Thank you for signing in early

The webinar will begin promptly at
12:00 pm ET, 9:00 am PT

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SERDP and ESTCP Webinar Series

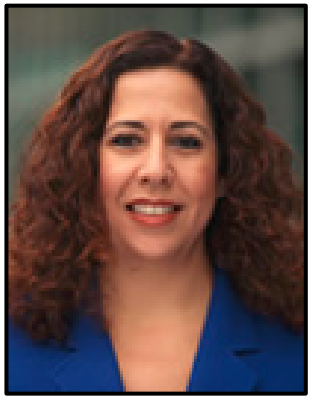
- The webinar will begin promptly at 12:00 pm ET, 9:00 am PT
- Two options for accessing the webinar audio
  - Listen to the broadcast audio if your computer is equipped with speakers
  - Call into the conference line
    - (646) 876-9923 or (408) 638-0986
    - Required conference ID: 554-261-448
- For questions or technical issues, please email serdp-estcp@noblis.org or call 571-372-6565

Forecasting Effective Site Characterization and Early Remediation Performance

October 18, 2018

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions



Rula A. Deeb, Ph.D.
Webinar Coordinator

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Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Dr. Andrea Leeson, SERDP and ESTCP
- **Effective Site Characterization and Remediation Decision Making: The Value of Information** (60 minutes + Q&A)
  Dr. Michael C. Kavanaugh, Geosyntec Consultants
  Dr. Kevin G. Mumford, Queen's University
  Dr. David A. Reynolds, Geosyntec Consultants
- **Final Q&A session**

In Case of Technical Difficulties

- Use a compatible browser (Firefox, IE or Edge)
- If material is not showing on your screen or if screen freezes
  - Key in Ctrl + F5 to do a hard refresh of your browser
- If connecting to computer audio
  - Click the arrow next to the "*Join Audio*" button
  - Select test "*Speaker and Microphone*"
  - Follow prompts
- If you continue to experience difficulties, call into the conference line
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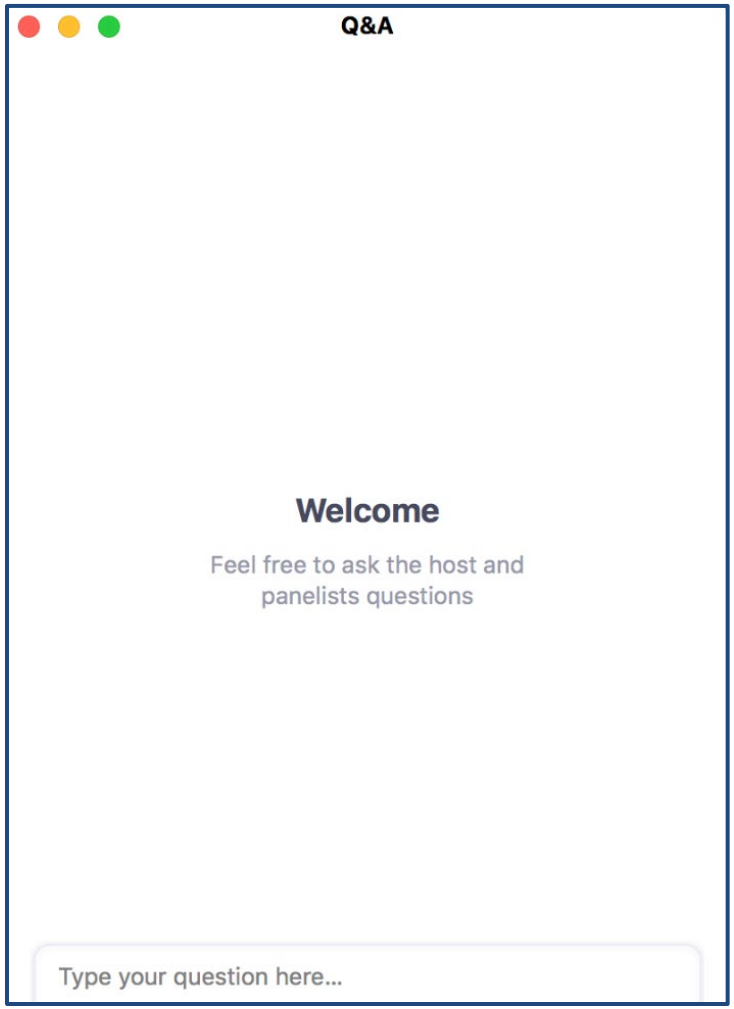
How to Ask Questions

- Find the Q&A button on your control bar and type in your question(s)
- Make sure to add your organization name at the end of your question so that we can identify you during the Q&A sessions



SERDP and ESTCP Overview

Andrea Leeson, Ph.D.
SERDP & ESTCP

SERDP DOD • EPA • DOE | ESTCP

DoD's Environmental Technology Programs

Science and Technology

- Statutory program established 1991
- DoD, DOE, EPA partnership
  - Advanced technology development to address near-term needs
  - Fundamental research to impact real world environmental management

Demonstration and Validation

- Demonstrate innovative cost-effective environmental and energy technologies
  - Transition technology out of the lab
  - Establish cost and performance
  - Partner with end user and regulator
  - Technology transfer
    - Accelerate commercialization or broader adoption
    - Direct technology insertion

Environmental Drivers

Sustaining Ranges, Facilities and Operations

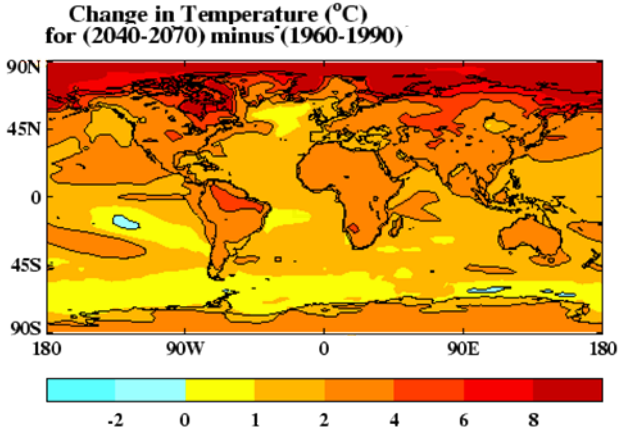
Maritime Sustainability
Threatened and Endangered Species

Toxic Air Emissions and Dust

UXO and Munitions Constituents

Noise

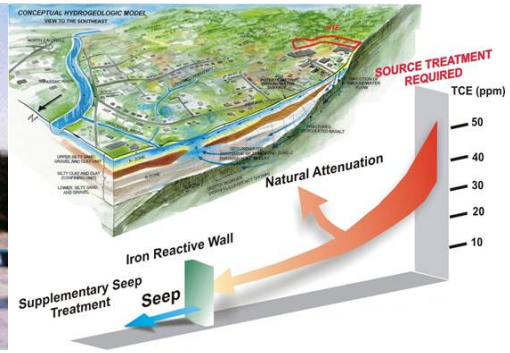
Sustainable FOB



Environmental Drivers

Reducing Current and Future Liability

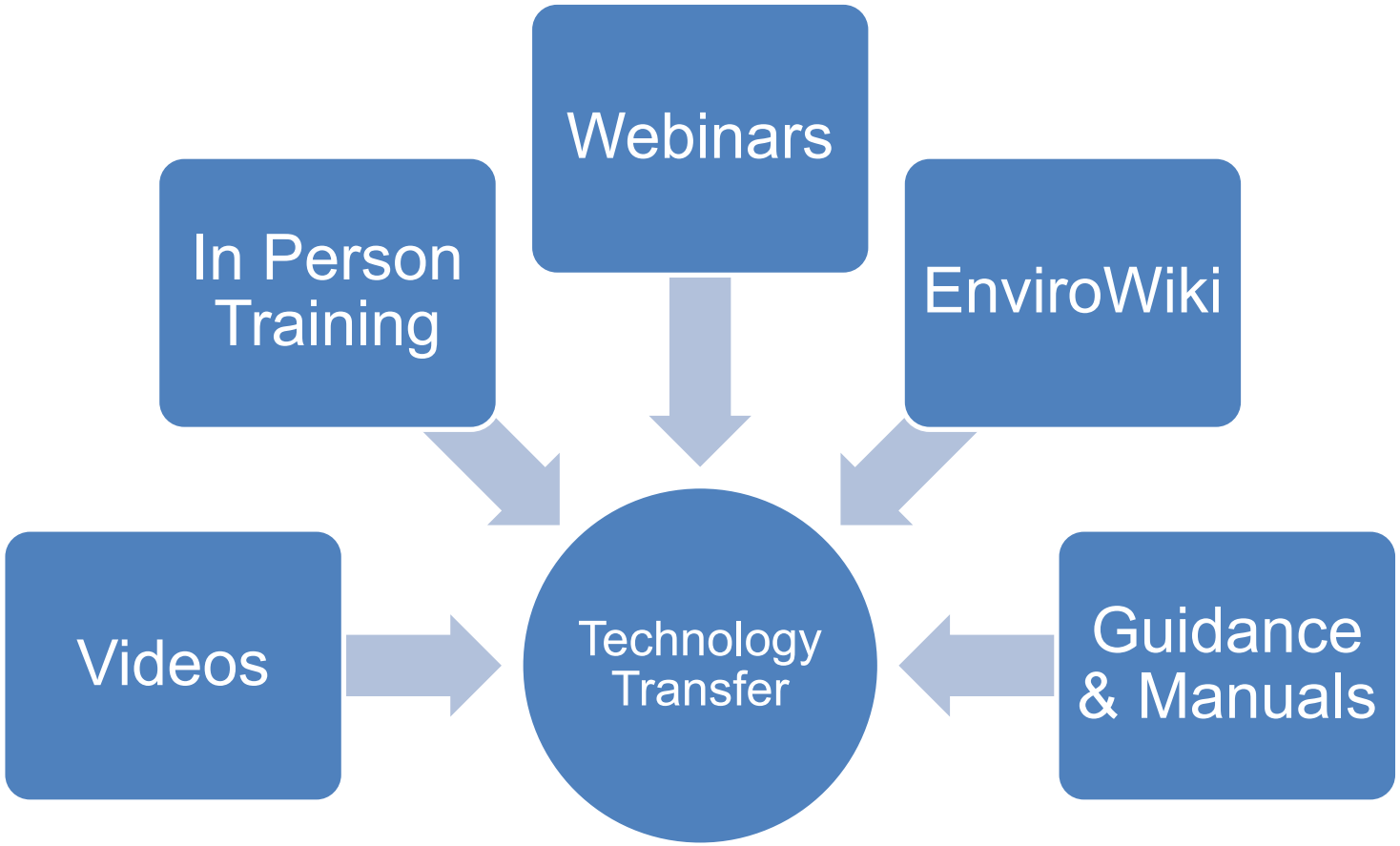
Contamination from Past Practices



- Groundwater, soils and sediments
- Large UXO liability
- Emerging contaminants

Pollution Prevention to Control Life Cycle Costs

- Elimination of pollutants and hazardous materials in manufacturing, maintenance, and operations
- Achieve compliance through pollution prevention


Webinars
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Webinars

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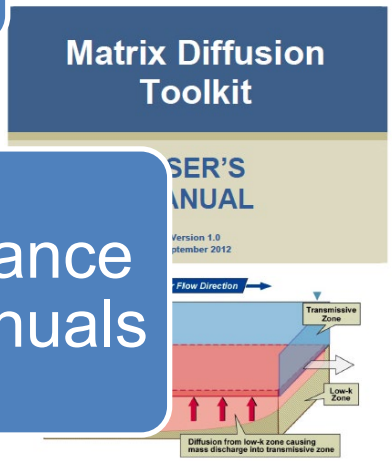

SERDP and ESTCP Webinar Series

Date	Topic
November 1, 2018	Supporting DoD Installation Sustainability Through Informed Stormwater Management
November 15, 2018	Stormwater Impacts on Sediment Recontamination
December 13, 2018	Installation Energy and Water Program Area Webinar

For upcoming webinars, please visit

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

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Save the Date!

SERDP • ESTCP
SYMPOSIUM
2018 | Enhancing DoD's Mission Effectiveness

A three-day symposium showcasing the latest technologies that enhance DoD's mission through improved environmental and energy performance

November 27-29, 2018

Washington Hilton Hotel

Registration is open

The DIVER Project: Using Perfect Information to Evaluate Strategies for Conceptual Site Model Development and Remediation at DNAPL Sites

Michael Kavanaugh, Geosyntec Consultants
Kevin Mumford, Queen's University
David Reynolds, Geosyntec Consultants

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DIVER Background

Michael Kavanaugh, Ph.D., P.E.
Geosyntec Consultants

Presentation Outline

- Problem definition
- DIVER background
- Site investigation
- Effective practice
- Remediation design
  - Conceptual site model (CSM) link to remediation design
- Conclusions

The DIVER Team

Geosyntec consultants

engineers | scientists | innovators

- Mike Kavanaugh
- David Reynolds
- David Major
- Silvia Mancini
- Cathy Crea
- Sean Bryck
- James Rayner
- Gary Wealthall

Queen's University

- Bernard Kueper
- Kevin Mumford
- Sumit Kalia

Stanford University

- Peter K. Kitanidis

Problem Definition

- Remediation of groundwater contaminated with chlorinated solvents is a significant DoD liability
- Adaptive management strategies require decisions on level of effort needed to characterize sites and assess remedial performance
- "Value of New Information" question
  - New decision tools needed

 Notes: DoD – Department of Defense

Defense Environmental Restoration

Programs Status Through 2016

- DoD Goal = 95% Remedy Complete (RC) at all sites by 2021
- 2016: DoD reported 85% RC
- 2018: IRP funding request $1 billion
  - Likely underestimates costs for mega sites
- Challenge: Remedial Action Goals at groundwater contaminated sites driven by absolute goal of Unlimited Use/Unrestricted Exposure (e.g. MCLs)

Source: www.denix.osd.mil/cleanup/, June 2018

IRP – Installation Restoration Program
MCLs – Maximum contaminant levels

The "Mega-Site" Problem

Transition to Long-Term Management

- "RC" at many sites does not mean restoration
- Challenge for DoD: transition sites to LTM and institutional controls
- What additional information (data) is needed to address risks of residual contamination?
- Value of Information (VOI) problem
  - Driver to improve decision-making at complex sites and reduce life cycle costs

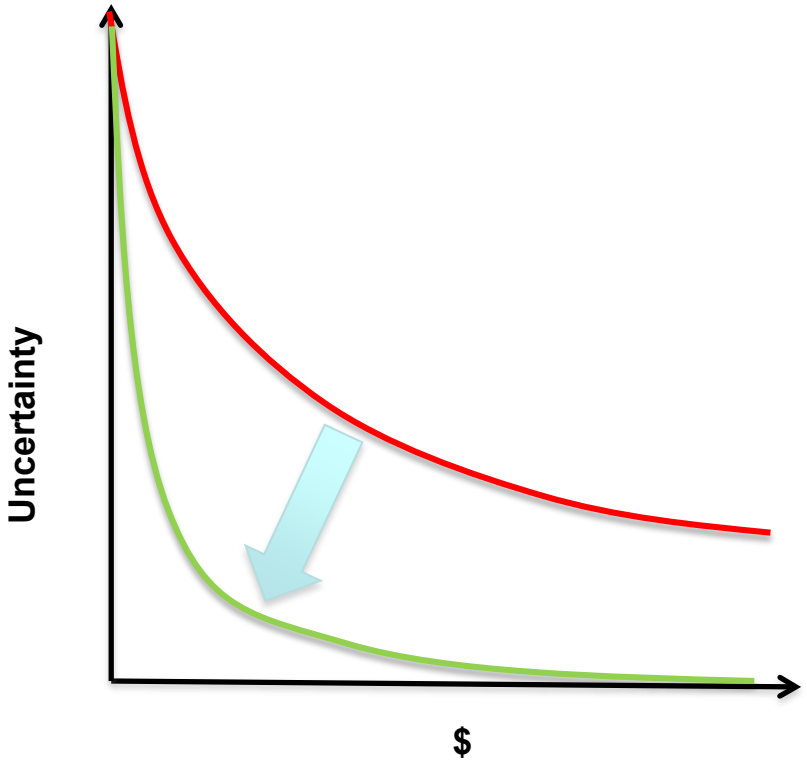
LTM – Long-term management

Introduction to the DIVER Project

- Question
  - Improve return on investment in site investigation for more efficient and cost-effective remediation?
- DIVER (Data Information Value to Evaluate Remediation)
  - Value of Information (VOI)-based approach for conceptual site models and remediation decision making
- DIVER aims to address the “how close is close enough” conundrum
  - Compare experienced practitioners against a stochastic approach – based on “perfect information”

Objective

- Develop a decision framework
  - Based on effective practice
  - Reduce total cost of investigation and remediation
  - Achieve remedial goals
  - Maximize likelihood of successful remedial strategies



Benefits of DIVER to DoD

- Guidance on effective practice for site investigation as a basis for remedy decision making and design at DNAPL impacted sites
- Scientifically sound and cost effective strategies to account for heterogeneity in remedial design and operation
  - Identify most valuable data for collection
- VOI analyses at key phases of site lifecycle
- Utility and limitations of different modeling approaches and assumptions

Site Investigation

Kevin Mumford, Ph.D.
Queen's University

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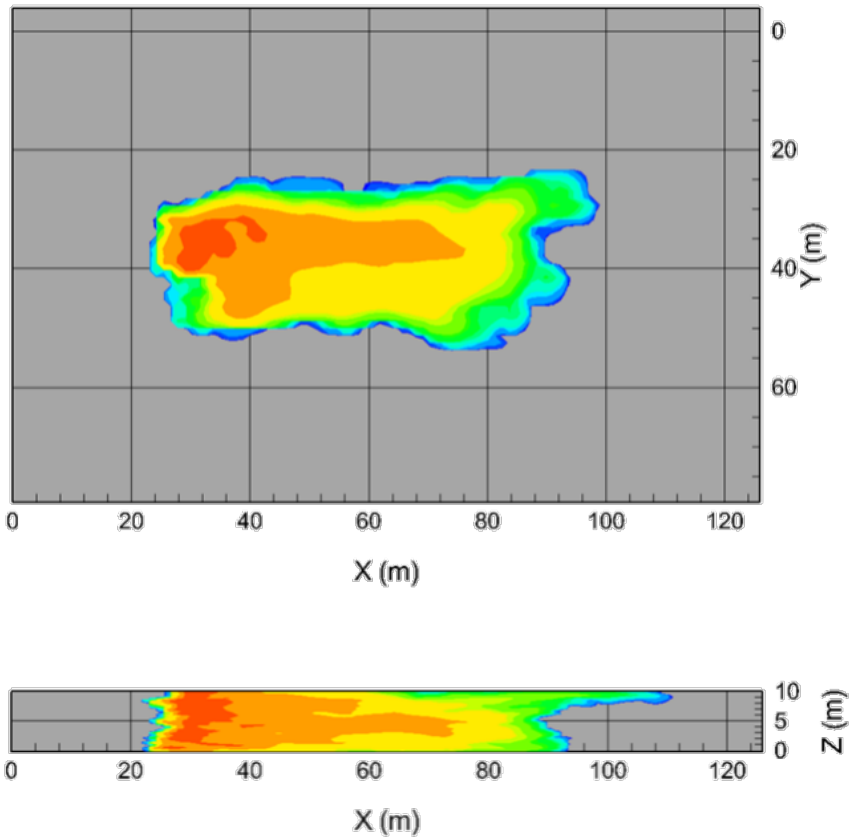
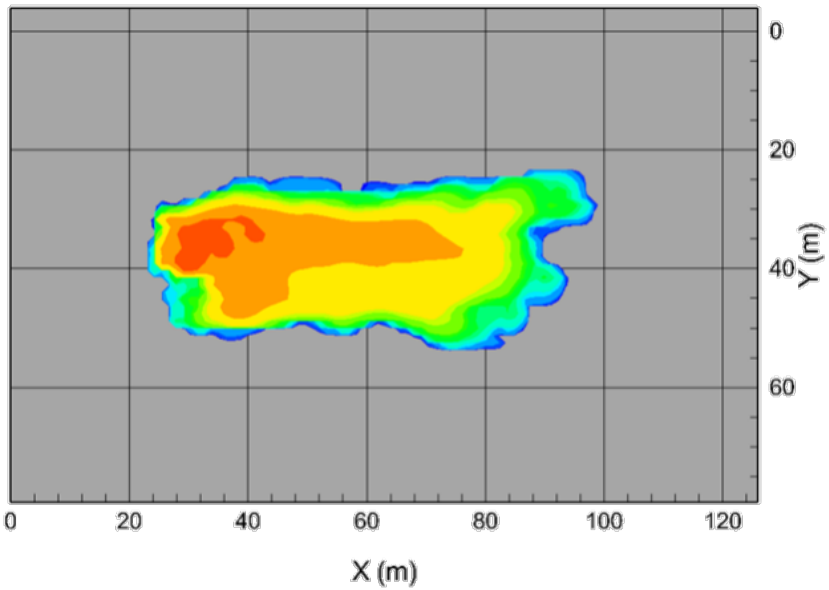
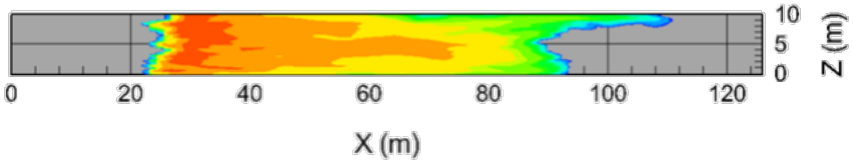
Perfect Understanding - Virtual Sites



