Starting Soon:
ITRC Sediment Cap Chemical Isolation

- Sediment Cap Chemical Isolation Guidance Document, sd-1.itrcweb.org
- CLU-IN training page at https://clu-in.org/conf/itrc/sd-1/. Under "Webinar Slides & References", you can download the slides

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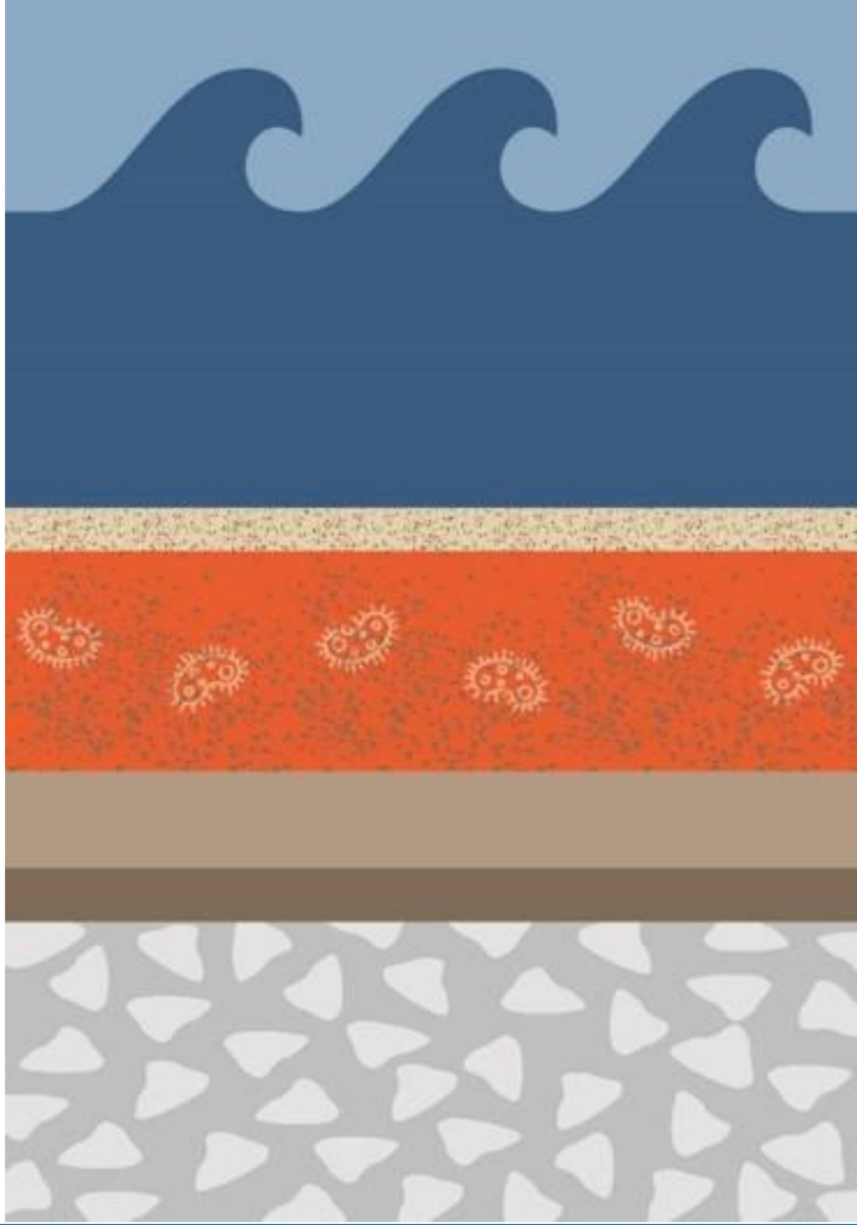

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https://sd-1.itrcweb.org/

Meet the ITRC Trainers

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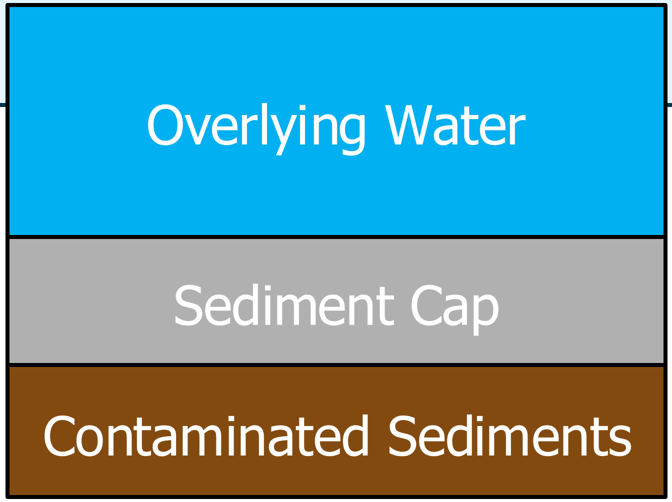
ITRC: 2014 Guidance vs. 2023 Guidance

Contaminated Sediments Remediation (2014)

- Guidance on contaminated sediment selection of remedial technologies
- Section 5 provides an overview of Amended and Unamended Capping



Sediment Cap Chemical Isolation (2023)

- Design, construction, and monitoring of the cap chemical isolation function
- Design approach for physical stability or erosion protection layer not discussed in this guidance

Training Roadmap

Introduction (Section 1)

Capping Overview (Section 2)

Performance Objectives & Design Concepts (Section 3)

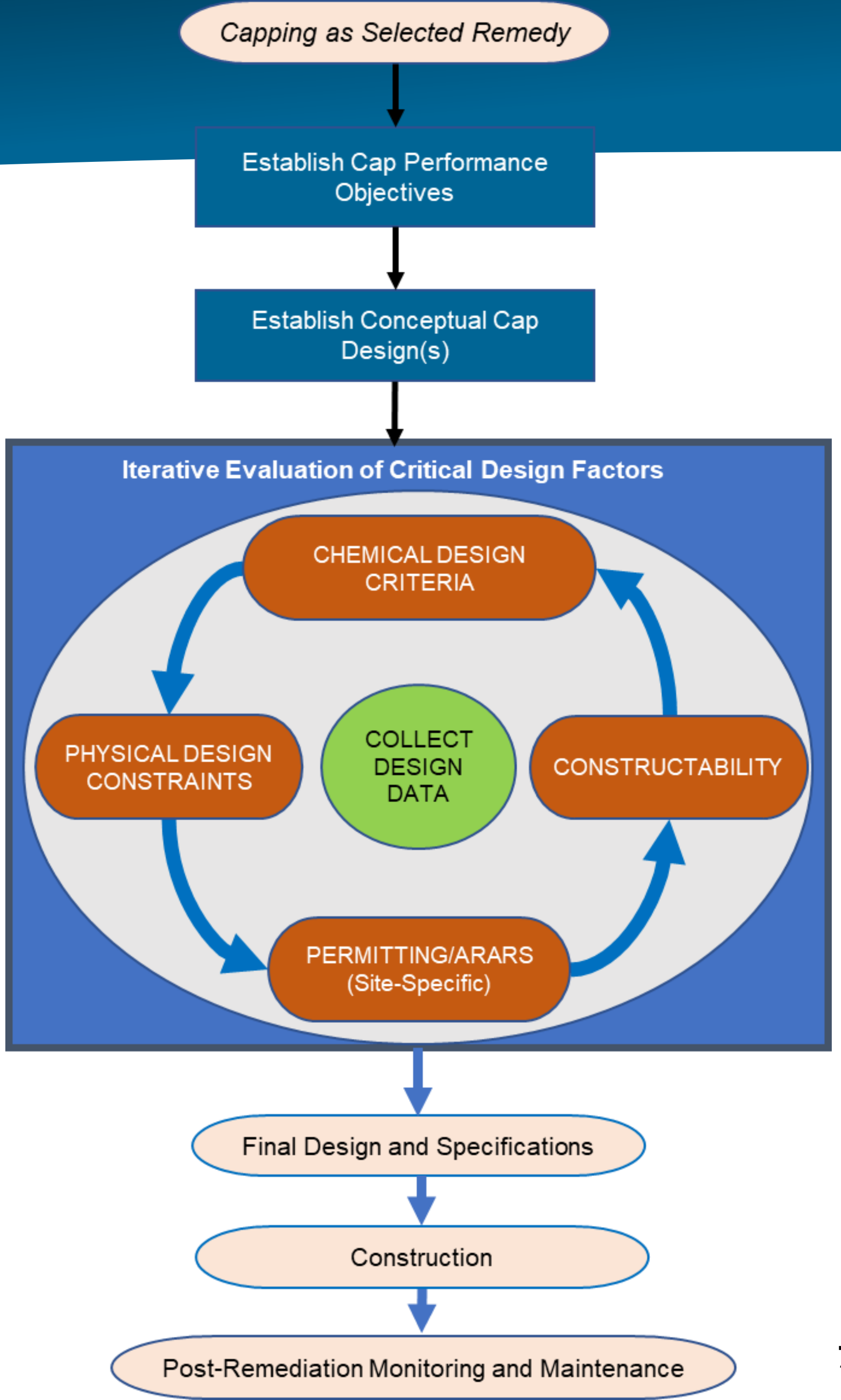
Chemical Isolation Layer Modeling (Section 5)

Q&A Break

Chemical Isolation Construction Considerations (Section 6)

Monitoring & Maintenance Objectives and Approaches (Section 7)

Q&A Break



Section 4: Chemical Isolation Design Data Needs

4 Chemical Isolation Design Data Needs

Table 4-1 summarizes the data that may be needed to support cap design, construction, and monitoring to meet the desired chemical isolation design criteria. Where noted in Table 4-1, detailed description of the key data needs specific to the CIL design is included in Appendix C. Although not all data are needed for every project or site, this checklist is a useful way to explicitly consider each possible data need during the respective stages of the project. These phases, presented in Table 4-1, are described in the following bullets:

- Design criteria: the key factors with respect to the site-specific CSM that would support the development of the chemical isolation design criteria.
- CIL modeling: the parameters recommended for informing or selecting model inputs for effective CIL design. Key modeling inputs are further described in Section 5.5.3.
- Construction: the key factors that would affect the placement of CIL and should be considered during the CIL design.
- Post-remediation monitoring: the key factors that should be considered during the development of the long-term monitoring plan for the CIL performance evaluation.

Table 4-1. Potential data needs for the chemical isolation design

Data Type	Description	CSM/ Design Criteria	CIL Modeling	Construction	Post-Remediation Monitoring
Chemical-Specific Properties					
Contaminant Type (e.g., Organics or Metals)	Site-specific contaminant(s) (i.e., COCs).	X	X		X
Contaminant Concentration in Porewater	Source of chemical to the cap (from beneath the cap). It is important to know whether concentrations represent total dissolved or freely dissolved contaminants. Additional details are provided in Appendix C.	X	X		X
Contaminant Distribution in Either Bulk	Concentrations of one chemical relative to the other chemicals, either individually or as individuals that make up a total (e.g., homologs of total PCBs).	X	X		

Design Criteria

CIL Modeling

Construction

Post-Remediation Monitoring

https://sd-1.itrcweb.org/4-chemical-isolation-design-data-needs/

Sediment Capping Objectives

Focus of Training & Resources is Chemical Isolation

1. Physical stabilization (stability) to prevent contaminant transport

2. Chemical isolation to contain or limit contaminant migration and exposure to contaminants of concern from the underlying sediments

3. Protection of benthic community by preventing direct contact with the underlying contaminated sediments

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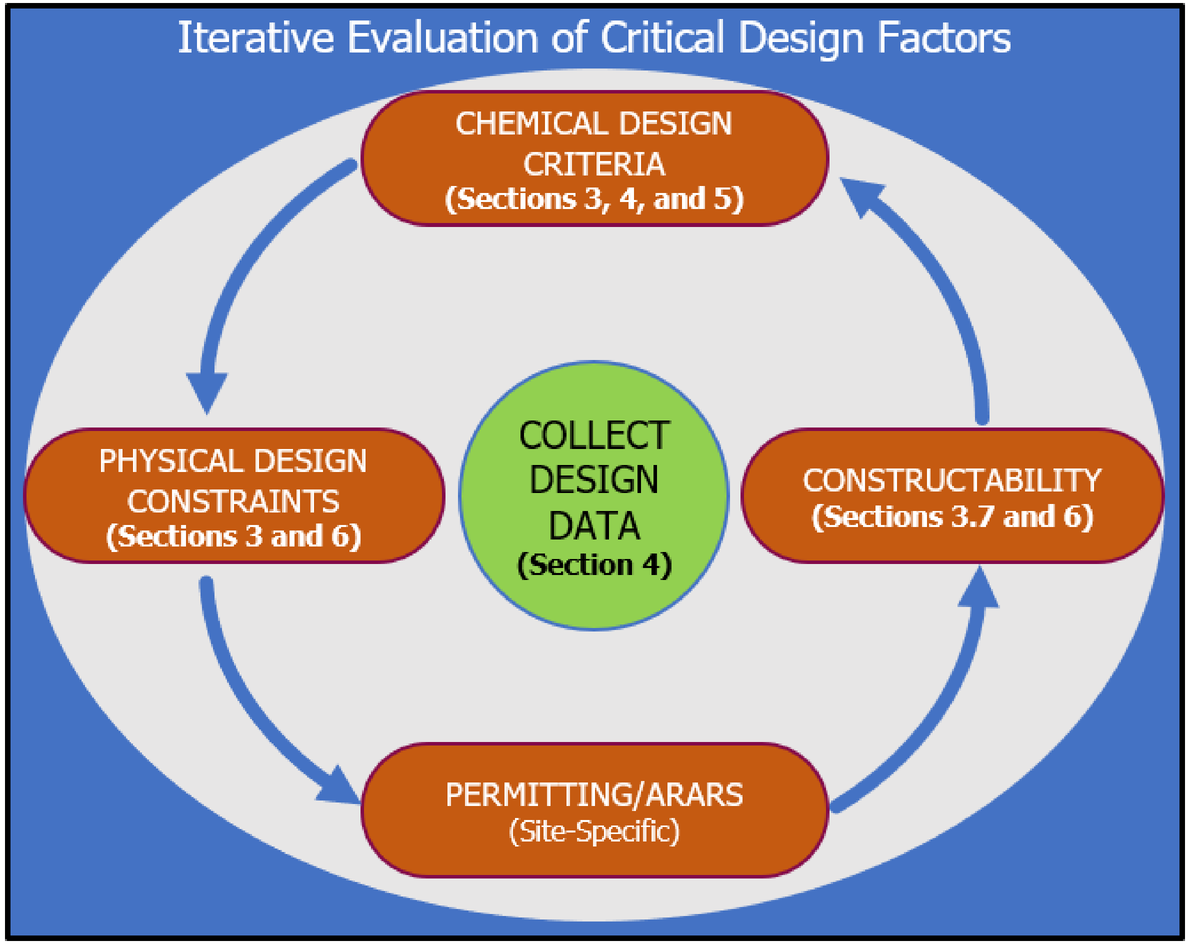
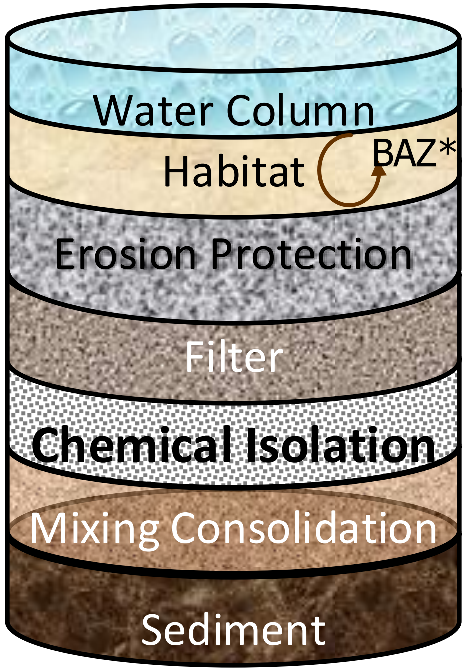


Capping Overview

Cap objectives can be achieved with a single cap layer or ***combination of multiple cap layers***

