Los Angeles and Long Beach Harbors and San Pedro Bay Modeling

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Presentation Outline

- Modeling Approach
- Status of Model Components
- Configuration of Sediment/Contaminant Model
- Sediment/Contaminant Calibration
- Uncertainty and Sensitivity Issues
- Evaluation and Performance Issues
- TMDL Modeling

Greater Harbors Modeling Approach

- Generic EFDC Modeling System
  - Hydrodynamics (Including S & T)
  - Sediment Transport
  - Contaminant Transport (Metals and Organics)
- Observational Data to Support Model Configuration and Calibration
- Modeling System + Configuration Data = Application Specific Model
- Model Calibration, Uncertainty, and Sensitivity Establish Utility of Model with Respect to TMDL Scenario Simulations

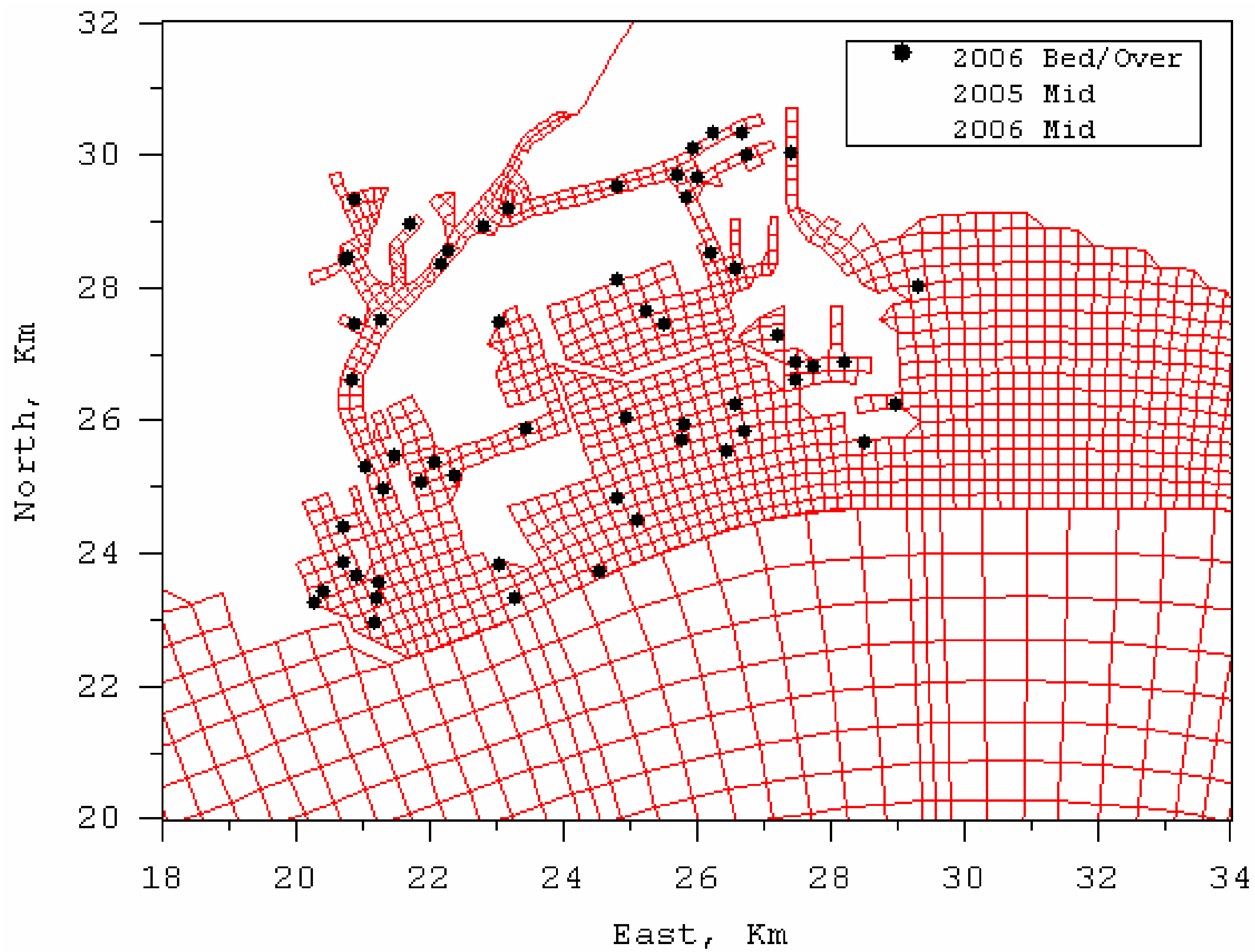
Status of Model Components

- Hydrodynamic Component Completed Fall 2006