- Series of 3 virtual site datasets (VSD-A, VSD-B, VSD-C)
  - Known geological, hydrogeological and biogeochemical parameters
- Created using DNAPL3D-RX
  - Multiphase flow of water and TCE
  - Dissolution and reactive transport
- Large, high-resolution domains
  - 300 to 500 m in lateral extent
  - Discretization of 10^0 m laterally and 10^{-1} m vertically
  - Heterogeneous permeability

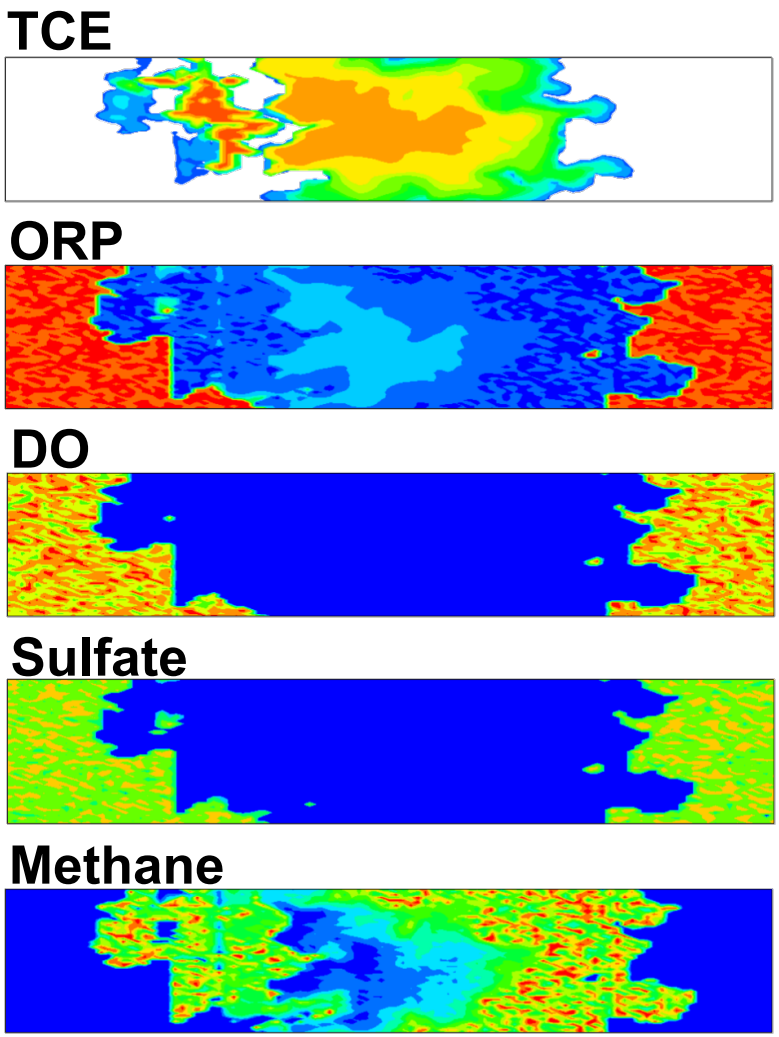
Perfect Understanding - Virtual Sites





- Simulation results = 'true' values
  - Hydraulic head
  - Permeability
  - Groundwater velocity
  - Fraction of organic carbon
  - DNAPL saturation
  - Dissolved TCE, cDCE, Cl^-
  - Sorbed TCE, cDCE
- Additional background
  - Dissolved metals, major ions

Perfect Understanding - Virtual Sites



- Biogeochemical parameters
  - ORP
  - DO
  - Sulfate
  - Hydrogen
  - Methane
  - Nitrate
  - Nitrite
  - Ammonia

0.5 to 1 billion data values stored for each virtual site

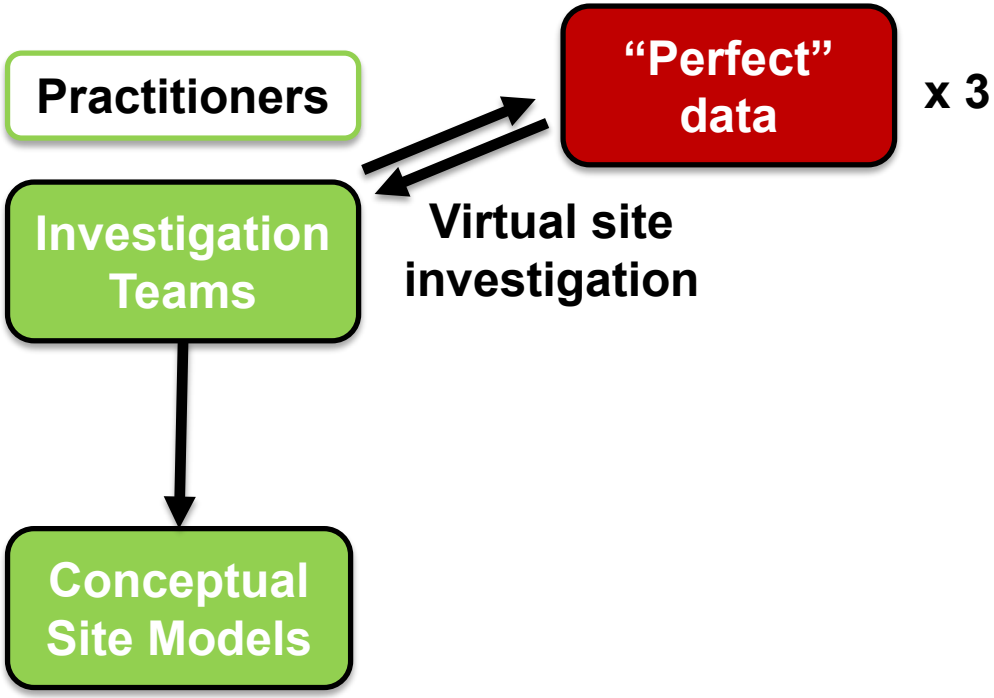
DIVER Technical Approach

Phase 1 - Site Investigation

"Perfect" data x 3

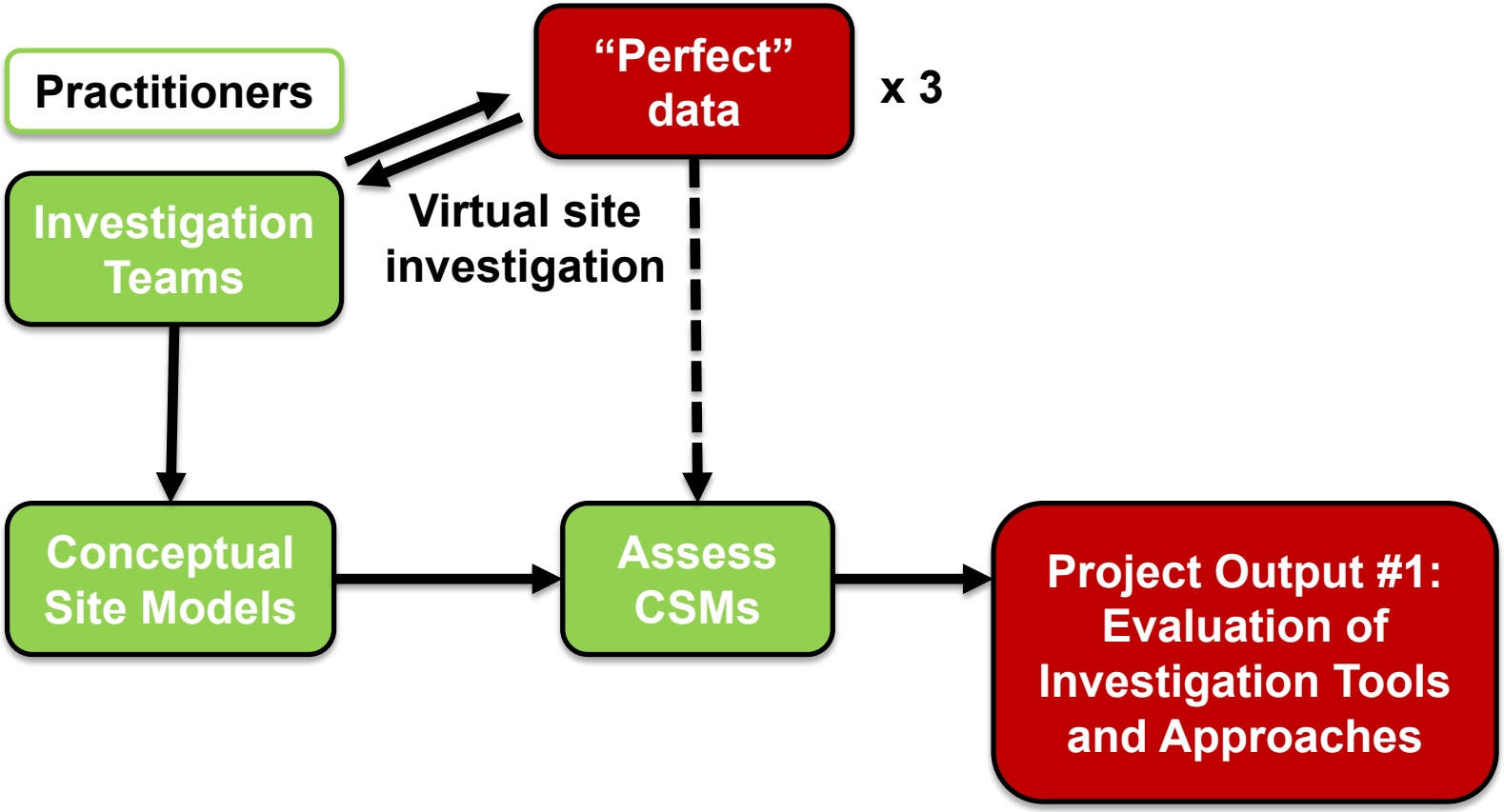
DIVER Technical Approach

Phase 1 - Site Investigation



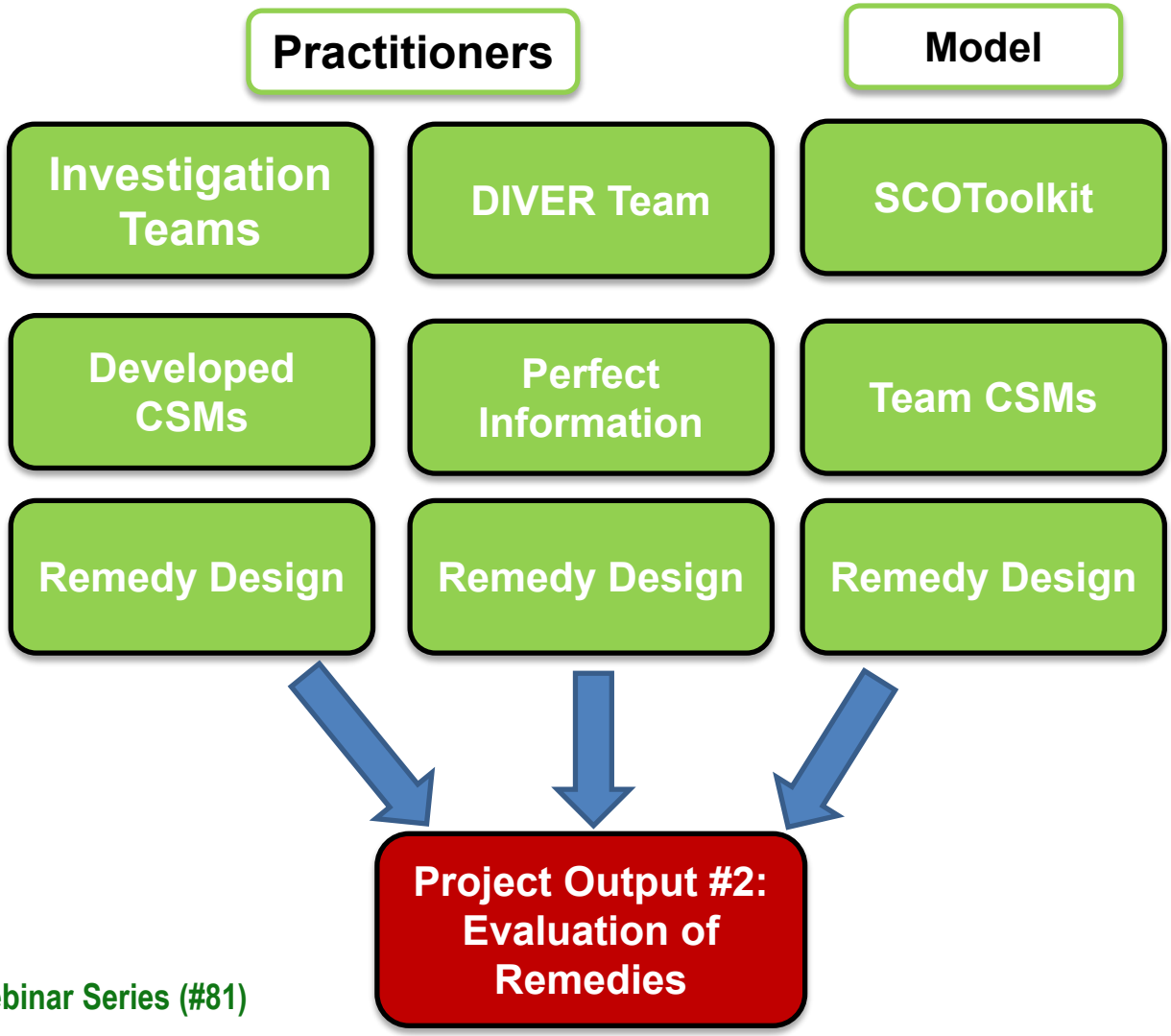
DIVER Technical Approach

Phase 1 - Site Investigation

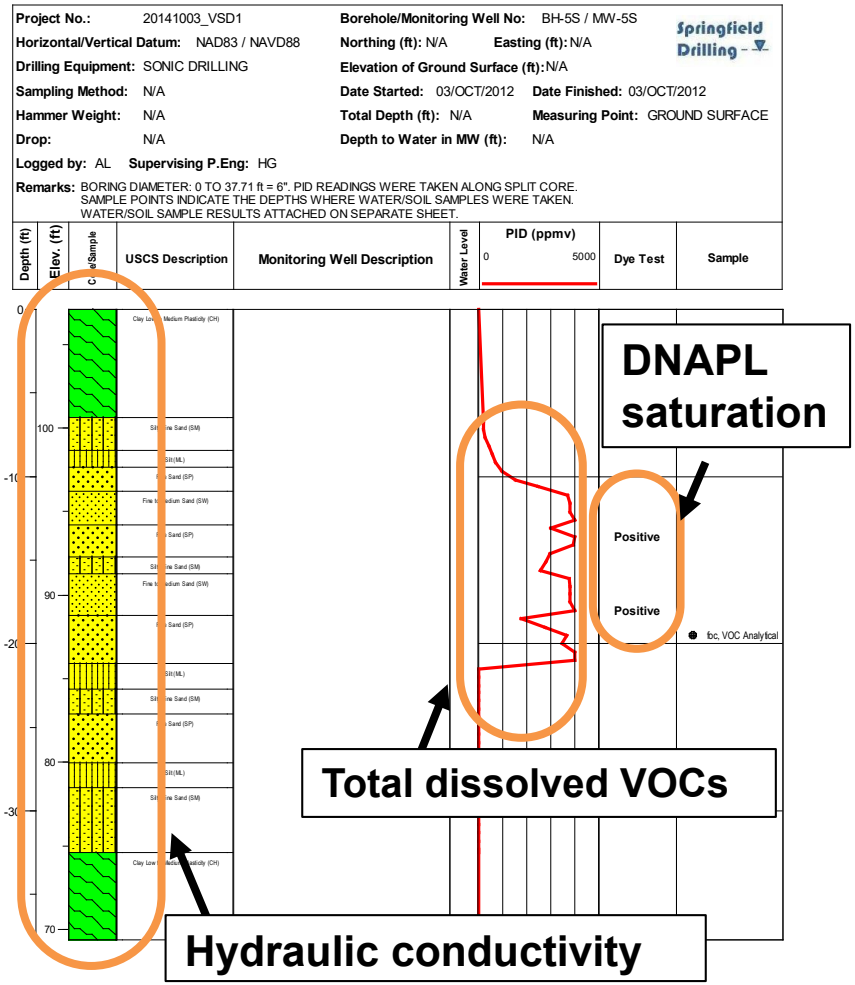


DIVER Technical Approach

Phase 2 - Remediation



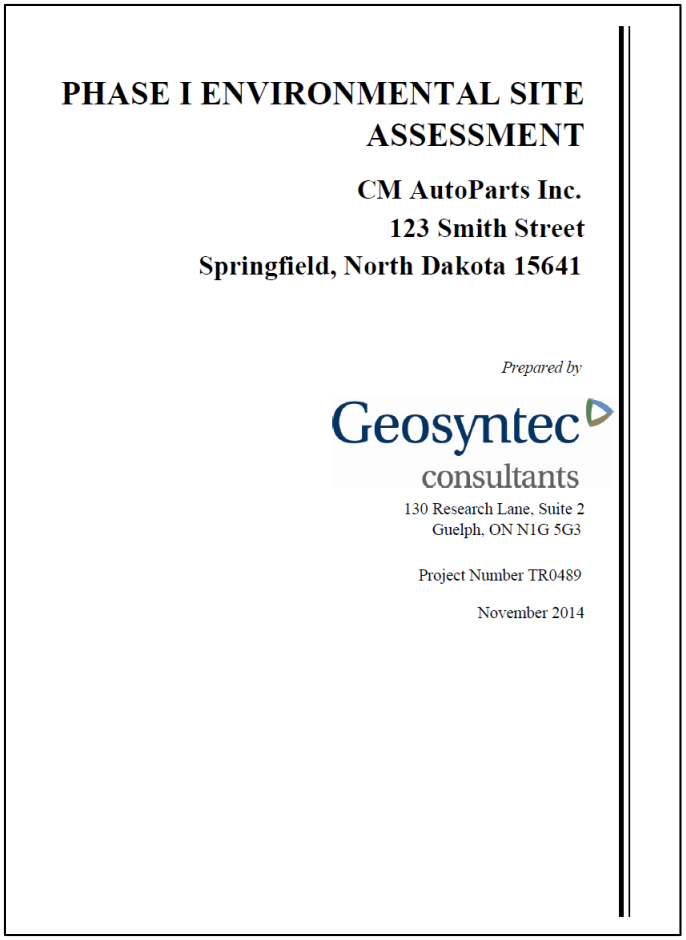
Phase 1 - Virtual Investigation Tools



- Model input and output transformed to measurements and formats obtained in the field
  - Soil boring
  - Monitoring well
  - CMT well
  - MIP-HPT
  - DyeLIF
  - Slug test
  - Pumping test
  - Groundwater sample
  - Soil sample
  - Hydrophobic dye test

