United States Environmental Protection Agency

Actionable Science for Communities

Flux-Based Site Management with a Focus on Recent Research Related to Measurement Uncertainty, SHC 3.61.2

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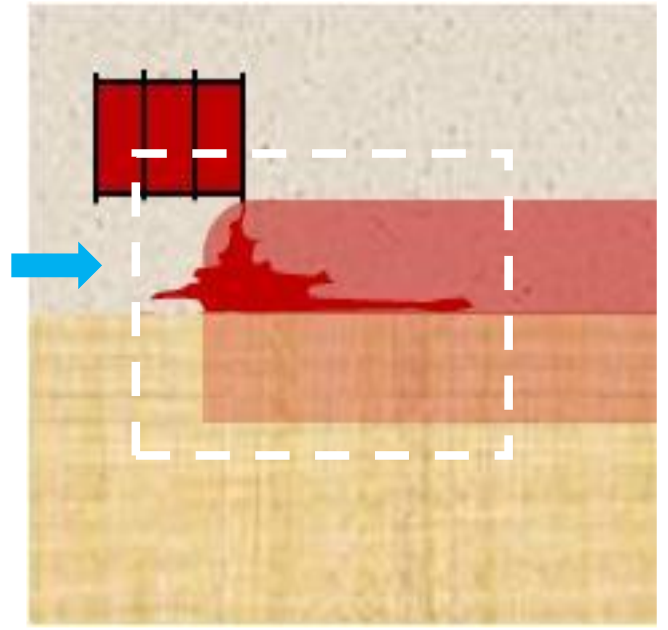
Purpose/Utility of Research

- How should we manage long-term contaminant problems?
- A key element needed to address this question is an understanding of how the contaminant source behaves over time, and how it responds to remedial treatment. This provides a foundation for making more accurate predictions, and thus improves management decisions.



A *simple* mass balance statement

Consider the box outlined with the white dashed line:

Change in mass inside the box =

Mass entering - Mass leaving - Mass destruction

$$\frac{dM}{dt} = -J(t)A - \Phi_M$$

$J(t)$ = Contaminant flux [mass per unit area per unit time]

$J(t)A$ = Contaminant mass discharge [mass per unit time]

- Flux combines two important features of contaminant risk: concentration and contaminant mobility.
- Flux-based site management entails the use of contaminant flux and mass discharge measurements for site management purposes.

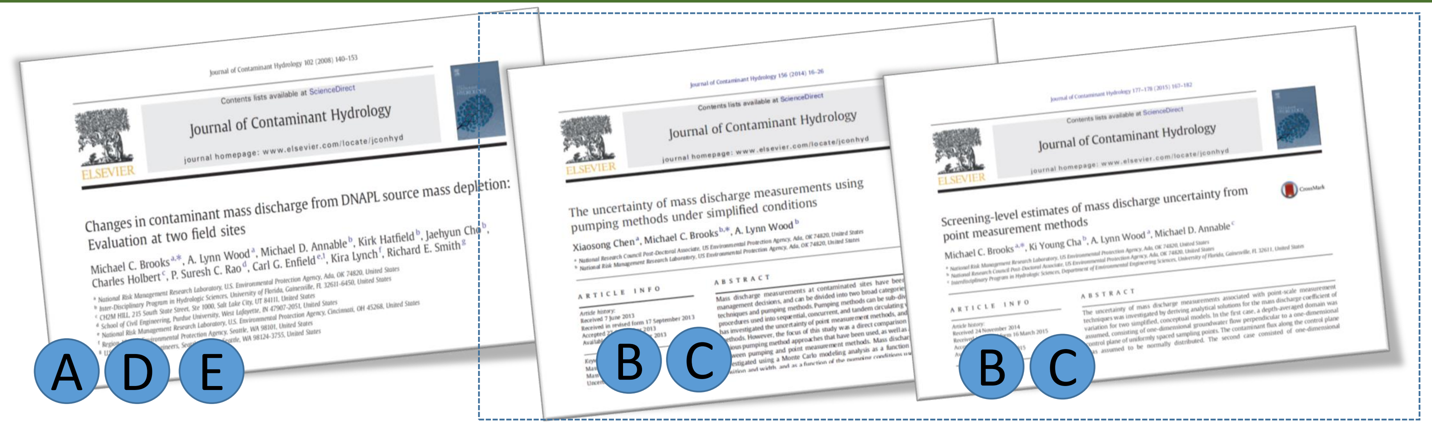
Science Questions

The following science questions summarize research goals that have been, and currently are being pursued within this research activity. Letters associated with Science Questions map research highlights to science questions.

