Impact of Mud Aggregate Processes on Sediment Transport in Dredging Projects

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CHL COASTAL & HYDRAULICS LABORATORY

US Army Corps of Engineers

ERDC ENGINEER RESEARCH & DEVELOPMENT CENTER

USACE Sediment Mission Areas

Manage sediment in ports/wetlands/coastal areas across the nation.

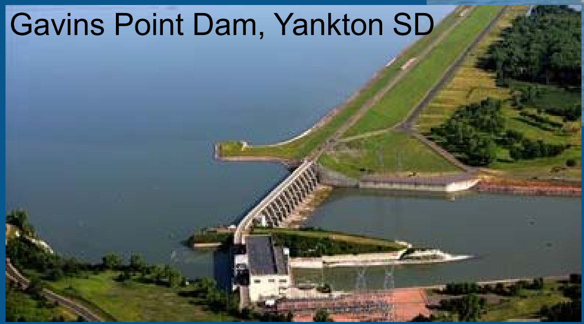
- **Navigation**
- **Flood & Coastal Protection**
- **Environmental Restoration**

Commonly, sediments are heterogeneous mixtures of sand, silt and clay that can produce bed aggregates.

USACE-ERDC mission to improve sediment management practices and transport modeling capabilities in these areas.

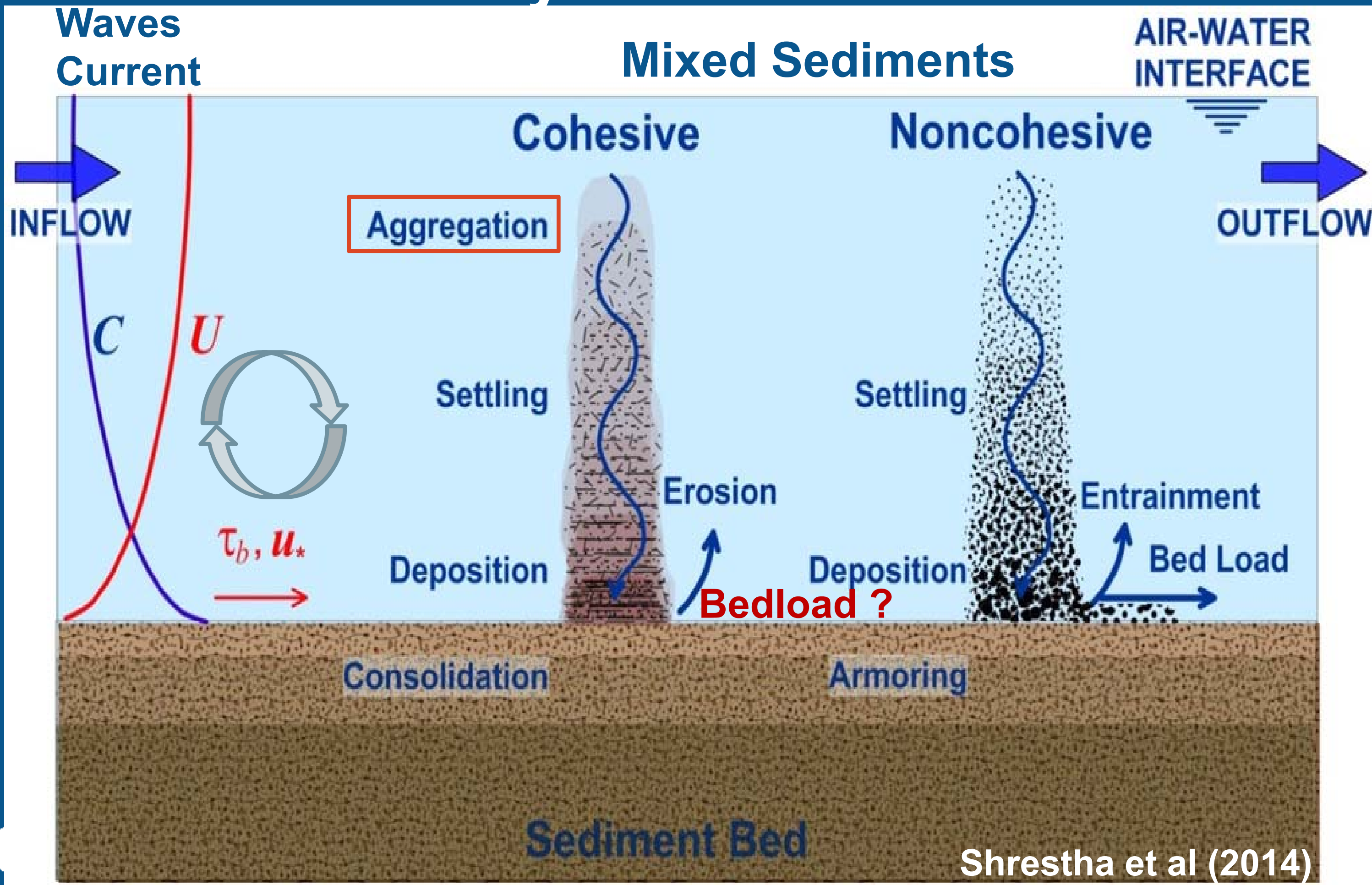
Current numerical models do not incorporate bed aggregate transport processes, but instead frequently rely on disaggregated GSD data.


