Remedial Options for Sediment Sites – Overview of Advantages and Disadvantages

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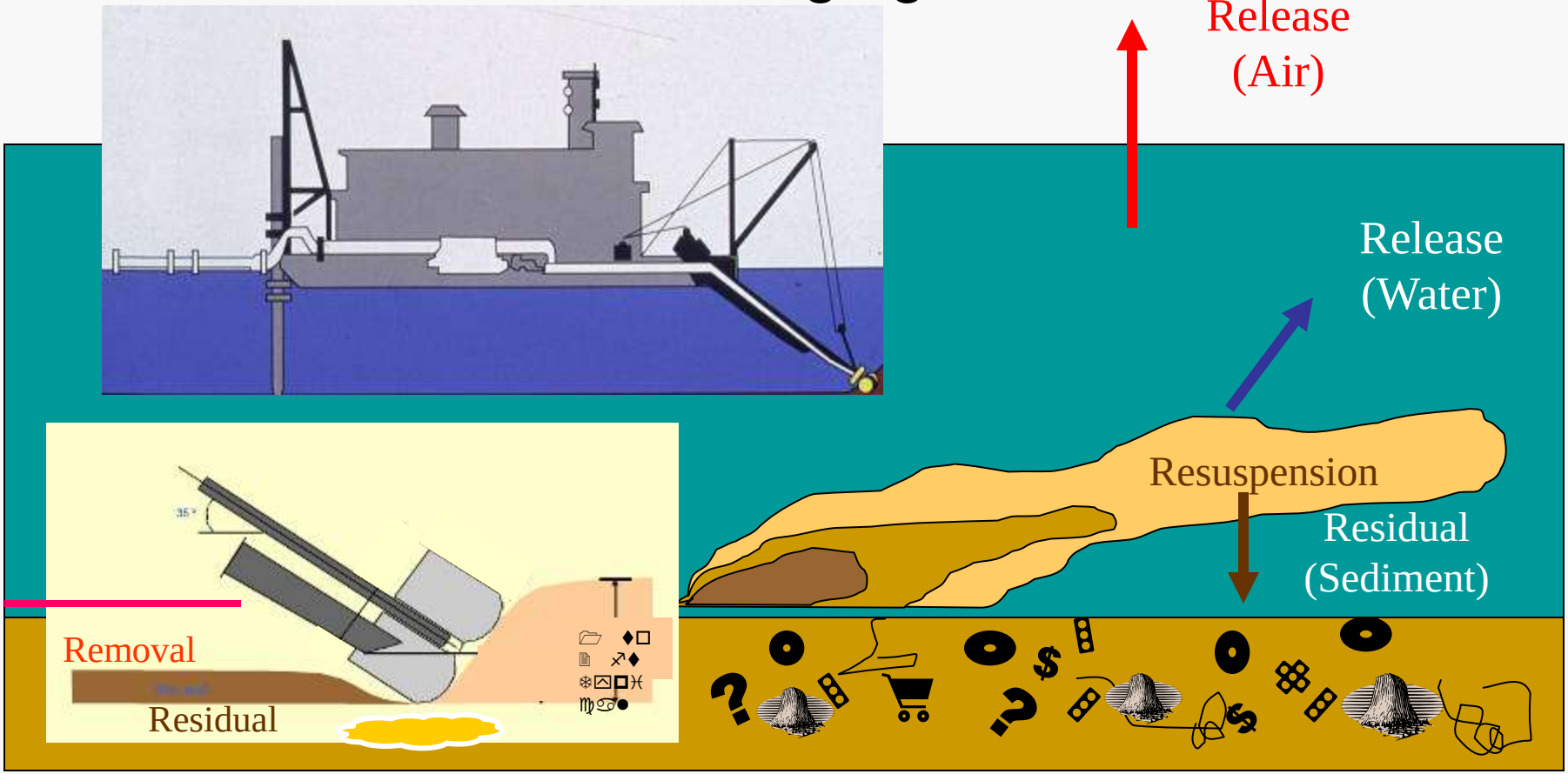
Saginaw - Tittabawassee Rivers Contamination
CAG Meeting, Sept. 17, 2012

Overview

- Primary Remedies: Dredging, Capping, Monitored Natural Recovery (MNR)
  - Remedy Description
  - Advantages
  - Limitations
  - Conditions Conducive to Choosing Each Remedy
  - Case Studies
  - FAQs
- In-Situ Amendments (e.g., activated carbon) Show Promise

Hydraulic and Mechanical Dredging

Conceptual Illustration Of Environmental Dredging And Processes



From D. Reible, 2007

Dredging Advantages

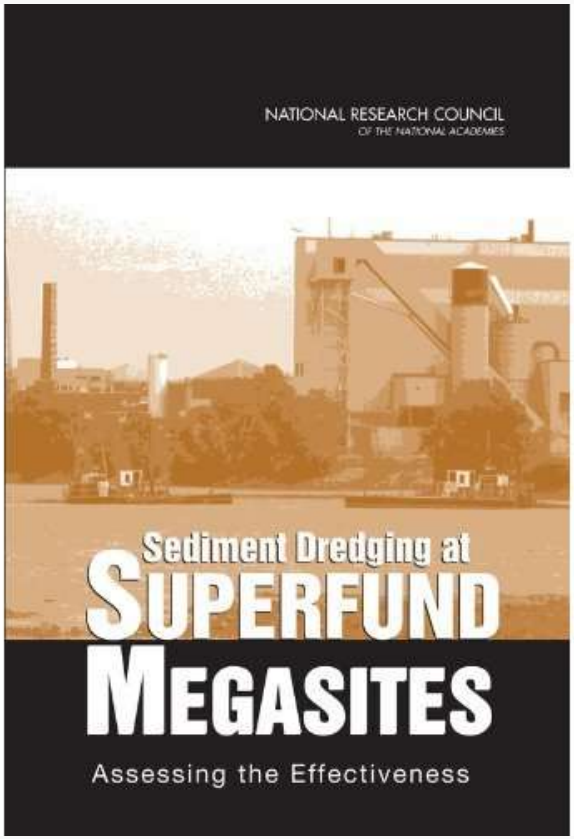
- Moves contaminants from the aquatic environment where they might be mobile to a landfill or to a confined disposal facility (CDF) or confined aquatic disposal facility (CAD)
- Does not limit future water body uses, unless a residual cap is also needed
- Does not reduce flood control capacity

Limitations Of Dredging

- Resuspension and release of contaminants to water, leading to temporary increase in risk
- Residual sediment contamination affects ability to achieve risk reduction goals
- Lack of capacity in disposal facilities, transport to distant facility can be very costly
- Complex and time-consuming to design and implement, large carbon footprint

"[R]esuspension, release, and residuals occur to some extent with all dredging projects."

Sediment Dredging At Superfund Megasites: Assessing The Effectiveness. 2007 National Research Council, p. 63.

