IN SITU SEDIMENT CAPPING

Russell Schuck P.G.
Haley & Aldrich Inc.

NEWMOA Workshop:
Remediation of
Contaminated
Sediment Sites
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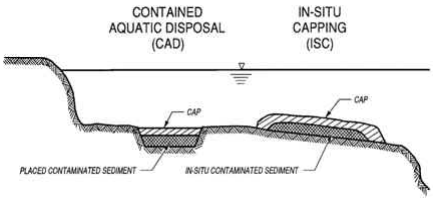
Contaminated Sediment Remediation Guidance for Hazardous Waste Sites

In situ Capping Overview

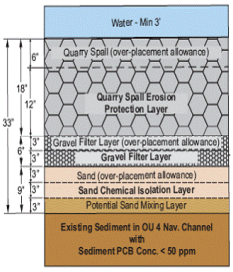
- Purpose of a cap
  - Prevent exposure to eliminate risks
  - Contain sediments from resuspension/migration
  - Prevent migration of contaminants
  - Provide suitable habitat



Types of Caps

- Simple granular caps
- Multilayer caps
- Active/reactive caps
- Thin caps

33-Inch Quarry Spall Armored Cap



When is the use of In situ Capping Appropriate?

In general cap is a reasonable option under the following conditions:

- *Low groundwater flux*
- *Lower velocity flows/lower susceptibility to erosion*
- *Site contaminants will remain stable after burial*
- *Deeper water bodies- no impacts to navigation, limited flood storage loss*
- *Small portion of a water body (minimal flood storage loss)*
- *RGs are not attainable via removal*
- *Area to be capped has a generally level bottom*

Poor Candidates for Capping

- *Shallow environments*
  - *Littoral zones—capping would create emergent conditions*
- *High erosion potential*
- *Flood prone areas*
- *High groundwater flux with dissolved contaminants*

Common Concerns about In-Situ Sediment Capping

- Increased truck or rail traffic
- Loss of resource/harvesting opportunities
- Increased flooding
- Disturbance of aquatic habitat
- Cap material source issues
- Loss of boat anchoring access
- Doubts about effectiveness due to cap erosion, disruption, or contaminant migration through cap
- Loss of privacy during construction
- Recreation and tourism impacts during construction
- Property value/transferability concerns with leaving significant contamination in place

Before you Cap…

- Understand additional sources of recontamination
  - CSOs
  - Upstream sources
    - Maintain a “Watershed View”
- Understand site hydrodynamics
  - Seasonal variability
  - Storm effects
  - Sediment stability
  - Groundwater discharge
- Biogeochemistry

EPA's Emphasis on Source Control

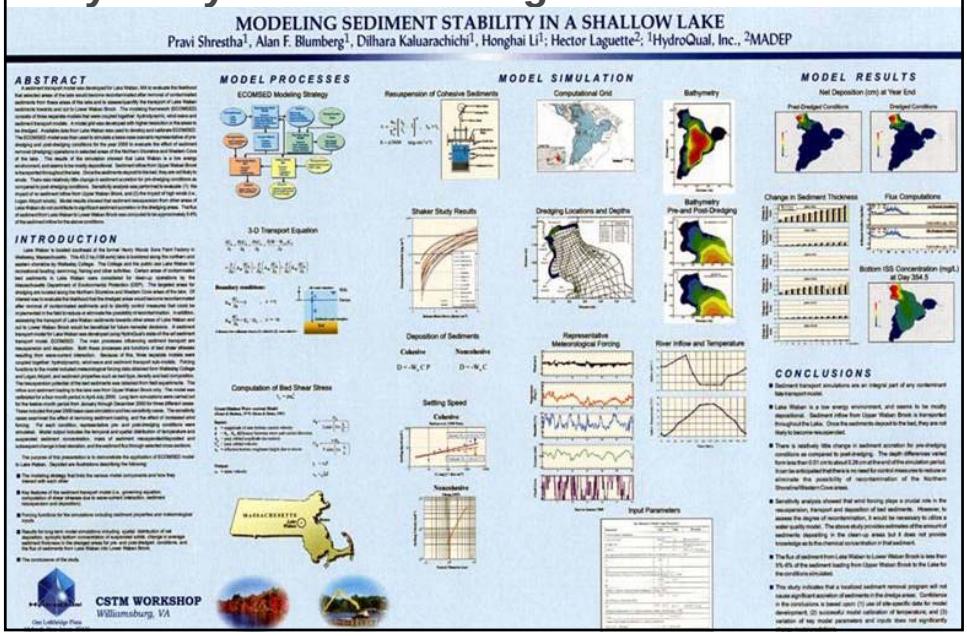
- *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (2002):
  - Principle #1: CONTROL SOURCES EARLY
- *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites* (2005):
  - "Identifying and controlling contaminant sources typically is critical to the effectiveness of any Superfund sediment cleanup." (p. 2-20)
  - "In most cases, before any sediment action is taken, project managers should consider the potential for recontamination and factor that potential into the remedy selection process." (p. 2-21)

