Understanding Environmental Site Conditions:

What do we need to know to select and implement effective remedies?

August 11, 2020

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Characterization & Remediation
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PNNL-SA-155181

Seminar Overview

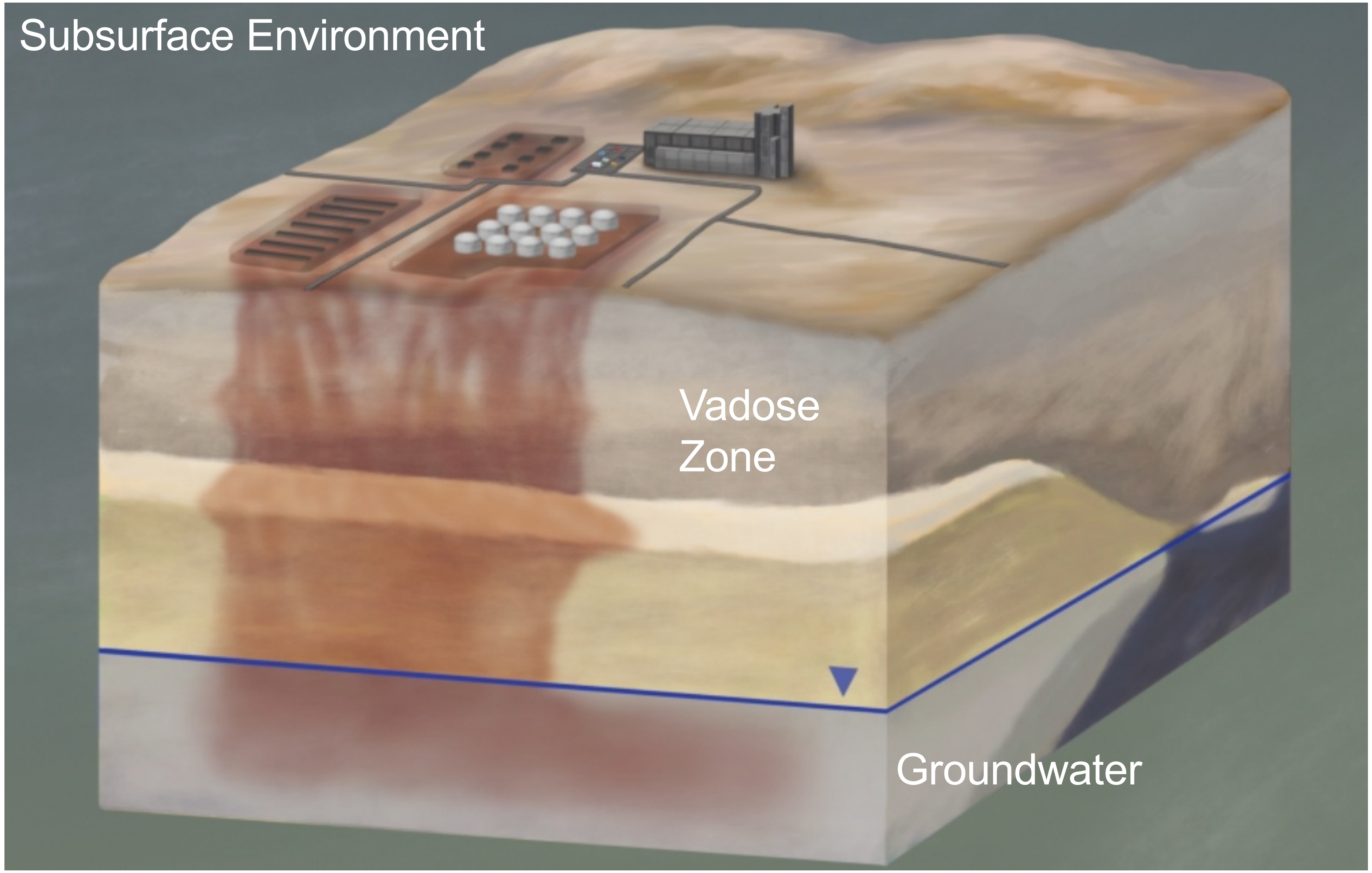
Objective: Identify an approach and resources for managing characterization and remediation at complex sites

Take-aways from today's seminar:

- Challenge: Determining the level of detail needed to provide technical defensibility for remediation decisions at complex sites.
- Approach: Objectives- and interpretation-driven site investigation and remedy implementation using technical guidance resources.
- Impact: Facilitate remedy decisions and effectively manage complex sites.

Environmental Remediation Context

- Describe the contamination issue
- Evaluate risk and determine the mitigation approach
- Implement remediation, evaluate performance, adapt as needed, and determine stopping point



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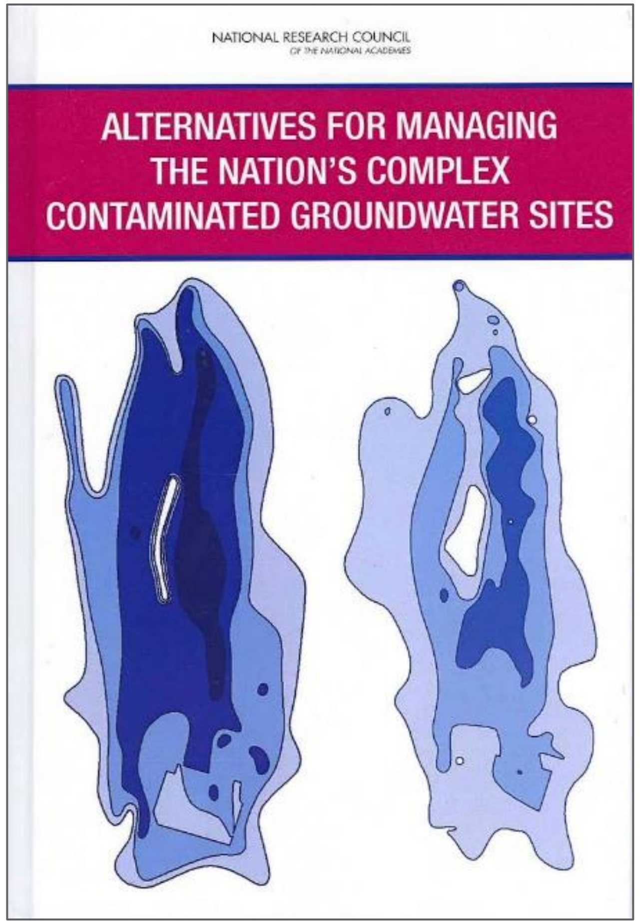
Remediation Challenges



National Research Council 2013

http://rmcs-1.itrcweb.org

Categories of Challenges

- Coupled Hydrogeochemical Dynamics
  - Groundwater – Surface Water
  - (Deep) Vadose Zone – Groundwater
- Interaction of Biogeochemistry and Contaminants
  - Co-mingled contaminants
  - Sorption behavior and reactions
  - Persistent/recalcitrant contaminants
  - Extreme environments/contaminant discharge chemistry
- Exit Strategies
  - Active to passive
  - Current to long-term management
  - Adaptive site management steps

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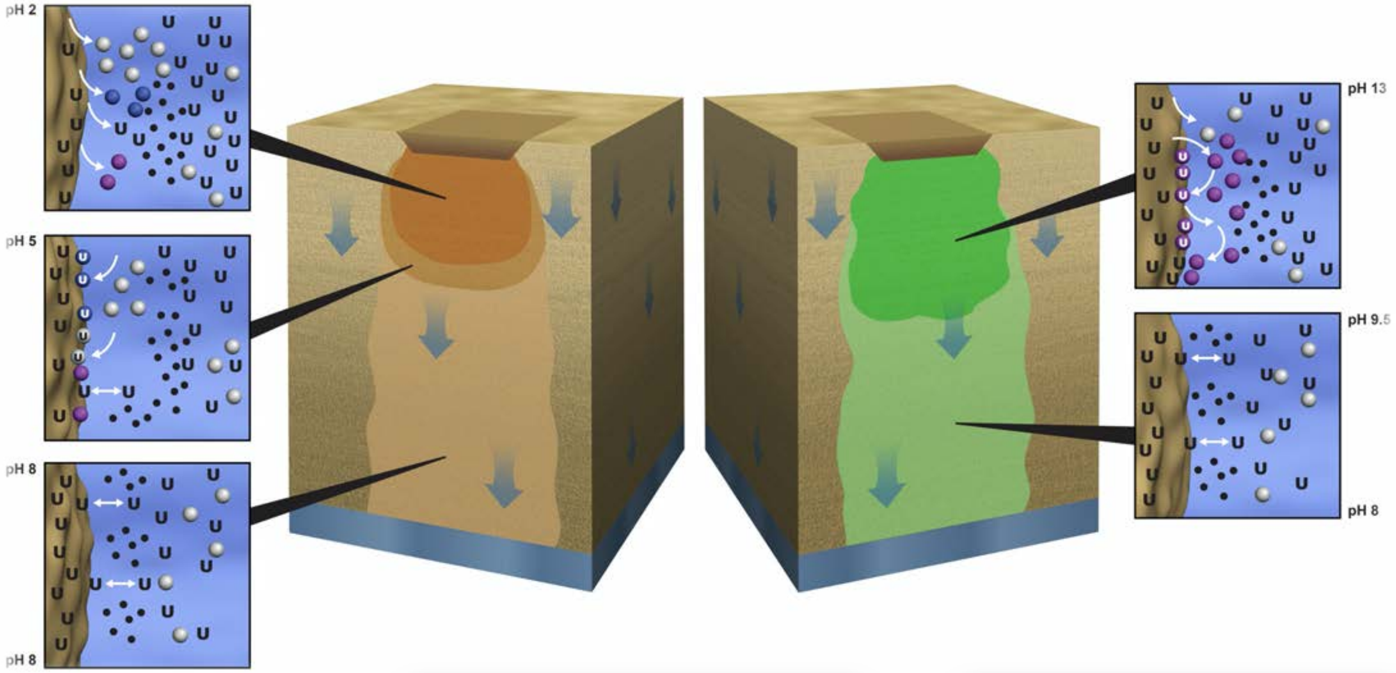
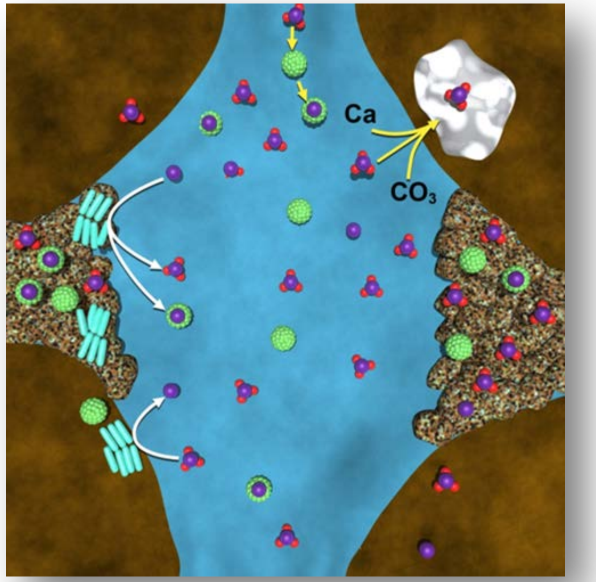
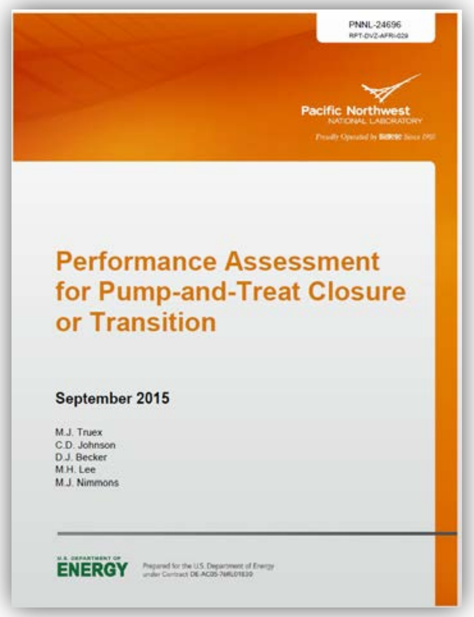
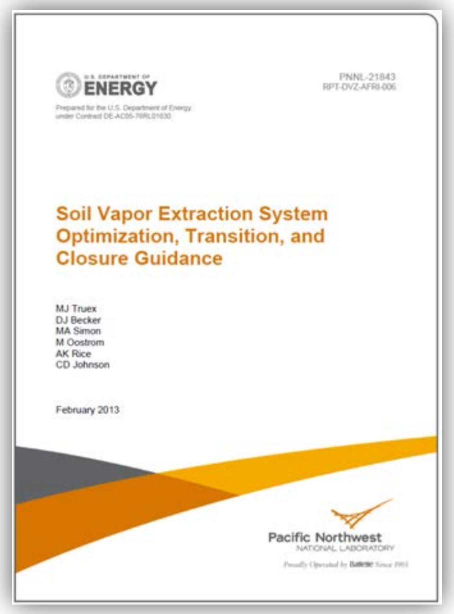





PNNL-24696
Pacific Northwest NATIONAL LABORATORY
Performance Assessment for Pump-and-Treat Closure or Transition
September 2015
M.J. Truex
C.D. Johnson
D.J. Becker
M.H. Lee
M.J. Nimmons
ENERGY

Truex et al. 2015a, 2017a


ENERGY
PNNL-21843
Soil Vapor Extraction System Optimization, Transition, and Closure Guidance
MJ Truex
DJ Becker
MA Simon
M Oostrom
AK Rice
CD Johnson
February 2013
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Truex et al. 2013

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Center for the Remediation of Complex Sites

The Center for the Remediation of Complex Sites (RemPlex) is a Pacific Northwest National Laboratory (PNNL) platform that couples unique core competencies and expertise with state-of-the-art facilities and physical assets to develop, mature, and deploy advanced technologies to solve complex issues of contaminated subsurface environments.