Starting Point

Phase 1 Environmental Site Assessment



PHASE I ENVIRONMENTAL SITE ASSESSMENT

CM AutoParts Inc.
123 Smith Street
Springfield, North Dakota 15641

Prepared by

Geosyntec consultants
130 Research Lane, Suite 2
Guelph, ON N1G 5G3

Project Number TR0489

November 2014

- 4 Investigation Teams from the consulting sector
  - Develop CSMs for 3 virtual sites given information in a typical Phase I report
  - Use virtual investigation tools and virtual sample analyses
  - Characterization for engineered in-situ bioremediation (EISB) design
  - All costs tracked
- Values from the teams compared to true values from the simulations
  - Multiple metrics considered

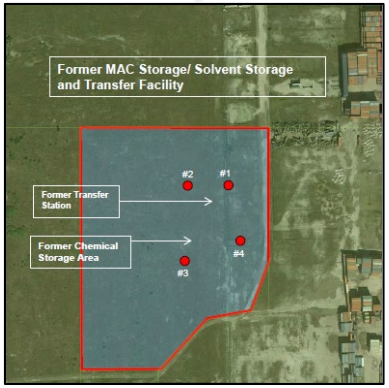
Conceptual Site Models

Investigation Teams

1 2 3 4

Virtual Site Datasets (VSD)

VSD-A: CM Autoparts Inc. (Springfield, ND)



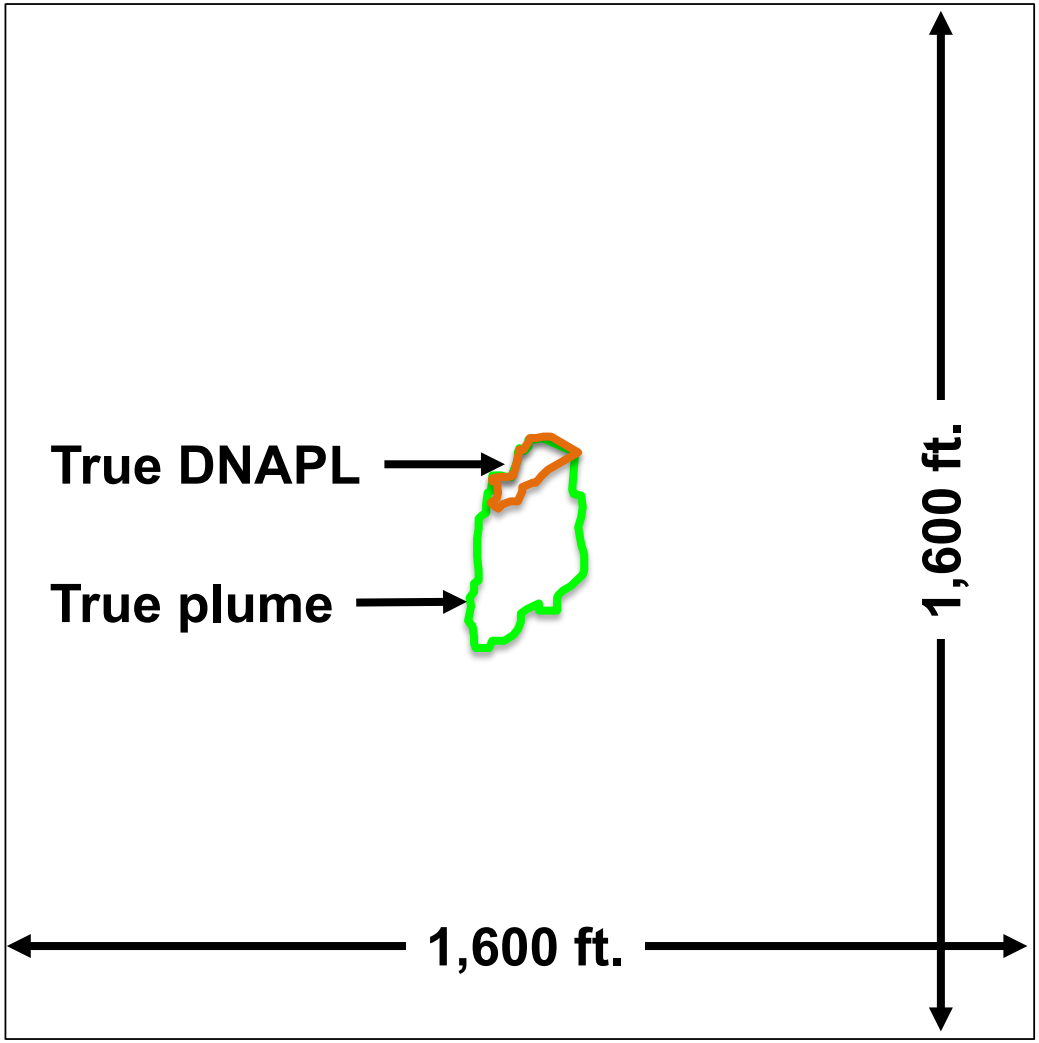
VSD-B: MAC Storage Inc. (Jackson, KS)

VSD-C: Silicon Electronics Inc. (Smithsville, MN)

Conceptual Site Models (CSM)

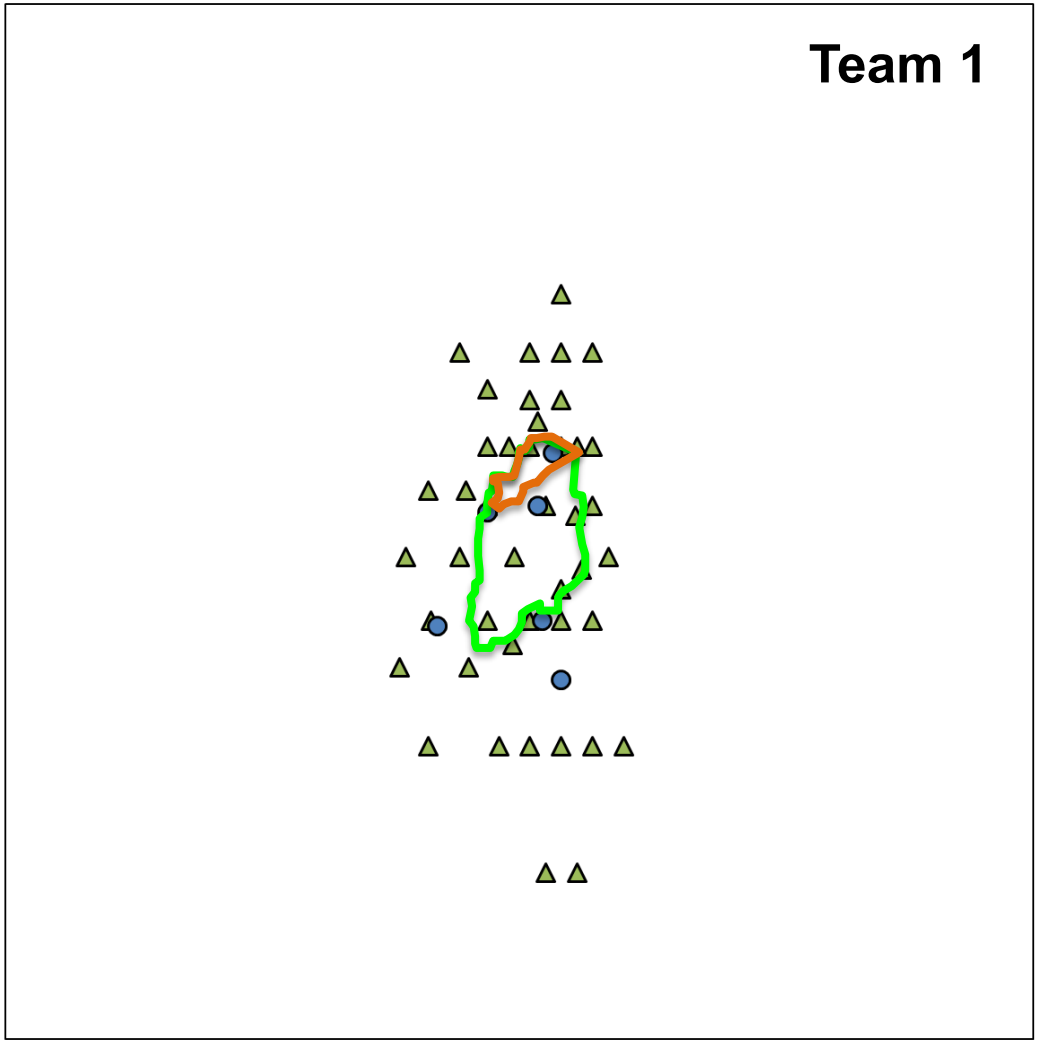
CSM-A-1	CSM-A-2	CSM-A-3	CSM-A-4
CSM-B-1	CSM-B-2	CSM-B-3	CSM-B-4
CSM-C-1	CSM-C-2	CSM-C-3	CSM-C-4

Example Tool Placement



Example Tool Placement

- Monitoring well
- CMT well
- Borehole
- MIP-HPT
- DyeLIF



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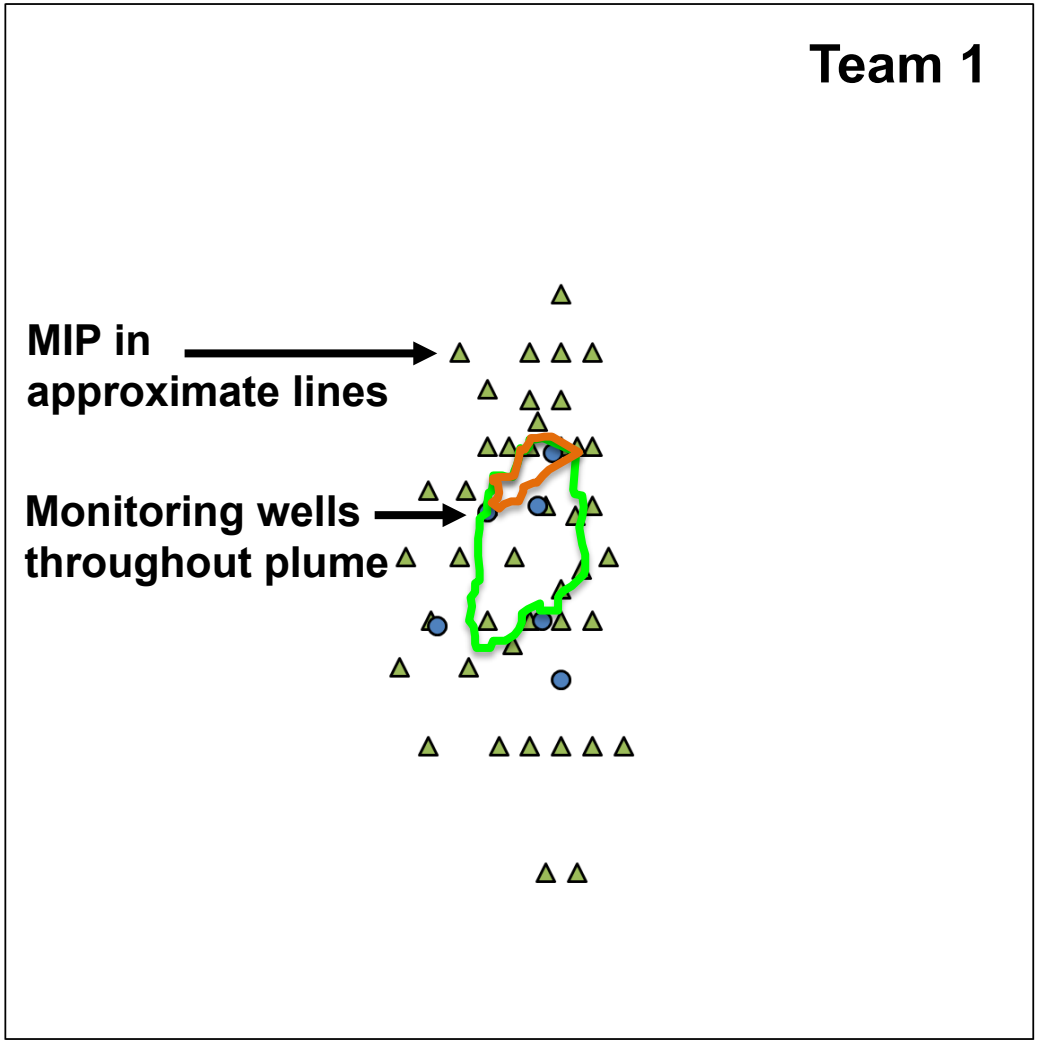

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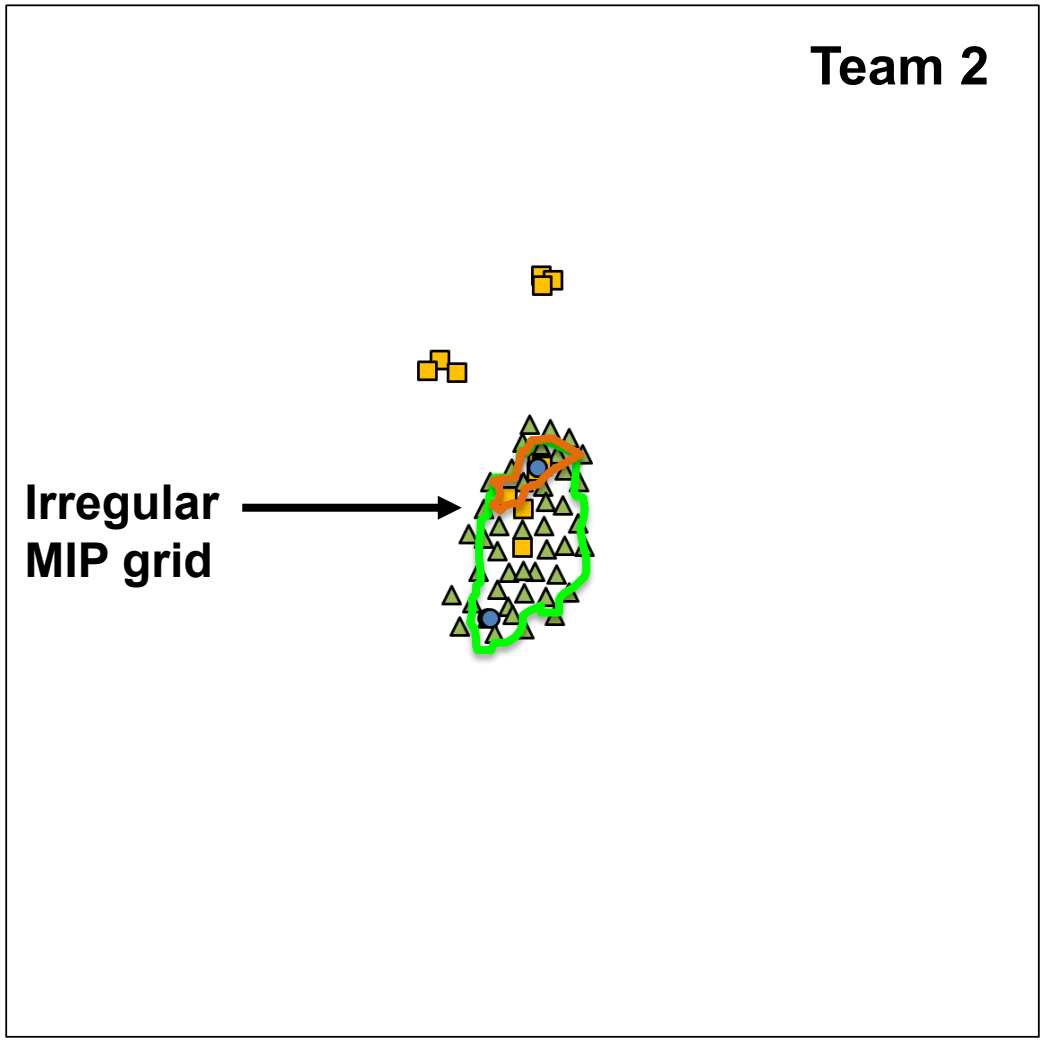

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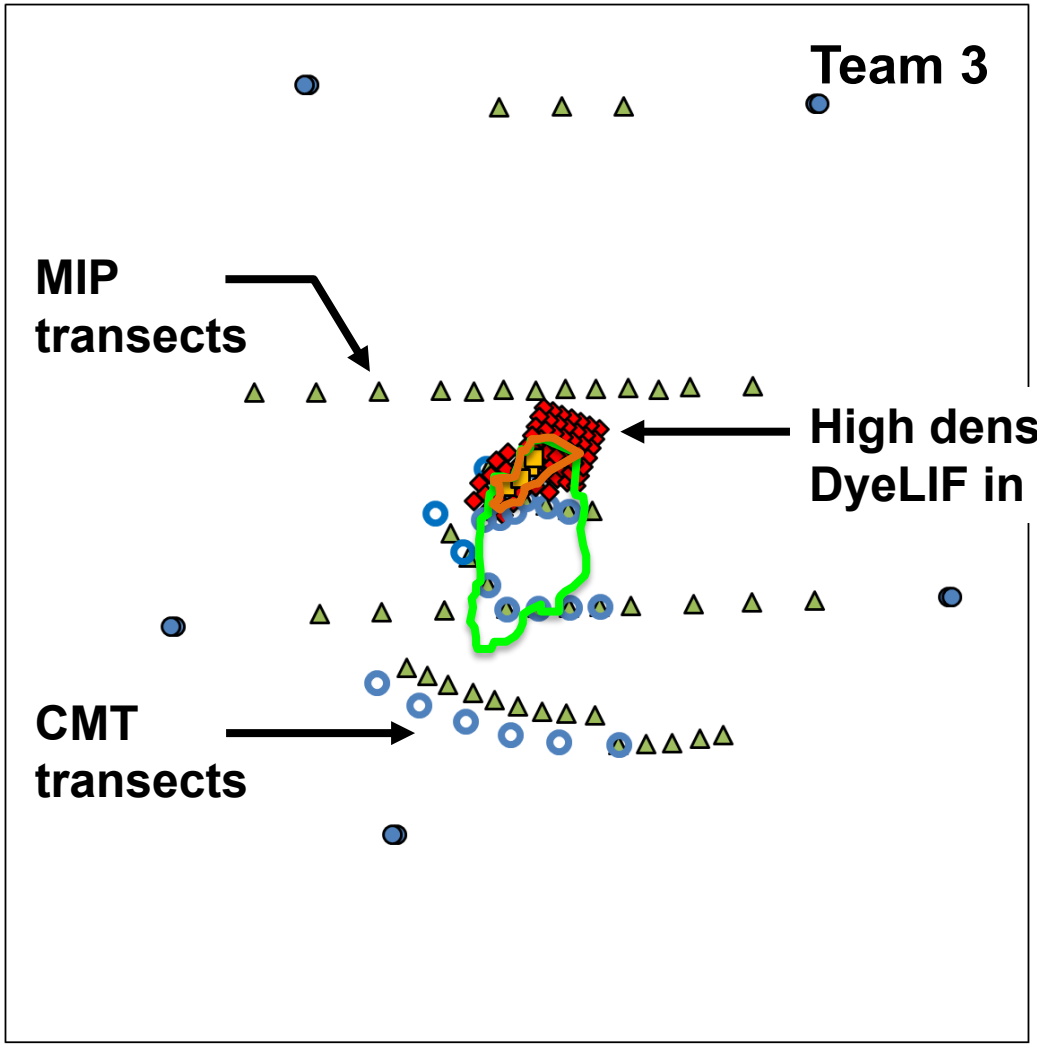