Channel Dredging, Wilmington NC
Photo courtesy USACE-SAW


Gavins Point Dam, Yankton SD
Photo courtesy USACE-NWD

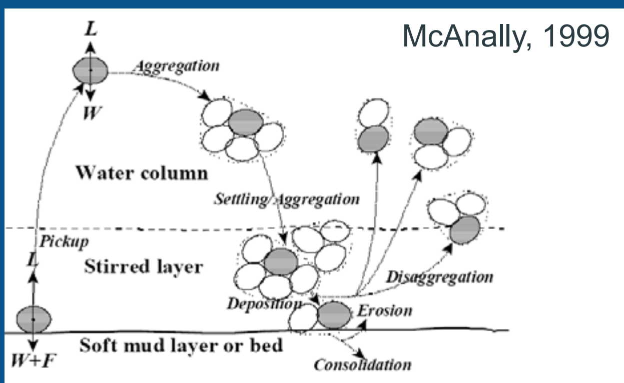

Thin-layer Marsh Placement
Photo courtesy The Nature Conservancy

Physical Processes

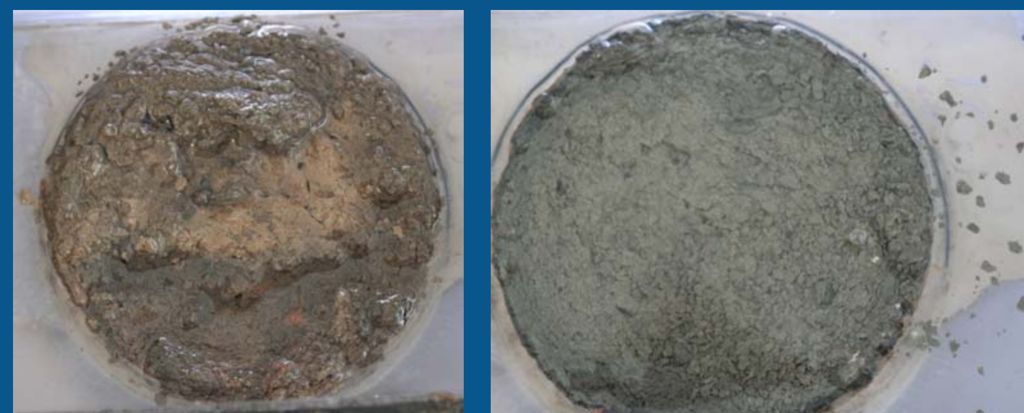


Mud Aggregates: Flocs vs Bed Aggregates

Flocs are aggregates of silt & clay particles formed in the water column

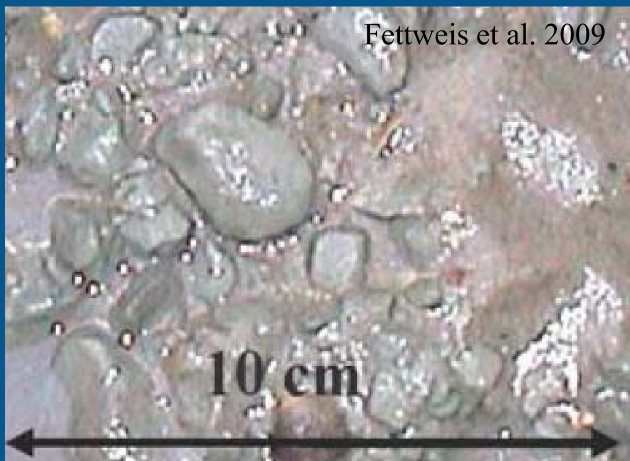


Bed aggregates result directly from erosion of the consolidated bed. Bed aggregate densities are equivalent to the bulk density of the bed.