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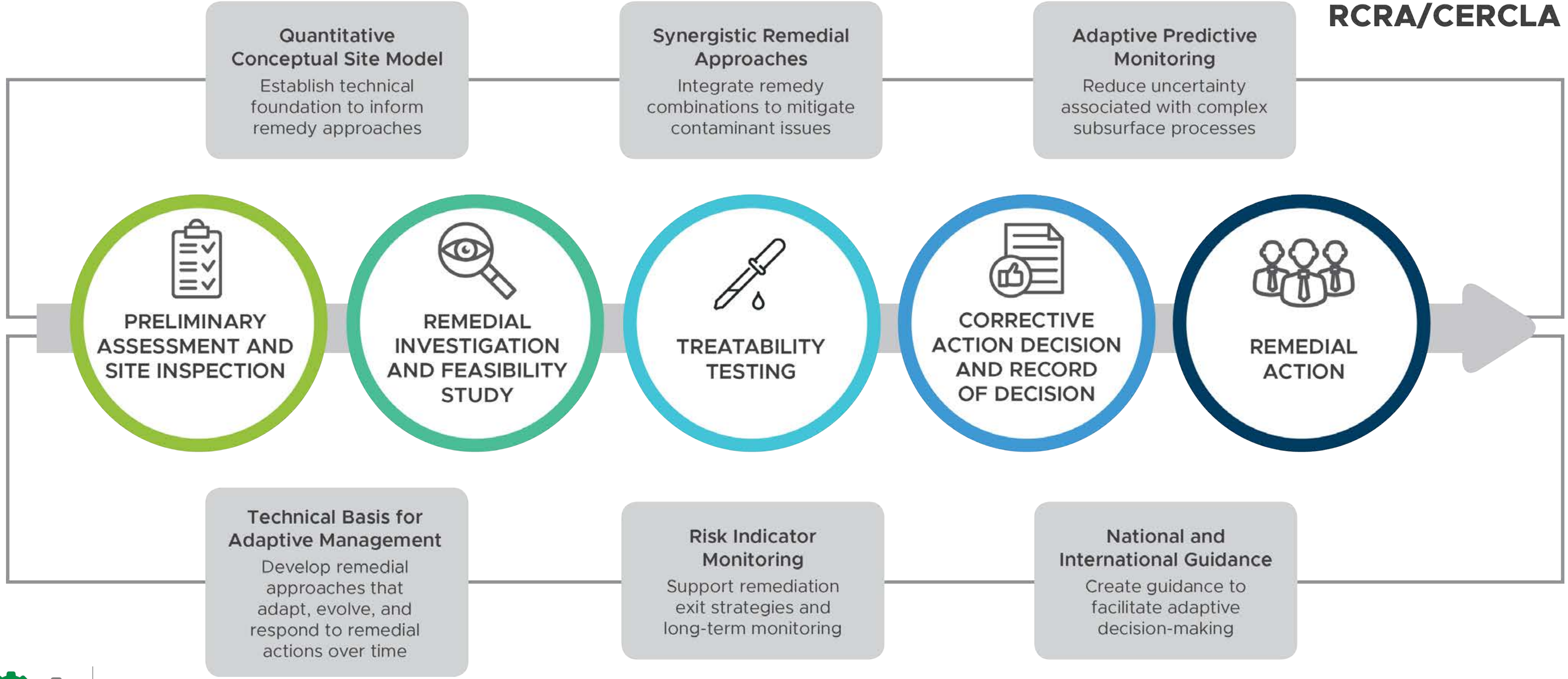
www.pnnl.gov/projects/remplex

Approach: Environmental Remediation Implementation



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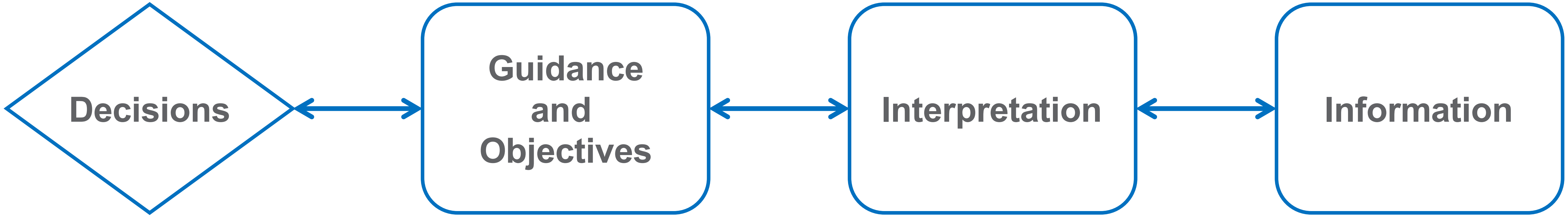
Complex Site Approach Elements

- Using technical guidance to define an objectives- and interpretation-driven approach focused on supporting remedy decisions can facilitate identifying characterization and remediation actions for complex sites



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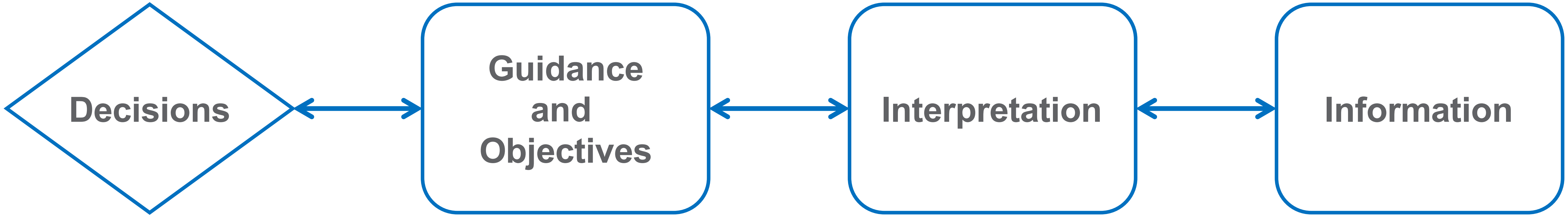
Complex Site Approach Elements



- Need for Mitigation
- Determine End State
- Select Remedy
- Manage/Optimize Remedy
- Remedy Closure

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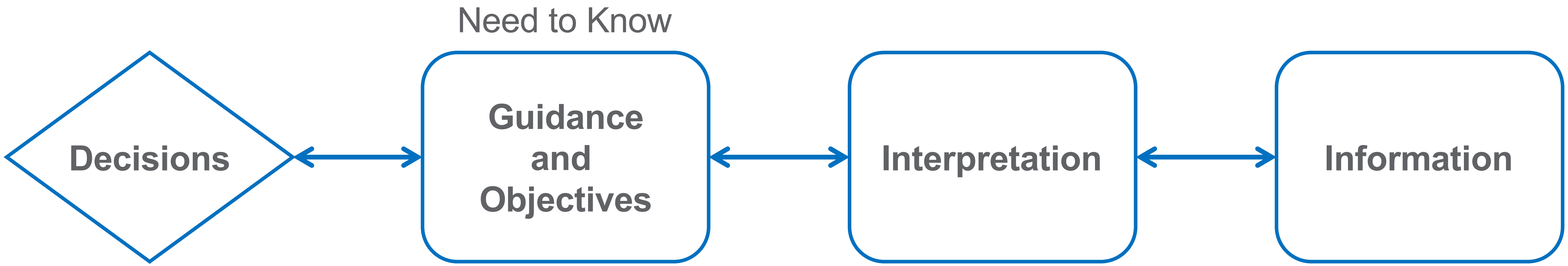
Complex Site Approach Elements



- Need for Mitigation
- Determine End State
- Select Remedy
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- Natural Attenuation
- EPA GW Road Map
- ITRC Complex Sites
- Adaptive Site Management
- Performance Assessment
- End State
- Data Quality Objectives

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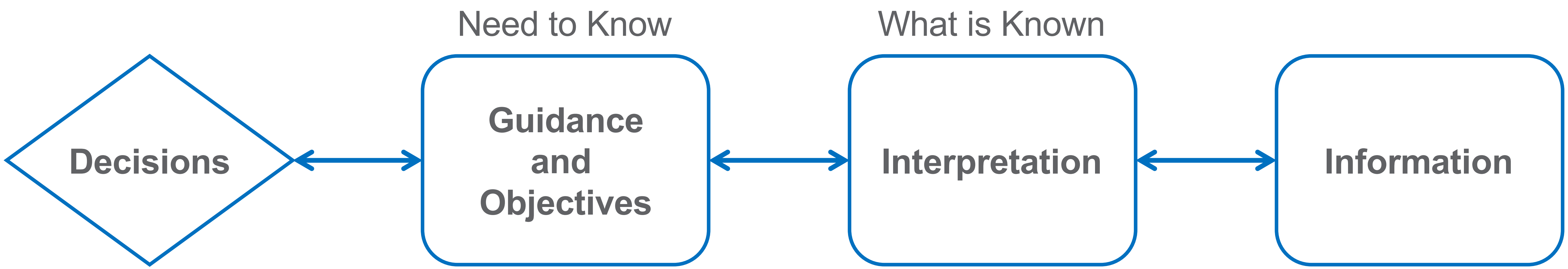
Complex Site Approach Elements



- Need for Mitigation
- Determine End State
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- Natural Attenuation
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- End State
- Data Quality Objectives

- Quantitative Conceptual Site Model
- Remedy Performance and Optimization Evaluations
- Predictive Modeling
- Data Analytics

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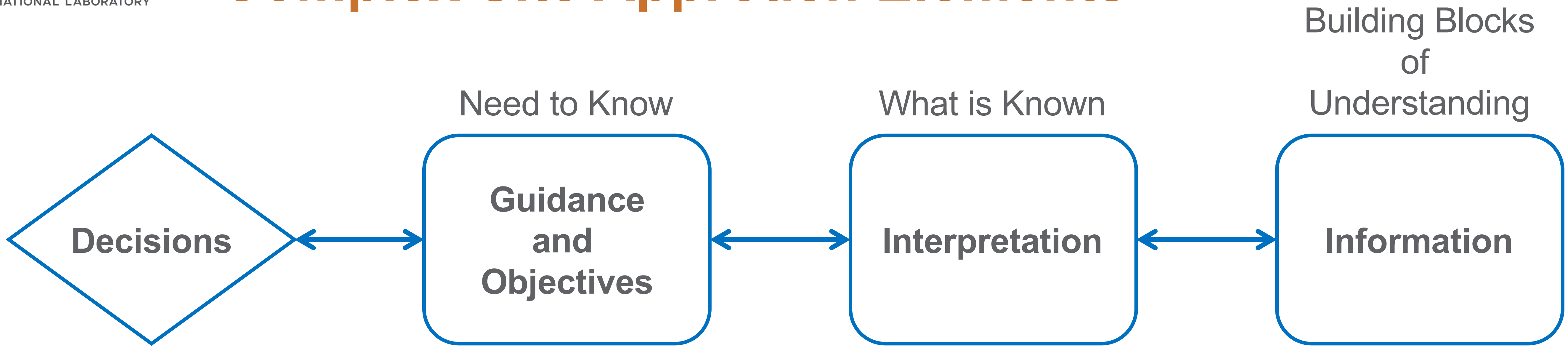
Complex Site Approach Elements



