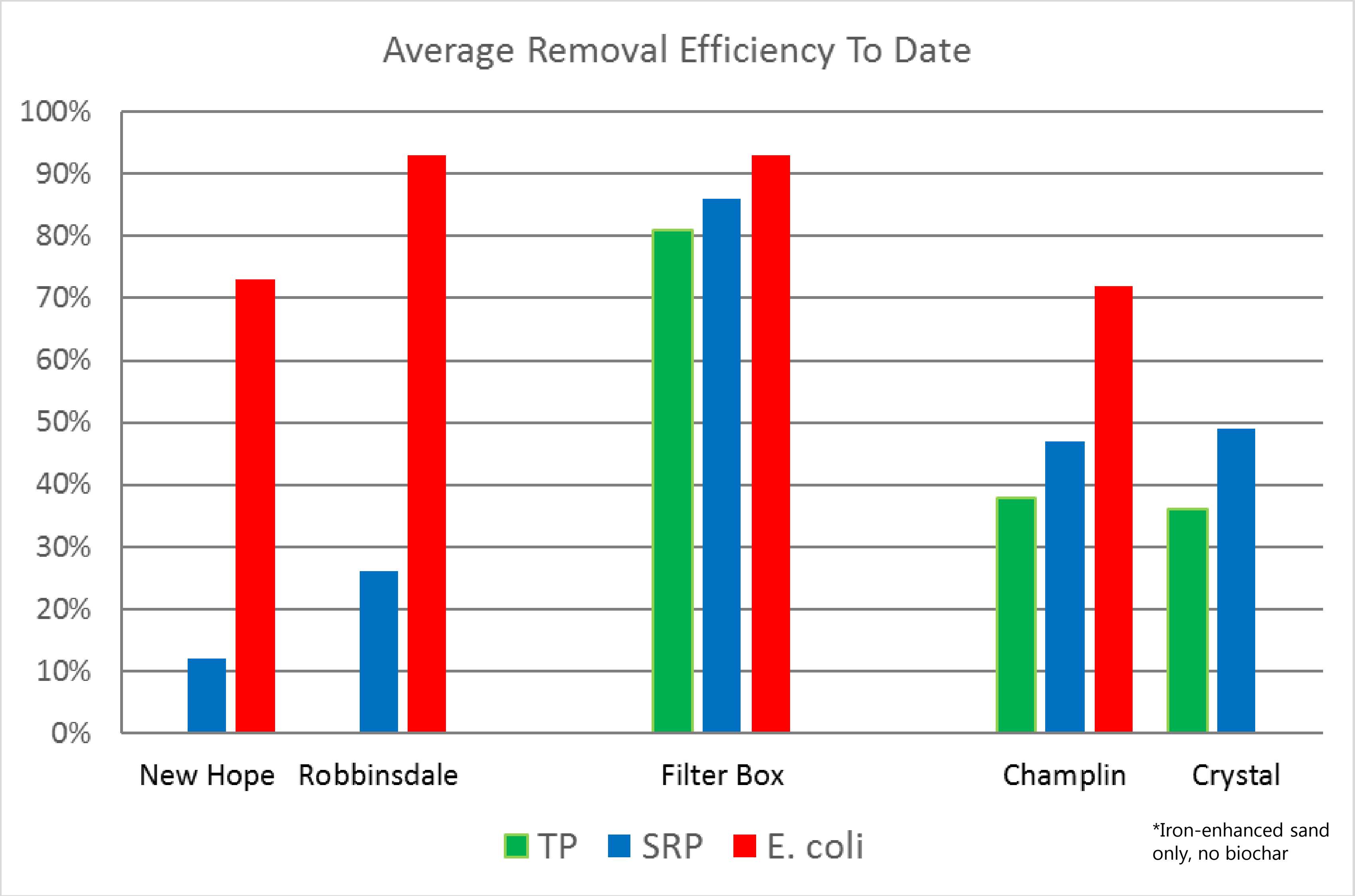
MINNEAPOLIS FILTER CONSTRUCTED

LEAKY WEIR = NO FILTER FLOW

POND FILTER REMOVAL EFFICIENCY



DATA SUMMARY

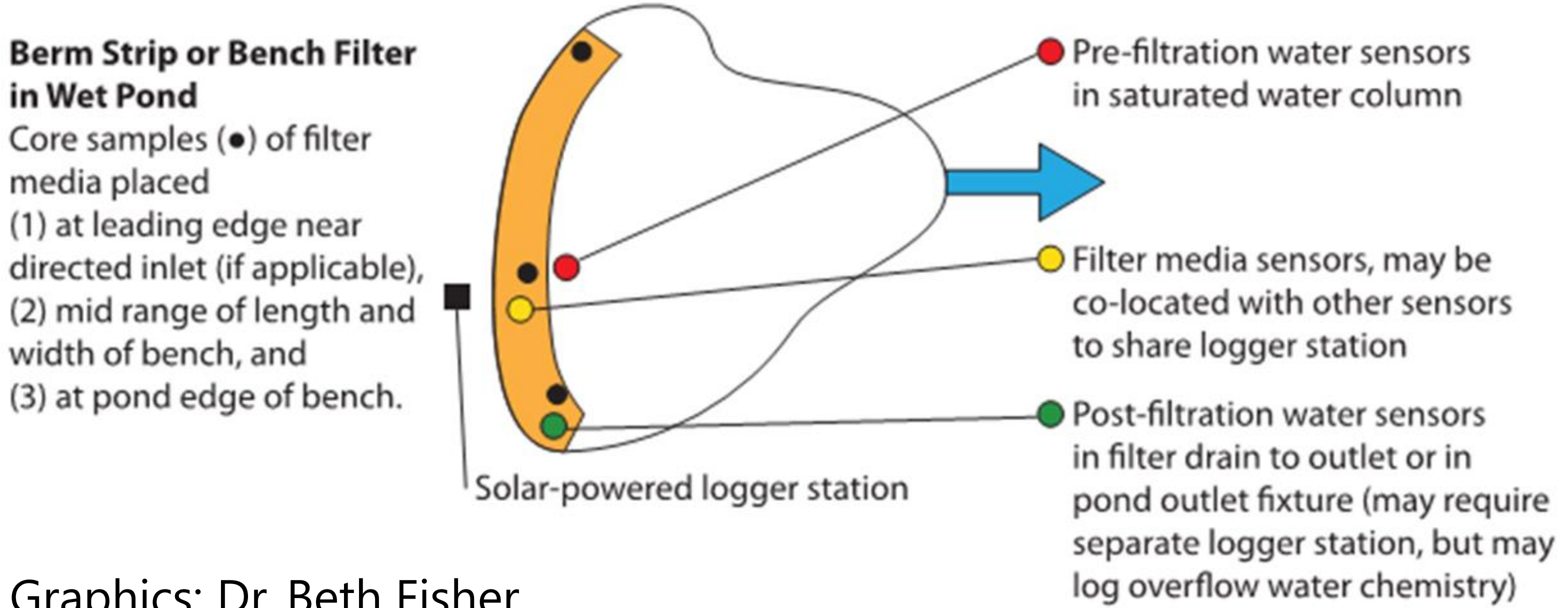


ADDITIONAL MONITORING

- Can we characterize media filter initial ability to remove phosphorus?
- What happens at the water-filter interface and does that affect filter effectiveness?
- Can we estimate the average life span based on treated volume and incoming water quality

ADDITIONAL MONITORING

- Install real time sensors to measure DO, oxidation reduction potential, water level, and conductivity
- Characterize the iron minerals within the filter to assess if iron minerology changes the filter's sorption capacity
- Directly measure the initial phosphorus sorption capacity of the filter media



Graphics: Dr. Beth Fisher

ADDITIONAL MONITORING STATUS

- Add sensors to measure DO, filter moisture, conductivity, and water depth
- Collect samples from each filter to assess physical characteristics
- Filter media being analyzed for several different parameters to assess initial conditions

Photos: Dr. Beth Fisher

SUMMARY

- Biochar – we know it works, but we don't know yet for how long
- Don't yet know how incoming water conditions impact the effectiveness of the filter
- Iron-sand appears to have minimal effect removing E. coli
- In catch basin inserts – accumulating leaf litter can overwhelm the phosphorus-removal capacity
- We don't know yet how biochar overwinters

QUESTIONS?

CONTACT INFORMATION

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