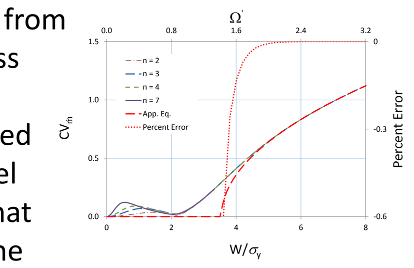
- How do you collect field-scale measurements of contaminant flux? (A)
- What is the uncertainty associated with contaminant flux measurements? (B)
- How can we minimize the cost and maximize the certainty of contaminant flux measurements? (C)
- How can we predict contaminant flux and mass discharge? (D)
- How will the contaminant plume respond to changes in contaminant source zone mass, and therefore changes in contaminant flux? (E)

Highlights

Products completed prior to the current FY16 to FY19 planning cycle (included to provide context to current activities)


A D E B C B C

Shown at right are results from research investigating mass discharge measurement uncertainty under simplified conditions. Screening level equations were derived that can be used to facilitate the collection of reliable mass discharge measurements.



$$\Omega' = \frac{\bar{J}_{max}}{\dot{m}S_D'}$$

$$S_D' = \frac{1}{WB}$$

$$CV_{\dot{m}} \cong \sqrt{\frac{\Omega'}{\sqrt{2}} - 1} \qquad CV_{\dot{m}} = f(\Omega') = f\left(\frac{\bar{J}_{max}}{\dot{m}S_D'}\right)$$

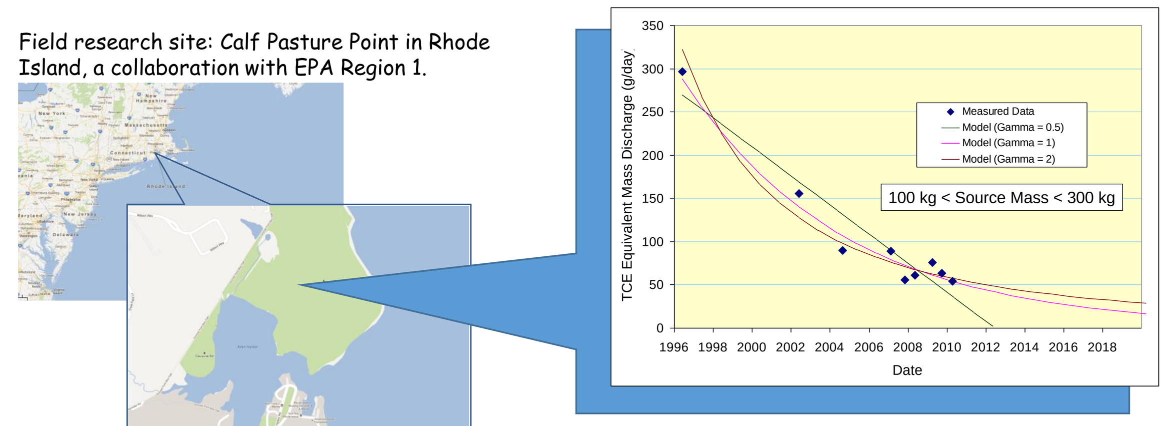
Milestones and products in the current FY16 to FY19 planning cycle

The blue dashed line highlights research on measurement uncertainty.

(D) Planned Product: **Flux-Based Site Management Summary Report**

This product will summarize research that has been completed under a collaborative research project funded by the Strategic Environmental Research and Development Program (SERDP) to investigate effective field-scale approaches based on flux measurements that can be coupled with appropriate predictive models to better link characterization, prediction, and decision making. This product will include research on the uncertainty of mass flux measurements and provide assistance in method selection (See Milestone at right).