- Development of Sediment and Contaminant Components Were on Hold Awaiting Fall 2006 Field Observations
- Observational Data Received in April 2006
- SED/CON Configuration and Preliminary Calibration Completed
- Final Calibration and Limited Sensitivity and Uncertainty Analysis Underway
- Ready for TMDL Modeling Oct/Nov 2007

Fall 2006 Observational Data

- Approximately 60 Bed and Overlying Observational Sites
- Bed Physical Properties: Grain Size Distribution, Bulk Density, Per Cent Organic Carbon
- Bed Chemical Properties: Dissolved and Particulate Metals and Organics Concentrations, Pore Water DO
- Overlying Water Sediment, DOC, and Total Metal and Organic Contaminant Concentrations
  - Missed Opportunity for Dissolved Phase Concentrations

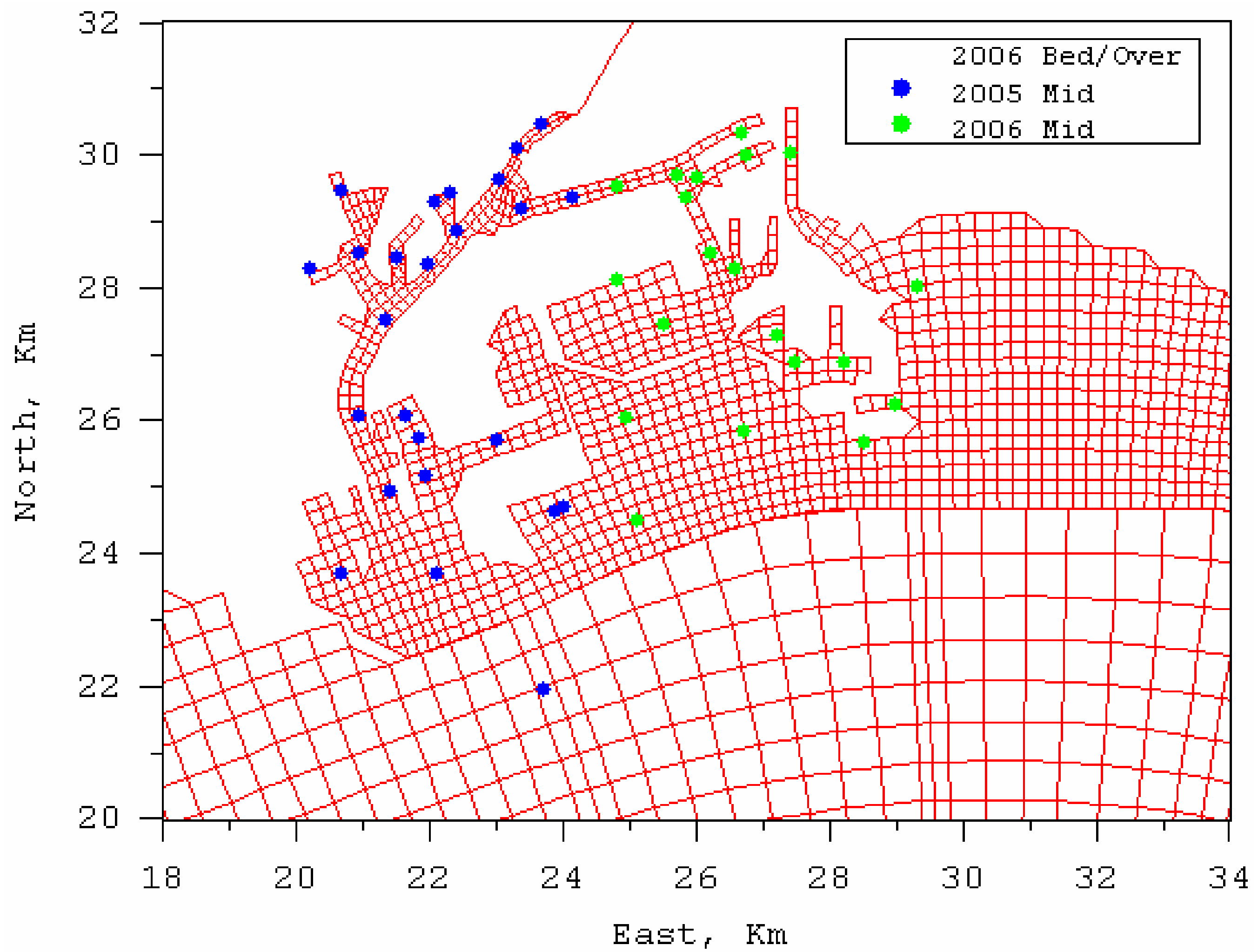
Fall 2006 Bed and Overlying Water Sites (Bed=>Initialization, Over=>Calibration)