Recontamination of Sediment Caps

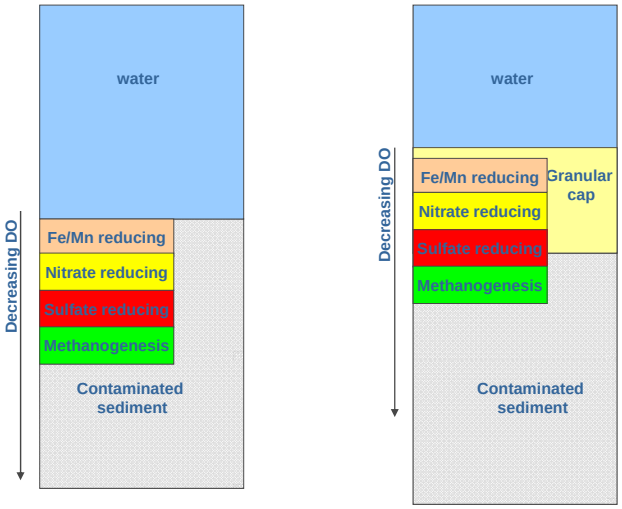
Sediment Capping Site	Date of Cap	Recontamination source
Anacostia River DC	2004	Urban sources, upstream sources
Convair Lagoon, CA	1998	Public storm drain discharges
Denny Way Site, WA	1990	CSO point source discharges
Eagle Harbor Site, WA	1994	"surface sources "offsite sources"
Long Beach North Energy Island Borrow Pit, CA	2001	"deposition from surrounding harbor"
Pier 51 Ferry Terminal, WA	1989	PAHs due to pile pulling, metals from sediment deposition
Pier 53-55, WA	1992	Prop wash resuspension near edges; PAHs due to pile removal
Pier 64-65, WA	1994	Piling repair work released creosote

Courtesy D. Reible

Hydrodynamic Modeling

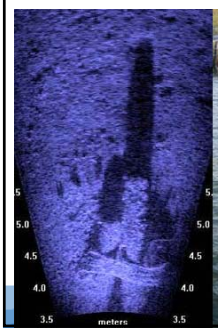


Biogeochemical Processes



Other considerations

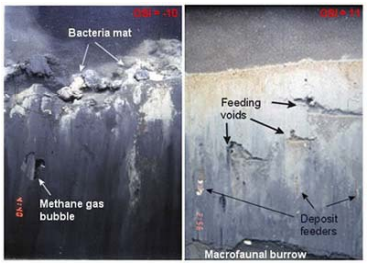
- Detailed bathymetry
  - To assess cap placement—pre vs. post bathymetry
  - To assess slopes
- Debris Survey
  - Debris can provide conduits to underlying contaminated sediments/pore water



