Advances in Sediment Characterization and Remediation

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Past RITS Topics on Sediment

1. Applying Environmental Forensics to Identify PCB Sources at Contaminated Sediment Sites (2012)
2. Sediments Part 1: Managing Sediment Sites Using Navy Policy and Guidance (Fall 2010)
3. Sediments Part 2: Establishing SMART Sediment Cleanup Goals (Fall 2010)
4. Sediment Remedy Effectiveness (Spring 2007)
5. Advanced Chemical Fingerprinting: Identifying Sources and Defining Background in Sediments (Fall 2004)
6. Sediments Part 1: Policy, Guidance, and Characterization (Spring 2002)
7. Sediments Part 2: Cleanup Alternatives (Spring 2002)
8. Rapid Sediment Screening Technologies (Fall 2000)
9. Contaminated Sediments: Confounding Factors (CF) in Toxicology (Spring 1999)

What's in it for the RPM this time?

- Despite years of research and discussions, challenges remain formidable
- This presentation draws upon field experience at numerous sites to provide practical tips on how to go about managing a contaminated sediment site

Presentation Overview

- ► **Sediment Characterization/Assessment**
- **Selecting Applicable Remedial Technologies**

Sediment Characterization Needs for Successful Remedy Selection

- A refined sediment Conceptual Site Model (CSM) is critical to remedial alternative development and remedy selection
- Data needs for sediment CSMs fall into four general categories that are required to support all remedies
  - Physical Characteristics
  - Sediment Geotechnical Characteristics
  - Contamination Characteristics
  - Land and Waterway Use Characteristics

Key Point Need to pick and choose carefully from long list of available tools those that are best applicable to your site

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Introductory slide for characterization section.

Sediment Characterization Needs for Successful Remedy Selection (cont.)

- The CSM is a dynamic model that is updated at several points in the environmental restoration process
- Site characterization is often a multi-stage process with different objectives and data requirements at each stage:
  - SI stage (Does the site merit detailed investigation?)
  - RI stage (Are there portions of the site that pose excess risk?)
  - RI or FS or Remedial Design stage (Do we have adequate data to select and design an appropriate remedy?)

Key Point Level of data collection has to be guided by the decisions that the data will support

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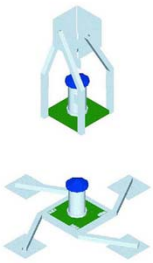
Introductory slide for characterization section.

Presentation Overview

- ► Sediment Characterization/Assessment
  - ► Physical Characteristics
  - – Sediment Geotechnical Characteristics
  - – Contamination Characteristics
  - – Land and Waterway Use Characteristics
  - – Summary
- Selecting Applicable Remedial Technologies

Physical Characteristics

- Physical characteristics are a critical, but <u>often overlooked component of the CSM</u>
- Physical characteristic data can identify potential sources and transport pathways that refine the CSM



<u>Acoustic Doppler Current Profiler (ADCP)</u> in the stored position (above) and deployed position (below) to measure vertical current distributions in the water column (US Navy)

- Key Physical Characteristics
  - Bathymetry
  - In-water infrastructure and presence of debris, and outfall information
  - Hydrodynamic processes (waves, currents, tides)

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Understanding the hydrodynamic processes occurring at sediment sites are the most critical data needed for the development, evaluation and implementation of MNR and EMNR remedies. Measures of the forces (discharge, waves, currents, tides) that drive the major sediment transport processes (erosion, water column transport, deposition) are necessary to effectively evaluate MNR and EMNR remedies.

Physical Characteristics Data Needs for Successful Remedy Implementation

Data Need	Tools	Purpose
Water Depth and Site Bathymetry	Single or multi-beam bathymetric survey	Remedy design and performance evaluation
In-water infrastructure, presence of debris	Multi-beam side scan sonar	Remedy design and operational planning
Hydrodynamics	*Acoustic Doppler Current Profiler (ADCP), current meters	MNR (deposition/erosion) evaluation, capping stability evaluation
Groundwater-Surface water interaction	Trident Probe	Identify groundwater seeps

*Underlining in 'Tools' column indicates important tool

Key Point ADCP could be useful at many more sites. Trident probe is common at sites with groundwater-surface water discharge.

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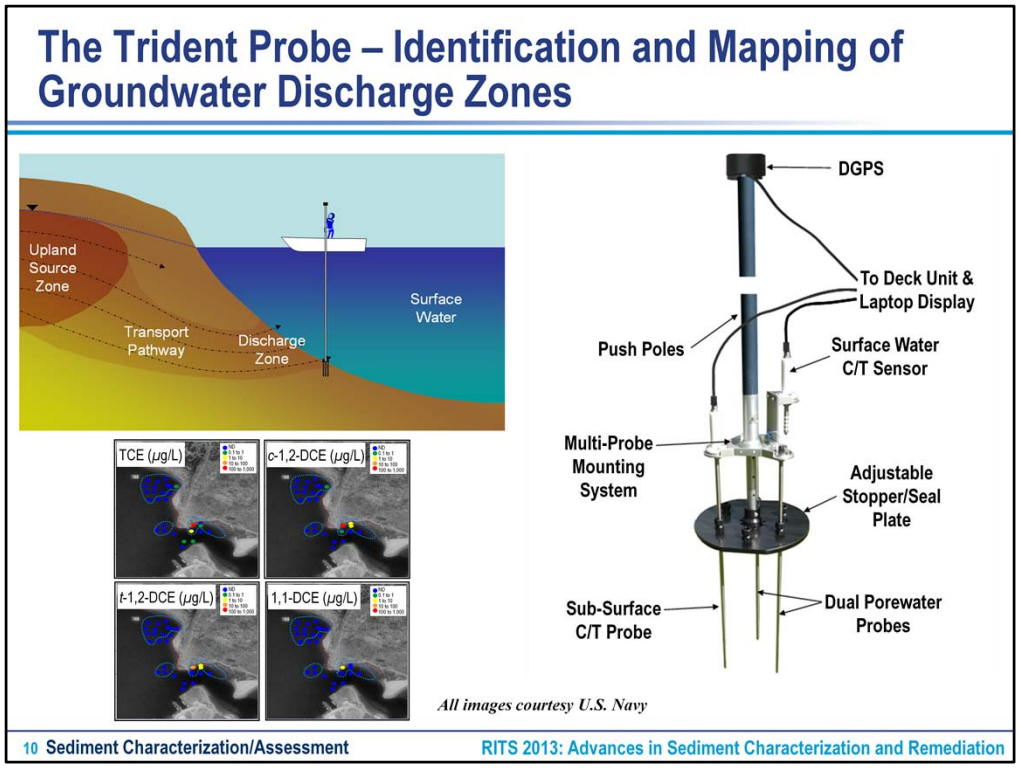
1. Highlights denote tools that are a bit outside the normal suite – more specialized tools and ones that are under development.
2. Bathymetry - Evaluating bottom elevations for comparison to design specifications, and evaluating sediment stability during natural recovery.
3. In-water infrastructure, presence of debris - All infrastructure (bridges, pilings, piers, and even shoreline) adjoining potential remedial footprint needs to be evaluated. Large and small debris poses challenges to dredging equipment and slows down operation.
4. Hydrodynamics - Waves, currents, and fluctuating water levels may determine feasibility of removal and certain controls, such as silt curtains.
5. Trident Probe – see subsequent slide



Trident Probe:

1. Mapping system for identification of potential ground water discharge zones.
2. Screening sensor maps potential discharge zones based on conductivity and temperature contrast.
3. Porewater probe allows subsurface sampling in potential discharge zones.

