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# A Power Analysis Tool in R to Enhance Monitoring Studies

## *Restoration Research Question*
## *What are the cumulative effects of watershed restoration activities within a watershed?*


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# What do we mean by monitoring?

- Monitoring means different things
  - Part of a hypothesis driven research project.
  - Requirement on a project, e.g. stream restoration.
  - Requirement for the MS4 permit.
- Monitoring designs
  - Paired watershed with control.
    - Combining these "one site monitoring" over time
  - Single watershed without control.
    - Monitoring for a long time.

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# Research effort: Optimizing Water Quality Monitoring

- Restoration Research Awards:
  - 13973: UMCES
  - 16925: Exponent
  - 20582: UMCES
- STAC 2023 Workshop

  *The State of the Science and Practice of Stream Restoration in the Chesapeake: Lessons Learned to Inform Better Implementation, Assessment and Outcome*

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# Project #13973 Objectives

- What is the optimal temporal frequency for sampling of pollutant loads within a watershed?
  - Assessed using high quality SERC weekly composite sampling data
- What is the optimal spatial design and scale of monitoring to detect a signal in water quality improvement within a watershed?
  - Leveraging Baltimore LTER data and Bayesian statistical tools to evaluate spatiotemporal sampling frequencies

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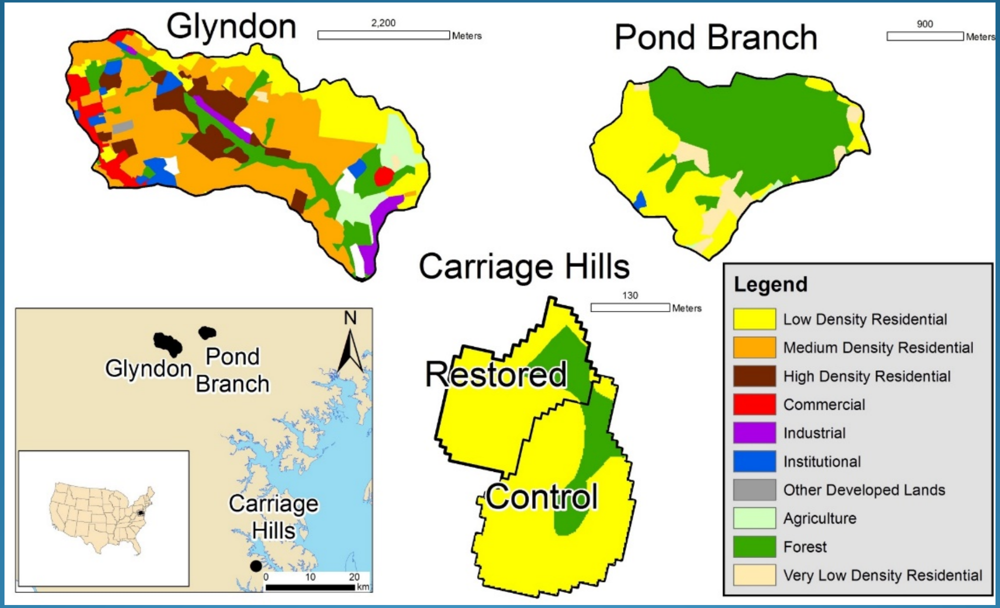
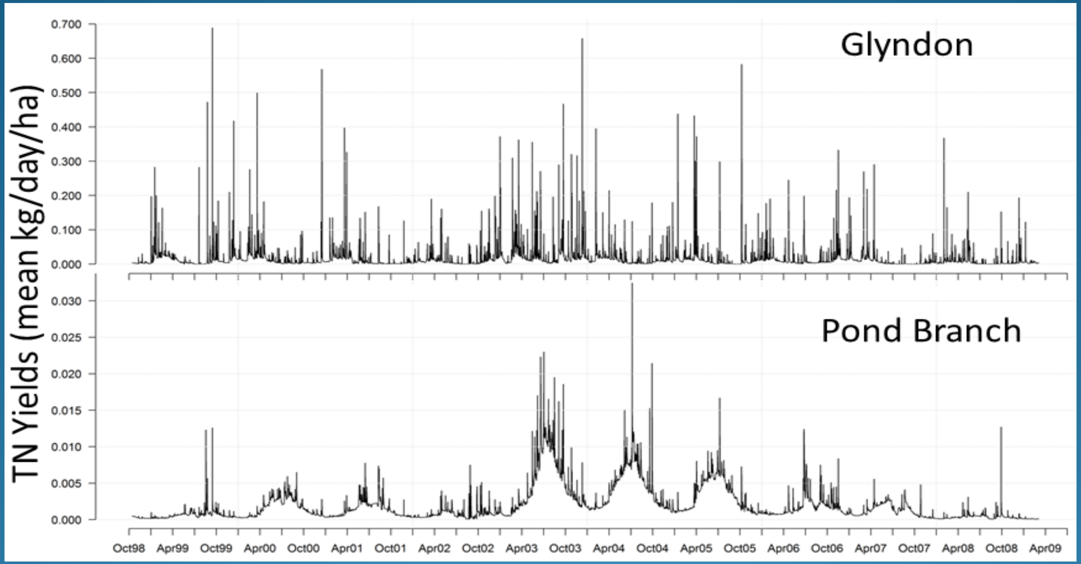
# Lesson 1: Monitor at the Right Spatial Scale




