Super High Resolution Multi-Parameter Stormwater Monitoring: Recommendations For Affordable Approaches To Nutrient Monitoring

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STORMWATER MONITORING AND MODEL VALIDATION PROJECT

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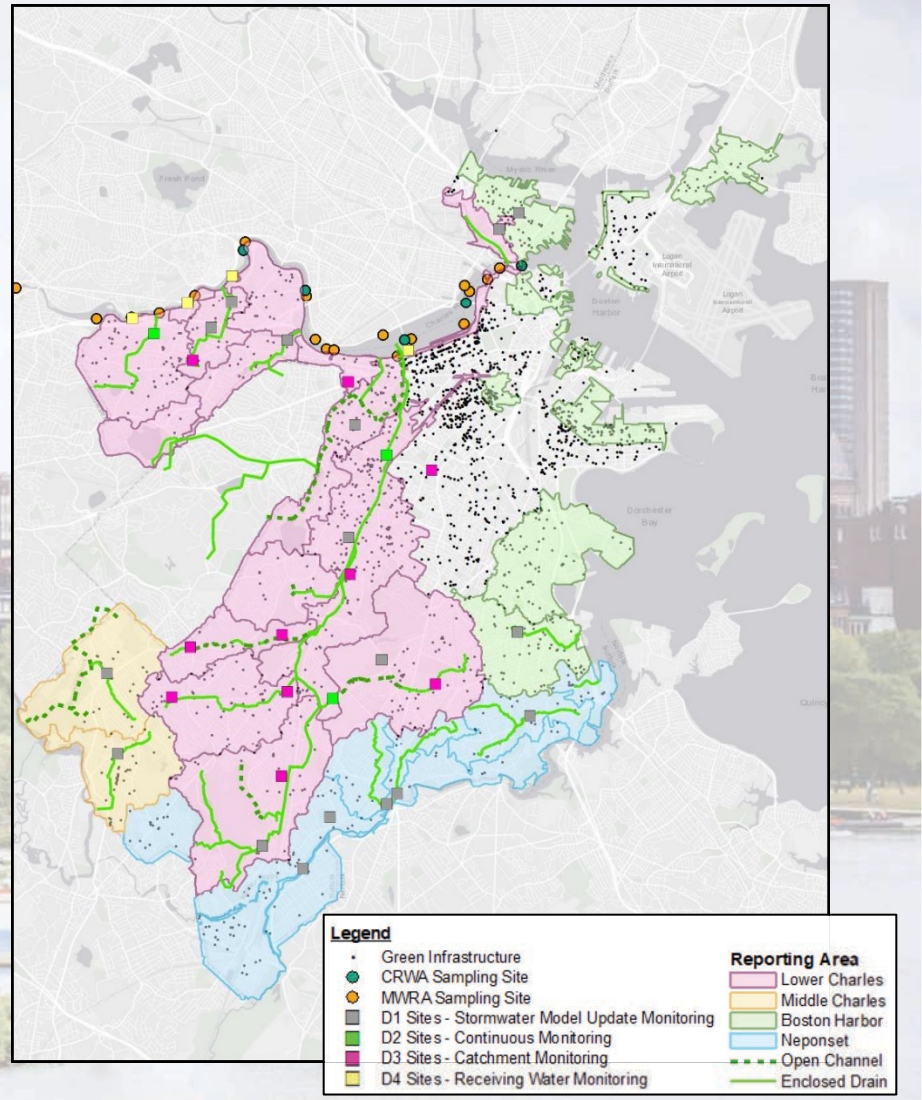
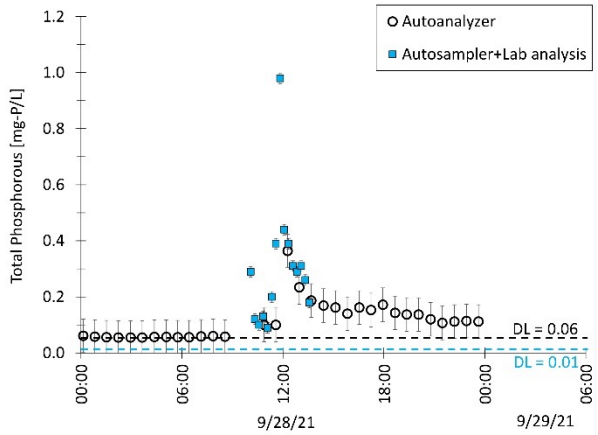
Project Goals:

1. Collect data to develop the most representative pollutant loads for Boston's land use
2. Assess Phosphorous and Pathogen reductions made in Boston's MS4 due to BMP/GI installations and IDDE activity since 2011
3. Evaluate the validity of the Commission's existing Stormwater Model



Project Storyline

Field Program → Gatehouse Install → Instrumentation → Results & Analysis



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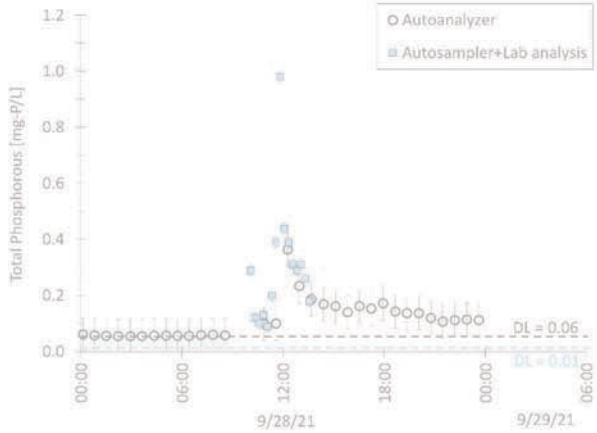
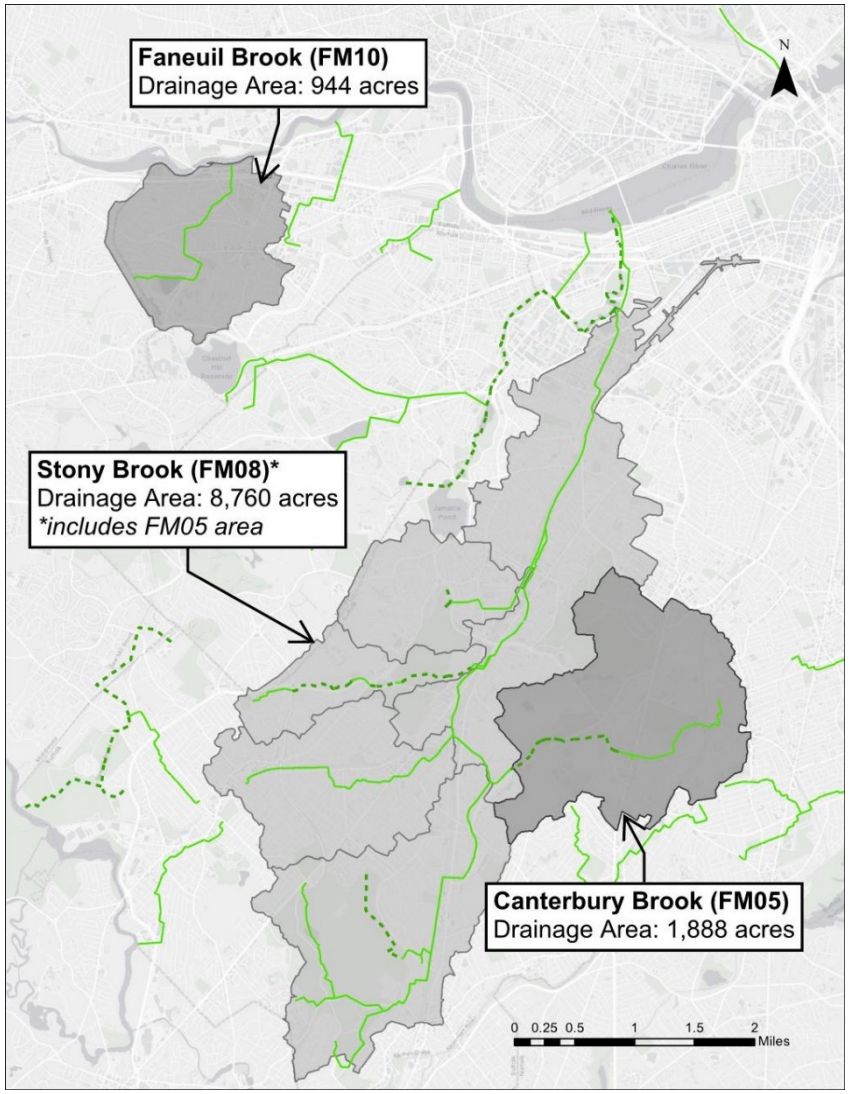
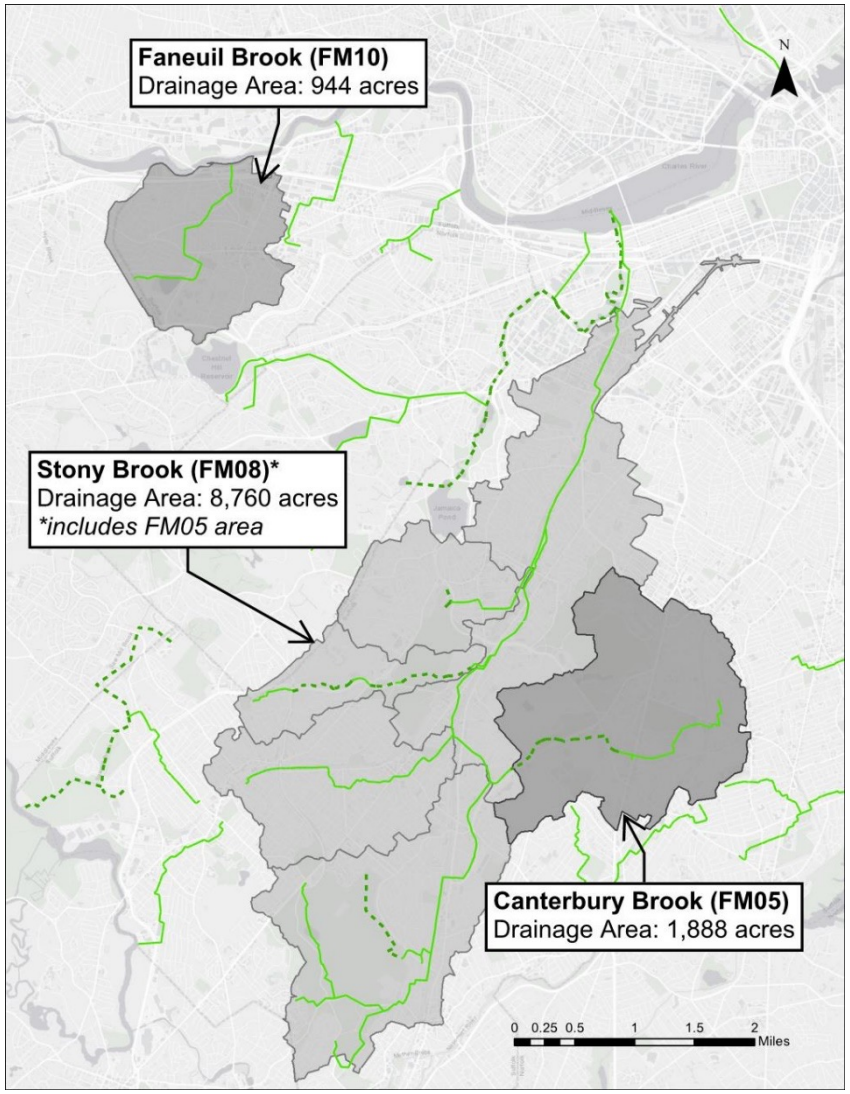