Example Tool Placement

- Monitoring well
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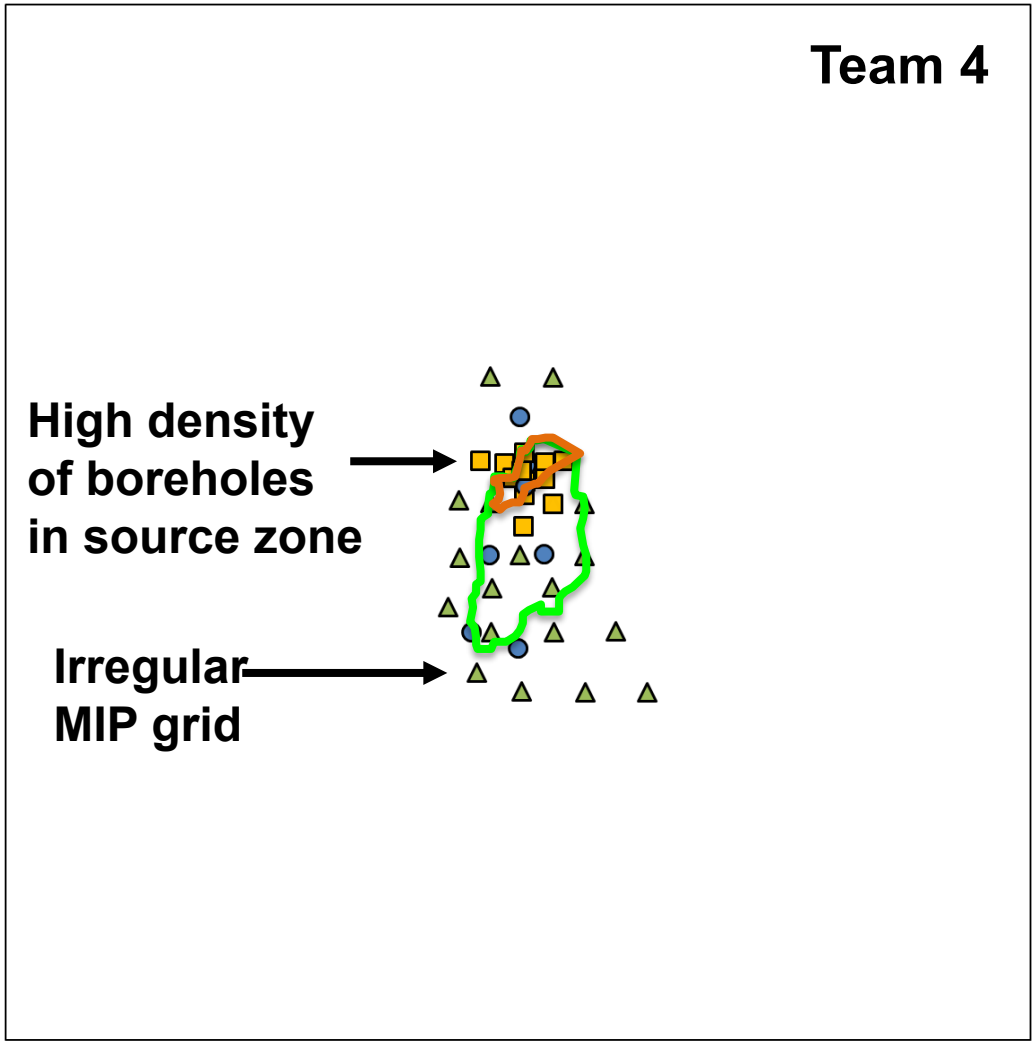
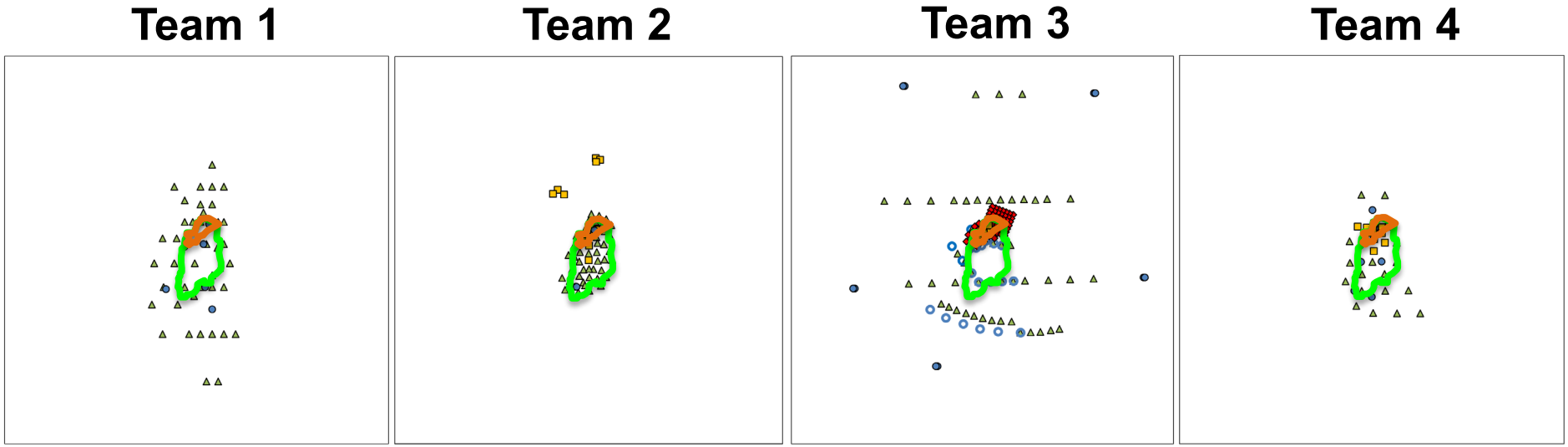
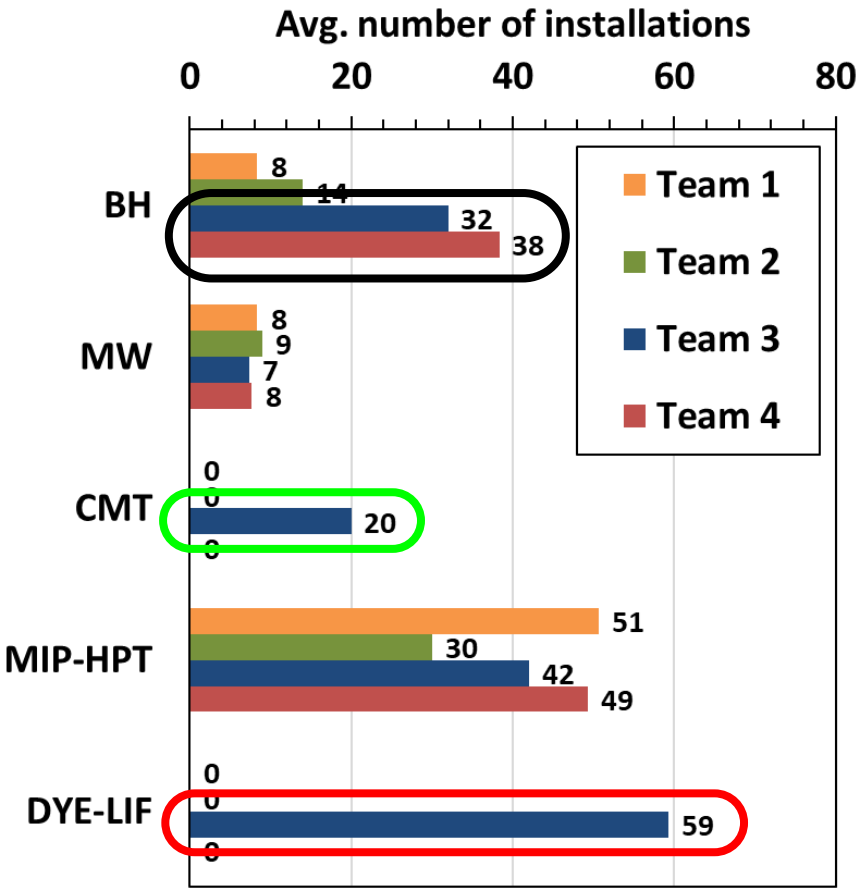


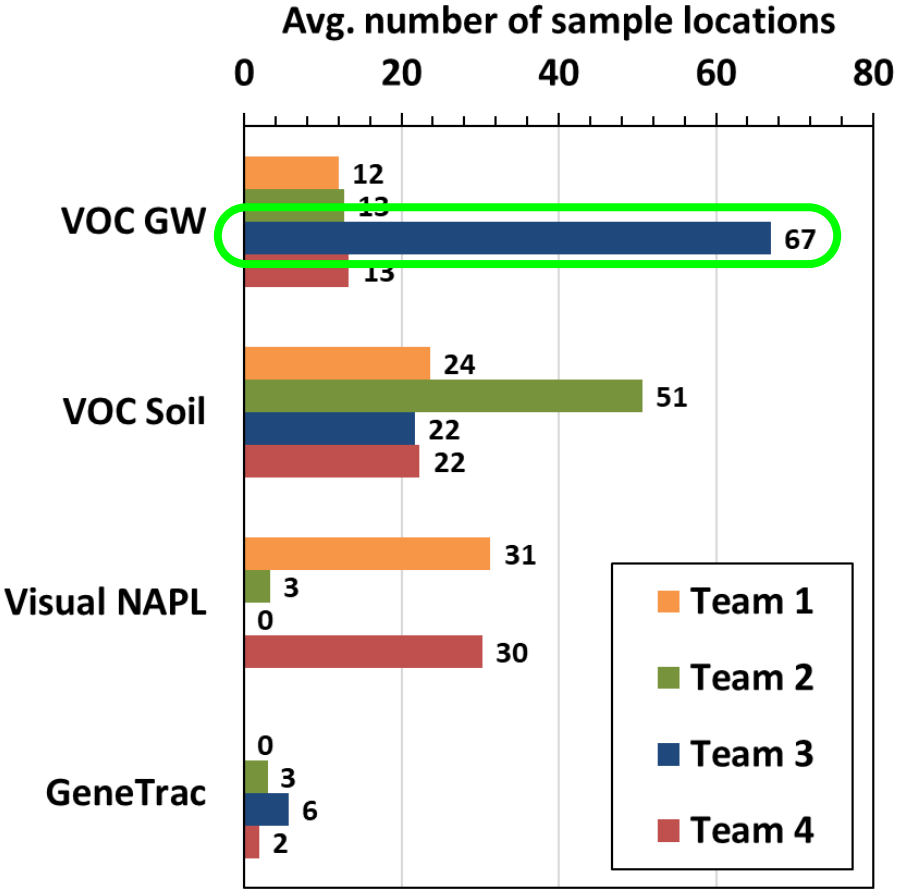
Comparing Sites and Teams



- Different strategies between teams for a given site
- Similar strategies between sites for a given team