- Moderate load reduction from concentration changes (20%) was detected at project scale, but not at watershed scale.
  - Highlighting the challenges in matching the monitoring with the scales of restoration.

# Lesson 2: Select Good Controls




- Moderate load reduction from concentration changes (20%) was not detected.
  - Highlighting the challenges in designing a BACI monitoring using non-BACI data.

# Lesson 3: Value of Coordinated Assessments

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| Site | Scenario | BA | | BACI | | BACI (n=2) | |
|---|---|---|---|---|---|---|---|
| | | SRS | STS | SRS | STS | SRS | STS |
| Glyndon (TN) | 20% | n.a. | n.a. | n.a. | n.a. | n.a. | n.a. |
| | 50% | 1075(92) | 823(63) | 1216(101) | 1001(72) | 664(61) | 582(49) |
| | 80% | 71(2) | 69(1) | 82(2) | 83(2) | 42(1) | 47(1) |

- Pseudo-controls provide the biggest reduction in sample size for determining pollutant loads.

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# Project #16925 Objectives

- What are the cumulative effects of restoration activities within a watershed?
  - Assessing Maryland MS4 monitoring data
- What degree of representative temporal sampling is required to determine accurate pollutant discharges?
  - Leveraging high-frequency data and surrogate parameters to evaluate temporal sampling frequencies

