PTM:
A Lagrangian Particle Tracking Model

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OUTLINE

- Motivation for sediment/constituent modeling system
- Objectives of modeling system
- Description of PTM
- PTM Example
- Summary

MOTIVATION

- Issues related to sediment/constituent transport are becoming more complex
  - Regulatory compliance
  - Risk Assessment
  - Site/lifecycle management
  - Beneficial use of sediment
  - Ecosystem/endangered species protection
- Models are one of several tools used to address these issues (line/lines of evidence)
- New class of models required to adequately address issues
- Sediment/constituent transport models used to quantify exposure
- Users need a suite of sediment/constituent transport modeling tools
  - Various levels of model (screening to detailed)
  - Address specific processes
- Models must interconnect with other models and databases to provide efficient use and maximum benefit
- Models must be adaptable for site-specific conditions

OBJECTIVES

- Develop/maintain a suite of tools, models and databases to address Corps issues related to sediment and constituents
  - Develop needed process descriptions for improved accuracy and range of applicability
  - Increased connectivity with other Corps models (hydro, waves, WQ), databases, and tools
  - Three tiers of models to address appropriate level of accuracy/user needs
- Decrease time required for model application and interpretation portion of project

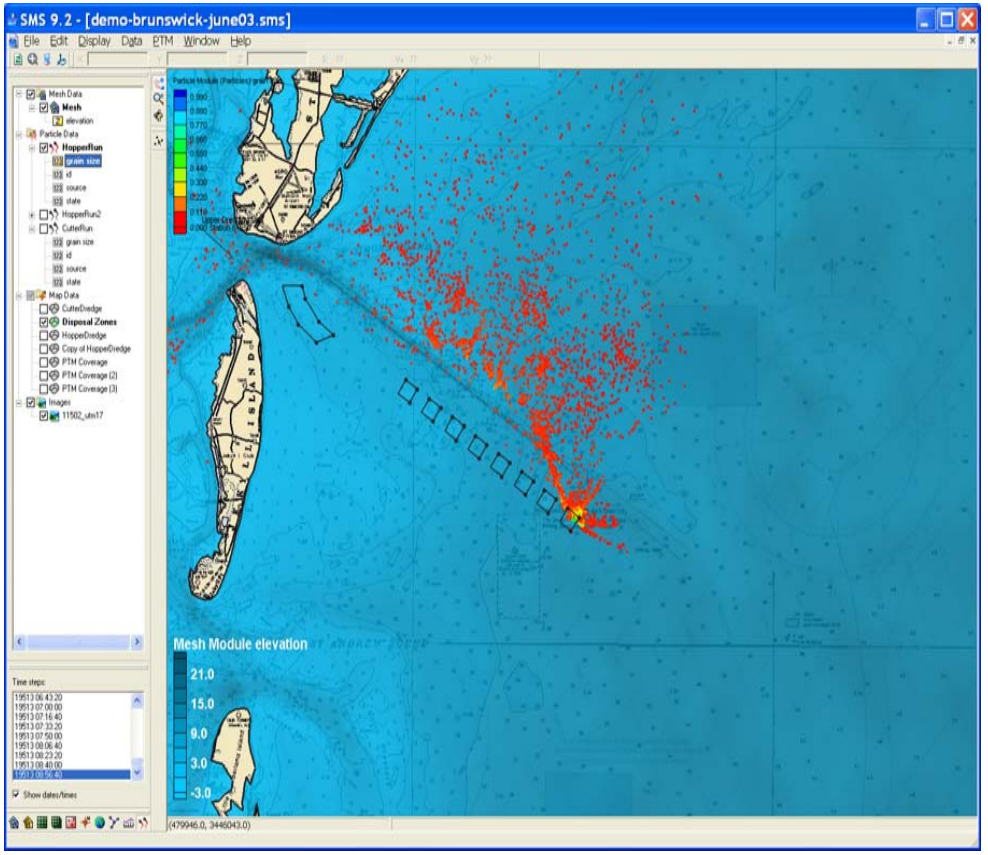
OBJECTIVE: Model Interconnectivity

- Models depend on both field data and large domain hydrodynamic model data
- SMS is the ERDC large-domain model interface
- Includes multiple hydrodynamic, wave, and atmospheric models
- Interactive capabilities with GIS
- Incorporate sediment/constituent transport models into SMS while maintaining stand-alone versions.
- Transport model output directed to WQ and other models within SMS