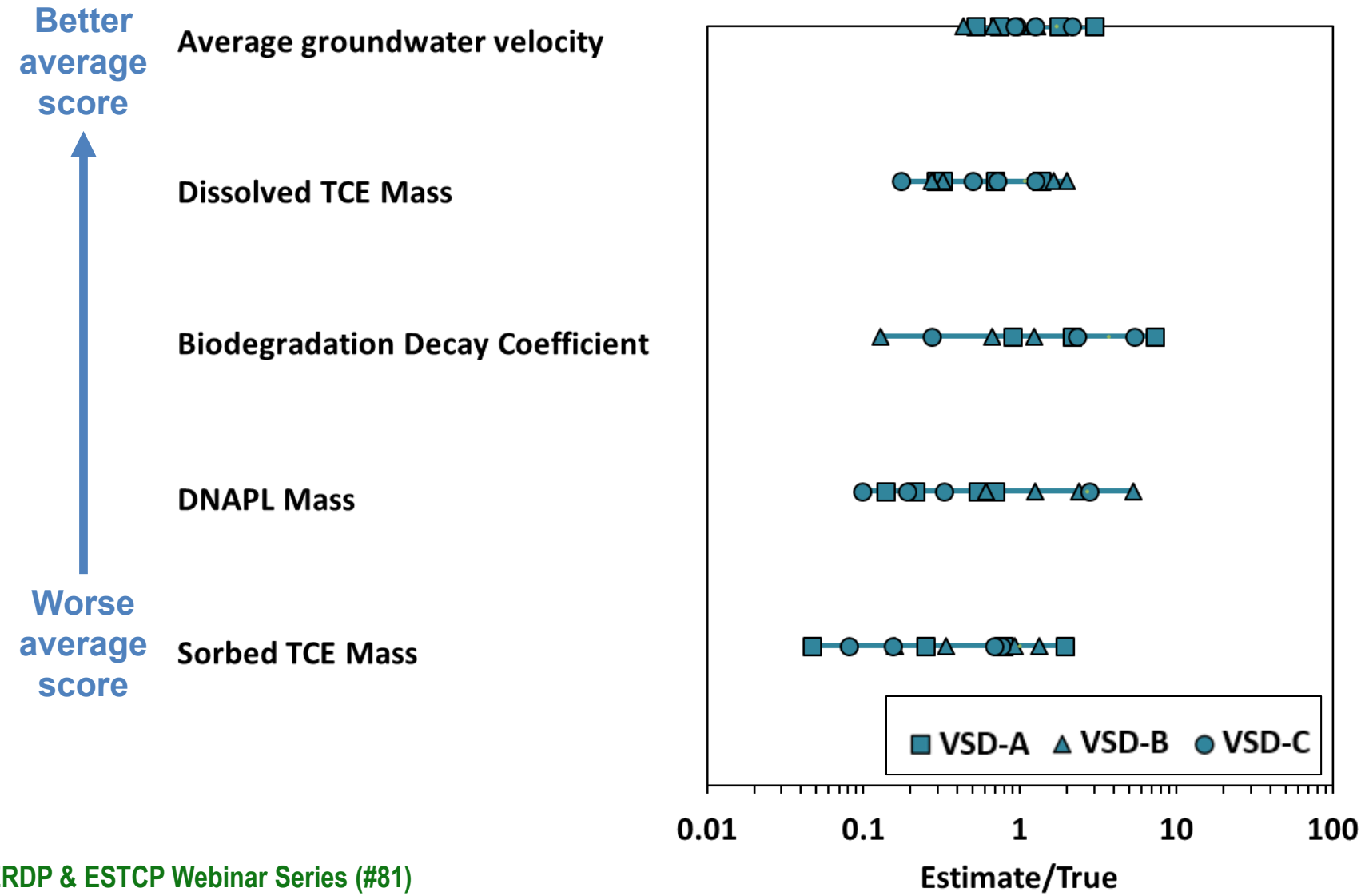
Tool and Sampling Choices





Averages are calculated across all three sites

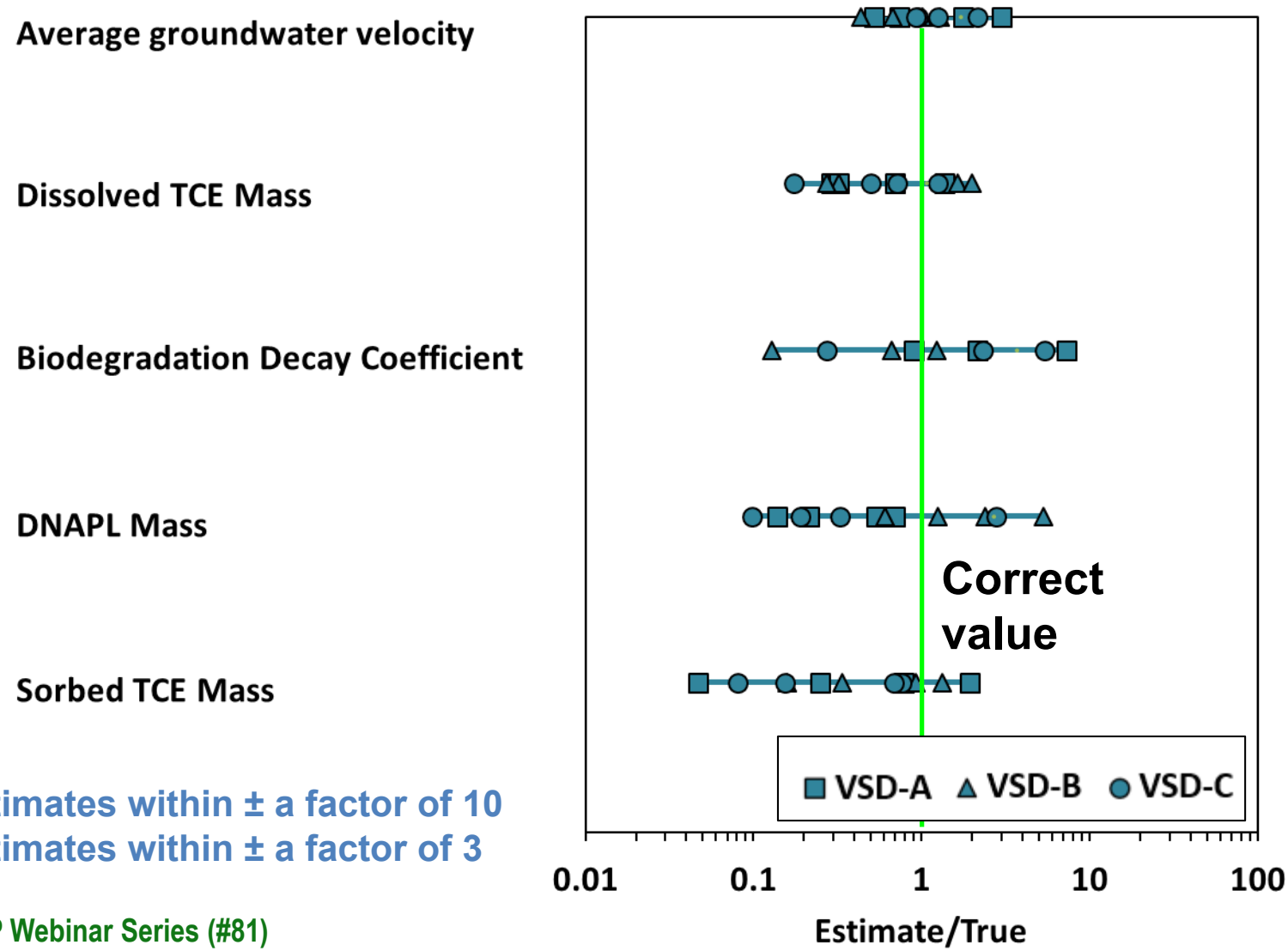
Evaluation: All Teams



Evaluation: All Teams

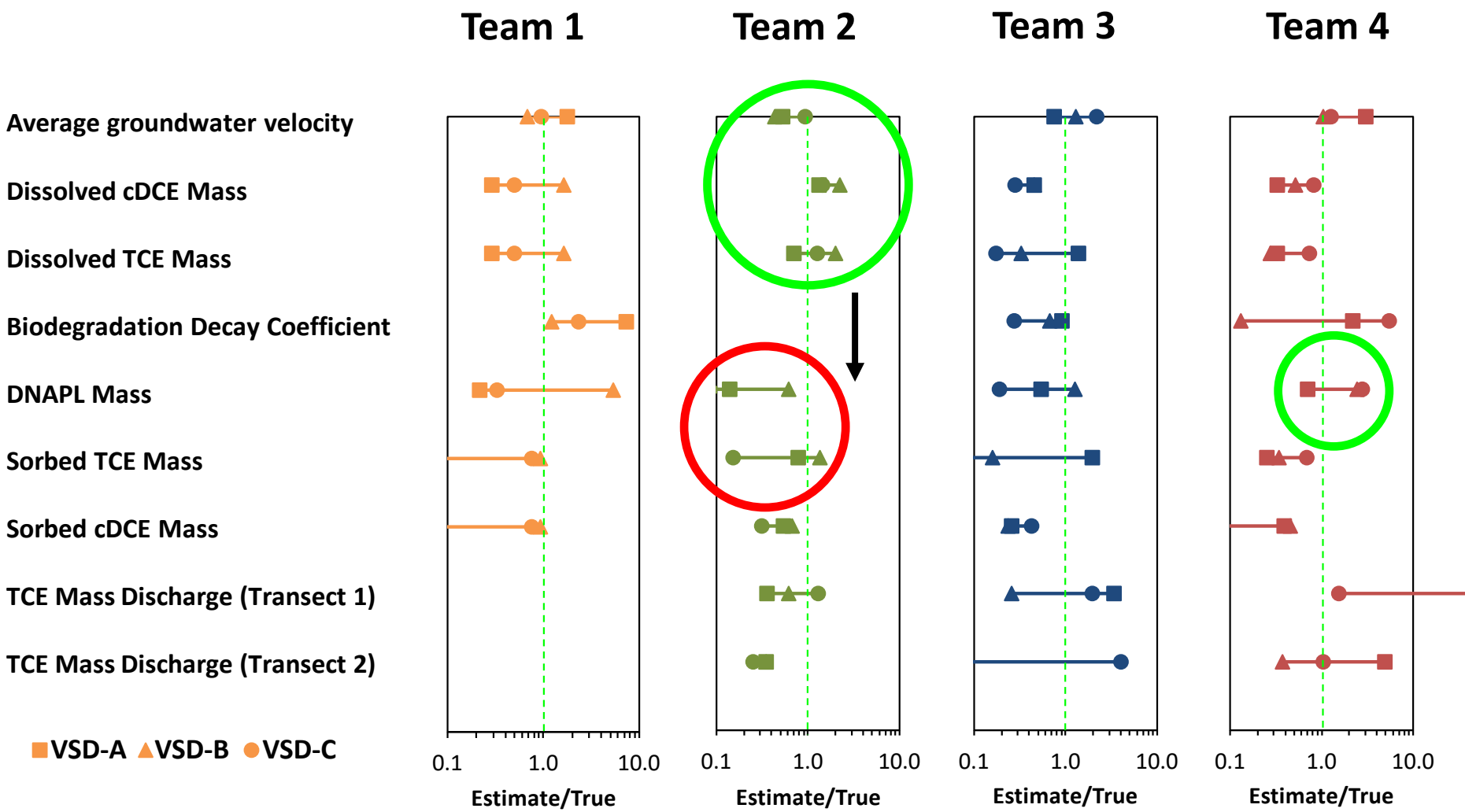
Better average score

Worse average score

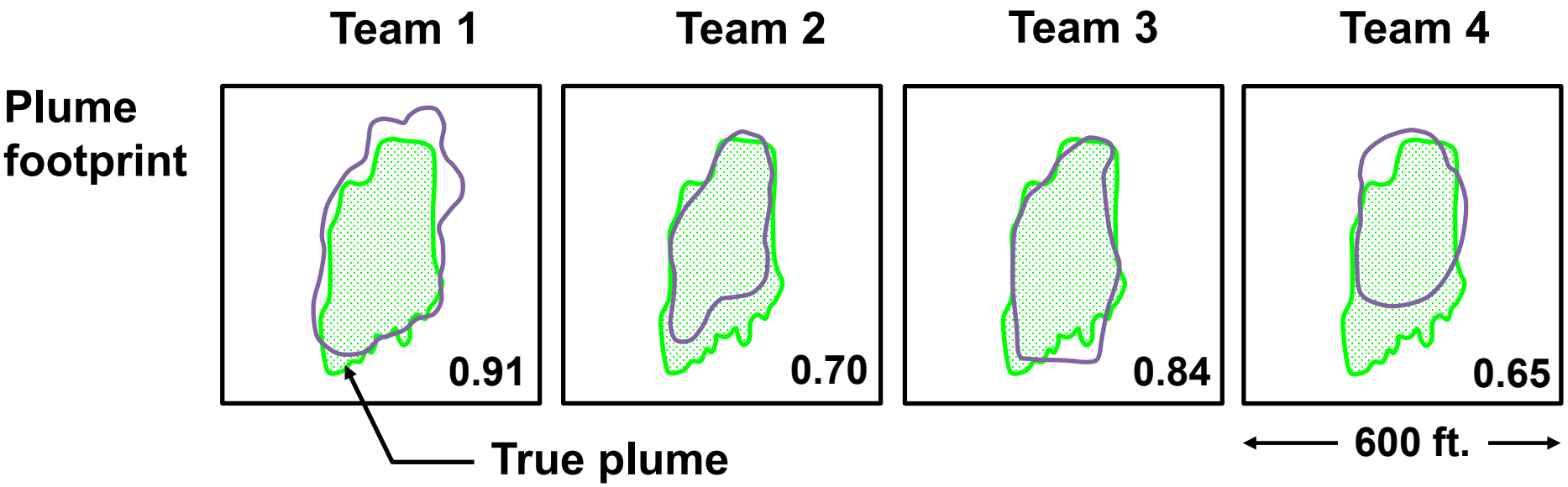


82% of estimates within ± a factor of 10
52% of estimates within ± a factor of 3

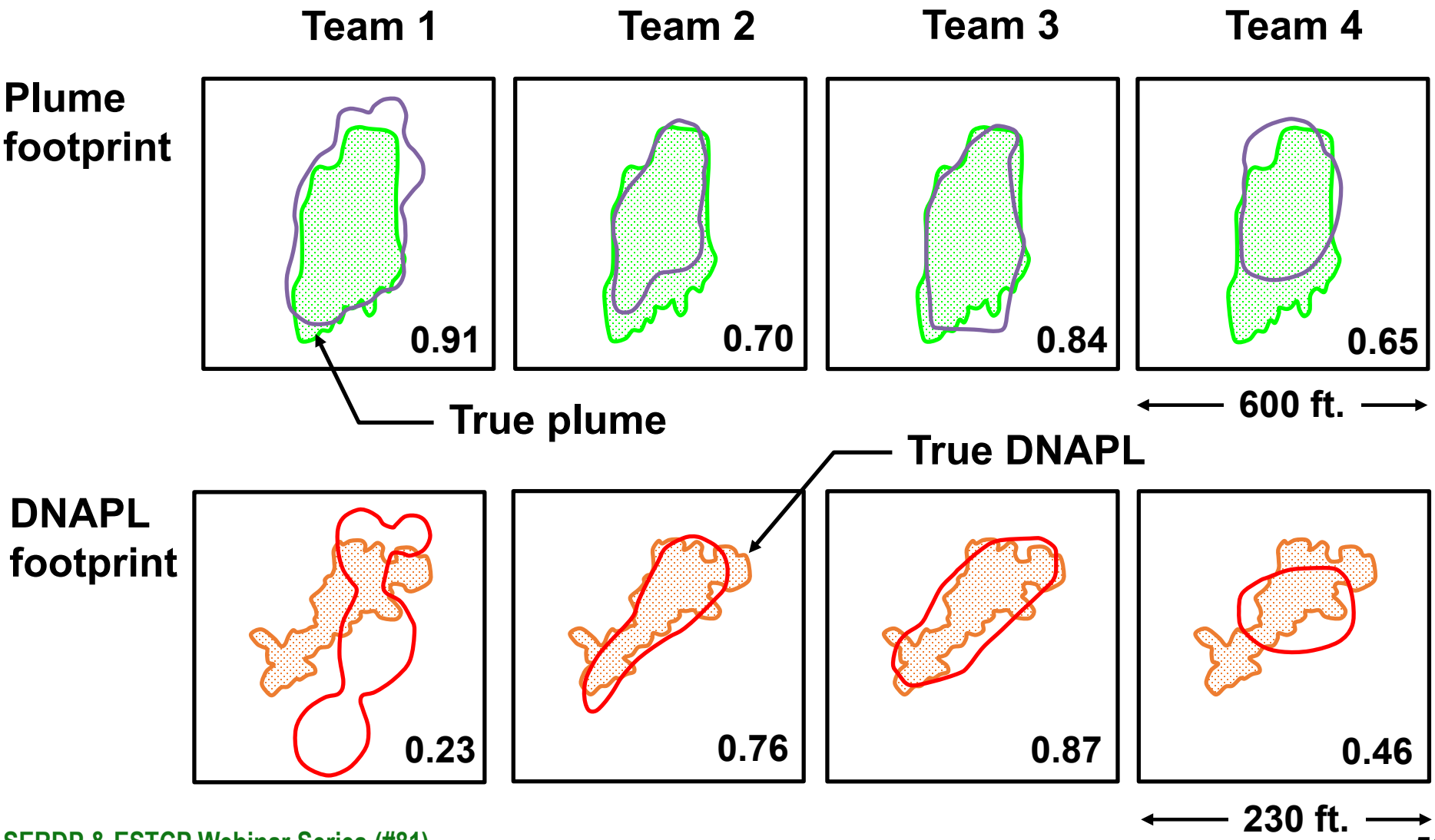
Evaluation: Team-by-Team



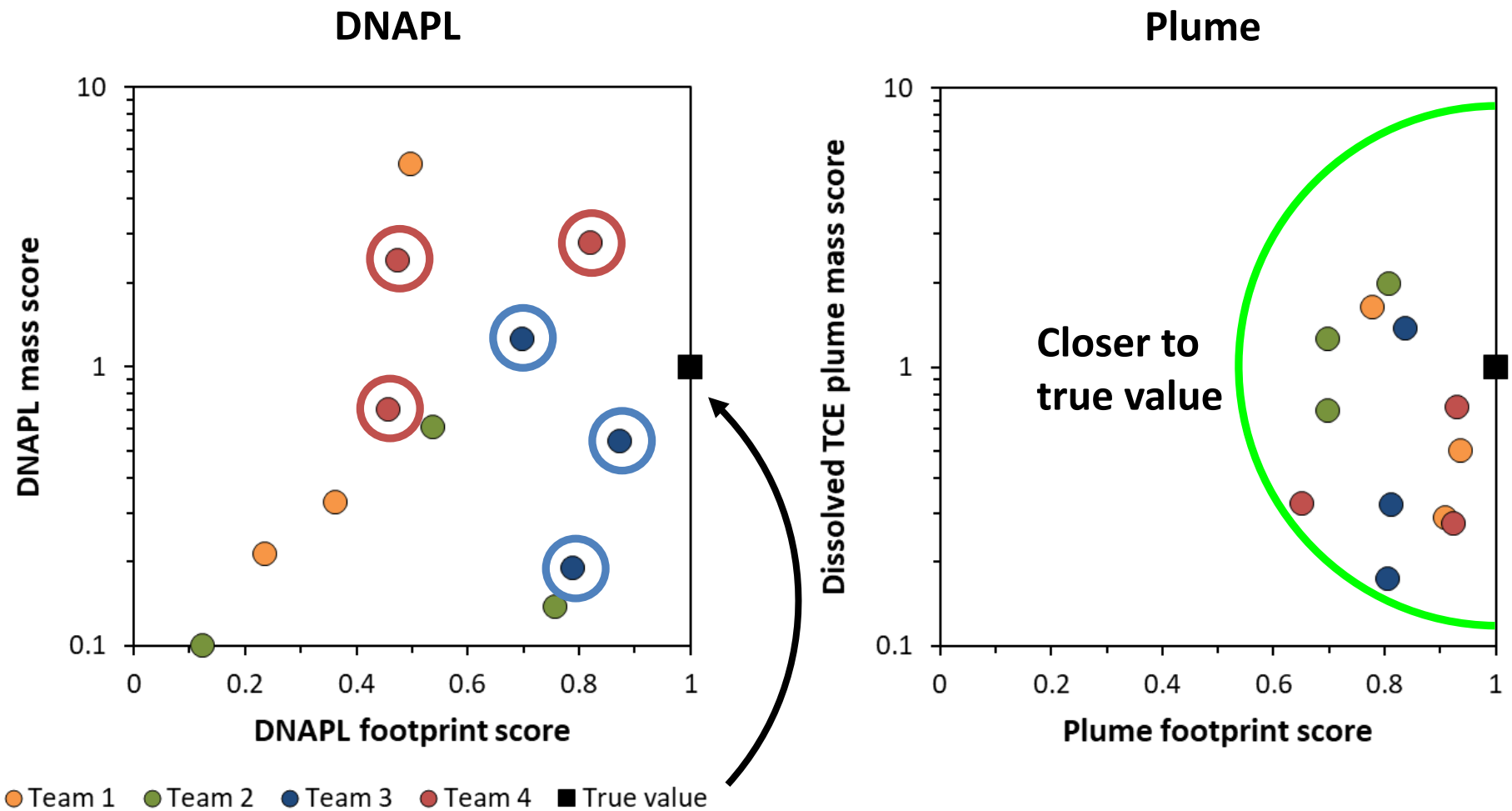
Evaluation: Delineation



Evaluation: Delineation



Multiple Metrics



Key Points - Site Investigation

- Different strategies were used
  - Strategies varied more between teams than between sites
  - What works for one aspect of a CSM may not work for another
- Most estimates were not accurate
  - 82% within a factor of 10 and 52% within a factor of 3
  - Plume estimates were more accurate than DNAPL estimates
  - Overestimates and underestimates of DNAPL footprint occurred
- Data analysis is as important as data collection
  - Higher accuracy in footprint (plume or DNAPL) did not necessarily result in higher accuracy in mass

Q&A Session 1

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Effective Practice

David Reynolds, Ph.D.
Geosyntec Consultants

SERDP DOD • EPA • DOE | ESTCP

Root Failure Analysis

Where Did the CSMs Go Wrong?

- DNAPL footprint
  - Using MIP response for presence of DNAPL
- Mass flux/discharge
  - Too few wells
- DNAPL mass
  - Using MIP response to estimate DNAPL mass
  - DNAPL mass calculated using unrealistic interpretation
    - Assumed DNAPL saturation (Sn) = 0.1 throughout the entire DNAPL footprint
    - Centred cylinders of Sn = 1.0 at location of visual observation and radius halfway to next clean borehole
    - DNAPL mass equal to the sum of dissolved and sorbed VOC concentrations

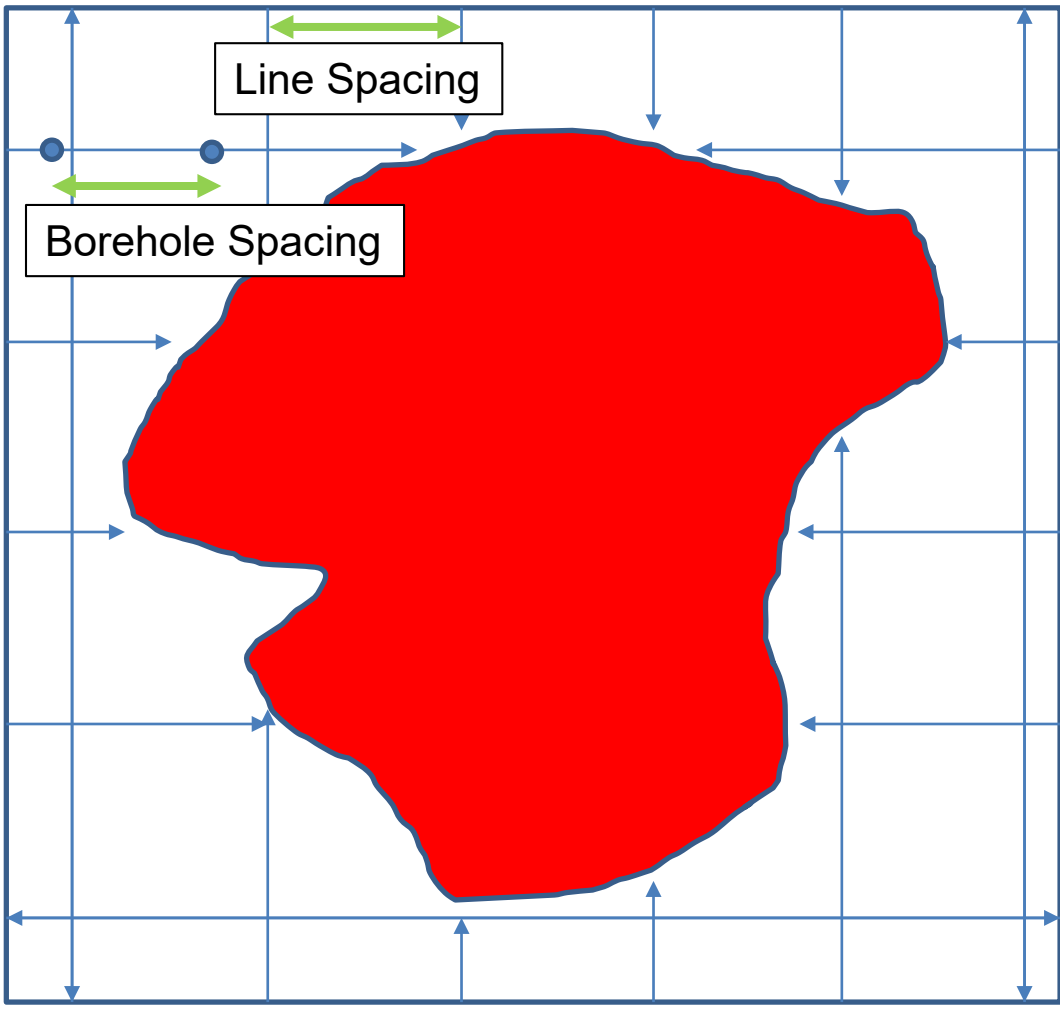
Can DIVER Teach Us?