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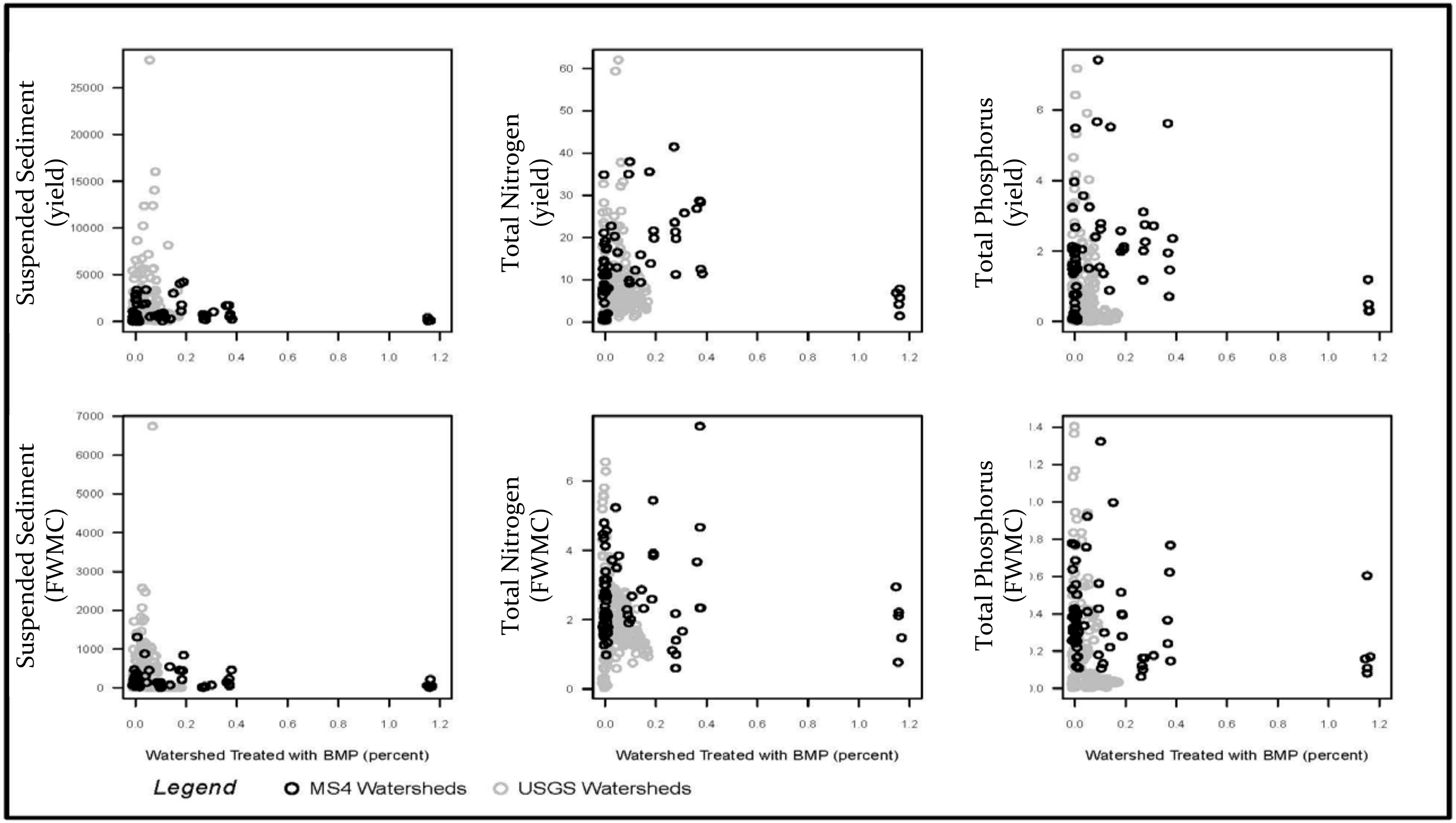
# Lesson 4: Determining the effect of stormwater restoration from existing monitoring programs is challenging