Decisions
- Need for Mitigation
- Determine End State
- Select Remedy
- Manage/Optimize Remedy
- Remedy Closure

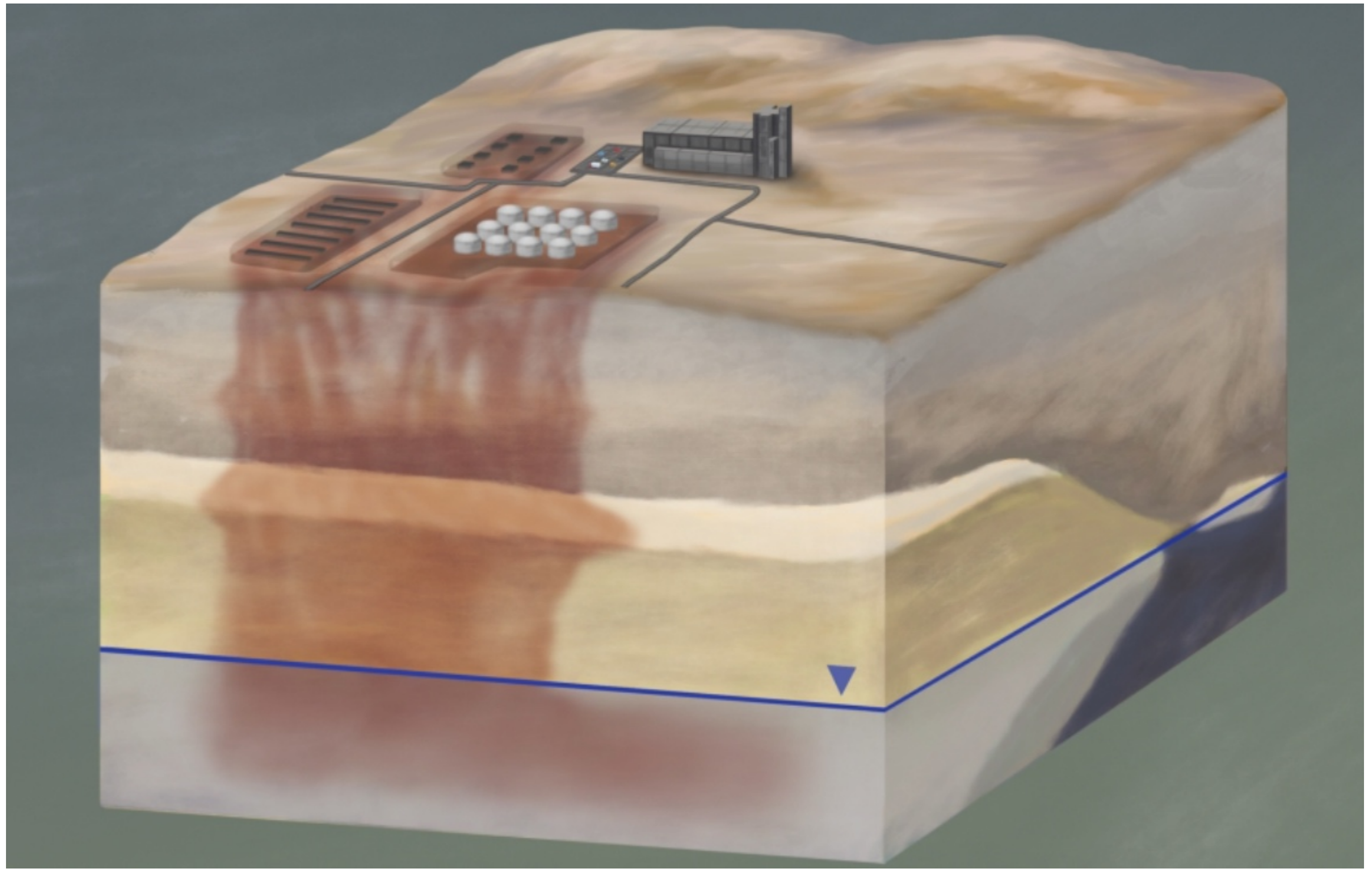
Guidance and Objectives
- Natural Attenuation
- EPA GW Road Map
- ITRC Complex Sites
- Adaptive Site Management
- Performance Assessment
- End State
- Data Quality Objectives

Interpretation
- Quantitative Conceptual Site Model
- Performance and Optimization Evaluations
- Predictive Modeling
- Data Analytics

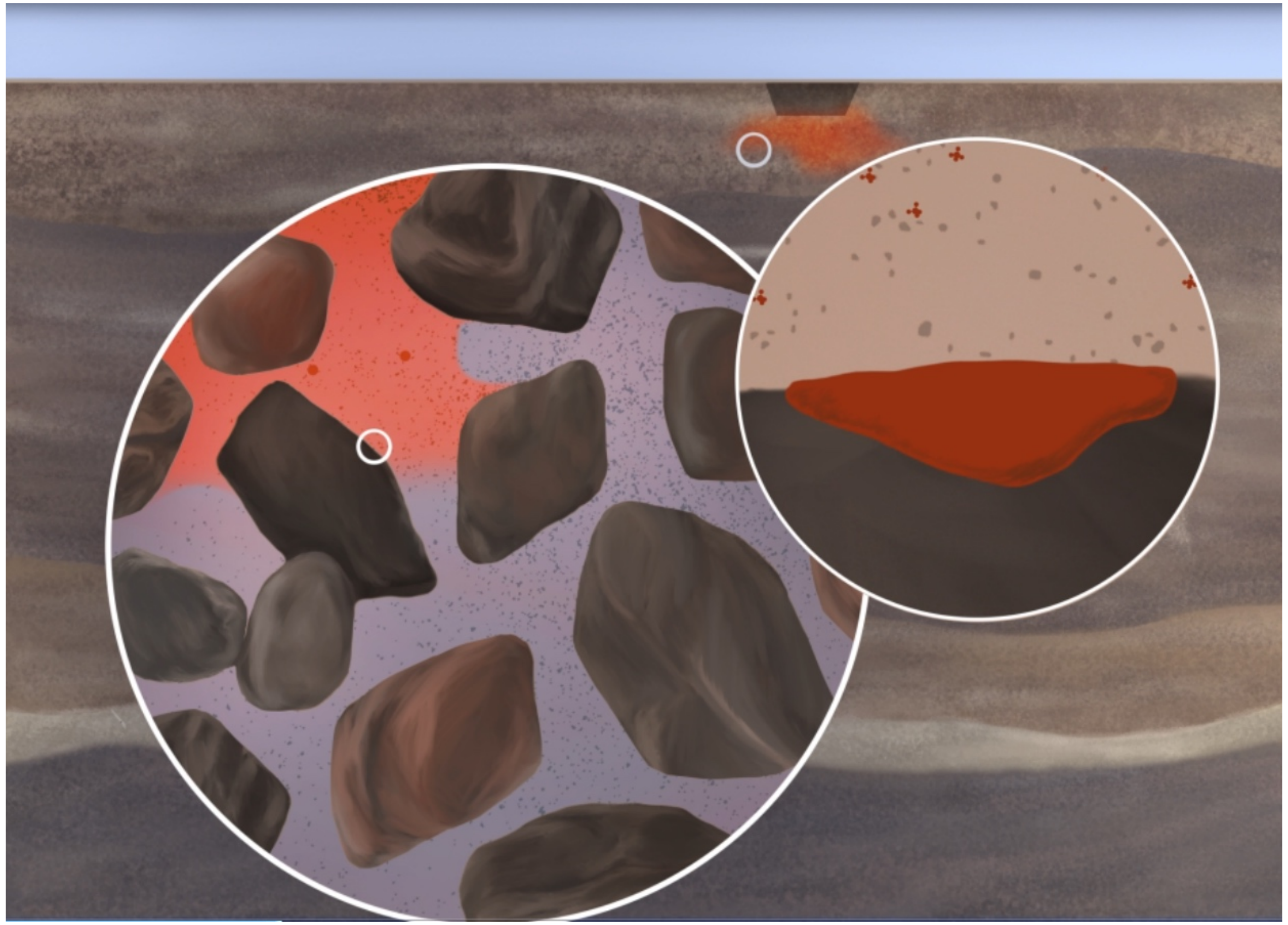
Information
- Site Properties
- Hydrology
- Attenuation Processes
- Remediation Processes
- Modeling Parameters
- Monitoring Data

Characterization: What do we need to know for contaminant mobility and controlling processes?

Field-Scale
Processes and Impacts



Underlying Controlling
Processes



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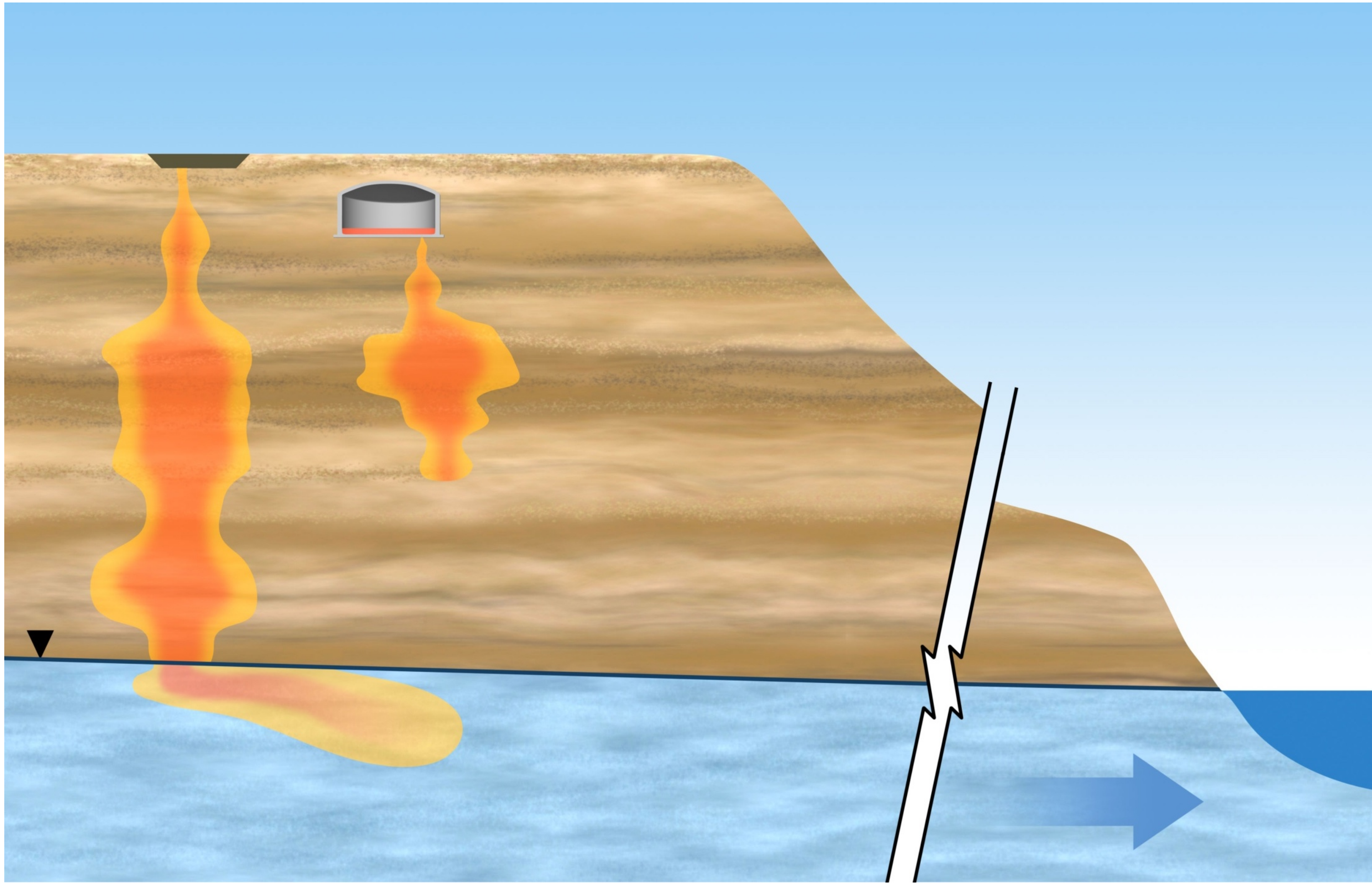
Hanford Site Example: Sources in the Vadose Zone

- Groundwater is a concern for contamination due to risk of exposure
- Contaminants in the vadose zone are a potential source to groundwater
- How do we evaluate the strength of this source?