PTM

Particle Tracking Model

- Purpose
- Model Attributes
- Basic Model Input/Output
- Example Applications



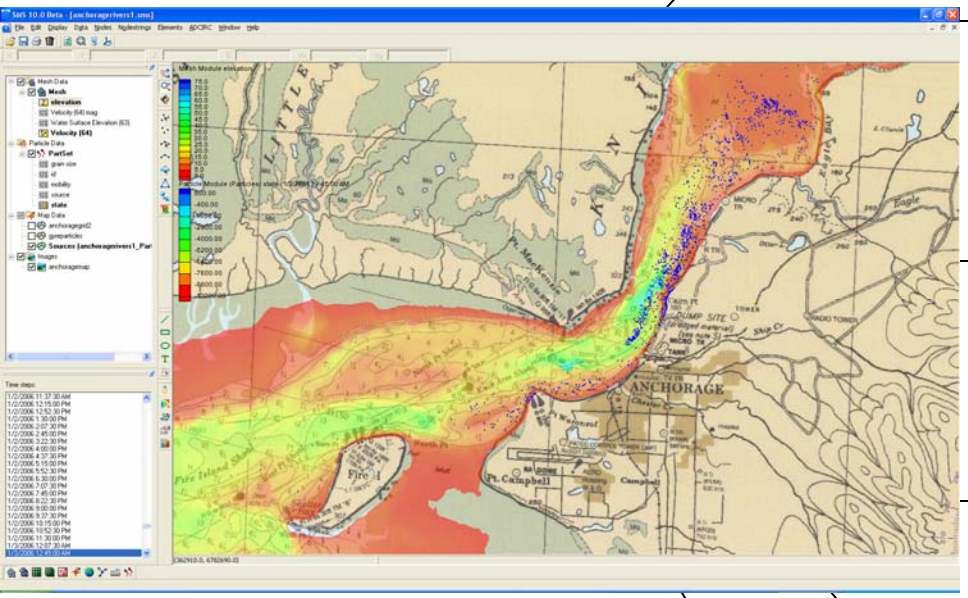
PTM Purpose

- Large domain sediment/constituent transport models are computationally intensive
- Yet we must understand sediment transport over large domains to assess impacts/risks of specific sources
- PTM permits this with nominal computational intensity by only modeling transport from specified sources
- Can perform multiple scenarios rapidly
- Source interactions with sediment bed treated through active layer dynamics
- Issues Addressed:
  - Far-field transport, deposition, and resuspension
  - Time-varying sediment and constituent concentration
  - Dose estimates

PTM Attributes

- Isolate and track sediment from specific sources (outfalls, dredging, placement, propeller, …)
- Estimate dosage to receptors
- Quantify sediment accretion and concentration
- Map sediment pathways (e.g. monitor movement of sediment from a specific source to receptors)
- Predict transport of neutrally buoyant and non-conservative constituents (contaminant, WQ)
- Dredge source term incorporated directly into PTM
- FATE model output accepted as PTM source input

PTM Attributes



Lagrangian particle tracker models multiple constituents that are discretized into representative parcels.

PTM models important transport processes: advection, settling, deposition, resuspension, burial.

PTM utilizes Hydrodynamic and wave input from multiple state of the art models as forcings.

Surface-water Modeling System (SMS) interface.

Unstructured grid permits modeling transport in complex regions

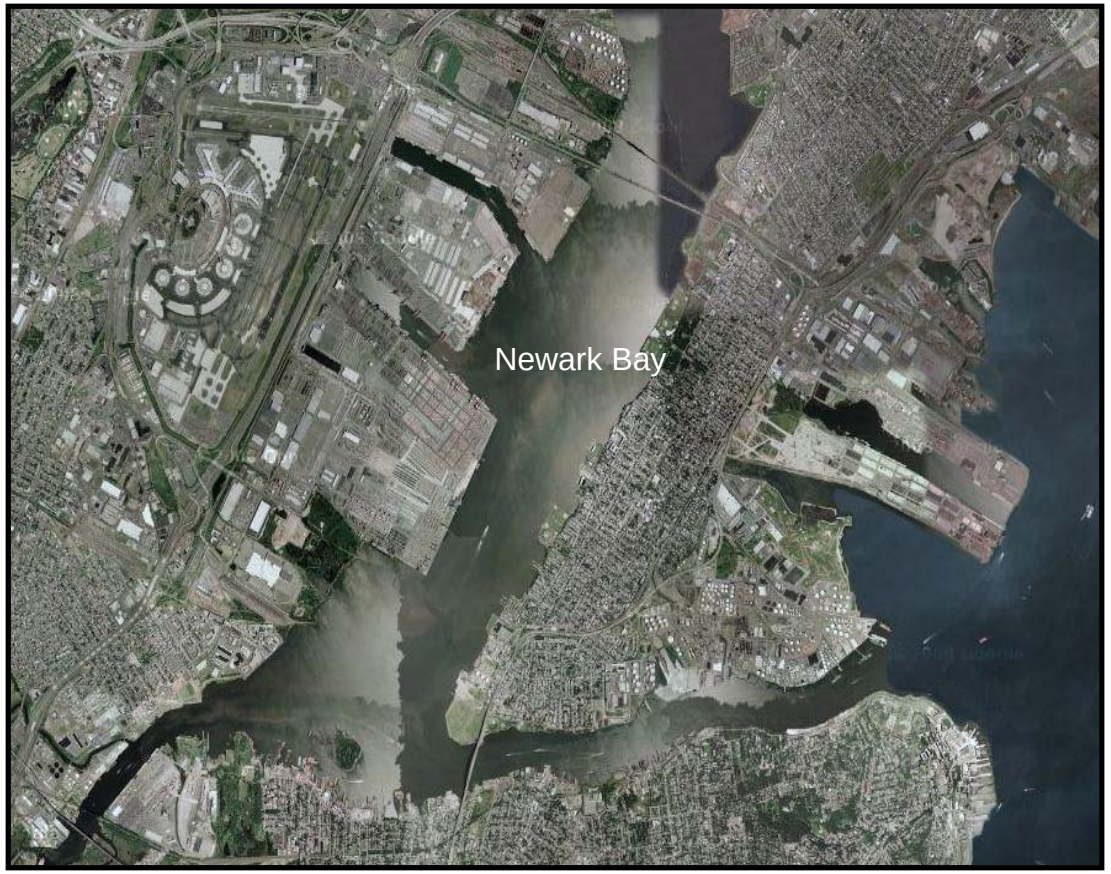
Sediment transport includes mixing with native sediments

PTM Input/Output

- Input:
  - Bathymetry
  - Hydrodynamic field from large-domain model (ADCIRC, ADH, POM, CH3D, EFDC, etc)
  - Wave field from near-shore wave transformation model (STWAVE, SWAN)
  - Dredging source term parameters, including loss rate description
  - Dredged sediment properties
  - Sediment bed properties
- Output
  - Final location, transport history, and properties of particles released from the source
  - Deposition and concentration patterns at user-specified times
  - Time history of concentration, deposition, etc at user-specified location.
  - 3-D cross-section contour plots
  - Dosage to receptors (exposure to sediments over time)

Newark Bay

- A tidal back bay of New York Harbor formed at the confluence of the Passaic and Hackensack Rivers.
- Part of the New York/New Jersey Harbor Estuary, in the center of one of the most industrialized parts of the nation.
- Port of Newark is the nation's third largest container port



- Newark Bay area is currently the site of an extensive and necessary channel deepening project.
- A major concern has been possible detrimental environmental impacts of sediment which has been resuspended during dredging.