Additional 2005/2006 Observational Data

- POLB 2006 Mid-Water Column, (20 Sites) and POLA 2005 Mid-Water Column, (55 Sites)
  - Dissolved and Particulate Metals Concentration
  - Organic Carbon Concentrations
  - Missed Opportunity for Suspended Sediment Concentrations
- SCCWP 2006 Organics Data
  - Water Column (1) and Pore Water (4) at Con Slip
- SPME 2006 Organics Data
  - (10 Sites with some reps)

2005 and 2006 Mid-Water Column Sites (Used for Metals Calibration)



The Rest of the Data

- Various Sediment Bed Physical Property Data Sets Going Back Until 1993
  - Did Not Use Data Inside Breakwater Prior to 1998
  - Extremely Limited Data Outside Breakwater
- Various Sediment and Water Column Total Metals and Organics Concentrations
  - Did Not Used Data Prior to 2000
  - Extremely Limited Data Outside Breakwater

How the Observational Data Is Used

- Sediment Bed Physical Property Data Used to Initialize the Bed for Sediment Transport
- Sediment Bed Metals and Organic Concentrations Use to Initialize the Bed for Contaminant Transport and Fate
- Above Two Data Types Used to Estimate Partition Coefficients
- Water Column Sediment and Contaminant Data Used for Calibration
- More Specifics in Subsequent Slides

Configuration of the Sediment/Contaminant Model Components

- Sediment and Contaminant Loads form Rivers and Near Shore Watersheds
- Sed/Con Boundary Conditions in San Pedro Bay
- Initial Sediment Bed Physical Properties
- Initial Contaminant Concentrations in Sediment Bed
- Water Column ICs Not Critical
- Sediment and Contaminant Transport Parameters From Observational Data and Literature

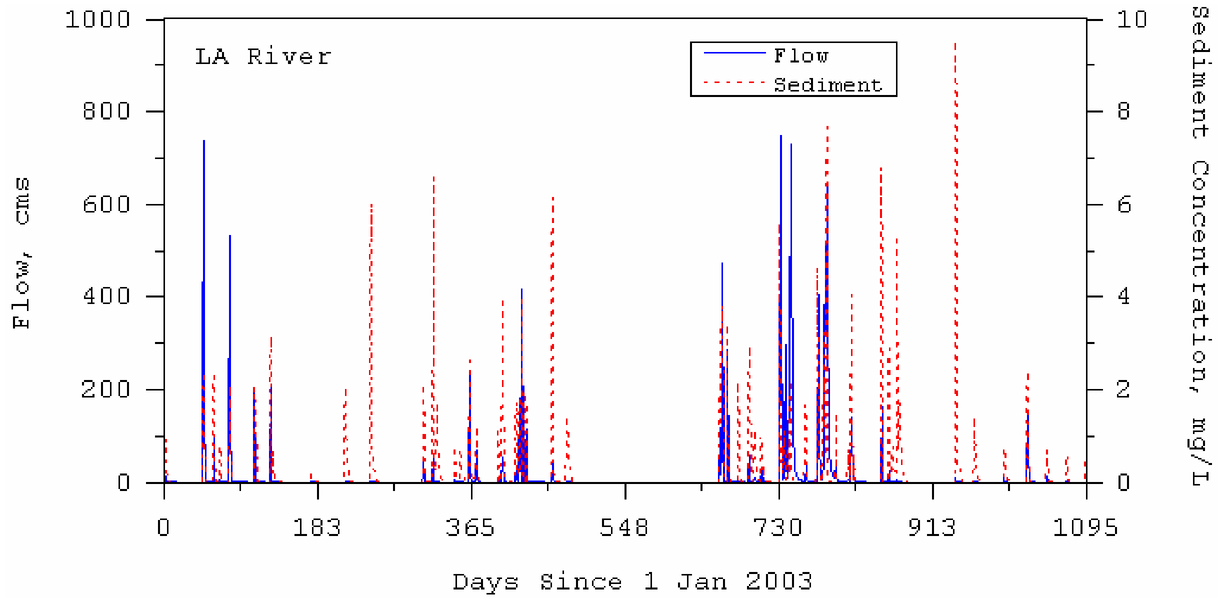
Sediment and Contaminant Loads and Open Boundary Conditions

