Iron Enhanced Sand Filtration for Dissolved Phosphorous Removal

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Outline

- The problem
- What is Iron Enhanced Sand Filtration (IESF)
- Field Applications
  - Urban surface sand filter
  - Agricultural surface sand filter
  - Pond perimeter sand filter
  - IESF rain garden
- Conclusions and lessons learned

Salt Creek, Porter County, IN

- Avg P = 3.2 mg/L
- Target = 0.08 mg/L
- Current watershed runoff: 732 lb P/year
- Watershed runoff target: 255 lb P/year
- 65% Reduction

Salt Creek Headwaters near Valparaiso, IN. Photo: Salt Creek Watershed Mgt Plan, 2008

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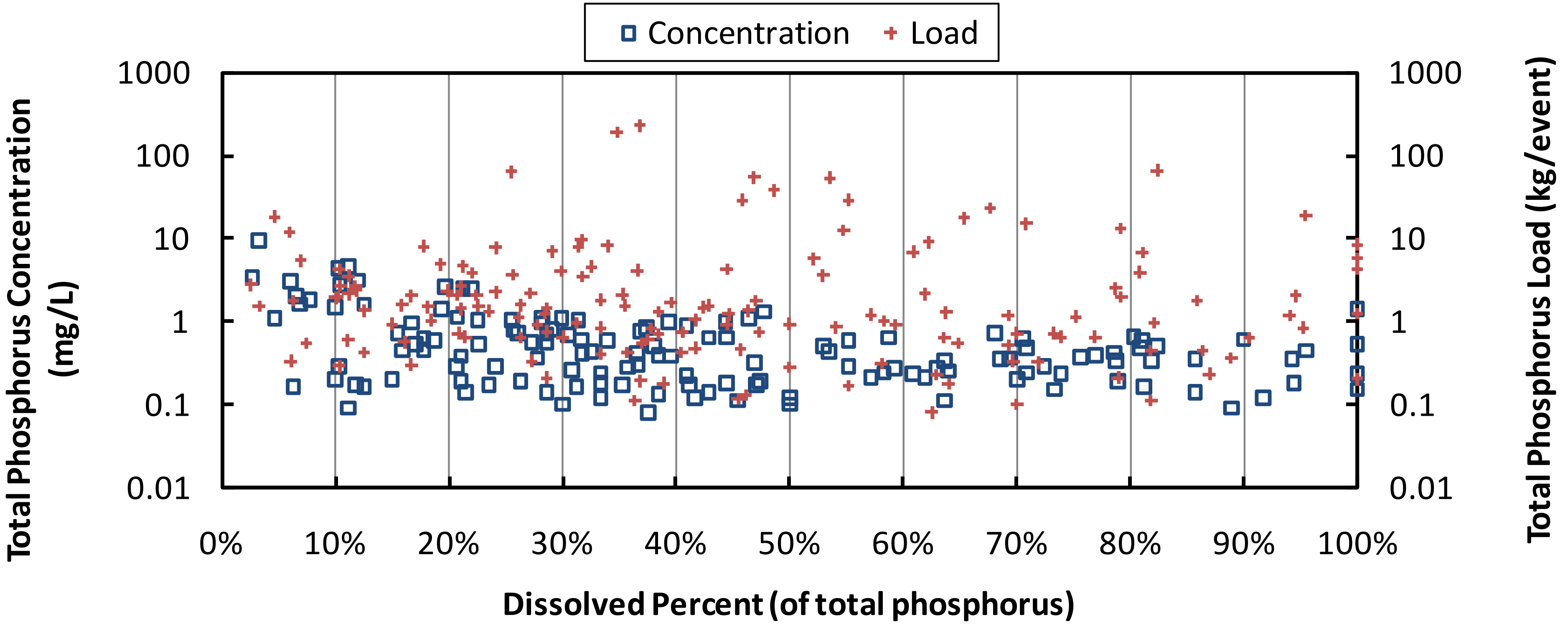
Phosphorous Loading

- **Average Values: Total=0.27 mg/L; Dissolved=0.12 mg/L**
    - **44% Dissolved and 56% particulate, on average**



Adapted from Brezonik and Stadelmann, 2002
Image Courtesy of Andy Erickson

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Must Target Dissolved Phosphorus

- TMDL's often target 60% or more P reduction
- Particulate P concentrations: 56% on average (or less)
- Dissolved P is more bioavailable
- Conventional SCM's typically do not retain dissolved P
- Some practices, like rain gardens, may export P

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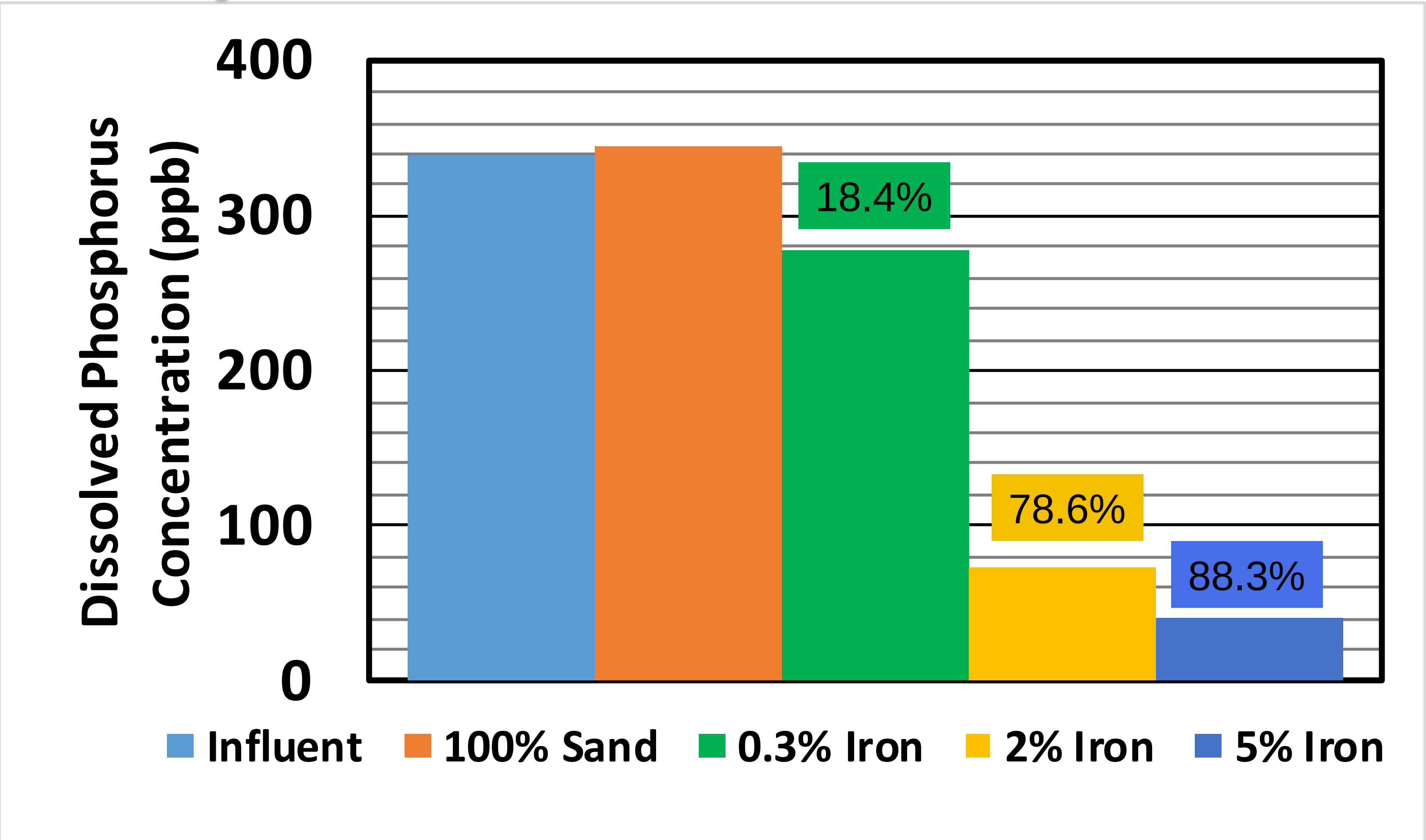
Iron-Enhanced Sand Filtration