Environmental Issues Due to Resuspended Dredged Material

- Total Suspended Solids (TSS) concentration
  - light attenuation
  - fish and larval migrations
- contaminants
- sediment deposition
  - egg burial

Winter flounder

Fish eggs

Objective

Determine the effects of a *hypothetical* dredging operation on suspected Winter Flounder spawning area within the Newark Bay region utilizing the Particle Tracking Model

- Dredged sediment fate
- Deposition in spawning regions
- Suspended sediment concentration in spawning regions
  - Start date January 15
  - Dredging goal - 50,000 cy

Particle Tracking Model

PTM models multiple sediment, chemical, or biological constituents that are discretized into representative parcels. PTM models processes such as:

- Advection/Diffusion
- Settling/Deposition
- Resuspension
- Particle-Bed Interactions

Input Requirements

- Grid/Bathymetry Data
- Hydrodynamic and/or Wave Data
- Native Sediment Data
- User Defined Source Data
  - Dredging
  - Placement

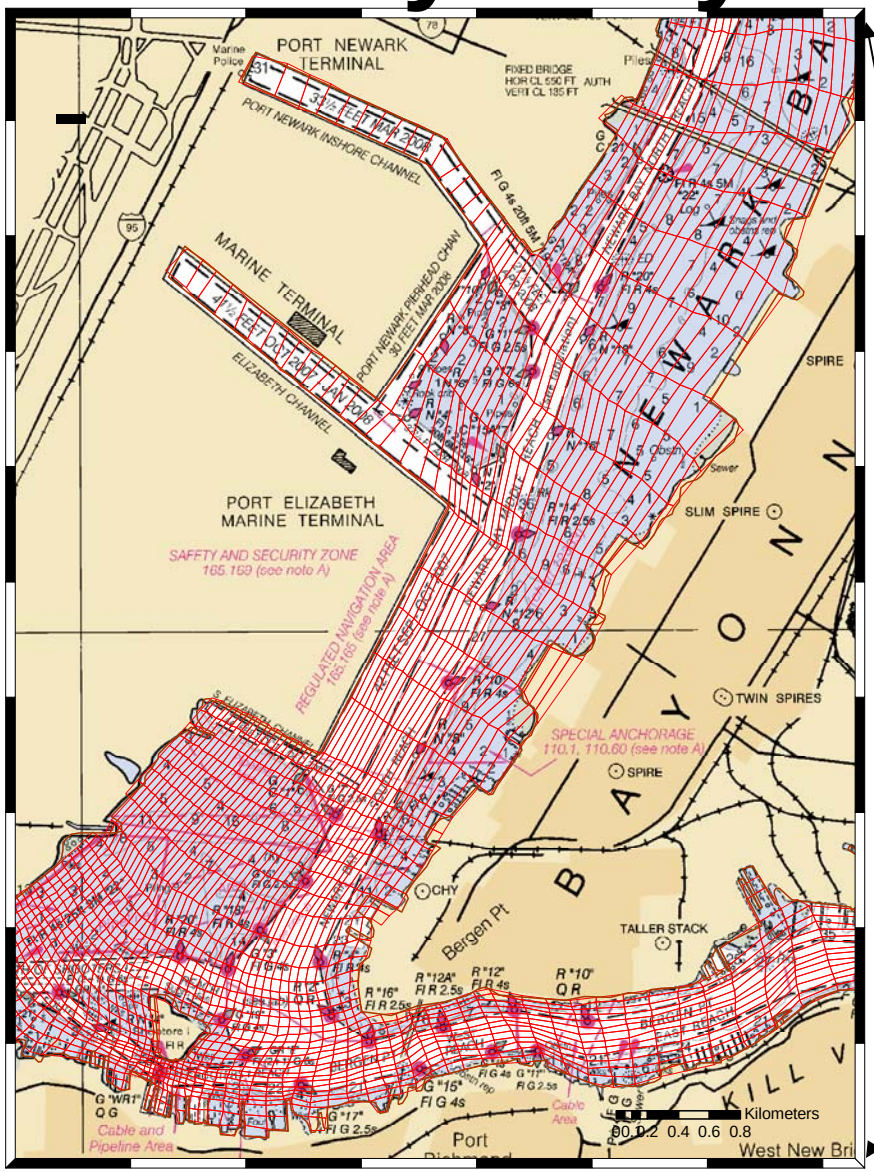
PTM

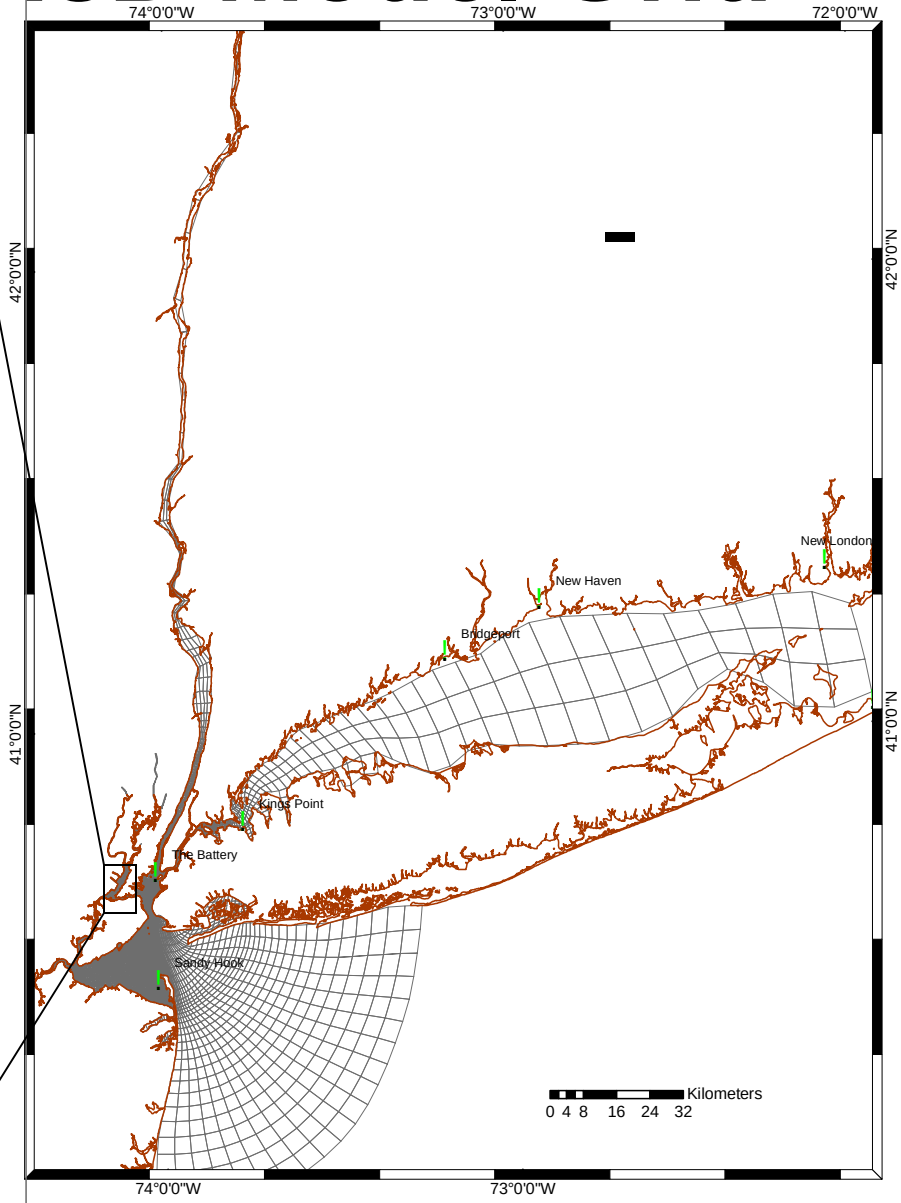
Time-dependent Particle Positions P(t,X,Y,Z)

SMS Data Analysis Toolkit

- Deposition
- Concentration
- Dose
- Exposure
- Accumulation

Bathymetry: CH3D Model Grid





Hydrodynamics: CH3D

Simulation – July 15-22
(Bottom Velocity)

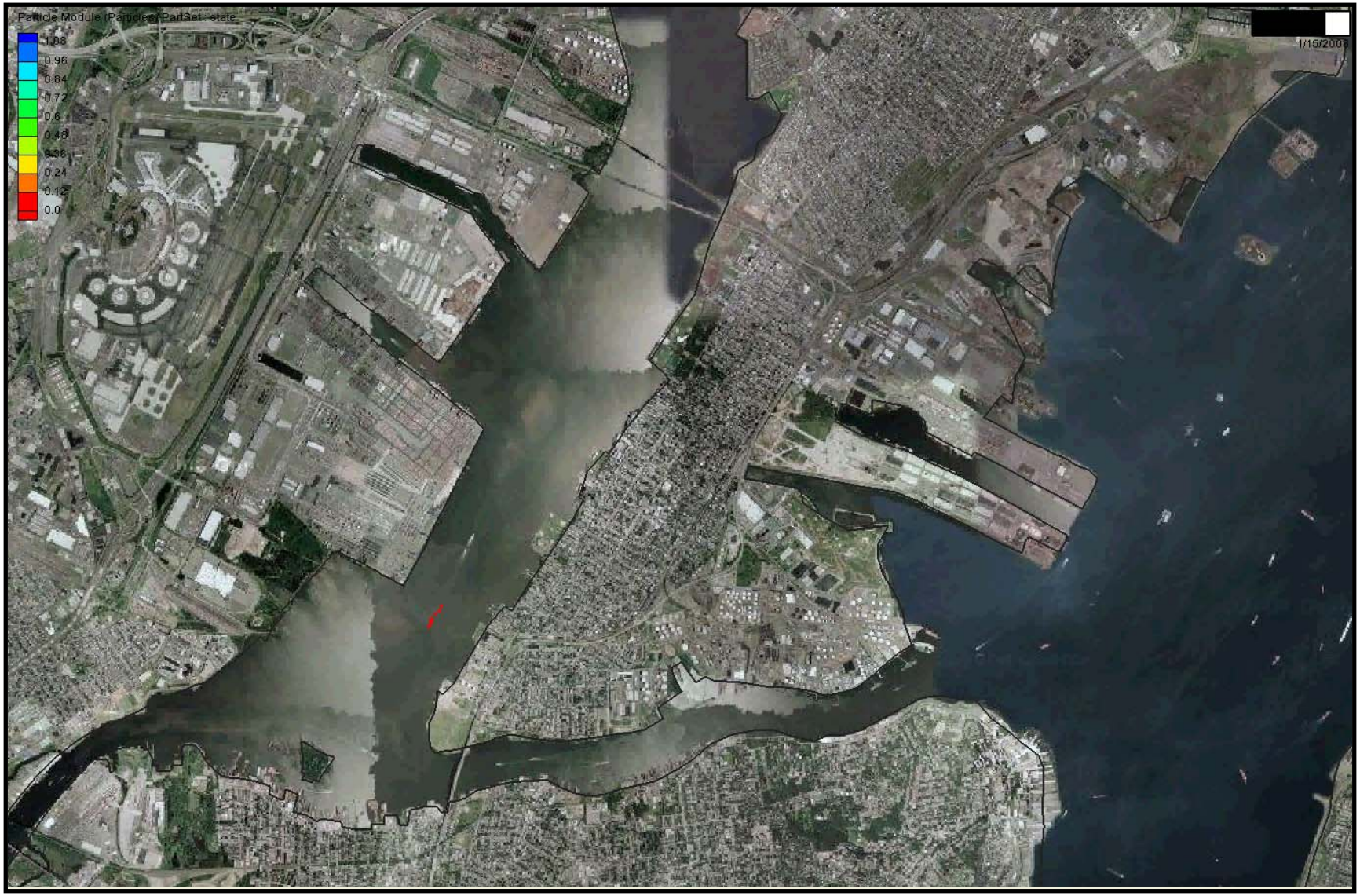
V_{mag} maximum
Channel =0.45m/s
Spawning habitat =0.12m/s