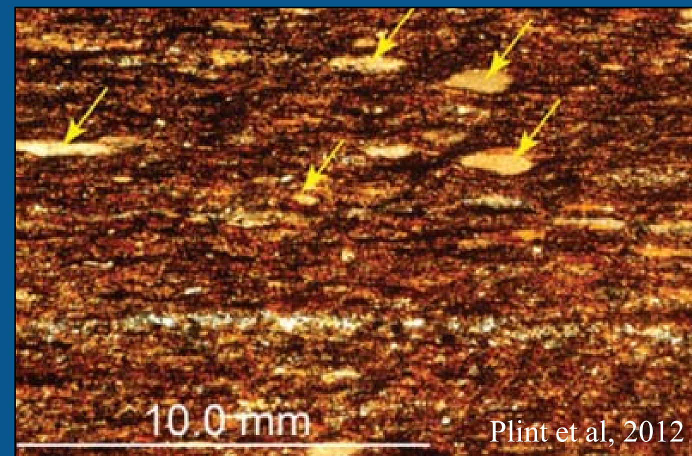


Cochiti Lake, NM

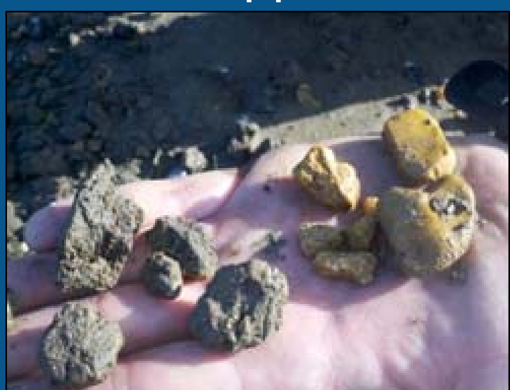
Belgian Coast



Western Canada

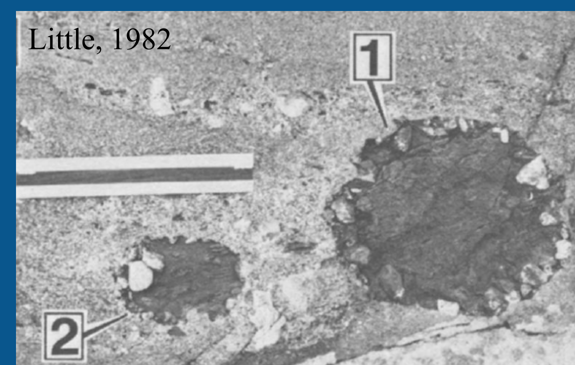


Mississippi River



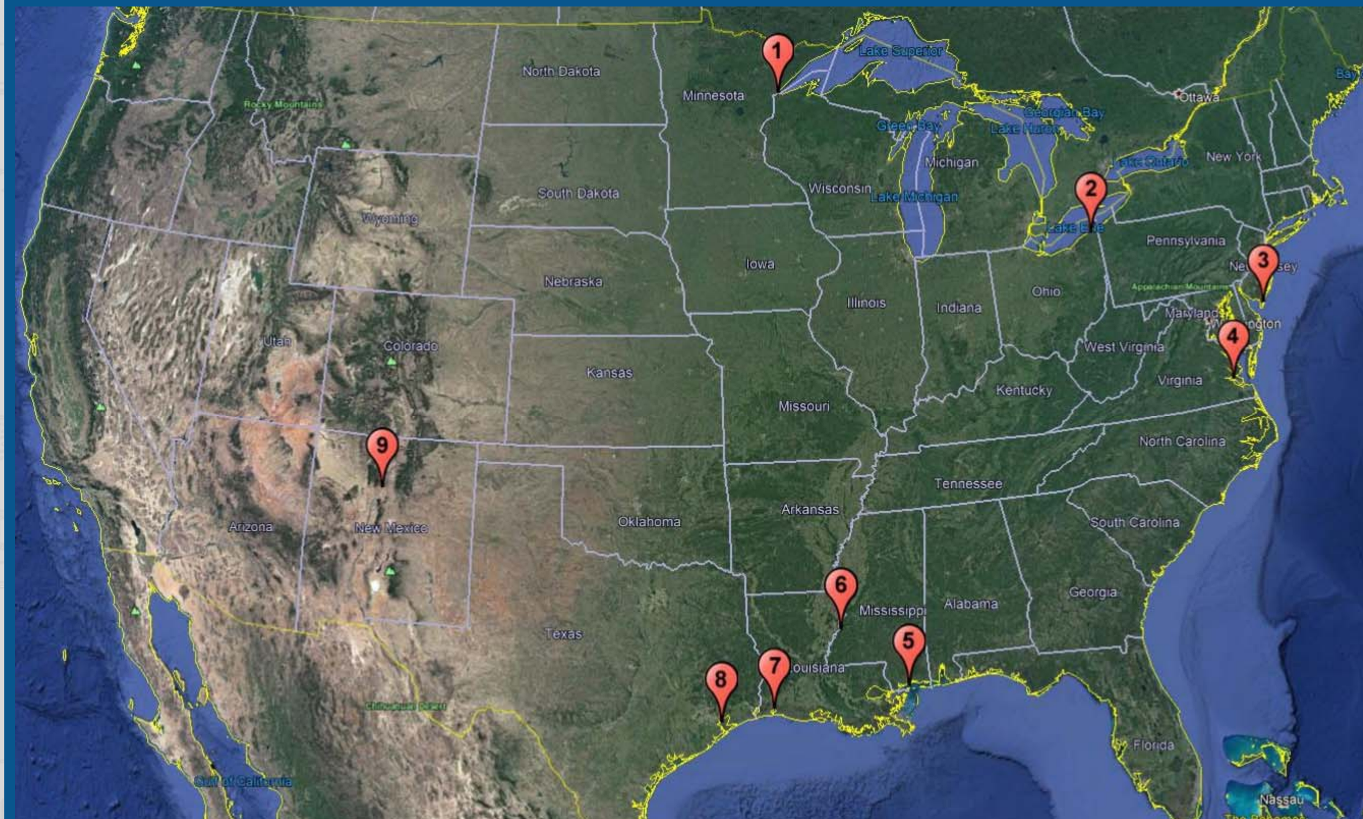
Lake Calcasieu, LA

Connecticut



Research Objectives

- **Document the presence and determine the potential impact of eroded mud aggregates on sediment transport and fate.**
- **Determine sediment characteristics that result in the generation of durable bed aggregates.**
- **Determine the sediment transport properties of eroded aggregates.**
- ***Develop guidance to assist districts in factoring the transport characteristics of mud aggregates into planning and design of projects.***



1) Duluth Harbor, MN
2) Ashtabula Harbor, OH
3) Seven Mile Island, NJ
4) James River, VA
5) Gulfport, MS
6) Mississippi River, MS
7) Lake Calcasieu, LA
8) Galveston Bay, TX
9) Cochiti Lake, NM

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James River Estuary

James River Estuary

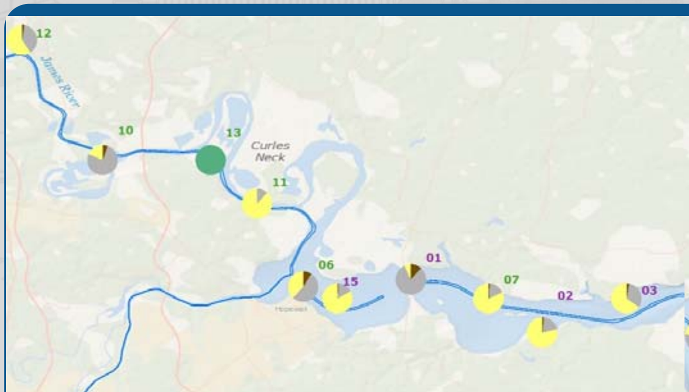
- ~90 mi of federally maintained channel
- >1 MCY material dredged annually
- Channel adjacent placement common
- Some areas dredged twice annually

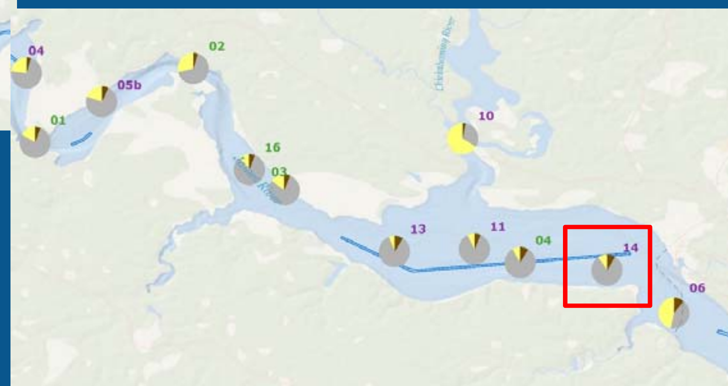
Study included erosion analysis to characterize the transport behavior of sediments within the estuary

Newly developed techniques were coupled with erosion testing to document the presence and properties of bed aggregates