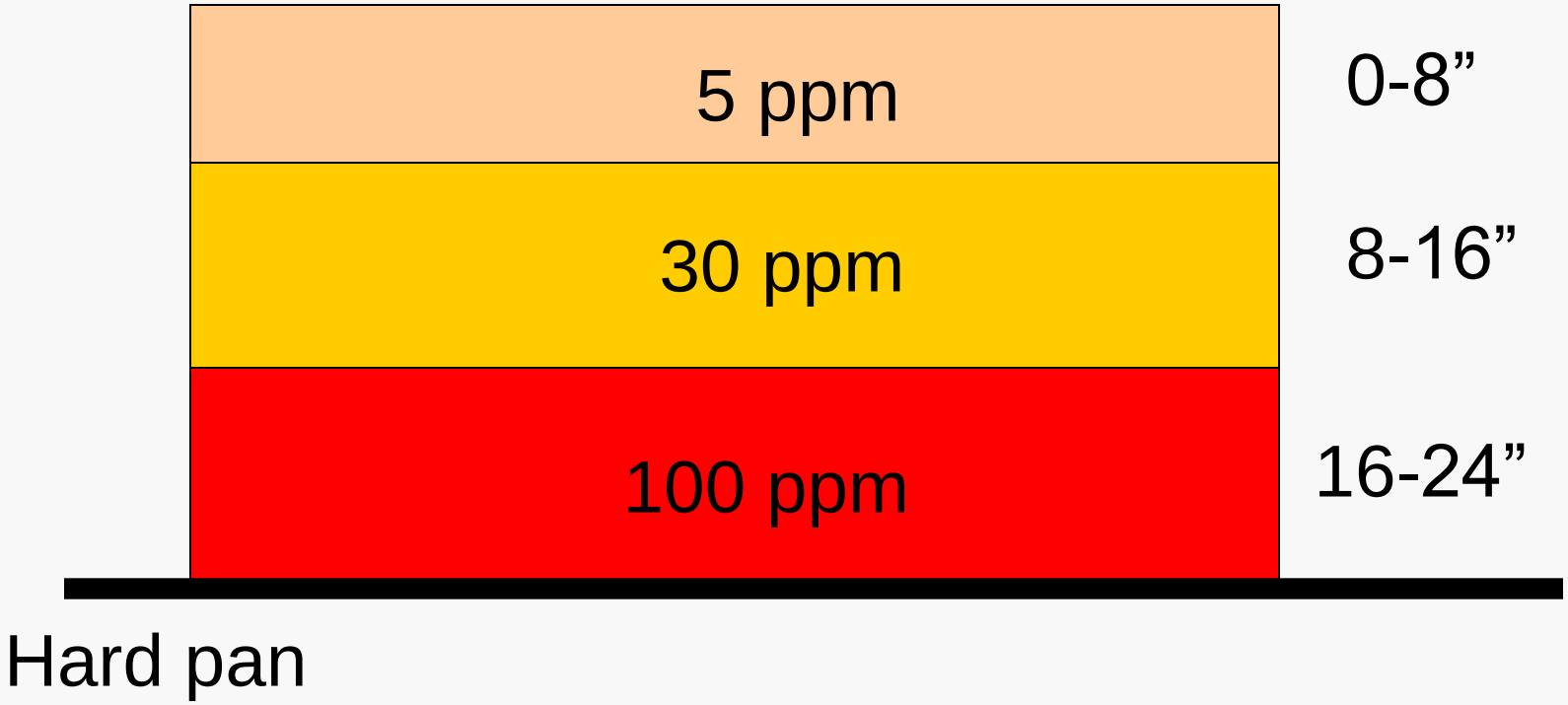


Conditions Especially Conducive To Dredging

- Contaminated sediment is underlain by clean sediment
- Low incidence of hardpan, bedrock, and debris
- Low incidence of low dry density sediment (“fluff layer”)
- Water diversion is practical; i.e., can “dredge” in the dry
- Discrete areas of higher contaminant concentrations (hot spots)
- Existing shoreline areas and infrastructure can accommodate dredging
- Suitable disposal sites are nearby

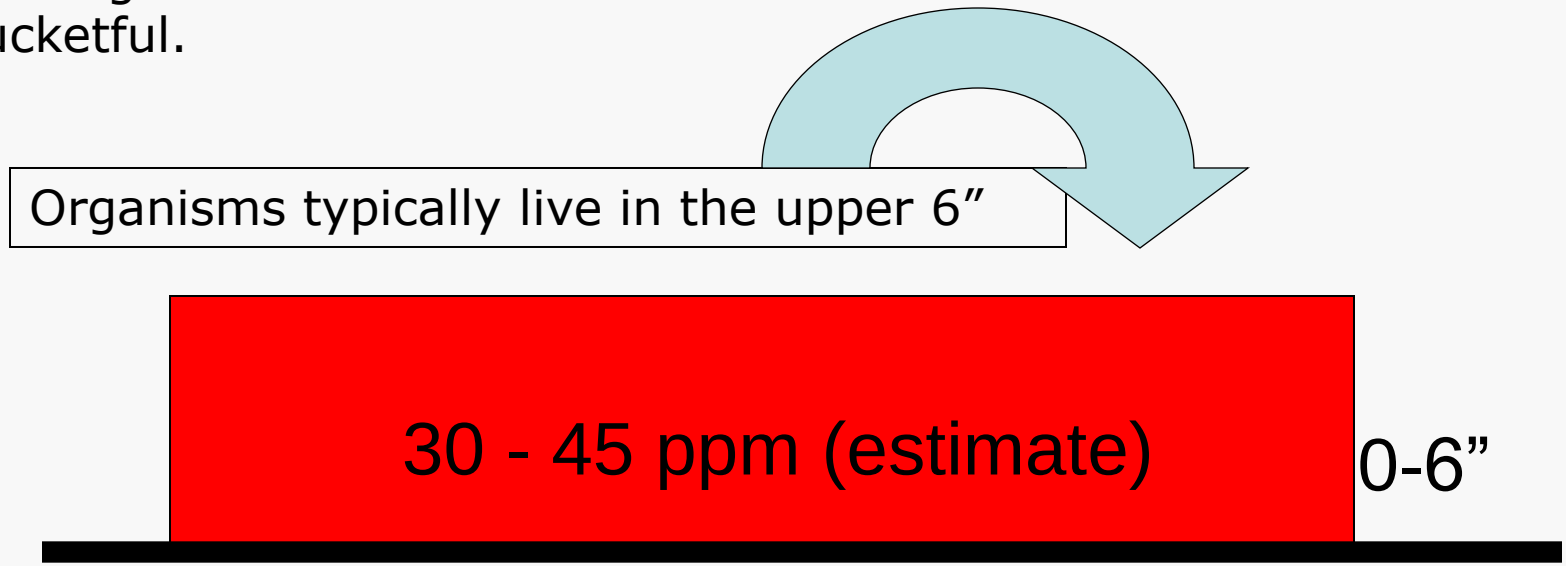
Debris is not conducive to dredging

Example: Pre-Dredge Contaminant Concentration In Sediment Column



Example: Post-Dredge Residual Sediment Contaminant Concentrations

Result is approximately the average of the original concentration in the last bucketful.