Sediment Source Details

Dredging Schedule (50,000cy takes approximately 4 days to dredge)

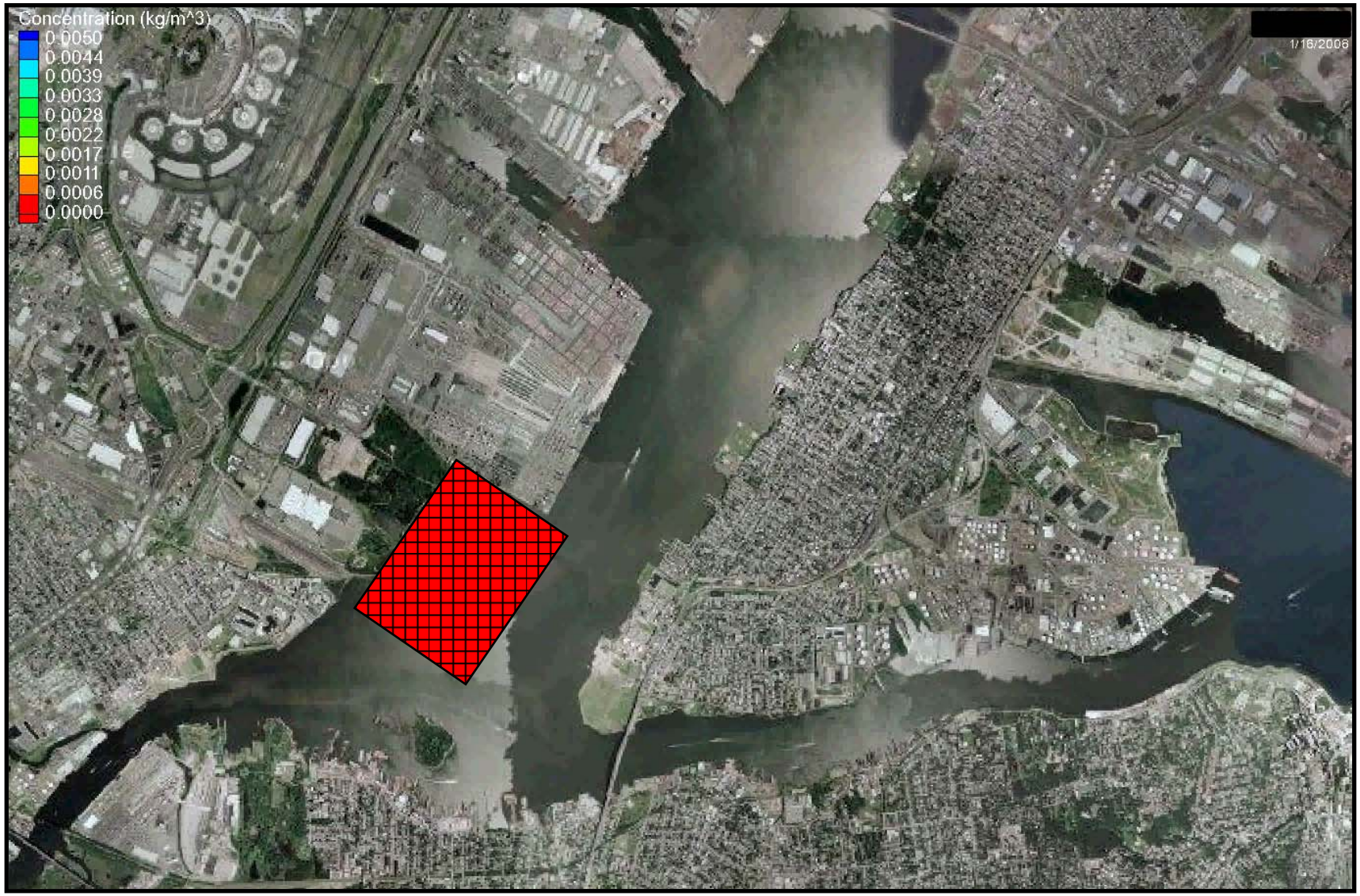
- Dredge 7 hours and 1 hour break
- Scow change every 2hr 20min
- Algorithms within PTM specify hourly loss rate and vertical distribution of losses