SSC San Diego TR 1903: Coastal Contaminant Migration Monitoring: The Trident Probe and UltraSeep System, June 2003

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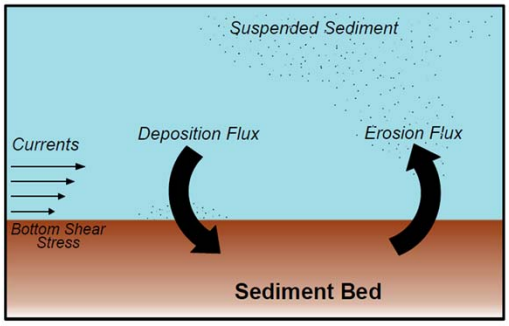
Sediment Geotechnical Characteristics

- User's Guide for Assessing Sediment Transport at Navy Facilities
- Success of many remediation approaches is directly affected by physical sediment transport processes



Key Transport Processes

1. Erosion
2. Movement of sediments in the water column
3. Deposition

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Sediment Transport Guide

1. It identifies and reviews methods and tools that can be used to characterize sediment transport.
2. Provides a framework that can be used to more clearly identify the types of measurements and data analysis methods that can be used at a contaminated sediment site.
3. Provides guidance on how the results of a well-designed sediment transport evaluation can be used to develop management decisions for contaminated sediment sites.

Sediment Geotechnical Characteristics (cont.)

Data Need	Tool	Purpose
Bulk geotechnical parameters	Standard analysis	Particle size distribution, bulk density, porosity, water content, plasticity, shear strength, compressibility may influence choice of remedy and removal equipment
Sediment Deposition Rate	Radio-isotope age dating, Sediment Traps	Helps determine extent of deposition and feasibility of natural recovery
Erosional potential of bedded sediment	Shaker/annular flume	Helps determine critical shear stress that would cause erosion

Key Point **Radio-isotope age dating is likely to be useful at many sites, especially when coupled with the ADCP**

See “Sediment Transport Tool Guidance Document” for detailed information on using these tools to address data needs.

Sediment Geotechnical Characteristics (cont.)

Data Need	Tool	Purpose
Sediment Stratigraphy	Sub-bottom Profiler Data	Changes in sediment subsurface layers, bioturbation and oxidation depths, and presence of gas bubbles
	Side Scan Sonar Data	Remote sensing to monitor the distribution of sediment types and bed forms; determine presence of debris
	Sediment Profile Camera Data	Changes in thin layering within sediment profiles, sediment grain sizes, bioturbation and oxidation depths, and presence of gas bubbles

Photo courtesy NOAA/Department of Commerce

See “Sediment Transport Tool Guidance Document” for detailed information on using these tools to address data needs.

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Contamination Characteristics

- An adequate understanding of types, concentrations, and distribution of contamination is critical for remedy development
- Implementation Guide For Assessing and Managing Contaminated Sediment at Navy Facilities (UG-2053-ENV, Jan. 2005)

- Key Contamination Characteristics
  - Horizontal and vertical extent of contamination
  - Site risks/toxicology and bioavailability of contamination
  - Background concentrations

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Guidance Document Discusses Critical Sediment Issues:

1. Addressing multiple contaminant sources (Navy and non-Navy);
2. Development of a detailed and accurate Conceptual Site Model (CSM);
3. Collection of important geochemical and physical information for characterizing the source, fate, and transport of chemicals in sediment and supporting the evaluation of remedial alternatives;
4. Selection and use of appropriate tests for ecological risk assessments (ERAs) (e.g., bioavailability evaluations, aquatic toxicity tests);
5. Use of background and reference site data in risk assessments;
6. Use of a weight-of-evidence (WOE) approach and other decision-making tools;
7. Development of site-specific risk-based cleanup goals; and
8. Evaluating remedial options for sediment and the risk and liabilities associated with each.

Contamination Characteristics Data Needs for Successful Remedy Implementation

Data Need	Tools	Purpose
Horizontal and Vertical Extent of Contamination	Sediment Grab Samplers	Collection of sediment samples for analysis
	Coring Devices (*e.g.*, Vibracore™, gravity piston, drop tube)	Vertical profile of sediment . Detection of contaminant movement through cap or naturally deposited clean sediment
	Rapid Sediment Characterization (RSC) Tools, such as XRD and Immunoassays	Semi-quantitative measurements of chemical, physical, or biological parameters on real-time or near real-time basis, in the field or laboratory

Key Point **See RITS Spring 2000 for discussion of RSC Tools, which can be cost-effective for preliminary characterization of large areas of contaminated sediment**

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Rapid Sediment Characterization (RSC) Tools

1. Semi-quantitative analytical tools that provide measurements of chemical, physical, or biological parameters on a real-time or near real-time basis and are used in a field or laboratory setting for sediment
2. DON policies invoke the use of advanced chemical and biological screening to identify potential sources of contamination and delineate areas of contamination
3. Rapid Sediment Characterization Tools, SSC San Diego TR 1970

Contamination Characteristics Data Needs for Successful Remedy Implementation (cont.)

Data Need	Tools	Purpose
Extent of Water Column Contamination	Direct Water Column Measurements (probes)	Measurement of parameters such as pH and dissolved oxygen in the water column
	Surface Water Samplers	Measurement of contaminant concentrations (dissolved and particulate) in the water column, during investigation or remedy implementation
	Semi-Permeable Membrane Devices	Measurement of dissolved contaminants at sediment-water interface
	Seepage Meters	Measurement of contaminant flux into the water column

Key Point: **Particulates are often measured during implementation of dredging or capping remedies to verify effectiveness of resuspension controls**

1. See Passive Sampler presentation for more information on semi-permeable membrane devices.
2. See SSC San Diego TR 1903: Coastal Contaminant Migration Monitoring: The Trident Probe and UltraSeep System, June 2003 for more information on Seepage Meters

Contamination Characteristics Data Needs for Successful Remedy Implementation (cont.)

Data Need	Tools	Purpose
Toxicity and Bioavailability of Contamination	Benthic Community Analysis	Evaluation of population size and diversity, and monitoring of recovery following remediation
	Toxicity Testing	Measurement of acute and long-term lethal or sub-lethal effects to help establish a protective range of remediation goals
	Tissue Sampling	Measurement of bioaccumulation, modeling trophic transfer potential, and estimating food web effects

See useful ITRC 2011 document, *Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites* Website

Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites Guidance Document:

1. Provides a basic understanding of bioavailability
2. Provides direction as to where bioavailability considerations may be pertinent in the human health and ecological exposure assessment processes
3. Describes the pertinence of assessing bioavailability during risk assessment process
4. Describes the tools available for bioavailability assessment and their application
5. Describes how bioavailability considerations can be used in risk management of contaminated sediment sites
6. Provides case studies that highlight the application of bioavailability assessment tools and methodologies in contaminated sediment site risk management

Contamination Characteristics Data Needs for Successful Remedy Implementation (cont.)

Data Need	Tools	Purpose
Toxicity and Bioavailability of Contamination	Sea Rings	*In situ* approach for assessing sediment ecological risk, remediation effectiveness, and storm water impacts
	Caged Fish/Invertebrate Studies	Monitoring change in uptake of contaminants by biota to measure the effect of remedy on bioaccumulation rates
	Sediment Profile Camera Studies	Indirect measurement of macroinvertebrate recolonization, for example, measuring population density of polychaetes by counting number of burrow tubes per cm along sediment-water interface
Sediment and Pore Water Geochemistry	Passive samplers	May impact fate and transport of contaminants during and after removal

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Passive Samplers – see RITS presentation on Passive Samplers

Navy Research Highlight

Sediment Ecosystem Assessment Protocol (SEAP) (ESTCP ER 201130)

- Improved *in situ* approach for assessing sediment ecological risk, remediation effectiveness, and storm water impacts
- SEAP technology integrates *in situ* biological uptake and effects measurements with passive sampling devices and physicochemical tools

Sediment Ecotoxicity Assessment Ring (SEA Ring)

Photo courtesy University of Michigan

The SEAP technology can be accessed from SPAWAR Pacific. See also ESTCP Project ER-201130.