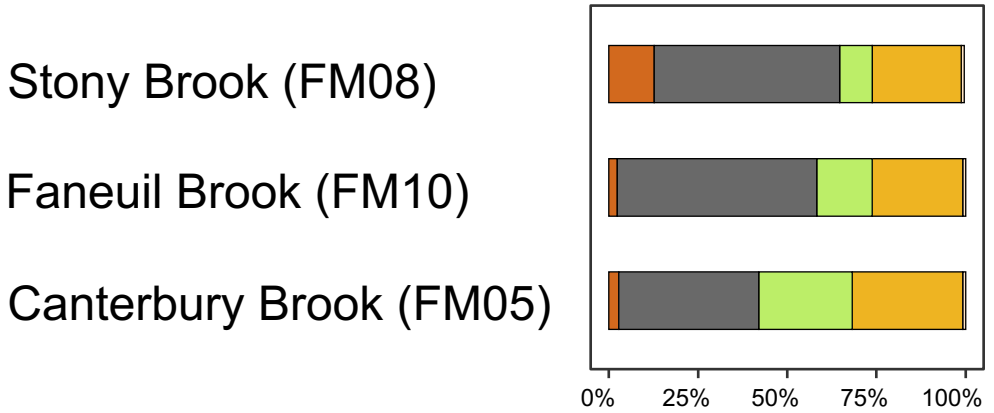
High Resolution Monitoring - Sampling



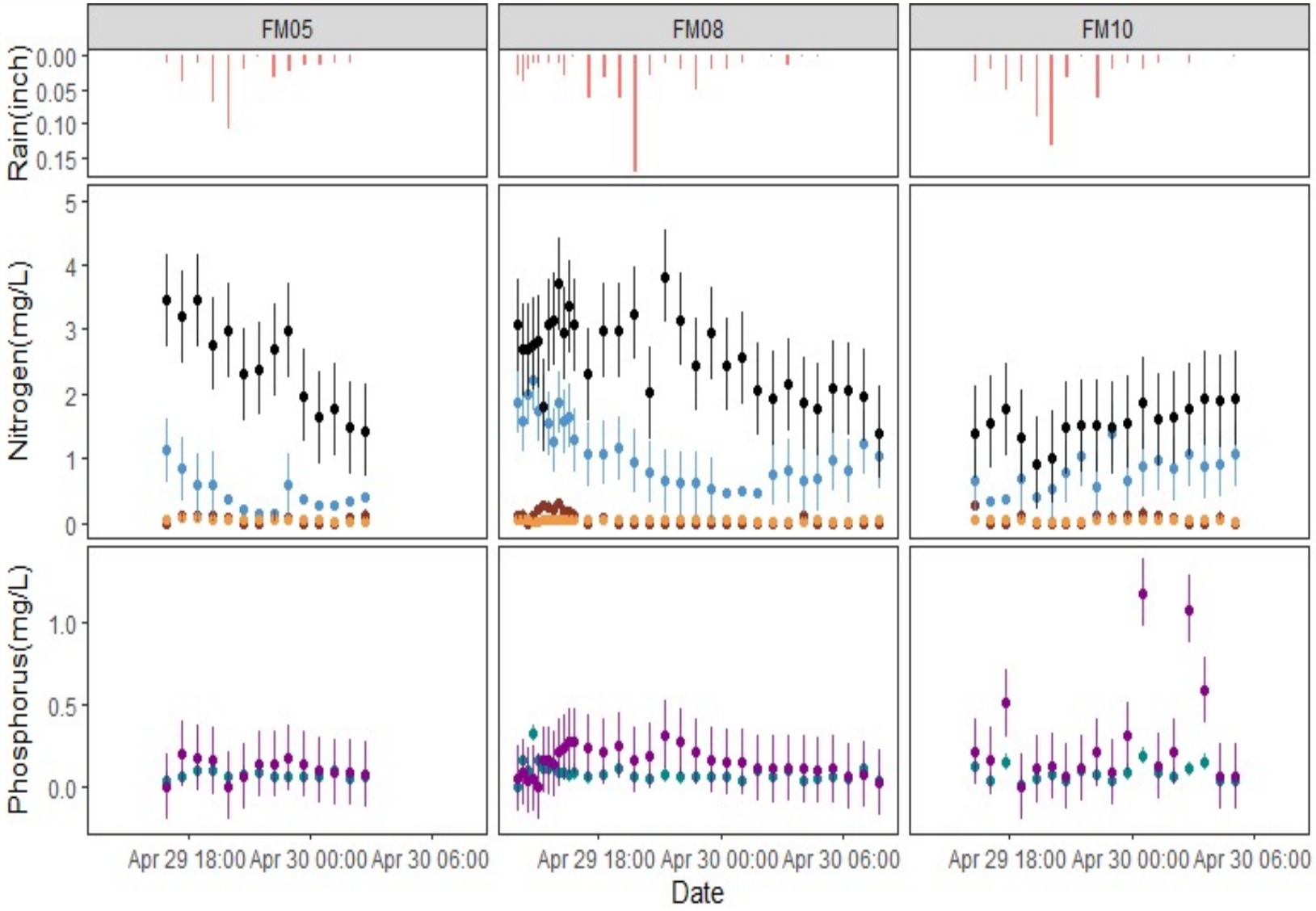
- **Weekly (86):** characterize SW baseflows
- **Wet Weather Events:** characterize results of precipitation and SW runoff (events ~0.5+")
  - ISCO autosamplers, trigger on hydrograph rising edge
  - 15 minute resolution for the first 1.5 hours
  - 15-45 minute resolution remainder of event
- **Targets:** nutrients, metals, general water quality parameters, biologicals
- **Today:** focus mainly on P

High Resolution Monitoring - Sampling





Representative Wet Weather Event *(4/30/21)*



- N dominated by NO_3^-, particulate/organic N
- P speciation highly variable

TN (black)

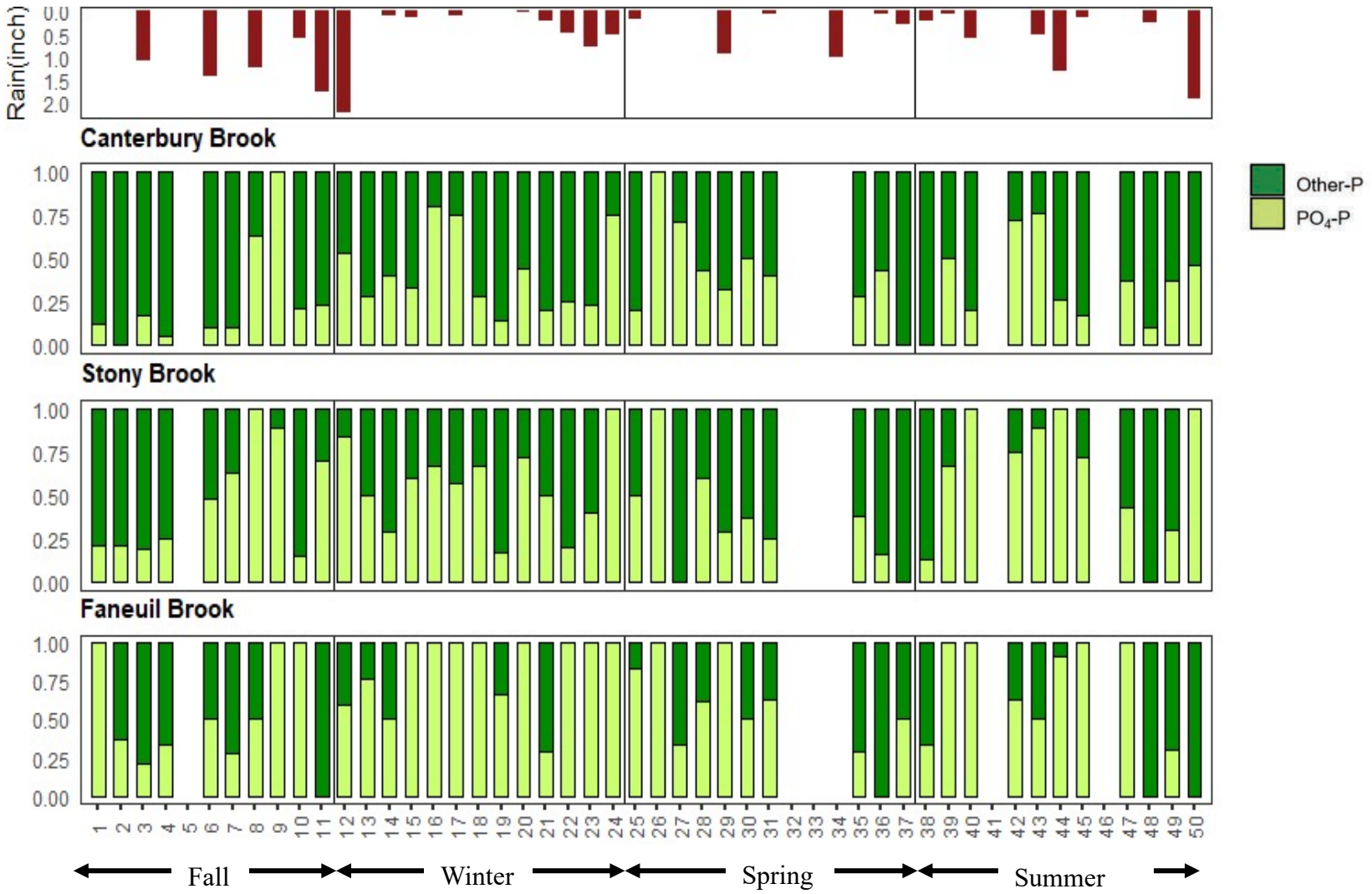
NO_3^- (blue)

NH_4^+ (red), NO_2^- (orange)

TP (purple)

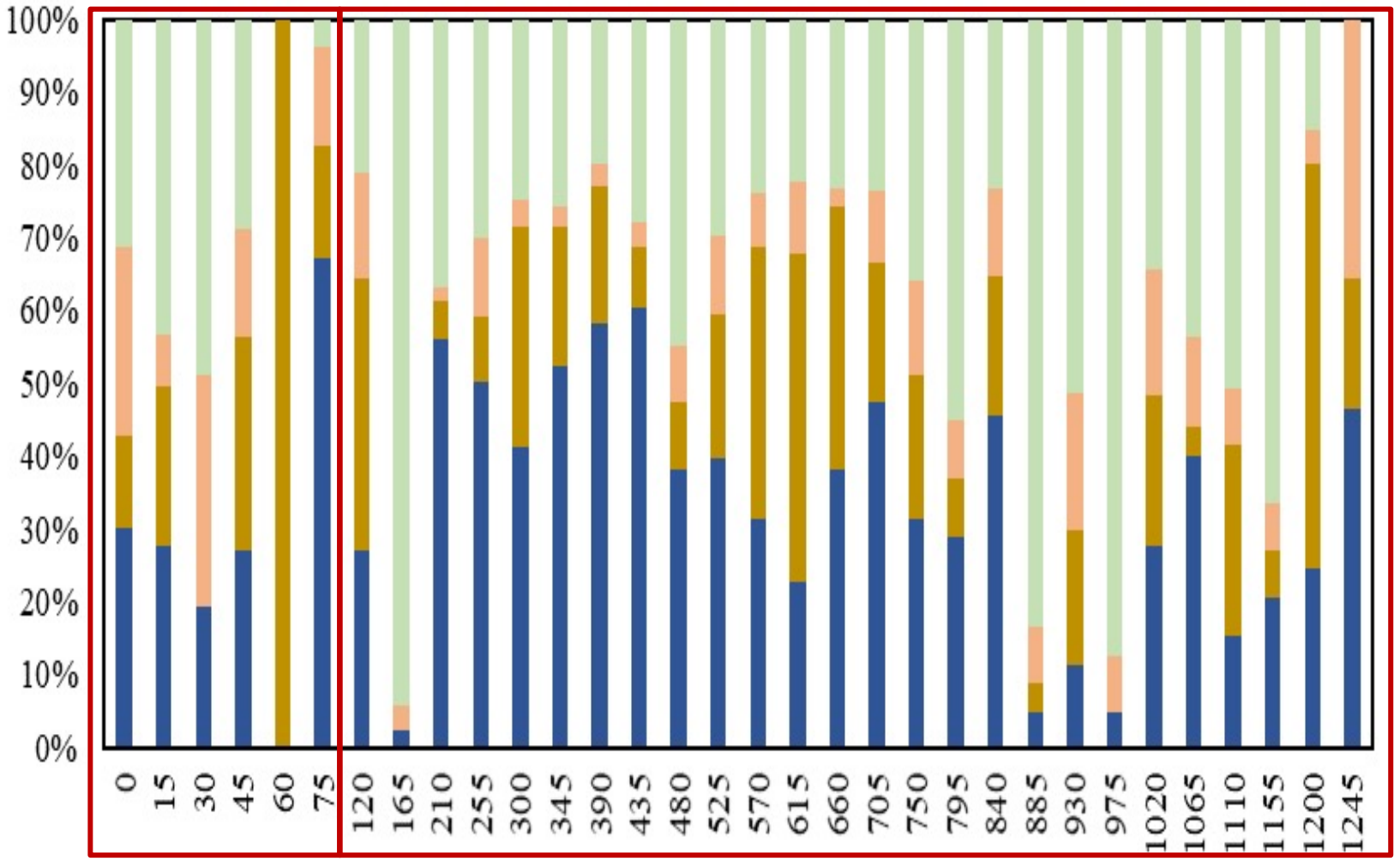
PO_4^{3-} (teal)