PTM Simulation – Sediment Fate



- Suspended - Deposited Simulation 1/15-1/20

PTM Simulation – Concentration Maps



Simulation 1/15-1/20 (1 kg/m^3 = 1000 mg/l) C_{max}=5mg/l

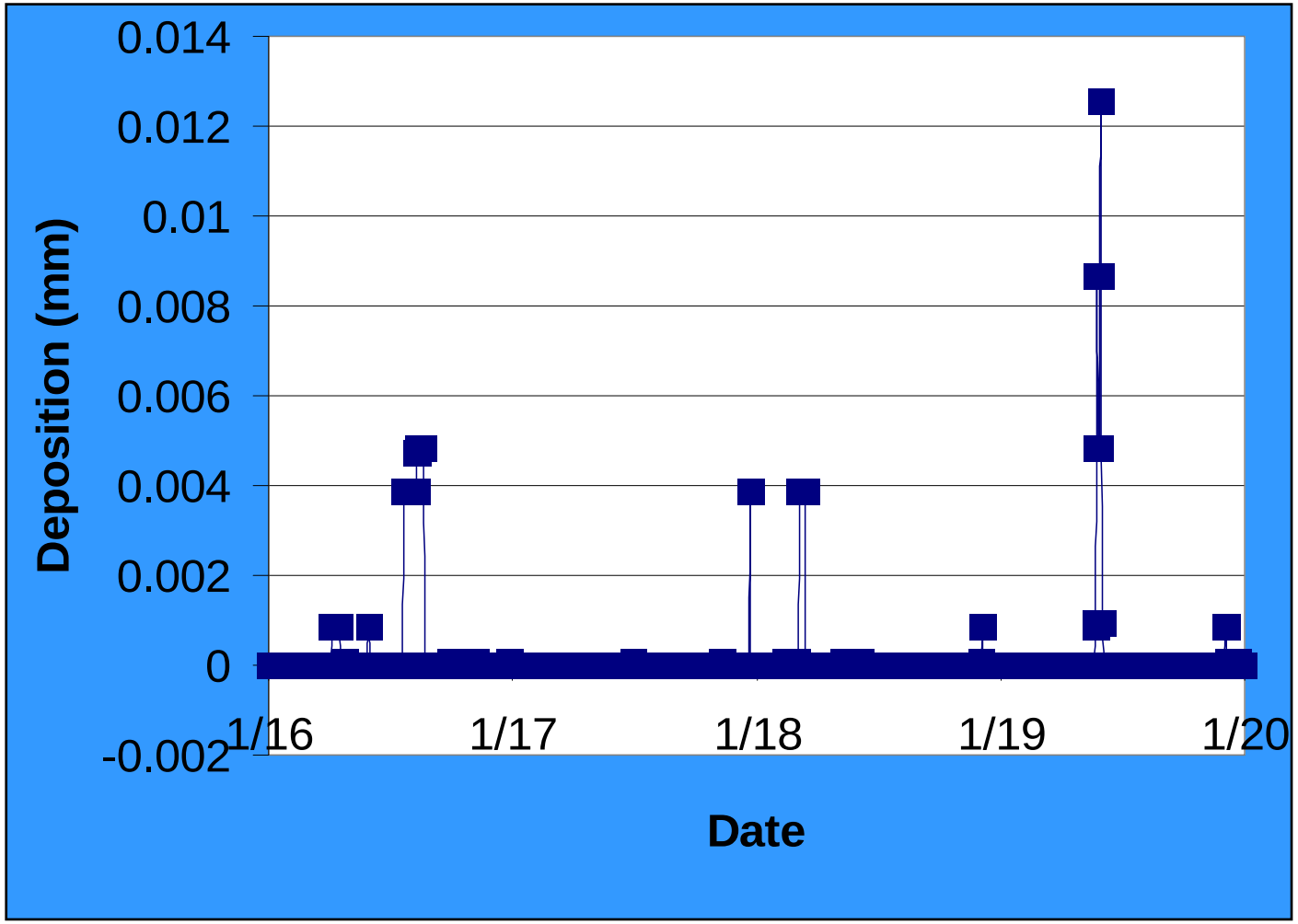
PTM Deposition Maps

1/17 – 8pm

1/19 – 10am

Time Series of Deposition

Rule of thumb
Egg burial depth
= ½ egg diameter
= .5 mm

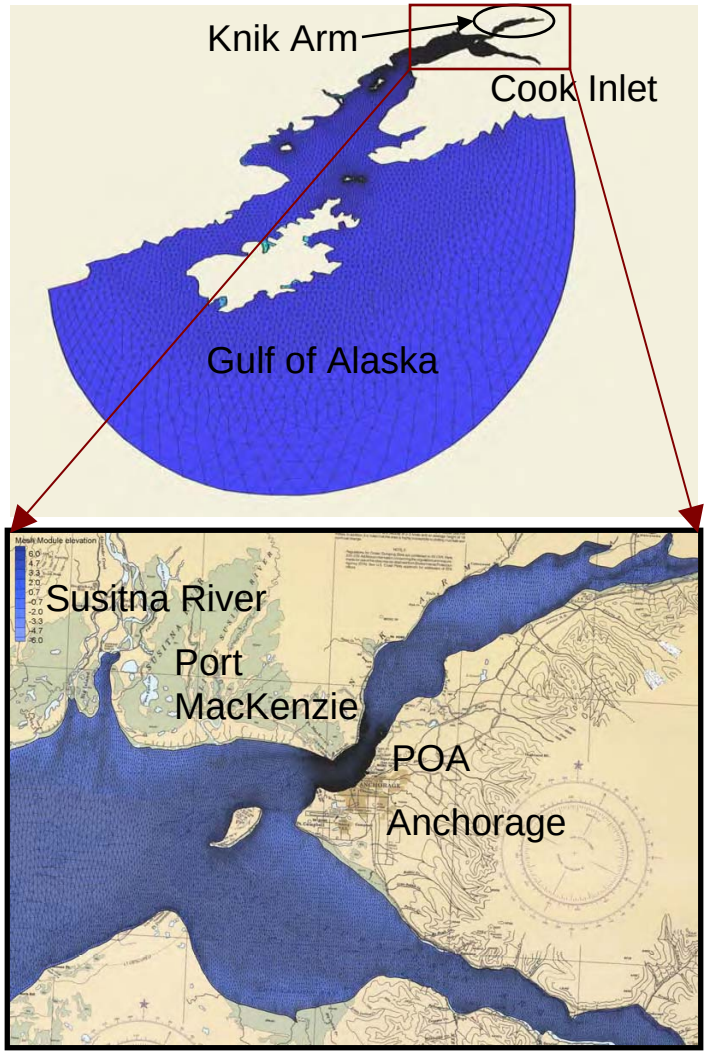


Summary

- PTM is a tier two model
- Computational efficiency permits numerous scenario simulations without computational overhead of 3-D Eularian transport models.
- PTM best suited for application where a specific number of sediment sources are primary concern.
- PTM requires accurate quantification of these sources
- Significant research in developing algorithms to quantify source terms (sediment erosion, outfalls, dredging events, ship passage, etc)
- Tools within PTM quantify exposure for risk assessment
- Flexible, modularized code for increased applicability