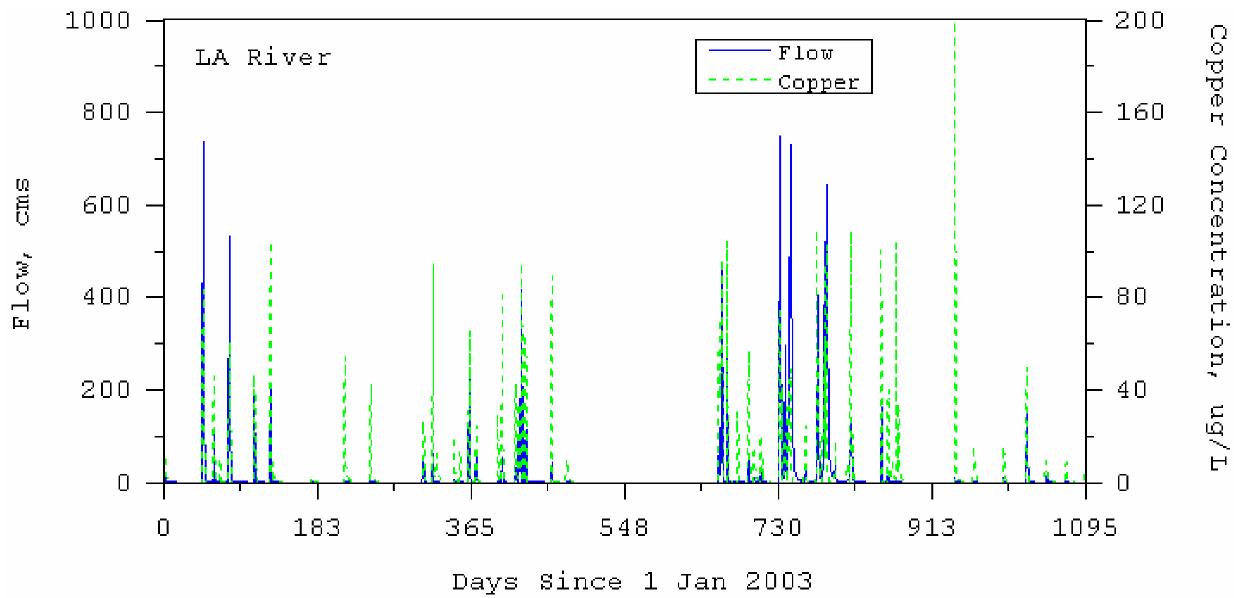
- Sediment and Contaminant Loads From Watershed Models
  - Sed and Metal Land Loads Reasonable
  - Organics Loads Used Different Procedure
  - Wet Loads Could Be Calibrated Further
  - LA River LSPC Reach-Res Problem Fixed
- Open Boundary Conditions in San Pedro Bay
  - Little Data Except for DDT
  - Calibrate and/or Demonstrate Low Sensitivity
  - Start With Lowest Interior Values