- Research at U of MN used steel wool
- Sand: ASTM C-33
- Column experiments with 0%, 0.3%, 2%, 5% iron by weight
- Iron rusts (+) & captures phosphate (-)

Column Experiments at U of MN.
Photo courtesy of Andy Erickson

Experimental Results at U of MN



Treated depth = 189 m

Erickson et al. 2012

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Field Applications of IESF

- Iron shavings: 5-7% by weight
- Add ~5-10% to total cost of new filter
- Capable of retaining TSS, particulate and dissolved P
- 40+ Installed

Iron enhanced surface sand filter, Maplewood, MN. Photo: RWMWD

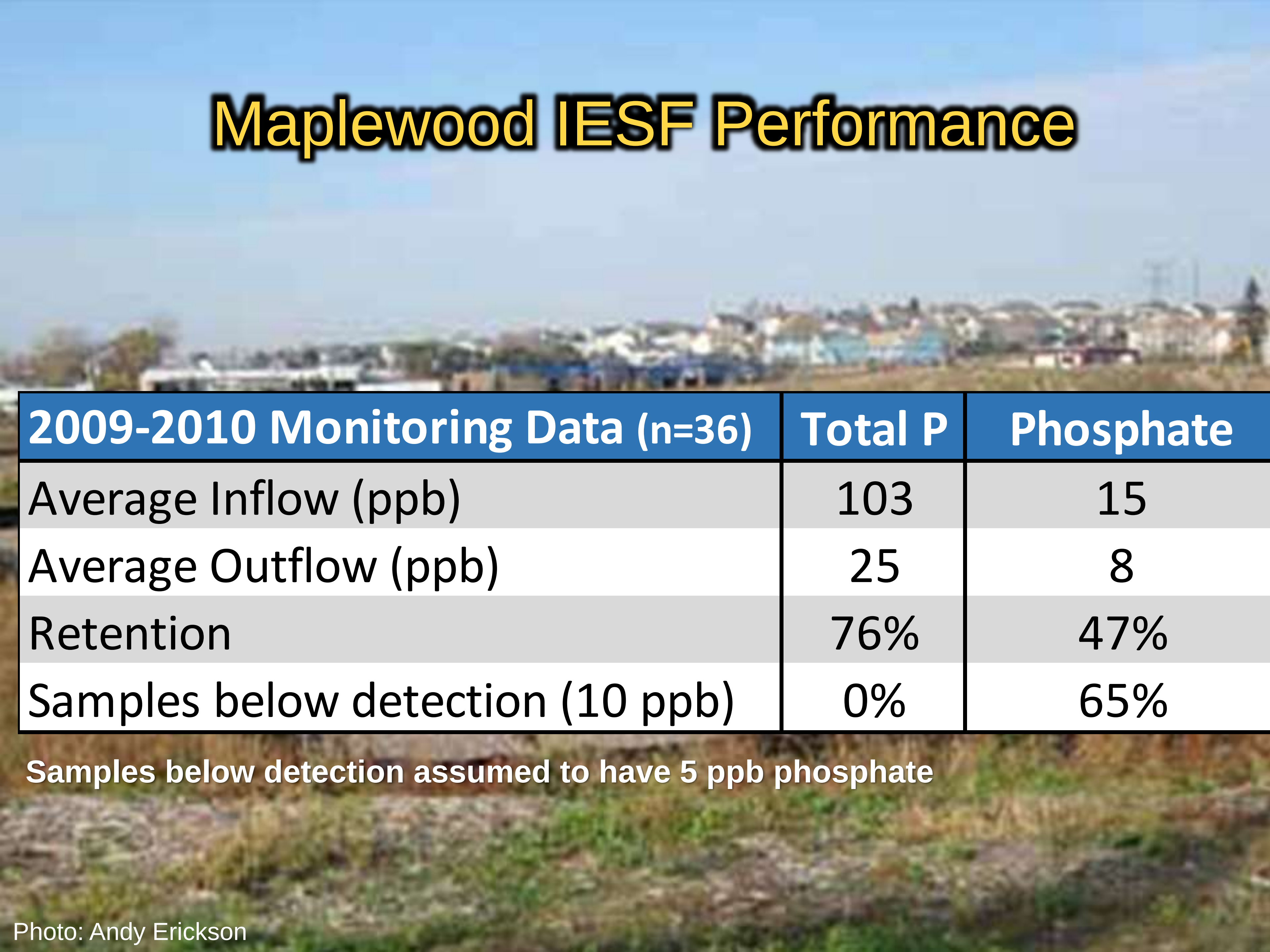
Maplewood, MN IESF

- 5% iron, mixed in parking lot
- Sand filter area = 0.27 acres
- Storage volume = 0.65 acre-feet
- Watershed: 8 acres, 81% impervious, mostly HSG B soils

Photo: RWMWD


Maplewood IESF Performance
Photo: Andy Erickson

Maplewood IESF Performance



2009-2010 Monitoring Data (n=36)	Total P	Phosphate
Average Inflow (ppb)	103	15
Average Outflow (ppb)	25	8
Retention	76%	47%
Samples below detection (10 ppb)	0%	65%