Sampling Locations

Nov 2017





Sample Numbers

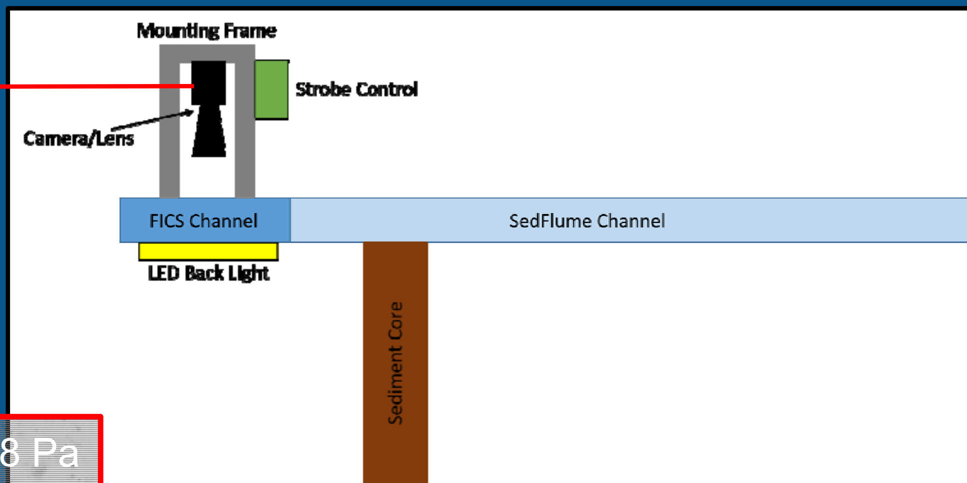
- Erosion Cores
- Surface Grabs

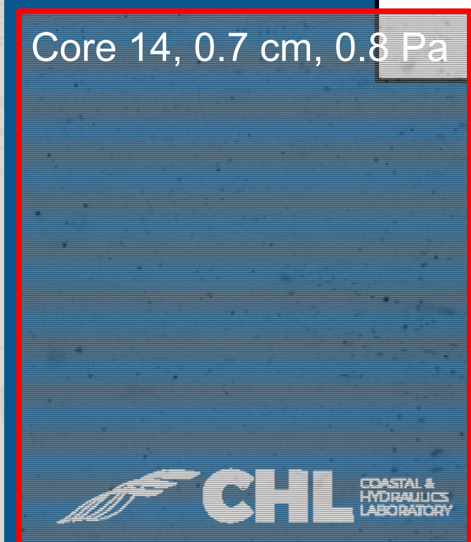
Pie Charts

Pebble	Sand
Silt	Clay

- Pie charts show surface grain size data (fraction pebble, sand, silt, clay)
- Majority of surface sediments were mud dominant (silt & clay)
- Purple numbered samples are cores run for erosion analysis

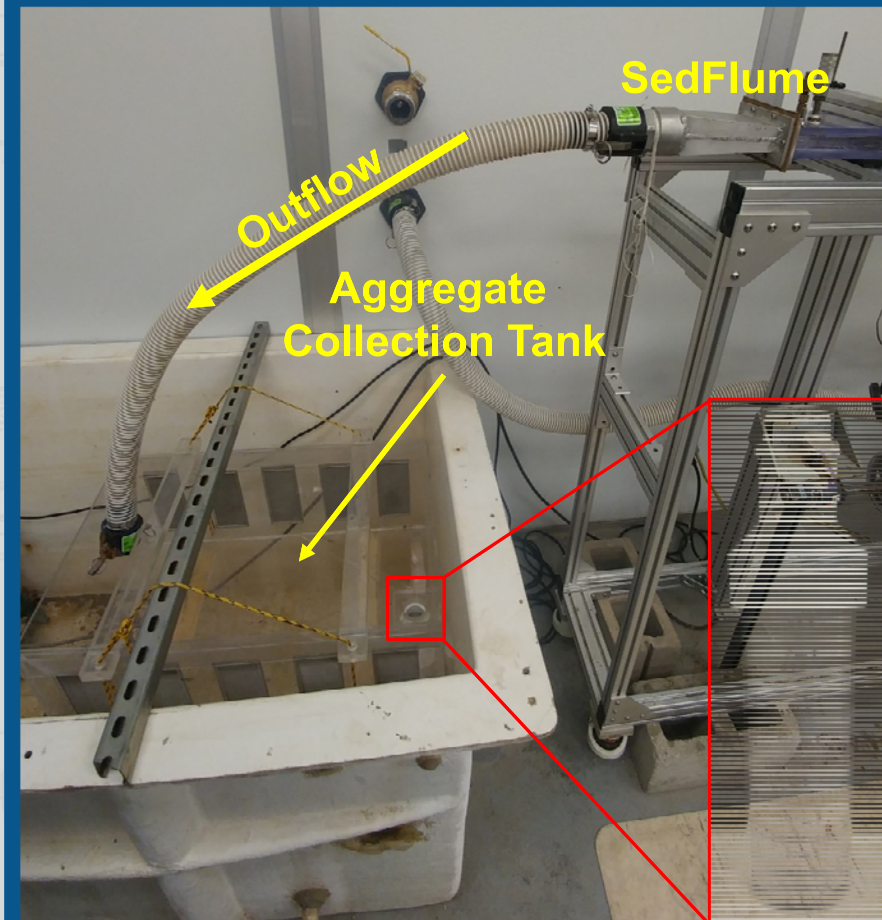
Flume Imaging Camera System: FICS

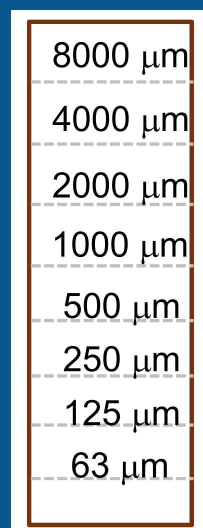




Viewing area ~ 5 cm x 5 cm
Image Pixels ~22 μm x 22 μm
Smallest sized particles ~66 μm