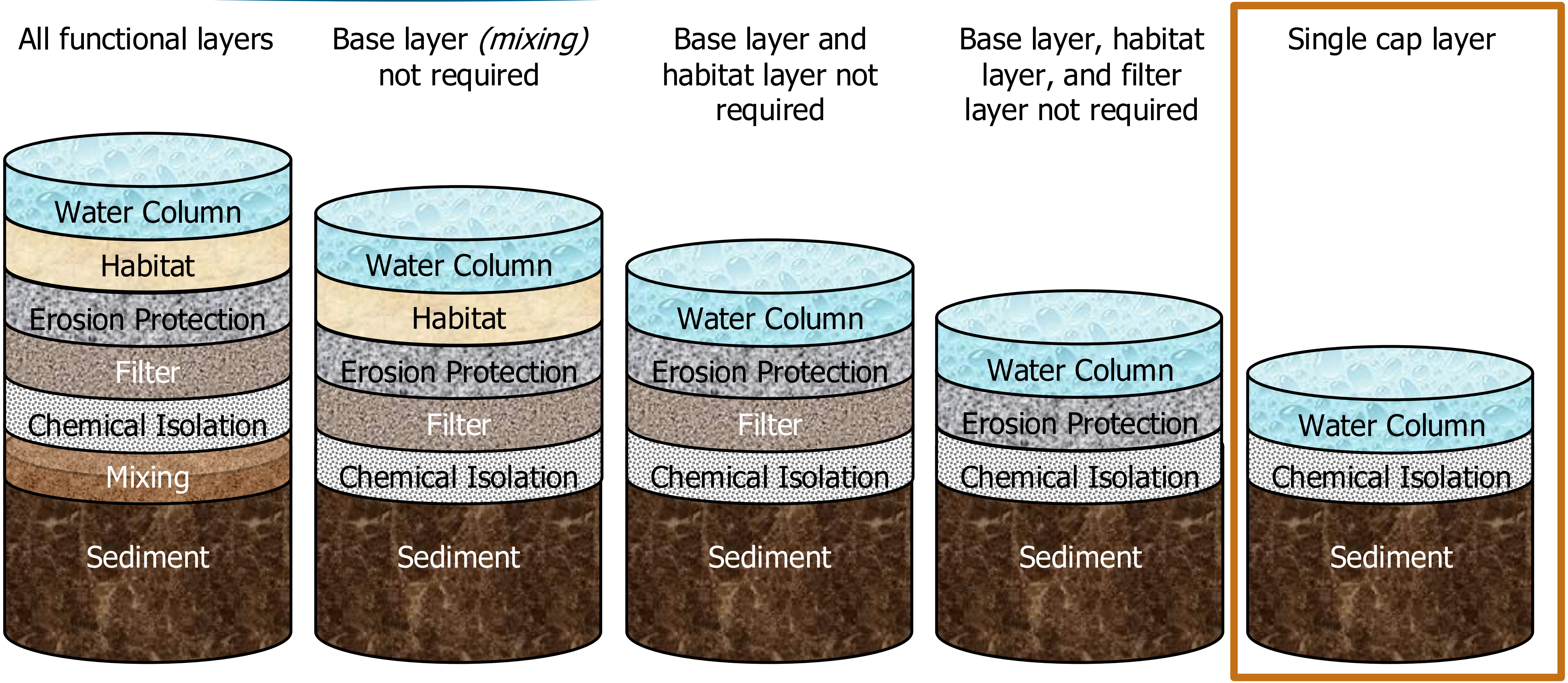


- Accommodates the benthic and aquatic communities and vegetation
- Stabilizes and protects CIL from erosive forces (e.g., waves, tides, current, prop wash)
- Buffers mixing of CIL and erosion protection layer
- **Provides chemical isolation**
- Creates level / stable base layer; prevents CIL from mixing with sediment

* The surface layer usually includes the biologically active zone (BAZ)

Source: Jeffrey Hale, Kleinfelder (used with permission)

Cap Layer Configurations



Source: Jeffrey Hale, Kleinfelder (used with permission)

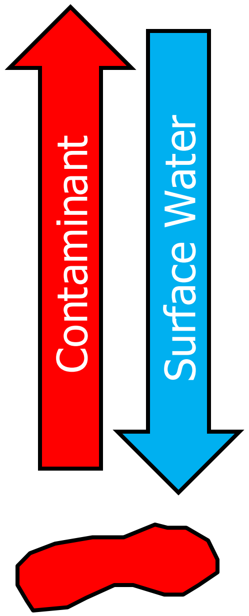
General Cap Types

Unamended Granular Caps

Low-permeability Caps

Amended Caps

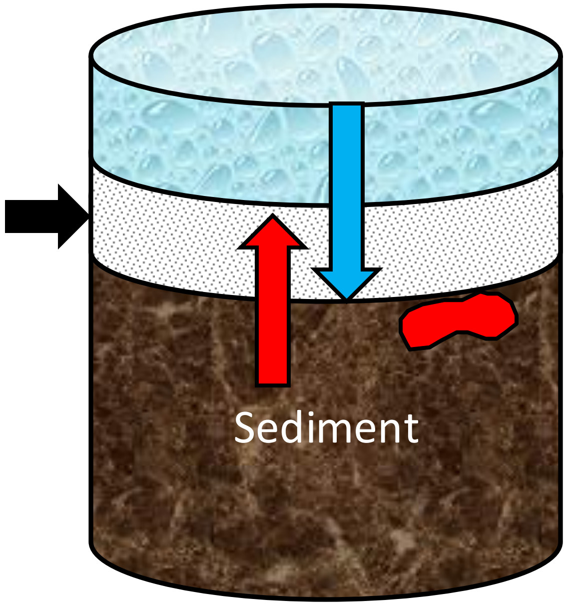
Unamended Granular Caps



Unretarded vertical fluid flux

Isolated immobile contaminant material

Unamended Granular Cap
(e.g., sand)

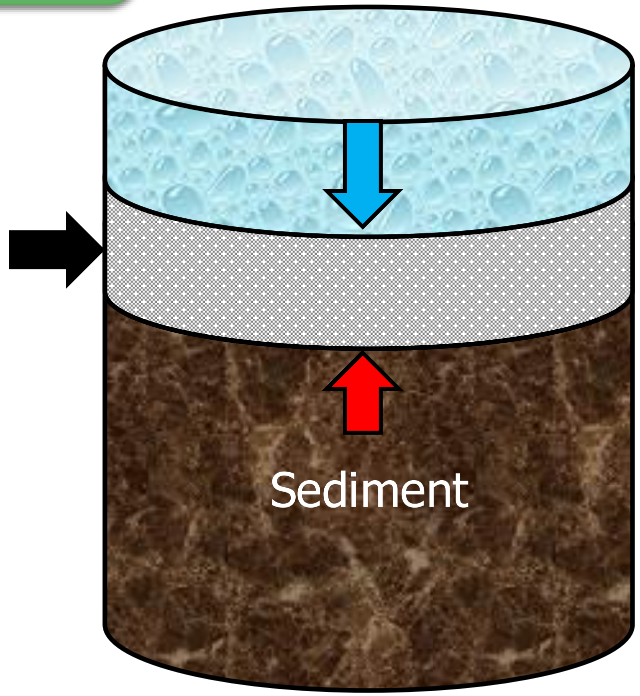


- Physical Separation
- Permeable
- Increased Attenuation Thickness
- Isolates Immobile Material

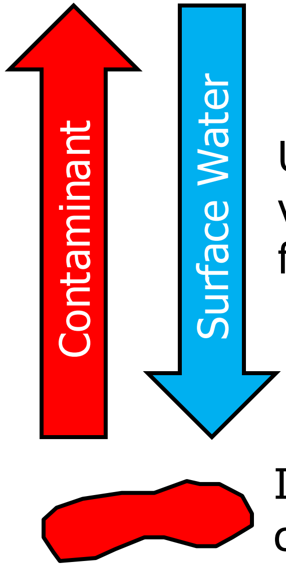
Source: Jeffrey Hale, Kleinfelder (used with permission)

Low-permeability Caps

Low-permeability Cap
(e.g., bentonite clay)



- Physical Separation
- Low-permeability Impedes Fluid Flow & Migration of Contaminants

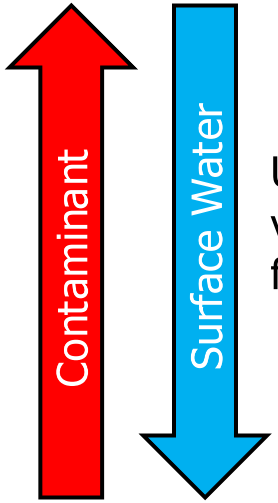


Unretarded vertical fluid flux

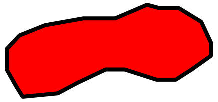
Isolated immobile contaminant material

Source: Jeffrey Hale, Kleinfelder (used with permission)

Amended Caps

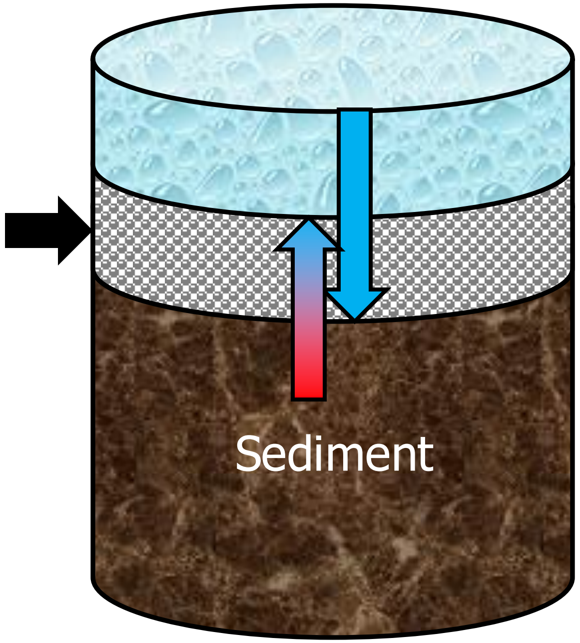


Unretarded vertical fluid flux



Isolated immobile contaminant material

Amended Cap
(e.g., sand and activated carbon)



- Physical Separation
- Permeable – Allows Upward Porewater Migration into Surface Water
- Sorptive or Reactive to Retard COC Migration

Source: Jeffrey Hale, Kleinfelder (used with permission)

Cap Design Considerations

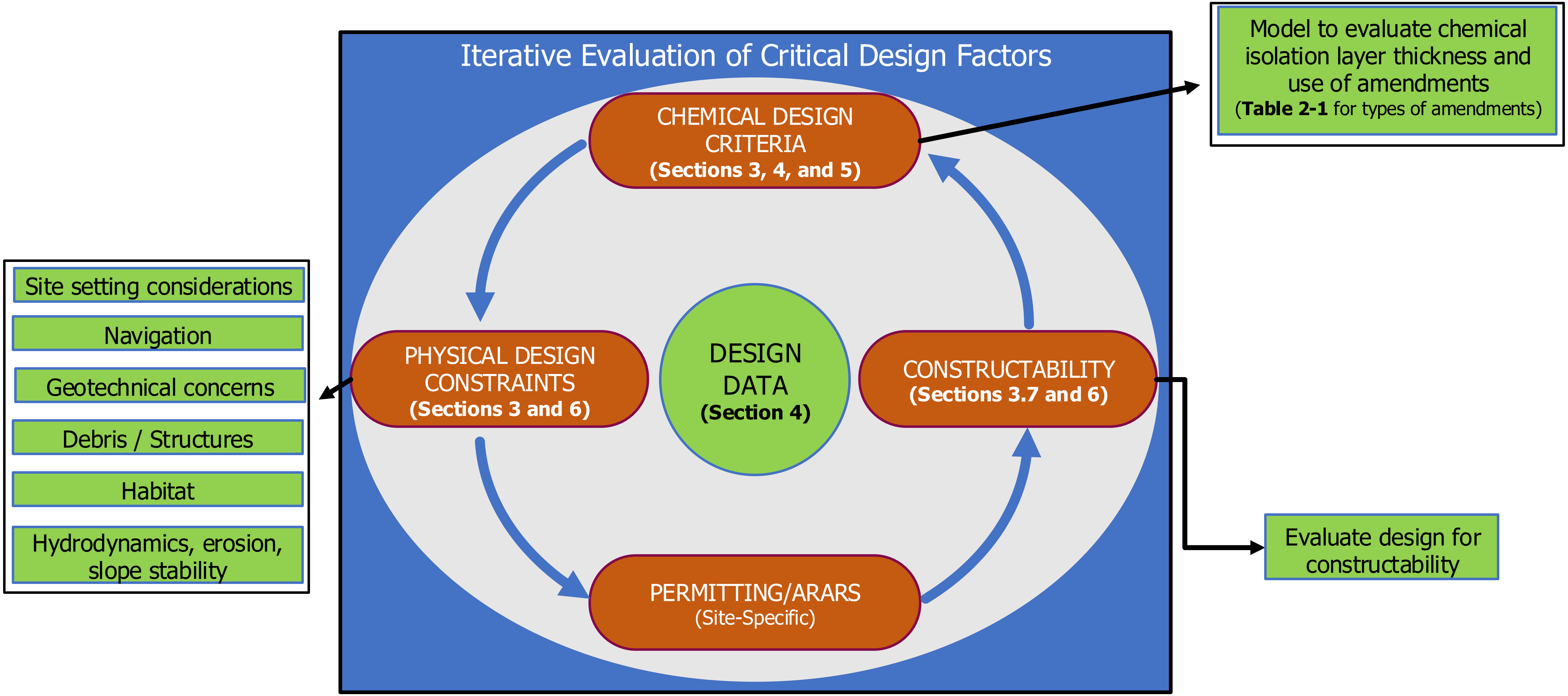


Figure 2-1: Sediment Cap Chemical Isolation Guidance (SD-1), 2023 (Modified)

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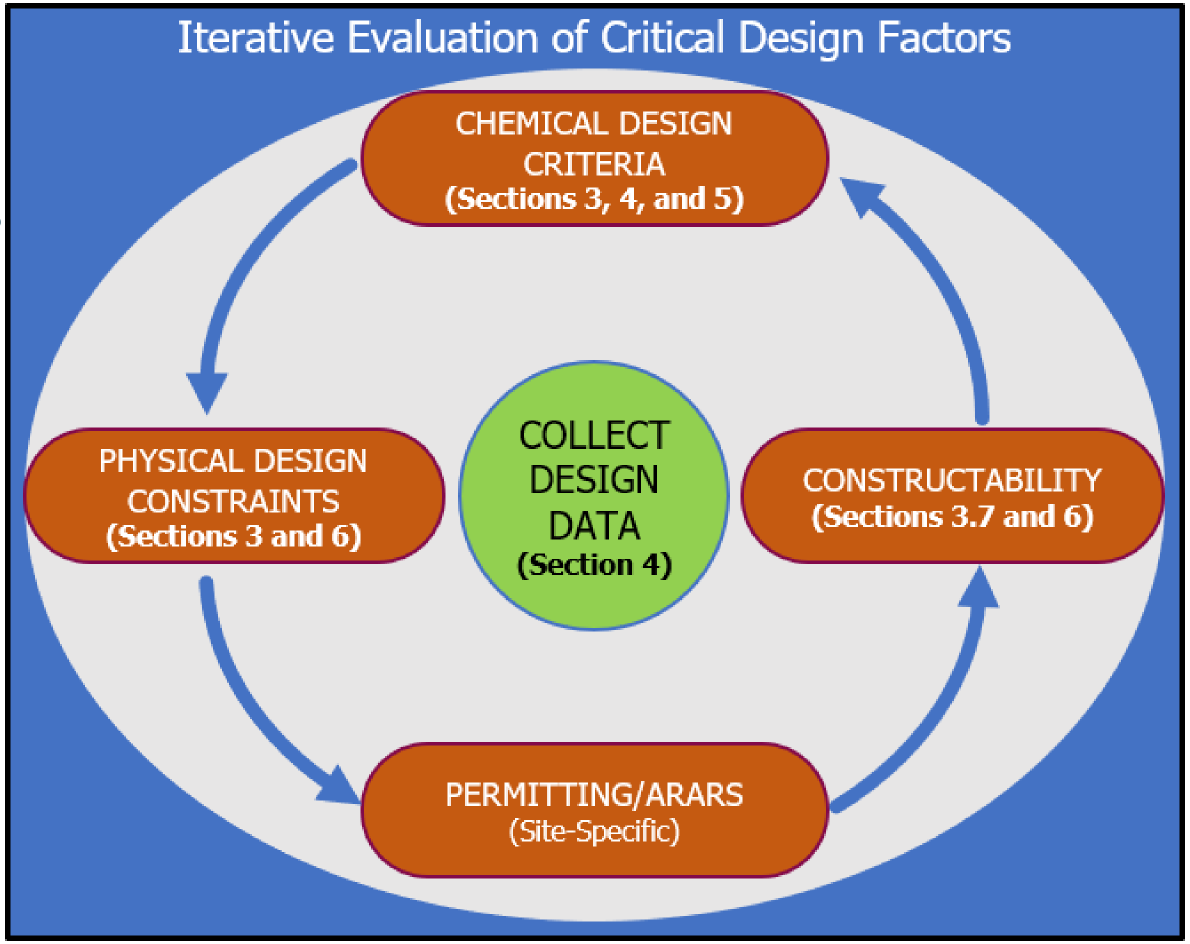


Chemical Isolation Performance Targets

Sediment remedy objectives are developed to achieve the Remedial Action Objectives (RAOs) and/or other project-specific risk reduction goals

Human Health

Reduce risks to adults and children from:

- incidental ingestion and dermal exposure
- consuming contaminated fish and shellfish

Ecological Risks

Reduce environmental toxicity to:

- benthic organisms
- higher trophic organisms

https://sd-1.itrcweb.org/3-performance-objectives-and-design-concepts/#3_1

Chemical Isolation Design Criteria

Components of chemical isolation performance targets

- Concentrations/fluxes
- Depths that the chemical isolation performance targets apply (Point of Compliance)
- Spatial scales
  - Surface weighted average concentration (SWAC) basis over specified area
  - Point-by-point basis
- Timeframe that the chemical isolation performance targets apply (Design Life)

Example Chemical Isolation Performance Targets

The porewater concentration of contaminant X shall not exceed 1 ng/L at a depth of 10 cm from the cap surface over 100 years

The flux of pollutant Y shall not exceed 1 µg/ m^2/yr at the bottom of the bioturbation zone over 100 years