Samples below detection assumed to have 5 ppb phosphate

Photo: Andy Erickson

Martha Lake, MN IESF

- **Installed in 2012**
- **Watershed: 19 acres of farmland**
- **Discharges to Martha Lake**

Martha Lake, MN IESF

IESF Design:

- **20 feet by 50 feet in area**
- **1 foot thick mix of ASTM C-33 sand and 5% iron shavings**
- **6 inches of pea gravel with a perforated underdrain system (2, 6-inch PVC pipes)**
- **Sand and gravel lined with an impermeable liner**

Photo: Erickson et al. 2017

Martha Lake, MN IESF

Construction: Excavation complete

Photo: Erickson et al. 2017

Martha Lake, MN IESF

Construction: Impermeable liner

Photo: Erickson et al. 2017

Martha Lake, MN IESF

Construction: Iron shavings spread on surface

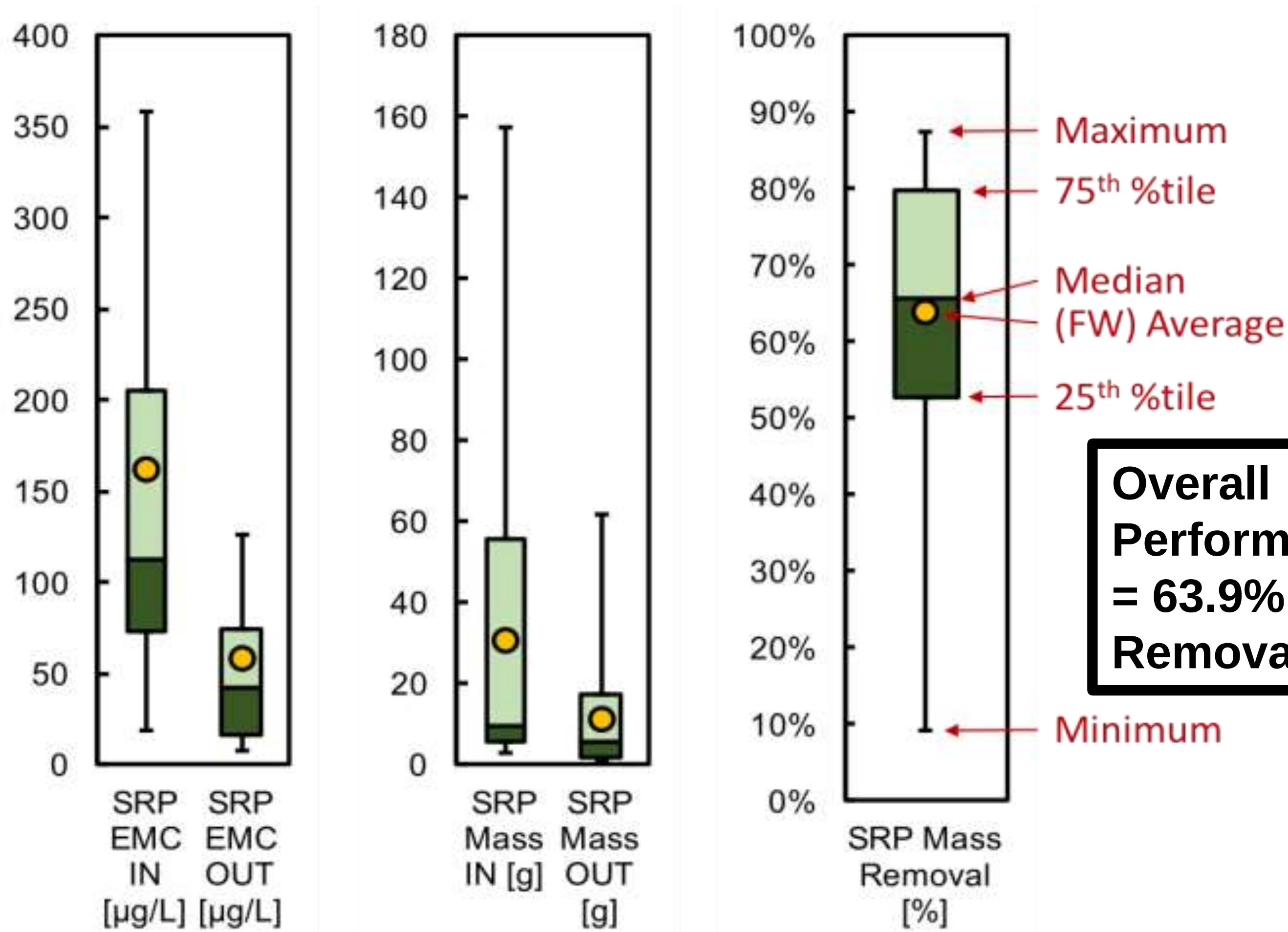
Photo: Erickson et al. 2017

Martha Lake, MN IESF

Construction: Iron shavings spread on surface. Plywood is to protect liner from rototiller blades.

Photo: Erickson et al. 2017

Martha Lake, MN IESF Performance



Overall Performance = 63.9% SRP Removal

2015-2016 Performance (n = 33, treated depth = 290 m)

(Erickson et al. 2017)

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Martha Lake, MN IESF Maintenance

Photo: Erickson et al. 2017

Martha Lake, MN IESF Maintenance

<u>IESF Routine Maintenance</u>:

- **Remove vegetation, algae, iron ochre**
- **Scrape and level surface**
- **Once or twice per month (May-Sept)**
- **1-2 people, < 1 hr each per visit**

<u>IESF Non-Routine Maintenance</u>:

- **May 2016: Remove substantial amounts of build up (2 people, 2 hrs each)**

<u>Future Potential Maintenance</u>:

- **Scrape and remove top layer**
- **Replace iron/sand mix that was removed**
- **Remove and replace entire media bed**