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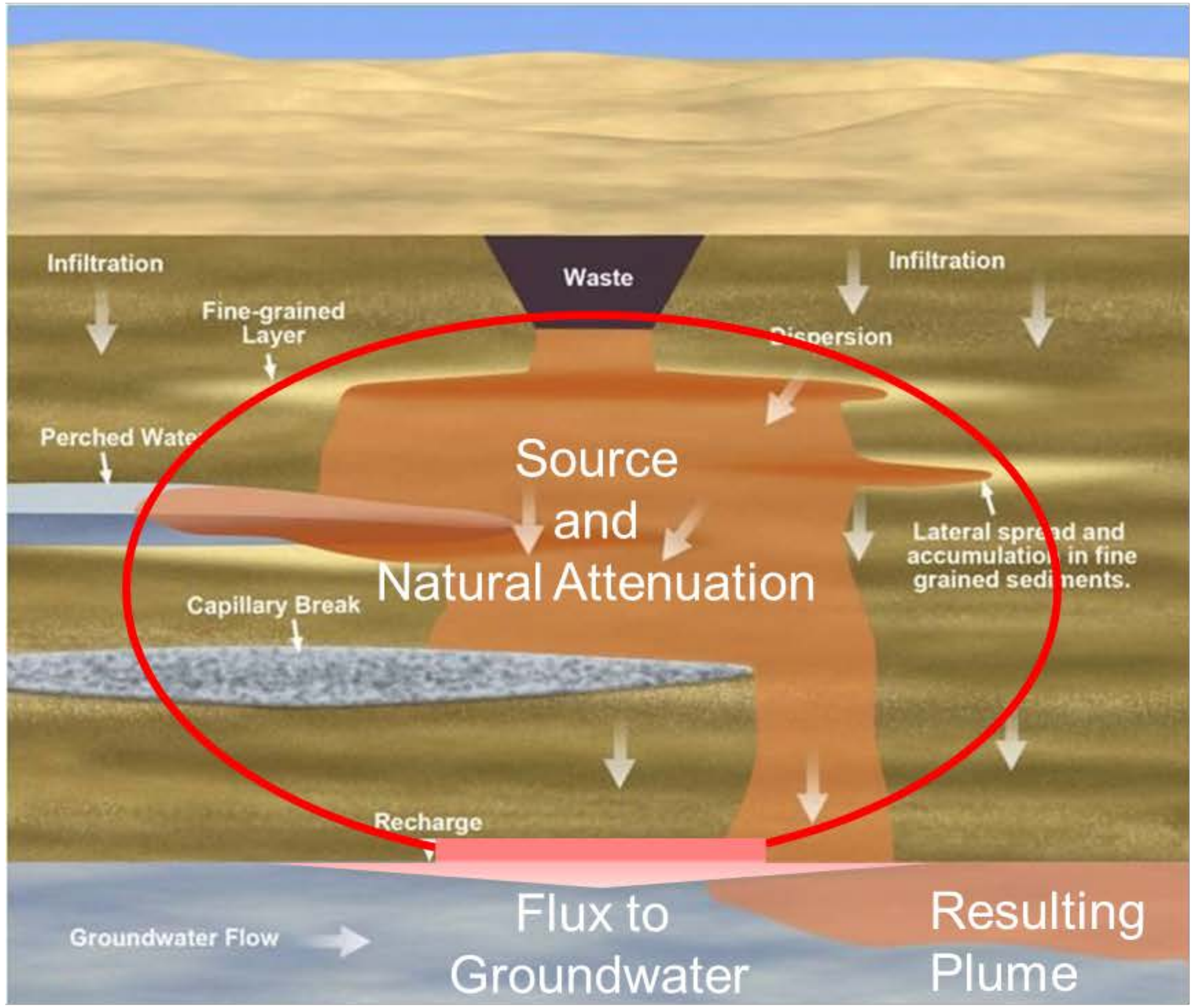
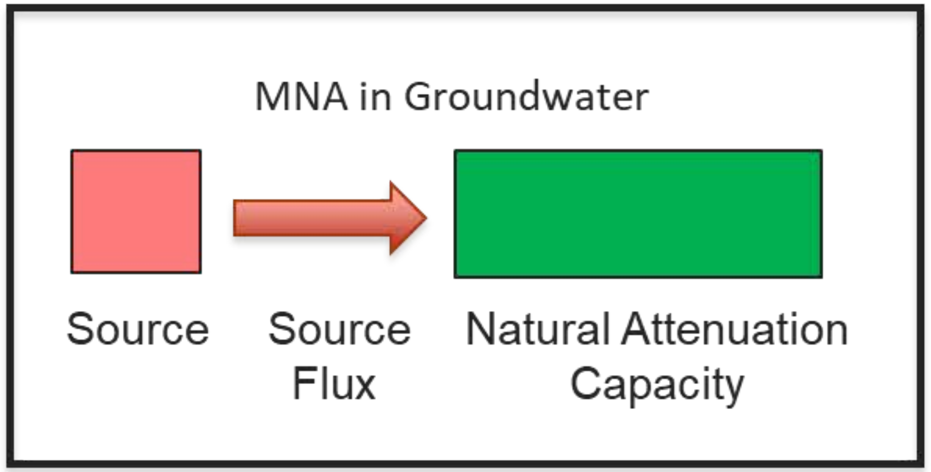
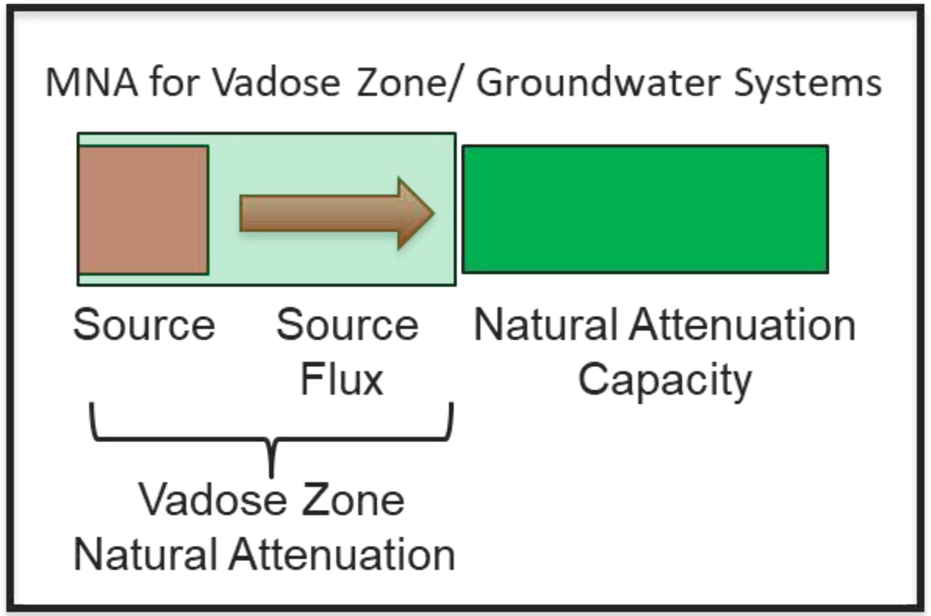
Vadose Zone Processes



Adapted from Dresel et al. 2011





Truex and Carroll 2013
Truex et. al 2015b
Oostrom et al., 2016

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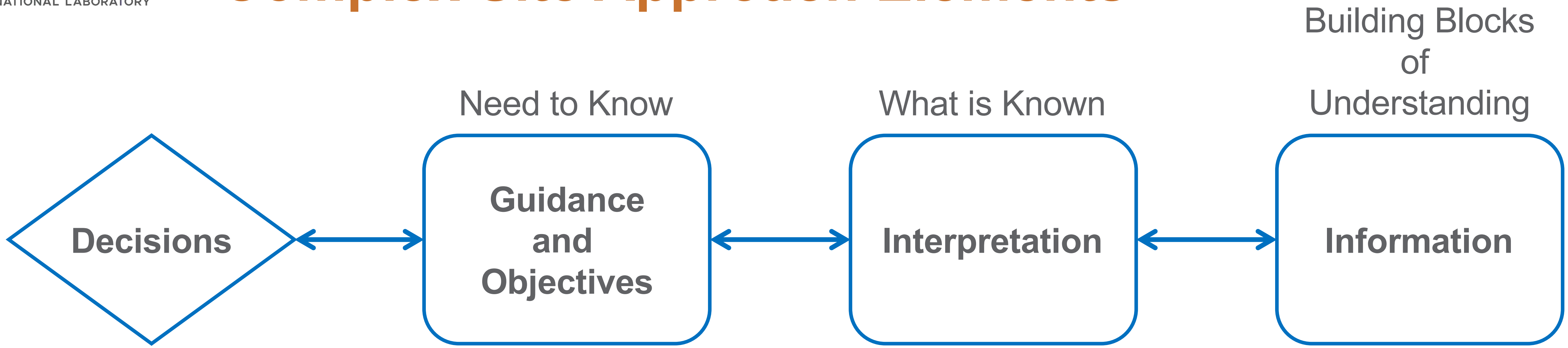
Complex Site Approach Elements



- **Need for Mitigation**
- Determine End State
- **Select Remedy**
- Manage/Optimize Remedy
- Remedy Closure

- **Guidance**: Natural Attenuation, Evaluating Source Flux
- **Objective**: Extent and Timing Needed for Source Remediation

- Quantitative Conceptual Site Model
- Performance and Optimization Evaluations
- **Predictive Modeling**
- Data Analytics

- Site Properties
- Hydrology
- **Attenuation Processes**
- Remediation Processes
- Modeling Parameters
- Monitoring Data