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Sediment Ecosystem Assessment Protocol (SEAP) (ESTCP ER 201130)

1. SEAP technology integrates in situ biological uptake and effects measures with passive sampling devices and physicochemical tools to assess the sediment-water interface, surficial sediment, overlying water, and advective exposure pathways at contaminated sediment sites.
2. Ongoing ESTCP Demonstration/Validation Project

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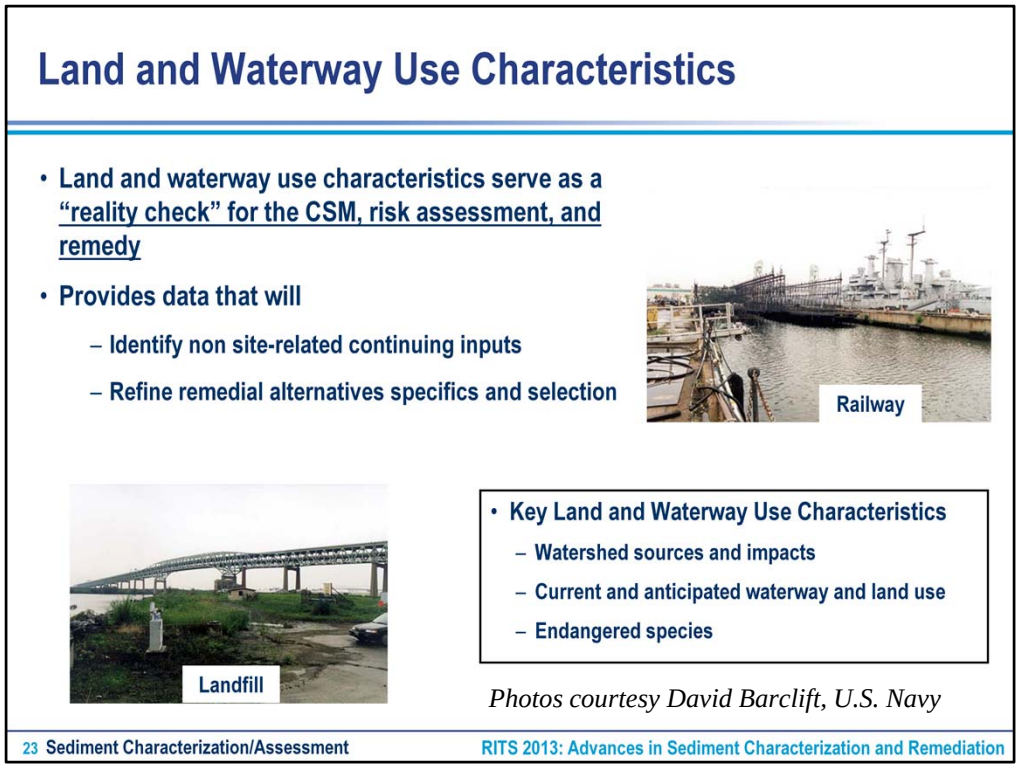

1. Cap Placement: If the site under consideration is adjacent to or within a water body used for navigation, recreation or flood control, the effect of cap placement on those uses should be evaluated. Other activities in and around the water body may also impact cap integrity and maintenance needs and should be evaluated. These include the following:
    - Water supply intakes;
    - Storm water or effluent discharge outfalls;
    - Utilities crossings;
    - Construction of bulkheads, piers, docks, and other waterfront structures;
    - Navigational dredging adjacent to the cap area; and
    - Future development of commercial navigation channels in the vicinity of the cap.
2. Dredging: Any evaluation of the feasibility of a dredging or excavation remedy should consider impacts to existing and reasonably anticipated future uses of a waterway. Waterway uses that may need to be considered when evaluating a sediment removal alternative include the following:
    - Navigation (e.g., commercial, military, recreational);
    - Residential/commercial/military moorage and anchorage;
    - Flood control;
    - Recreation;
    - Fishing (e.g., subsistence, commercial, recreational);
    - Water supply, such as presence of intakes;
    - Storm water or effluent discharge outfalls;
    - Use by fish and wildlife, especially sensitive or important aquatic habitats;
    - Waterfront development;
    - Utility crossings; and
    - Existing dredge disposal sites.

Land and Waterway Use Characteristics Data Needs for Successful Remedy Implementation

Data Needs	Tools	Purpose
Watershed Sources and Impacts	Watershed Contaminant Source Document (WCSD)	Upland (and upstream) sources that may contribute to background concentrations of contamination in sediment need to be determined and addressed to prevent recontamination following remedy
Cultural and Archeological Resources	Multi-beam side scan sonar, sub-bottom profiler	May need to develop a plan to address any cultural resources through avoidance during removal or by other alternatives
Site Access (staging, treatment, transport, disposal)		Important factor influencing types of capping or removal equipment that can be deployed and how removed sediment will be handled

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Watershed Contaminant Sources Document (WCSD) (CNO Policy)

- Summary document 2 to 10 pages
- Lists all sources
- Identifies potential contaminated sources, releases, transport routes, etc.
- Documents the existence of non-Navy sources
- Conducted only when there are potential other sources
- Contains a pictorial CSM
- Given to regulators

Land and Waterway Use Characteristics Data Needs for Successful Remedy Implementation (cont.)

Data Needs	Tools	Purpose
Anthropogenic activities (current and future land and water use)	Information on outfalls, past and future dredging, navigation, construction, water use	Influence risk assessment, remedy selection, types of ICs
Presence of unique or sensitive Endangered Species and/or Habitat	Multi beam side scan sonar, diver surveys	May influence remedy selection, types of controls deployed if removal selected, and management of residuals

Innovative Sediment Corer with Metal Detection

- Sediment coring barrel whose leading edge can detect metal objects, such as utilities and munitions and explosives of concern (MEC), in advance of its penetration in the sediment bed
  - 20 mm at 10 inches
  - 40 mm at 13 inches
  - 80 mm at 16 inches
  - 105 mm at 21 inches

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Summary – Sediment Characterization/Assessment

- Many tools. Choose most applicable ones for your site
- Don't forget your CSM and data quality objectives (DQOs)
  - Make sure you know why you need the data and how you plan to use them to make good decisions
- DON Guidance for Planning and Optimizing Monitoring Strategies: Chapter 6 Contaminated Sediments, NFESC UG-2081-ENV Rev 1 (Navy 2010)

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Remainder of presentation provides more information on data needs and measurement techniques.