The SWAC of pollutant Z shall not exceed 1 ng/L over 100 years

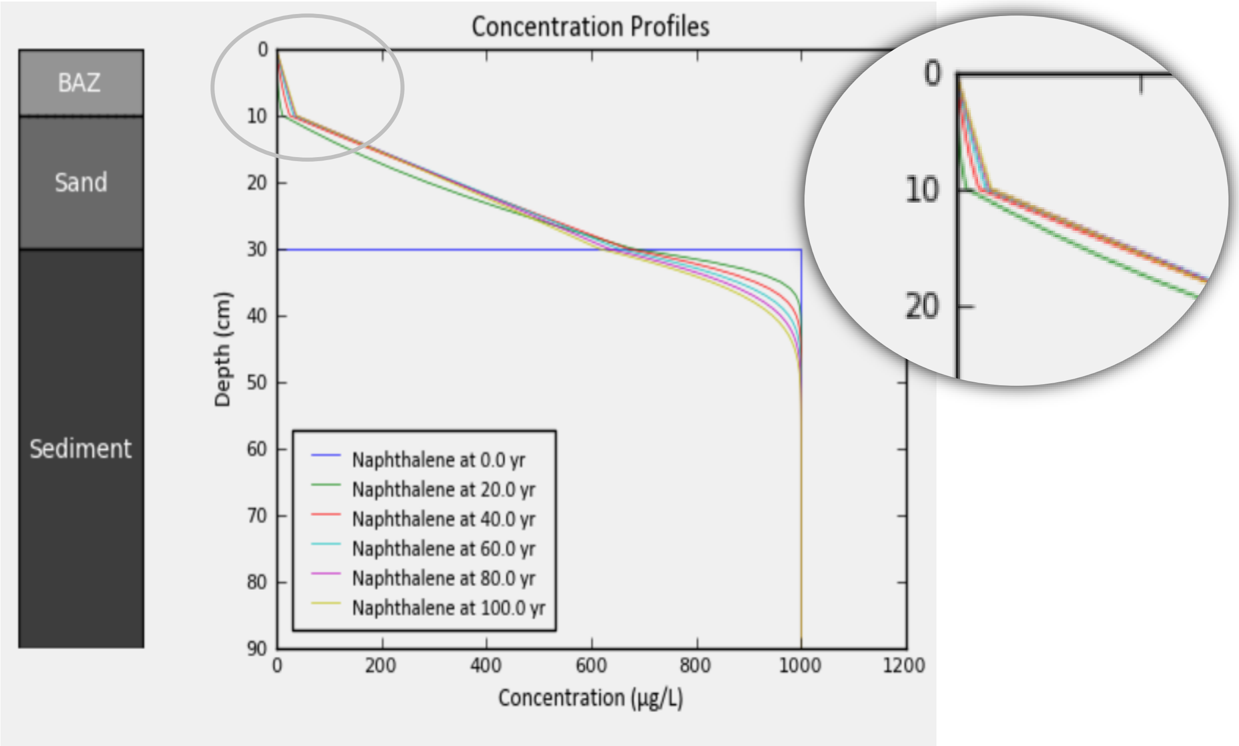
Discussion Topic

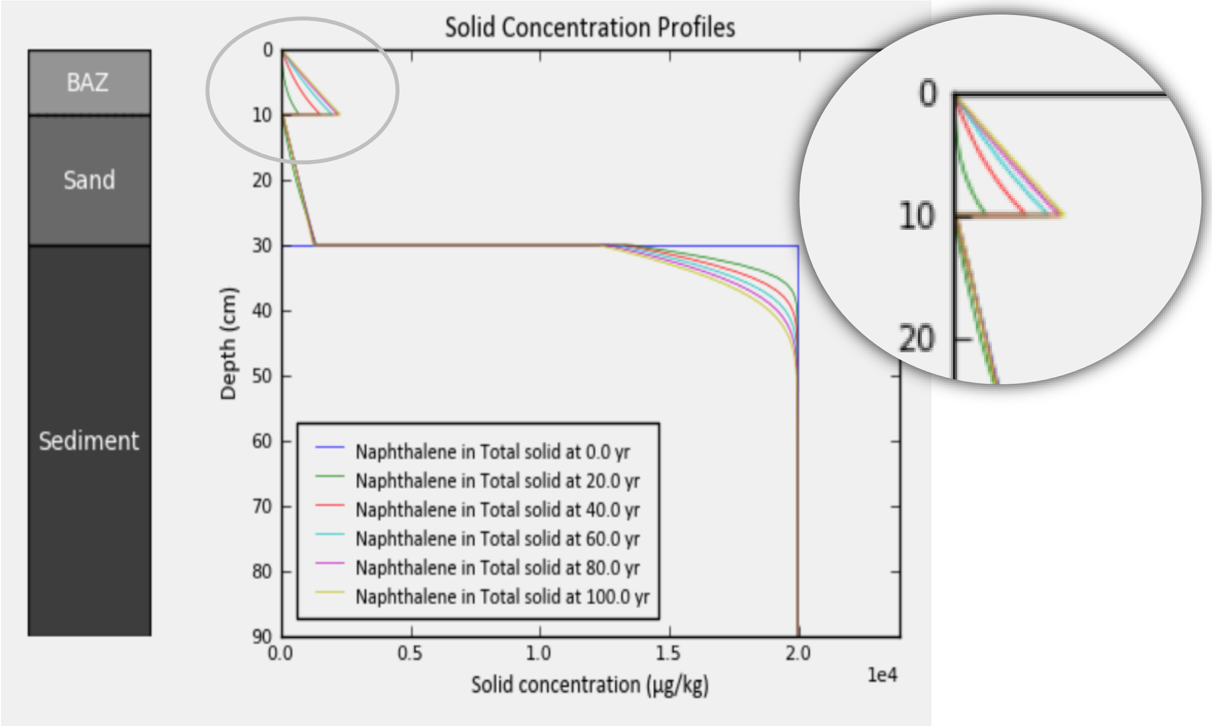
What are potential issues you encountered with establishing your remedial goals?

https://www.shiksha.com/

Performance Targets

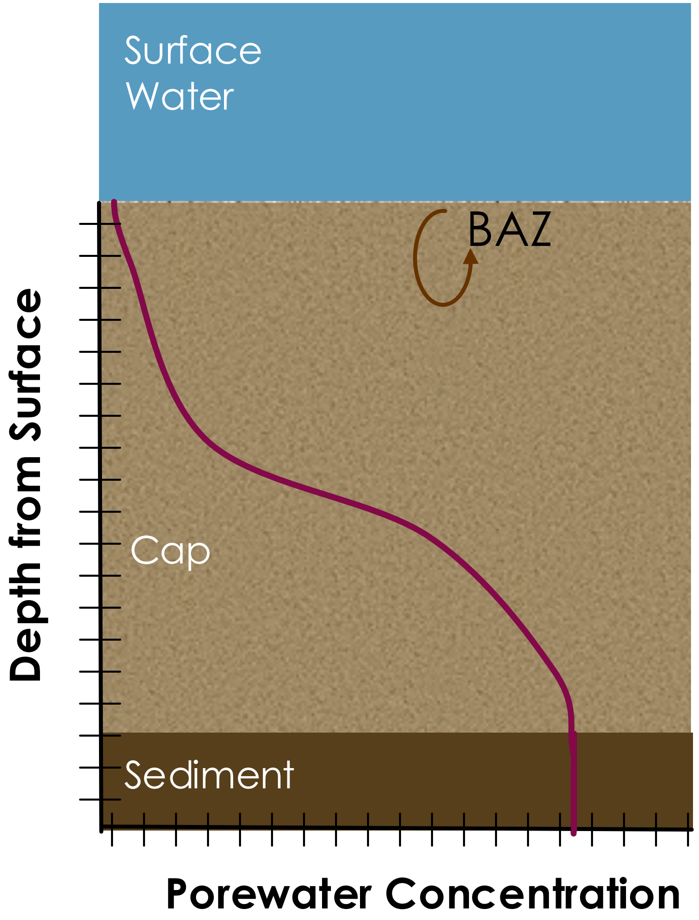
It is helpful to evaluate the performance of the cap (design and monitoring) on a porewater concentration basis

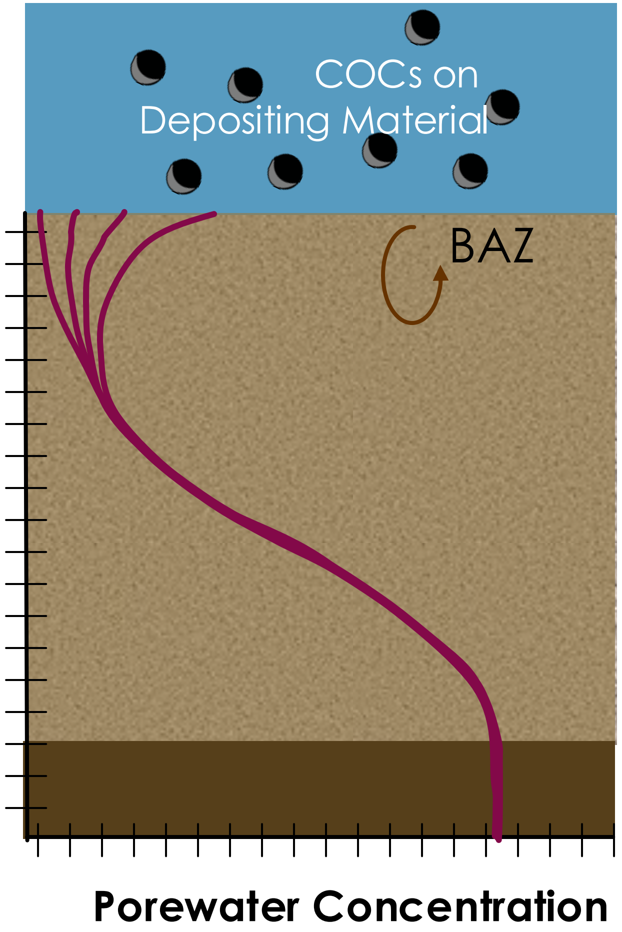




Source: CapSim 4.1 Software (used with permission)

Importance of Background Conditions



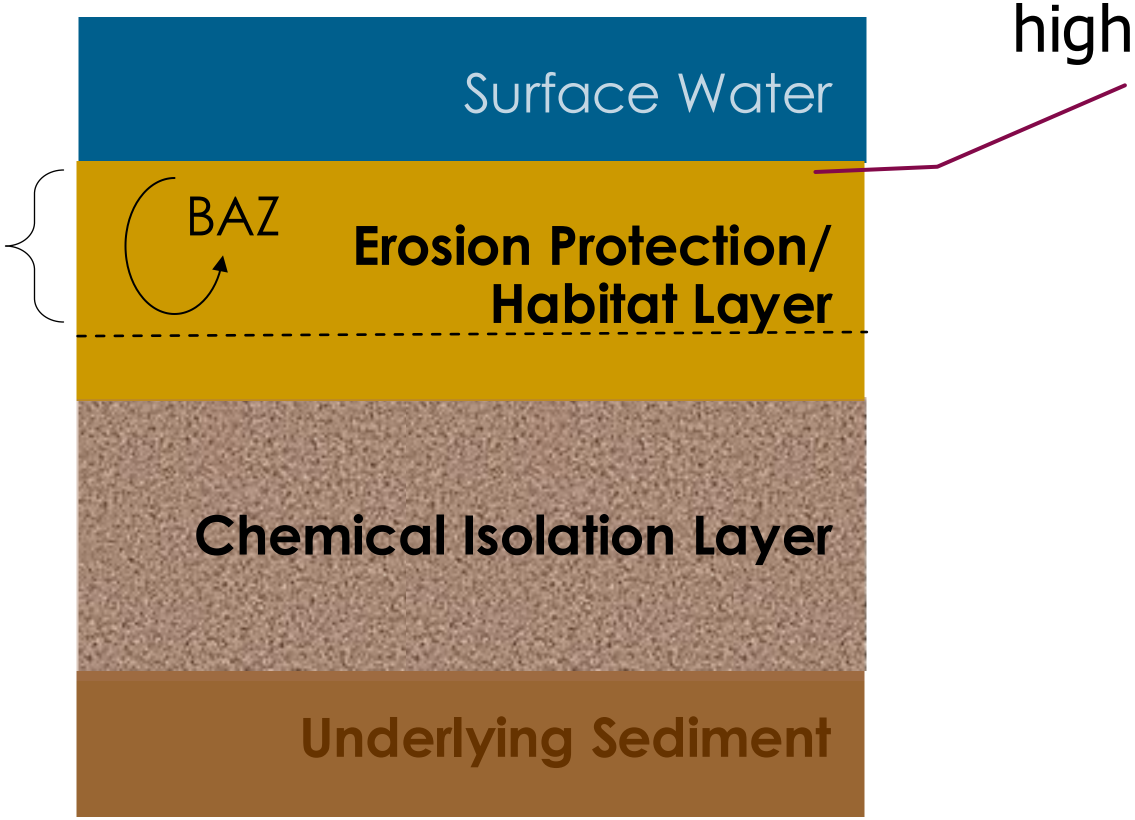


Source: Deirdre Reidy, Anchor QEA (used with permission)

Point of Compliance Directly Related to RGs

RGs established to be protective of **ambient water quality or fish** at higher trophic levels

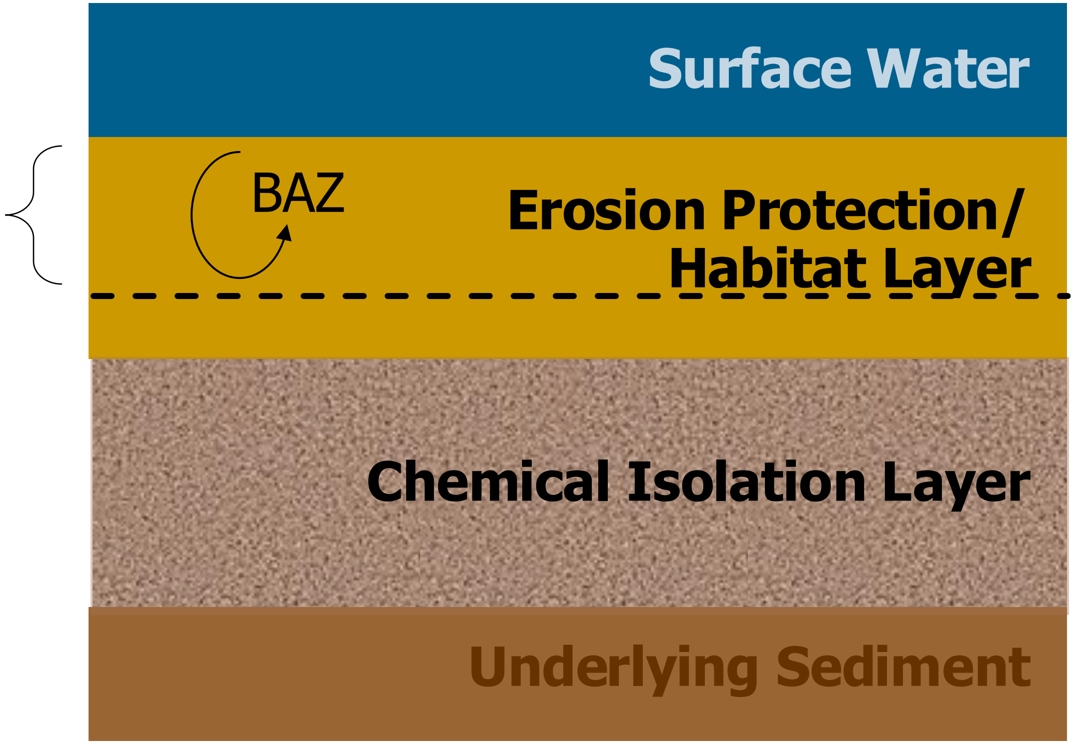
RGs established to be protective of **benthic organisms**



Source: Modified from Arcadis U.S., Inc. (used with permission)