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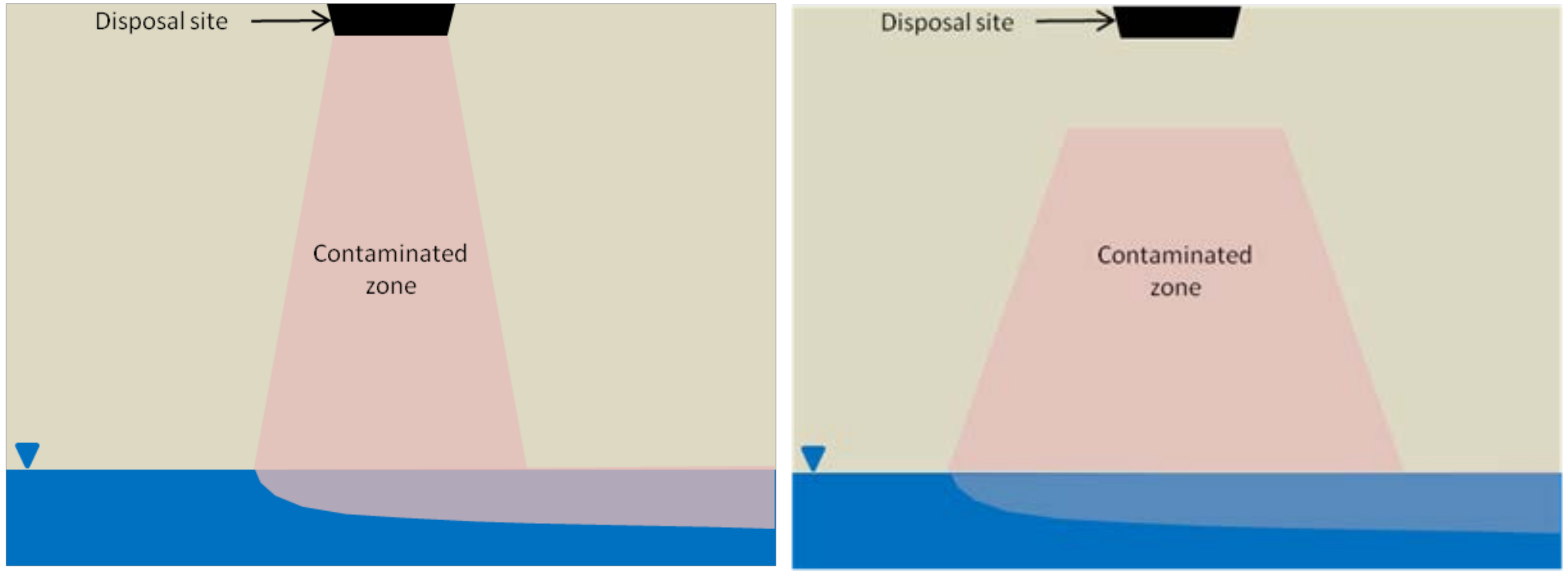
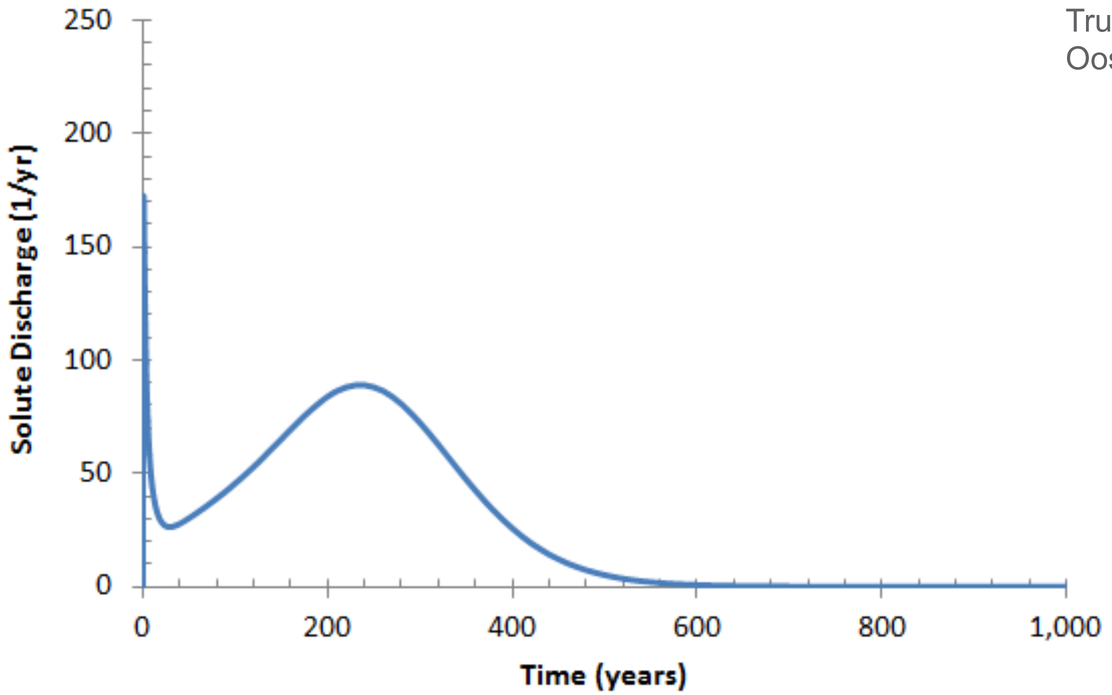
Interpretation

- Scoping
  - Based on the aqueous discharge volume and site characteristics, what is the estimated flux profile to groundwater?
- Addressing uncertainties
  - Attenuation processes
- Flux estimates for decisions and verification





Truex et al. 2015c
Oostrom et al. 2016

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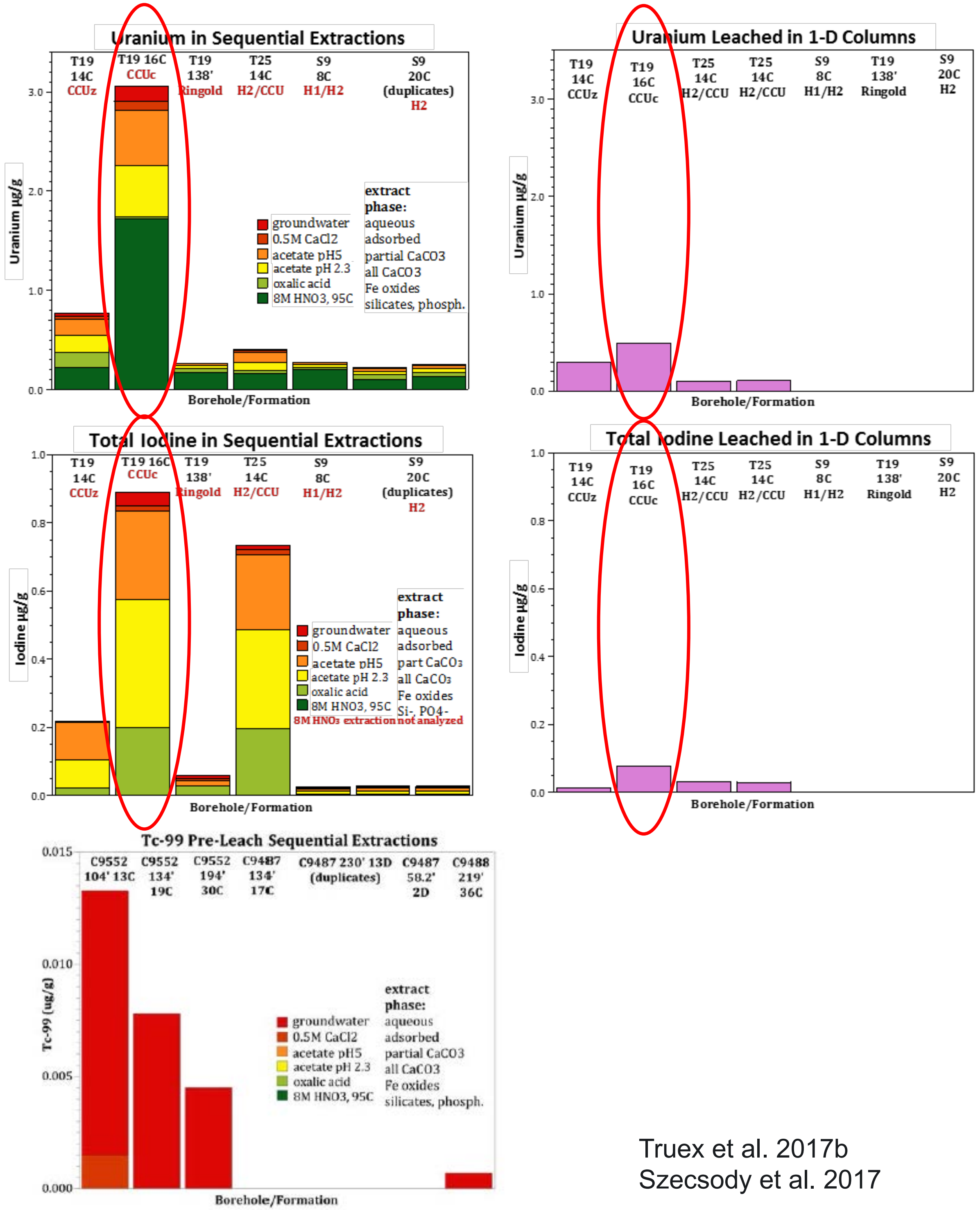
Attenuation Processes

- Use a graded approach
  - What portion of the contaminant inventory is mobile?
  - How mobile is the contaminant (transport parameters)?
  - What are the controlling processes (mechanisms)
- Integrate with predictive modeling to refine estimates and define verification approach



Truex et al. 2017b
Szecsody et al. 2017

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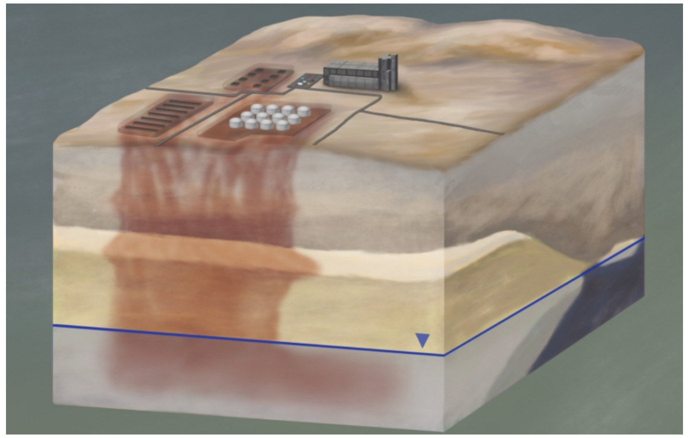
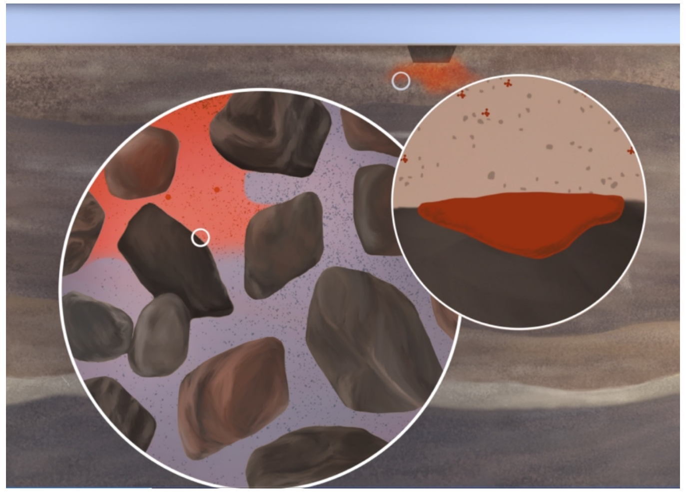
Remediation: How do we enhance design, implementation, monitoring, and optimization?

Controlling Processes





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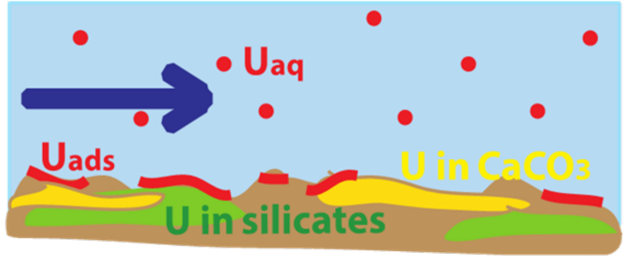
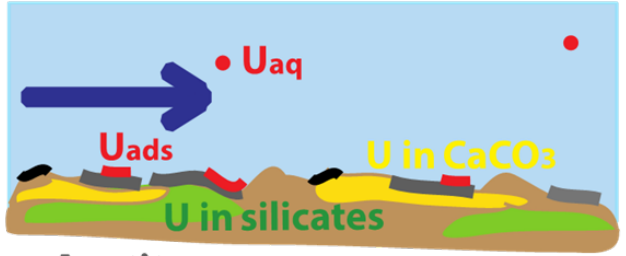
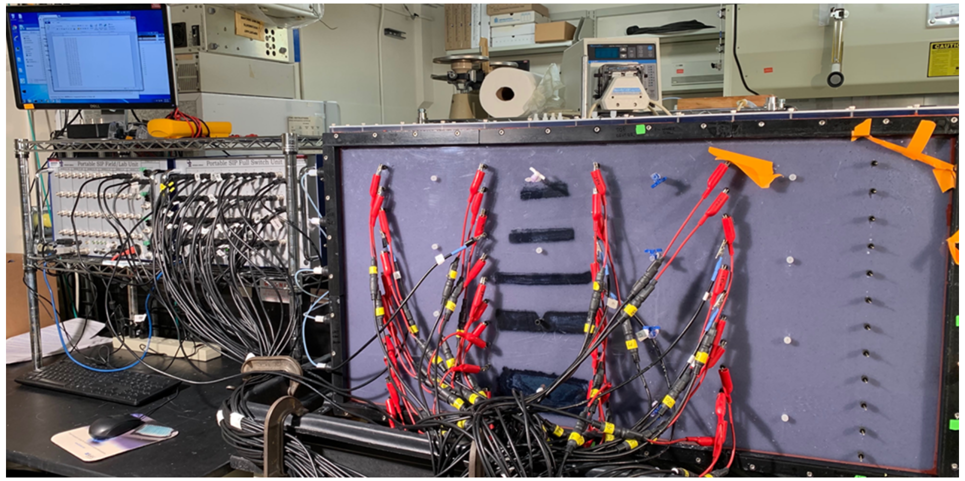
Effectiveness and Implementability