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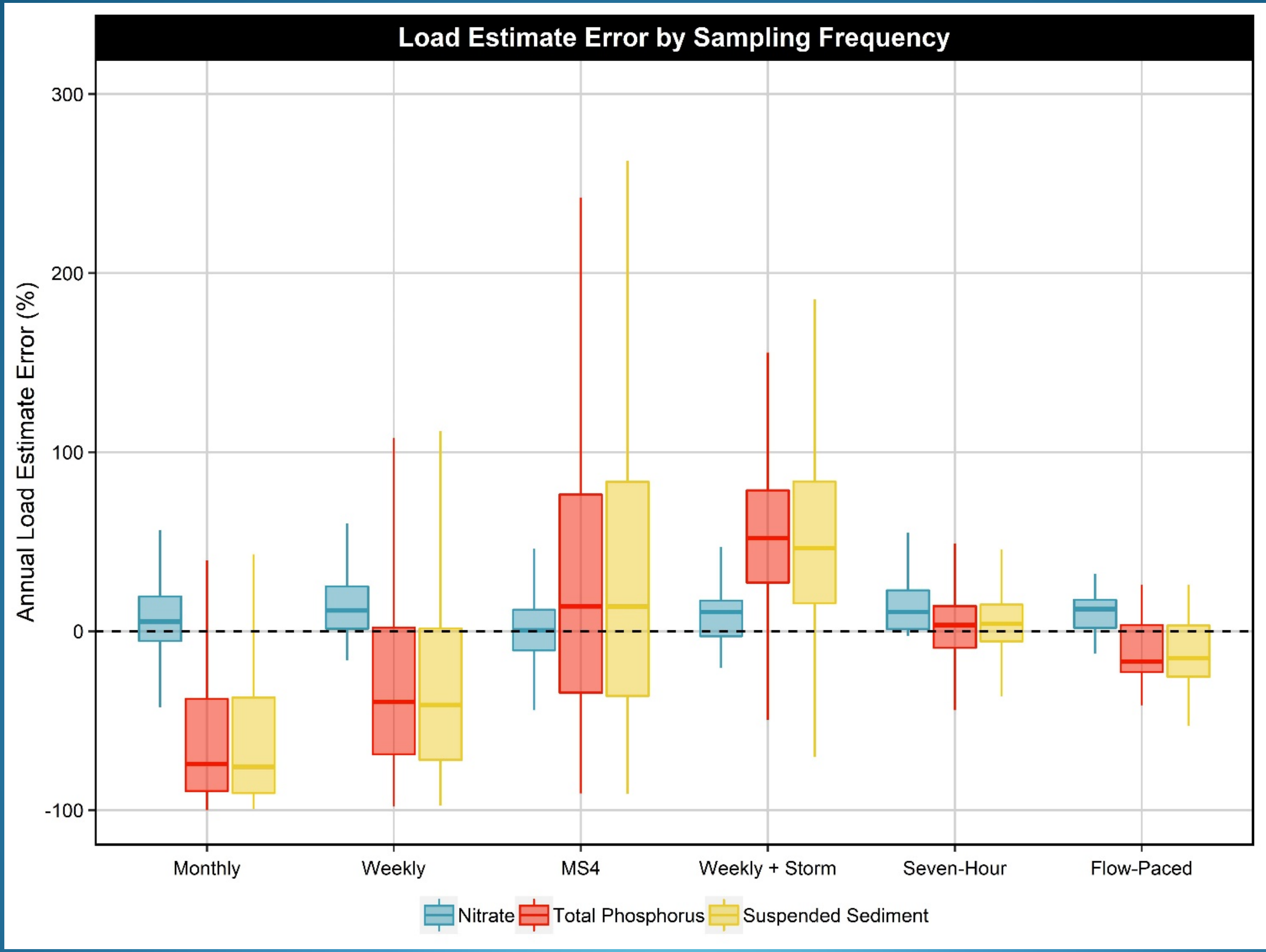
# Lesson 5: Sampling frequency and watershed characteristics influence load uncertainty

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# Lesson 5: Sampling frequency and watershed characteristics influence load uncertainty