Phosphorous Speciation: Week-by-Week



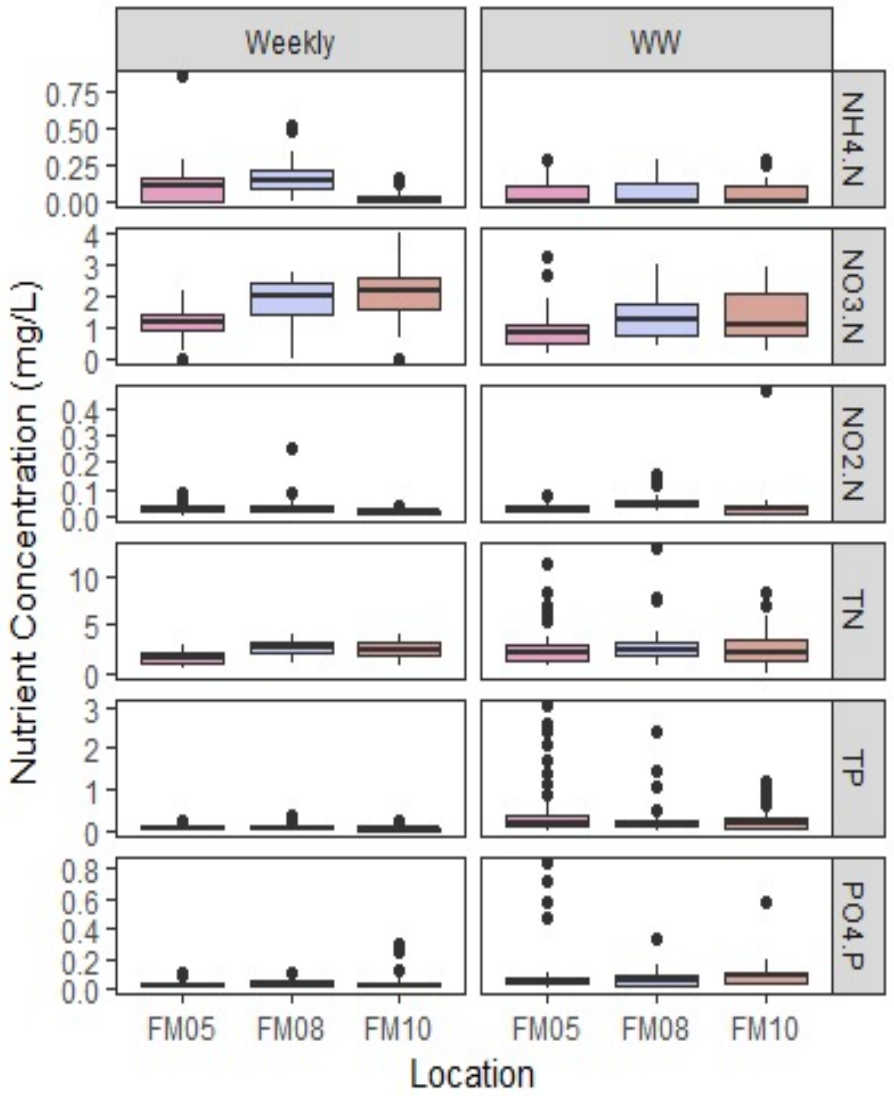
- Fraction of P associated with particles varies with location, by season
- Rainfall not significant driver of this variability

Particulate P *(site FM-08, event 4/30/21)*



- Particle size of non-dissolved P highly variable
- Within storms, between sites, across seasons
- Story more complex than hydraulics or first flush

Effect of Wet Weather on Nutrients



- TN not significantly* different between weekly/events, but…
- N speciation changes
  - mean NH_4^+, NO_3^- both lower during events
- TP significantly* higher during events

*$p<0.05$

High Resolution Monitoring - Instrumentation

Question: Can we understand dynamics at higher resolution than the sampling campaign provides?

- What can we learn?
- Could this be affordable, scalable?

Focus: High resolution understanding of **phosphorous** dynamics

Challenges

- Lack of commercial **sensors** for orthoP or TP
- High (and variable) TSS
- Total phosphorous (TP) - requires digestion which limits temporal resolution

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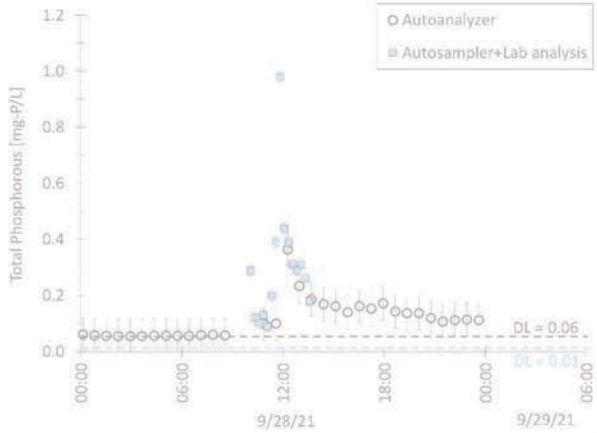
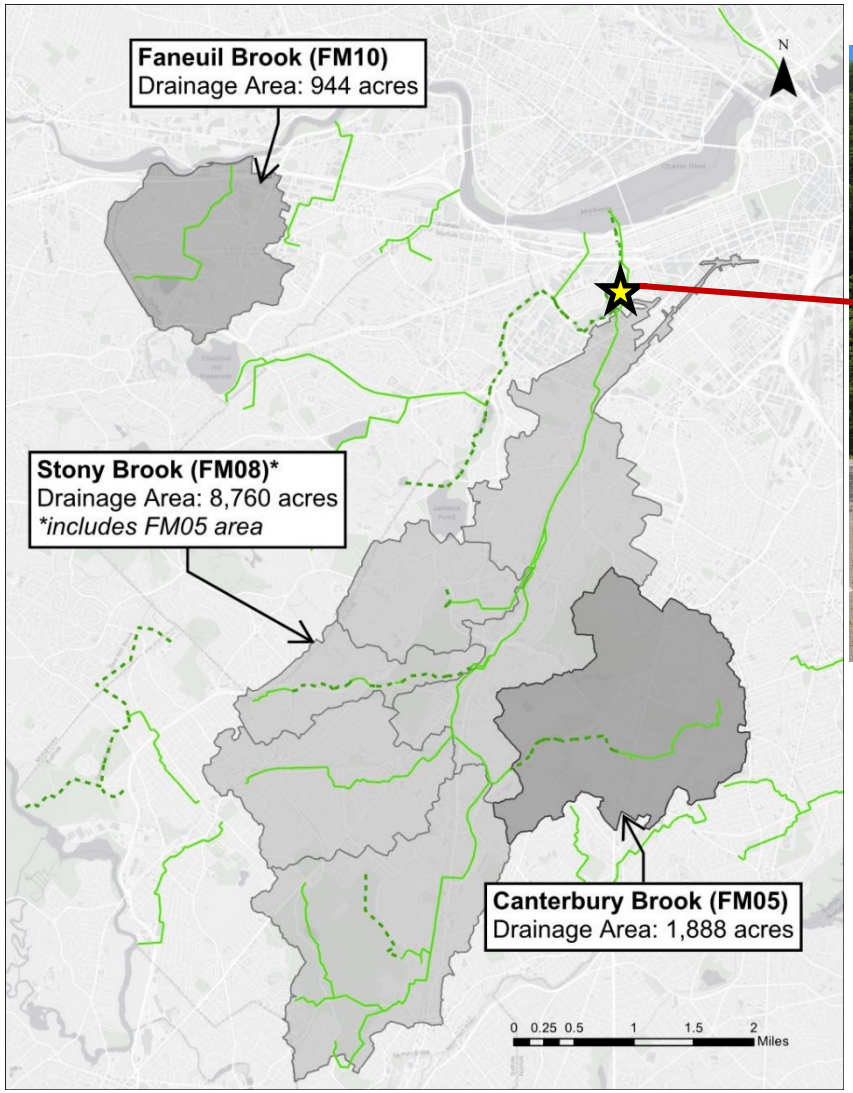
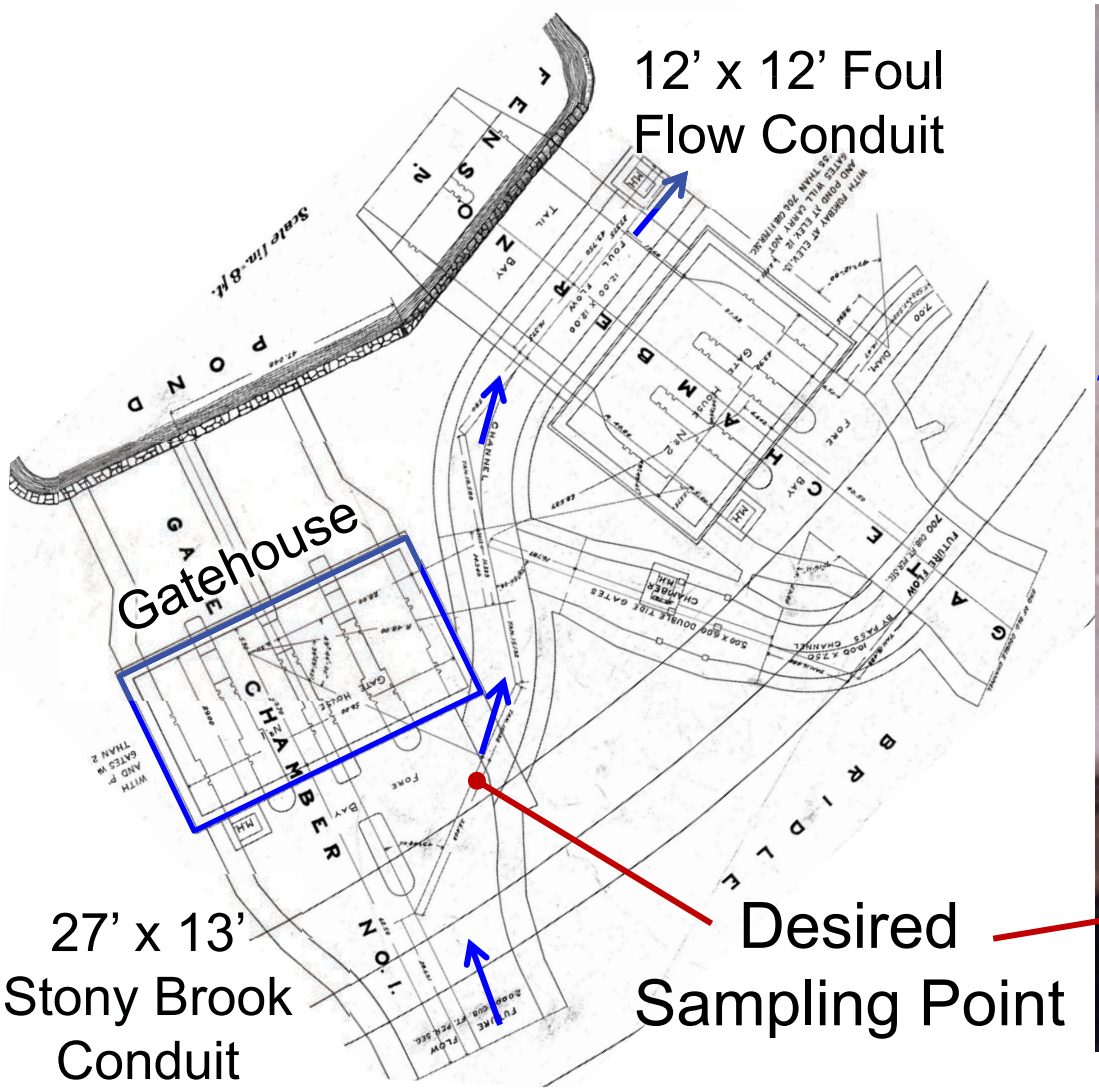