Hard pan

Head of Hylebos, WA

- Project
  - Dredged 404,000 cy from 2004 – 2006
- Contaminants
  - PCBs, PAHs, Arsenic
- Project Goals
  - PCBs: 0.3 ppm
  - PAHs: 17 ppm
- Results
  - Average surficial PCB concentrations decreased from 0.69 ppm to 0.07 ppm
  - One area had to be capped

Note: A semi-tractor trailer 40’ long can hold ~90 cy of material.
1000 ppm/1 ppb = 1 drop in a swimming pool

Head of Hylebos, WA

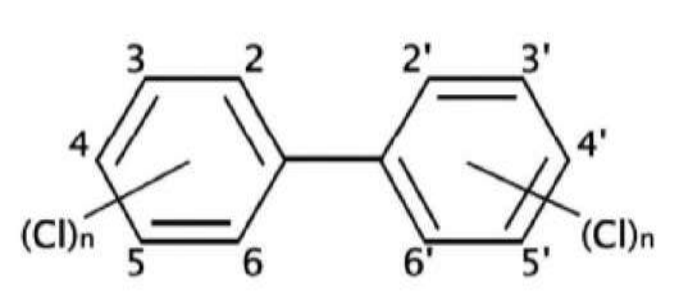
- Was Successful - Site conditions were conducive to dredging
  - Source control prior to dredging was critical
  - Soft black muck over clean sand provided clear visual differentiation between impacted and clean sediment
  - Overdredging feasible
  - Relatively little debris

Case Study: Grasse River Pilot, NY – 2005

- Project
  - 20,600 cy dredged over 4 months
- Contaminants
  - PCBs
- Project Goals
  - Evaluate effectiveness of debris removal and different dredge types under site-specific conditions
- Results
  - Average surficial concentrations increased from 4 to 150 ppm in main channel
  - Average depth of residuals was 16”
  - Average conc. in nearshore area was reduced from 19 to 1.9 ppm
  - Concentrations of PCBs in fish increased temporarily

Grasse River Pilot

- Not So Successful – Conditions not conducive to dredging
  - Low sediment levels not achieved despite significant dredging efforts
  - Complex and hard bottom conditions/rock and cobble hampered ability to remove all targeted sediments
  - Unable to characterize site sub-bottom conditions prior to dredging despite state-of-the-art technology
  - Higher PCBs levels at depth



Dredging Frequently Asked Questions

Won't removing contaminated sediments immediately and permanently reduce risk?

- Maybe. According to a review by the National Research Council "Simple mass removal … may not reduce risk."
- Cannot remove ***all*** contamination, will be some level of residual contamination that may need to be managed (e.g., a residual cap)

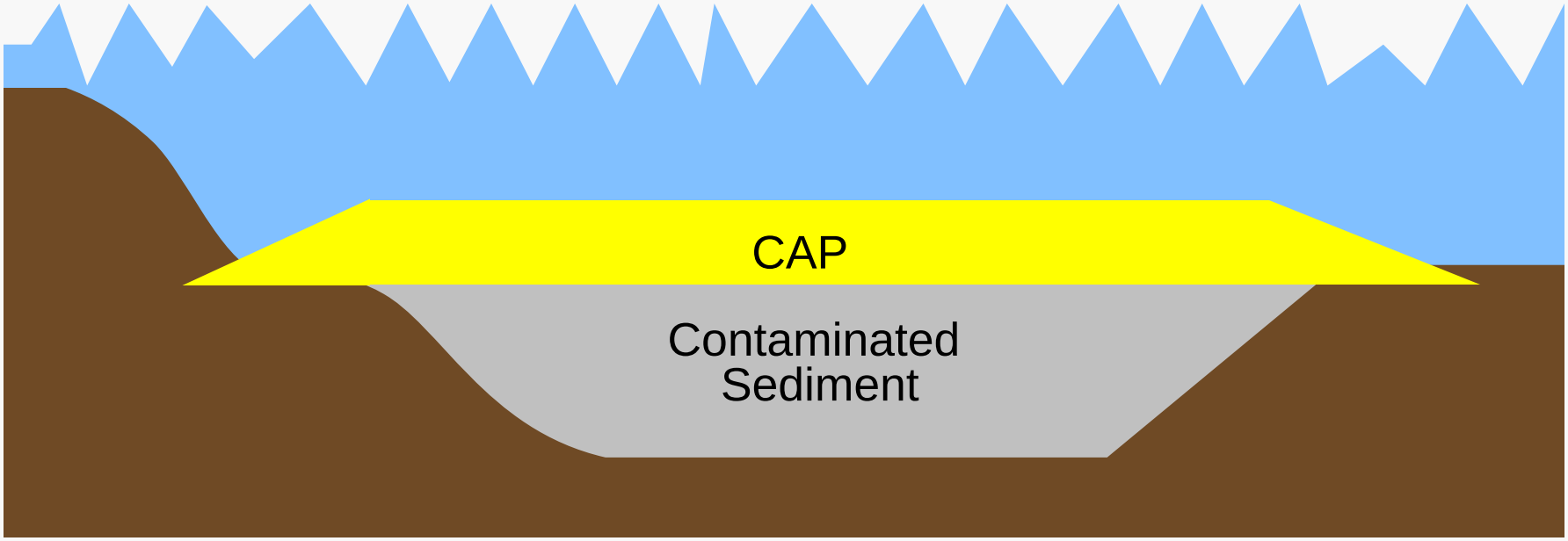
Sediment Dredging At Superfund Megasites: Assessing The Effectiveness. 2007 National Research Council.

Dredging Frequently Asked Questions

Will I be able to eat the fish after dredging is completed?

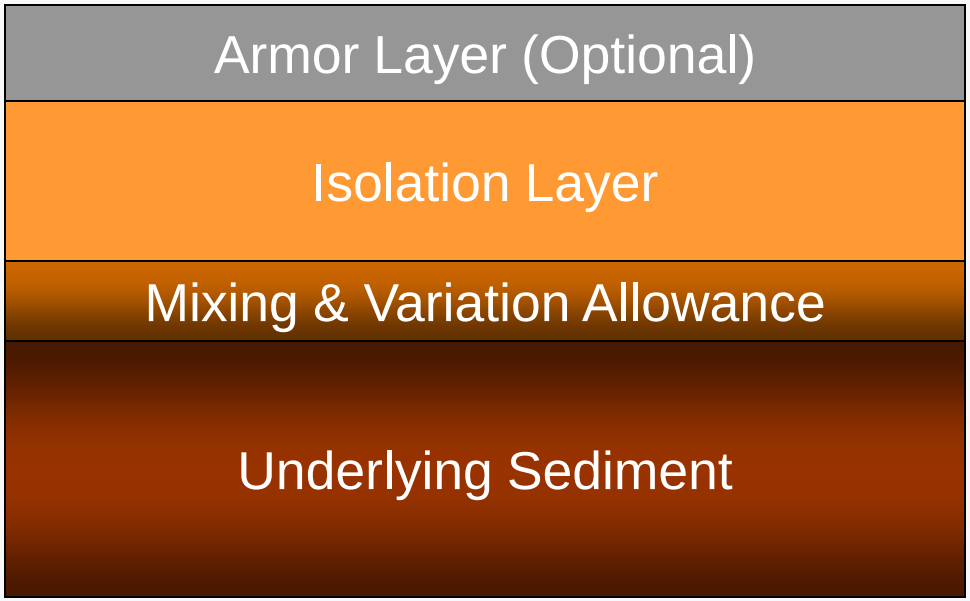
- Not for a while. Will be a short-term increase in tissue levels, duration depends on time to complete remediation.
- Will be an increase in number of fish meals/yr, but reducing impacts to the food chain can take a long time.
- Fish consumption advisories typically continue for a number of years following dredging.
- For some sites, “safe” concentrations may not be reached for over 50 years.

