THIN-LAYER PLACEMENT SEDIMENT DEPOSITION MODEL

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OBJECTIVE

Estimate post-dredging surface elevations across a thin-layer placement site using a mechanistically correct model for movement and thickening of hydraulically-dredged sediment given specific confinement conditions.

Topics

- Existing Models
- Model Formulation
- Application
- Research Needs
- Summary

EXISTING MODELS

- **CORMIX (Doneker and Jirka 1990)**
  - Mixing model for buoyant discharges. Predicts WQ changes resulting from discharges with a density lower than receiving waters (usually because of temperature)
- **D-CORMIX**
  - Implementation of CORMIX for suspended sediments, i.e. non-buoyant plume. Computes sediment deposition thicknesses.
- **CDFATE (Havis 1994)**
  - Inverted implementation of CORMIX for “sinking” plume. Computes suspended solids concentrations and sediment deposition thicknesses.

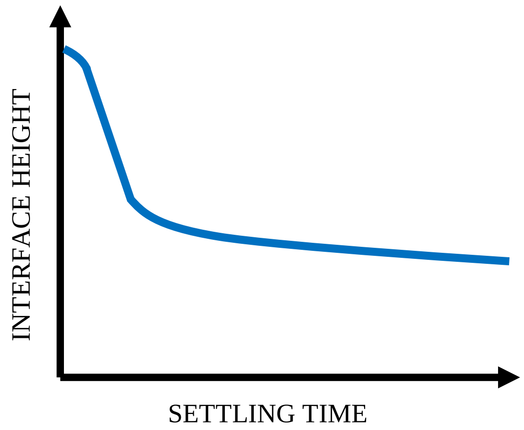
MODEL FORMULATION

INFLUENT CHARACTERISTICS

- **Typical density range**
  - ~100 kg/m^3 (100% fines)
  - ~200 kg/m^3 (100% sand)
- **Solids content**
  - Fine Material (silts, clays)
  - Coarse material (sands, gravel)
  - Clumps

AFTER DISCHARGE

- Coarse materials settle near the point of discharge, quickly reaching their maximum density
- Remaining components very mobile:
  - Thin, fine sediment slurry
  - Water with suspended sediment
- Result:
  - Complete separation by particle size
  - Lateral movement to a point of stability



RAPIDLY SETTLING SOLIDS

- **Some solids deposit at or very near the point of discharge**
- **Clumps**
  - Mounds with side slopes 1:5 or less
  - Individual clumps at in situ density; overall mound density depends on clump size and resulting voids
  - Higher density displaces fine slurry deposits
- **Coarse material (sands, gravel)**
  - Mounds with side slopes ~ 1:10
  - Settled dry density ~ 1600 kg/m^3 (100 lb/ft^3)
  - Higher density displaces fine slurry deposits

FINE PARTICLE SLURRY

- Zone Settling Regime (1^{st} day)
  - Fine solids coalesce to form “thin slurry”
  - Thin slurry is a dense fluid
  - More dense than water; exists on bottom
  - Moves laterally until reaches a stable slope (~1H:1000V)
  - Usually transitions to Compression Settling in 6-12 hrs
  - Lateral velocity depends on slurry viscosity
- Compression Settling Regime
  - Transition occurs at ~ 250 kg/m^3
  - Final densities depend on settling time and in situ density; > 350 kg/m^3 common
  - Lateral movement slower due to increased viscosity
  - Stable slope ~ 1H:100V