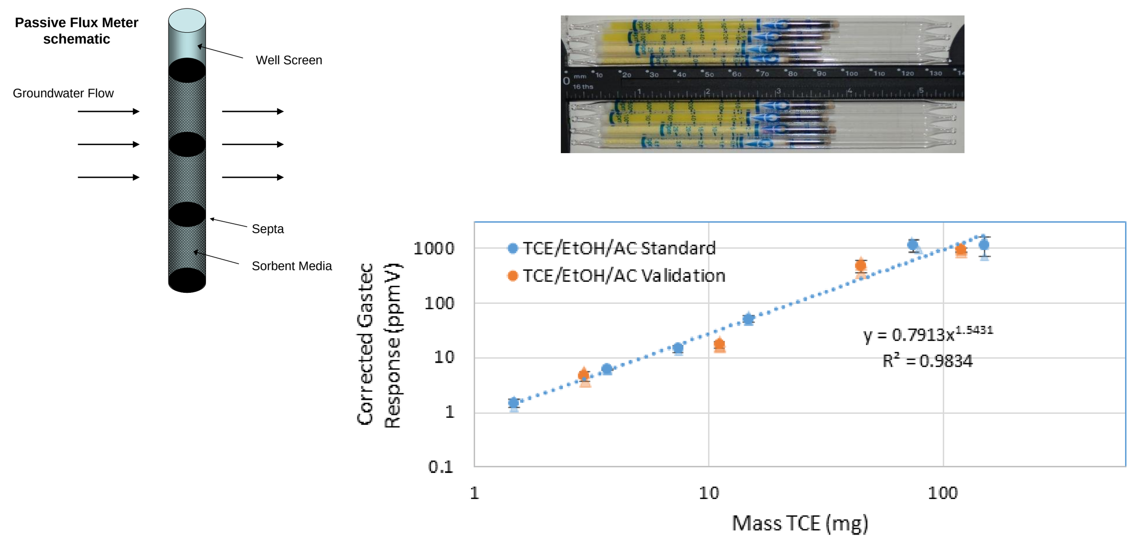
Field research site: Calf Pasture Point in Rhode Island, a collaboration with EPA Region 1.



The graphic above illustrate the concept of fitting models to mass discharge measurements to predict source behavior, and to better link characterization, prediction, and decision making.

Planned Product: **A High Resolution Passive Flux Meter Approach Based on Colorimetric Responses**

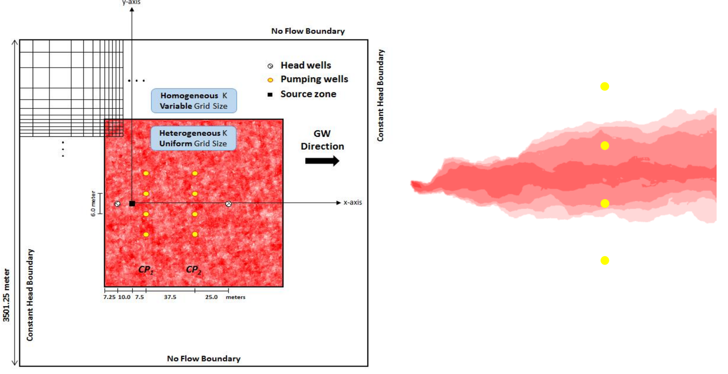
This product will summarize research to modify a current technology for flux measurements (e.g., the passive flux meter) so that the required laboratory based analysis of the technology can be replaced with a more rapid and less expensive colorimetric field-based analysis. Doing so will promote high-resolution sampling by making sample analysis cheaper and faster.



The lower right graphic above shows results from experiments conducted to investigate the use of Gastec tubes (upper right) as a field-based analysis method for passive flux meters. Passive flux meters are used to measure contaminant flux, and a conceptual depiction is shown in the left graphic above.