Capping



From D. Reible, 2007

Conceptual Illustration of Common Cap Design



Note: Some caps do not need an armor layer.

Capping Advantages

- Can achieve greater risk reduction more quickly (are no dredge residuals)
- Less short-term risk from resuspension
- Implemented relatively quickly; fewer quality of life issues
- Requires much less work area than dredging
- Can facilitate habitat restoration

Limitations Of Capping

- Contamination remains in the aquatic environment, but isolated by an engineered barrier
- Water depths reduced (if not dredged first); need to consider flooding impacts
- Long term monitoring/maintenance required
- Institutional controls may be required to prevent cap disruption; may limit some types of waterbody uses

Note: Institutional controls are non-engineering measures designed to affect human activities to limit exposure to hazardous substances (e.g., no-wake zones, fish consumption advisories).

Conditions Especially Conducive To Capping

- Water depth is adequate to accommodate cap with anticipated uses (e.g., navigation, flood control) or depth can be changed to maintain adequate water depth
- Rate of contaminant movement through cap can be accommodated in cap design
- Hydrodynamic conditions (e.g., floods, ice) are not likely to compromise cap or can be accommodated in design
- Anticipated or existing infrastructure (e.g., piers, pilings, buried cables) is compatible with cap

Case Study: St. Paul Waterway, WA

- Project
  - Early capping project - 1988
  - 17 acres capped in place plus habitat enhancement
- Contaminants
  - phenols, PAHs, copper, dioxins, furans
- Project Goals
  - Maintain integrity of the cap
  - Chemically stable
  - Biological recovery within 2 yrs of completion of cap

Case Study: St. Paul Waterway, WA

- Results
  - 10 yrs of intensive monitoring showed:
    - No chemical migration through cap
    - No contaminants in the surficial layer of cap
    - Rapid recolonization of cap by biota
    - Biotic communities indistinguishable from reference area communities

Case Study: Grasse River Pilots

- Pilot Study Projects
  - 7 acre study area, several small sand/soil caps in channel (2001)
  - 1 acre armored cap in channel (2005)
  - 0.5 acre thin cap near shore (2005)
- Contaminants
  - PCBs
- Project Goals
  - Evaluate effectiveness of different cap designs under different river conditions
- Results
  - Unpredicted ice jam in 2003 scoured large area of non-armored cap
  - 2005 caps were placed successfully
  - Benthic recolonization was rapid

Capping Frequently Asked Questions

Won't all caps leak eventually?

- Not if properly designed. Contaminant movement from the sediment, through the cap and into the overlying water, is highly dependent on rates of groundwater flow and water solubility of the contaminant. There are engineering solutions that can reduce contaminant flux to inconsequential amounts.

Capping Frequently Asked Questions

I heard all caps will eventually be washed away. Is that true?

- No. When caps erode, it usually is in localized areas. Erosion can be effectively addressed by engineering solutions during cap design.
- Caps require monitoring to determine if maintenance is needed. Many caps have been successfully in place for decades.

Monitored Natural Recovery (MNR)

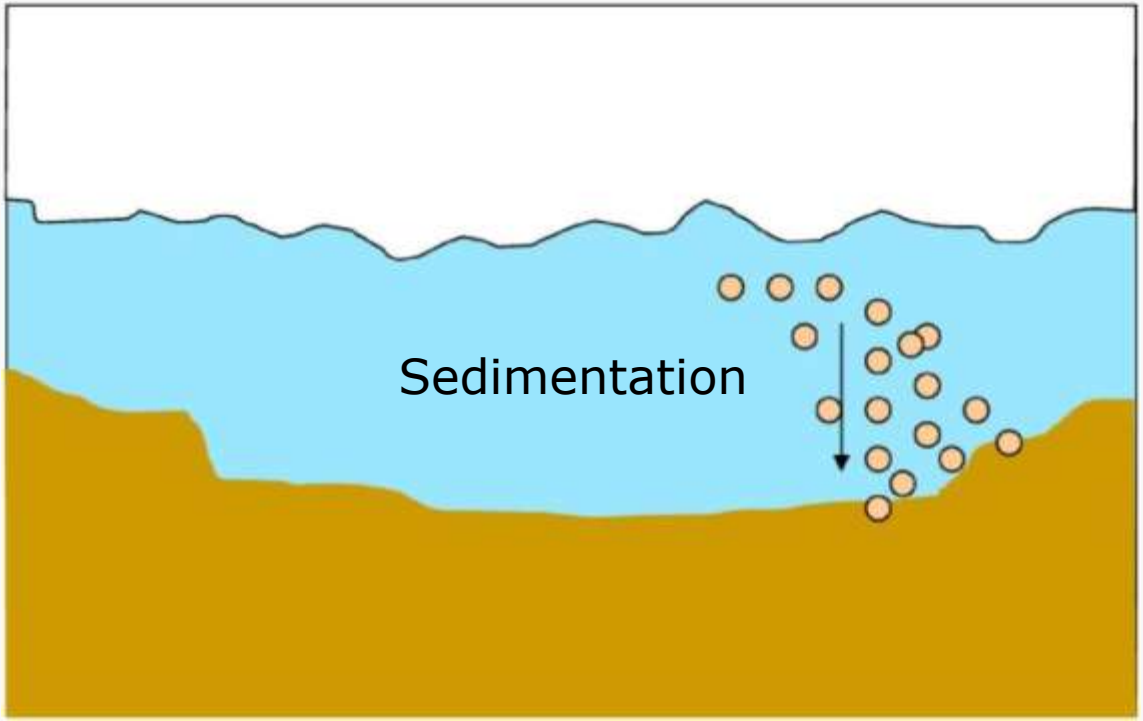
MNR Defined

- MNR allows natural processes to reduce the bioavailability or toxicity of contaminants in sediment
- Some natural processes that reduce the bioavailability or toxicity of contaminants in sediment include:
  - Transformation/biodegradation of contaminants reduces toxicity
  - Burial by deposition of clean sediment reduces exposure

MNR Defined

- MNR remedy includes:
  - Setting remedial action objectives
  - Monitoring to measure MNR process and assess whether risk is being reduced as expected

Conceptual Illustration of MNR



Note: Sedimentation is the most common of several processes that could contribute to MNR.