Presentation Overview

- Sediment Characterization/Assessment
- ► Selecting Applicable Remedial Technologies

New ITRC Guidance Document on Sediment Management

- ***Remedy Selection Framework for Contaminated Sediments***, ITRC 2013 (expected)
  - Selecting applicable technologies
  - Monitored Natural Recovery (MNR)
  - *In situ* treatment
  - Conventional and amended capping
  - Removal
  - Monitoring
  - Stakeholder concerns

New Guidance Document that Addresses Underwater Munitions

- ***Remediation of Sediments Containing Military Munitions***, expected 2013 release
- Prepared for Chief of Naval Operations (N45)
- Useful guidance on what RPMs can do if underwater munitions are encountered at a sediment site

Photos courtesy U.S. Navy

Presentation Overview

- Sediment Characterization/Assessment
- ► Selecting Applicable Remedial Technologies
  - ► Selecting Applicable Approaches
  - – Monitored Natural Recovery (MNR)
  - – Capping
  - – Dredging
  - – Innovative *In Situ* Treatments
  - – Natural Resource Injury (NRI) and Natural Resource Damage Assessment (NRDA)
  - – Summary

Selecting a Suitable Sediment Management Approach

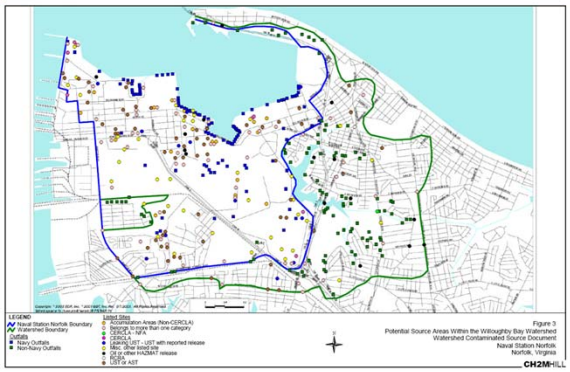
- Human health risk (fishing, swimming, drinking)
- Ecological risk (benthic organisms, fish, birds)
- Sediment volumes impacted are often large. Remedies are costly.
- Greater need than ever to balance risk reduction and cost
- Recent moves to develop ARARs for sediment

Selecting a Suitable Sediment Management Approach (cont.)

- Define risk, develop preliminary remediation goals (PRGs)
  - Account for overly conservative assumptions (*e.g.*, subsistence fisherman)
- Source Evaluation
  - At many sediment sites in industrial and urban settings, there could be significant background levels or non-Navy sources
  - Chemical fingerprinting can help (see RITS Fall 2004)

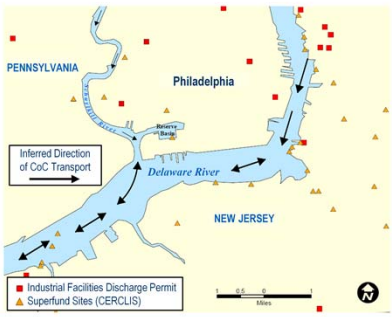
DON Policy on the Use of Background Chemical Levels (January, 2004)

DON Policy on Sediment Site Investigation and Response Action (February 8, 2002)



"All sources shall be identified to determine if the Navy is solely responsible for the contamination."

Watershed Contaminated Source Document, CNO N45 (March 2003)



"The project team will generate a <u>Watershed Contaminated Source Document</u> if there are potentially other non-Navy sources contributing to the contamination of the sediment"

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Selecting a Suitable Sediment Management Approach (cont.)

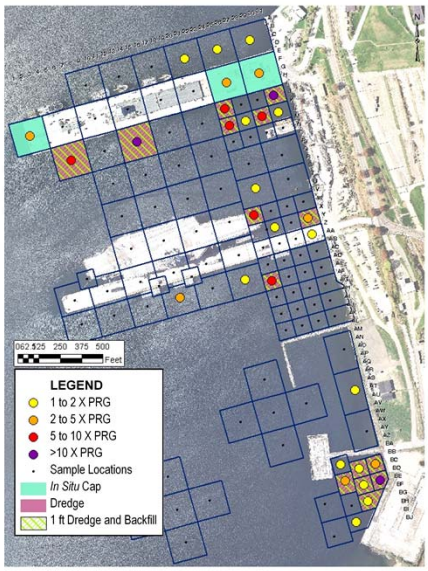
- When selecting remedial alternatives, do not confuse protectiveness with resource management
  - Need to discuss projected land and water uses in detail with stakeholders
  - Not every site will encounter future use as a cruise ship terminal or aircraft carrier dock

Selecting a Suitable Sediment Management Approach (cont.)

- **Define the start and end points for remediation**
  - **Point-by-point achievement of PRGs**
    - Most conservative, generally unnecessary
  - **Statistical test (confidence levels)**
  - **Surface-weighted average concentration (SWAC) less than or equal to PRG**

Case Study: Defining Remediation Start and End Points at Navy's Derecktor Shipyard, RI

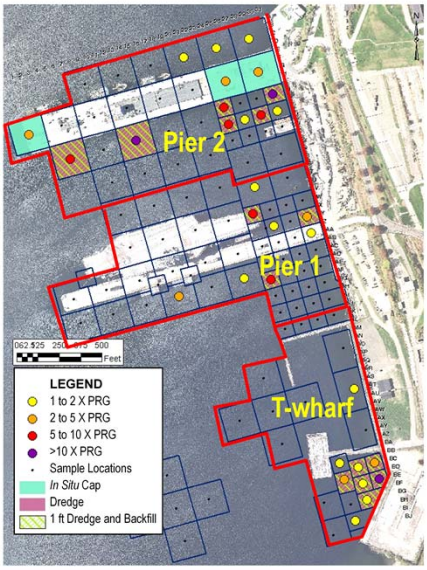
- PCBs > 10 ppm in hot spots
- PRG = 1 ppm
- Areas of exceedance requiring action defined by <u>site-wide SWAC</u> > 1 ppm
- Surface sediment defined by 0- to 1-foot interval



Courtesy U.S. Navy

Case Study: Defining Remediation Start and End Points at Navy's Derecktor Shipyard, RI (cont.)

- Another scenario: Divide site into open water areas and under pier areas and calculate SWAC
- Another scenario: Divide site into three units and calculate SWAC for each:
  - Pier 1
  - Pier 2
  - T-wharf area
- Be careful which baseline is chosen:
  - Grid cells > PRG (more conservative)
  - All cells (less conservative, but may make sense at some sites)



Courtesy U.S. Navy

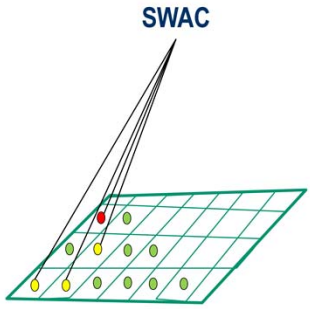
Case Study: Defining Remediation Start and End Points at Navy's Derecktor Shipyard, RI (cont.)

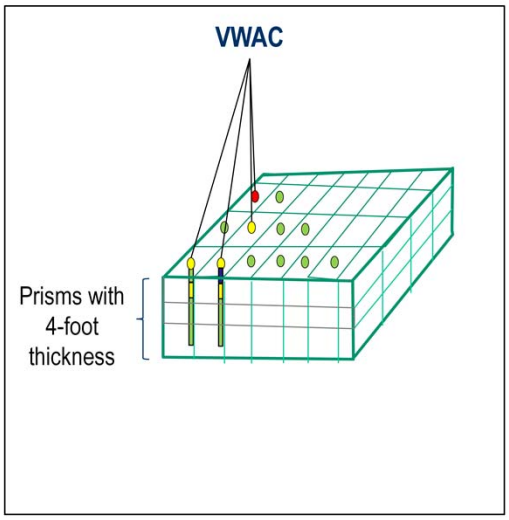
- What do we do about deeper sediment?
  - Remove?
  - Cap?
  - MNR?
  - Institutional Controls (ICs) and LTM?