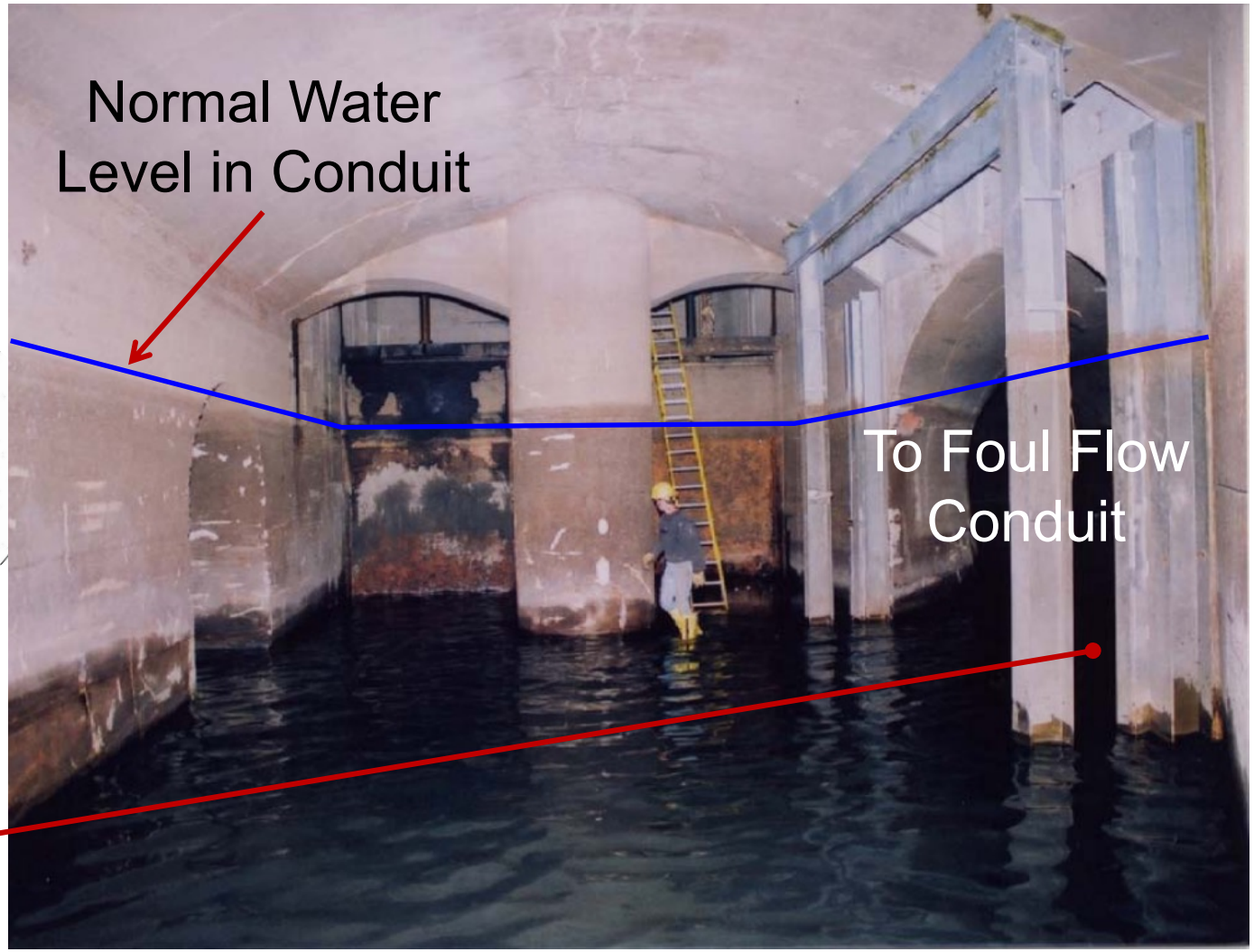
Stony Brook Gatehouse Installation Site



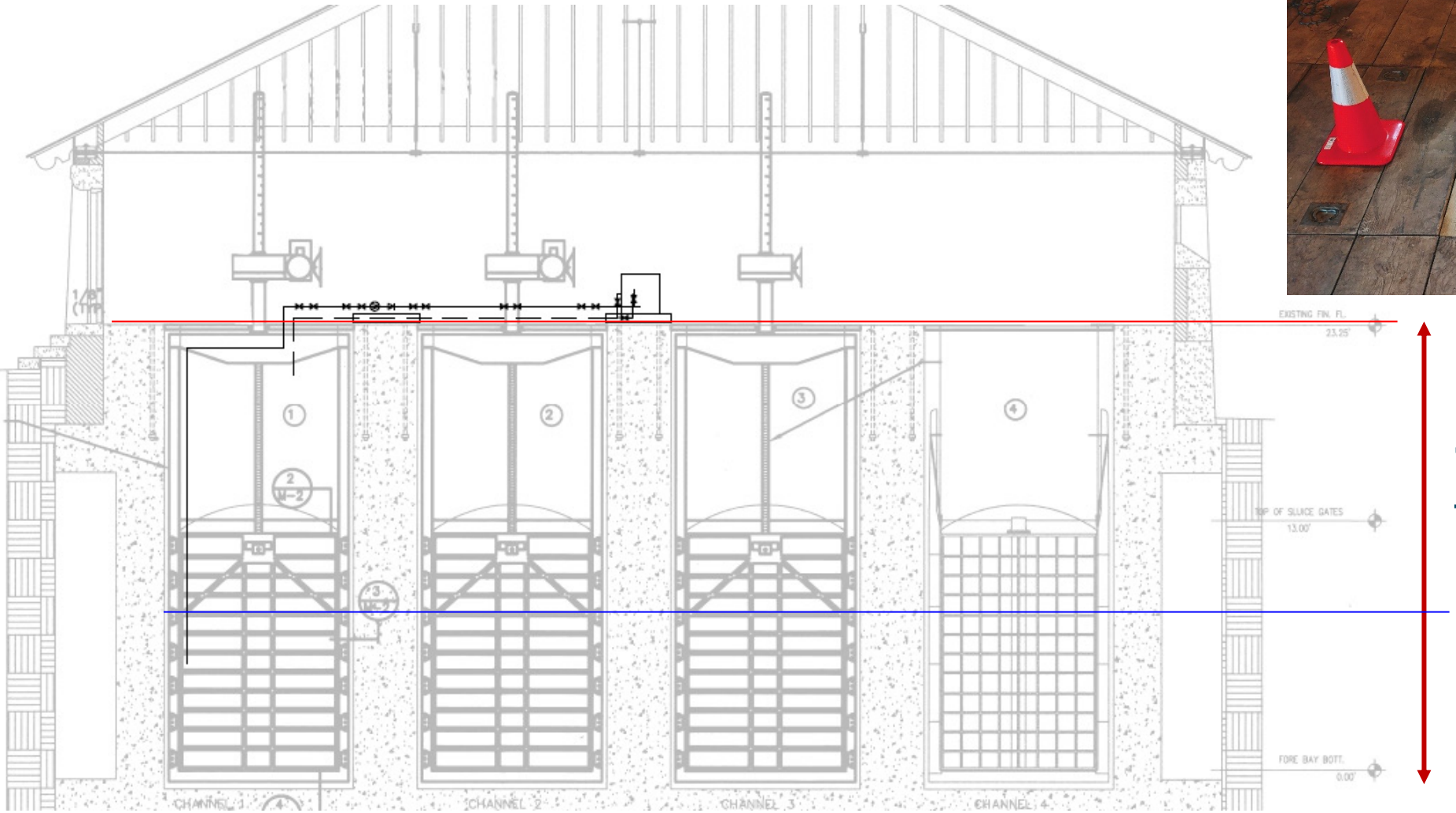
Gatehouse

Gatehouse Conduit Configuration





Gatehouse Facility Configuration

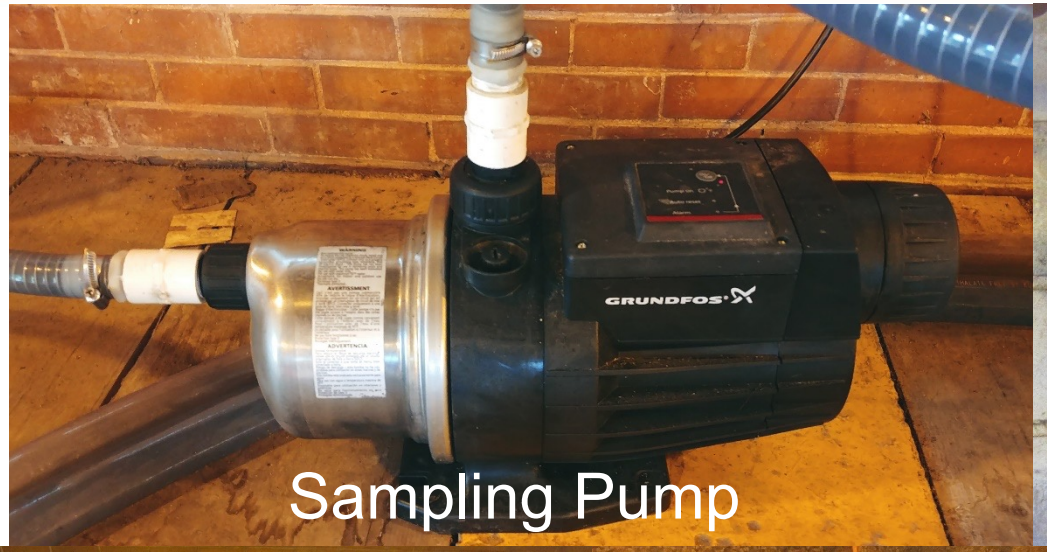


~23 feet floor to invert

~8 feet normal depth of flow

Flow Delivery System Setup

So, What's Needed for the System Setup??



Sampling Pump


Power Supply


1" Clear PVC Tubing


Valves/Fittings


Boat

Flow Delivery System Setup

Suction Line Installed for Sampling from Conduit

**credit to Vortex Services*

Completed Flow Delivery System to Gatehouse Instrumentation

Flow Delivery System Challenges

1. Replaced/Removed Suction Strainers
2. Replaced Tubing Due to Suction/ Vacuum Pressure
3. Maintaining Clean Tubing and Tanks
4. Maintain Steady Flow During Dry/Wet Weather

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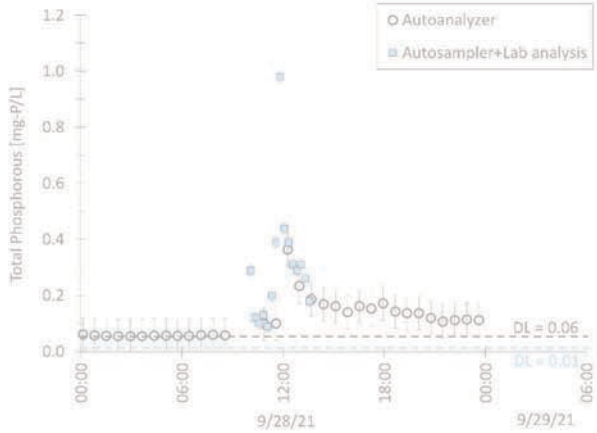
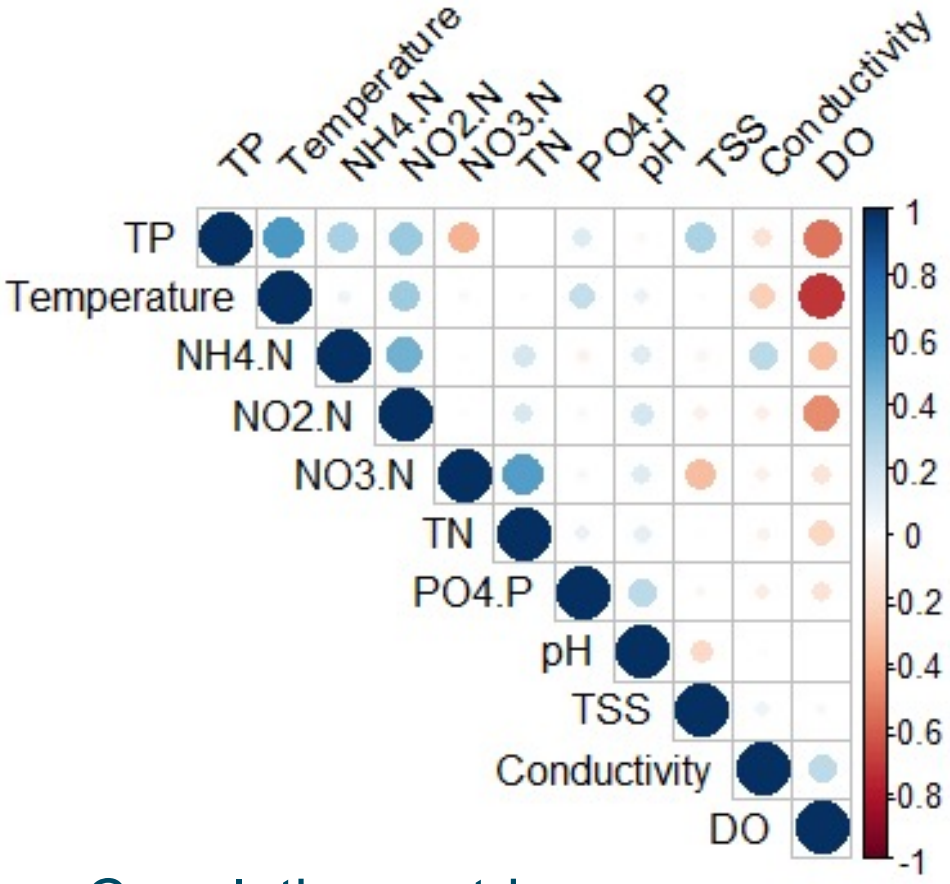