MNR Advantages

- MNR allows the existing eco-system to remain in place
- MNR avoids disruption to uses of the waterbody

Excavation of river bed.

MNR Advantages

- MNR avoids disruption to the surrounding neighborhood
- MNR does not require transport of contaminated sediment or capping materials through the neighboring community and beyond
- MNR is less costly than dredging and capping

Limitations Of Monitored Natural Recovery

- Leaves contaminants in place
- Time to reduce risks is longer compared to active remedies, although when total timeframes for dredging/capping design and implementation are considered, this time difference may not be significant
- Future natural recovery processes and rates may not be similar to historical processes and rates

Conditions Especially Conducive To MNR

- Anticipated land and waterbody uses compatible with MNR
- Contaminant concentrations in biota and in the biologically active zone of sediment are moving towards risk-based goals
- Natural recovery reasonably anticipated to reduce risk within an acceptable time frame
- All significant sources have been identified and controlled

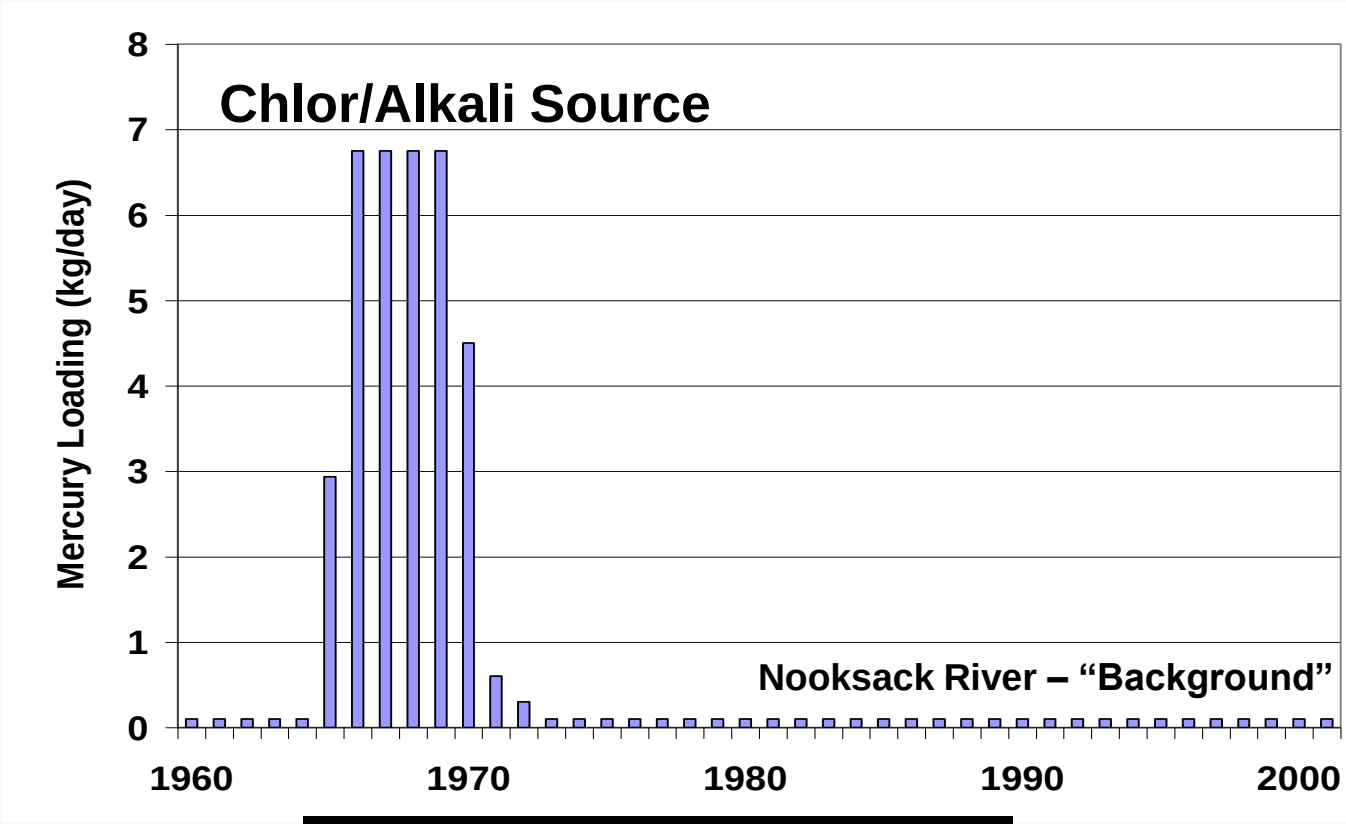
Conditions Especially Conducive To MNR

- Current human exposure is low or manageable using ICs
- Site includes sensitive or unique habitats that should not be impacted by active remediation
- Sediment deposition is occurring in areas of contamination
- Hydrodynamic conditions are not likely to compromise natural recovery

Bellingham Bay, WA

- Project
  - Chronic toxicity to bottom dwelling organisms in the sediment from mercury (Hg)
  - MNR following source control (partial source control – 1971; complete source control – 1979)
- Project Goals
  - Cleanup level: 1.2 mg/kg Hg
- Results
  - After source control, Hg reduced to near or below target cleanup level
  - Toxicity to bottom dwelling organisms significantly reduced
  - Natural recovery is functioning well

Bellingham Bay: Mercury Release and Source Control



Data Source: Georgia-Pacific (2004)

MNR Frequently Asked Questions

Isn't MNR really a "do nothing" remedy; a "wink and a walk"?

- Should not be. MNR is a remedy that recognizes ***demonstrated*** natural processes will achieve remedial goals within an acceptable length of time. The system is monitored to assess whether the system is recovering as predicted.

MNR Frequently Asked Questions

If the risk posed by sediment is unacceptable, shouldn't we do something about it now?

- Maybe. Depending on site conditions and size, a dredging or capping project will take several years or even decades to plan and implement.
- Site-specific conditions may make dredging ineffective at reducing risk or speeding up risk reduction (due to risk from resuspension, releases and residuals).
- Both short-term and long-term risks of all cleanup alternatives must be evaluated and compared to select the most effective and efficient remedy or combination of remedies while considering the needs of the community.