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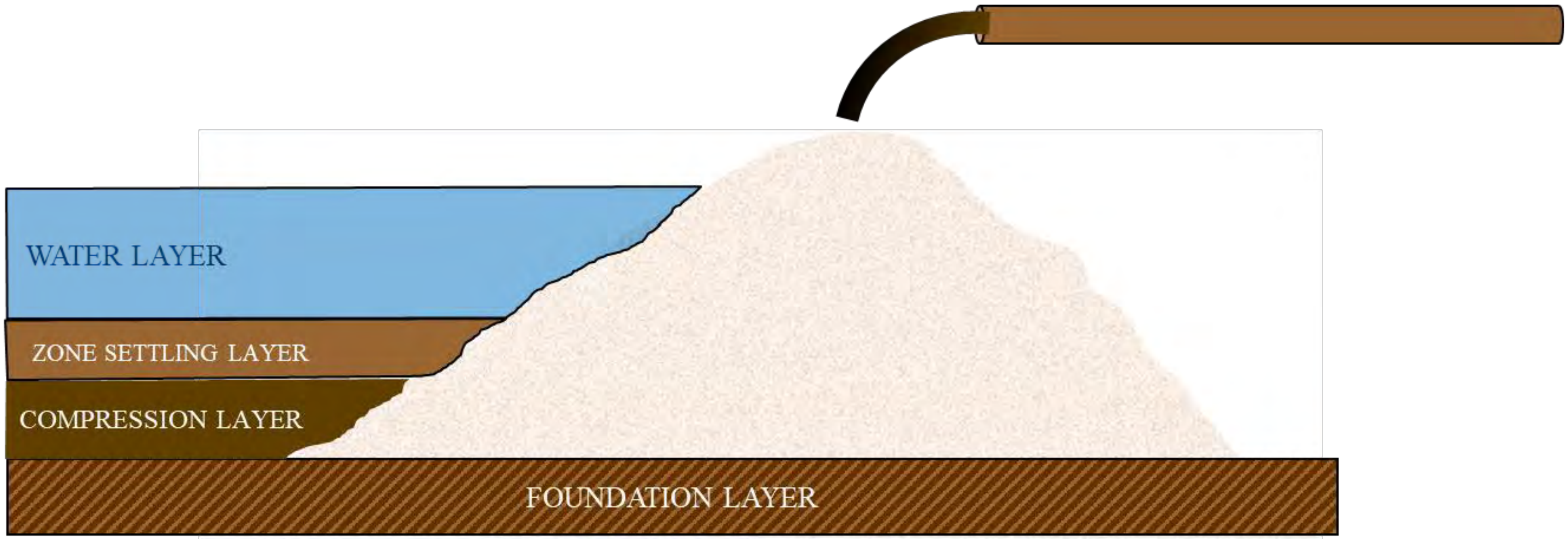
LAYER DEFINITIONS