Photo courtesy U.S. Navy

- One Approach: No Further Action (NFA), if volume-weighted average concentration (VWAC) can be reduced below PRG

Calculating Surface-Weighted and Volume-Weighted Average Concentrations (SWAC & VWAC)





Case Study: Defining Remediation Start and End Points at Army's Pegan Cove Site, Natick, MA

Achieved NFA
in 2011 after SWAC of 1 ppm for PCBs
was met cove-wide
by dredging three hot spots

Select Appropriate Technology to Help the Site Along to the Endpoint in the Most Efficient Manner

1. Is MNR viable?
   - If not, can enhanced MNR make it viable?
2. Is capping viable?
3. Is dredging required?
4. Will some combination of MNR, capping, and/or dredging work?

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- Sediment Characterization/Assessment
- ► Selecting Applicable Remedial Technologies
  - Selecting Applicable Approaches
  - ► Monitored Natural Recovery (MNR)
  - Capping
  - Dredging
  - Innovative *In Situ* Treatments
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MNR for Sediments

- Left to natural processes, will the site (or portions of the site) achieve PRGs in an acceptable timeframe?
- How long will it take to gather sufficient evidence that MNR is working?
  - Already have convincing data?
  - Will it take another year?
  - Another 3 years?

Photo courtesy U.S. Fish & Wildlife Service

45 Monitored Natural Recovery (MNR) RITS 2013: Advances in Sediment Characterization and Remediation

What are the initial contaminant levels in surface sediment:

With reference to PRGs?

With reference to human health and ecological risk thresholds?

With reference to background levels?

Mechanisms of MNR

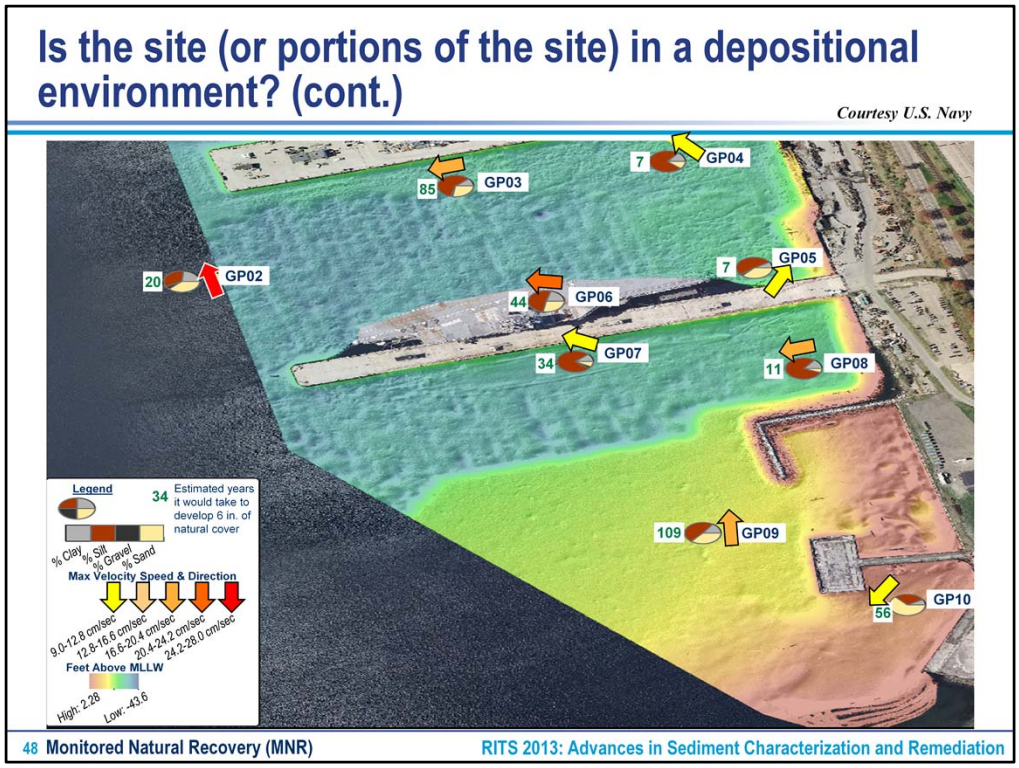
- Is there evidence of chemical or biological transformation of contaminant to non-toxic products?
  - Difficult to nail this factor, unless VOCs or certain redox-sensitive metals are involved
- Is erosion causing dispersion?
  - Dispersion mentioned as MNR mechanism in EPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, 2005, but acceptance is difficult
- Is there evidence of natural deposition?

Key Point MNR often comes down to ability to show depositional environment

Is the site (or portions of the site) in a depositional environment?

Useful Measurements at Most Sites

- Bathymetry
- Contaminant levels versus depth in sediment
- Visual evidence of bedding in cores
- Sediment accumulation rates measured by isotope analysis
- Current velocity of overlying water versus critical shear stress of sediment
  - Acoustic Doppler Current Profiler



Fewer monitoring points required for these physical measurements than for mapping contaminant distribution

MNR for Sediments – Long Term Viability

- **How resilient is MNR to frequent or infrequent disruptive events?**
  - **100-year storms/floods?**
    - Answer is usually complex
  - **Ship traffic?**
    - Depends on the ships and location of contamination

Question is difficult to answer and RPMs must be ready to discuss with stakeholders, if it comes up. Typically, contamination deeper in sediment is less of a risk because disruptive events tend to mix deeper contamination with overlying and/or surrounding cleaner sediment. Another reason why volume-weighted average concentrations (VWAC) make sense – risk of deeper sediment is weighted appropriately.

Will MNR be sufficiently protective in the long term? – Importance of Projected Site Use

USCG Tigershark,
Draft 6 feet

Photo courtesy U.S. Coast Guard

USCG Juniper,
Draft 13 feet

NOAA H.B. Bigelow,
Draft 19 feet

Photo Courtesy NOAA

50 Monitored Natural Recovery (MNR) RITS 2013: Advances in Sediment Characterization and Remediation

Some ships have shallower draft than other ships. Important to recognize projected use of waterway, while discussing long-term viability of MNR or ICs.

MNR and ICs
– Which ICs are required and are they enforceable?

- Are ICs necessary while MNR is underway?
  - ICs for fishing? For swimming?
  - Recreational boating? Commercial shipping? Cruise ships?
  - Anchoring?
- Are required ICs <u>enforceable</u>?
  - At operational Navy sites, case for ICs can be strong
  - At BRAC sites, need careful consideration
- ICs are tied to <u>land and water use</u>

MNR Applicability

- If MNR is not viable in all parts of the site, is it viable in some parts?
- What is the burden of long-term monitoring and ICs going to be with MNR (or capping)? How does it compare to dredging?

Key Point: Question (MNR versus dredging) has become important, given recent developments on remediation endpoint

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If enough dredging can be done to meet SWACs and VWACs of PRG or less and if that makes the site ready for NFA status, higher initial cost of dredging may be economical in the long run, compared to long-term costs of MNR and monitoring (or capping and monitoring).