Enhanced Natural Recovery

- When natural recovery may be an appropriate remedy, but the rate of recovery is too slow, engineering means can be used to accelerate recovery
- Enhanced means:
  - Adding a thin-layer of clean sand/sediment over contaminated sediment
  - Installing flow control structures to enhance deposition

Thin cap ("sand cover")

6-inch thick sand

Mixing zone

Contaminated sediment

In-Situ Amendments – A new Approach

- 2006 Pilot Study – Grasse River, NY
- Project Goals
  - Evaluate reductions of bioavailable PCBs in water and fish due to additions of activated carbon using different placement techniques in a 0.5 acre plot
- Results
  - 92% reduction in biota uptake (aquatic worm)
  - 98% reduction in water conc.
  - No impact on benthos
  - Slight increase in sediment erosion potential

Fox River, WI OU 1, – A Combination Remedy 2004 - 2009

- Project
  - Dredge only - 173 acres (370,000 yd3)
  - Dredge and sand cover – 36 acres
  - Engineered cap - 114 acres
  - Thin sand cover – 106 acres
  - Not actively remediated – 935 acres
- Contaminants
  - PCBs
- Project Goals
  - Remedial Action Level: 1.0 ppm
  - Remedial Goal: post-remediation SWAC – 0.25 ppm
- Results
  - Post-dredging surficial concentration ranged from <0.013 – 9.2 ppm, average = 0.41 ppm
  - SWAC over entire OU = 0.23 ppm

- SWAC = Surface Weighted Average Concentration

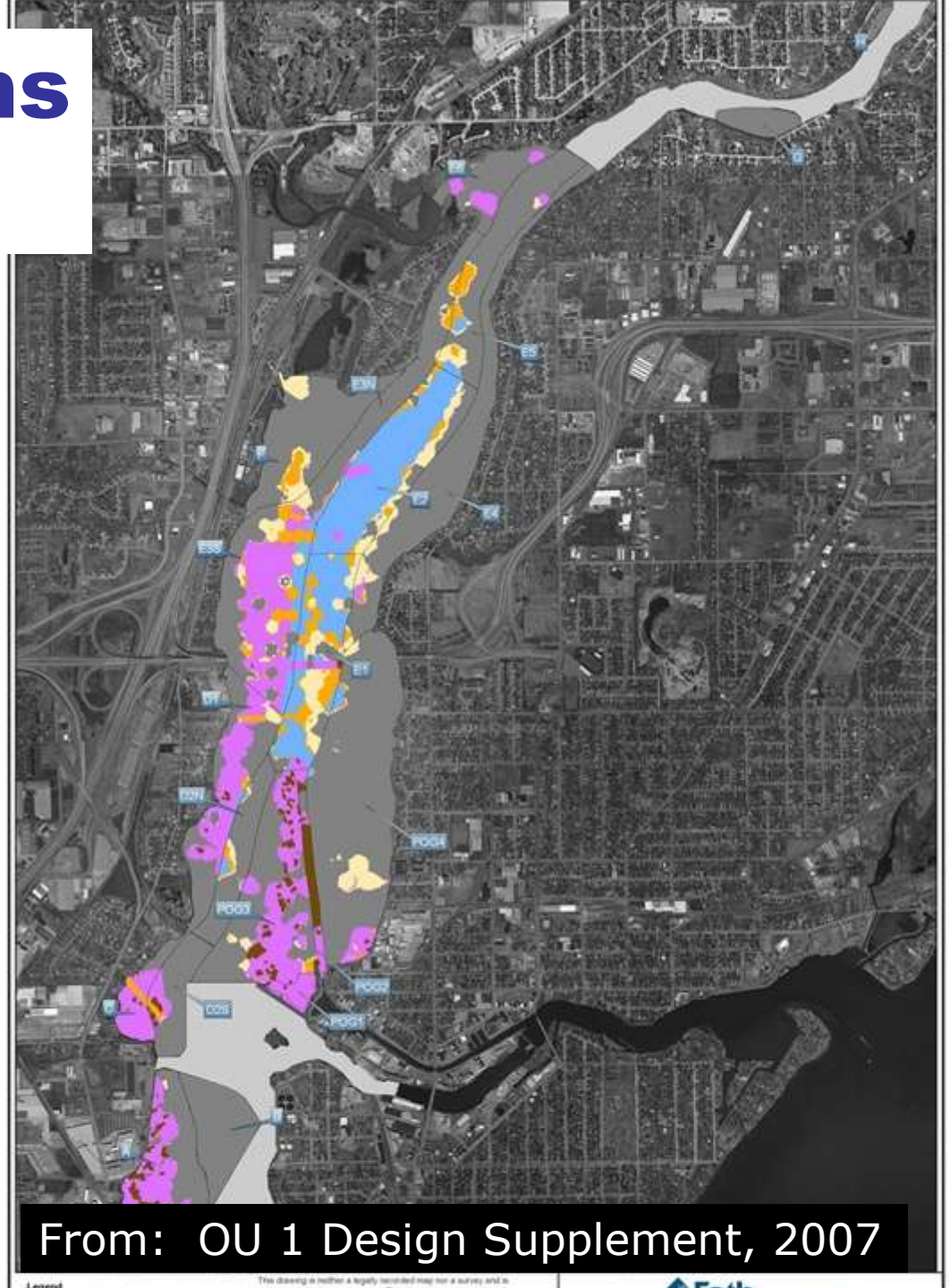
Fox River, WI – OU 1 Remedial Action

- Lessons Learned
  - Despite use of different dredge heads, dredging could not achieve 0.25 ppm everywhere, added sand cover where needed
  - Combination of remedies was successful in meeting remedial goal
  - Walleye concentrations have decreased 73%, other species 32 – 64% in one year

Cleanup actions upper river

Legend

- Dredging
- Capping
- Sand cover (3″ / 6″)



From: OU 1 Design Supplement, 2007

Upcoming Site Decisions

- Centredale Manor, RI – dioxins
- Housatonic River, MA/CT – PCBs
- Lower Duwamish Waterway, WA - PCBs
- Passaic River, NJ – dioxins and PCBs
- Portland Harbor, OR – PCBs, PAHs, metals
- Grasse River, NY – PCBs
- Gowanus Canal, NY – PAHs
- Tittabawassee/Saginaw R., MI – dioxins

Take Home Messages

Take Home Message - Dredging

- Dredging can be an effective remedy if site conditions are conducive (e.g., low debris and underlain by clean sediment)
- Important to identify conditions that reduce dredging effectiveness (e.g., concentrations at depth are much higher)
- Dredging is a highly complex and costly integrated train of processes (e.g., removal, transport, treatment, disposal)

Take Home Message - Capping

- Capping can be an effective remedy
- Provides immediate exposure control
- Conventional sand caps are easy to place
- Less short-term risks than dredging
- Must consider impact on flooding
- Must monitor, especially after big storm

Take Home Message - MNR

- Can be an effective remedy either as a stand alone remedy or as part of a combination remedy, is part of most remedies
- Monitoring is an integral component of MNR to measure long-term protectiveness
- Enhanced MNR, such as adding sand, also may be used to accelerate achievement of risk reduction goals
- Like all remedies, must have adequate source control to achieve risk reduction

Take Home Message – Combination Remedies

- Site conditions drive remedy selection
- At large or complex sites, there is no one-size fits all remedy, combination remedies are now the norm
- Use of in-situ amendments such as granular activated carbon is very promising, can be used alone or as part of a cap to reduce contaminant flux. May be particularly effective at sites with continuing sources that can not be readily controlled.