Gatehouse Instrumentation Design

Considerations

- **Accuracy** of sensors/instrumentation
- **Selectivity** (resilience against interference)
- **Minimal/no** sample pre-processing (e.g., filtering)
- **Proxy** parameter evaluation
  - Variability in time and space
  - No simple 1:1 relationships



Correlation matrix

(all sites, all sample types)

Instrumentation – Objectives

- Assess utility of high accuracy instrumentation for stormwaters
- Assess trade-offs between **ACCURACY**, **TEMPORAL RESOLUTION**, **COST**

Target Analytes	Instrument Deployed	Measurement Frequency	Accuracy	Interferences	Cost
PO_4^{3-} (orthoP)	Hach EZ1032 – colorimetric autoanalyzer	~7 min	0.03 mg-P/L	Minimal (color)	$$$
Total Phosphorous	Endress+Hauser CA80TP – colorimetric autoanalyzer	45-60 min	0.06 mg-P/L	Minimal (color)	$$$$
T, DO, pH, conductivity, NO_3^-	AquaTroll-500	<1 min		Significant (N)	$
NO_2^-, NO_3^-	Southwest Sensor – microfluidic colorimetric autoanalyzer	<1 min		Minimal	$$
NH_4^+, NO_2^-, NO_3^-, Cu^{2+}, Na^+, Cl^-	NICO ELIT ion selective electrode (ISE) array	<1 min		Significant (all)	$

Gatehouse Instrumentation

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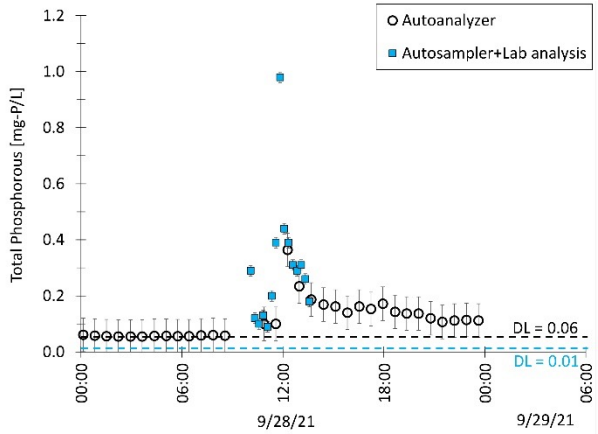
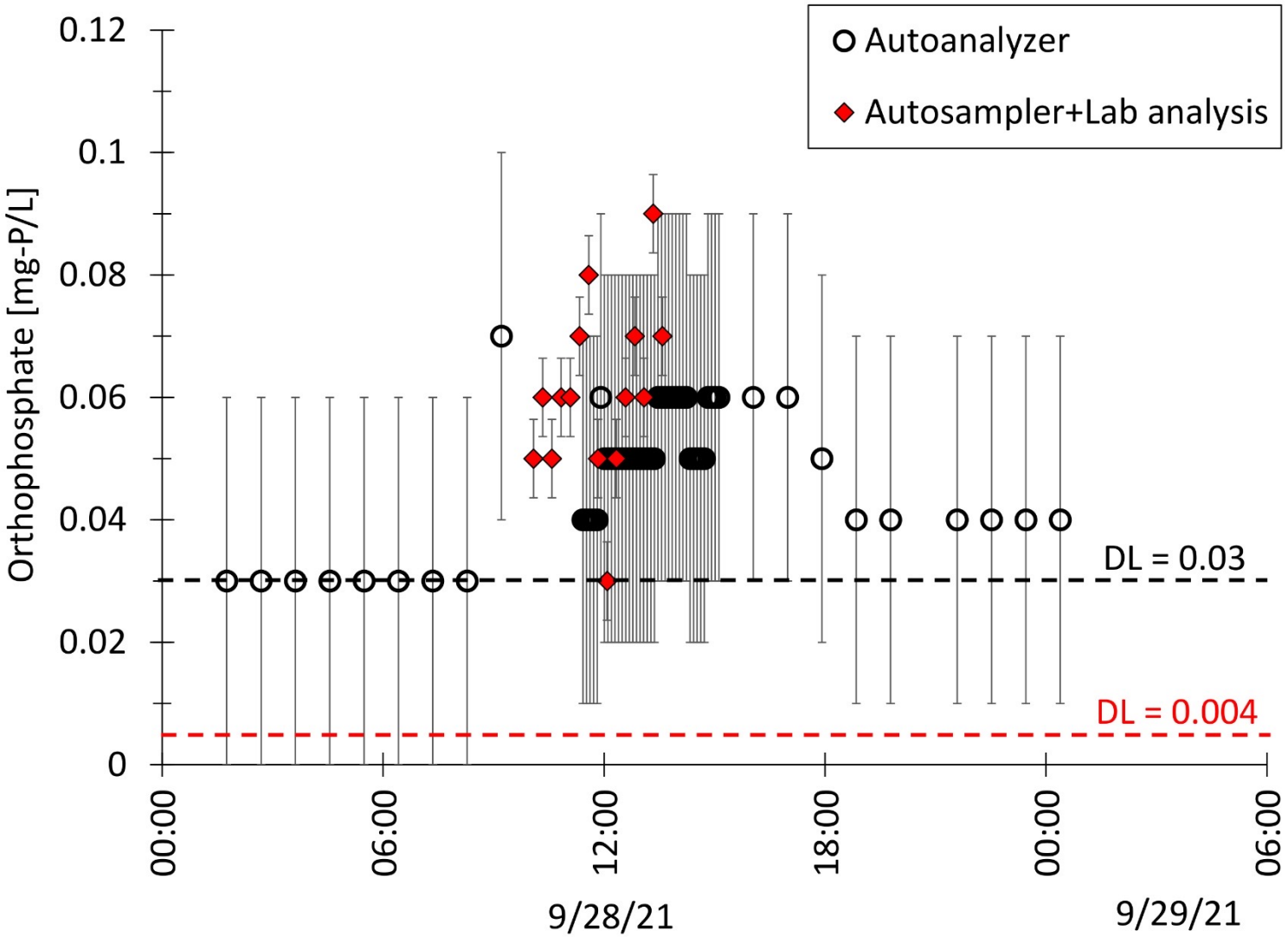


Super-High Resolution Study Period

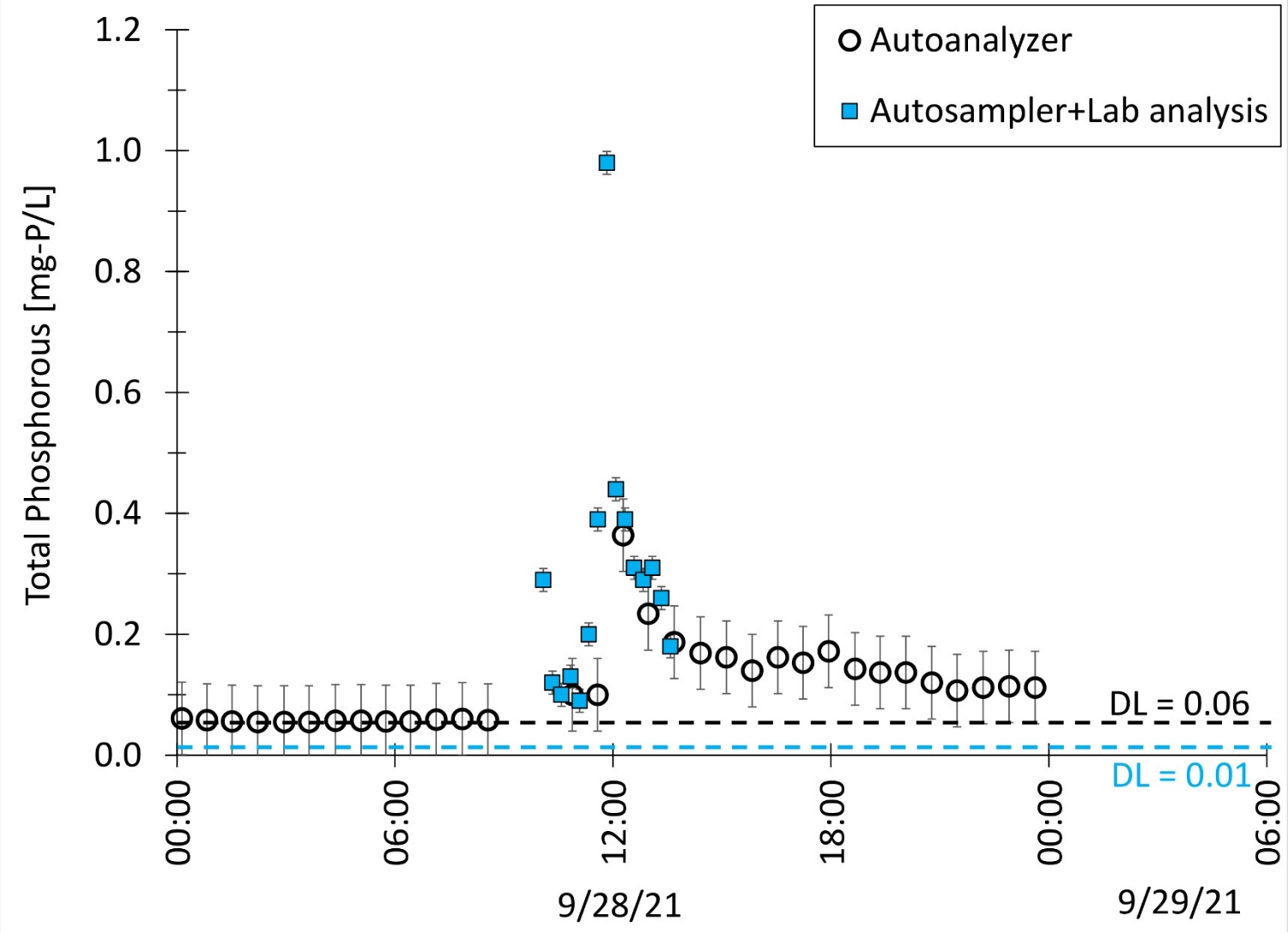
- Instrumentation deployed: April – November 2021
  - ~5 wet weather events
  - Weekly samples collected from pumped loop
- Maintenance approximately weekly
  - Pump + flow-through loop cleaning
  - Calibration of Aquatroll sensors
  - Replacement of filter (50 micron, required for Hach EZ1032)
  - Instrument reagents/waste streams
- OP/TP instruments have built-in auto-calibration sequences