Photo: Erickson et al. 2017

Prior Lake Pond Perimeter Trenches

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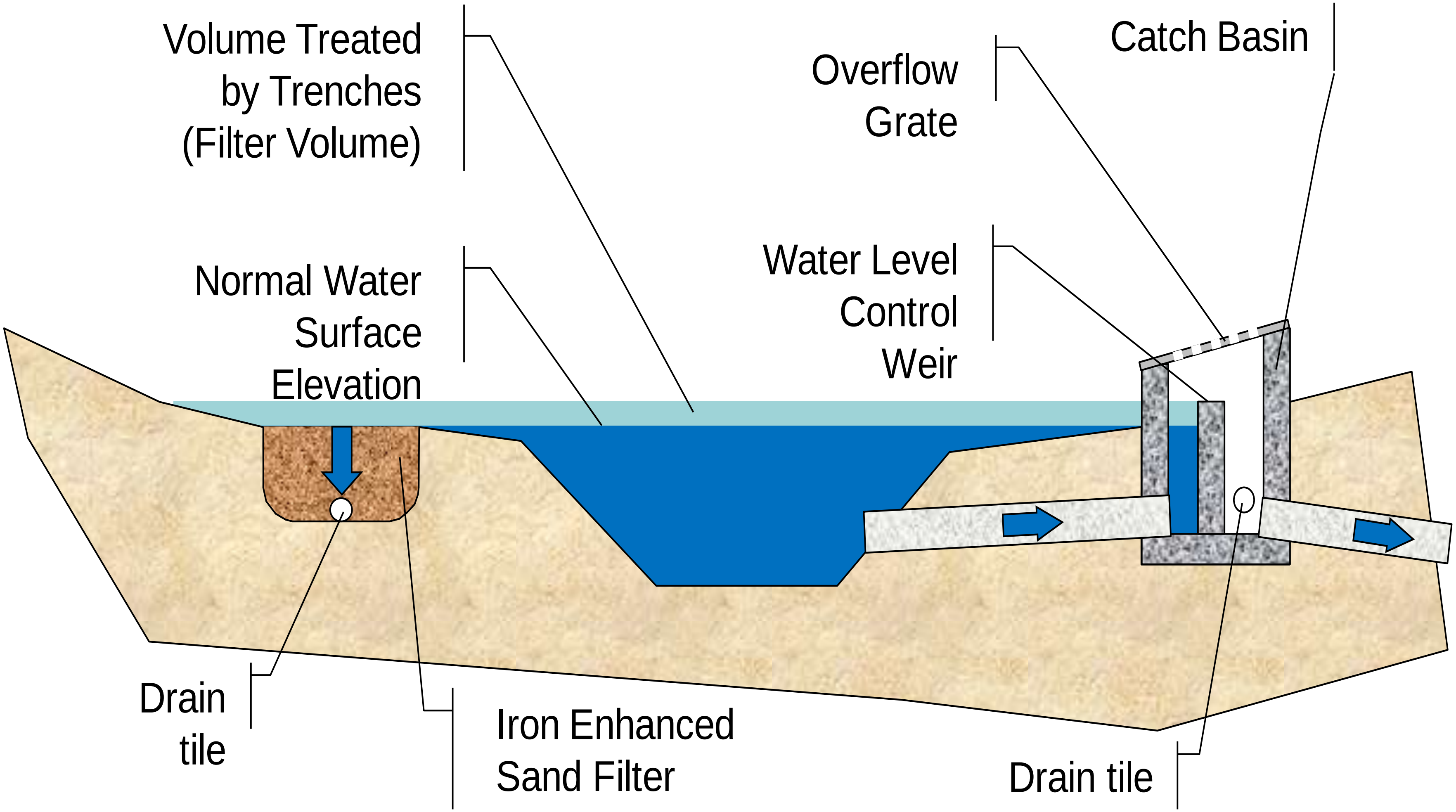
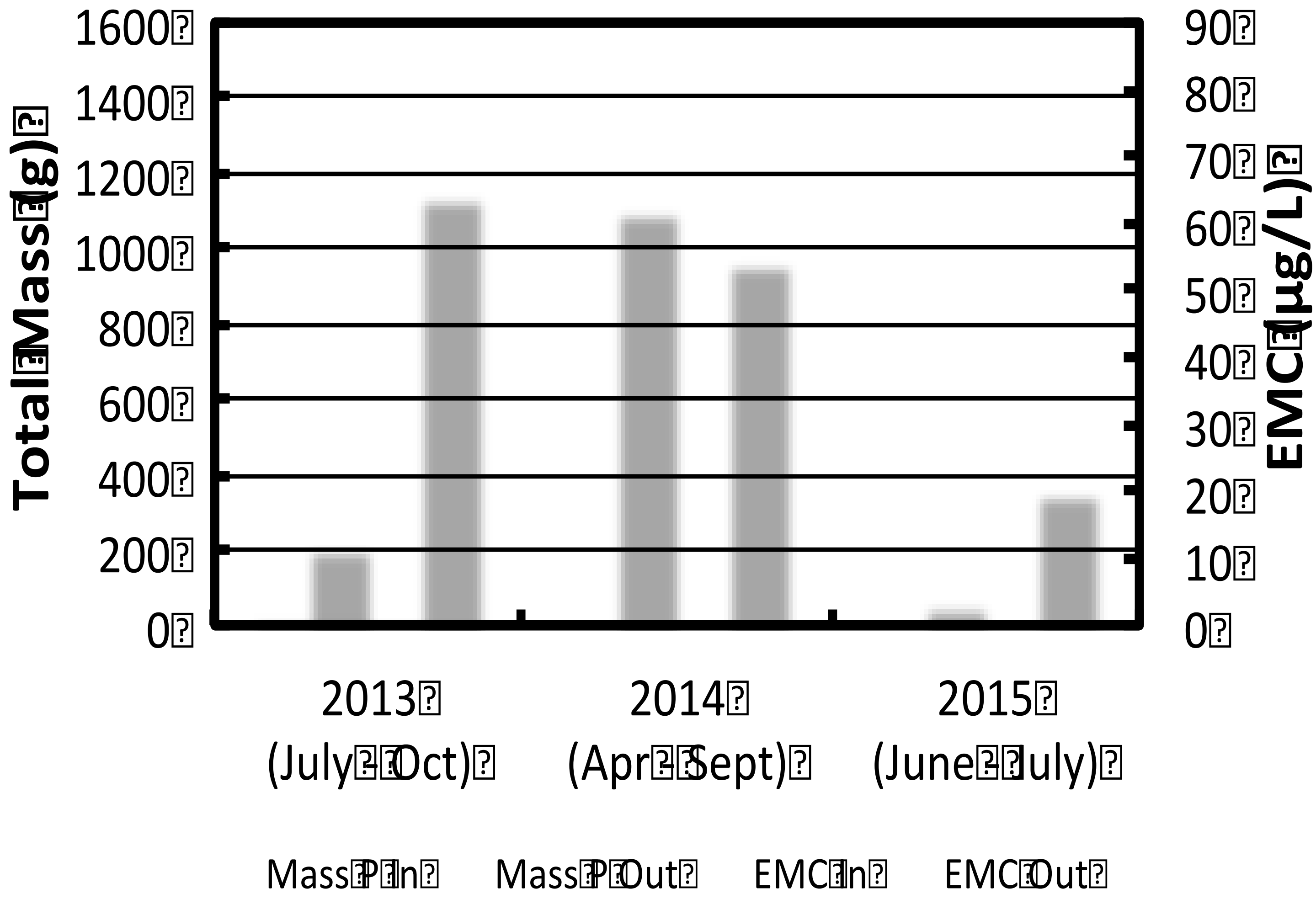