Key Quotes From 2005 Seds Guidance

- EPA's policy has been and continues to be that there is no presumptive remedy for any contaminated sediment site, regardless of the contaminant or level of risk…. project managers should evaluate each of the three potential remedy approaches (i.e., MNR, in-situ capping, and removal through dredging or excavation) at every sediment site. Project managers should develop a conceptual site model that considers key site uncertainties. Such a model can be used within an adaptive management approach to control sources and to implement a cost-effective remedy that will achieve long-term protection while minimizing short-term impacts…. (Pp. 7-16,17)

Second Key Quote

- Project managers should keep in mind that deeper contaminated sediment that is not currently bioavailable or bioaccessible, and that analyses have shown to be stable to a reasonable degree, do not necessarily contribute to site risks. In evaluating whether to leave buried contaminated sediment in place, project managers should include an analysis of several factors, including the depth to which significant populations of organisms burrow, the potential for erosion due to natural or anthropogenic (man-made) forces, the potential for contaminant movement via ground water, and the effectiveness of any institutional controls (ICs) to limit sediment disturbance. (P. 7-3)

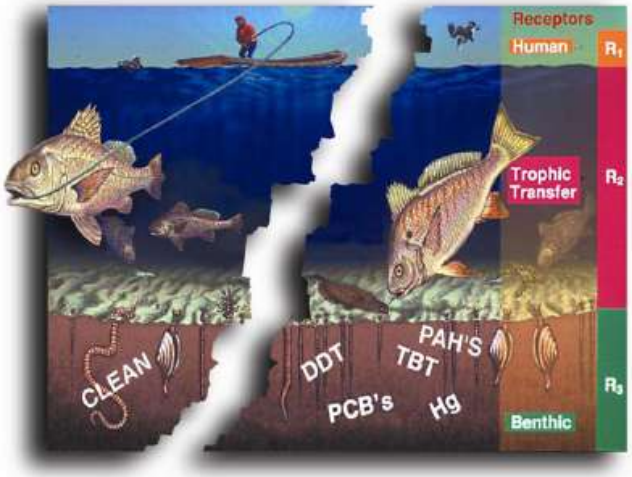
Available Technical Resources

Contaminated Sediment Remediation Guidance for Hazardous Waste Sites

Office of Superfund Remediation and Technology Innovation
and
Office of Research and Development

Sediment Assessment and Monitoring Sheet (SAMS) #1

Using Fish Tissue Data to Monitor Remedy Effectiveness



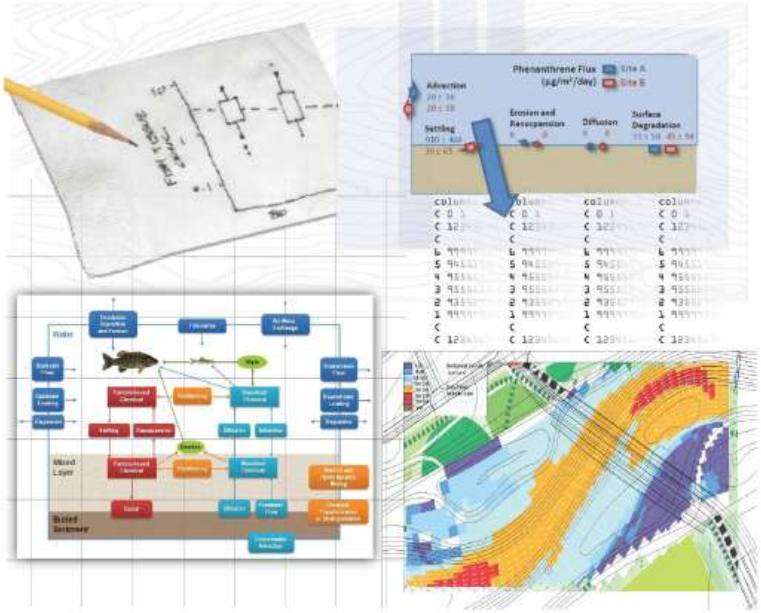
OSWER Directive 9200.1-77D

July 2008

Office of Superfund Remediation and Technology Innovation

Sediment Assessment and Monitoring Sheet (SAMS) #2

Understanding the Use of Models in Predicting the Effectiveness of Proposed Remedial Actions at Superfund Sediment Sites



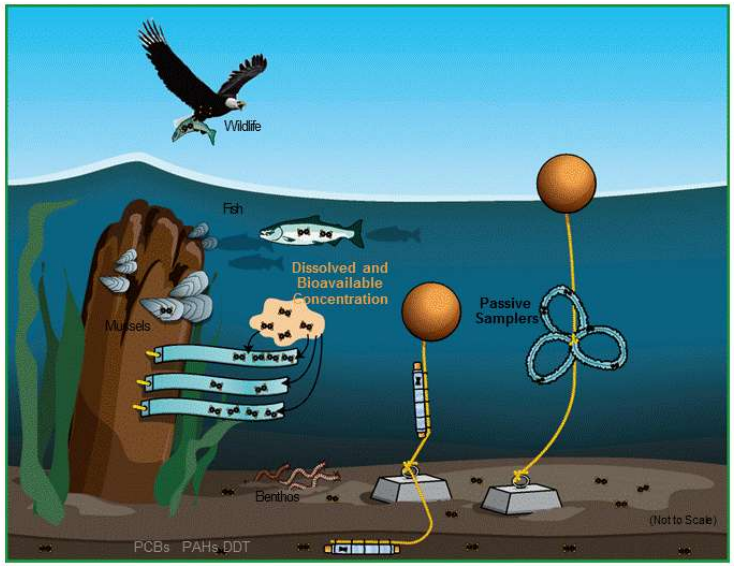
OSWER Directive 9200.1-96FS

November 2009

Office of Superfund Remediation and Technology Innovation and
Office of Research and Development

Sediment Assessment and Monitoring Sheet (SAMS) # 3

Guidelines for Using Passive Samplers to Monitor Organic Contaminants at Superfund Sediment Sites



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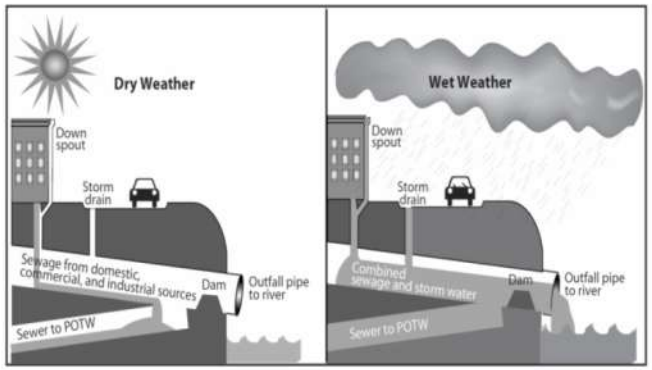
September 2012

OSWER Directive 9200.1-110 FS

Office of Superfund Remediation and Technology Innovation

Sediment Assessment and Monitoring Sheet (SAMS) # 4

A Primer for Superfund Sediment Site RPMs on the Development of Water Quality Standards and the Regulation of CSOs under the Clean Water Act



DRAFT, not for citation

ERDC/EL TR-08-4

Environmental Laboratory

US Army Corps of Engineers®
Engineer Research and Development Center

Dredging Operations and Environmental Research Program

The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk

Todd S. Bridges, Stephen Ells, Donald Hayes, David Mount, Steven C. Nadeau, Michael R. Palermo, Clay Patmont, and Paul Schroeder

January 2008

Evaluating *the* Effectiveness *of* Contaminated-Sediment DREDGING

J. F. BRENNAN CO., INC.

As the science of environmental dredging and sediment management changes, adaptive management strategies can help long-term remediation projects keep pace.