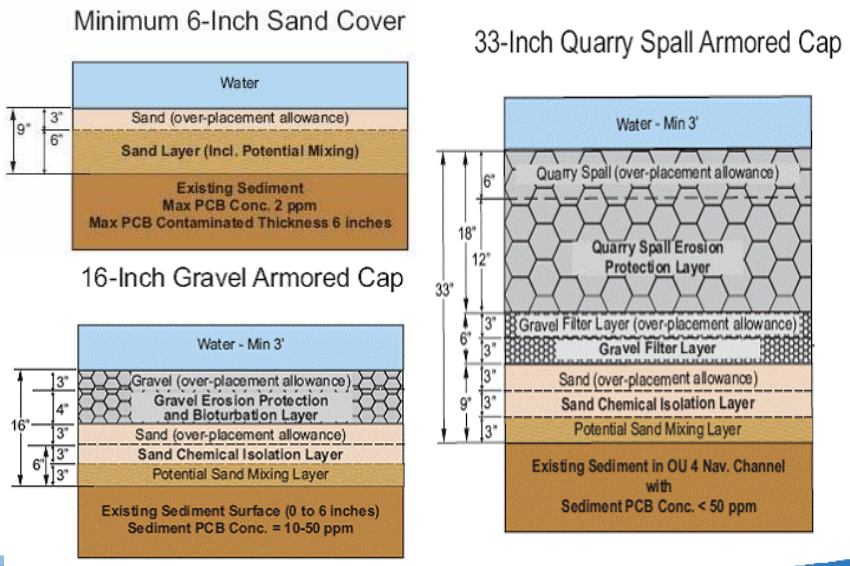


Other considerations

- Cap design
  - Geotechnical properties of sediment
    - Compressibility
    - Resuspension potential
    - Need for geotextile
  - Granular cap composition
    - Grain size
    - Organic carbon content
    - Armoring
  - Bioturbation
  - Gas generation
  - Need for active/reactive component

Cap Design Examples



Cap Placement

- Traditional techniques

Cap Placement

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Cap Placement

Cap Placement

- Broadcast spreader

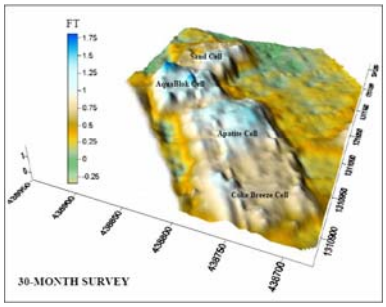
Ensuring Adequate Cap Placement

- Integrated software provides operator control of cap placement

WINOPS Real-Time Display

Customized Capping System

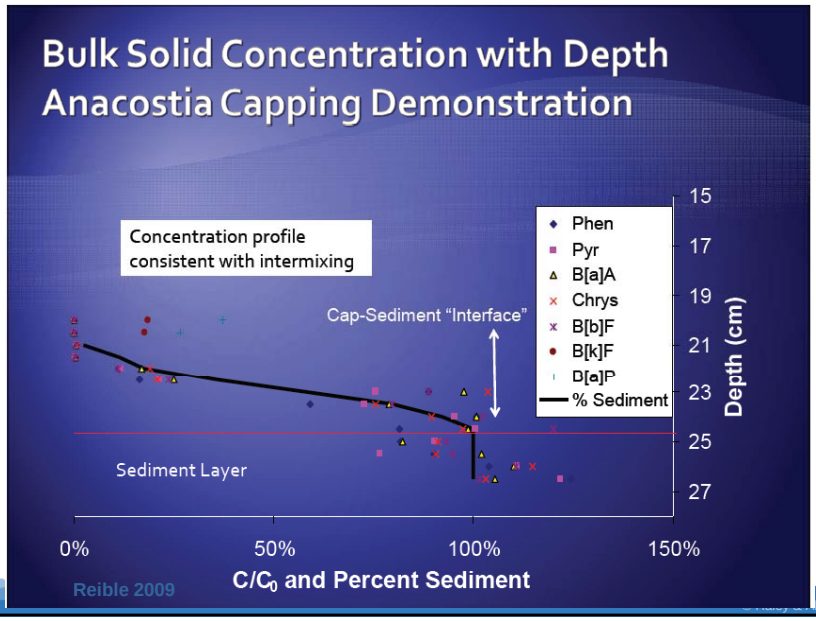
Verifying Cap Placement



Sediment Cores

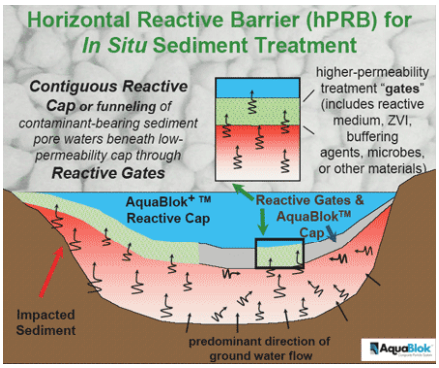
- Cores of the cap can be used to:
  - evaluate cap thickness
  - extent of cap contamination during placement

Cap Contamination During Placement



Active/reactive caps

- These caps actively prevent migration of contaminants
- Sorption
- Reaction
- Fixation
- Reduced permeability



Active/Reactive Caps

- Different cap constituents being evaluated or considered:
  - Clays (e.g., bentonite) for permeability control
  - Activated Carbon or other carbon sequestration agent
  - Organoclays for NAPL control & some dissolved control
  - Clay and sequestration agent mixtures
  - Phosphate additives for metals
  - Iron Sulfide for Hg and MeHg control
  - Siderite (FeCO3) for pH control
  - Zero valent iron
  - Oxygen or hydrogen release compounds/technologies
  - Biopolymers
  - Electrochemical controls on redox conditions Speculative