Untreated

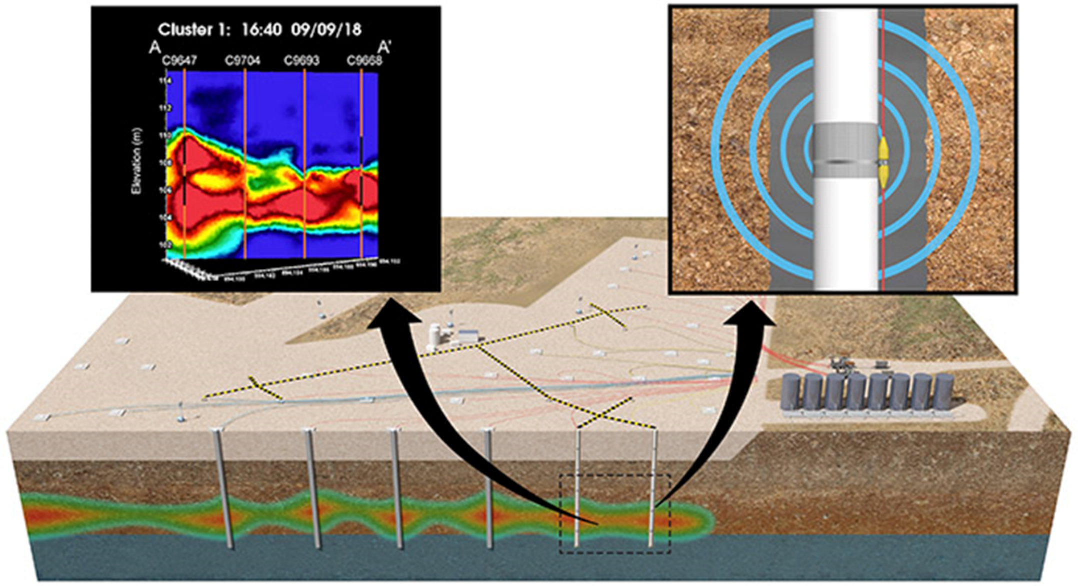


PolyPO$_4$ Treated



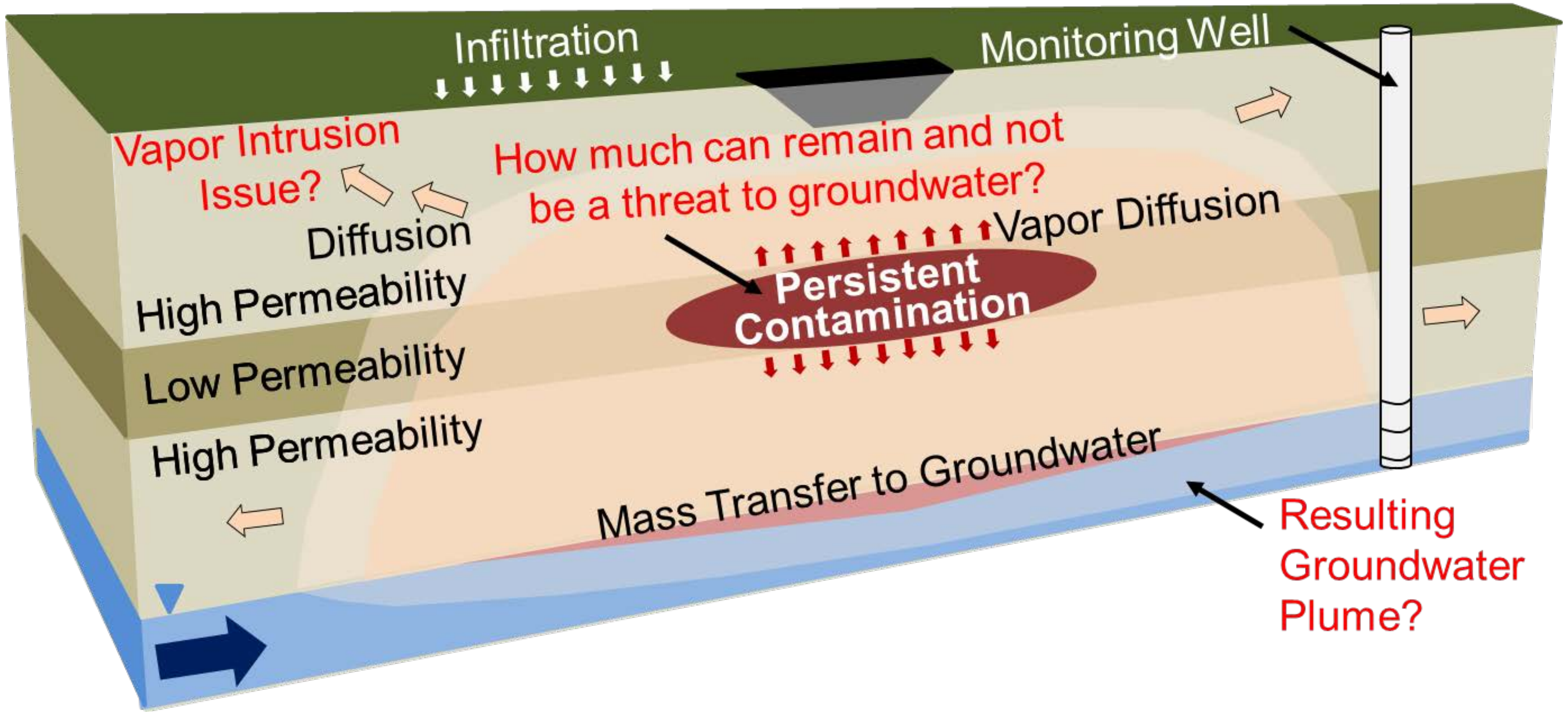


Monitoring, Evaluation and Optimization



Soil Vapor Extraction (SVE) Endstate

- SVE is effective but will experience diminishing returns
- How do we evaluate when SVE should be terminated?



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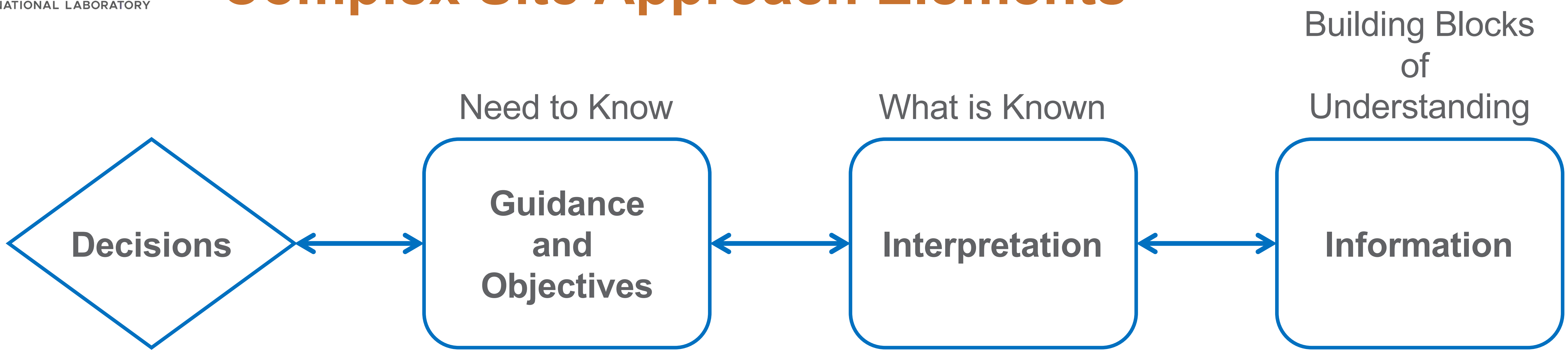
Complex Site Approach Elements



- Need for Mitigation
- Determine End State
- Select Remedy
- Manage/Optimize Remedy
- **Remedy Closure**

- **Guidance**: SVE Endstate Guidance
- **Objective**: Determine when remaining contamination does not pose a risk

- Quantitative Conceptual Site Model
- Performance and Optimization Evaluations
- **Predictive Modeling**
- Data Analytics

- Site Properties
- Hydrology
- Attenuation Processes
- Remediation Processes
- **Modeling Parameters**
- **Monitoring Data**