Effective Practice in Site Investigation

- Using results of:
  - Site investigation phase
  - Stochastic simulation
  - Personal experience
  - Discussion with other practitioners
- DIVER team developed **effective practice** for:
  - DNAPL footprint delineation
  - DNAPL mass estimation
  - Mass flux estimation

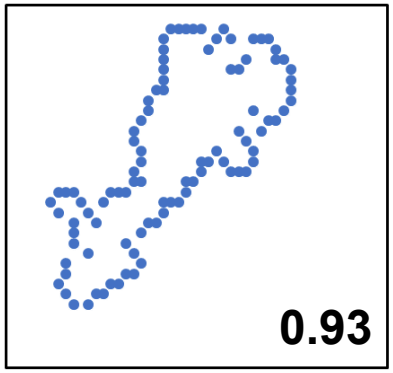
DNAPL Footprint via Boreholes/DPT

- "Outside-in" approach used along "lines" with various spacing between lines and with various sample location spacings along lines
- Tool independent (cores, dye testing, DYE-LIF, etc.)
- Assumes DNAPL present is always seen at every location (no false negatives)

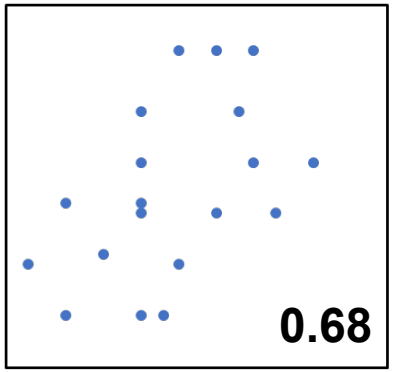


Effective Practice vs. DM Teams

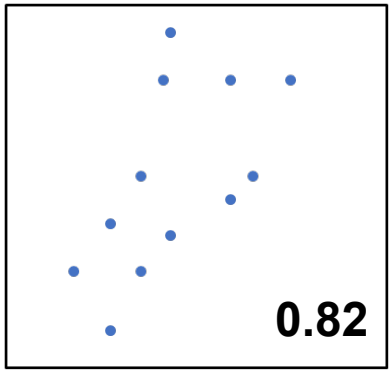
Close Spacing → Wide Spacing



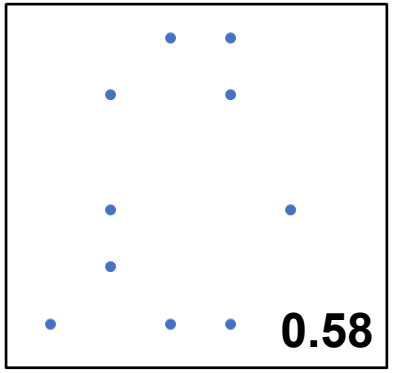
$10,400,000



$450,000



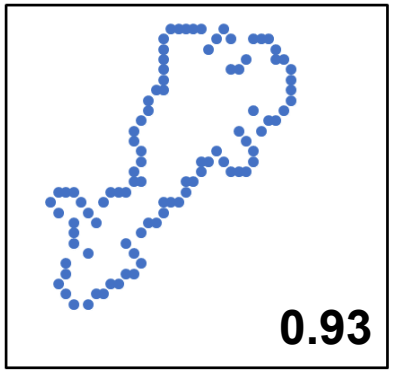
$460,000



$195,000

Effective Practice vs. DM Teams

Close Spacing → Wide Spacing



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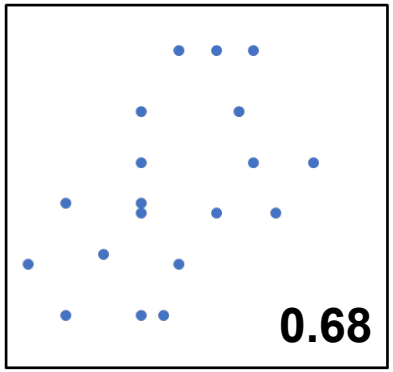

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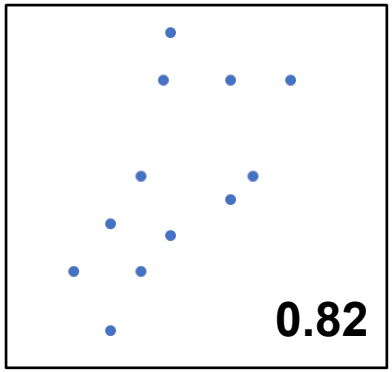

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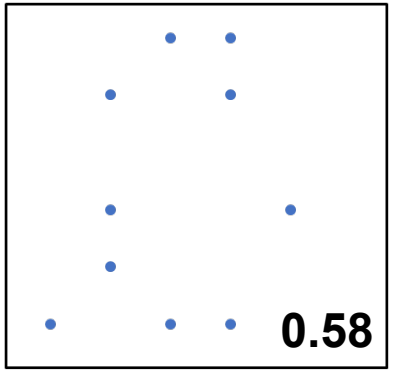
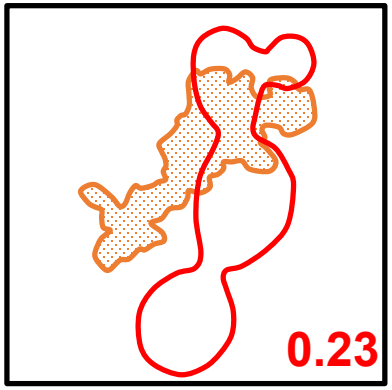
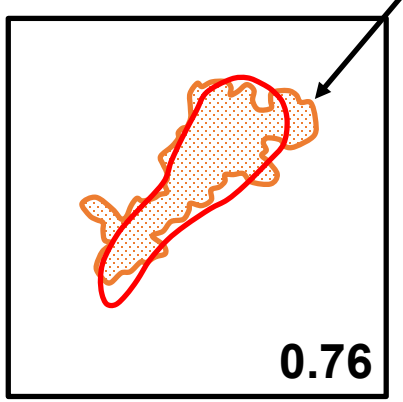


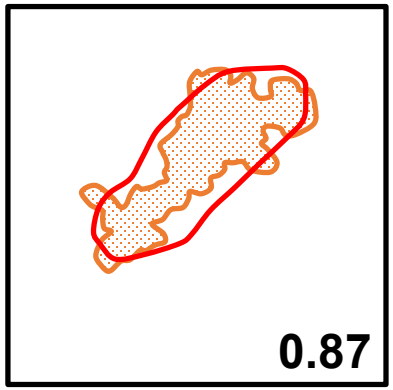
$195,000

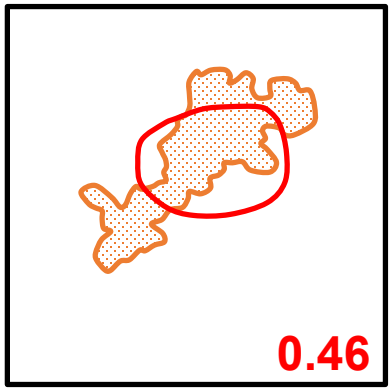
True DNAPL

DNAPL Footprint





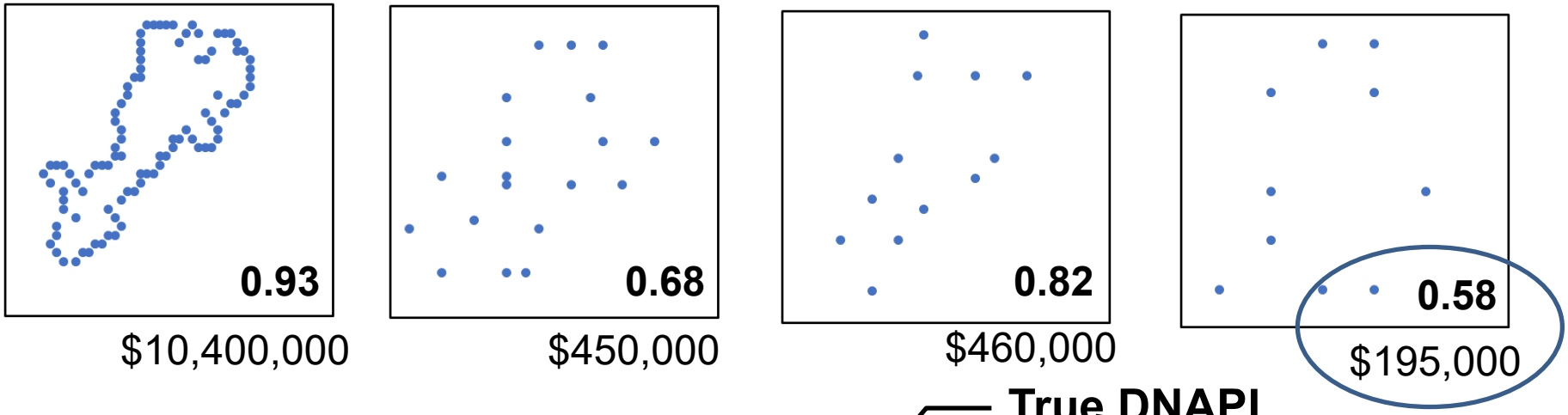




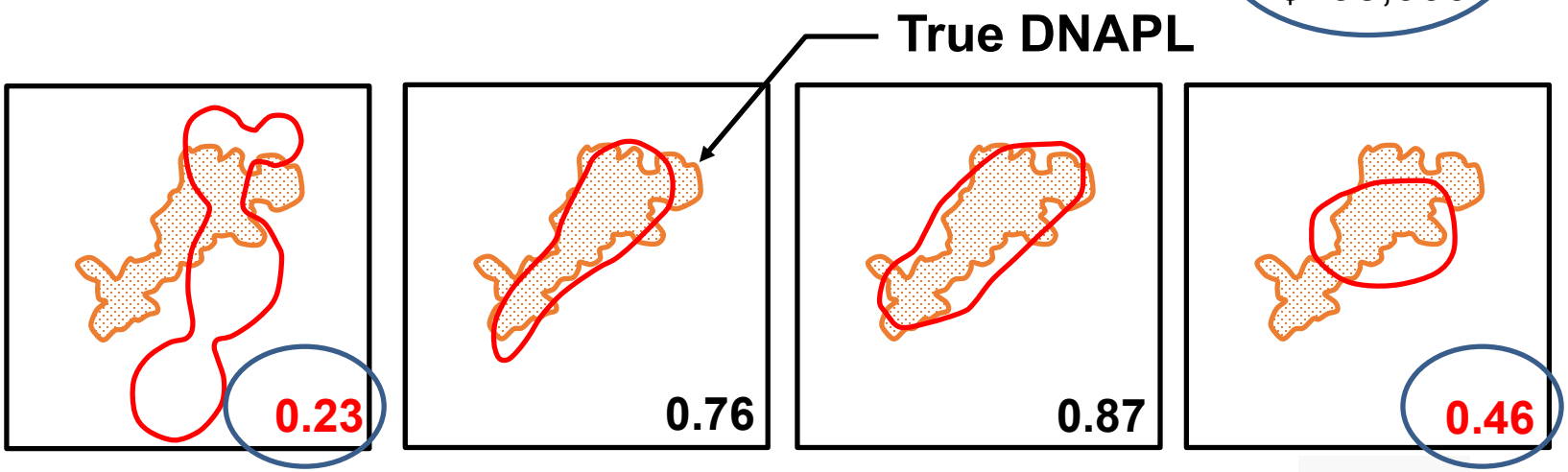
← 230 ft. →

Effective Practice vs. DM Teams

Close Spacing → Wide Spacing

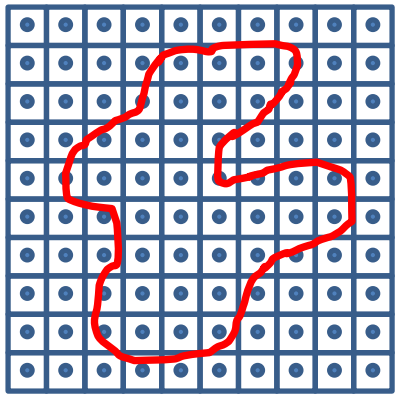


DNAPL Footprint



DNAPL Mass - Soil Sampling

- Is soil sampling and calculation of bulk retention effective practice for estimating DNAPL mass? Yes
- Stochastic, incremental sampling approach taken for all DIVER VSDs



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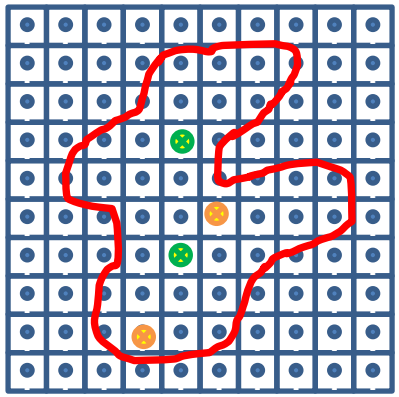
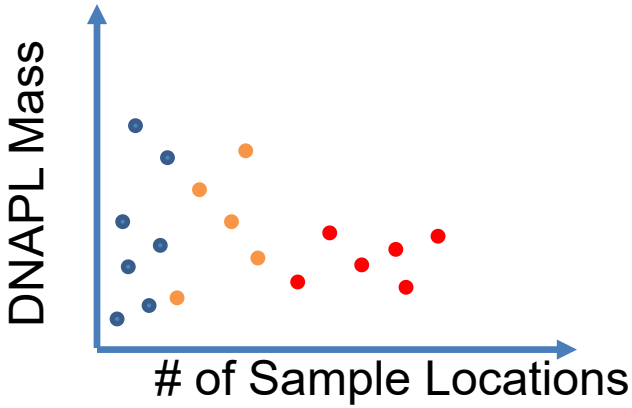
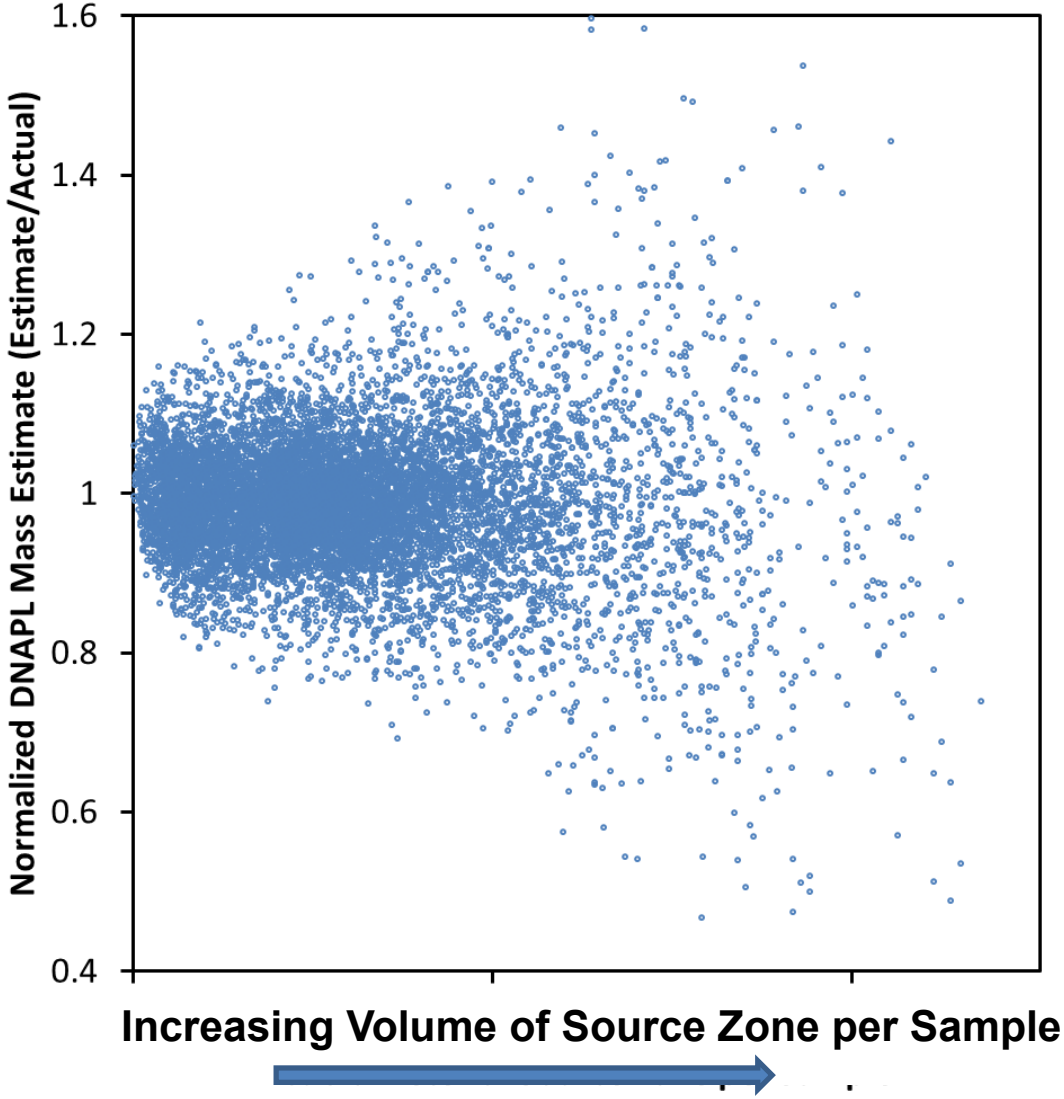




How Accurate is This Approach?