Enhanced MNR

- Common situation: PRP and stakeholders agree that the site is in a depositional environment, but sediment accumulation rates are too slow
- What is too slow? Answer is usually complex.
- Thin layer placement of clean material on top of native sediment to help MNR get a running start
- Although settling and bioturbation may cause some mixing of clean (added) and contaminated (native) sediment, the surface sediment may meet PRGs in critical biologically active layer (top 15 cm)
- ICs may still be needed to avoid disruption of surface sediment

Case Study: OU-5, Catherine Mines & Skaggs Tailings Subsites, MO

- **Risk**
  - Heavy metals (As, Co, Mn, Pb) in sediment
  - Designated use of water is recreational, but sediment RAOs were based on ecological risk drivers
- **Selected remedy for sediment (September 2012 ROD)**
  - Dredging, On-site Disposal, and MNR with present value (PV) of $5.9 million
  - The sediment and surface water in Logtown Branch <u>will be sampled annually for five or more years to determine MNR success</u>
  - If MNR is not successful, stream sediment will be addressed as part of the response action for OU7 in the future

Photo courtesy NOAA/Department of Commerce

Case Study:
Bremerton Navy Complex, OU B, Sinclair Inlet, WA

- MNR part of remedy for PCBs in sediment
  - Dredging, isolation capping, thin layer cap selected for 61 acres
  - MNR selected for 230 acres
- Primary natural recovery process is deposition aided by shoreline erosion controls
  - Sedimentation rates (0.5 – 0.75 cm/yr) measured by comparative bathymetry
  - Sediment Profile Imaging (SPI) used to characterize recently deposited layers
- Recent monitoring indicates that PCBs will meet cleanup goal target date of 2014 and PCB concentrations will meet background sediment concentrations by 2034

Case Study:
Hackensack River, Study Area 7, Hudson County, NJ

- MNR for chromium in areas where surface sediment did not exceed cleanup goals, but subsurface sediment did exceed cleanup goals
  - MNR for 53 acres
  - Dredging for 0.5 acres and capping selected for 30 acres
- Primary natural recovery process is chemical transformation [Cr(VI) to Cr(III)]; secondary mechanism is physical isolation (burial)
  - Transformation of Cr(VI) to less available and less toxic Cr(III) measured by sediment redox test; resuspension and oxidation test; toxicity tests and tissue concentrations
  - Physical isolation measured by radioisotope age dating, sediment traps, shear stress evaluation and hydrodynamic modeling
- MNR will be considered successful if 5 years of routine monitoring and 15 years of severe event monitoring show acceptable bed elevations through bathymetry

Case Study: Lower Fox River and Green Bay, WI

- MNR selected as part of multi-component remedy for PCBs (primary), other COCs
  - MNR selected for 20 miles of Fox River and 2,650 acres in Green Bay
  - Capping and dredging selected for 19 miles of Fox River and 50 acres in Green Bay
- Primary natural recovery processes are dispersion and physical isolation
- MNR success will be determined through LTM (40 years)
  - LTM data includes: tissue sampling; surface water samples to determine downstream transport of PCB mass; surface sediment chemistry to assess potential recontamination; population studies to assess reproductive viability of piscivorous birds

Photo courtesy NOAA/Department of Commerce

Presentation Overview

- Sediment Characterization/Assessment
- ► Selecting Applicable Remedial Technologies
  - Selecting Applicable Approaches
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Engineered Cap or Cover

- Purpose is to physically and/or chemically isolate contaminants from water column above (and create a new benthic community zone)
  - Physical isolation: design appropriate cap thickness
    - Sand or clean sediment
    - Binders (*e.g.*, Aquablok™)
  - Chemical isolation: cap with special and innovative materials, if required (otherwise, sand or clean sediment is generally used)
    - Activated carbon (filled geo-textile mats, Sedimite™)
    - Other (*e.g.*, zeolite, organically modified clay)

Photo courtesy NOAA/Department of Commerce

Capping – Field Experience (ITRC 2013)

- **27 full-scale applications**
  - **All 27 sites capped with sand or silt**
    - 10 sites had caps < 2 ft thick
    - 8 sites had caps < 3 ft thick
    - Rest were < 2 or 3 ft in some areas, but thicker in hot spots
  - **Some site caps were reinforced by adding special materials to sand/silt**
    - Armoring for erosion control (gravel, rocks, rip rap, geotextile)
    - Activated carbon for extra isolation of contaminants and to minimize cap thickness

Engineered Cap – Methods of Placement

- Direct mechanical placement
- Dumping (from a barge)
- Spreading
  - Spreader or diffuser
  - Tremie
  - Split hull barge
- Innovative placement of filled <u>geotextile mats</u>

Photos courtesy EPA

Innovative Capping – Field Pilot Projects

- Parcel F, Hunters Point Naval Shipyard, CA (2006)
  - Activated carbon mixed with tidal mud-flat sediment using a rototiller or slurry injection for sequestering PCBs
- Aberdeen Proving Ground, MD (2006, 2011)
  - Permeable reactive mat filled with peat, compost, and dechlorinating microbes used to cap groundwater seep containing chlorinated solvents
  - Activated carbon cap for methyl mercury
- NAS Dallas, TX (2008)
  - Geotextile mats with mixture of activated carbon, organo-clay, and apatite for capping sediment with heavy metals and PAHs

Innovative Capping – Field Pilot Projects (cont.)

- **Puget Sound Naval Shipyard, WA (2011)**
  - Activated carbon mixed with clay, other aggregate substrates, to form pellets deposited thru the water to cap PCBs and mercury
- **Grasse River, NY (2006)**
  - Activated carbon mixed with sediment containing PCBs at a water depth of 15 ft with a rototiller
- **James River, VA (2008)**
  - Surface broadcasting of pelletized activated carbon
- **Anacostia River, MD (2004)**
  - Activated carbon in geotextile mats

Photo courtesy NOAA/Department of Commerce

Case Study: Stryker Bay, Duluth, MN

- PAHs in bay sediment – dredged in some places, capped in other places (full-scale application)
- Activated carbon and sand cap
  - Place 6" sand over sediments,
  - Place activated carbon
  - Place 3.5' sand cover and 4.5-6.5' surcharge load to encourage additional consolidation
  - After consolidation, the surcharge sand removed
- Surcharge sand removed and placed in a Contained Aquatic Disposal (CAD) cell

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Dredging

- Removal of contaminated sediment from its natural bedded environment
  - Mechanical dredging
  - Hydraulic dredging
- Dewatering
- Transfer to a more controlled environment (*e.g.*, landfill)
- Beneficial reuse
  - Many pilots, but few full-scale applications

Photo courtesy USACE, New England District

Mechanical Dredging

Photo courtesy USACE, New England District

- Mechanical dredging equipment
  - Backhoe
  - Clamshell
- Most common dredging method (used at 23 of 42 sites studied by ITRC 2013)
  - Effective with many types of sediment (*e.g.*, soft and stiff sediment)
  - Can handle debris
  - Works better in more inaccessible areas
  - Better control than other methods

Photo courtesy NOAA/Department of Commerce

Mechanical Dredging – Dry Excavation

- Sheet pile enclosure or cofferdam
- Dewater inside enclosure
- Excavate under relatively dry conditions, with mechanical dredging equipment
- Used at 6 of 23 sites with mechanical dredging in ITRC guide (2013)
- Usually done in near-shore areas
- *e.g.*, Housatonic River site
- Two main advantages often cited:
  - Improved access for dredging equipment
  - Reduced dewatering requirements after dredging

Hydraulic Dredging

- Fluidize sediment
  - Cutter head
  - Auger
  - Pure vacuum hose is rare
- Pump to the surface
- Pump to onshore dewatering facility
  - Higher water content than mechanical dredging
  - More extensive dewatering
- Used at 19 of 42 sites studied by ITRC 2013

Photo courtesy EPA

Dredging Under Piers or Wharfs: Is it feasible?

- **San Diego Bay, CA – Shipyard Sediment Site**

  Tentative Cleanup and Abatement Order (CAO) signed by San Diego Water Board on Sept. 15, 2010 requiring 15.2 acres of sediment be dredged. Of these 15.2 acres, it identified 2.3 acres that were "inaccessible or under-pier areas", that would be remediated "by one or more methods other than dredging, most likely by sand cover".