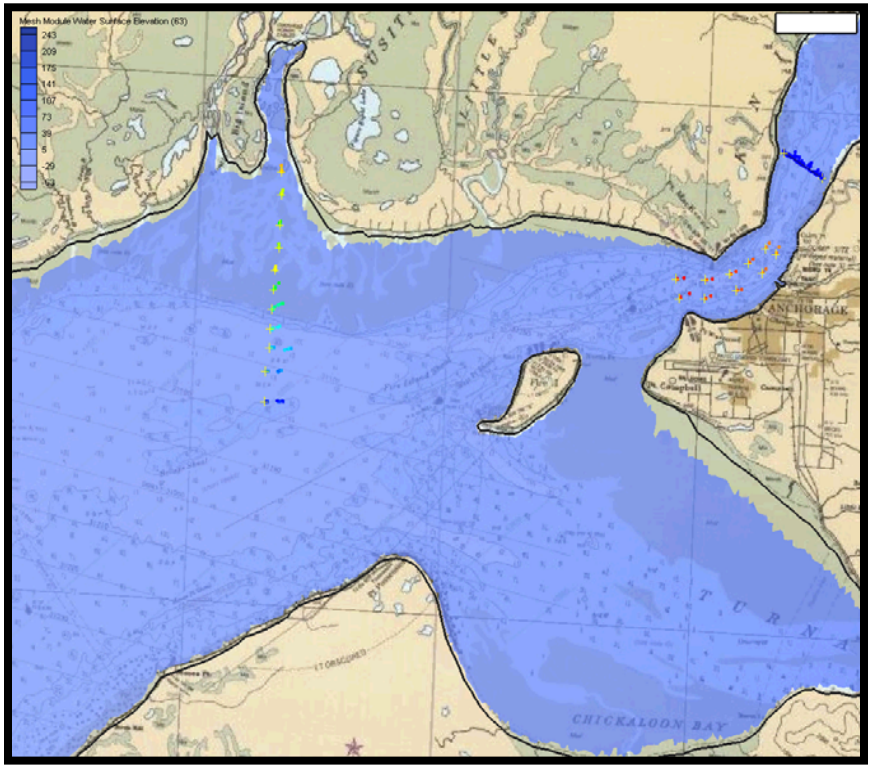
PTM Example – Suspended Sediment Transport in Northern Cook Inlet and Knik Arm, AK

Background:
Knik Arm is a 45-km-long extension of Cook Inlet. The Port of Anchorage (POA) is situated on the SE shore.



The primary objective of this study is to quickly and interactively investigate transport from sediment sources northern Cook Inlet and Knik Arm.

Example – Cook Inlet and Knik Arm, AK



Particles colors indicate sources

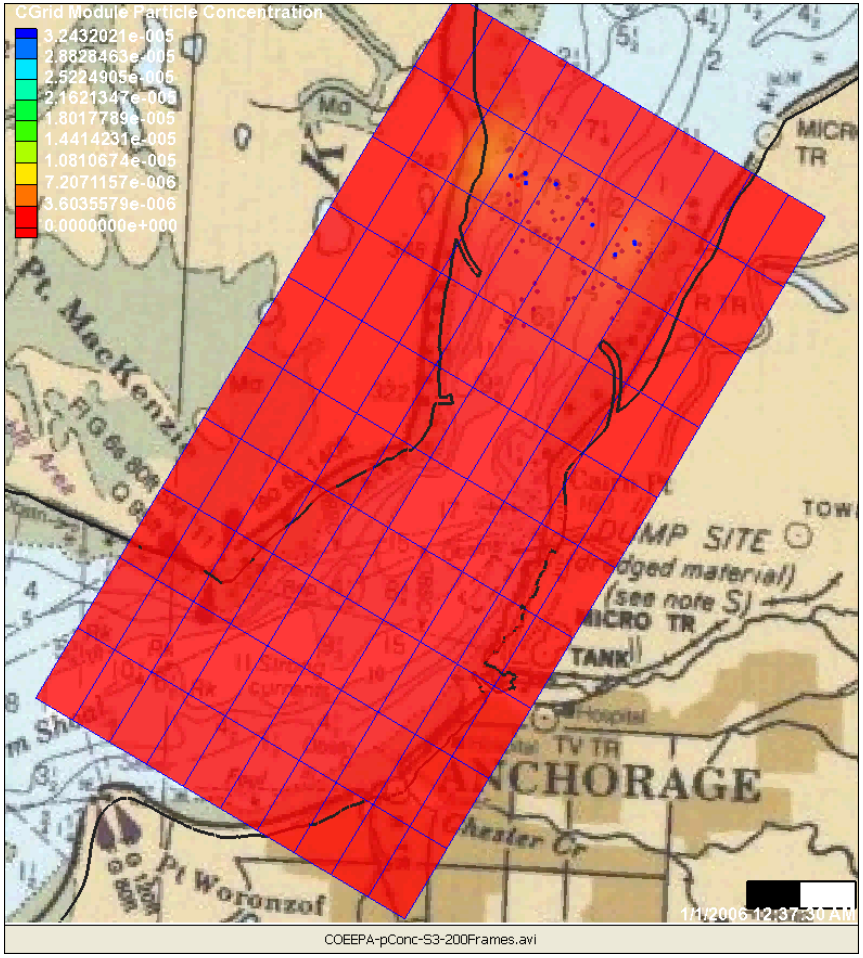
Simulation Details:

- 6 days between 19-25 July 2005 during spring tide (no waves)
- 2D - ADCIRC Hydrodynamics
- Particle Source – Coarse Silt & fine sand (D50=0.065mm)

Major Results:

- Deposition of silt particles is limited predominantly to areas adjacent to intertidal mud flats.
- Strong tidal flows in main channel produce sufficiently large bed shear stresses to flush fine sediment.
- Preliminary results suggest sediment introduced near Susitna River is not a significant source of sediment to lower Knik Arm.