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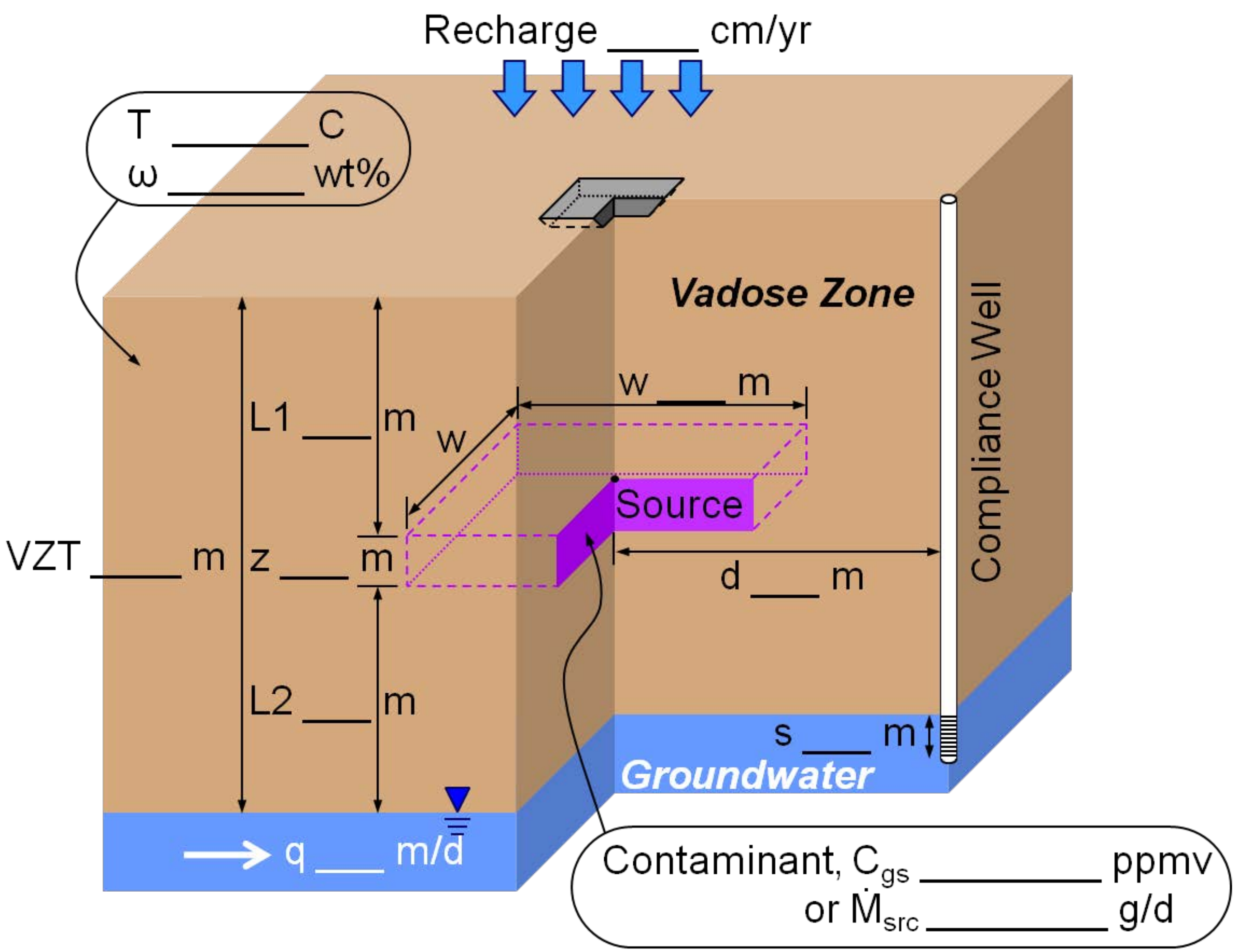
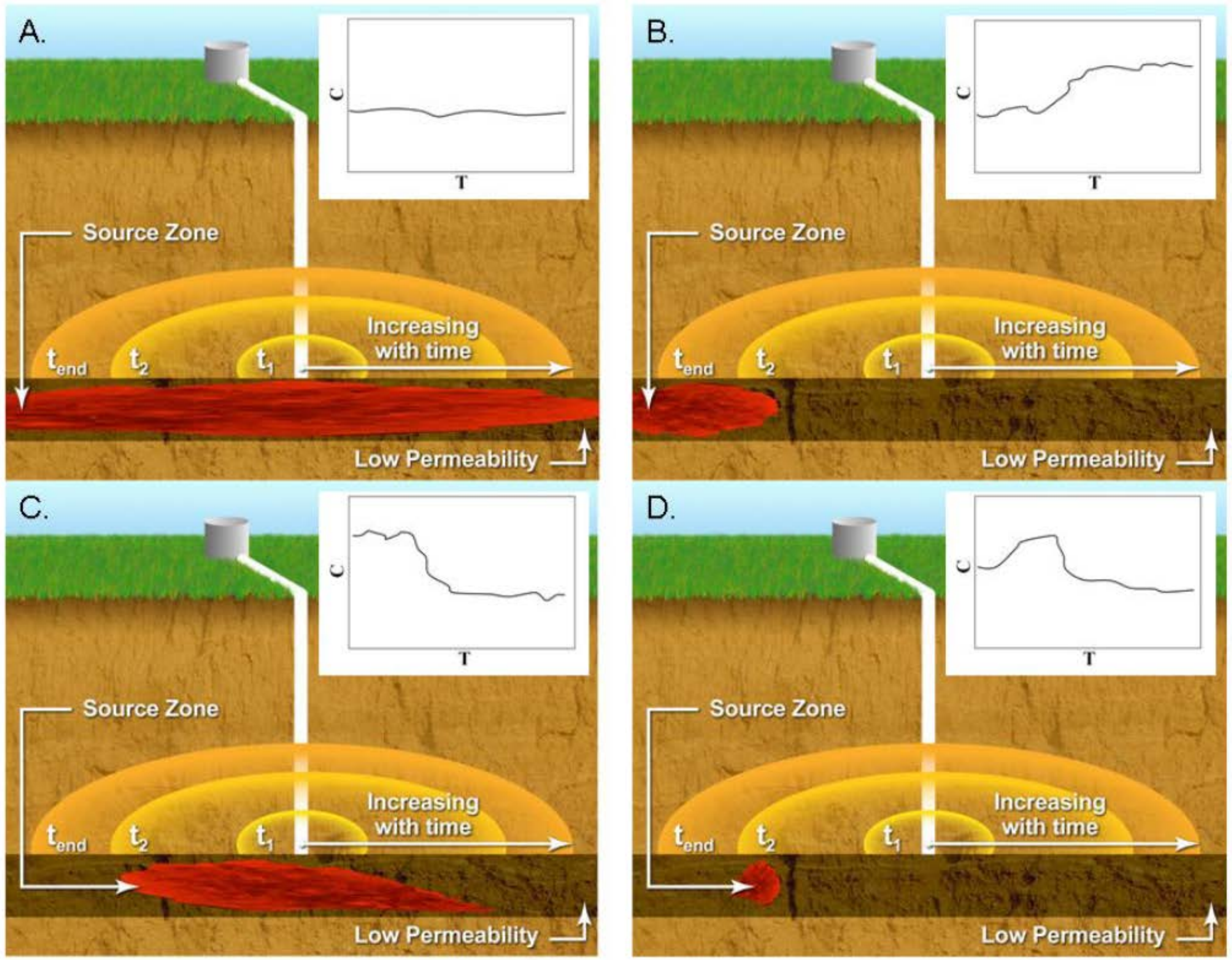
Modeling and Source Definition Approach



Truex et al. 2013



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SVE Endstate Transport Analysis

- Conduct estimates, evaluate uncertainty, and define verification approach

http://bioprocess.pnnl.gov/SVEET_Request.htm

SVE Endstate Tool (SVEET) Version 1.0.0

Described in: *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance* 2012-Sep-24

User Input					
	Scenario Name:	—	Case A	Case B	Case C
	Contaminant:	—	CT	TCE	TCE
T	Temperature:	[°C]	19.6	20	20
ω	Avg. Moisture Content:	[wt %]	8	1	1
R	Avg. Recharge:	[cm/yr]	0.5	0.5	0.5
VZT	Vadose Zone Thickness:	[m]	60	30	30
L1	Depth to Top of Source:	[m]	40	21	21
z	Source Thickness:	[m]	10	5	5
w (= l)	Source Width (= Length):	[m]	50	15	15
q	GW Darcy Velocity:	[m/day]	0.3	0.165	0.165
d	Distance to Compliance Well:	[m]	25	50	50
s	Compl. Well Screen Length:	[m]	5	10	10
	Source Strength Input Type:	—	Gas Concentration	Gas Concentration	Mass Discharge
C_{gs}	Source Gas Concentration:	[ppmv]	159	50	
$\dot{M}_{src}$	Source Mass Discharge:	[g/day]			10
Calculated Input					
STR	Source Thickness Ratio*:	[--]	0.167	0.167	0.167
SA	Areal Footprint of Source*:	[m²]	2500	225	225
RSP	Relative Source Position*:	[--]	4.00	5.25	5.25
L2	Distance – Source to GW:	[m]	10.00	4.00	4.00
H	Henry's Law Constant**:	[--]	0.890	0.263	0.263
Result – Estimated Groundwater Contaminant Concentration at Selected Compliance Well					
C_w	Final Groundwater Conc'n:	[µg/L]	16	15	31

* See below for permissible ranges of intermediate calculated values.

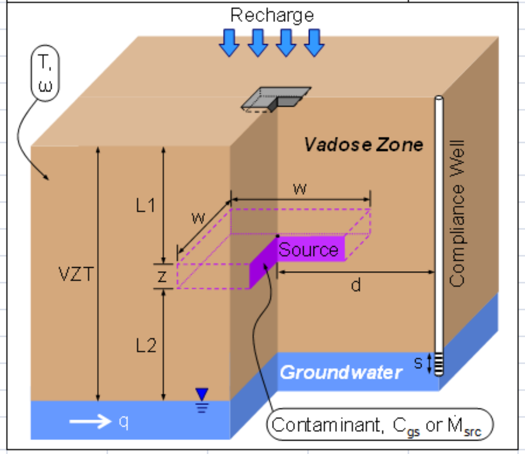
** See the 'HLC' worksheet for details of the temperature-dependent calculation of H.

Parameter Name	Permissible Range	Key Values
T	10 - 30	20
ω	1 - 9[a]	1, 5, 9[a]
R	0.4 - 7.5[b]	0.4
VZT	10 - 60	10, 30, 60
L1	varies[c]	—
z	varies[d]	—
w	10 - 50[e]	—
q	0.005 - 0.3	0.005, 0.03, 0.3
d	10[f], 25, 50, 75, 100	10, 25, 50, 75, 100
s	5 - 30	5
C_{gs}	1 - 2000	159
$\dot{M}_{src}$	0.1 - 5000	from STOMP simulations at 3 months elapsed time

See footnotes below.

Allow ω down to Sr = 0.05?

FALSE



Parameter Name	Permissible Range	Key Values
STR	0.1 - 0.5	0.1, 0.25, 0.5
SA	100 - 2500	100, 400, 900, 2500
RSP	0.1 - 10	0.1, 1, 10
L2	0.5 - 49	—
H	contaminant-specific	0.89

[a] The pre-modeled scenarios actually use residual saturation (S_r), not gravimetric moisture content. However, for user convenience gravimetric moisture content is used as the input parameter. The key values for S_r were 0.05, 0.3, and 0.55, which correspond to moisture content values of 0.8078, 4.843, and 8.879, respectively. Again for convenience, the moisture content range is truncated at 1 wt% and extended to 9 wt%, although values at or above 8.879 wt% are treated as S_r values of 0.55.

[b] The applicability of the estimation approach used here should be confirmed for sites with recharge between 2.5 and 7.5 cm/yr. See Section 4.2.2.1 of the PNNL report entitled *Soil Vapor Extraction System Optimization, Transition, and Closure Guidance* for further discussion.

[c] The range for L1 is variable (with a maximum range of 0.5 - 49 m) because it is a function of the permissible range for RSP and the input values of z and VZT.

[d] The range for z is variable (with a maximum range of 1 - 30 m) because it is a function of the permissible range for STR and the input value of VZT.

[e] The range for w is a function of the permissible range for SA and the square footprint of the source area.

[f] The source width must be less than or equal to 20 m to use d = 10.

Notice | SVEET | HLC

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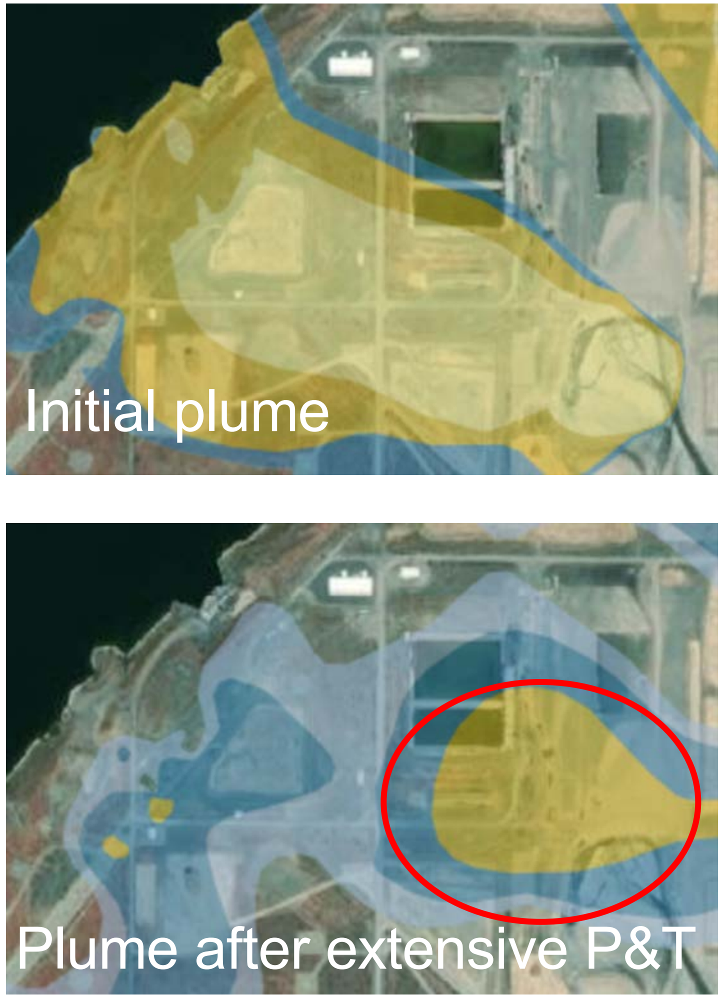
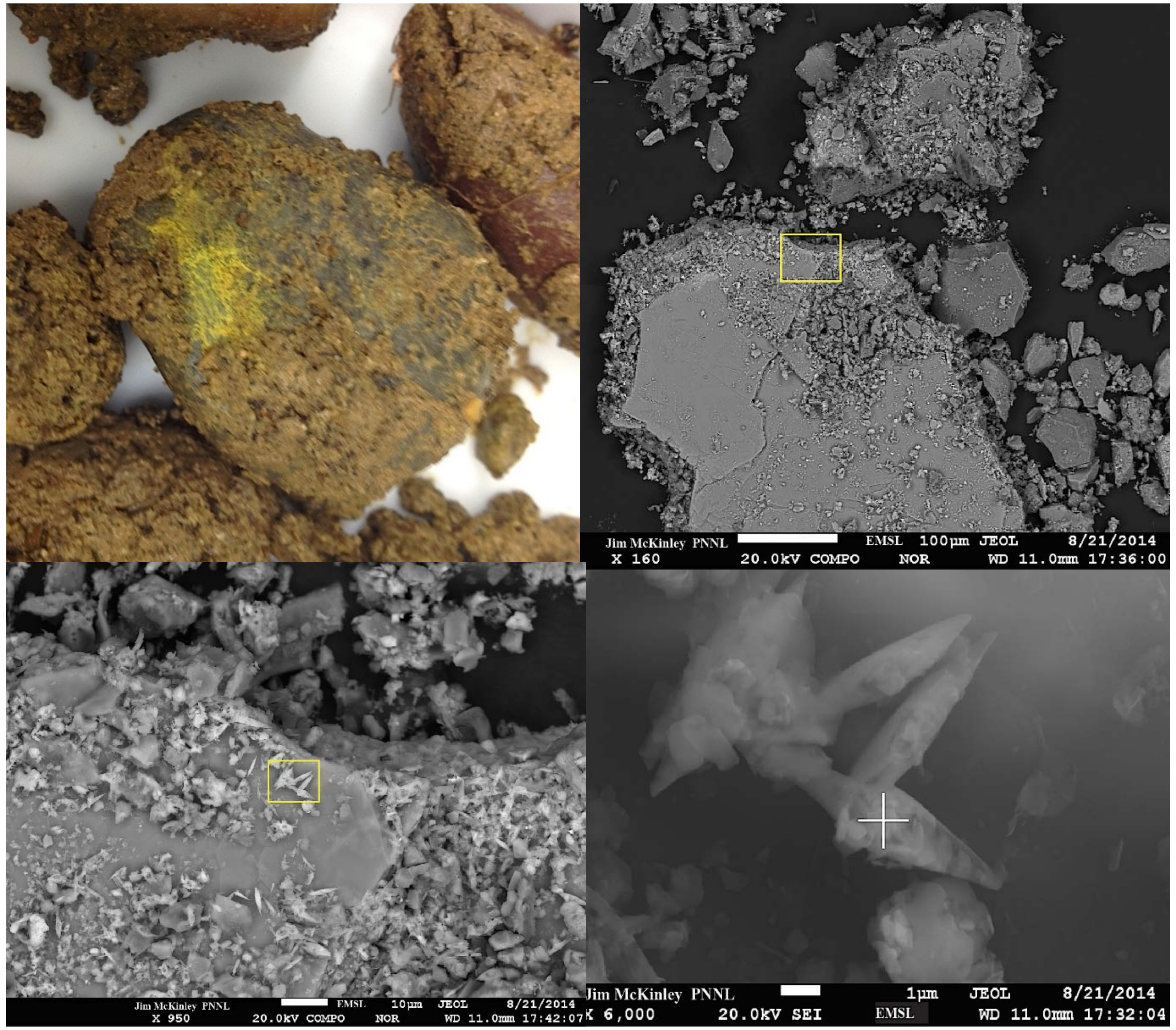
P&T Performance Assessment and Exit Strategy