Physical Collection of Aggregates



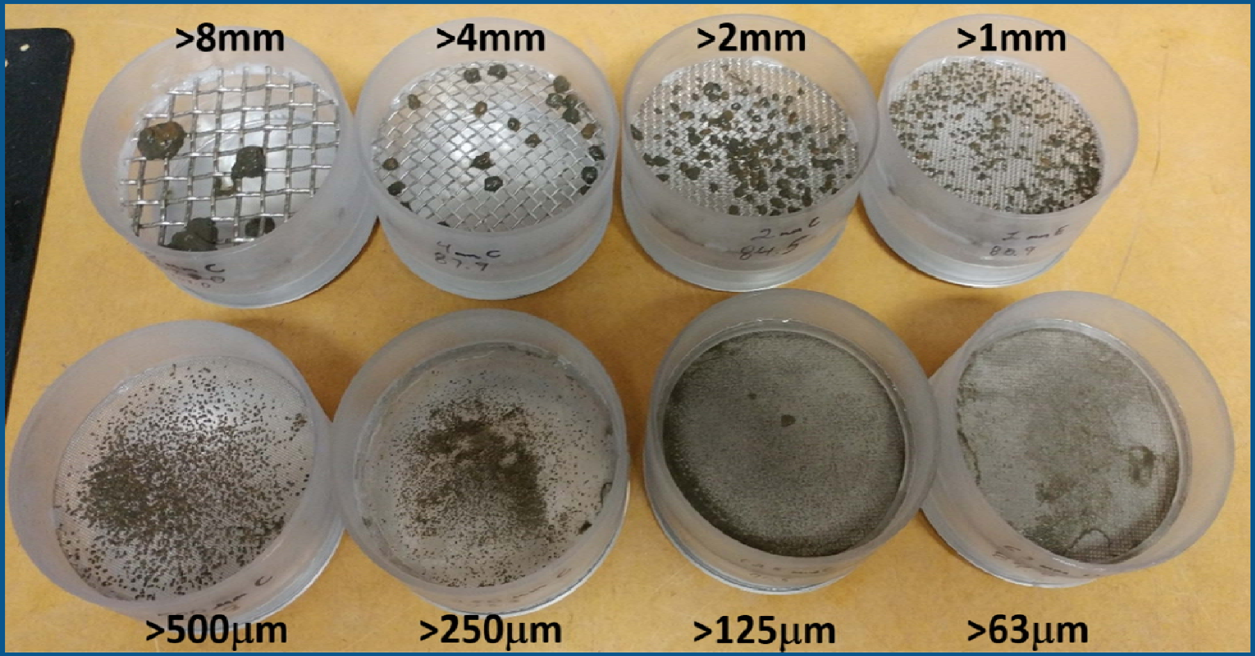


Subset of 7 cores selected

Basket retains >63µm material

Settling column trap with sieves

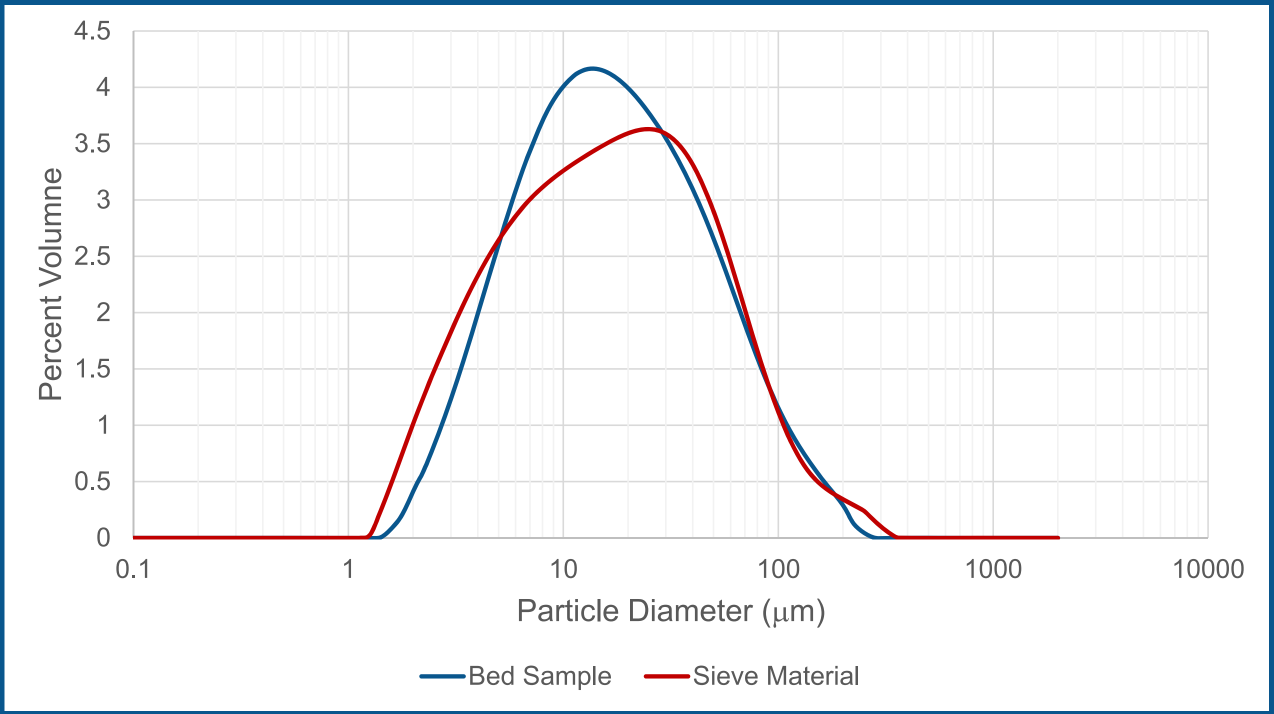
Core 14: Retained Eroded Material



Visible mud aggregates retained on sieves

Retained material compiled & disaggregated : 89.3% was <63 µm

Disaggregated Bed vs Disaggregated Sieve Material Core 14 ~1cm

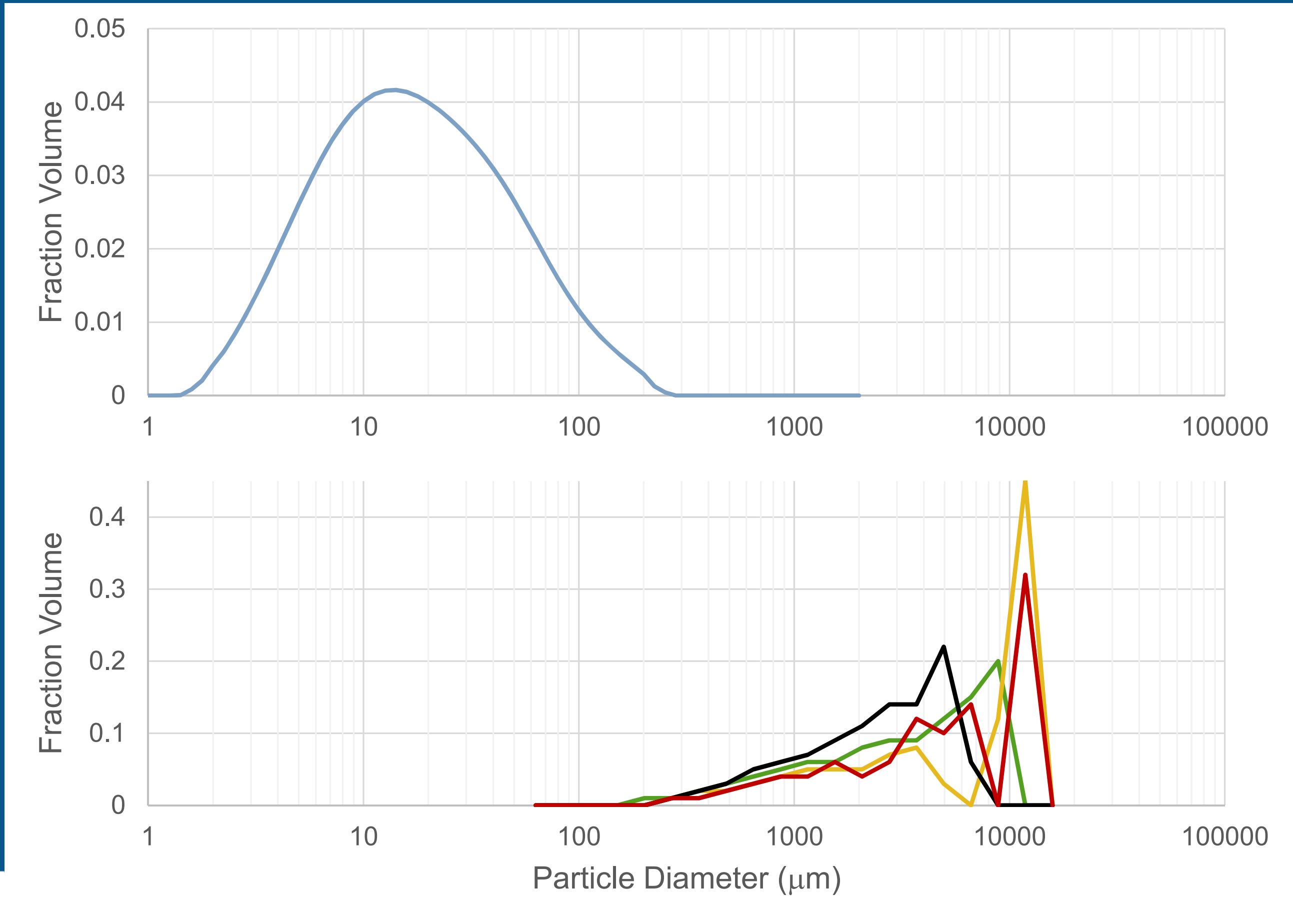