2013-2015 Performance



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2014 Monitoring Results

Event	Total Mass Loading Influent Load (grams)	Total Mass Loading Effluent Load (grams)	% Mass Load Retained
1	0.6	3.7	-470
2 to 5	425	310	27
6	13	31	-127
7	35	42	-21
8	74	42	42
9	23	35	-51
10	0.3	3.1	-990
11	118	71	40
Total	**689**	**538**	**22**

Pond Perimeter Trenches-Investigation

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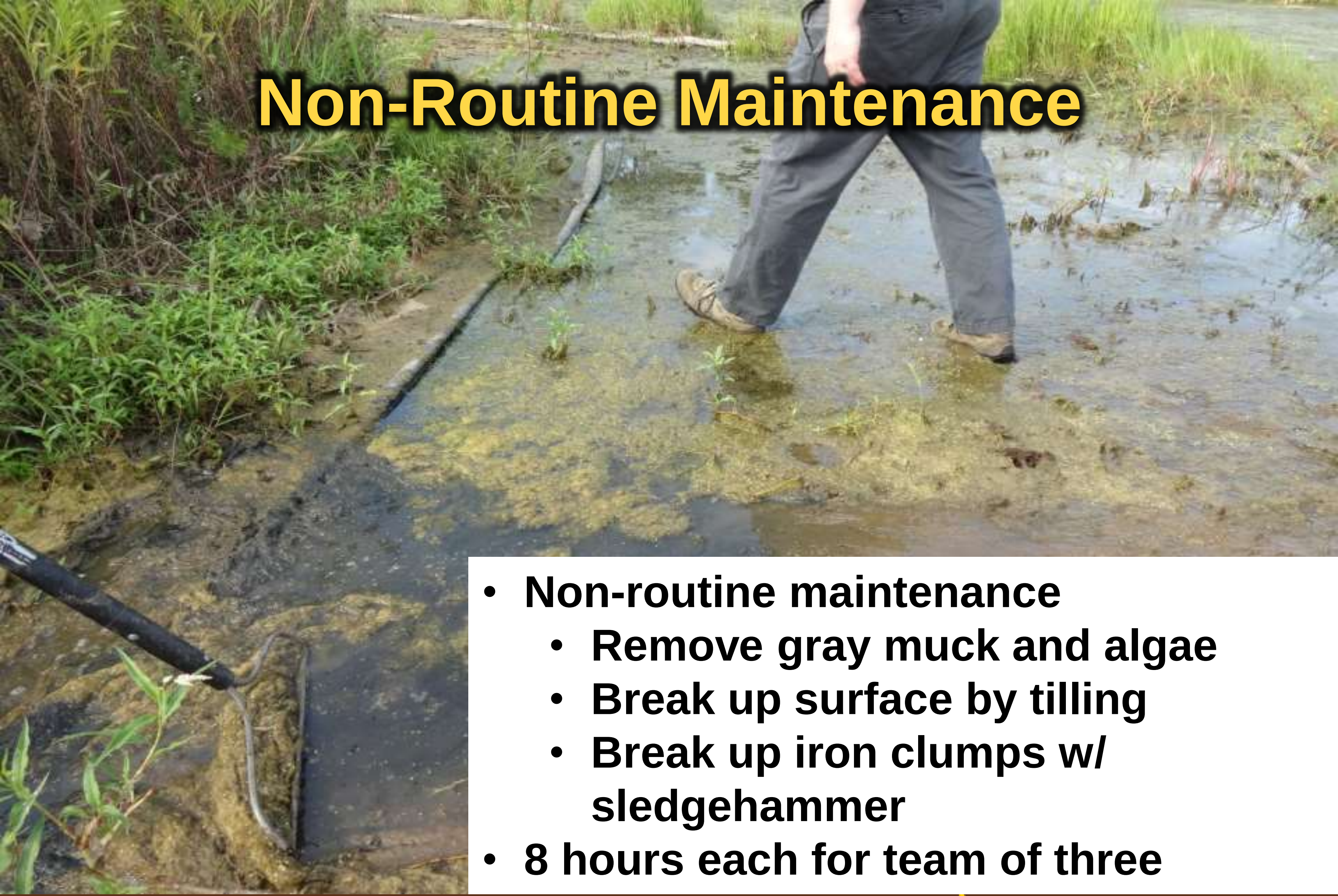
Pond Perimeter Trenches-Investigation

- Routine maintenance < 1 month
  - Pulling or raking weeds
  - Remove deposited vegetation
  - Raking surface (disturb filter to depth of 1-3”)
- Need for non-routine maintenance

Non-Routine Maintenance



- Non-routine maintenance
  - Remove gray muck and algae
  - Break up surface by tilling
  - Break up iron clumps w/ sledgehammer
- 8 hours each for team of three