Design Evaluation Depth

Point of Compliance/
Design Evaluation Depth



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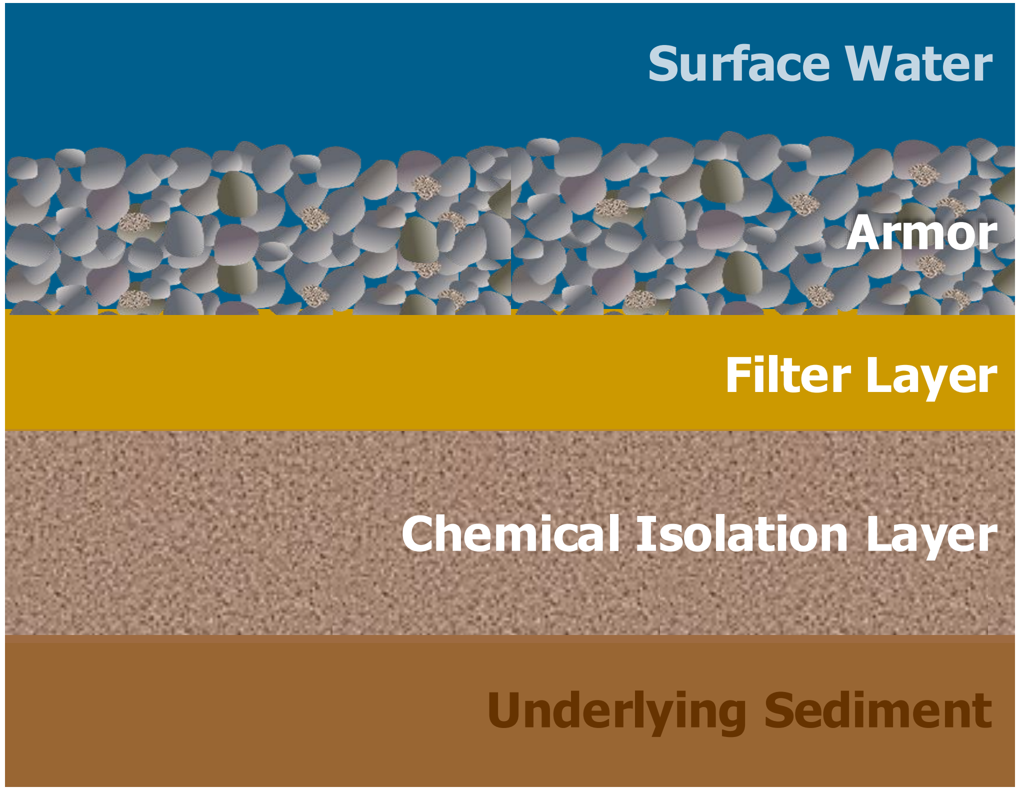
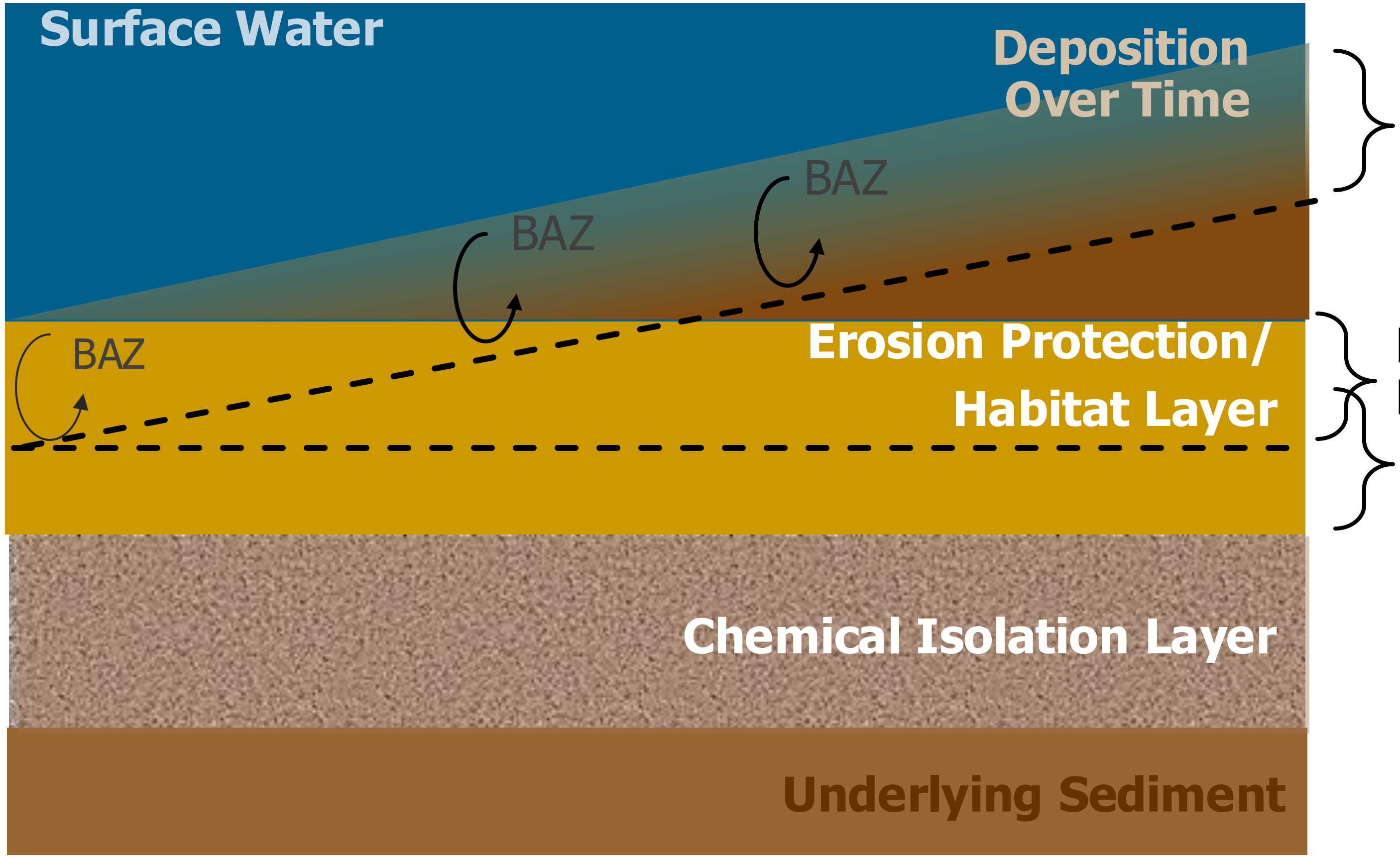
Design Evaluation Depth – Large Armor Stone Scenario



More appropriate to evaluate cap effectiveness below the armor stone

Source: Modified from Arcadis U.S., Inc. (used with permission)

Design Evaluation Depth – Deposition Scenario

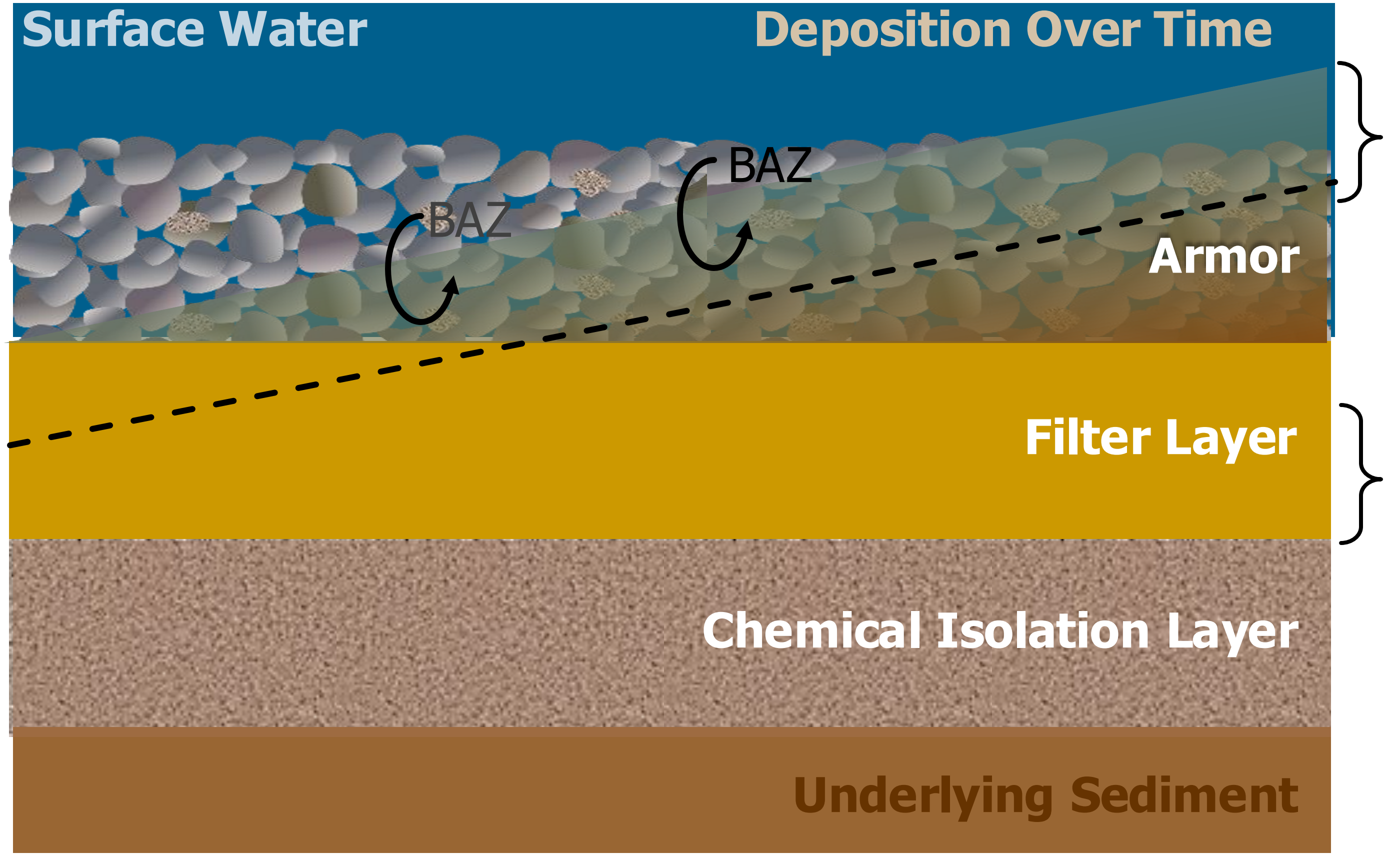


Point of Compliance/
Design Evaluation Depth A
Considers additional attenuation provided by deposition

Point of Compliance/
Design Evaluation Depth
Design
Evaluation Depth B
Avoids influence of depositing material

Source: Modified from Arcadis U.S., Inc. (used with permission)

Design Evaluation Depth – Large Armor Stone Scenario & Deposition



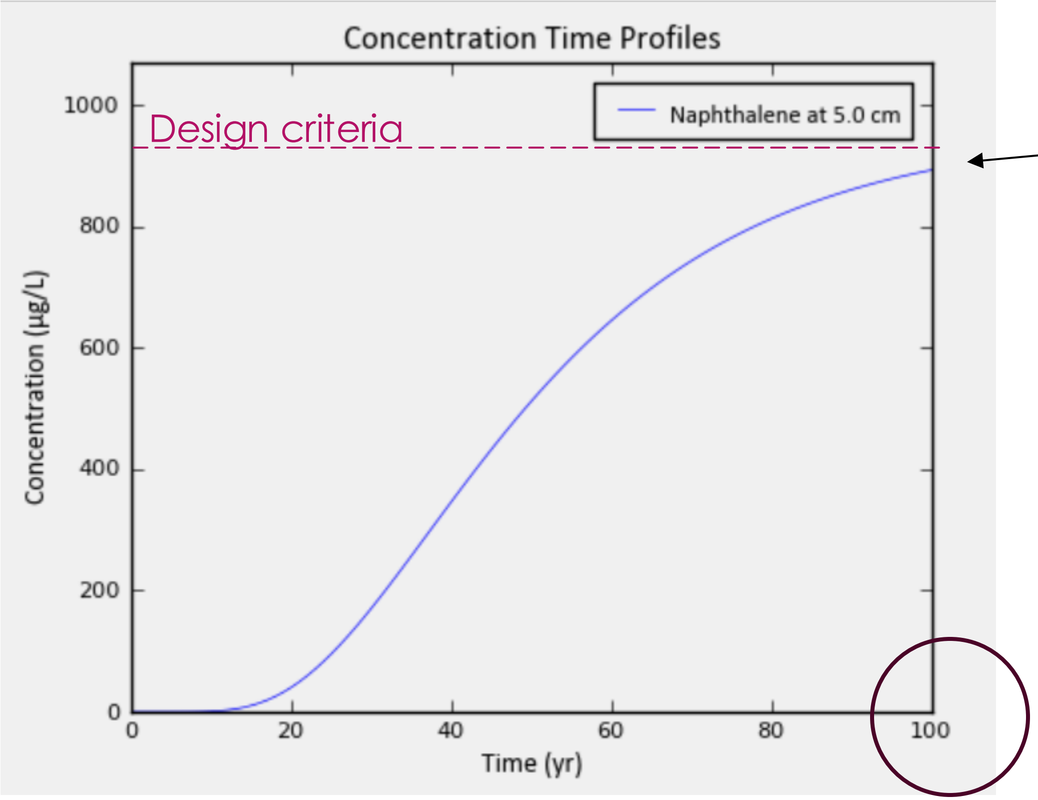
Point of Compliance/
Design Evaluation Depth (A)
Considers additional attenuation provided by infilling deposition

Design
Evaluation Depth (B)
Avoids influence of depositing material

Source: Modified from Arcadis U.S., Inc. (used with permission)

Design Life

The minimum period over which the cap is designed to meet the design criteria



Note, **performance life** of cap expected to be longer due to conservativism in the design process

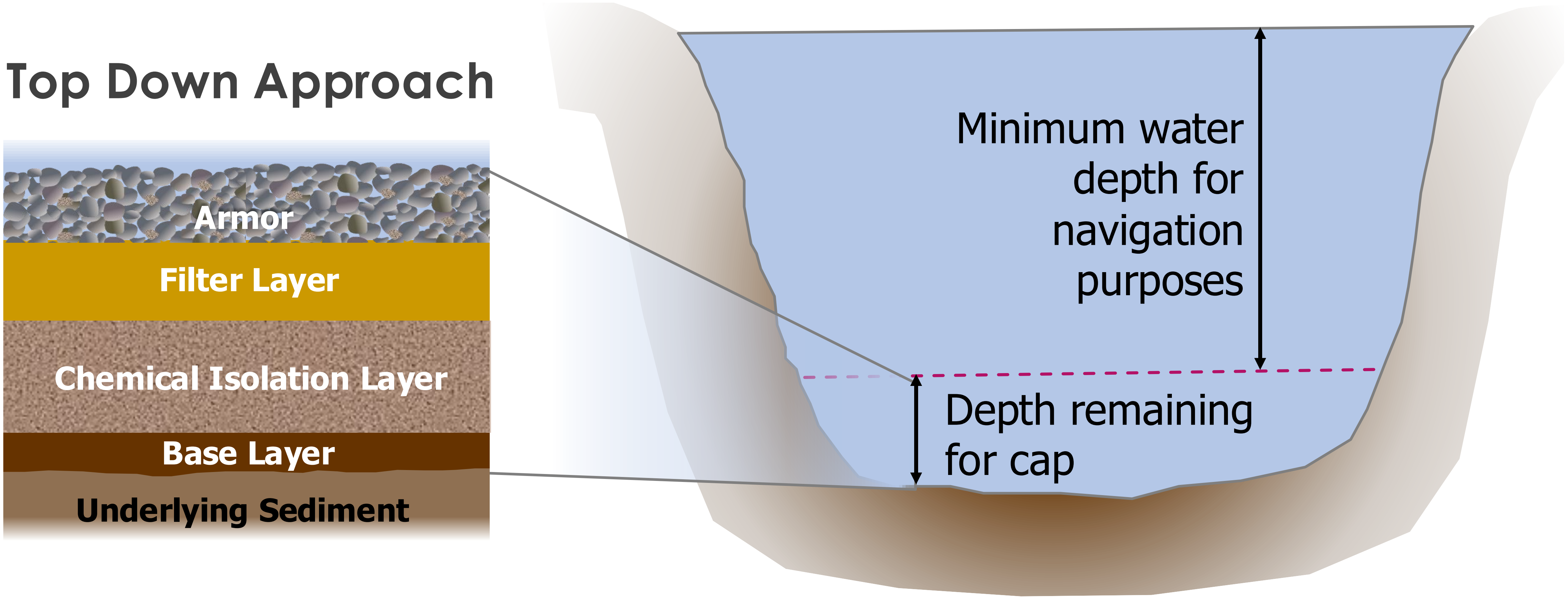
Typical design life = 100 years

Source: CapSim 4.1 Software (used with permission)

Cap Design – Conservativism

- Design criteria (e.g., conservativism built into risk assessments)
- Input parameter values used in model evaluations
  - Inputs with the largest influence on model results:
    - Groundwater seepage rates
    - Contaminant concentrations in porewater
    - Partitioning characteristics
    - Deposition rates
- Material specifications during design
  - E.g., minimum thickness and amendment dose to meet criteria
- Material placement during construction
  - E.g., the contractor material placement quantities may exceed the design specifications

Constraints on Chemical Isolation Layer Thickness



Source: Deirdre Reidy, Anchor QEA (used with permission)

Cap Amendments

- Cap amendments are often required to meet performance targets
- Amendment types depend on the CoCs
  - A combination of amendments may be needed
  - Can be added as discrete layers, mixed with other cap materials, or direct addition to sediment
- Data collection is recommended to support modeling for cap design
- Benthic community impacts should be considered

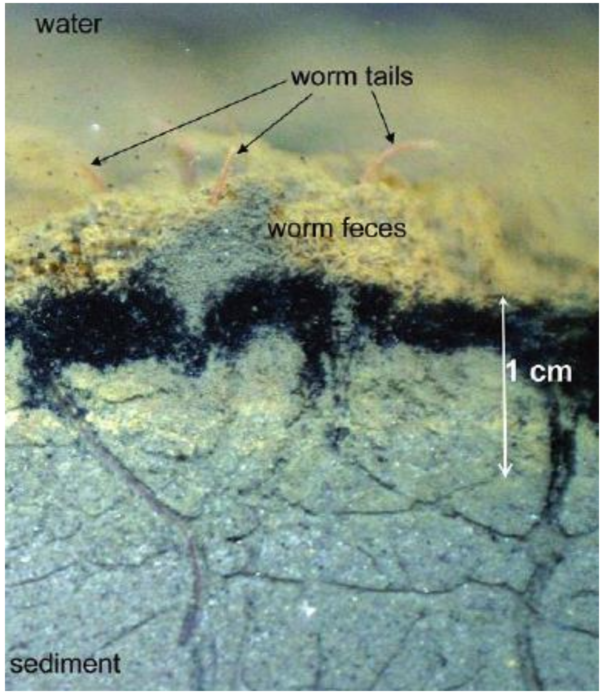
Site Characteristics for Chemical Isolation Design