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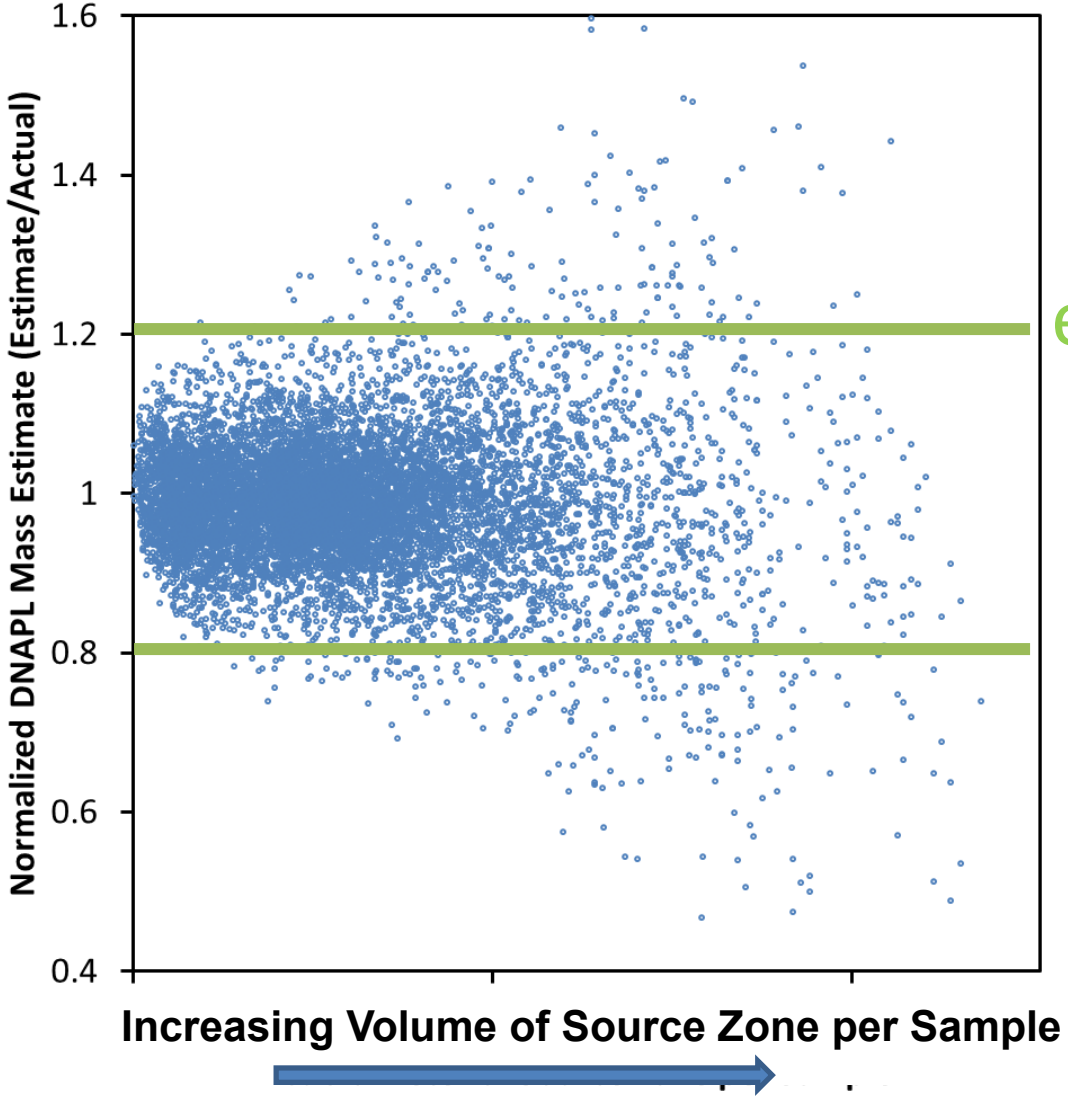
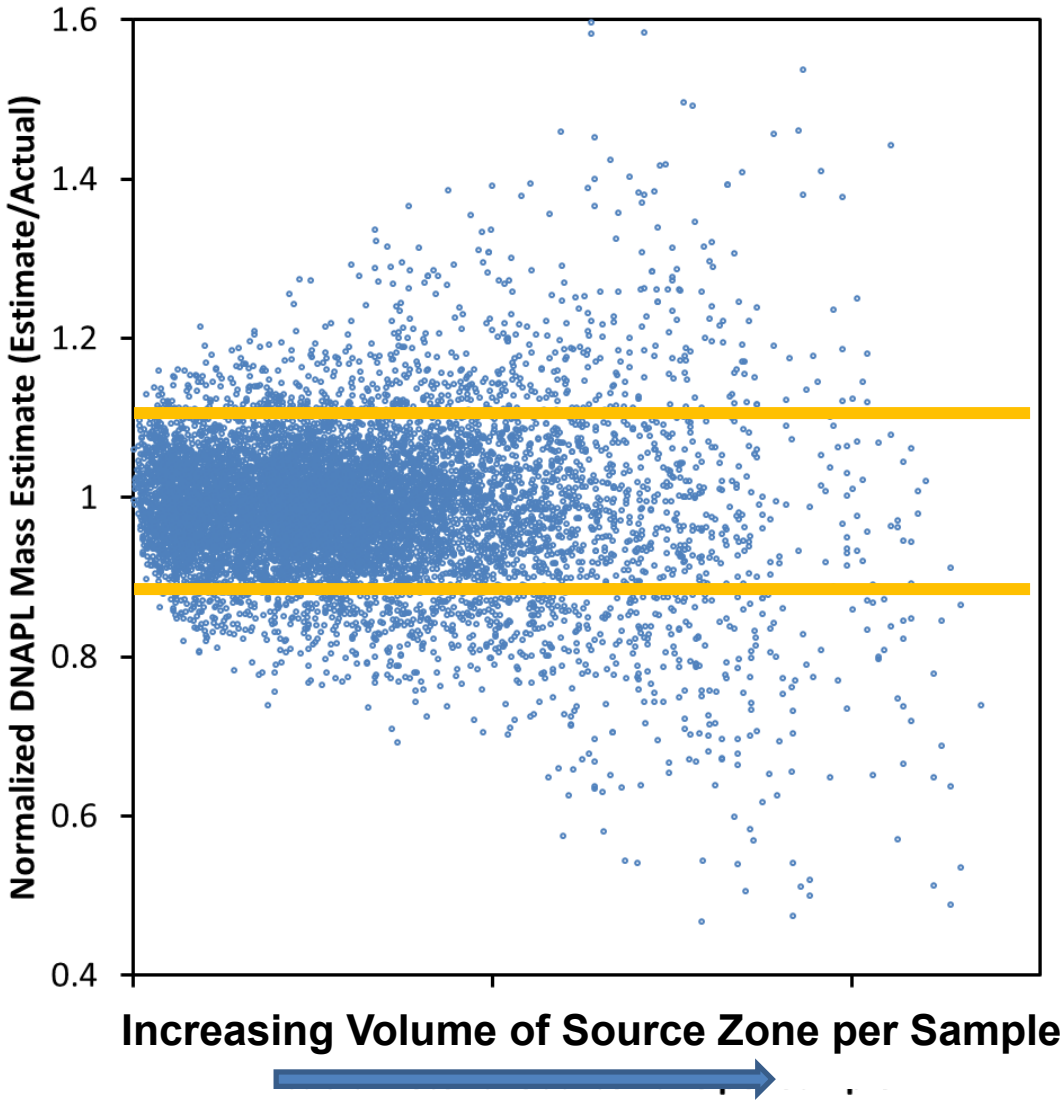
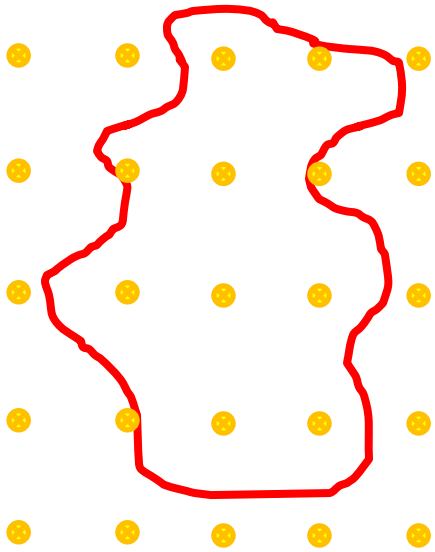


+/- 20% is reasonable expectation regardless of strategy for picking locations considering accurate DNAPL footprint

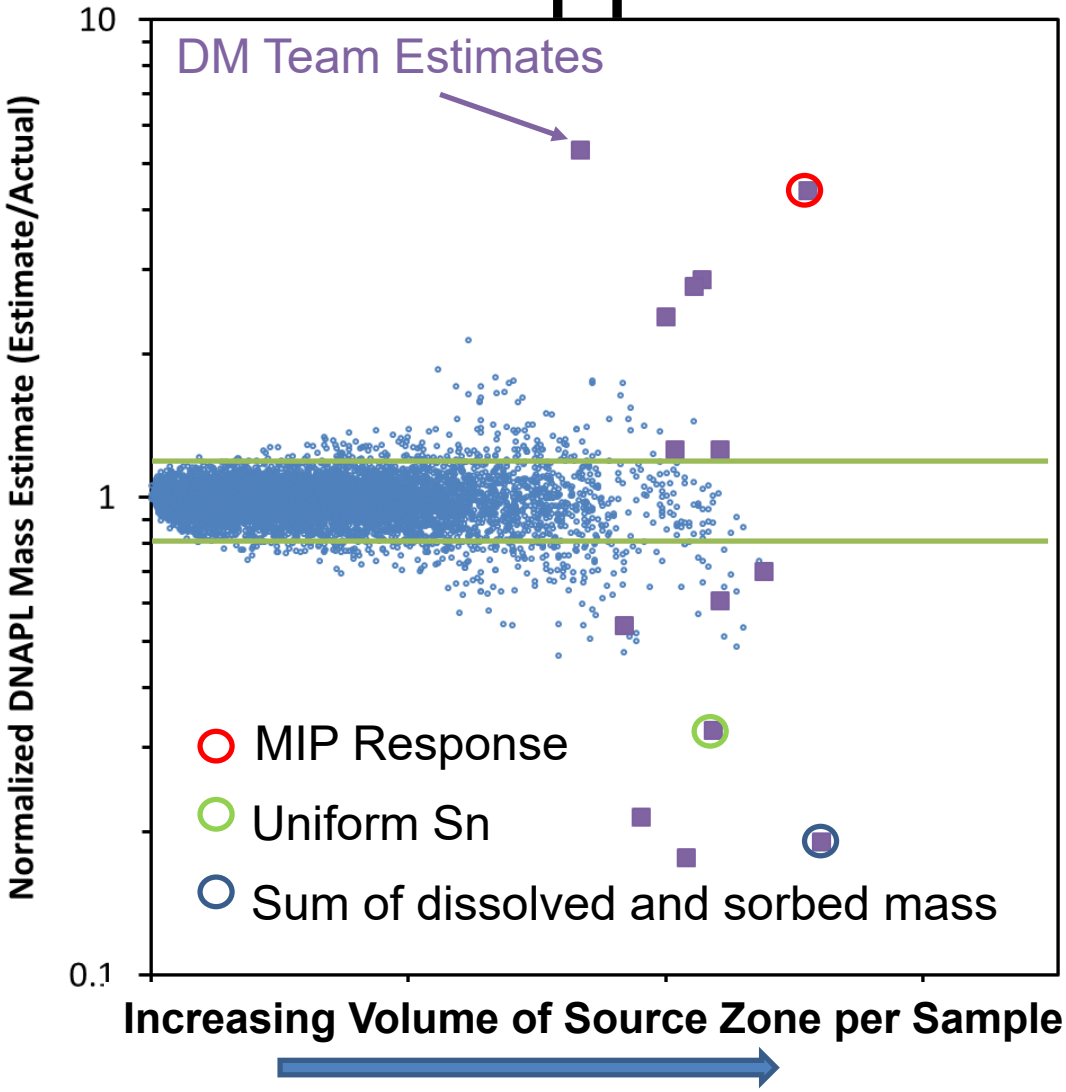
How Accurate is This Approach?



+/- 10% is likely using a uniform grid approach



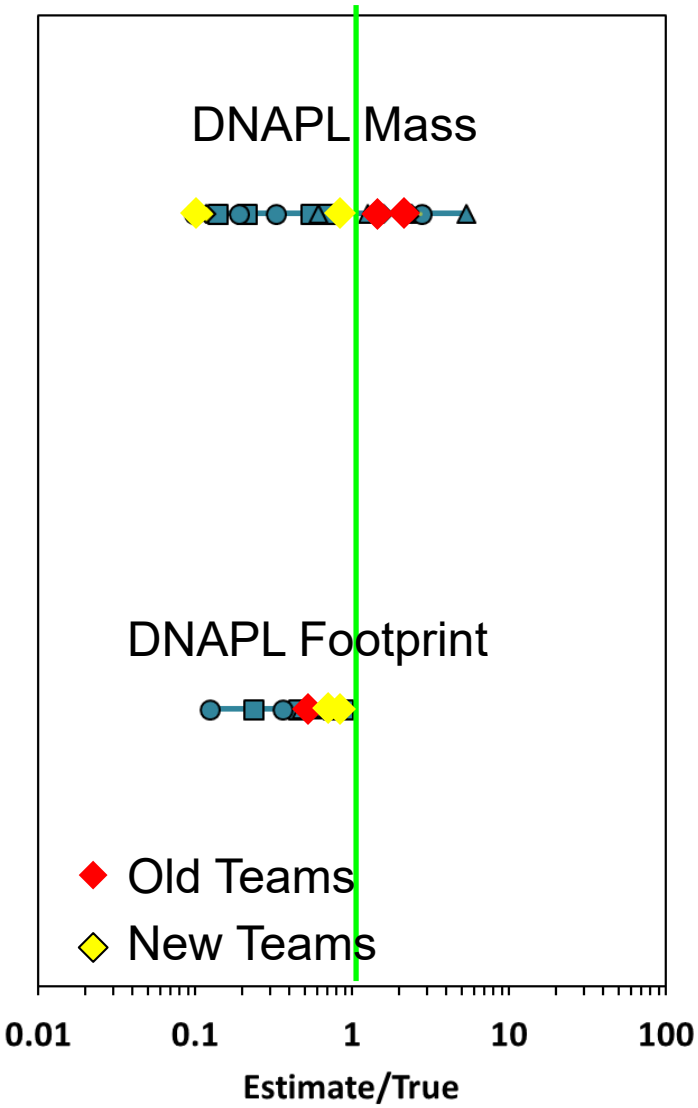
Is This Approach More Effective?



- Yes
- No DM Team achieved what is "worst expectation" using proposed effective practice

Does Using Effective Practice Help?

- Two new teams added to original four teams to investigate new site (VSD-D)
  - Original teams asked to use DIVER Effective Practice
  - New teams allowed to use their own preferred approach



Remediation Design

David Reynolds, Ph.D.
Geosyntec Consultants

SERDP DOD • EPA • DOE | ESTCP

CSMs to Remediation Designs

- Teams asked to design an EISB remedy based on their CSMs
- Asked to achieve the following metrics within 10 years of implementation

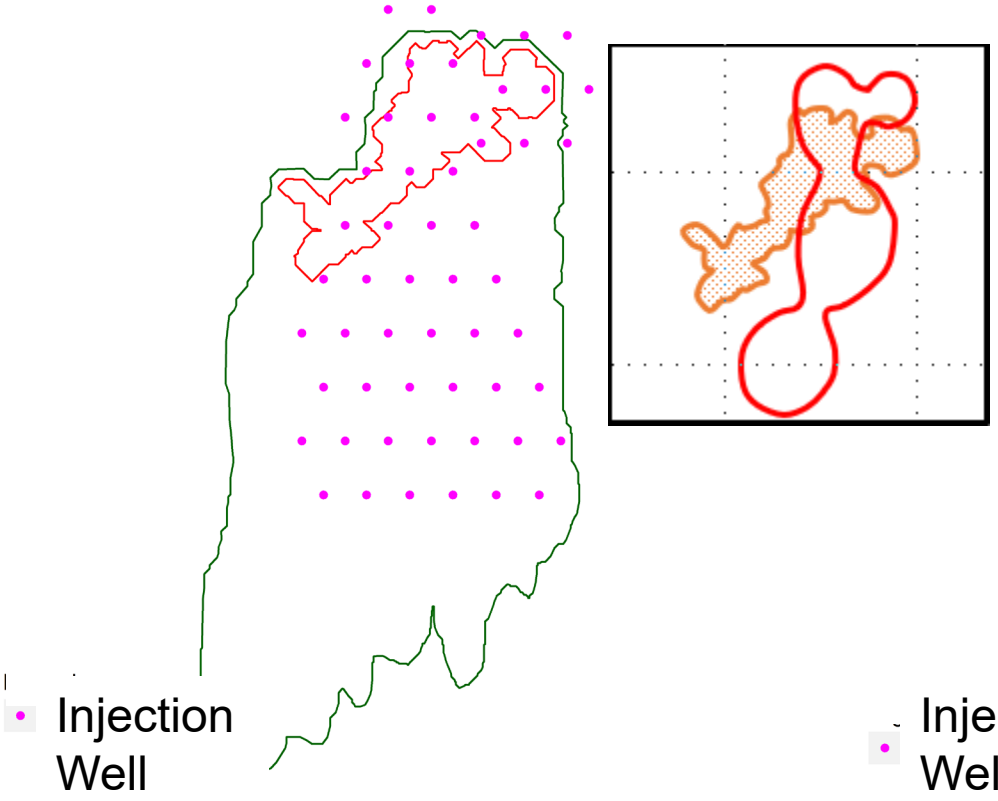
Metric	VSD A	VSD B	VSD C
DNAPL Mass Removal	30%	25%	25%
Mass Discharge Reduction	50%	50%	50%
Average Concentration Reduction	60%	50%	50%

Constraints

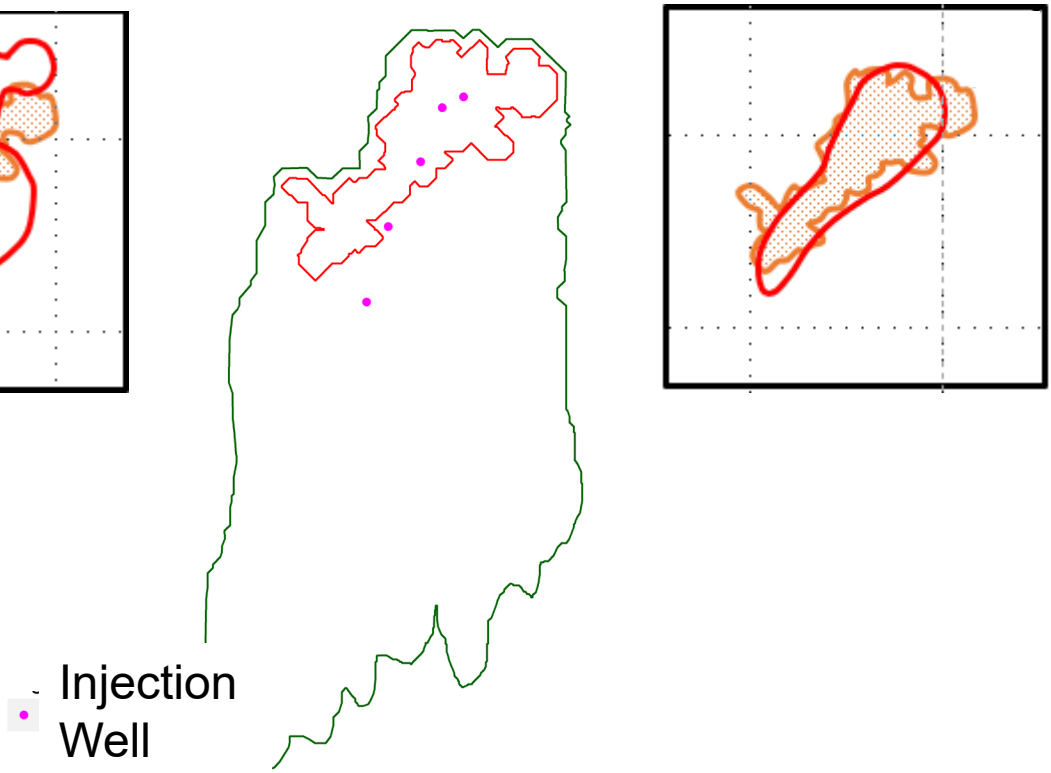
- 5 years (maximum) of active remediation
- One design change allowed

Team Remediation Designs

Team 1

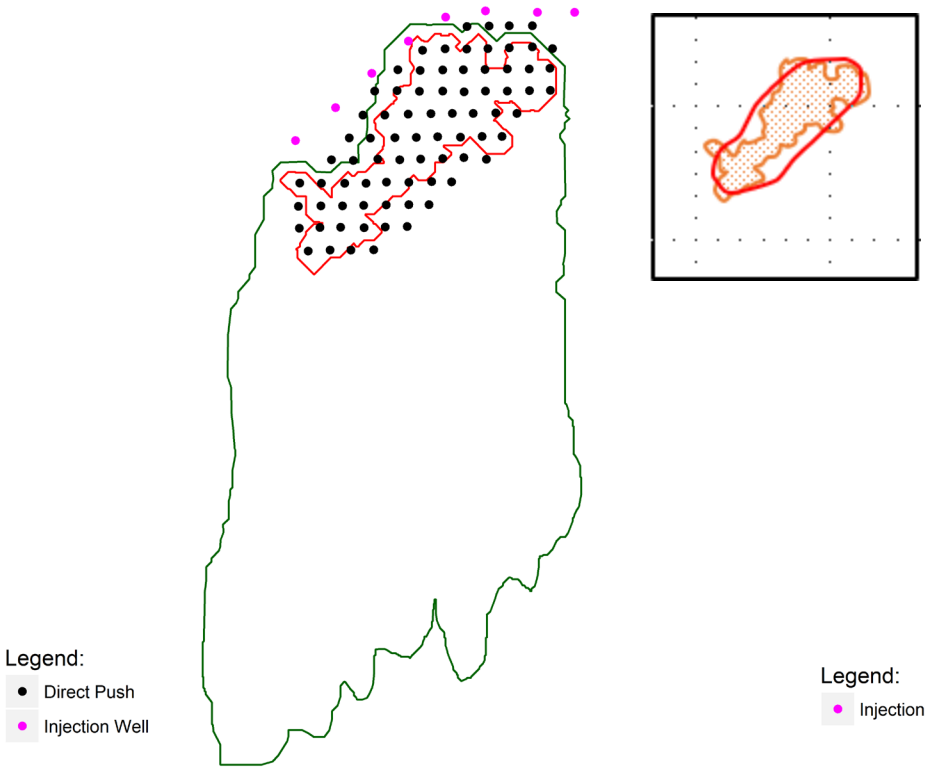


Team 2

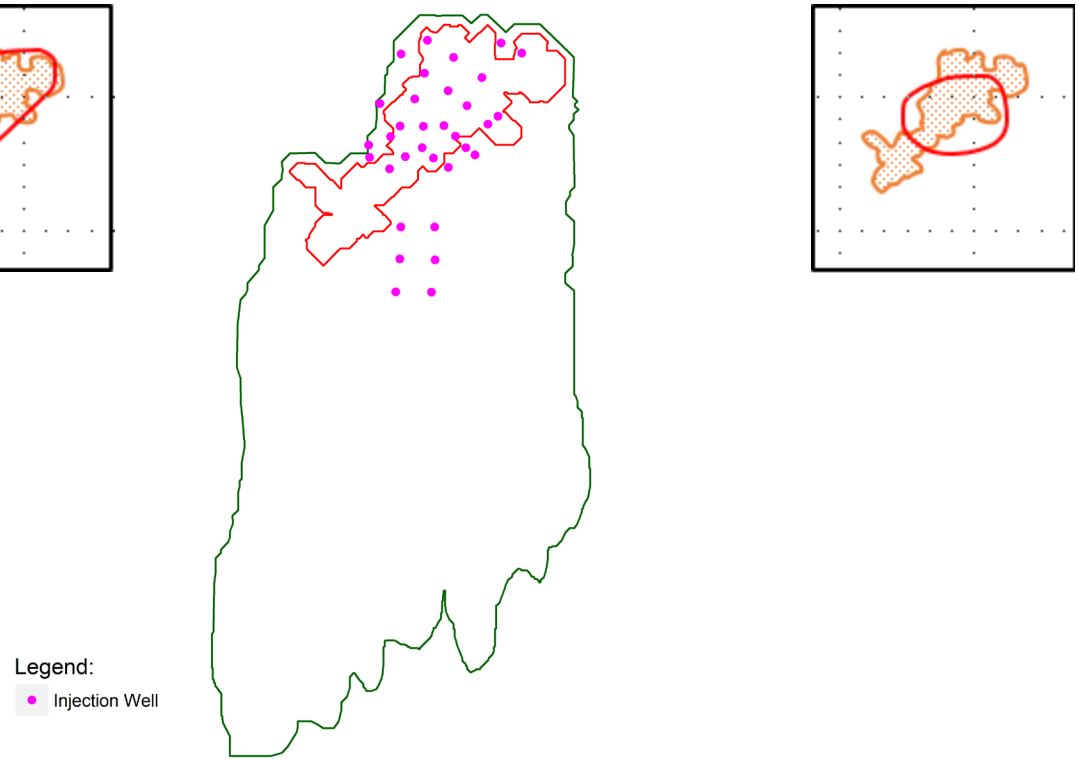


Team Remediation Designs

Team 3



Team 4



Remediation Performance

Performance Metric	Remedial Goal	DM Team 1	DM Team 2	DM Team 3	DM Team 4	Optimum
DNAPL Mass Removal (%)	*30%*	64%	43%	41%	71%	80%
Total cVOC Mass Discharge Reduction (%)	*50%*	53%	-27%	25%	43%	70%
Average TCE Concentration Reduction (%)	*60%*	81%	19%	39%	65%	63%
Cost (Million Dollars)		$1.6	$0.5	$1.2	$1.5	$0.6