Non-Routine Maintenance

Non-Routine Maintenance

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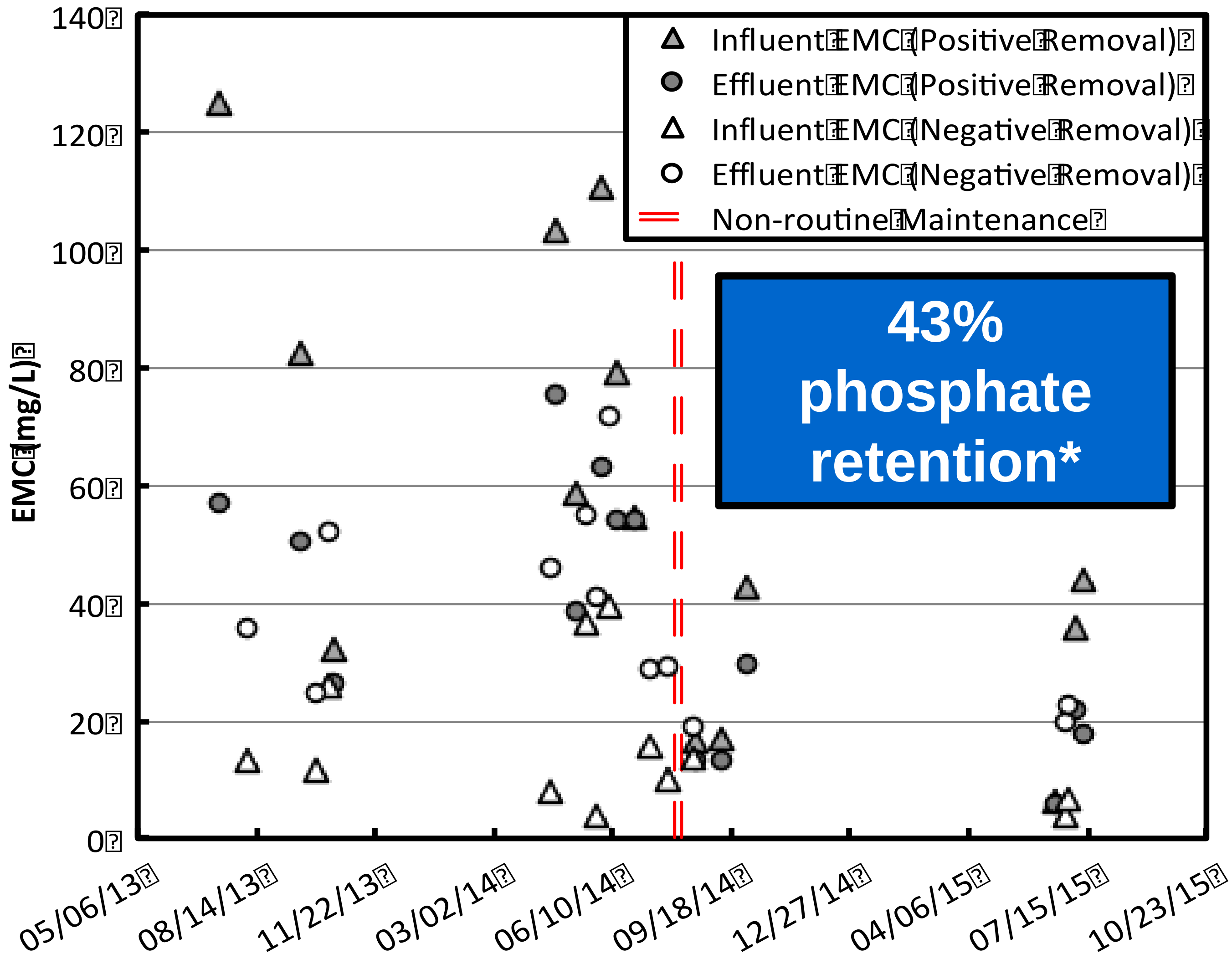
Impact of Non-Routine Maintenance



* After non-routine maintenance

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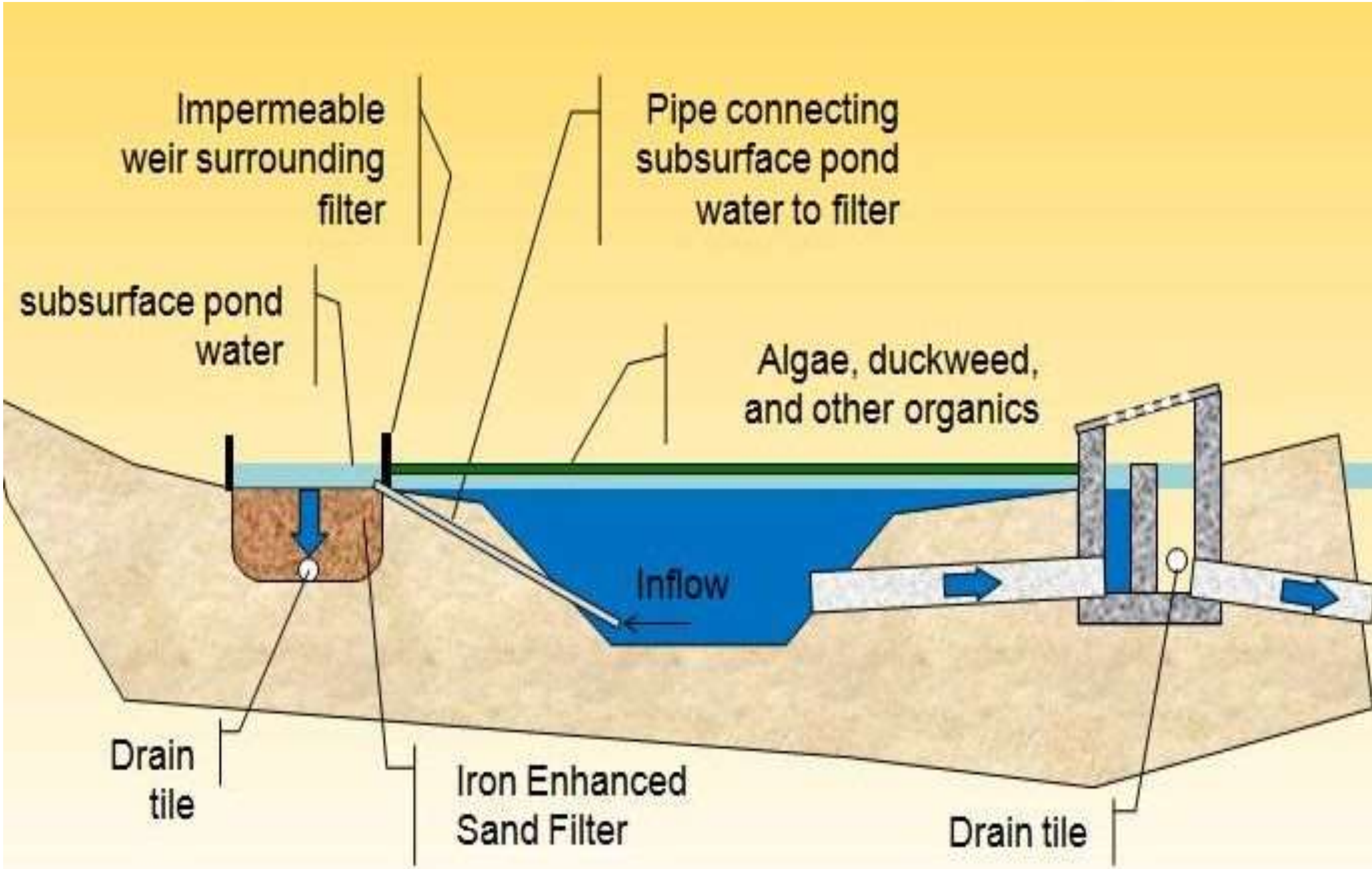
Proposed Revised Design



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IESF Capacity/Lifespan

Application	Estimated Treated Depth (m)	Average Influent (µg/L)	Influent Mass (g/m^2)	Phosphate Load Captured
Laboratory (5%)	189	340	64.3	88%
Surface Sand (Agricultural)	290	162	47.0	64%
Pond-Perimeter Trench (Urban)	548	69	37.8	43%*

***After non-routine maintenance**

Slide courtesy of Andy Erickson

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Rain Gardens

- **Aesthetically pleasing**
- **Reduce runoff volume**
- **Remove TSS & metals**
- **Often export PO_4^{-3}**
  1. **Exported 100% more P**
  2. **Influent P = 0.13 mg/L, effluent P up to 0.50 mg/L**
  3. **Others found similar results**