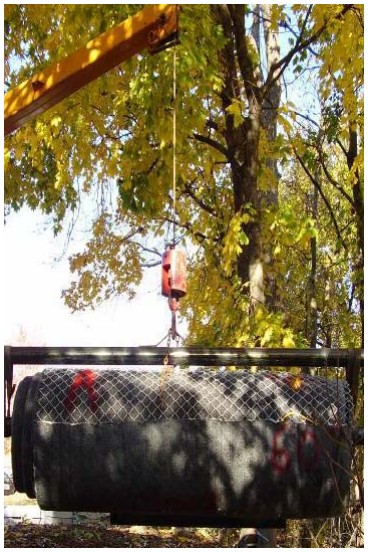
Reactive Core Mat (RCM) Case Study

- Cetco® RCM with Organoclay® absorbent

Organoclay

- Absorbent: sequesters NAPL and dissolved phase organics
- Thin: less than ½ inch thick

RCM Installation



Performance Monitoring

- Regular visual Inspection (i.e., sheen, odor)
- Hexane Extractable Material, Total PAHs

Monitoring Results

6 MONTHS: JUNE 2009

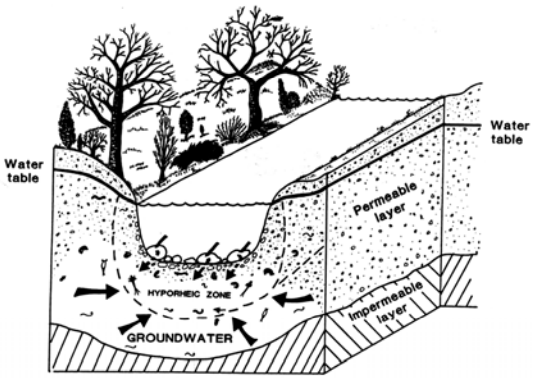
HEM analysis indicates less than 5% absorbent capacity exhausted

12 MONTHS: OCT 2009

Again, less than 5% exhaustion; however a color difference is noted.

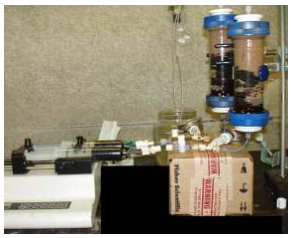
Understanding Groundwater Flux

- Groundwater discharge can contaminate the cap material
- Cap may prevent groundwater discharge causing groundwater mounding
- Potential for isolated breakthrough
- May dictate lifespan of active cap



Bench Studies

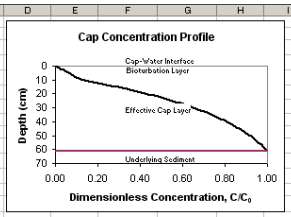
- Column studies and models used to develop RCM cap design



Active Layer Design Model

- Download from Dr. Danny Reibles Research Group at http://www.caee.utexas.edu/reiblegroup/downloads.html

	A	B	C
8	**Contaminant Properties**		
9	Contaminant	Chlorobenzene	
10	Organic carbon partition coefficient, log K'_{oc}	2.52	log L/kg
11	Colloidal organic carbon partition coefficient, log K'_{OC}	2.15	log L/kg
12	Water diffusivity, D'_w	6.0E-06	cm²/s
13	Cap decay rate (porewater basis), λ_1	0.00	yr⁻¹
14	Bioturbation layer decay rate (porewater basis), λ_2	0.00	yr⁻¹
15			
16	**Sediment/Bioturbation Layer Properties**		
17	Contaminant pore water concentration, C_d	1	ug/L
18	Biological active zone fraction organic carbon, (f'_{oc} / λ_2	0.05	
19	Colloidal organic carbon concentration, ρ_{OC}	10	mg/L
20	Darcy velocity, V	2	cm/yr
21	Depositional velocity, V_{dep}	0	cm/yr
22	Bioturbation layer thickness, h_{bio}	10	cm
23	Pore water biodiffusion coefficient, D'_{bio}	100	cm²/yr
24	Particle biodiffusion coefficient, D'_{bio}	1	cm²/yr
25	Boundary layer mass transfer coefficient, k_w	0.75	cm/hr
26	Effective retardation factor in sediment	16	
27			
28	**Active Layer Properties**		
29	Layer thickness	1.0	cm
30	Ratio of effective diffusion in active layer to conventional layer	1.00	
31	Equivalent active layer thickness (steady state equivalent)	1.0	cm
32	Effective Partition Coefficient	330	L/kg
33	Active adsorbent loading	3.81	kg/m^2/cm
34	Effective retardation factor, active layer	123	
35	Equivalent sandy cap thickness (transient equivalent)	11.88	cm
36			
37	**Conventional Cap Properties**		
38	Depth of specific interest below cap-water interface, z	10	cm
39	Fraction organic carbon at depth of interest, $f_{oc}(z)$	0.05	