Example – Cook Inlet and Knik Arm, AK



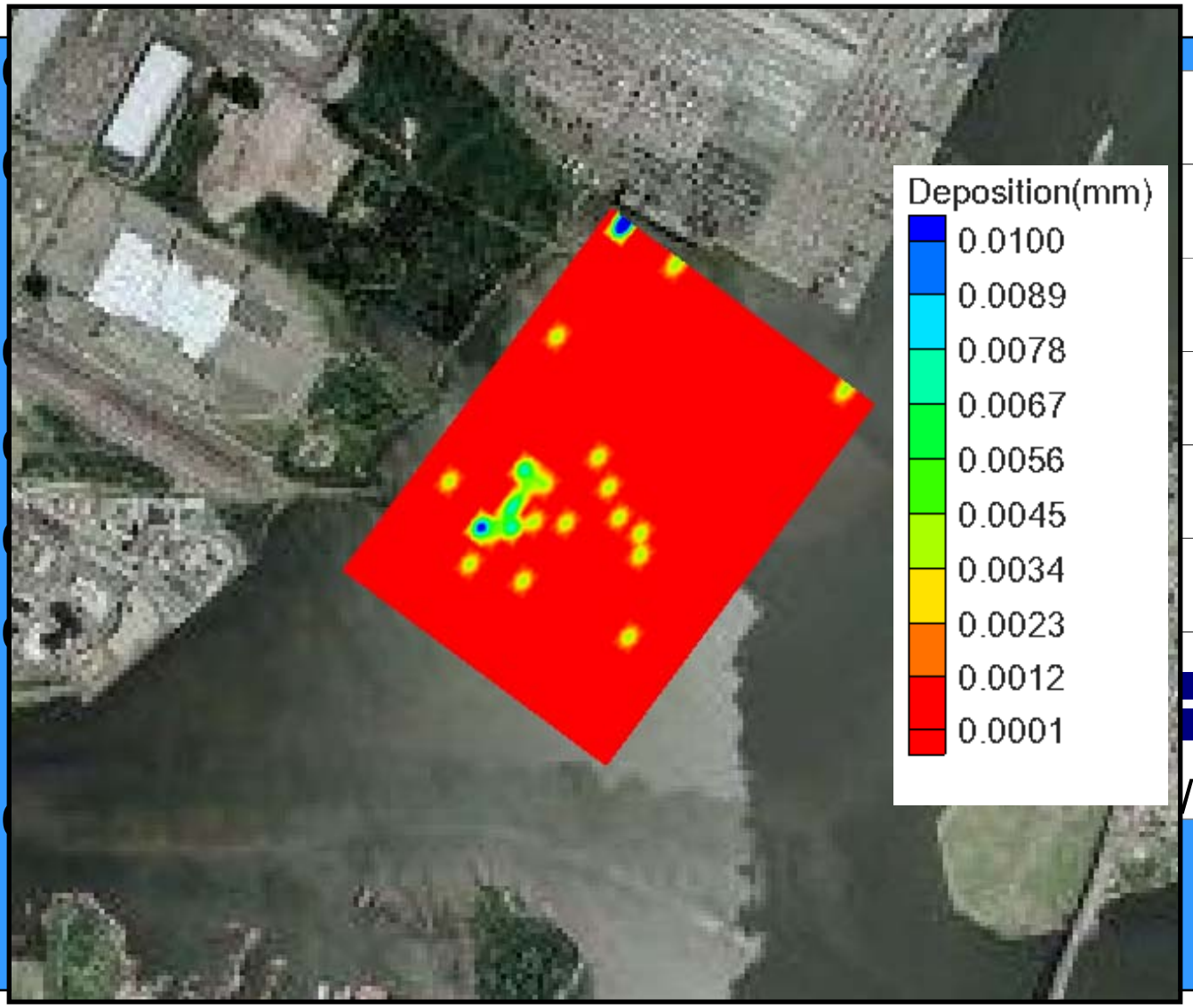
Simulation Details:

- Post-processing to develop contour plots of concentration and deposition
- These contour plots can be time-variable
- Data collected at user-specified points or regions used to estimate dosage
- Dosage data transferred to effects models and databases
- Particle colors represent deposited (red) and suspended (blue) sediments

Summary

- Models provide important lines of evidence when developing CSM and estimating exposure
- Multiple models are required
- Model development is ongoing to address changing needs of Corps users
  - Continued advancement of three tiers of dredging tools for screening level through advanced applications
  - Development of new interfaces and systems for easy interaction between dredging models and post-processing/analysis of model output
  - Continued research to understand dredging and sediment processes to support modeling
- Model exposure estimates are used in risk assessment

Time Series of Deposition



Rule of thumb
Egg burial de
= ½ egg dian
= .5 mm

Deposition (mm)

/20

OBJECTIVE: Process Descriptions

- Mixed sand/silt/clay behavior is not as well understood as pure sand
- Sediment/constituent processes related to dredging, outfalls, propellers, storms and other issues must be quantified
- Ongoing research in relevant processes is supporting modeling
  - Mixed sediment erosion, settling and transport
  - Dredge, outfall and propeller releases
  - Long-term dispersion and consolidation
  - Chemical Processes
  - Fish larvae behavior