Understand spatial differences in site characteristics that affect CIL design

- Chemical concentrations and contaminant distribution
  - Includes geochemistry, which may be important for some contaminants of concern
- Presence of NAPL
- Seepage rates
- Deposition/erosion potential

Benthic community structure and bioturbation

- Bioturbation depths of 5-10 cm are common, but site-specific data may be needed from benthic surveys to inform models
- May inform point of compliance



Sun and Ghosh 2007

Performance Objectives & Design Concepts – Wrap Up

Understanding what we are designing the cap to protect

Defining design criteria – the "what", "where" and "how long"

Design constraints

e.g., surface elevation requirements

Site characteristics for chemical isolation design

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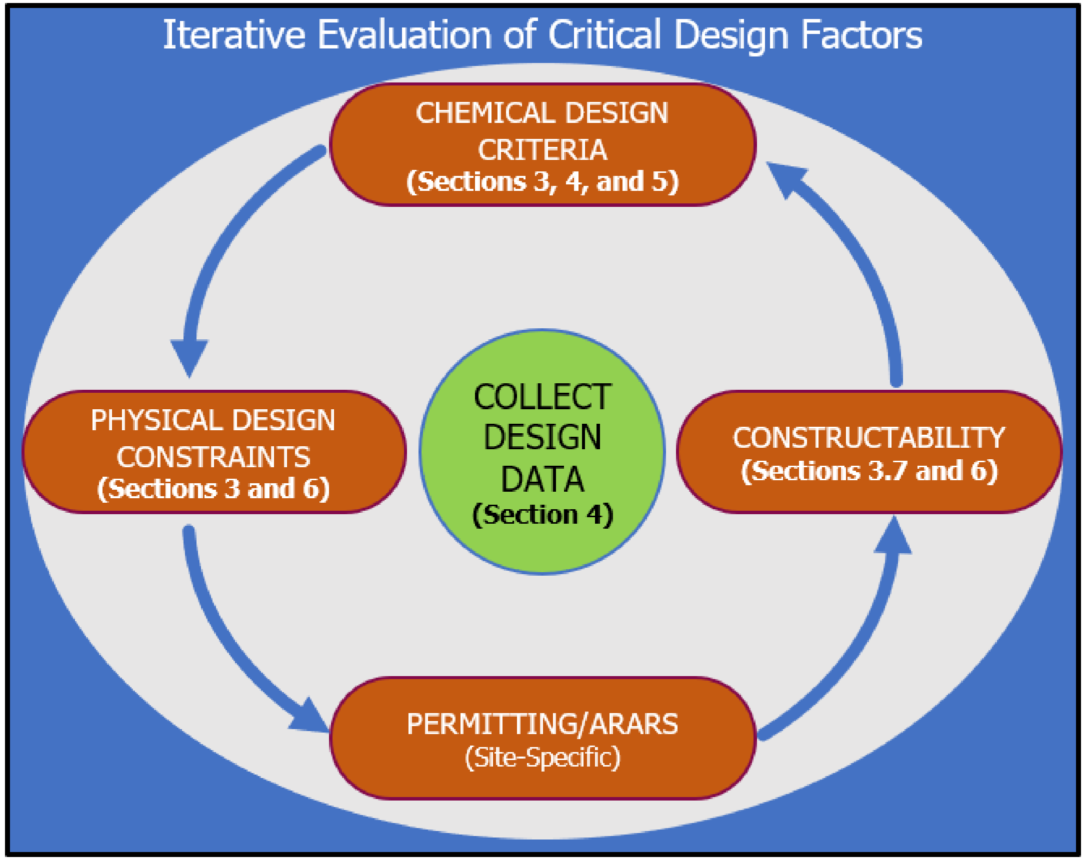
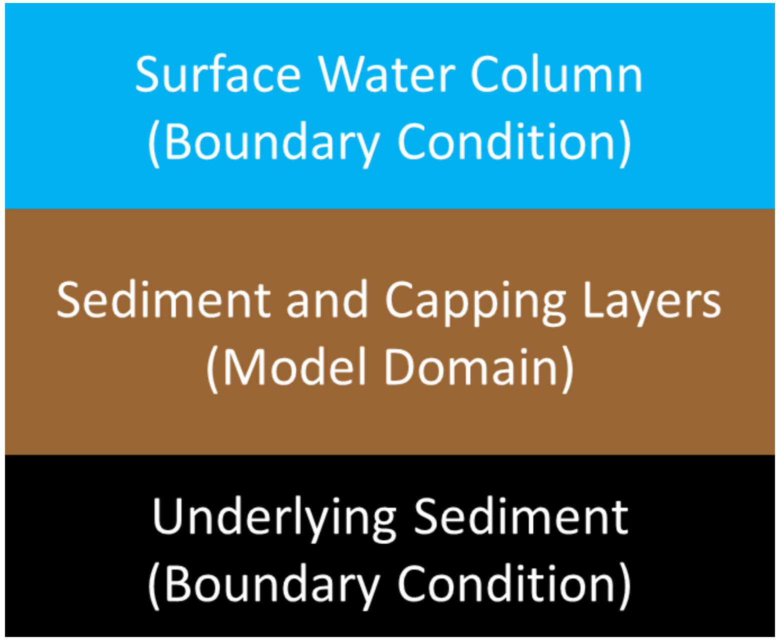


Chemical Isolation Layer Modeling

- Purpose of Modeling
- Why a cap model?
- What models are available?
- What are important parameters?
- Sensitivity and Uncertainty



Purpose of Cap Modeling

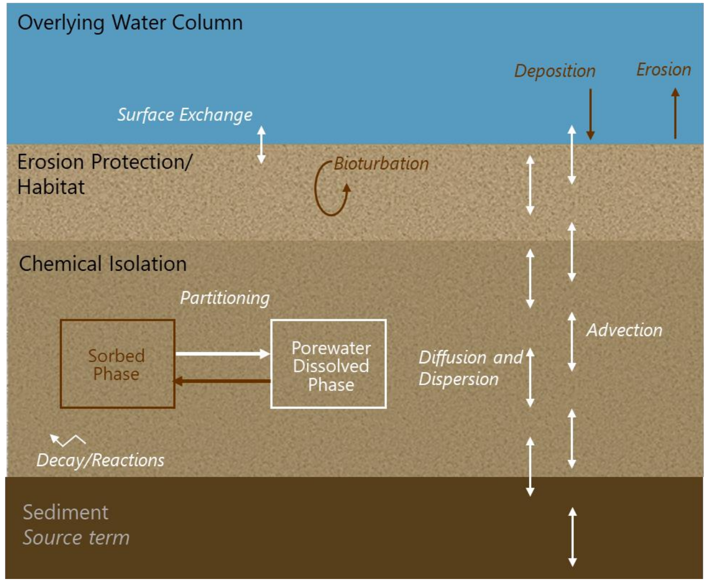
Predict performance of a cap into the future for purposes of evaluating designs

- How thick of a CIL?
- Composition of the CIL?
- Sensitivity to key model uncertainties?
- Compare to monitoring data after construction?

Source: Danny Reible, Anacostia demonstration project (used with permission)

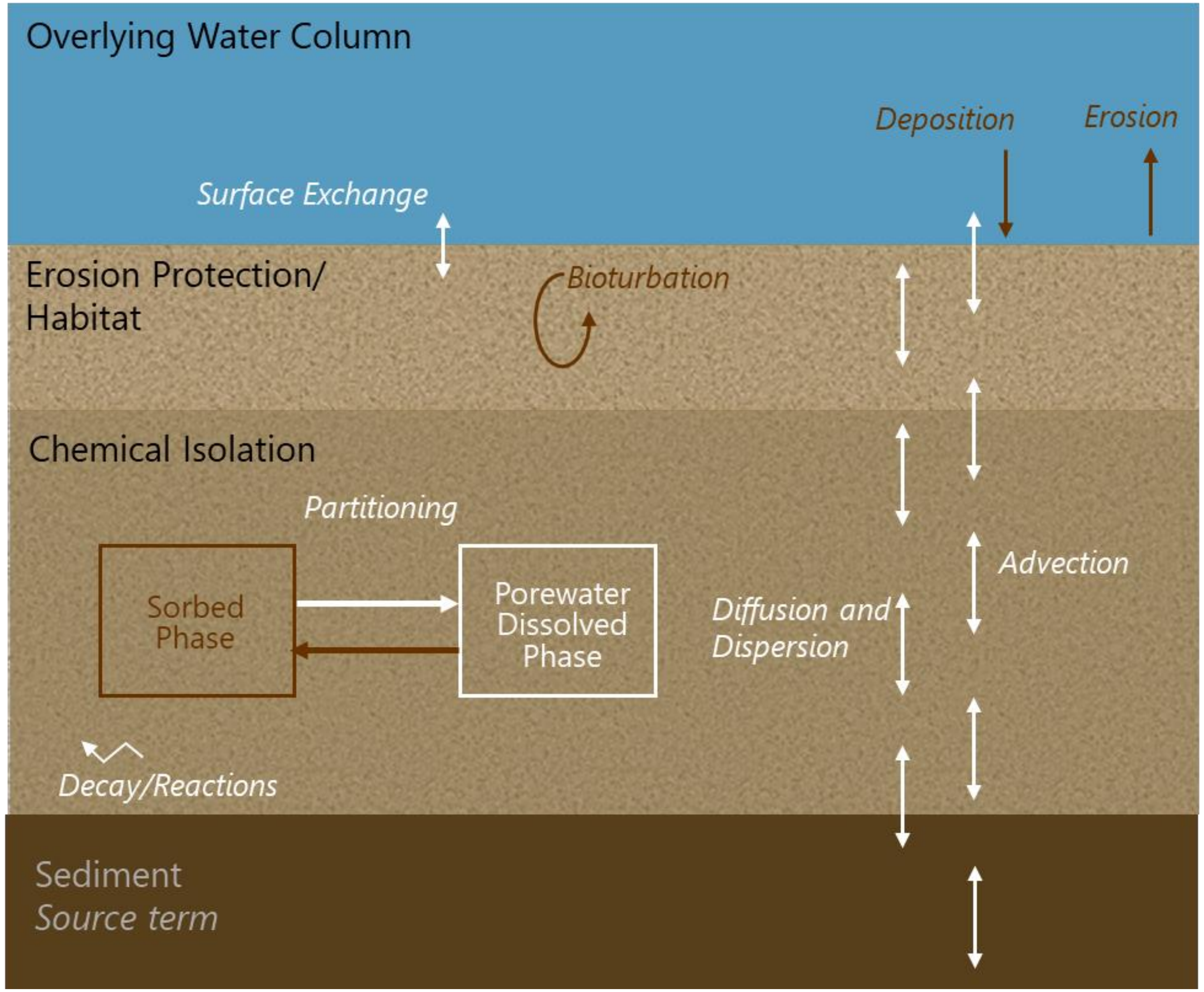
Why Cap Models?

- Surface water quality and hydrodynamic models describe water column processes and interactions with the sediment boundary
- Groundwater models describe processes in adjacent aquifers
- Neither address the unique processes that occur in the upper 10-100 cm of the sediment



What Are Those Processes in Surficial Sediments?

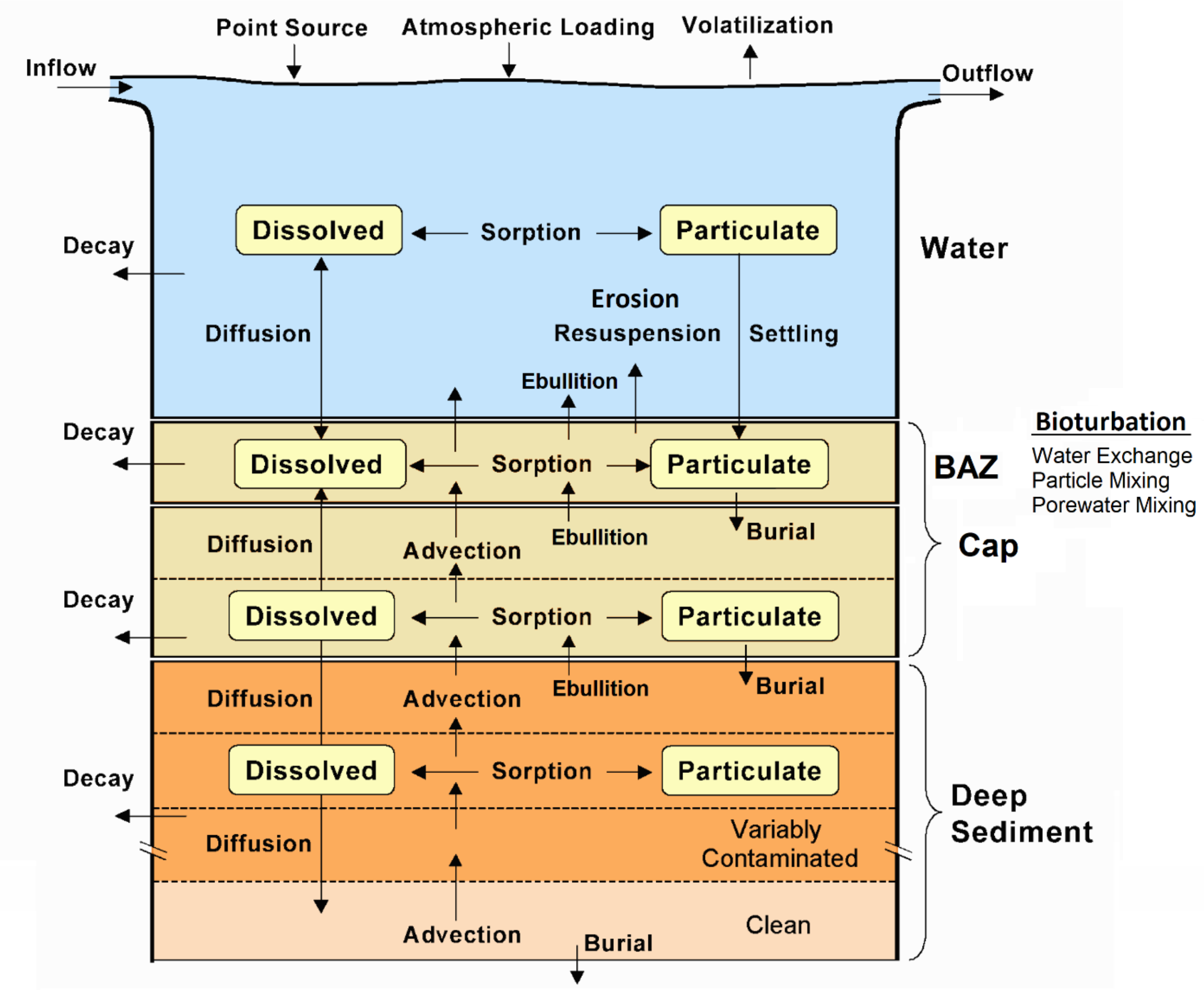
- Erosion protection to ensure cap stability
- Mobile contaminants in porewater
- Redox changes with depth
- Bioturbation by near surface benthic organisms
- Benthic boundary layer
- Hyporheic exchange



What Tools Are Available – Recovery (USACE ERDC ERDC/EL SR-D-00-1)

- Models a mixed sediment layer and deeper sediment layers
- Dissolved & particulate contaminants

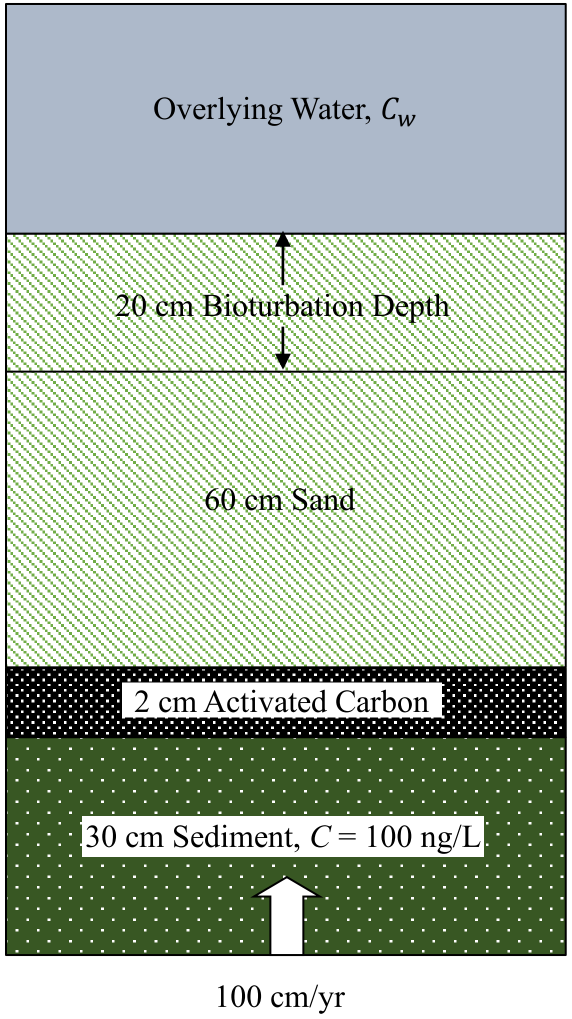
  Migration, Resuspension, Burial
- Simple overlying water conditions