Key Points - Remediation

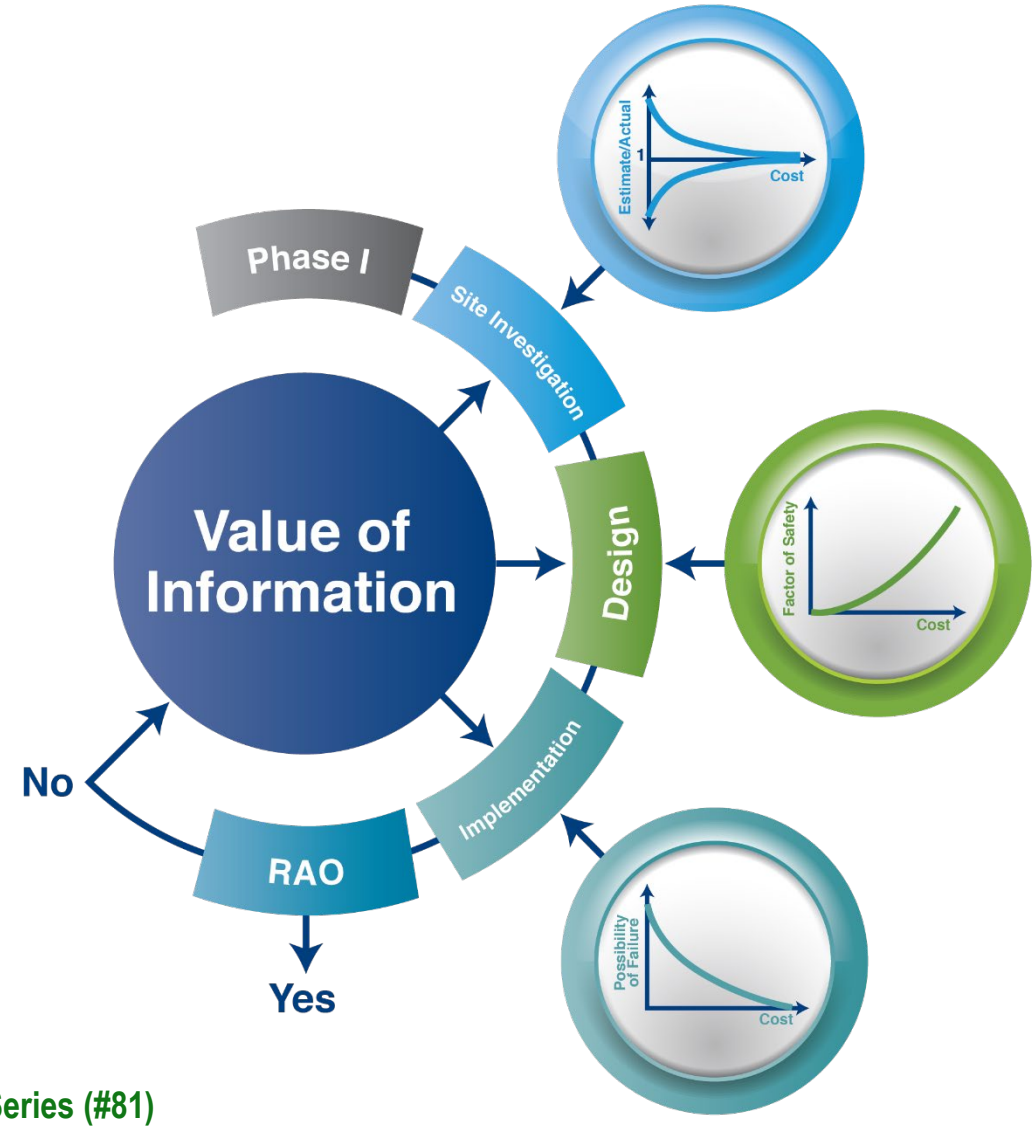
- All designs contained a significant factor of safety
- However, where the CSM contained a critical failure, the factor of safety could not overcome the deficiency of the CSM

Team	DNAPL Mass (Estimate/ Actual)	Theoretical Lactate Mass Required (kg)	Lactate Mass Added During Remediation (kg)	Factor of Safety	DNAPL Mass Removed (% of estimate)	# of Metrics Achieved
1	0.21	776	246,634	318	300	3
2	0.04	139	7,598	55	1,111	1
3	0.55	1,961	66,756	34	77	1
4	0.71	2,537	70,622	28	101	2

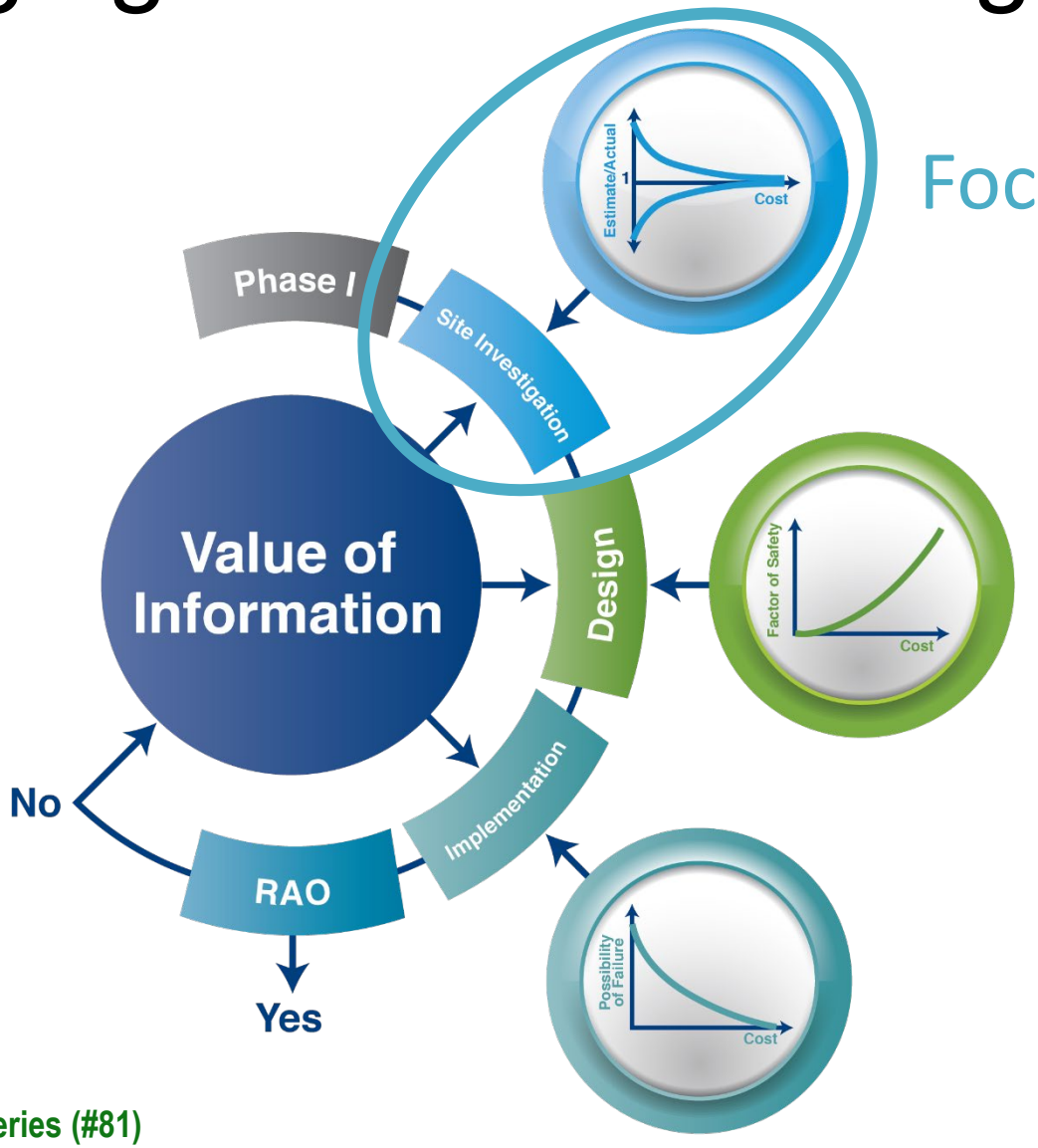
Bringing All the Pieces Together

- Prioritize metrics and appropriate level of investment to estimate metrics
- Safety factors cannot overcome poor data interpretation or collection
- Safety factors are a useful approach for considering VOI and risk

Bringing All the Pieces Together

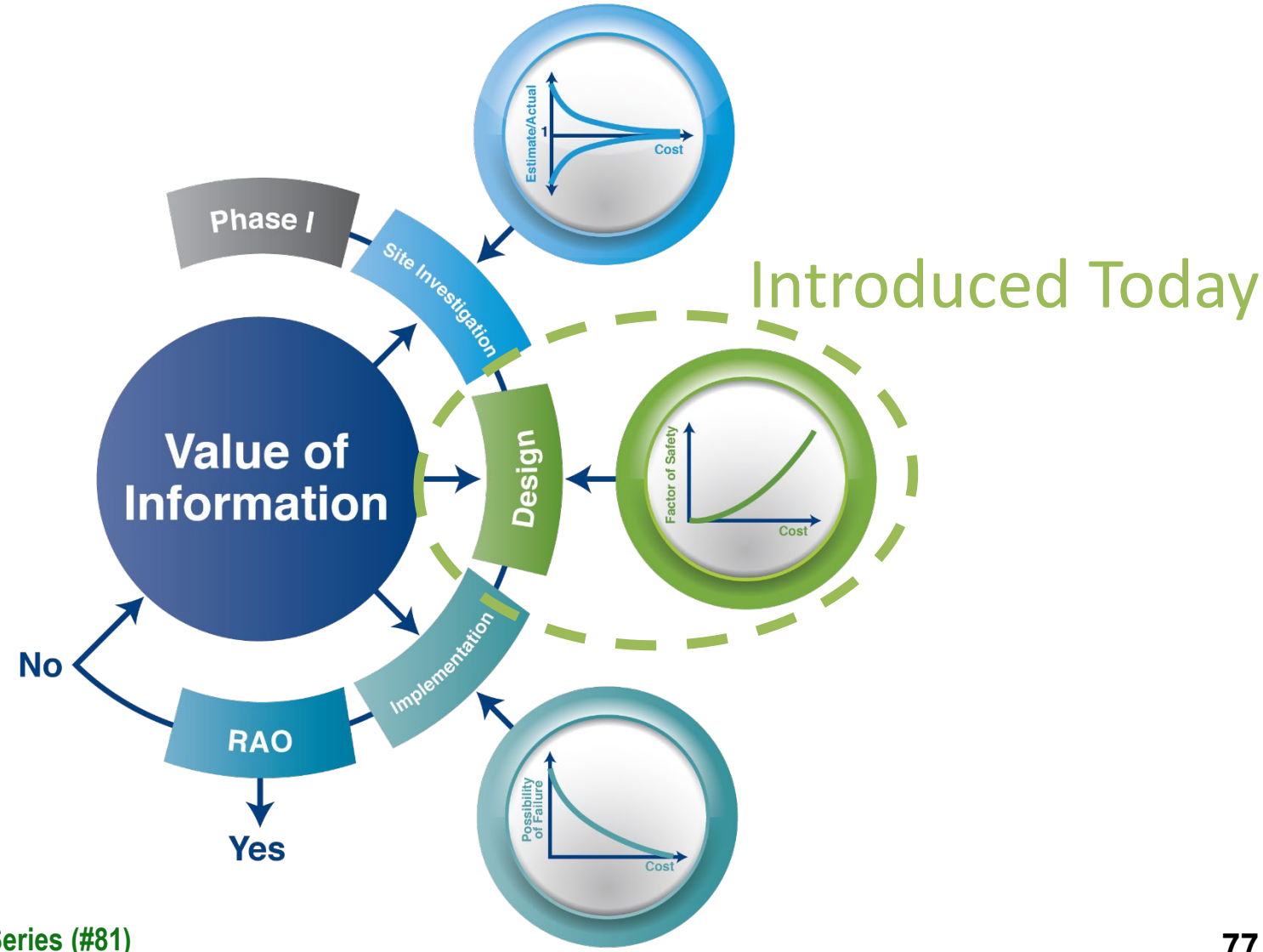


Bringing All the Pieces Together

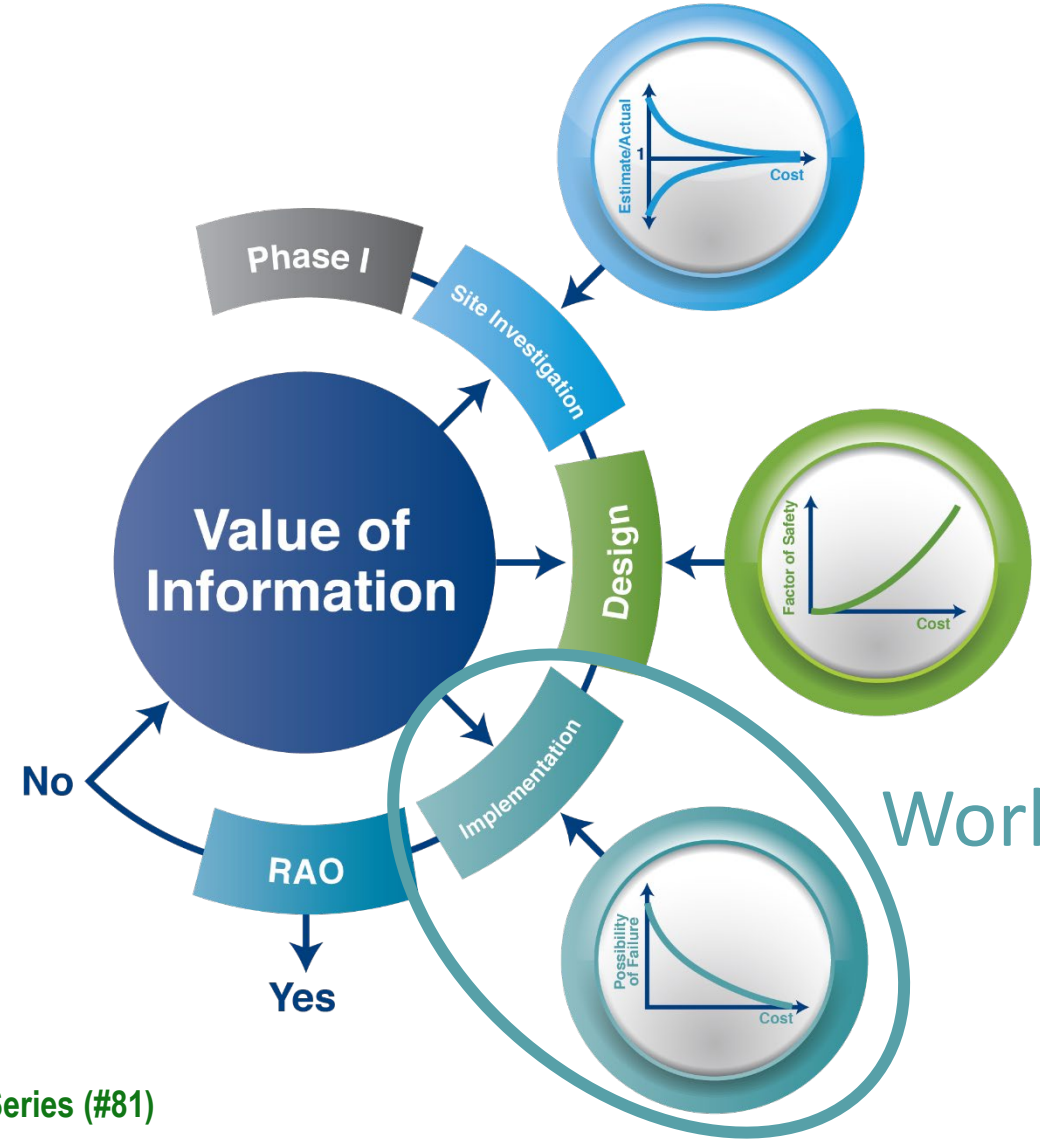


Focus of Today

Bringing All the Pieces Together



Bringing All the Pieces Together



Work in Progress

Value of DIVER to DoD

- Implications for practice at DoD sites going forward
  - Transition to alternative active remedies or LTM where restoration “not practicable” – basis for sufficient characterization and metric estimates to support decision
  - Best practices for characterization and remedy selection at VOC impacted sites – translates to lifecycle savings
  - Application of best practices to “mega-sites” will reduce lifecycle costs
  - DIVER as basis for teaching tool (TEMPO) and dissemination of “best practices” at VOC-impacted sites

Want to See How You Can Do?

PRJWEB03.GEOSYNTEC.COM/TEMPO/GEOFORM

TEMPO

ESTCP

Geosyntec consultants

Queen's University

Note: TEMPO works best with Chrome or Firefox

For additional information, please visit

https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-2313

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Q&A Session 2

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The next webinar is on November 1, 2018

Supporting DoD Installation Sustainability Through Informed Stormwater Management

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Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends

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