- **Harbor Island Site, WA – Todd Shipyard**

  Dredging under pier proposed in 1996 ROD, but ROD also said that final remedy for under-pier portion would be determined in design. Remedial Design abandoned under-pier dredging and implemented a cap under pier in 2007.

- **Harbor Island Site, WA – Lockheed Shipyard**

  Dredging under pier proposed in 1996 ROD. When difficulties became apparent, ESD in 2002 required that pier be removed, so that a cap could be left in place. Wooden pier was easier to remove. Completed in 2005.

Resuspension, Residuals, Releases (RRR)

- Collateral impacts to ecosystem can last for months or years (fish studies)
- RRR increase effort and cost of meeting cleanup goals

Photo courtesy USACE, New England District

Key Point All dredging operations generate RRR

Resuspension, Residuals, Releases (RRR) Controls

- Equipment modifications (*e.g.*, fully enclosed or sealed buckets) can limit, but not eliminate RRR
- Somewhat better results with operational controls
  - Operator experience difficult to replicate
  - Greater operational controls often result in lower production rate, higher cost
- Silt curtains common

Photo courtesy EPA

Case Study: Innovations at Lower Fox River Site, WI

- USACE conducting dredging with USEPA oversight
- Enclosed-bucket dredge increases recovery, reduces losses
- State-of-the-art Real Time Kinetic (RTK) Positioning System custom designed for site has led to <u>increased accuracy, less need for overdredging</u>
- Cost of system was high, but EPA reported that it saved time and money

Dredged Material Handling – Dewatering

- Vital step to management of removed sediment, significant cost
- Facilitates reduction of the volume occupied by the material in the disposal facility
- Reduces the weight of the disposed sediment
- Reduces transportation cost and creates a stable matrix preferred for further treatment

Photo courtesy EPA

Dredged Material Handling – Disposal Methods

- Landfill (most common at 42 sites studied by ITRC 2013)
  - Needs dewatering, sometimes on-site treatment
  - Eliminates need to manage on-site disposal facility forever
- Confined Disposal Facility (CDF)
  - May be economical at large sites
- Contained Aquatic Disposal (CAD)
  - Regulators seem open to this option
- Open Water Disposal
  - Coupled with navigational dredging?

Confined Disposal Facility
Photo courtesy Ohio Department of Natural Resources

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Landfill: cost of transporting and landfilling large volumes of sediment tends to make this disposal method somewhat less desirable than other solutions

Contained Aquatic Disposal: dredged material is deposited within a water body at a nearby location

Confined Disposal Facility: constructed to isolate dredged sediment from the surrounding environment

Dredged Material Handling – Treatment

- Physical Separation
- Bioremediation
- Chemical Treatment
- Sediment Washing
- Solidification/Stabilization
- Thermal Treatment

Photo courtesy USACE

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Physical Separation: used to achieve material homogeneity to facilitate treatment

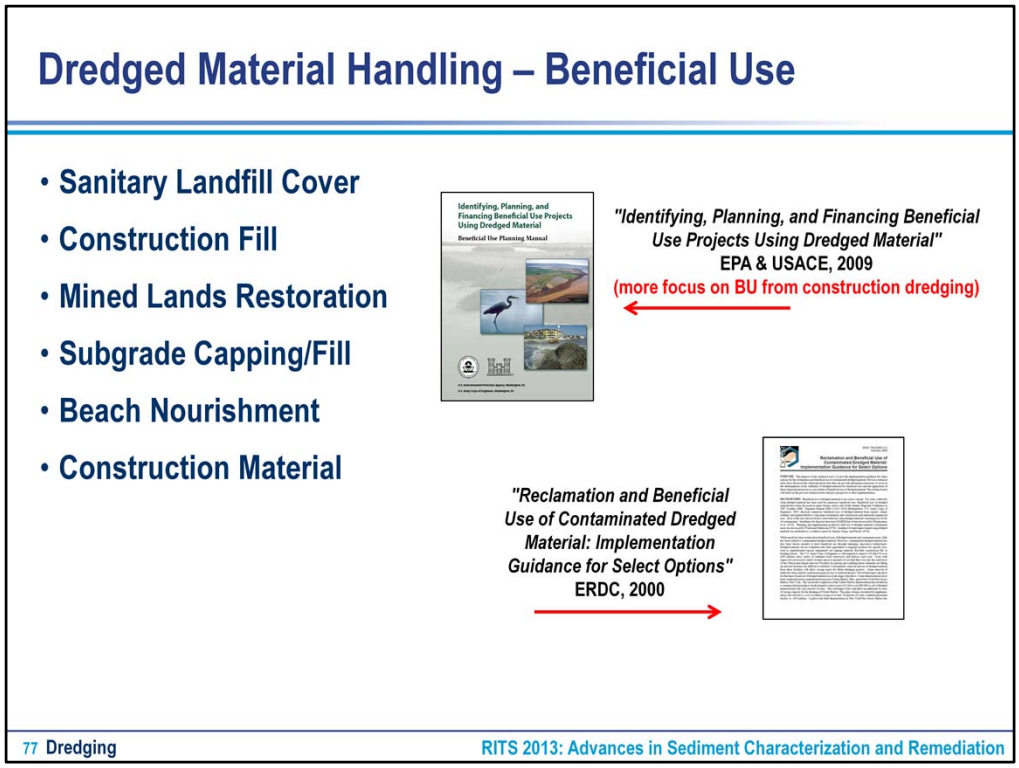
Bioremediation: Fuses microbiological organisms to consume harmful contaminants and convert them into less harmful forms

Chemical Treatment: most beneficial for use with inorganics

Sediment Washing: mixing of extracted sediment with a water and chemical solvent mixture. Organic contaminants separate from the sediment into a concentrated organic solvent.

Solidification/Stabilization: binding of inorganics to the sediment to prevent leachability

Thermal Treatment: incineration, pyrolysis, thermal desorption, and other processes that share the common goal of heating sediment to temperatures capable of destroying organic compounds.



Sanitary Landfill Cover: ideal for use as a daily cap for a sanitary landfill

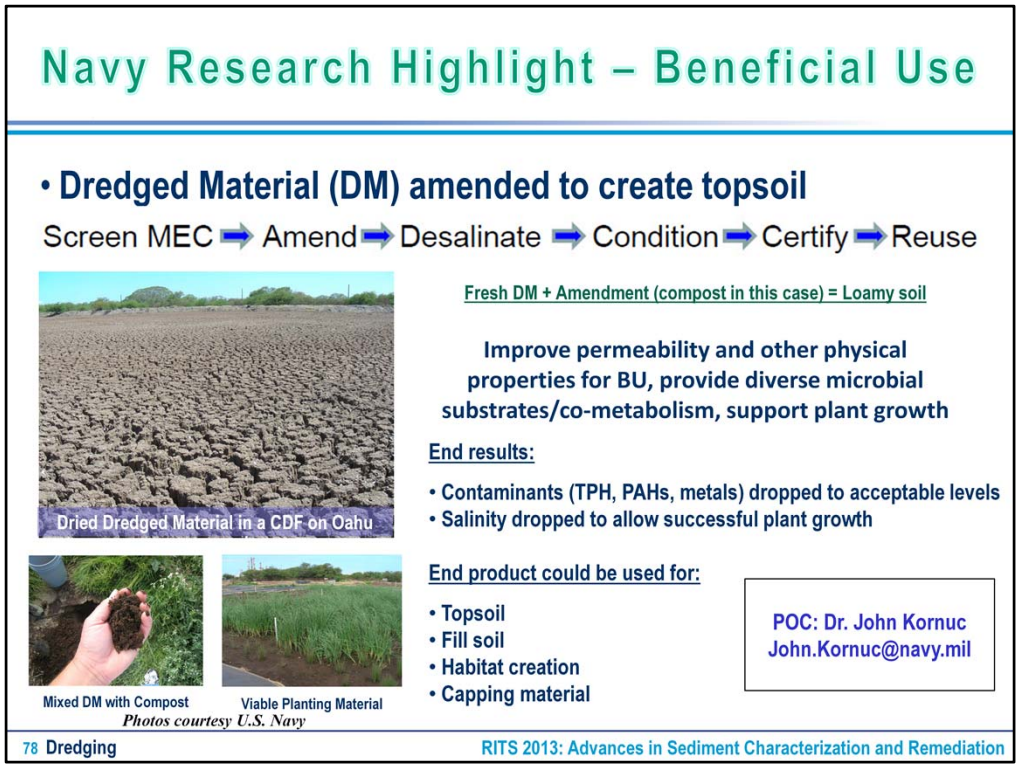
Construction Fill: highly desirable as construction fill based on its physical and chemical properties