**Table 1. Results of stepwise linear regression models for suspended sediment concentrations**

| Model Fit | Monthly | | Weekly | | Weekly+Storm | | Seven-Hour | | Flow-Paced | | MDE MS4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AIC | -12.19 | | 28.76 | | 125.78 | | 111.72 | | 98.28 | | 77.91 | |
| Adjusted R-squared | 62.7% | | 69.3% | | 13.0% | | 35.7% | | 23.6% | | 3.5% | |
| Overall p-value | <0.0001 | | <0.0001 | | 0.0094 | | <0.0001 | | 0.0005 | | 0.1168 | |
| Residual standard error (df) | 0.1972 (40) | | 0.3110 (39) | | 0.9661 (42) | | 0.8146 (41) | | 0.7067 (42) | | 0.5607 (42) | |
| **Model Terms** | **Coef.** | **P-value** | **Coef.** | **P-value** | **Coef.** | **P-value** | **Coef.** | **P-value** | **Coef.** | **P-value** | **Coef.** | **P-value** |
| Intercept | 0.08140 | 0.4594 | -0.9875 | 0.0038 | -2.265 | 0.0003 | -0.7647 | 0.0054 | 1.148 | 0.1670 | -1.115 | 0.0018 |
| Log Watershed Size | -0.06871 | 0.0002 | -0.1657 | <0.0001 | -- | -- | -0.2140 | 0.0002 | -- | -- | -- | -- |
| Log Discharge | -- | -- | -- | -- | -- | -- | -- | -- | -0.1693 | 0.0005 | -- | -- |
| Baseflow Index | -- | -- | 2.253 | 0.0028 | 4.499 | 0.0094 | -- | -- | -- | -- | 1.537 | 0.1168 |
| Flashiness Index | -- | -- | 0.0203 | 0.0362 | -- | -- | -- | -- | -- | -- | -- | -- |
| % Developed Low Intensity | -0.5668 | 0.0858 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| % Woody Wetlands | -14.30 | <0.0001 | -18.00 | <0.0001 | -- | -- | -16.98 | 0.0773 | -- | -- | -- | -- |

- Watershed characteristics influence the accuracy and precision of load estimates from different temporal sampling frequencies.

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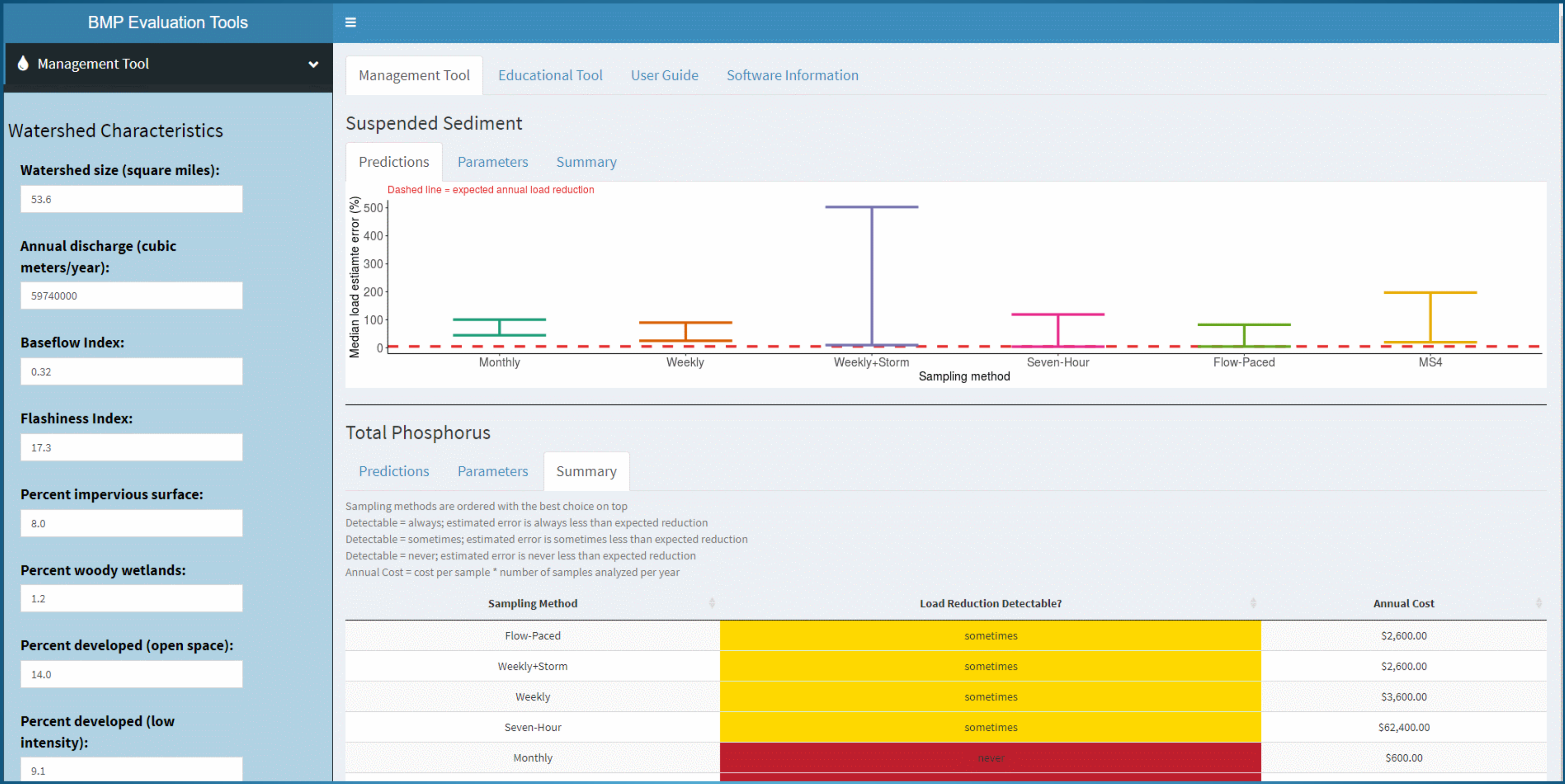
# Lesson 6: Decision support tools can help optimize monitoring programs