	Bed (1.4 cm)	Sieves (0.7 cm)
% Sand	8.3	13.4
% Silt	81.5	75.9
% Clay	10.2	10.7

Suggests that bed is not being winnowed of fines

Core 14: Surface Results

1.4 cm

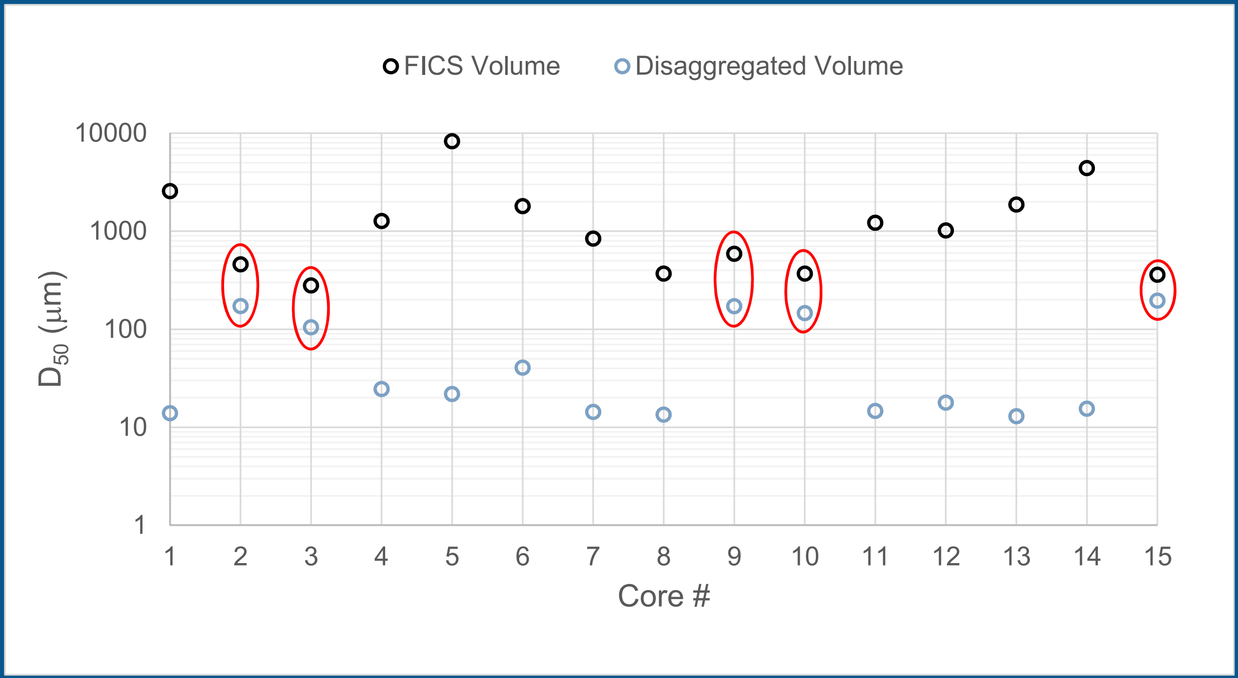


Laser Diffraction

FICS Distribution

0.15 cm, 0.4 Pa
0.35 cm, 0.6 Pa
0.7 cm, 0.8 Pa
1.1 cm, 1.2 Pa

FICS & LDPA Disaggregated Results at All Core Surfaces

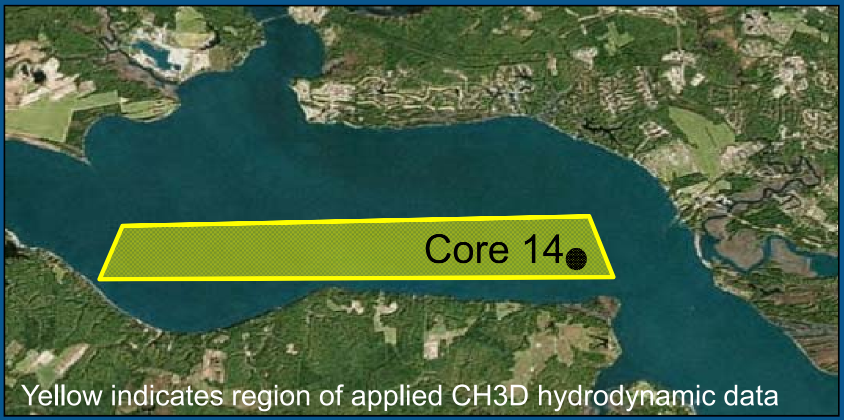