Mined Lands Restoration: used to regrade and restore mined lands

Subgrade capping/fill: reduce the cost of bringing in large quantities of clean fill for purposes of habitat restoration or local construction

Beach Nourishment: ideal for application to nearby beaches to replenish material lost to erosion

Construction Material: cement mixed sediment is resistant to leaching and can be prepared with sufficient durability



What do you do with contaminated dredged material when you start running out of room for disposal? In Hawaii, Contained Disposal Facilities (CDFs) are beginning to run low on room and there is land restraints to expanding them. What is an RPM to do? BU!!

Starting sediment contaminants (*i.e.*, pre-treatment) included TPH (diesel range and heavier), PAHs, metals, and PCBs. Of these, TPH, PAHs and copper were above the Hawaii DOH Environmental Action Levels (EALs) for the most stringent category (unrestricted use, within 150 m of a surface water body). TPH and PAH concentrations fell to below EAL guidance within 3 months of treatment (though benzo-a-pyrene, a PAH of high toxicity due to suspected carcinogen properties, was just above the EAL even after treatment), while copper initially decreased (first 3 months), but then rebounded after 6 months, eventually reaching starting concentrations.

The rapid decrease of TPH and most PAHs can be attributed to their biodegradation, enhanced by the microbial populations associated with the compost amendment. The initial decrease in copper was thought to be attributable to plant uptake, but this was probably not the case since copper (and other metals including lead, nickel, and zinc) similarly rebounded. The rebound was likely due to the disappearance of the compost amendment through plant growth and other biological processes, leaving the inorganic fraction, including the metals, behind, effectively concentrating them. Copper was a concern initially since the intent was to have unrestricted use of the treated product, but upon inspection of the origin of the values used as the EAL, it is shown that as long as the material is not used in a setting where sensitive receptors could complete a pathway (i.e. marine invertebrates), the concentrations of copper (250 mg/kg vs. 230 mg/kg EAL) were determined not to be an issue. Furthermore, during the course of the project the HDOH increased the EAL from 230 to 400 for copper.

The addition of compost also has other benefits besides enhancing the biodegradation of TPH and PAHs which include improving the physical characteristic of the sediment, *i.e.,* porosity or permeability. The native sediment is mostly clay/silt, an undesirable material for many beneficial use options. The compost acts as a bulking agent to improve the drainage of the sediment. This not only results in a more loamy final product, it also allows the sediment to desalinate by the flushing action of water applied in the early stage of treatment, as well as via rainwater percolation throughout treatment.

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Innovative *In Situ* Treatments

- Treatment of contaminants with sediments in place
- Treatment technologies are similar to ones for soil and groundwater
  - Bioremediation (ozone, calcium nitrate)
  - Chemical (ZVI)
  - Physical
    - Sorption (zeolite, apatite, carbon, iron oxides), fixation (lime, fly ash)
- Delivery and management of the treatment agent in the sediment is primary challenge
- ITRC 2013 discusses about 10 sites, for which *in situ* treatment has been tested on bench scale
  - Two of them tested in field-pilot system

Innovative *In Situ* Treatments (cont.)

- Chopawamsic Creek, VA (2004-2008)
  - Apatite reacts with heavy metals in sediment to form insoluble phosphates
- Golder Associates (2003)
  - A special injection system with nozzles to introduce calcium nitrate to promote biodegradation of PAHs, BTEX, and TPH

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Natural Resource Injury (NRI) and Natural Resource Damage Assessment (NRDA)

- **CERCLA and OPA authorize certain organizations to act on behalf of the public as Natural Resource Trustees**
  - **U.S. Government**
    - Department of the Interior (often, USFWS)
    - Department of Commerce (often, NOAA)
    - DoD (Navy is trustee of its own property)
    - Department of Energy
    - Department of Agriculture
    - Other agencies authorized to manage natural resources
  - **State Governments (for resources within the State's boundary or for resources belonging to or controlled by the State)**
  - **Indian Tribes (for natural resources belonging to, managed by, controlled by, or appertaining to the Indian Tribe, or held in trust for the benefit of such Indian Tribe**

Photo courtesy NOAA/Department of Commerce

83 Natural Resource Damage Assessment RITS 2013: Advances in Sediment Characterization and Remediation

Oil Pollution Act of 1990 (OPA)

Natural Resource Injury (NRI) and Natural Resource Damage Assessment (NRDA) (cont.)

- Trustees conduct NRDAs, which consist of three steps:
  1. Injury determination
  2. Quantification
  3. Damage determination
- Paying NRD and conducting NRDA are not ER,N or BRAC funding eligible
- Trustees often obtain NRD through the legal system

Navy/Marine Corps Policy on Natural Resource Injury and Damages in the Installation Restoration Program, 2001

Key Point: RPM should select the response alternative, wherever practicable, that will result in the least amount of residual injury

Oil Pollution Act of 1990 (OPA)

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Summary – Sediment Remediation

- Considerable site history available to draw upon, but industry still struggling with basic issues that are inherently problematic and costly:
  - Large volumes of contaminated sediment
  - Proximity to receptors and associated risk
  - Difficulty of operating on water and under water
  - Long-term costs of MNR and cap monitoring
  - Dredged material handling requirements
  - Habitat restoration

Sediment Remediation – Recommendations

- Obtain agreement with regulators and other stakeholders on a well-defined remedy for well-defined risk reduction with well-defined costs as early as possible
  - At 42 sites studied, many sites ended up dredging more sediment than planned
  - Ballpark cost estimates in FS often change into much higher costs during remedy design and implementation

Photo courtesy NOAA/Department of Commerce

Useful References

- Remedy Selection Framework for Contaminated Sediments, ITRC 2013 (expected)
- Incorporating Bioavailability Considerations into the Evaluation of Contaminated Sediment Sites Website, ITRC 2011
- Technical Guide: Monitored Natural Recovery at Contaminated Sediment Sites, ESTCP 2009
- The Four Rs of Environmental Dredging: Resuspension, Release, Residual, and Risk, USACE 2008
- EPA Contaminated Sediment Remediation Guidance for Hazardous Waste Sites, 2005
- Technical Guidelines for Environmental Dredging of Contaminated Sediments, USACE 2008

Useful References (cont.)

- Implementation Guide for Assessing and Managing Contaminated Sediment at Navy Facilities, NAVFAC 2005
- DON Policy on the Use of Background Chemical Levels (January, 2004)
- Watershed Contaminated Source Document, CNO N45 (March 2003)
- DON Policy on Sediment Site Investigation and Response Action (February 8, 2002)
- Navy/Marine Corps Policy on Natural Resource Injury and Damages in the Installation Restoration Program, 2001