Source: Modified from Ruiz et al., 2007 (used with permission)

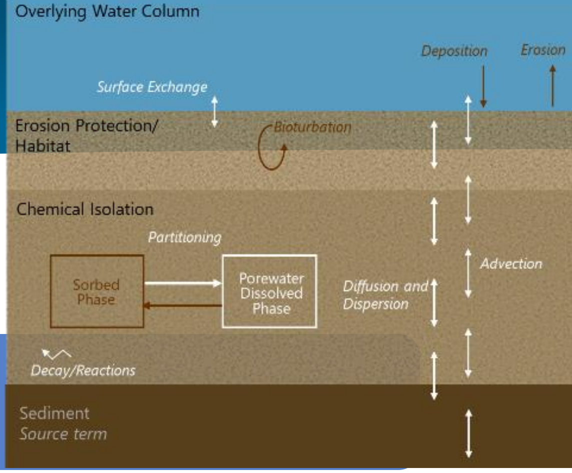
What Tools Are Available – CapSim (Texas Tech University)

- Model sediment as layers of different depths and conditions
- Graphical User Interface
- Explicitly models bioturbation, hyporheic exchange
- Capable of modelling sorption kinetics or equilibrium
- Capable of modeling multiple reactions (contaminant as well as biogeochemical conditions)
- Commercial cap materials available
- Tools for estimating a variety of model parameters



www.depts.ttu.edu/ceweb/research/reiblesgroup/capsim.php

Key Model Inputs That **ARE** Important



Contaminant of Concern (CoC) & concentration

- Chosen by significance, importance to design, spatial distribution and mobility
- Porewater concentration modelled, but input could be sediment concentration

Sorption coefficients of CoC in CIL

Groundwater seepage rates

Sediment deposition rates

Depth within cap for evaluating design (may be point of compliance)

https://sd-1.itrcweb.org/

Source: Modified from Anchor QEA (2019) (used with permission)

Model Inputs That **MAY BE** Important

Intensity of sediment-water exchange

Especially if design evaluation depth near sediment - water interface

Kinetics of sorption onto strongly sorbing phases

e.g., granular activated carbon

Reactivity of non-conservative contaminants

Often assumed negligible due to slow rate and uncertainty but likely important over cap design life

Interpreting Model Results

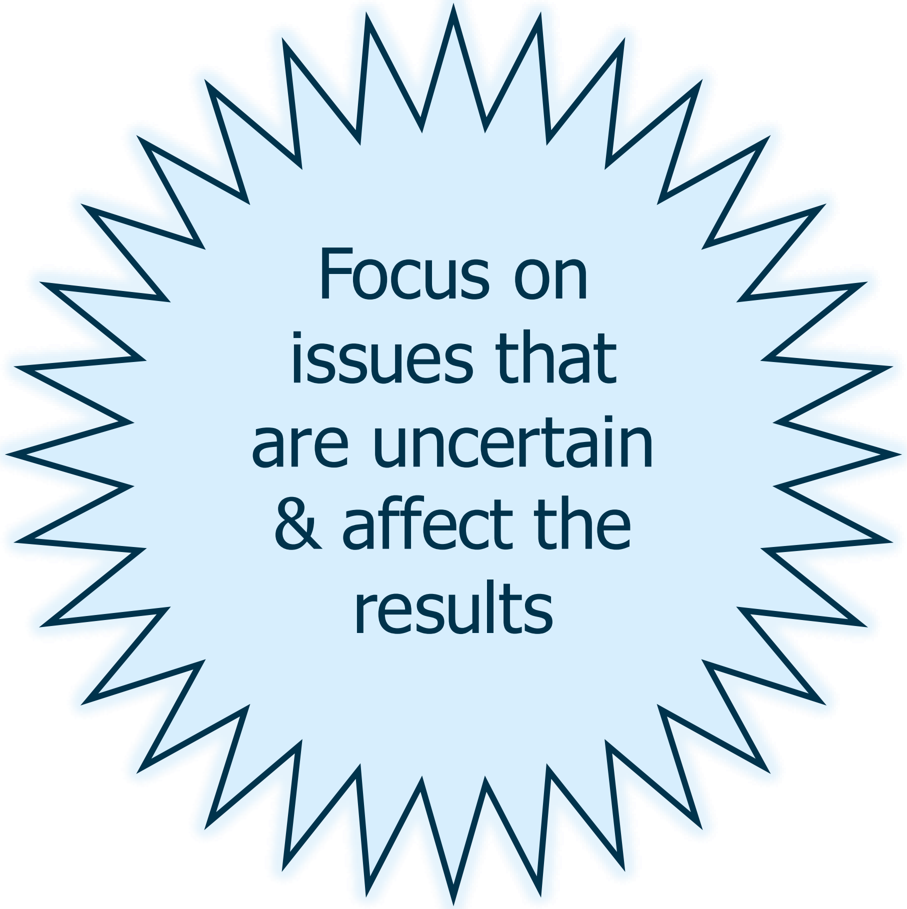
REMINDER: Capping is an areal remedy!

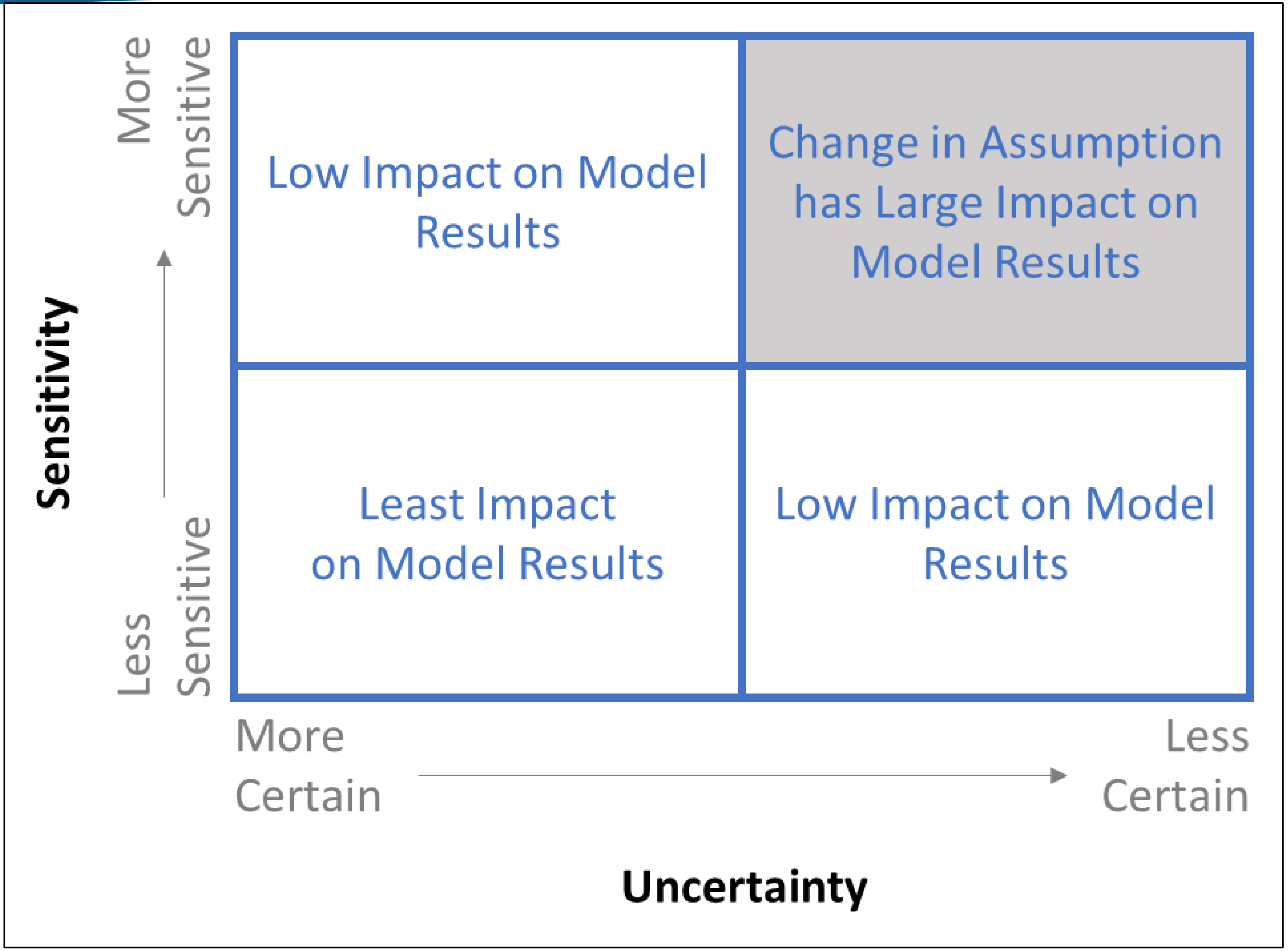
Be careful of interpreting concentrations at cap-water interface

Concentrations at cap-water interface generally controlled by water column dynamics, not CIL

Flux at cap-water interface is controlled by cap design and is useful

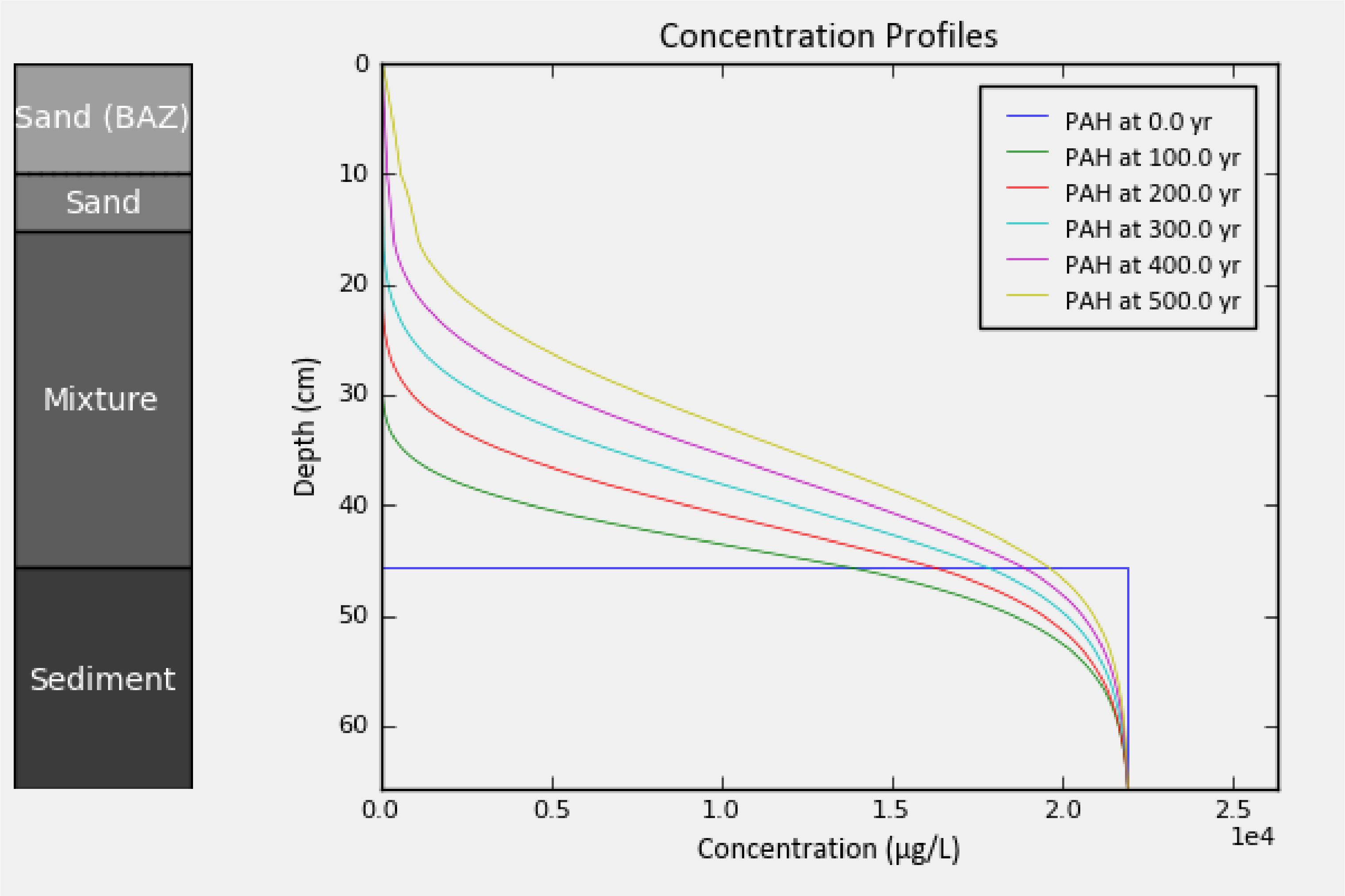
Model Uncertainty and Sensitivity





Source: Deirdre Reidy, Anchor QEA (used with permission)

Model Output



Source: CapSim 4.1 Software (used with permission)

Questions

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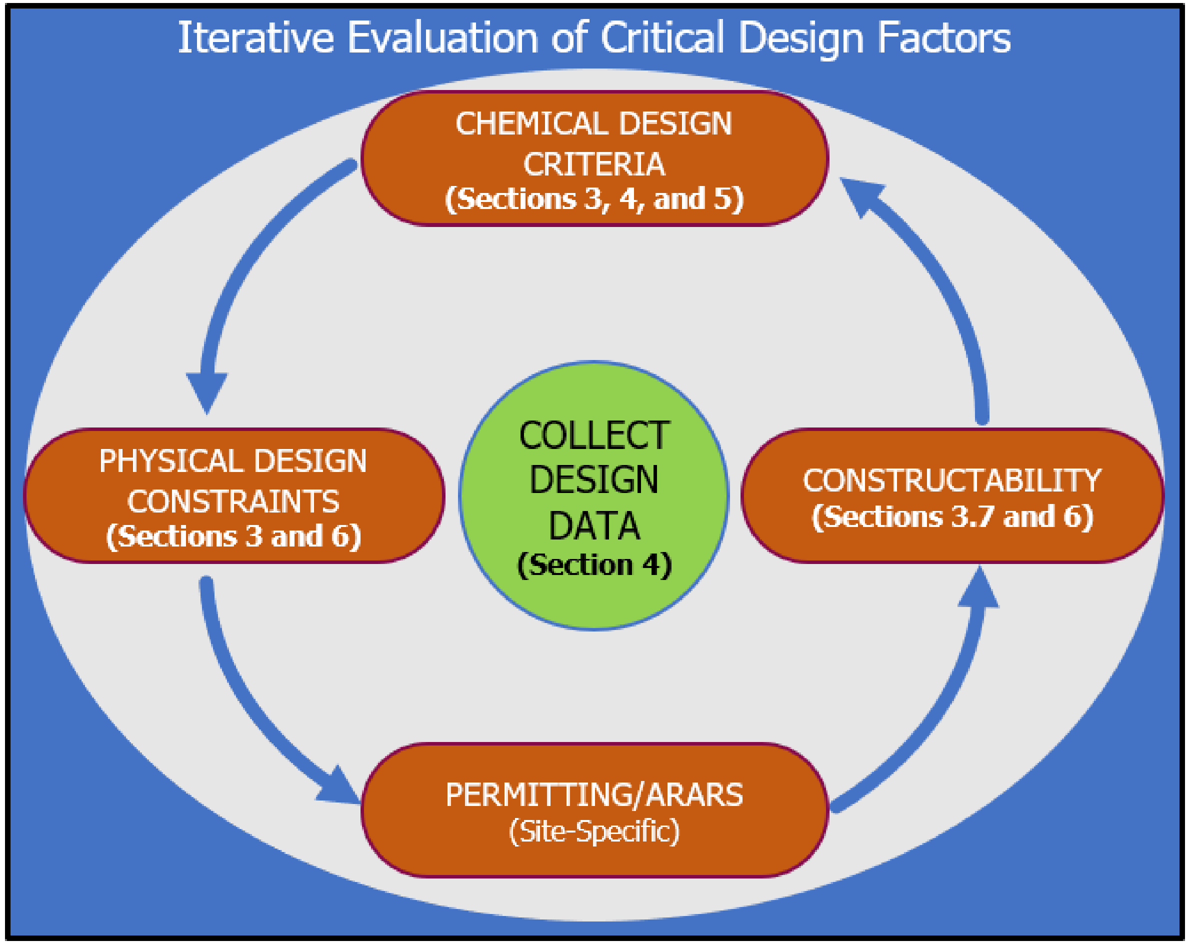
Chemical Isolation Layer Modeling (Section 5)