Instrumentation Utility - OrthoP



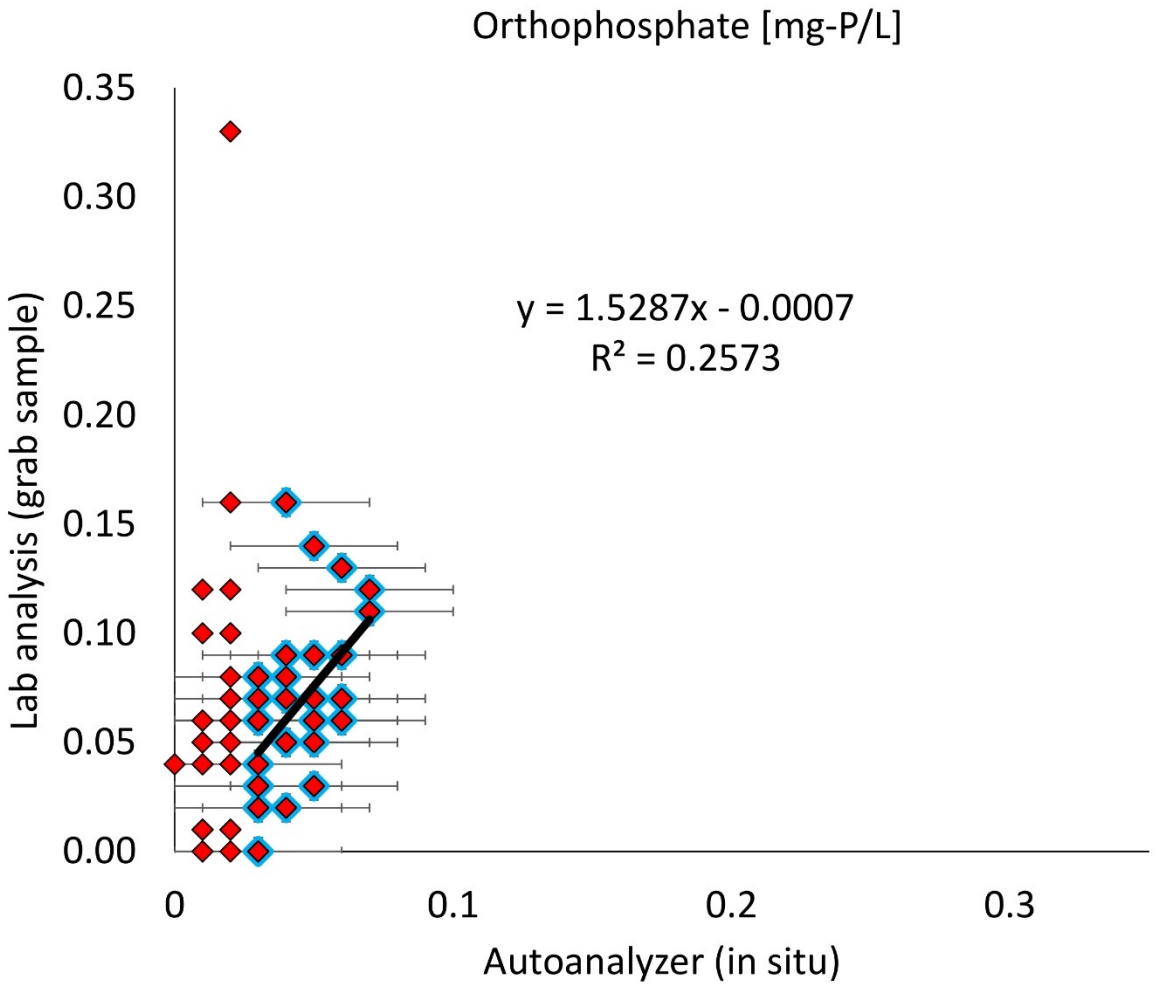
- Stormwater orthoP concentrations at/near instrument detection limit
- Temporal resolution good (but reagent consumption high)
- Not 100% “in situ friendly”

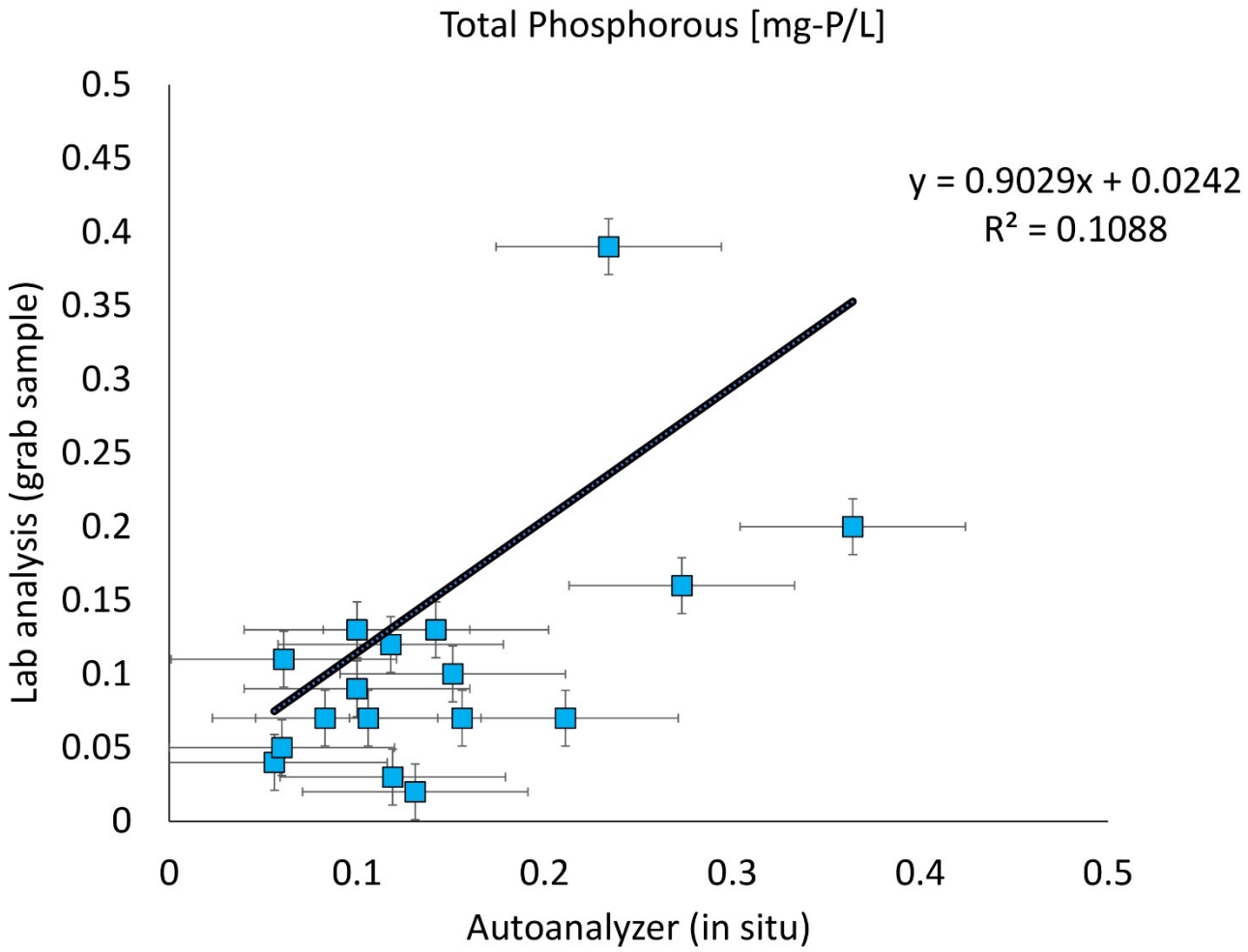
Instrumentation Utility - TP



- Accuracy, detection limit reasonable for stormwaters
- Temporal resolution extremely limiting for event characterization
- Not 100% “in situ friendly”

Accuracy of Instrumentation vs. Lab Analyses





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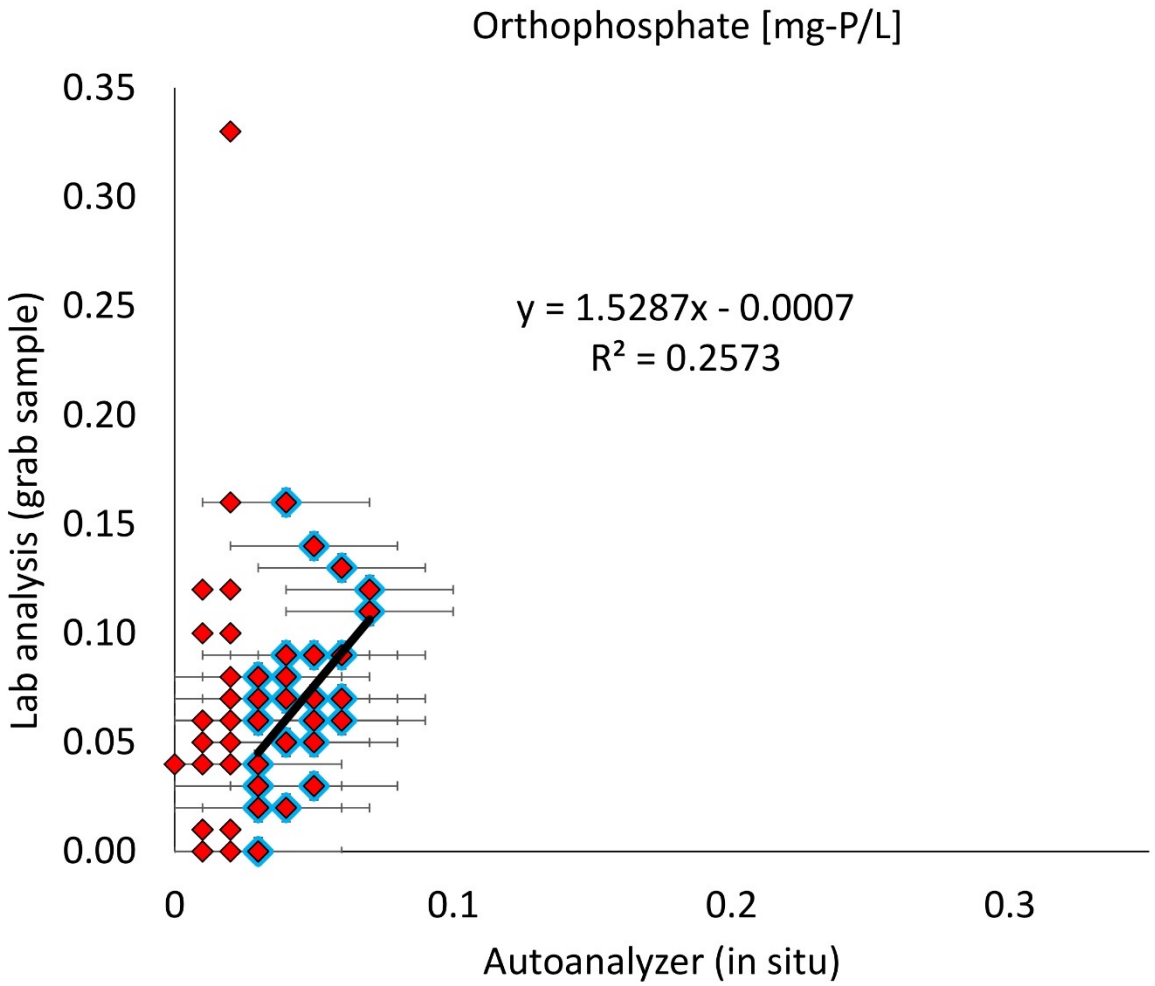
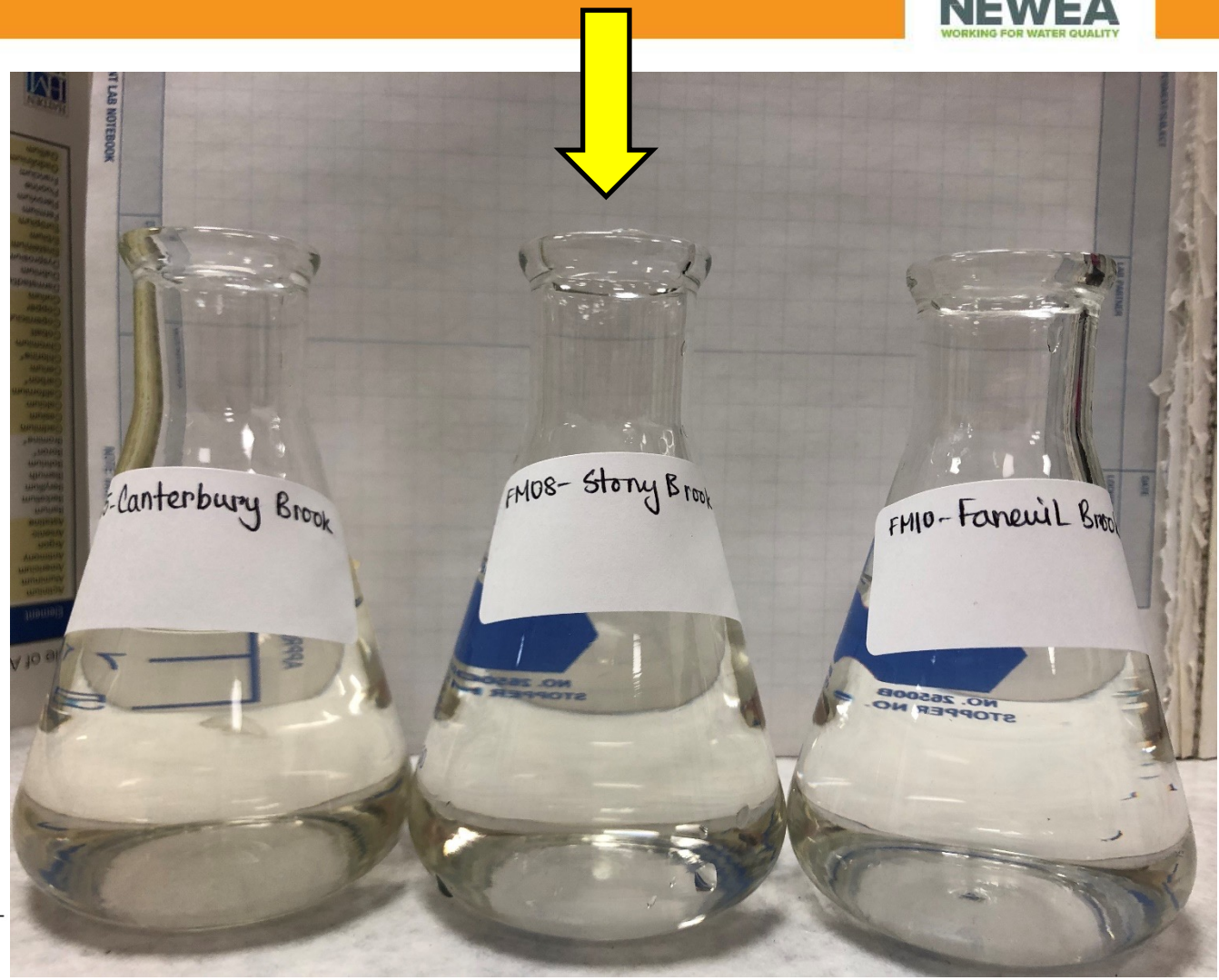
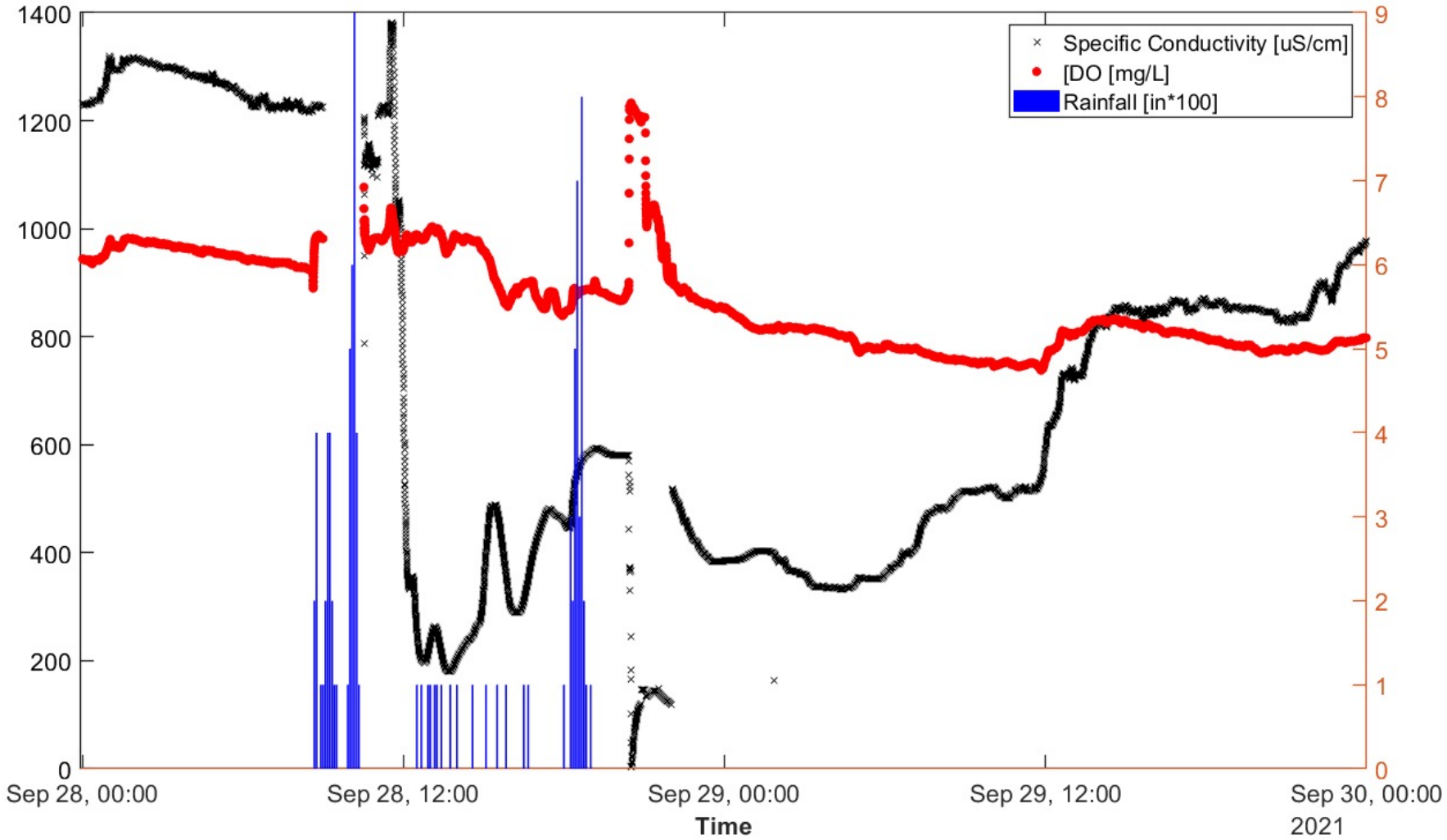