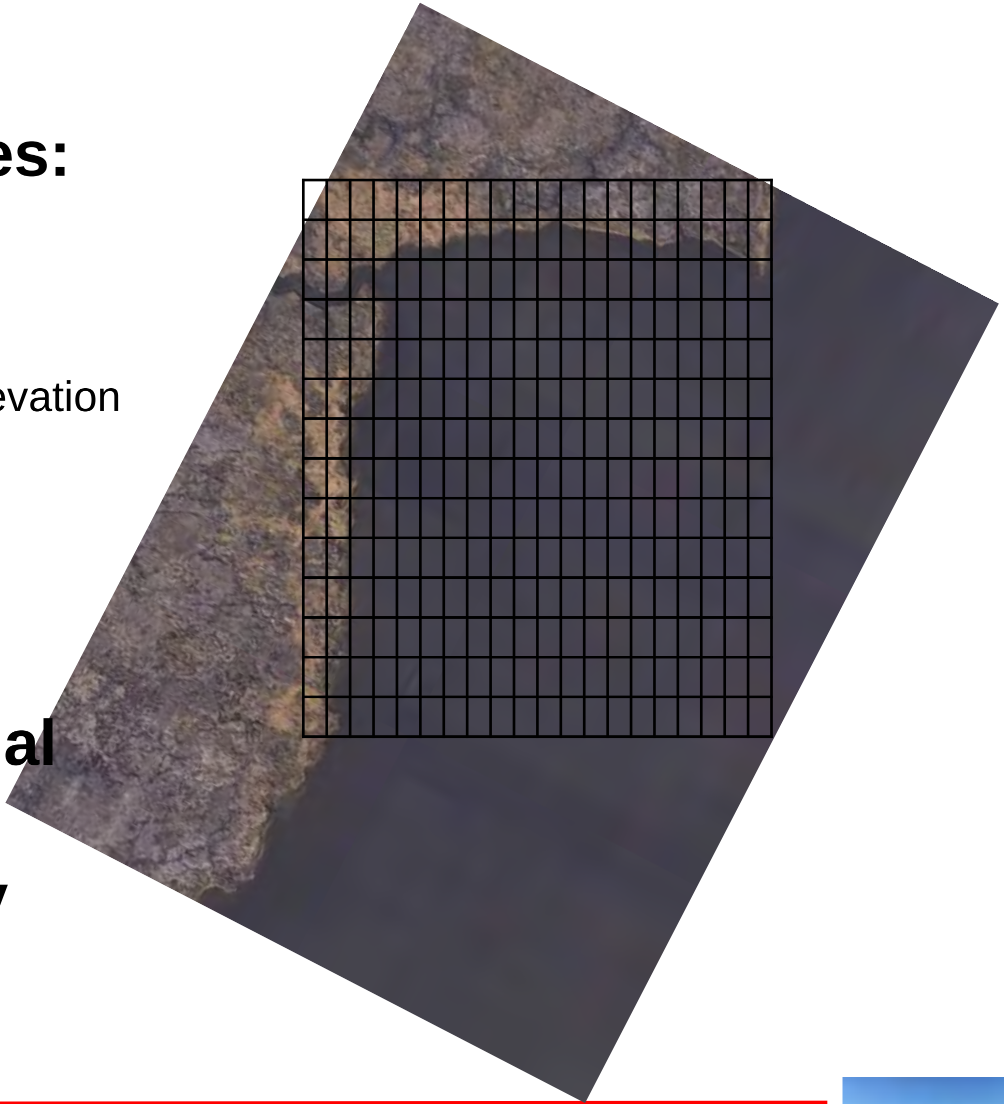
SLURRY THICKENING

- Flocculent Settling in supernatant (WL)
  - Typical concentrations < 100 mg/L
  - Mass not sufficient to significantly affect deposition depths
- Zone Settling (ZL)
  - Initial concentrations > 100 kg/m^3
  - Begins within 1 hour, usually minutes
  - Transitions to Compression Settling within 24 hrs
- Compression Settling (CL)
  - Volume reduction much slower than Zone Settling
- Secondary Consolidation (FL)
  - Not significant during dredging operation

MODEL APPLICATION

SITE DEFINITION

- **Rectangular grid**
- **User-defined Cell types:**
  - ➢ Land cell
    - – Elevation
  - ➢ Water cell
    - – Pre-dredging sediment elevation
    - – Vegetation density
  - ➢ Containment cell
    - – Elevation
  - ➢ Flow restriction cell
    - – Degree of restriction
- **Model requires external "ring" of cells for mathematical stability**



NECESSARY INFORMATION

- **Dredged sediment characteristics**
  - In Situ Density
  - Grain-size distribution
  - Sedimentation properties (CST)
- **Site Information**
  - Pre-dredging site topography
  - Degree/extent of confinement
  - Water surface elevations (e.g. tides)
  - Ambient currents
- **Project information**
  - Discharge location
  - Discharge rate and density

SEDIMENT MASS BALANCES

- **Parse influent discharge into appropriate layers**
  - Coarse sediment added to FL
  - Sediment slurry added to ZL
  - Excess water added to WL
- **Layer changes over time**
  - Foundation Layer (FL)
    - Settled coarse material & clumps add sediment mass
    - Settled fines from supernatant settles adds mass

SEDIMENT MASS BALANCES

- **Water Layer**
  - Newly discharged suspended sediments increase mass
  - Settled sediment moving to FL decreases mass
  - Lateral flows may increase or decrease mass
- **Zone Layer**
  - Newly discharged fine sediments increase mass
  - Thickened sediments move to CL, decrease mass
  - Lateral flows may increase or decrease mass
- **Compression Layer**
  - Thickened ZL sediments move to CL, adding mass
  - All CL sediment retained in layer for duration of dredging

VOLUME BALANCES

- **Total cell volumes defined by:**
  - Pre-dredging bathymetry (Foundation Layer)
  - Water surface (which may vary by time step)
- **Foundation Layer**
  - Settled coarse material & clumps increase elevation; constant density assumed
  - Settled fines from supernatant increase elevation; minimal volume
- **Compression Layer**
  - Thickened ZL sediments increase thickness
  - Density increases reduce thickness

VOLUME BALANCES

- **Zone Layer**
  - Fine sediment discharges add volume
  - Thickened ZL sediments move to CL, decrease volume
  - Lateral sediment movement may increase or decrease volume
- **Water Layer**
  - Only exists if ZL + CL + FL volumes are lower than externally prescribed water layer

COMPUTATIONAL APPROACH

- Start at t = 0
- Time step 1
  - Calculate inflows to FL (coarse material), ZL (fine material), and WL (fine material)
  - Calculate lateral movements in WL and ZL for all cells
  - Calculate mass and water balance for FL for all cells
  - Calculate mass and water balance for CL for all cells
  - Calculate mass and water balance for ZL for all cells
  - Calculate mass and water balance for WL for all cells
- Repeat for all remaining time steps, starting at time period 2.

SUMMARY

- Although in-water placement models exist, their forte' is water quality rather than sediment movement and thickening
- Basic formulation of thin-layer placement model
- Sedimentation processes modeled using CST results
- Formulation allows evaluation of a wide range of placement strategies

Questions?