Q&A Break

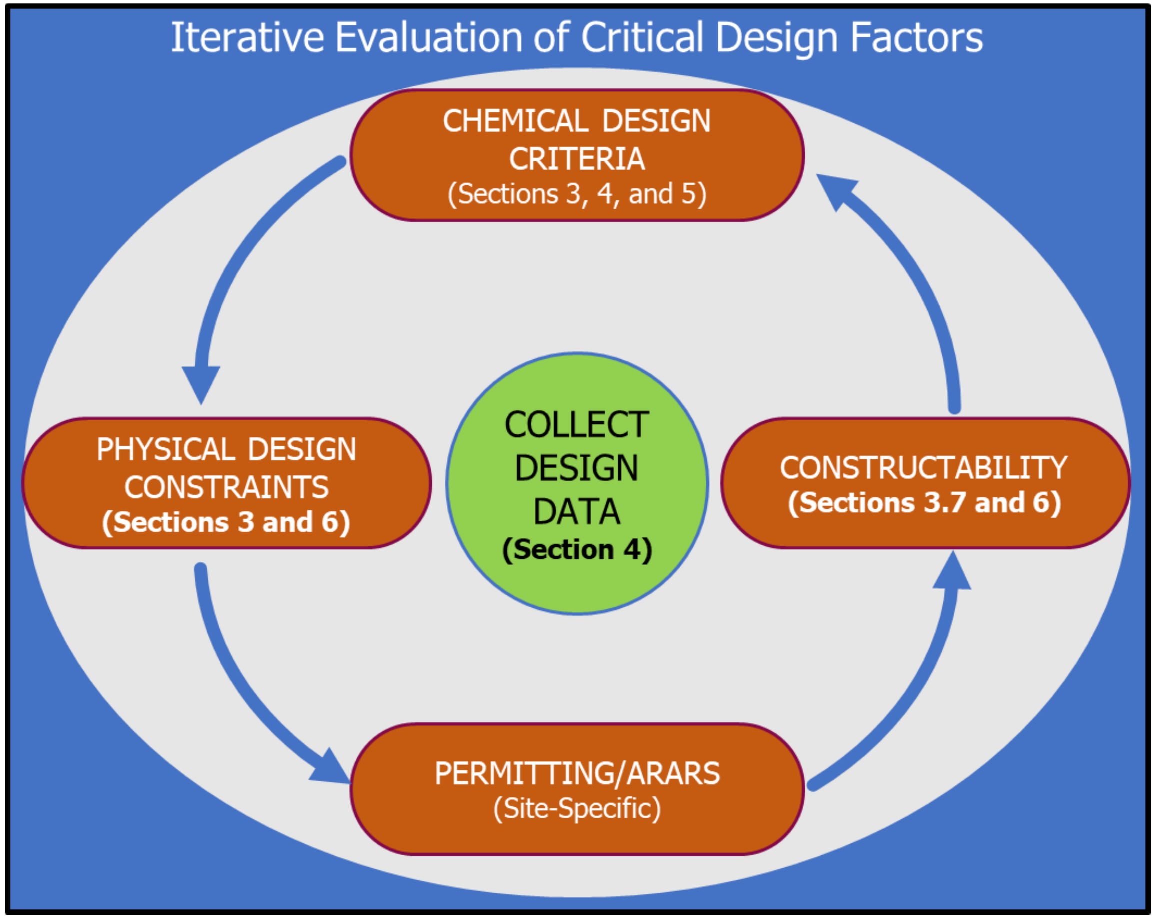
Chemical Isolation Construction Considerations (Section 6)

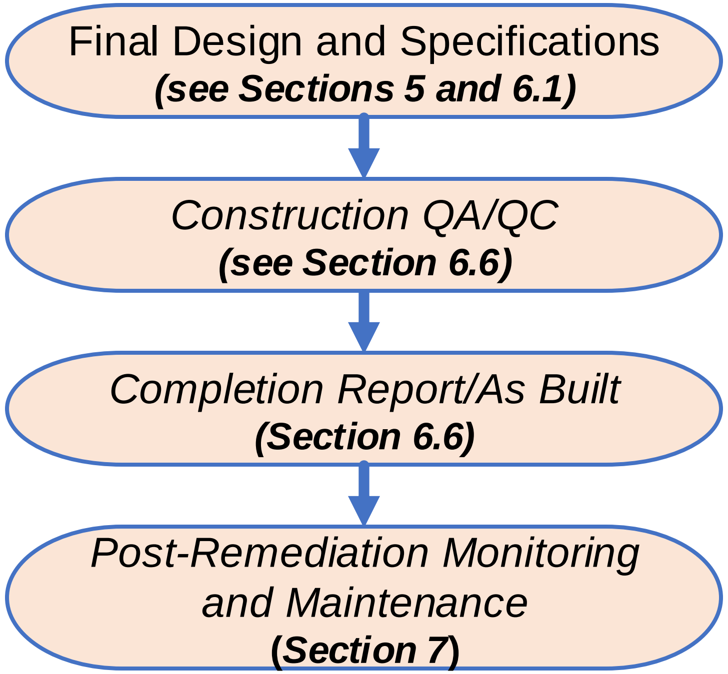
Monitoring & Maintenance Objectives and Approaches (Section 7)

Q&A Break



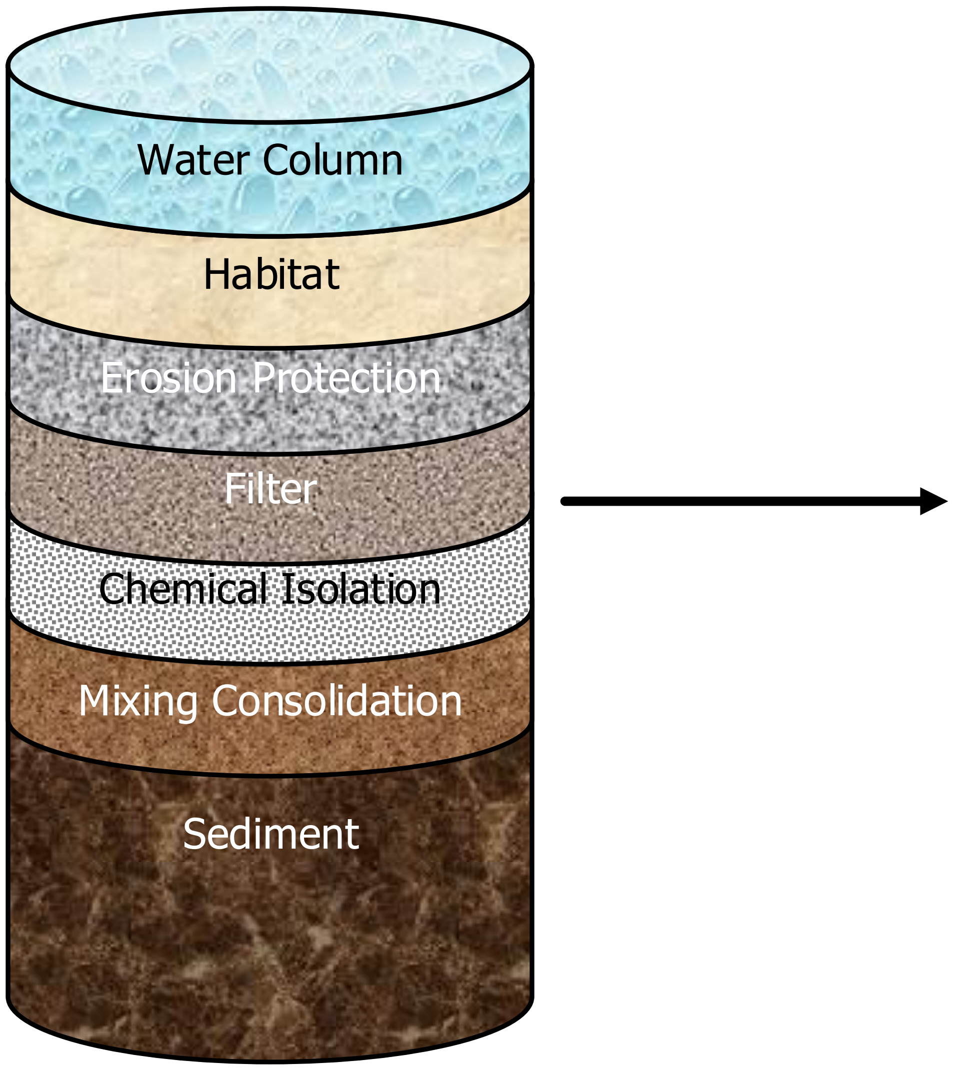
Construction Considerations – Overview





Source: Modified from Figure 2-1 of Guidance Document

Construction Considerations

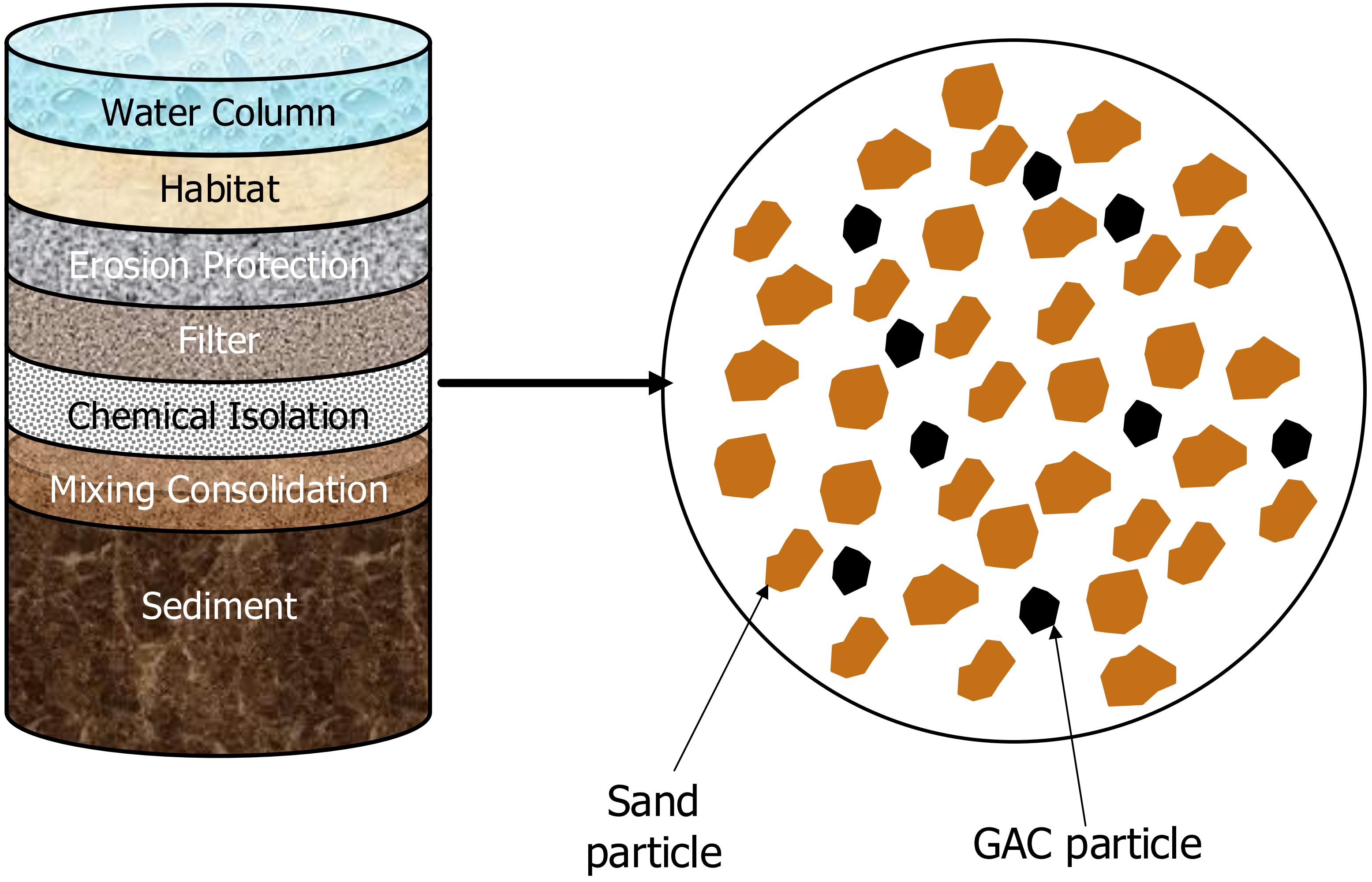


Material Placement

- Materials Spread
- Riverward to Shoreward
- Upstream to Downstream

Mixing Consolidation Layer

Construction Considerations – Cap Amendment



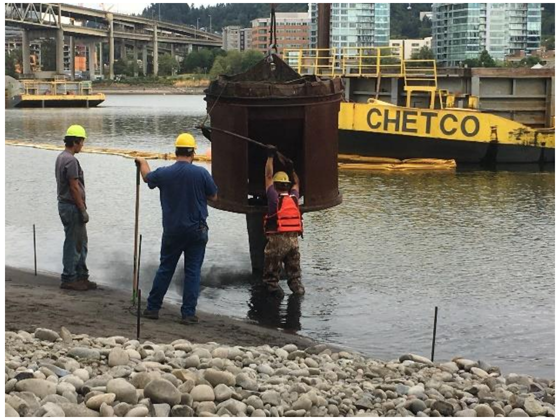
Dosing and Mixing Considerations:

- Dose Requirements
- Well-mixed Distribution
- Amendment Integrity

Source: Jeffrey Hale, Kleinfelder (used with permission)

Placement Methods: Conventional Broadcast

Concrete Bucket



Advantages:
Low-cost method
Shoreline or barge based

Disadvantages:
Crew access
Lift control

Excavator

Advantages:
Commonly available
Shoreline or barge based

Disadvantages:
Lift control
Low production rate

Clamshell

Advantages:
Commonly available marine equipment
High production rates

Disadvantages:
Lift control challenging
Overhead obstructions

Conveyor Delivery

Advantages:
High production rate
Available in most cities

Disadvantages:
Material delivery access needed

Sources: Oregon Department of Environmental Quality (used with permission); Maul Foster & Alongi, Inc. (used with permission)

Placement Methods: Proprietary

Spreader with Hydraulic Delivery

Advantages:
Hydraulic delivery, dry spreading
High production rate

Disadvantages:
Hard to reach tight areas
Water column effects

Hydraulic Placement and Delivery

Advantages:
Hydraulic delivery and spreading
High production rate

Disadvantages:
Hard to reach tight areas
Water column effects

Sources: J.F. Brennan Company, Inc. (used with permission); Sevenson Environmental Services Inc. (used with permission)

Placement Related Issues – Key Considerations

Placement Accuracy and Tracking

- Operator experience is a major factor
- Bucket type placement tend toward less uniform
  (smooth lipped excavator, clamshell, others)
- High accuracy achieved with conveyor delivery and certain proprietary systems
- Essential QC measures include <u>where</u> lifts are placed, <u>what quantity</u> is placed, and the <u>uniformity</u> of material placement
- Best practices include RTK-GPS, routine bathymetric survey, and direct measurement

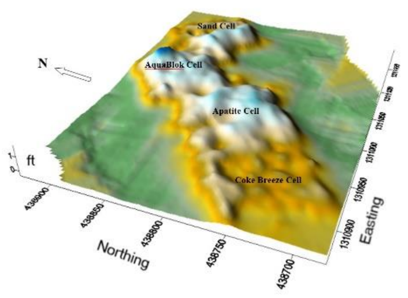
Material Loss During Placement

- Material loss during placement is a function of three factors: (a) material properties, (b) equipment accuracy, and (c) the placement conditions
- Managing material loss includes: realistic expectations; evaluating water column dynamics; and continual operator optimization of placement technique
- Fine grain and low bulk density materials are especially challenging due to particle drift
- Reactive materials may separate from sand during placement. Consider wetting, overdosing, or other practical means to deliver target dose

CIL Placement Quality Assurance Methods

- Weight of evidence approach, as no one method provides sufficient verifiable data
- Verify important design & construction specifications, including thickness, delivery of amendment material, and tolerances.