Proposed New Design: Iron-Enhanced Rain Gardens

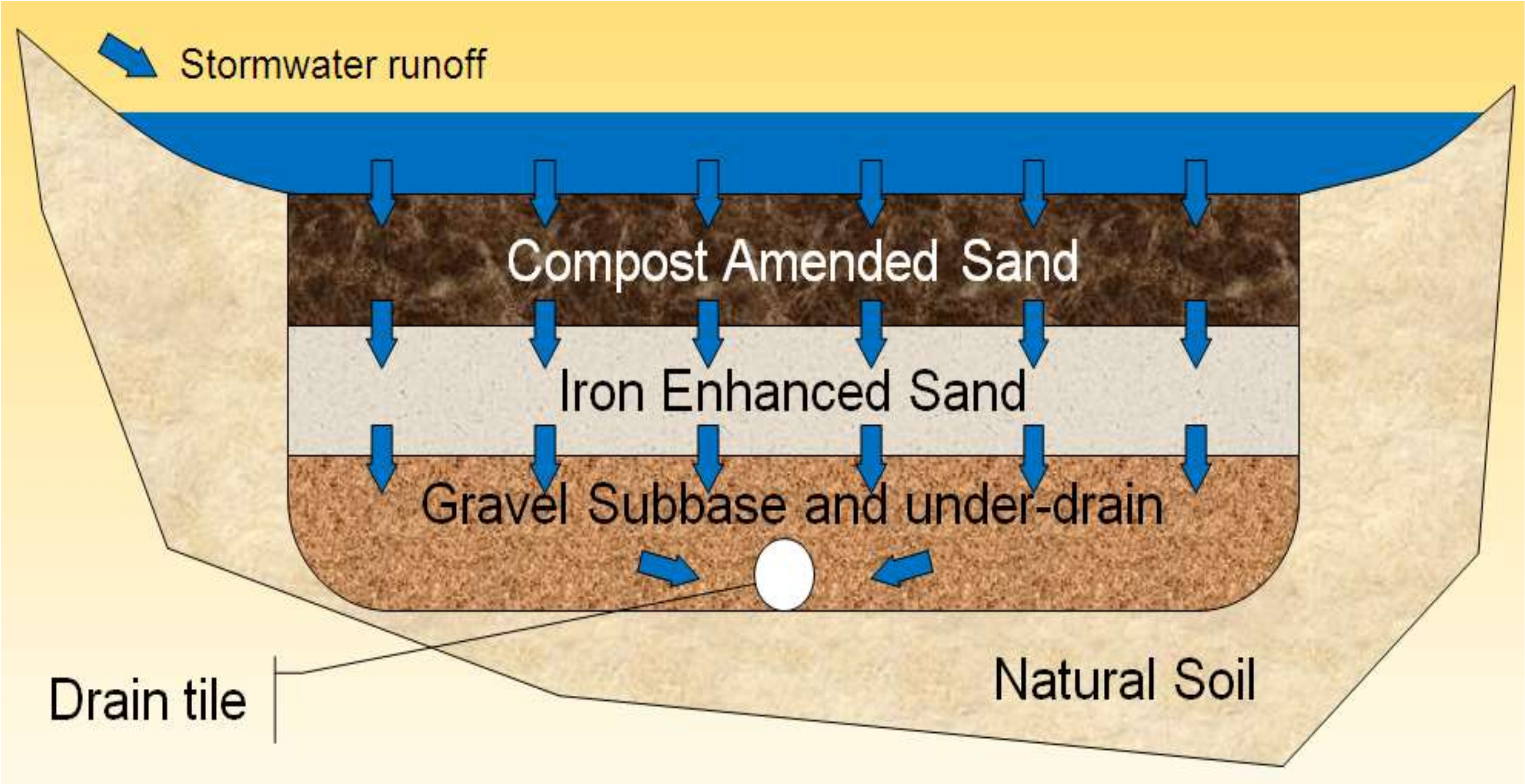

Image: Andy Erickson

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Experimental Iron-Enhanced Rain Gardens

- **Assess gardens constructed in plastic boxes with drain tile**
  - **15 cm gravel (2.5-5 cm) layer**
  - **46 cm sand layer**
  - **30 cm compost (15%) and sand (85%) mix**

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Influent Phosphorous Levels

- **Influent Total Phosphorous**
  - **Average of 0.54 mg/L P**
- **Influent SRP (i.e. dissolved phosphorus)**
  - **Average of 0.50 mg/L P**
- **Stormwater Median Values (Maestre and Pitt 2005)**
  - **TP = 0.27 mg/L (COV = 1.5)**
  - **SRP = 0.13 mg/L (COV = 1.6)**

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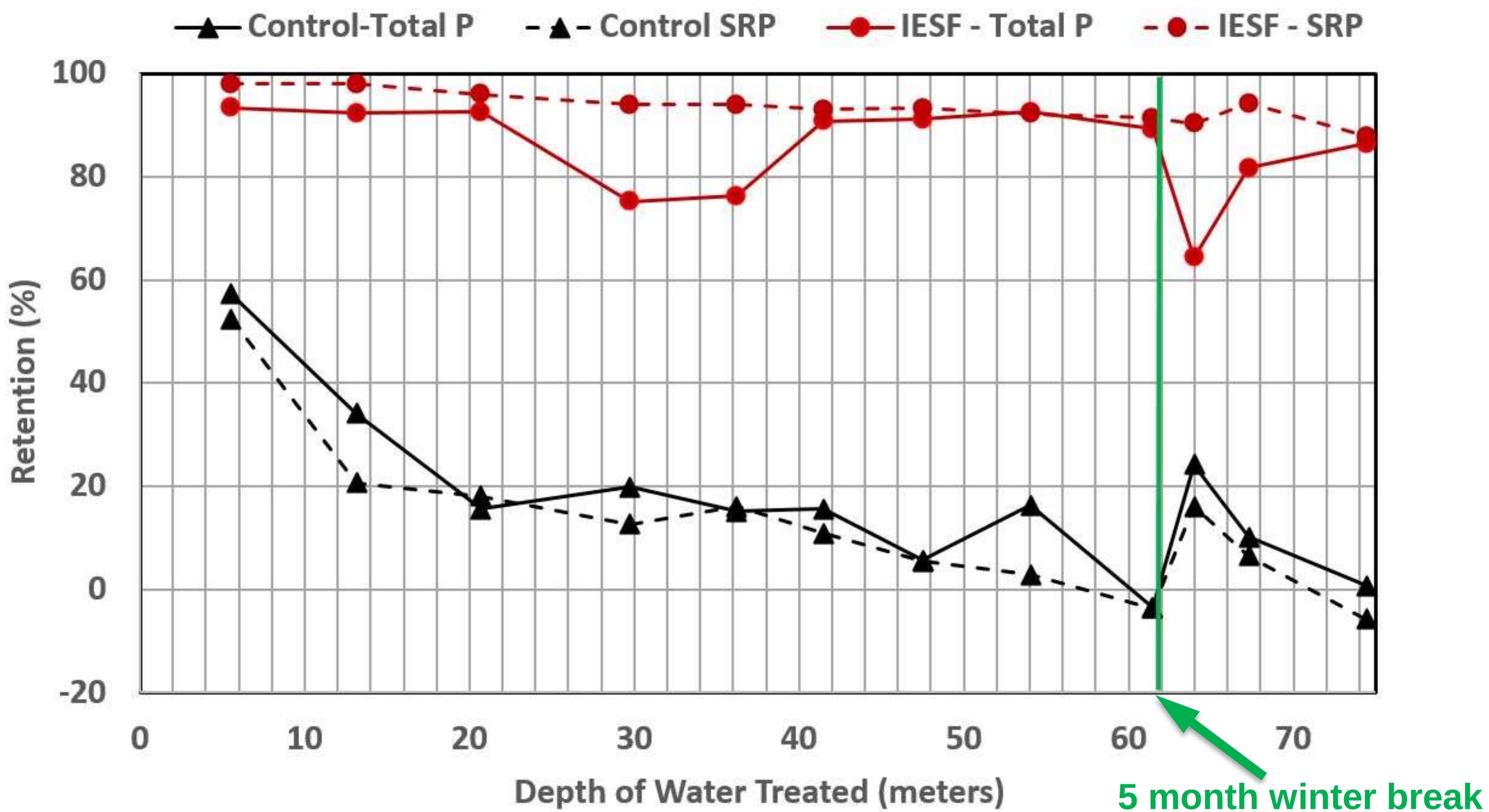
IESF Rain Garden Results