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LIMNOTECH

Water bodies fed by current or former industrial, agricultural, or mining areas frequently contain contaminated sediments, and throughout the U.S., miles of riverbeds and vast areas of harbors, lakes, and estuaries are affected (*1, 2*). Contaminants in sediments can have direct toxic effects on organisms and can accumulate in organisms consumed by humans. The presence of sediment contamination also limits the productive use of a water body and its associated economic benefits (e.g., Ref. 3). The Hudson River in New York State is probably the best-known example of a large river system with widespread sediment contamination. The proposed cleanup addresses the upper 40 miles of river where 2.65 million cubic yards are slated to be removed (*4*). Cleanup has yet to begin, although dredging of 265,000 cubic yards

ERDC/EL TR-08-29

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Technical Guidelines for Environmental Dredging of Contaminated Sediments

Michael R. Palermo, Paul R. Schroeder, Trudy J. Estes, and Norman R. Francingues

September 2008

TECHNICAL REPORT 1960
September 2007

User's Guide for Assessing Sediment Transport at Navy Facilities

A. C. Blake
D. B. Chadwick
SSC San Diego

P. J. White
CH2M HILL

C. A. Jones
Sea Engineering, Inc.

SPAWAR
Systems Center
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TECHNICAL GUIDE

Monitored Natural Recovery at Contaminated Sediment Sites

ESTCP Project ER-0622

MAY 2009

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ESTCP

Environmental Security Technology Certification Program

EPA Database on Sediment Site Characteristics and Effectiveness

- Historically, EPA did not have a central repository of information on sediment sites.
- Need for a well-referenced compendium on sites to summarize national experience.
- Reference tool to query site characteristics.
- Track progress and performance at sites.
- Compare effectiveness of technologies
- Publicly available in late 2012

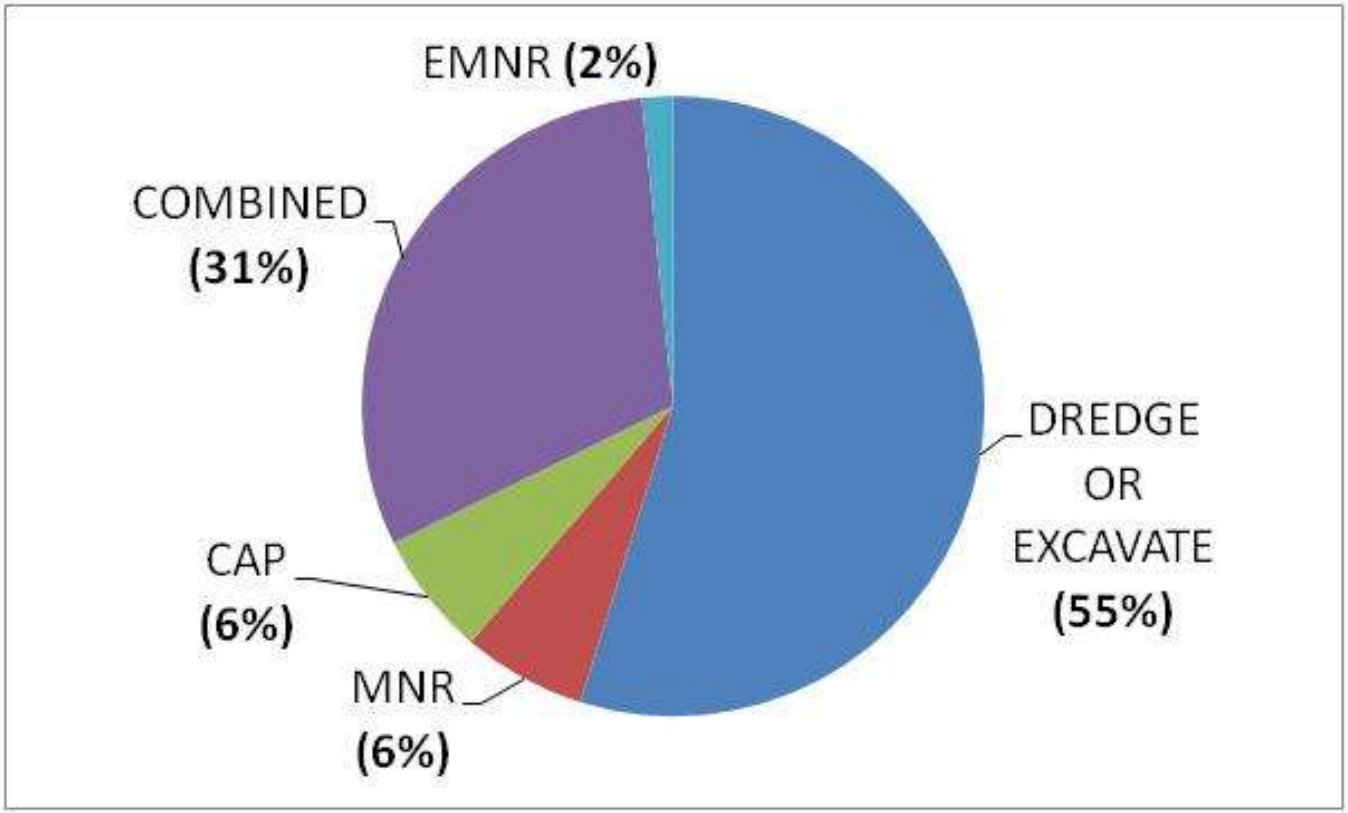
Compilation of Sites

- List developed from polling EPA Regions on sites with significant sediment contamination
- Supplemented with other sources
- Tier 1 Site Criteria
  - Signed Decision Document
  - 10,000 cy or more removal
  - 5 acres capping or MNR
  - Not waste pits, lagoons, or settling basins
- 70 Sites, 120 Areas within those Sites

Site Characteristics

- Site / Operable Units / Area Name
- Websites (Superfund, Region)
- Fieldwork Dates / Remedy Status
- Remedy (Dredge, Backfill, Excavation, Cap, MNR, EMNR)
- Volume Removed or Area Capped or MNR
- Contaminants of Concern
- Action Level and Cleanup Levels (CULs)
- Fish Tissue Goal
- Remedial Action Objectives (RAOs)
- Estimated and Actual Cost

Remedy Selection at Superfund Sediment Sites



- OSRTI Contaminated Sediments Homepage: http://www.epa.gov/superfund/health/conmedia/sediment/index.htm
- Contaminated Sites Clean-Up Information (Clu-In): http://www.clu-in.org/contaminantfocus/default.focus/sec/Sediments/cat/Overview/
- USACE Dredging Operations & Environmental Research: http://el.erdc.usace.army.mil/dots/doer/doer.html
- Interactive Sediment Remedy Assessment Portal: (Navy SPAWAR, 2010, http://www.ert2.org/israp/)