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# Project #20582 Objective

- To co-develop a software tool to help plan BMP monitoring studies and enhance restoration research.
  - Co-developed by practitioners and researchers, and data experts.
  - Informed by high frequency data
  - Deployed in an open source and web-enabled cyberinfrastructure.

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# Co-Development Process

- Meeting with MDE State Regulatory Staff
- Target: County Scientists/Staff
  - Site visit to Anne Arundel County
  - Virtual meeting with Baltimore County
  - Site visit to Carroll County
- STAC workshop

# Acknowledgements

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# Translation Slides

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# What does this mean for me?

- Experimental design can make or break a monitoring program. The choice of monitoring scale, BACI based-frameworks and controls, sampling size and frequency should be carefully considered before designing a monitoring study.

- Evolving from broader regulatory monitoring to hypothesis-driven monitoring, with greater coordination between researchers, practitioners, state, and local agencies, will help maximize the scientific value of monitoring dollars and better audit implementation dollars.

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# What do I take from this if I am a practitioner?

- The smaller the pollutant reductions from a project, the larger the investment needed in high-resolution monitoring and greater consideration of experimental designs able to detect expected water quality benefits.

- Decision support tools developed from these projects (current and forthcoming) can be beneficial when deciding whether monitoring will be a worthwhile component of a project, given the required resources.

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# What do I take from this if I am a regulator?

- Inadequate experimental designs and temporally coarse monitoring will likely be ineffective at evaluating a restoration program's success. The financial burden of a such a monitoring program can often outweigh the benefits of the information gained.

- Evolving from broader regulatory monitoring to hypothesis-driven monitoring, with greater coordination between researchers, practitioners, state, and local agencies, will help maximize the scientific value of monitoring dollars and better audit implementation dollars.

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# Monitoring Discussion

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# Questions for County Scientists/Staff

- *What is the goal of your stream monitoring?*
- *Within your department, what incentivize you to do monitoring?*
- *What resources are available “in-house” in county government?*
- *How have you designed your monitoring efforts in the past?*

# Questions for County Scientists/Staff (Cont.)

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- *What kind of stream restoration monitoring are you carrying out?*
- *Does it include automated flow-weighted composite sampling, hierarchical sampling of baseflow and storms….?*

# Questions for County Scientists/Staff (Cont.)

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- *How as the monitoring supported financially?*
- *Can you estimate the costs for supporting a station?*
  - *If possible, please break into analyte chemistry cost versus labor for data collection versus labor for interpretation and administration.*

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# Data Requirements?

- How can we get more "perfect" data?
  - Data format is "uniform", and available for access/re-use?
- Open-source software development and sharing
  - R-Shiny based light-weight applications.
- Web-enabled cyberinfrastructure
  - Facilitate data sharing, visualization and modeling