LDPSA physical samples from ~1cm compared to FICS at closest depth

Median size of eroded particles 1-2 orders of magnitude larger than disaggregated samples

5 cores <1order of magnitude difference in D_{50} had sand content >65%

Impacts on Transport Mode of Sediment



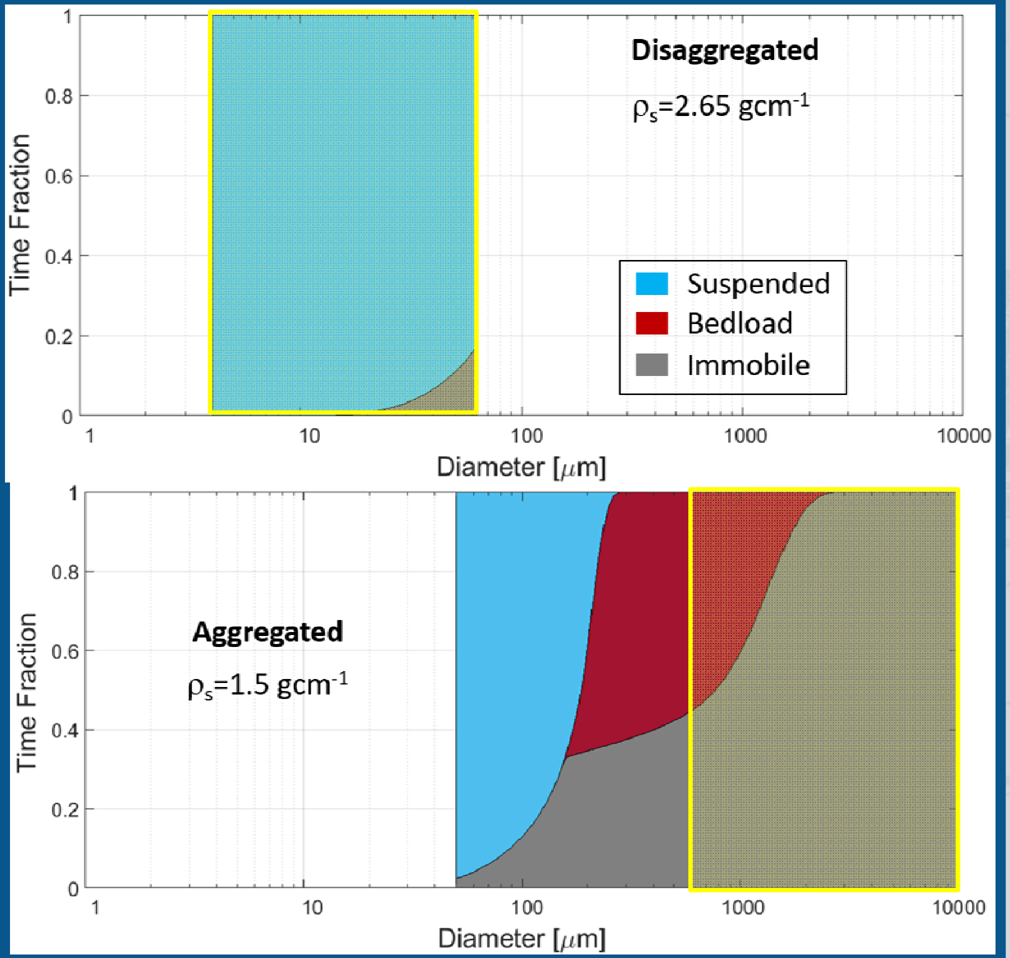


Chart to the right shows differences in transport modes of disaggregated primary particles (top) & mud aggregates (bottom). (Based on CH3D data)