- Chromate is mobile and should be amenable to P&T
- Persistent areas of plumes: identify cause and address as part of exit strategy
- Sediment and leaching analysis identify source characteristics and soil flushing options

Chromate plume



Chromate precipitate in source area



Truex et al. 2015c

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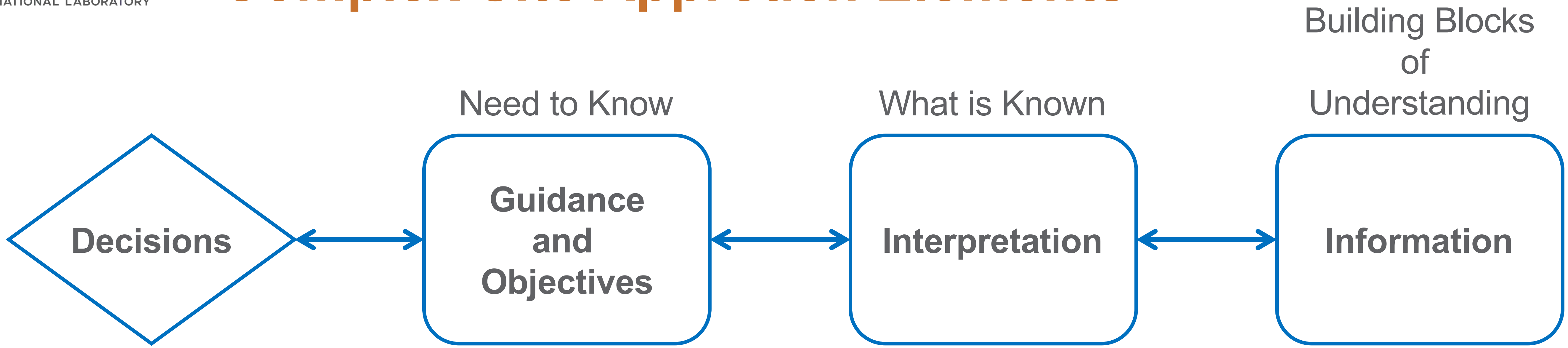
Complex Site Approach Elements



- Need for Mitigation
- Determine End State
- Select Remedy
- **Manage/Optimize Remedy**
- Remedy Closure

- **Guidance**: P&T Exit Strategy, Evaluating Source Flux
- **Objective**: Quantify Secondary Source Strength

- Quantitative Conceptual Site Model
- **Performance and Optimization Evaluations**
- Predictive Modeling
- Data Analytics

- Site Properties
- Hydrology
- **Attenuation Processes**
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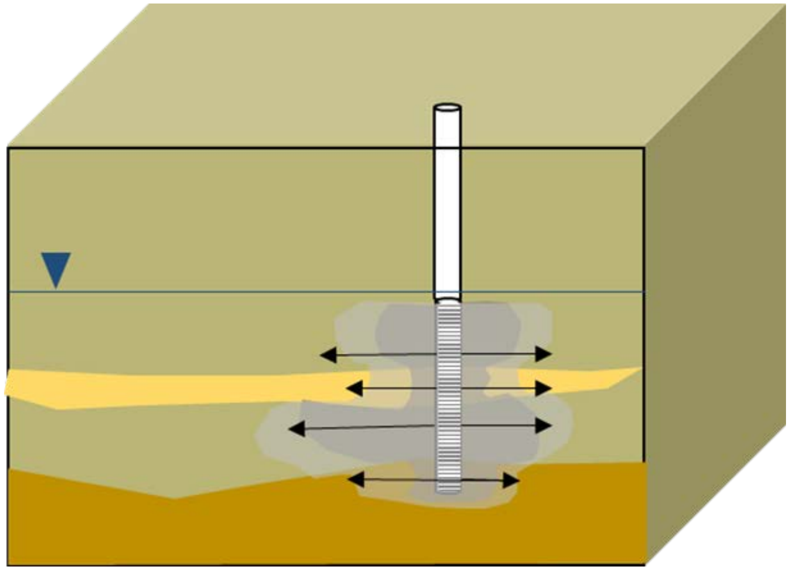
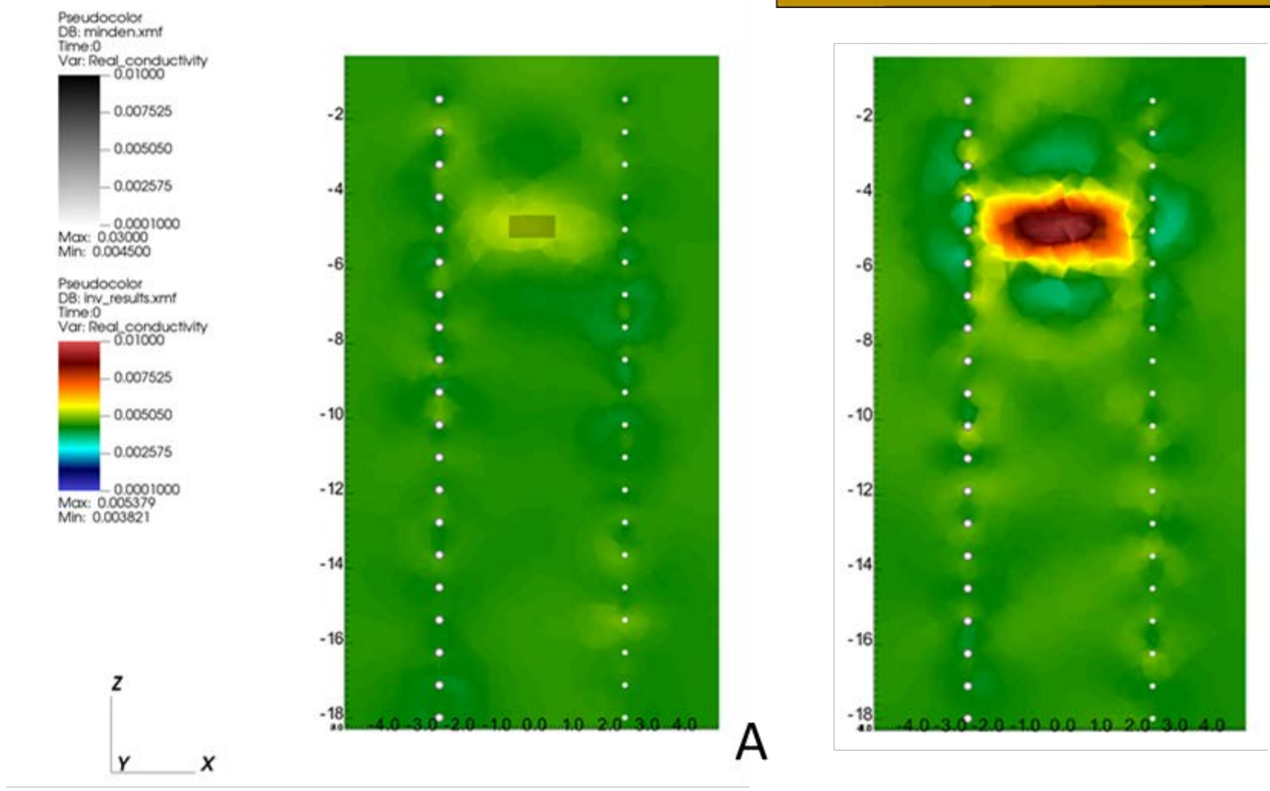
Design-Stage Decisions: Amendment Injection Monitoring

- Concern about evaluating in situ distribution of particulate amendments
- Can geophysics be applied to image the distribution?
- Data inversion techniques allow for upfront synthetic evaluation of geophysics resolution

Particulate amendment





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Complex Site Approach Elements

Decisions	Guidance and Objectives	Interpretation	Information
	Need to Know	What is Known	Building Blocks of Understanding
- Need for Mitigation - Determine End State - Select Remedy - **Manage/Optimize Remedy** - Remedy Closure	- **Guidance**: Geophysics Data Inversion Approaches (E4D) - **Objective**: Measure in situ amendment distribution	- Quantitative Conceptual Site Model - Performance and Optimization Evaluations - **Predictive Modeling** - Data Analytics	- Site Properties - Hydrology - Attenuation Processes - Remediation Processes - Modeling Parameters - **Monitoring Data**

Decisions ⟷ Guidance and Objectives ⟷ Interpretation ⟷ Information

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Implications and Applications

- Technical guidance and use of objectives- and interpretation-driven approaches facilitate remedy decisions

- Applying and developing technical guidance, fostering appropriate capabilities, and enabling collaborative efforts are key elements for REMPLEX
  - Develop and make available technical guidance documents as resources
  - Develop interpretation tools such as data analytics, modeling, and geophysical data inversion
  - Make available and apply laboratory and field investigation capabilities to obtain actionable information
  - Promote collaborative efforts to address environmental site issues, especially for complex sites

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Summary

- Technical resources are needed to support defining the right level of detail for remedy decisions at complex sites
- An integrated approach tying information, interpretation, objectives, and guidance to decisions can facilitate efforts at complex sites
- Determining what we “need to know” can use an integrated approach and technical guidance that provide a framework for identifying information sufficient for decision making

Thank you

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Technical Leadership

Independent technical resource with proven track record of supporting deployment of advanced technologies and alternative strategies

Multi-institutional Collaborations

Integration and leveraging across federal and private partnerships to facilitate solution development

Solution Development

Leverage existing capabilities spanning all TRLs to provide solutions in adaptive remediation and long-term stewardship that enable risk-based remediation

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