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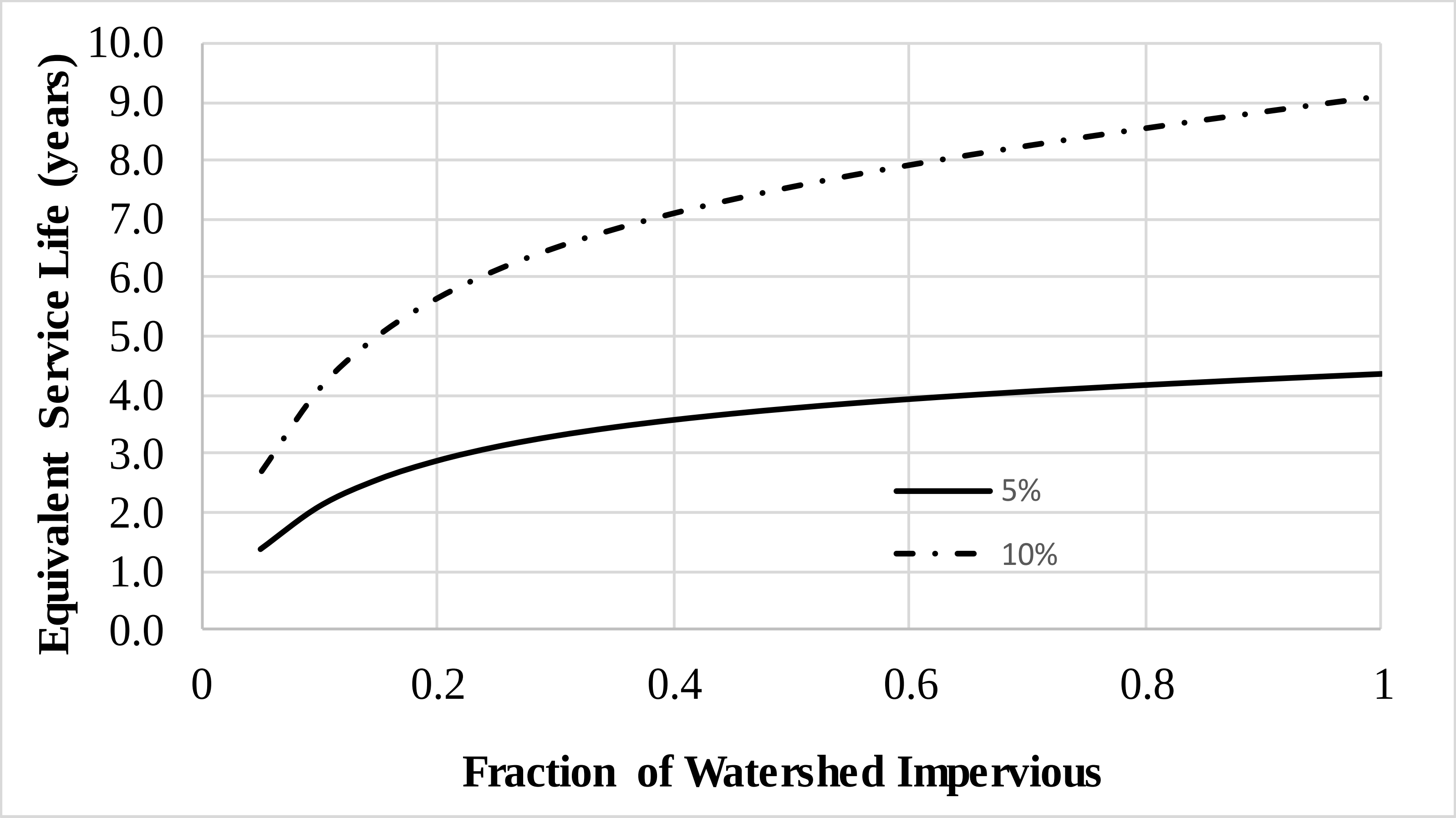
Analysis of a Field Application

(87% Retention of SRP)



Conclusions & Lessons Learned

- IESF can increase dissolved phosphorus retention
- Routine maintenance is a must (4 times/year to 2 times/month)
- Non-routine maintenance ~1 time/year (pond perimeter filters)
- Minimize vegetative deposition on filter surface
- Filter should dry between events (drain time = 48 hours)

Connelly-GPM Iron Aggregate ETI CC-1004

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Conclusions & Lessons Learned

- Verify purity & effectiveness of iron
- Size underdrains to not limit flow
- Water contact time with iron must be adequate
- Iron enhancement can eliminate net export of phosphorus from rain gardens

Connelly-GPM Iron Aggregate
ETI CC-1004

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Thank you for your attention!

Questions?

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Golden Lake Iron Enhanced Sand Filter, Centennial Green Park, Blaine, MN.

Photo: Rice Creek Watershed District (MN)

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