Larger, aggregated particles from Core 14 transport as bedload & susceptible to deposition in depressions/channels

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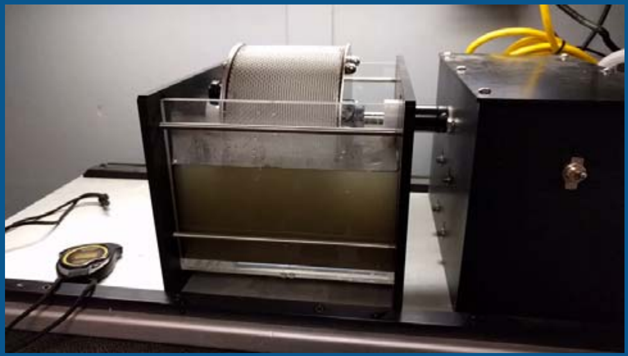
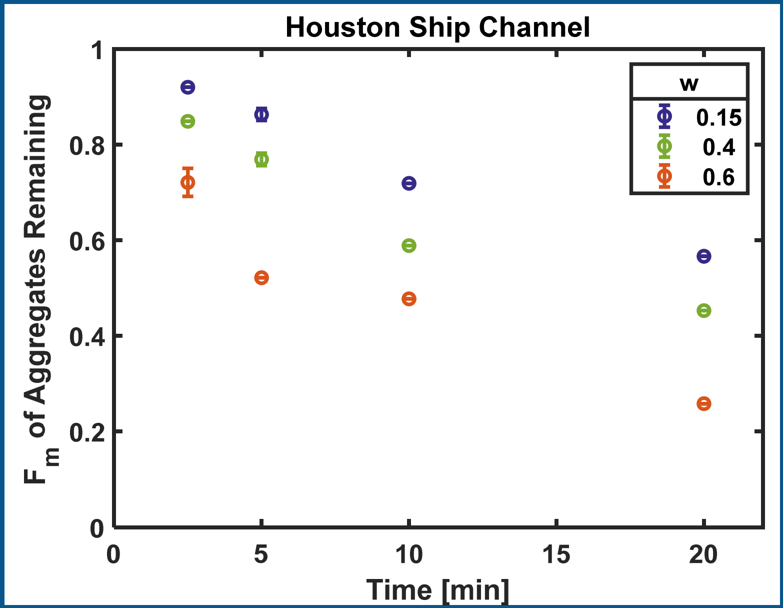
Durability Testing

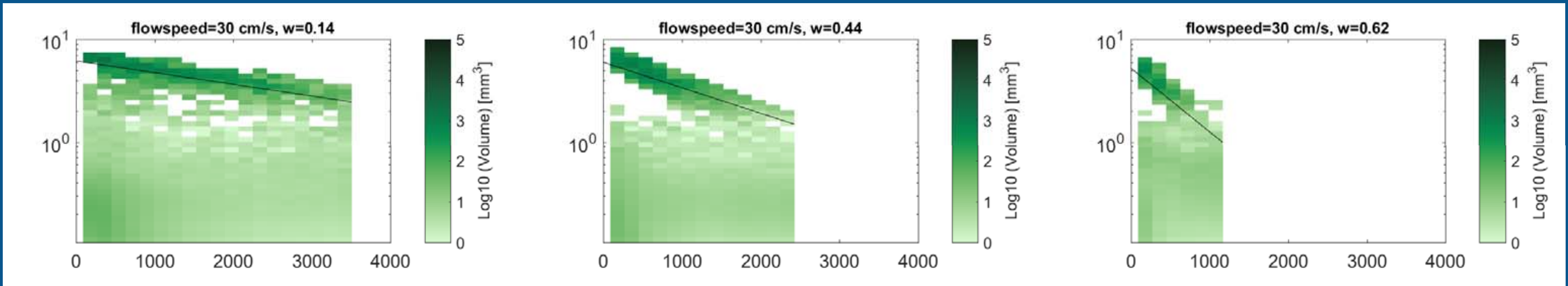
Aggregate Durability Tumbler



Aggregate Durability Flume

Aggregate Durability Testing





Research Products

Publications

- Technical Notes and Reports documenting the findings.
- Journal Article(s)

Testing Methods

- Tiered Evaluation Methods:
  - Sediment Properties
    - USCS classification
    - Clay Content
    - Atterburg Limits
  - Sedflume Testing
  - Aggregate Tumbler Testing
  - Aggregate Flume Testing

Future Research and Development Topics

Research

- Mud aggregate characteristics associated with dredge type.
- Aggregate breakup in hydraulic pumping operations.
- Time-dependent changes in aggregate strength associated with swelling clays.
- Evaluating the role of aggregate transport in strategic placement of dredged material.

Development

- Model algorithms for aggregate transport and breakup.

Implications for Practice

- Dredged Material Management
  - Channel-adjacent placement
- Beneficial Use Practices
  - Strategic Placement
    - Nearshore Placement
    - Wetland Sediment Supply
  - Thin Layer Placement
- Beach Nourishment
  - Formation of Clay Balls
- Construction of containment structures with muddy dredged material
- Environmental Impacts
  - Fate of Fine Sediment
  - Fate of Contaminants
- Riverine and Reservoir Sediment Management
  - Sediment Bypassing
  - Bank Erosion and Transport
  - Reservoir Sedimentation
  - Riverine Sediment Diversions

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Conclusions

Erosion of muddy sediment often (but not always) occurs in the form of mud aggregates.

Eroded bed aggregates are commonly 1-3 orders of magnitude larger than their constituent particles.

- Larger size impacts settling velocity and transport mode.
- Transport mode alters the ultimate fate of these particles.
- Fate impacts project outcome.

When robust aggregates are likely to form, their transport effects should be represented in project planning and design.

Evaluation methods and guidance are in final stages of development, to be published in FY20.

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Acknowledgements

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Dredging Operations Environmental Program

Coastal Inlets Research Program

USACE-NAO