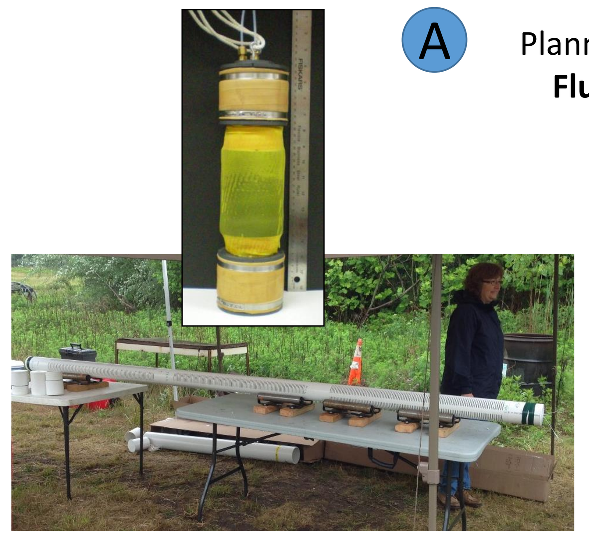
(B) (C) Milestone: **Mass discharge measurement uncertainty due to hydraulic conductivity heterogeneity**

- Study based on a Monte Carlo Analysis
- Pumping methods and point measurement methods were considered in the analysis
- Three levels of heterogeneity were examined: variance of log-transformed hydraulic conductivity = {0.25, 1.0, 4.0}



Selected Results

- Bias for all conditions tested ranged from 0 to -60%, and was strongly influenced by the method used to measure groundwater flux.
- Uncertainty ranged from 4% to 28% for all conditions tested, and increased as heterogeneity increased.
- Uncertainty was less for all methods at the downgradient control plane, reflecting the influence of the wider plume relative to the well spacing.



(A) Planned Product: **Measuring Contaminant Mass Flux and Groundwater Velocity in a Fractured Rock Aquifer Using Passive Flux Meters**

Purpose: evaluate the performance of innovative tools – a ***fractured rock passive flux meter*** and ***modified standard passive flux meter*** – to measure groundwater flow velocity and mass flux in a fractured bedrock setting and to compare the results to current technology. (A separate poster on this project is being presented by Diana Cutt as an example of a Regional/ORD collaboration.)

Application & Translation

Example applications:

- Research within the FY16 to FY19 planning cycle is ongoing, and its too early to identify specific applications from current research.
- Example applications associated with previous research include mass discharge reduction as an interim remedial goal for source treatment at two sites in Region 10, and mass discharge being used to assess contributions from multiple sources at a site in Region 9.

Research results will…

- Be used to improve source zone characterization.
- Improve predictions of source zone behavior.
- Provide a better understanding of flux measurement uncertainty.
- Improve reliability of flux measurements.

Intended End Users

End users of this research include federal and state regulators, and consultants engaged in groundwater contaminated site management.

Results and proposed products originate from numerous research partnerships and collaborations with the organizations shown below.

UF University of Florida; Region 2; Air Force Institute of Technology; Region 1; SERDP; Region 10; Purdue; OLEM; Clemson University; US Army Corps of Engineers Seattle District; USGS science for a changing world; Interstate Technology Regulatory Council (ITRC)

The diversified number of organizations illustrate the wide interest in flux measurements for contaminated site management purposes. Moreover, many of these organizations have been active participants in the research and have contributed to its development.

Lessons Learned

- Research within the FY16 to FY19 planning cycle is ongoing.
- A milestone has been completed showing the impacts of heterogeneity on mass flux measurements.
- A report is being completed summarizing results from a RARE project that investigated contaminant flux measurements in a fractured rock setting.
- Lessons learned from previous research: quantified benefits of aggressive source zone remediation, and showed that significant (>90%) reductions in source mass discharge can occur.
- Derived screening-level equations for the uncertainty of contaminant flux measurements.

Acknowledgements

Christine Williams (R1) and Bill Brandon (R1) are acknowledged for their support and contribution to the research shown on this poster related to the Calf Pasture Point Site. Diana Cutt (ORD\STL) and Katherine Mishkin (R2) are acknowledged for their contribution and support for the project related to flux measurements in fractured rock settings. Kira Lynch (ORD/STL) is acknowledged for her contributions and support of flux-based site management. Numerous individuals at GWERD have contributed to the work represented on this poster. The following list is limited to those currently employed at GWERD: Kiyoung Cha, Eric Daiber, Lisa Costantino, John Hoggatt, Junqi Huang, Xiaoling Liu, Chase Tillar, Justin Groves, Russell Neill, Ken Jewell, Tony Lee, Susan Mravik, John Skender, and Kathy Tynsky. Moreover, recognition is given to recently retired Dr. Lynn Wood for his contributions to the work shown on the poster.