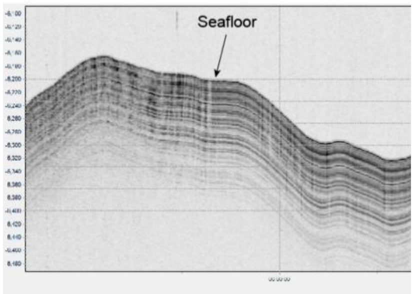
Bathymetric Survey



Advantages:
Area-wide Analysis
Commonly Available

Disadvantages:
No Settling or Mixing Layer
No Amendment Info

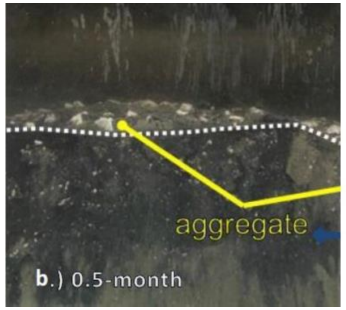
Sub-Bottom Profile



Advantages:
Approx Cap Thickness
Includes Settling

Disadvantages:
Location Specific - Line
No Amendment Info

Sediment Profile Imaging



Advantages:
View In-Place Material
View Amendments

Disadvantages:
Location Specific - Point
Limited Thickness

Settling Pans

Advantages:
View Placed Materials
Assess Amendments

Disadvantages:
Location Specific - Point
No Settling or Mixing Layer

Core Collection

Advantages:
View Placed Materials
Assess Mixing Layer
Assess Amendments

Disadvantages:
Location Specific - Point
Subject to Drawdown

Source: Barth; NOAA Office of Exploration: Sub-Bottom Profiler, Battelle 2018 Chlorinated Conference Proceedings, Dalton Olmsted Fuglevand, Battelle 2017 Remediation and Management of Contaminated Sediments Conference Proceedings

Chemical Isolation Construction Considerations – Wrap Up

Important Concepts

- Evaluate Proposed Equipment
- Controlled Placement of Layers
- Amendment Delivery
- Quality Assurance Program

Training Roadmap

Introduction (Section 1)

Capping Overview (Section 2)

Performance Objectives & Design Concepts (Section 3)

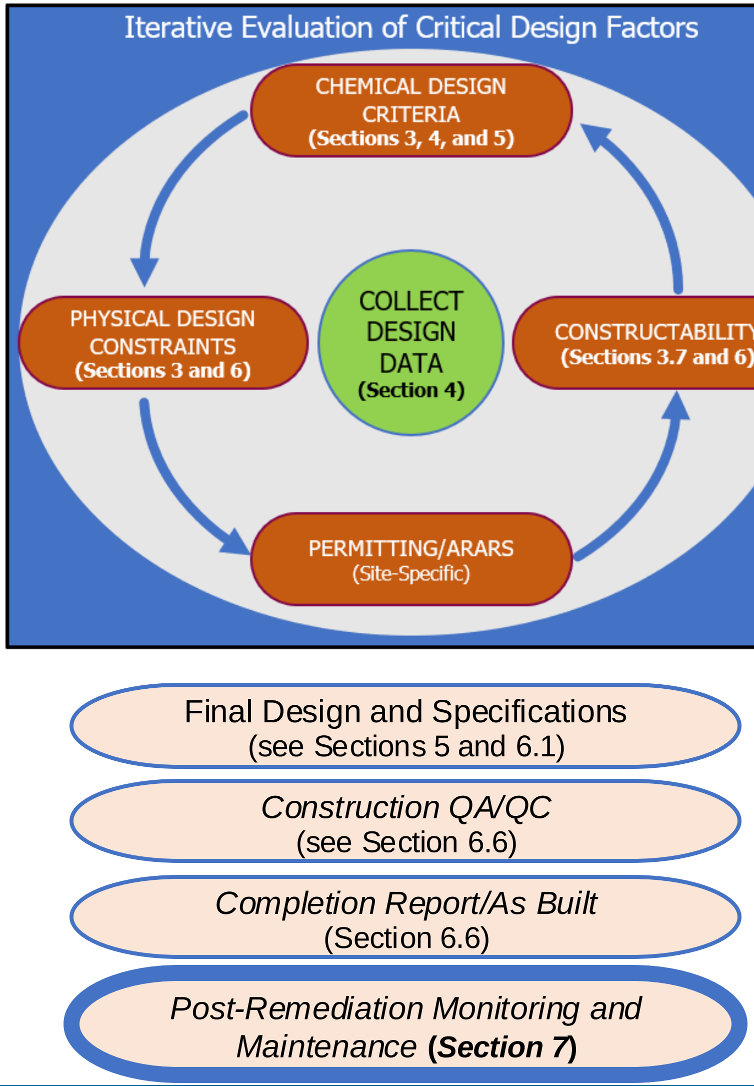
Chemical Isolation Layer Modeling (Section 5)

Q&A Break

Chemical Isolation Construction Considerations (Section 6)

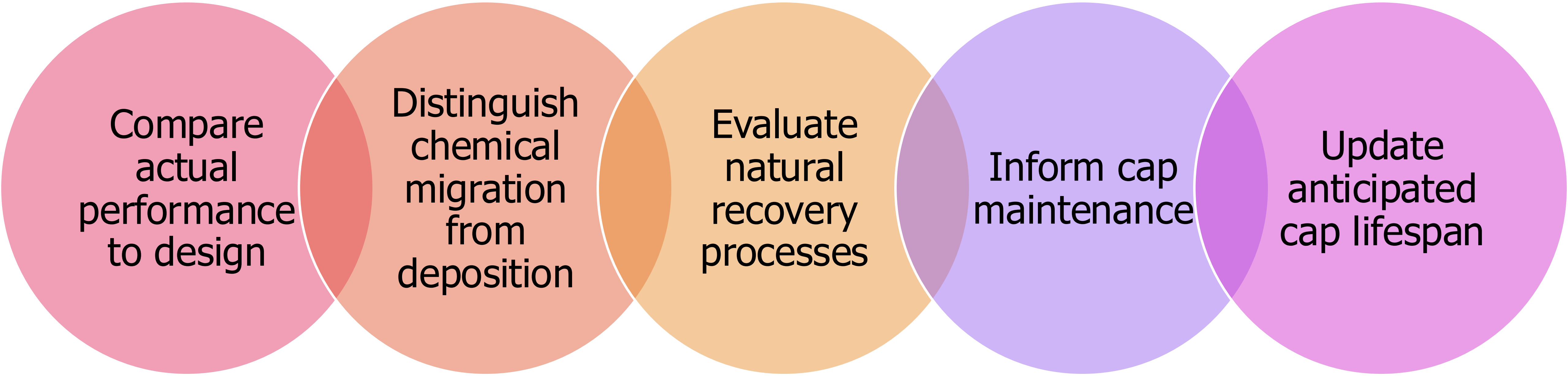
Monitoring & Maintenance Objectives and Approaches (Section 7)

Q&A Break



Cap Performance Monitoring

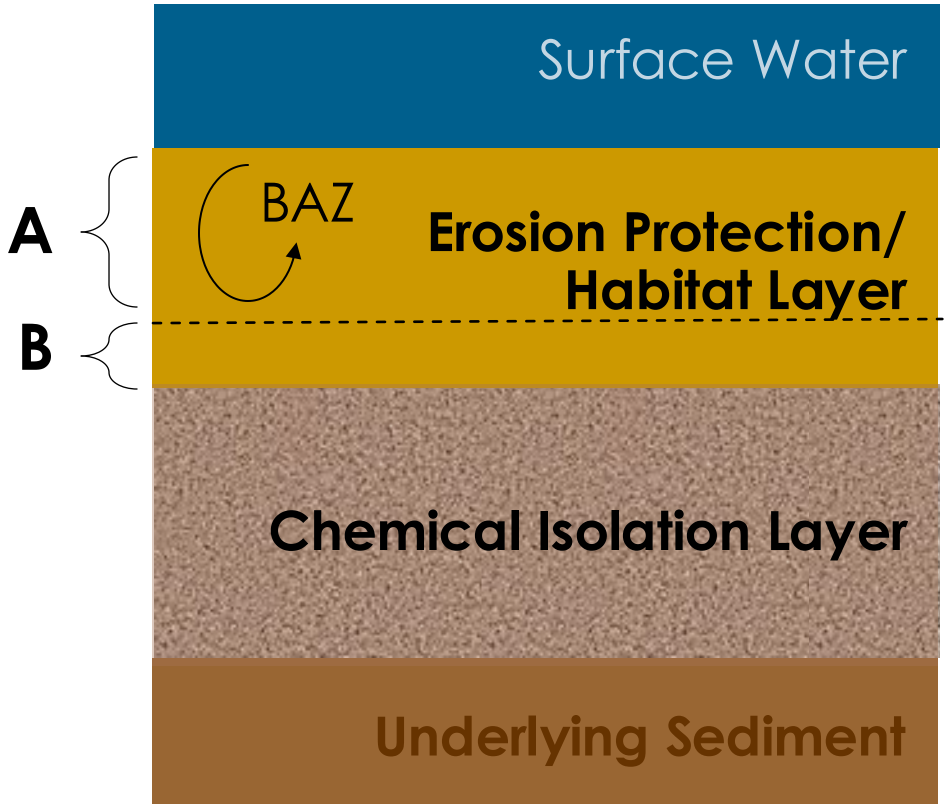
How can monitoring help assess cap performance?



Monitoring Cap Performance – Chemical Isolation

Sampling Depths

- At a minimum, sample at the point of compliance (A), and if different, the design evaluation depth (B)
- Multiple depths throughout cap is helpful for understanding transport mechanism
- A sample within the chemical isolation layer can serve as an "early warning" of potential issues in the future



Monitoring Cap Performance – Chemical Isolation

Evaluate COC concentrations at multiple depths (vertical profiling)

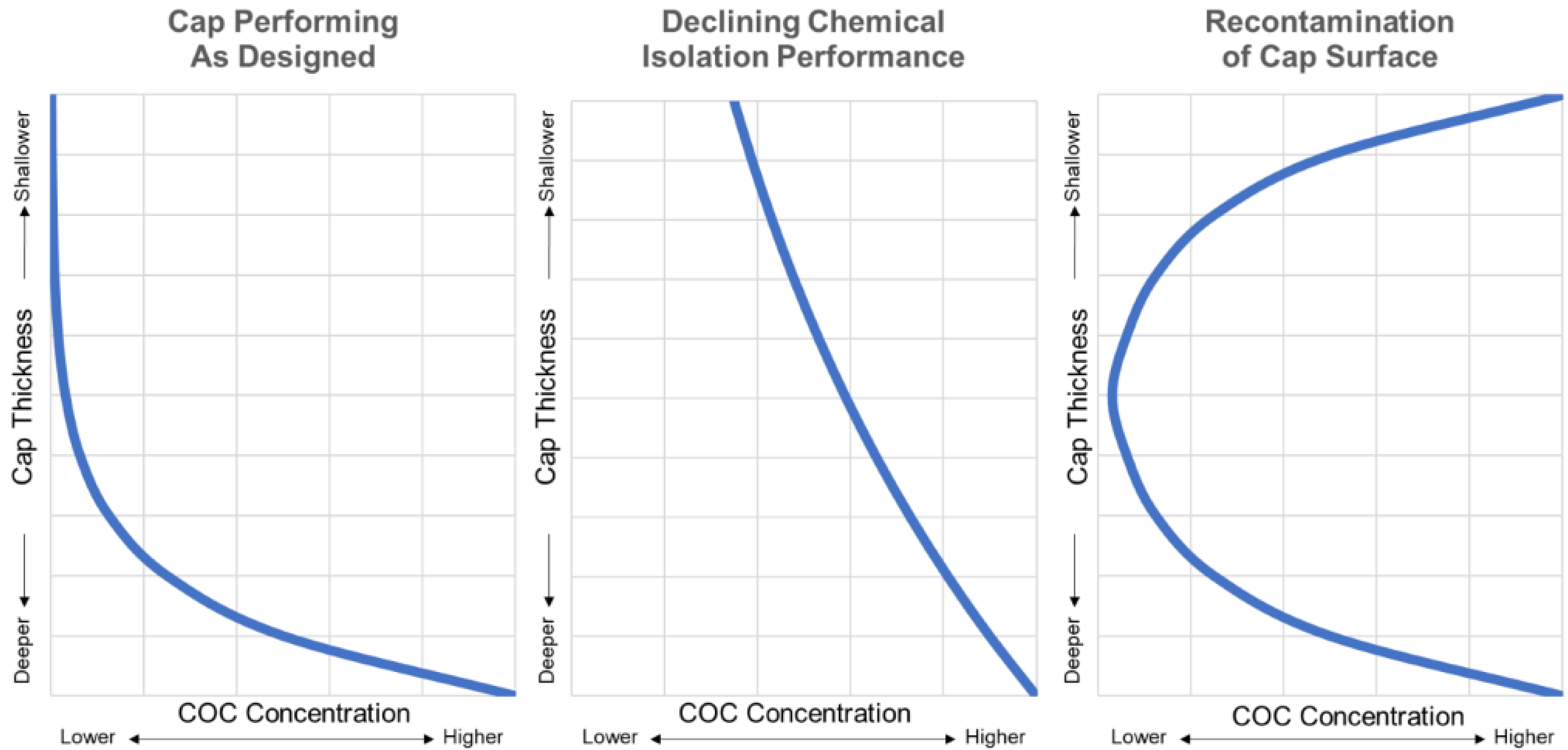


Figure 7-2. Conceptual illustration of vertical concentration profiles

Monitoring Cap Performance – Chemical

Porewater

Direct indicator of CIL performance

Solid Phase

Commonly used to evaluate CIL performance

Surface Water

Not a straightforward indicator of CIL performance

Biota

Not a straightforward indicator of CIL performance

Maintenance Triggers

When do caps need repair?

- COC migration through cap
- Excessive consolidation
  - Of cap material
  - Of underlying sediment
- Slope instability
- Erosion; high energy events
- Current and future uses
  - Prop wash scour
  - Anchoring
  - Sunken vessels

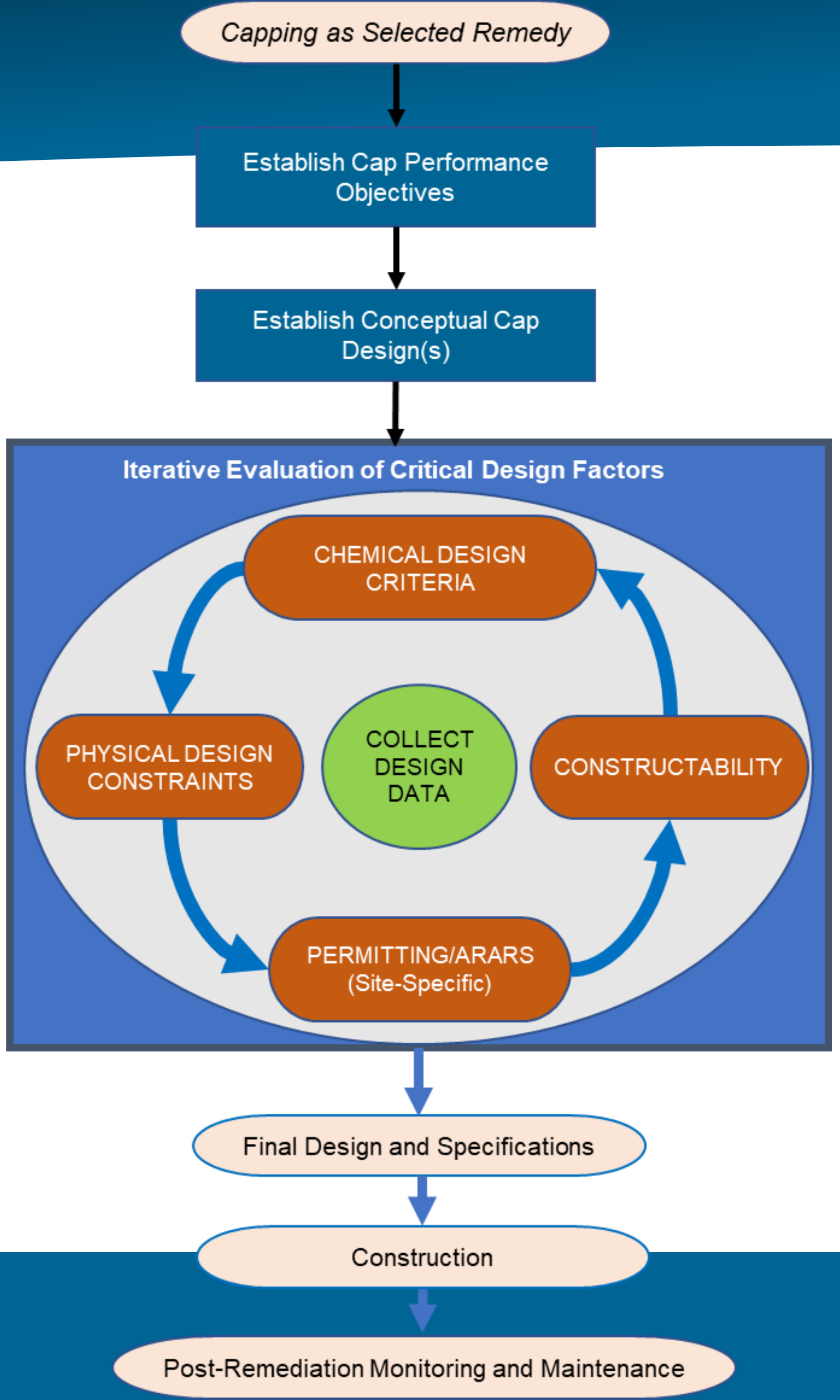
Source: Louisiana Department of Environmental Quality (used with permission)

Monitoring & Maintenance Objectives/Approaches

- Plan for cap maintenance in the same manner as any built asset
- Maintenance plans should include "trigger" criteria for action
  - physical criteria (e.g., thickness)
  - chemical criteria (e.g., COC concentrations)
- Response may include increased frequency of monitoring, diagnostic investigation, or repairs
- Consider whether minor or localized deviations are likely to reduce cap effectiveness

Summary

- Chemical isolation is achieved through various mechanisms (impeding fluid flow, addition of sorbents, physical attenuation distance)
- Chemical isolation cap design is an iterative process that considers risk reduction goals, contaminant properties, fate and transport characteristics, physical constraints, constructability, and permitting requirements
- Construction quality assurance is critical to demonstrate that the chemical design criteria are achieved in the field
- Monitoring should include approaches to evaluate RAO attainment and assess cap performance monitoring
- Maintenance needs should be tied to pre-determined ‘triggers’ informed by cap performance monitoring results



Questions

ITRC Sediment Cap Chemical Isolation Guidance Document sd-1.itrcweb.org

Certificate of Completion

https://clu-in.org/conf/itrc/sd-1/

(emailed after you complete the Feedback Form)