Steady State Model Equations

$$C_1 = \frac{C_{w,0}\theta^{\frac{Pe_1}{2}-\gamma_1'} - C_d\theta^{-\alpha}}{2\sinh\beta}\exp\left[\left(\frac{Pe_1}{2}+\beta\right)\frac{h_{cap}-z}{h_{eff}}\right] + \frac{C_{w,0}\theta^{\alpha} - C_{w,0}\theta^{\frac{Pe_1}{2}-\gamma_1'}}{2\sinh\beta}\exp\left[\left(\frac{Pe_1}{2}-\beta\right)\frac{h_{cap}-z}{h_{eff}}\right]$$

$$Pe_1 = \frac{Uh_{eff}}{D_1} \qquad Da_1 = \frac{\varepsilon k_1 h_{eff}^2}{D_1} \qquad \beta = \sqrt{\frac{Pe_1^2}{4} + Da_1}$$

$$C_2 = \frac{C_{w,0}\theta^{\frac{Pe_2}{2}} - C_{w,0}\theta^{-\gamma}}{2\sinh\gamma}\exp\left[\left(\frac{Pe_2}{2}+\gamma\right)\frac{h_{cap}-z}{h_{cap}}\right] + \frac{C_{w,0}\theta^{\gamma} - C_{w,0}\theta^{\frac{Pe_2}{2}}}{2\sinh\gamma}\exp\left[\left(\frac{Pe_2}{2}-\gamma\right)\frac{h_{cap}-z}{h_{cap}}\right]$$

$$Pe_2 = \frac{Uh_{cap}}{D_2} \qquad Da_2 = \frac{\varepsilon k_2 h_{cap}^2}{D_2} \qquad \gamma = \sqrt{\frac{Pe_2^2}{4} + Da_2}$$

Useful Links

- Contaminated Sediment Remediation Guidance for Hazardous Waste Sites: http://www.epa.gov/superfund/health/conmedia/sediment/pdfs/guidance.pdf
- Great Lakes Contaminated Sediment Program Guidance for In-Situ Subaqueous Capping of Contaminated Sediments : http://www.epa.gov/glnpo/sediment/iscmain/index.html#TOC
- Superfund Sediment Resource Center: http://www.epa.gov/superfund/health/conmedia/sediment/ssrc.htm
- SMWG website: www.smwg.org
- Active Capping resources:
  - Dr. Danny Reibles Research Group @ University of Texas http://www.caee.utexas.edu/reiblegroup/downloads.html

Regulations Specific to ISC

- **Construction in Waterways**
  - Section 10 of the Rivers & Harbors Act of 1899 (33 CFR 403). Any structures or work that impact the course, capacity, or condition of a navigable water of the United States must be permitted by the USACE.
  - For an ISC project, Section 10 permitting will require consideration of the cap as an obstruction to navigation. In addition, the potential for the cap to obstruct flows, cause flooding or erosion are considered. If the ISC is within an authorized Federal navigation project, Congressional action is needed to deauthorize the project or modify the authority.
- **Discharge of Dredged or Fill Materials**
  - Section 404 of the Clean Water Act of 1972 regulates the disposal of dredged or fill materials to waters of the United States, and designates the USACE as the lead Federal agency
  - Cap material is a dredged or fill material (depending on its origin), and its placement in "waters of the U.S.", which includes wetlands, requires a permit under Section 404 and a certification of water quality compliance from the state under Section 401.

In situ Capping Summary

- Conventional granular caps are readily implemented and are effective at
  - Reducing exposure by physical separation of organisms from contaminants
  - Contain contaminated sediments from further migration
  - Minimize contaminant migration
- Active caps can also be designed and implemented for sites with
  - NAPL in sediments subject to migration/seeps
  - dissolved contaminants subject to migration