Sediment Resuspension by Dredges: Defining the Issues

Doug Clarke
Environmental Laboratory
U.S. Army Corps of Engineers
Engineer Research and Development Center
Topics

• Dredge types
• Definition
  – Related processes
• Persistent issues
  – Loss terms
  – Perceptions versus reality
• Discussion issues
  – Comparison of resuspension sources
  – Adaptive monitoring requirements
• Conclusions
MECHANICAL DREDGES

BUCKET DREDGE

EXCAVATOR DREDGE
HOPPER DREDGES

Draghead Assembly

Surge Compensators
Cutter Rotation
3 – 10 rpm*

Direction of Cutterhead Movement

15 – 60 cm/sec Swing Rate

Sediment

H₂O

Intake
Why Does Resuspension Matter?

• Fundamental determinant of impacts related to exposure to elevated suspended sediment concentrations, turbidity, and contaminants

• Longstanding concerns for potentially sensitive receptors, including SAV, shellfish beds, migratory fishes, etc.

• Critical consideration for the conduct of all navigation/environmental/remedial dredging projects
THE 4 R’S

- **Resuspension** – Dislodging of bedded sediment particles during the dredging process, and consequent transport and settlement of those particles at a new location
- **Release** – Transport of dissolved constituents of disturbed pore water or constituents desorbed from sediment particles
- **Residuals** – Disturbed sediments remaining after cessation of dredging
- **Risk** – Consequences of resuspension, release, and creation of residuals
RISK ASSESSMENT PARADIGM

Problem Formulation → Exposure Assessment → Risk Characterization → Risk Management

Risk = f (Exposure + Effect)

Economic Analysis, Stakeholder Input, Engineering Feasibility → Best Management Practices
Persistent Issues

42 Years after NEPA

• What are the rates of resuspension associated with basic modes of dredging?
• What are the relevant spatial and temporal scales of resuspension?
• What thresholds of suspended and deposited sediment exposure trigger biologically meaningful detrimental responses?
Effects of TSS and Turbidity

On spawning habitat

On oysters

On fish migration

On T&E Spp

On seagrass beds
Juvenile Salmonids

![Graph showing the relationship between concentration (mg/l) and duration (days) for behavioral, sublethal, and lethal effects.](image-url)
Factors That Influence Resuspension

• Mode of dredging
  – Mechanical vs. hydraulic

• Hydrodynamics
  – Prevailing current velocities and vectors
  – Bathymetry

• In situ sediment properties
  – Grain size distribution
  – Water content/bulk density
  – Atterberg Limits (Liquid and Plastic)

• Depth and salinity
Factors That Influence Resuspension

- Operational factors (e.g., bucket dredge)
  - Bucket type
  - Size, volume, exposed surface area
  - Ascent speed
  - Descent speed
  - Reset frequency
  - Cycle time
  - Production rate
  - Sediment adhesion
  - Leakage from seals
  - Debris
  - Bottom sweeping/bed leveling
  - Anchoring and spud movements
  - Barge overflow
  - Tug and tender maneuvering
  - Operator skill
Perceptions vs. Reality

• Prevailing assumption that resuspension controls provide environmental protection
• Controls frequently slow down production rates
• Tradeoffs are often ignored
  – e.g., many critters tolerate short, intense insults better than chronic insults
  – e.g., air quality effects due to prolonged emissions
CONCEPTUAL PLUME DYNAMICS

- True source
- Virtual release
- Practical source
- Practical range of field measurement

- Mass of sediment in suspension
- 'Fall-out' of large lumps
- Turbulence due to dredging equipment
- Initially dynamic, tending to passive with time
- Progressive settling of coarse particles
- Fine sediment remains in suspension until quiescent water is encountered
- Essentially passive plume

- Dredging Zone
- Near-field Plume
- Far-field Plume

- Seconds
  Minutes
  Hours
Plume Spatial/Temporal Scales

Dredge

Dredging Zone or Initial Mixing Zone

FLOW

Seconds - Meters

Minutes - 100s of Meters

Hours - > 1,000 Meters

Near-Field

Far-Field

Residual Plume
Characterization of Spatial Dimensions

FLOW

Dredge

Dredging Zone

Near-field Plume

Far-field Plume

ADCP Transects
Characterization of Temporal Dynamics

FLOW

OBS Time Series Stations

Dredging Zone
Near-field Plume
Far-field Plume

Ambient
Bucket Dredge Plume Components…

- slewing
- exit and initial leakage
- hoisting
- bed impact and separation

Dredging Research Ltd
Comparative Resuspension Rates

- Mean loss rate for mechanical dredges = 2.1%
  - Nakai – 0.02 to 0.6%
  - Hayes and Wu – 0.2 to 0.9%
  - Pennekamp - 0.3 to 1% open bucket, 0.3 to 2% closed bucket
  - Tavolaro – 2%
  - Bohlen, Anchor Environmental – 1 to 3%
  - Land and Clarke – 5 to 9%

- Mean loss rate for hydraulic dredges = 0.77%
  - Nakai – 0.01-0.04% in sand
  - Nakai – 0.17-2.56% in silty clay
  - Pennekamp – 0.01%
  - Hayes and Wu – 0.02-0.13% in clay and silt
PLUME SIMULATION TOOLS & FIELD CHARACTERIZATIONS

• Monitoring methodologies
  • To calibrate and verify models
  • To provide adaptive management input

• Dredging process models

• Far-field plume models
Particle Tracking Model (PTM)

- 3D dynamic transport
- Follows size classes of sediment through complex grids
- Accepts external source term
- Ability to compute deposition and re-entrainment
- Adding modules to track water quality and contaminants
- Adding module to calculate exposures of organisms to suspended or deposited sediment
Discussion Issues

• Placing dredging into perspective with other sources (e.g., ship traffic, storms, freshets)

• Effectiveness of controls incorporated into navigation dredging WQ certificates
  – silt curtains
  – bucket types
  – operational measures
  – environmental windows
Ships as a Source of Resuspension

Plume Generated by Bow Thruster

Tug Plume
Conclusions

- Resuspension issues form a basis for a majority of problematic environmental concerns
- These issues have proven to be exceedingly difficult to resolve
- Progress needed toward reasonable, science-based, technically defensible solutions
- Mutual objective – management practices that minimize risk while maintaining dredging project flexibility
Questions?