Higher-Resolution Instrumentation (Aquatroll)



- Matches / improves on 5-min rain data available
- Resolves dynamics in stormwater flows, hydrograph visible in many signals

So: Can High Resolution Data Inform on P?

Orthophosphate

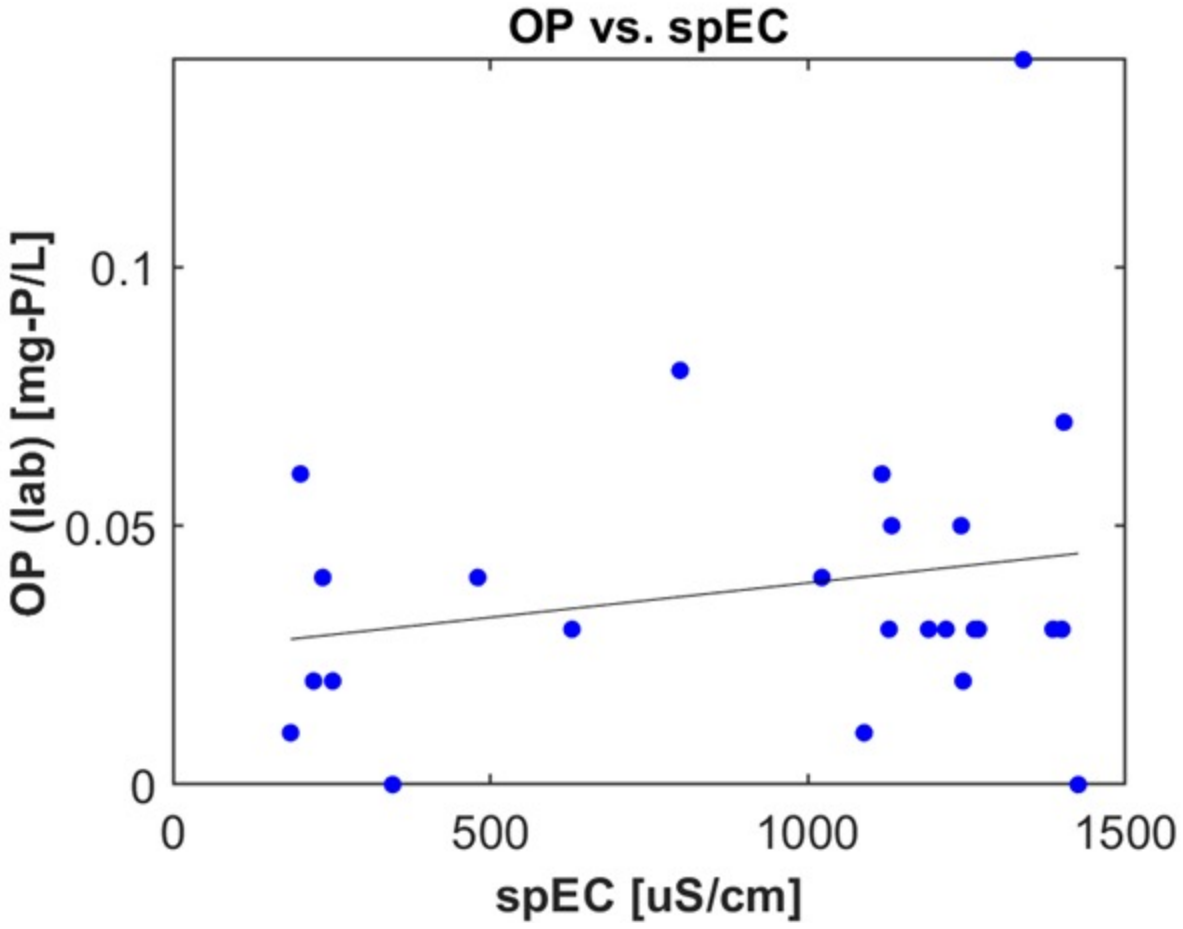
- Contributes to **specific conductivity**, but many other (charged) parameters covary (e.g., NO_3^-)

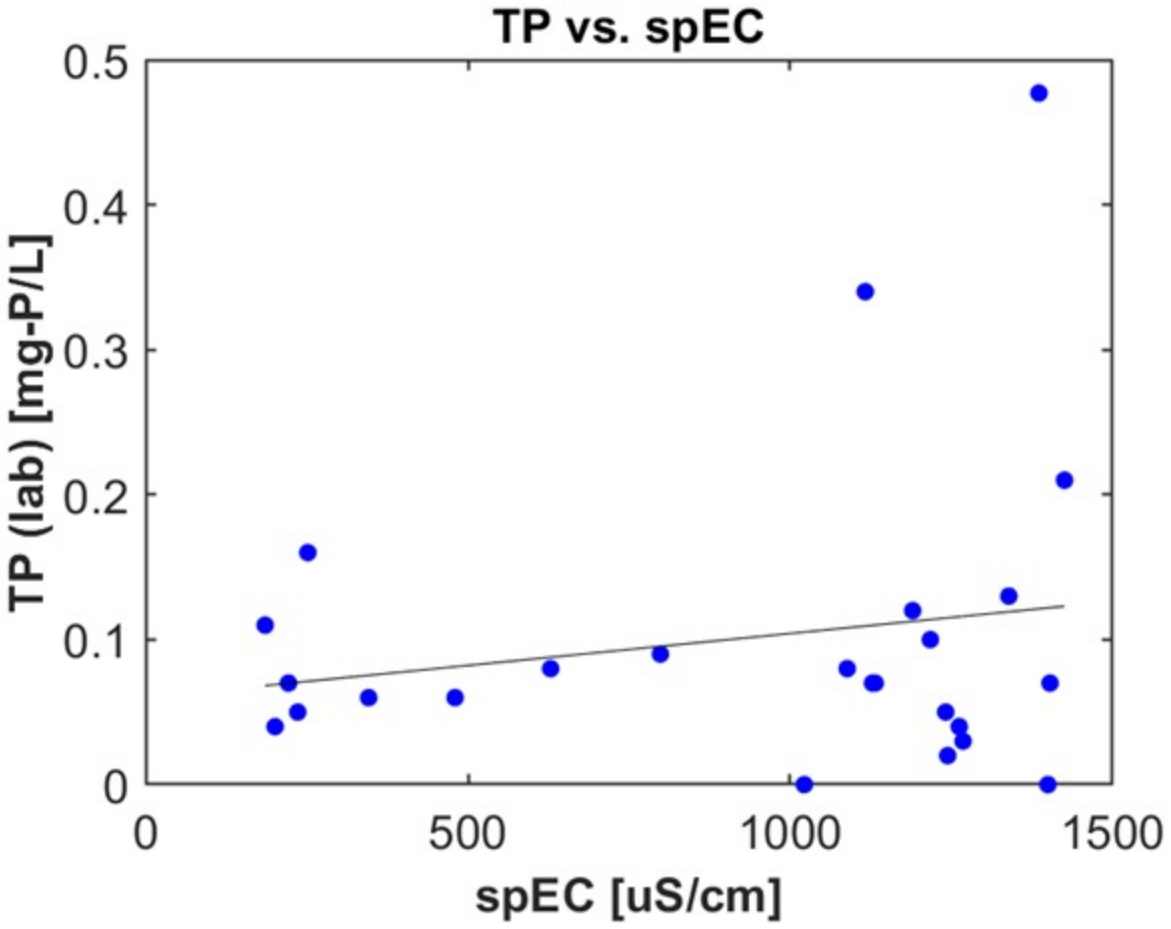
Total phosphorous

- **TSS** relevant, but does not resolve size fractions (and P associated with size fractions varies)

Other signals have information on water source (baseflow, runoff…)

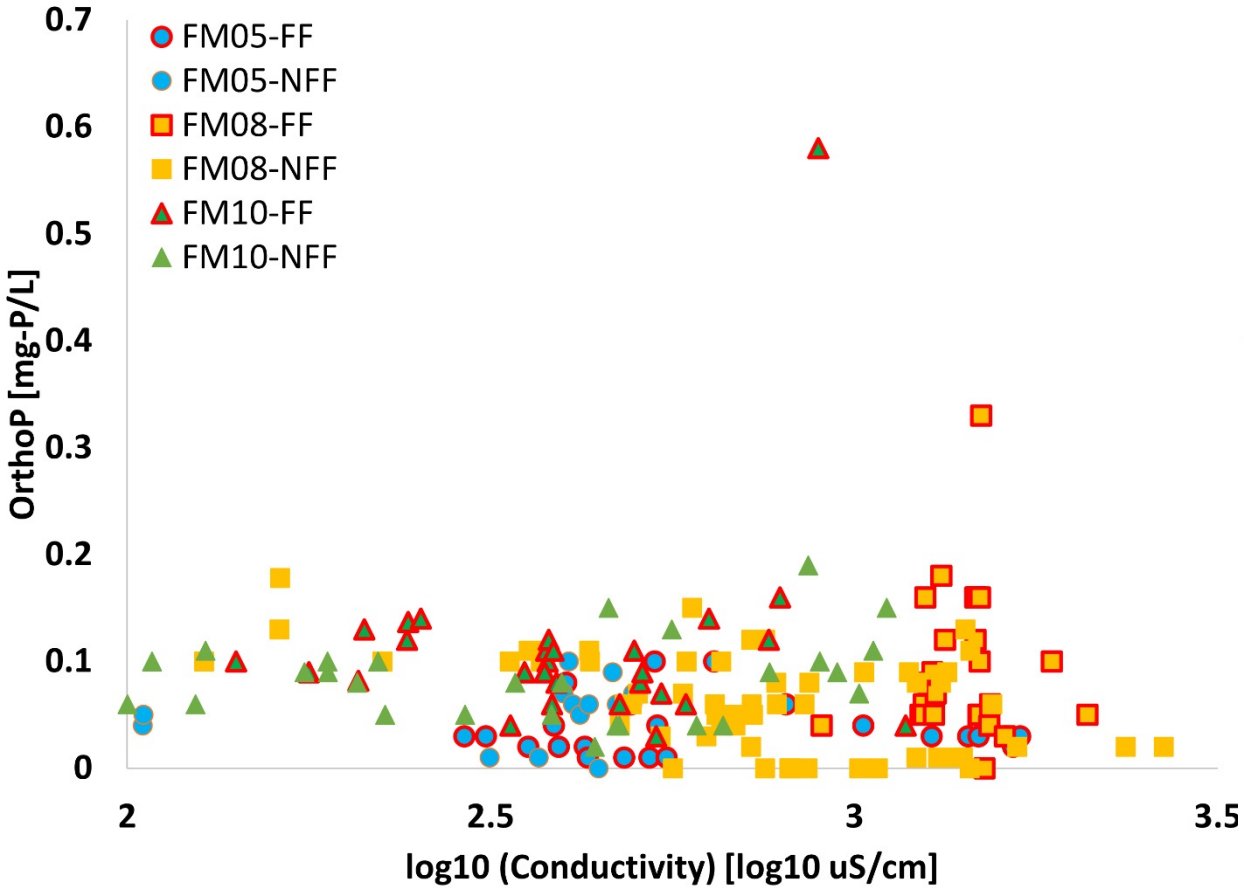
Simple Proxies Useful but Insufficient



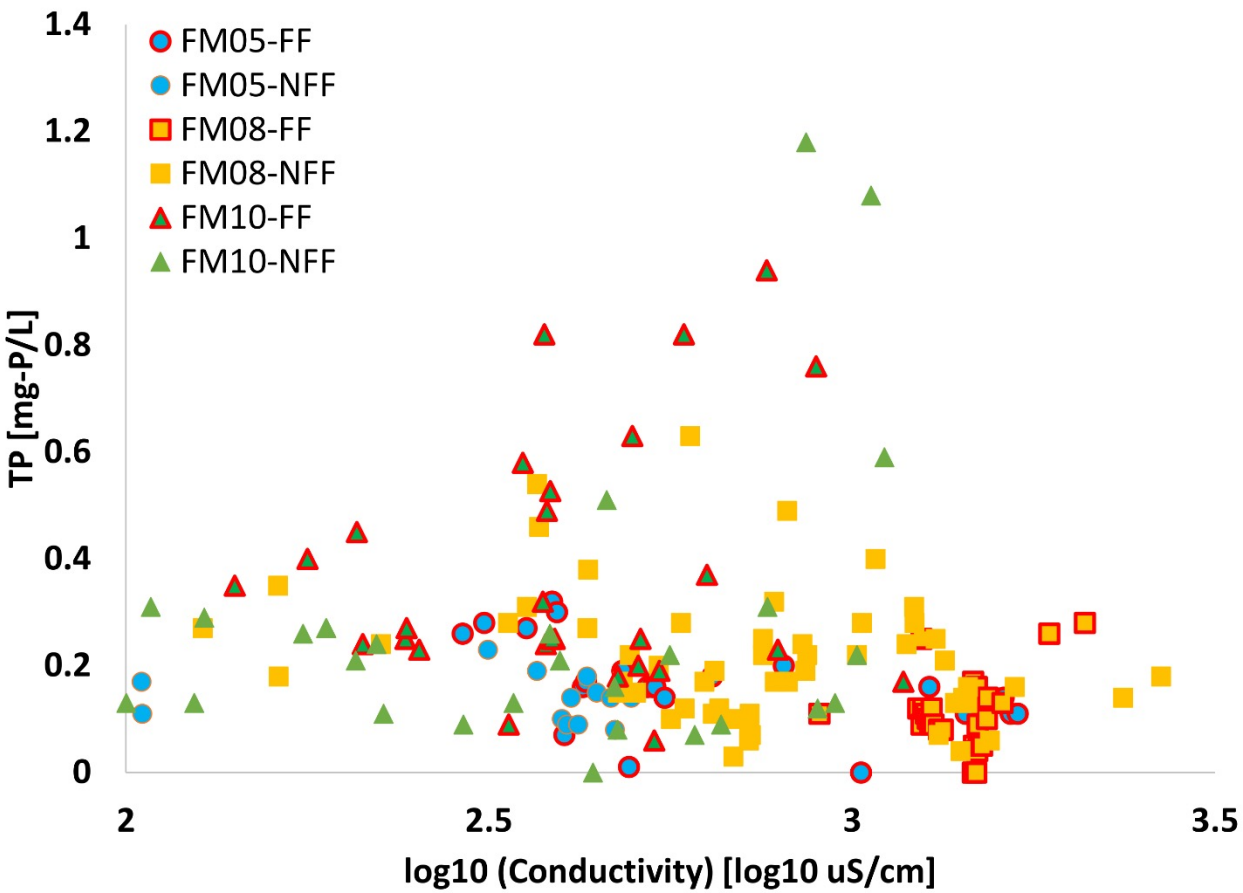


But inter-site transferability is high

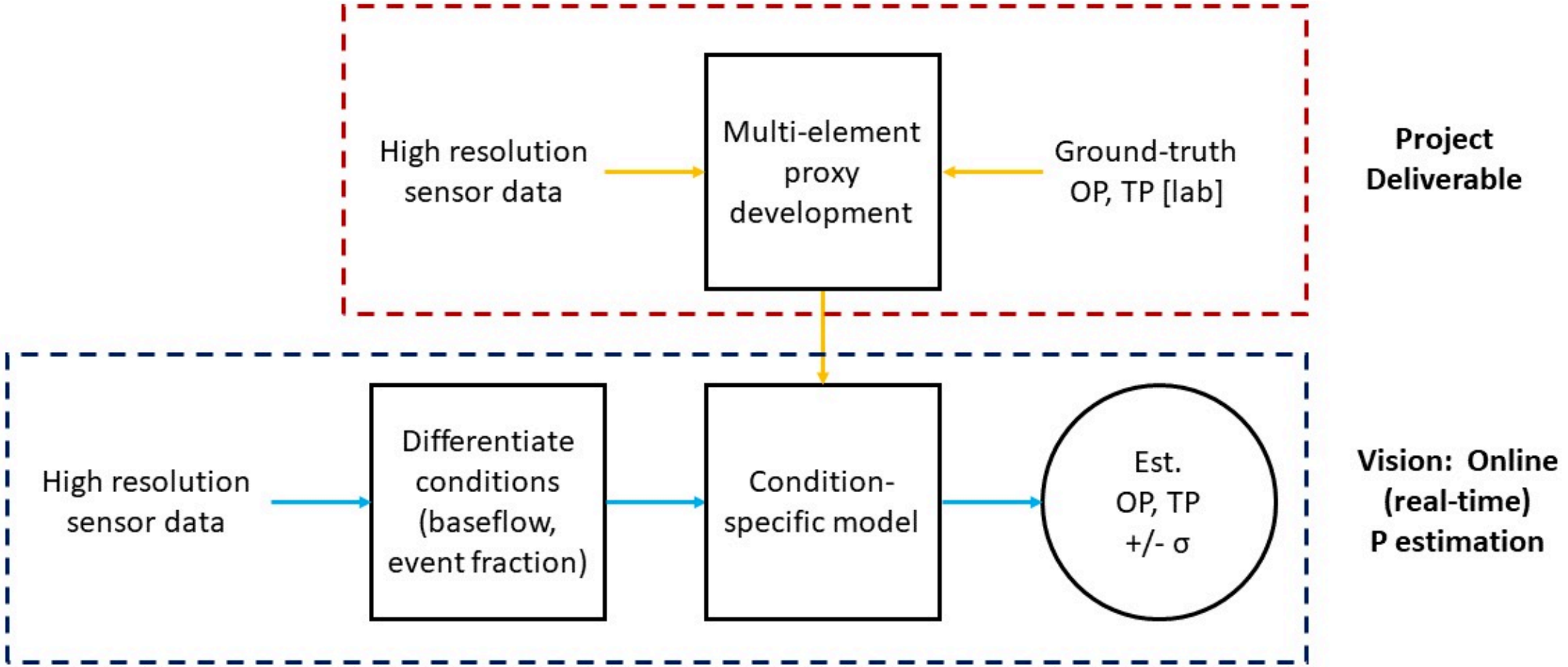
Orthophosphate (WW)



Total Phosphorous (WW)



Complex Proxy Model – Approach



Take Homes

High resolution study

- Nutrient fingerprint of stormwater, baseflow differentiable
- Stormwater flows detectable in high resolution in many signals
- Chemical fingerprints similar across sites consistent (results transferable)

Online analyzers

- Detection limits very close to stormwater conditions
- Some challenges with *in-situ* deployment (size, cost, power, reagents)
- Use of other sensors as proxies promising **[study ongoing]**

Ongoing Work

- Further modeling / proxy development for "online" OP/TP
  - Include data from additional "experimental" sensors (ISE array)
- Assess utility of instrumentation for
  - Nitrogen species
  - Metals (Zn, Cu)
- Weekly sampling through May 2022

Acknowledgements & Questions?

- Boston Water and Sewer Commission
  - Paul Canavan, Demetrios Vidalis, & Antonio Barbosa – Gatehouse Support
- Northeastern Field, Lab, Data Teams
  - Sadia Khan, Gilly Moore, Lauren Macdonald, Shannon Butler, Morgan Connelly, Jackie Helliwell, Alex Renaud, Arwa Almutabagani, & Audrey Berlin
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- Flow Assessment Services
  - Gary Welch, John Sokol, & Paul Casey – Autosampler & Flow Meter Support

Northeastern University

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