Sediment

LA River Flow and Load

Copper

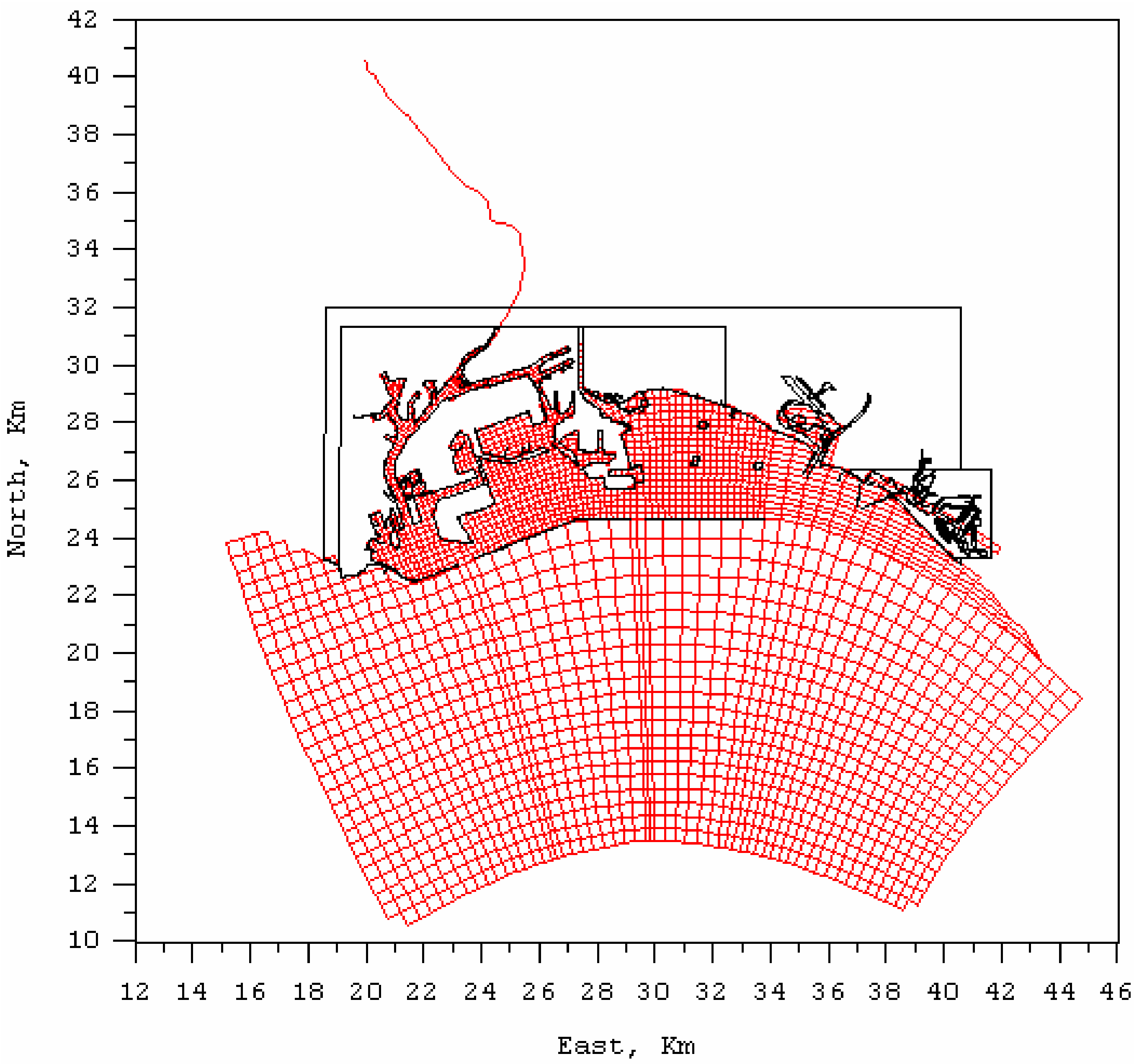




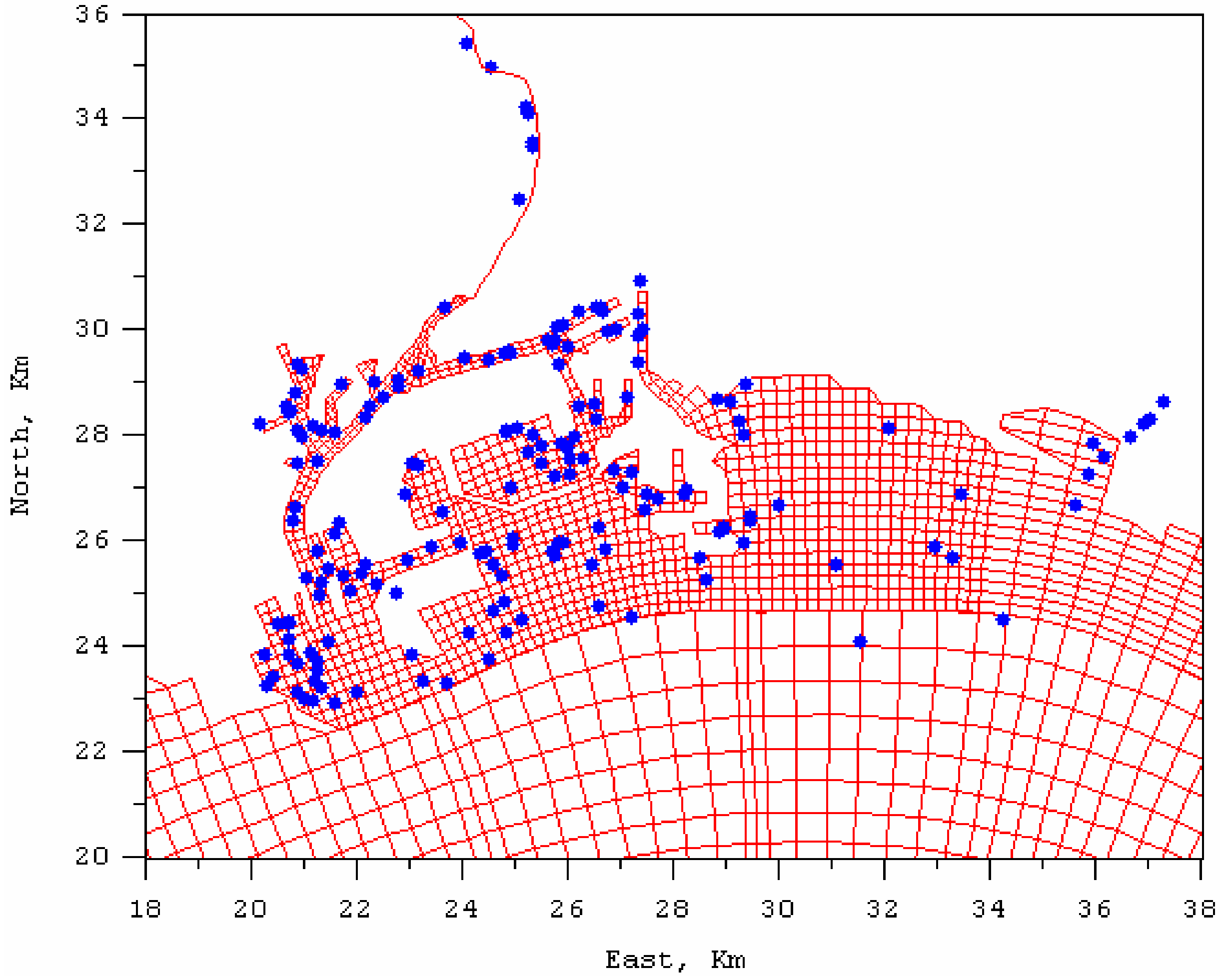
Initialization of the Bed Sediment

- Contaminants Are Adsorbed to Bed Sediment
- Model Needs Sediment Size Class Fractional Composition, Porosity (or Bulk Density), and TOC
- Best Data Has Grain Size Distribute, Porosity, and Organic Carbon Fraction
- Worst Data Has Fraction of Fines
  - Correlate Porosity and FOC with Fraction Fines Using Best Data
- Size Classes
  - Cohesive Behaving or Fine Class (<63 um)
  - 1-3 Noncohesive Behaving Classes

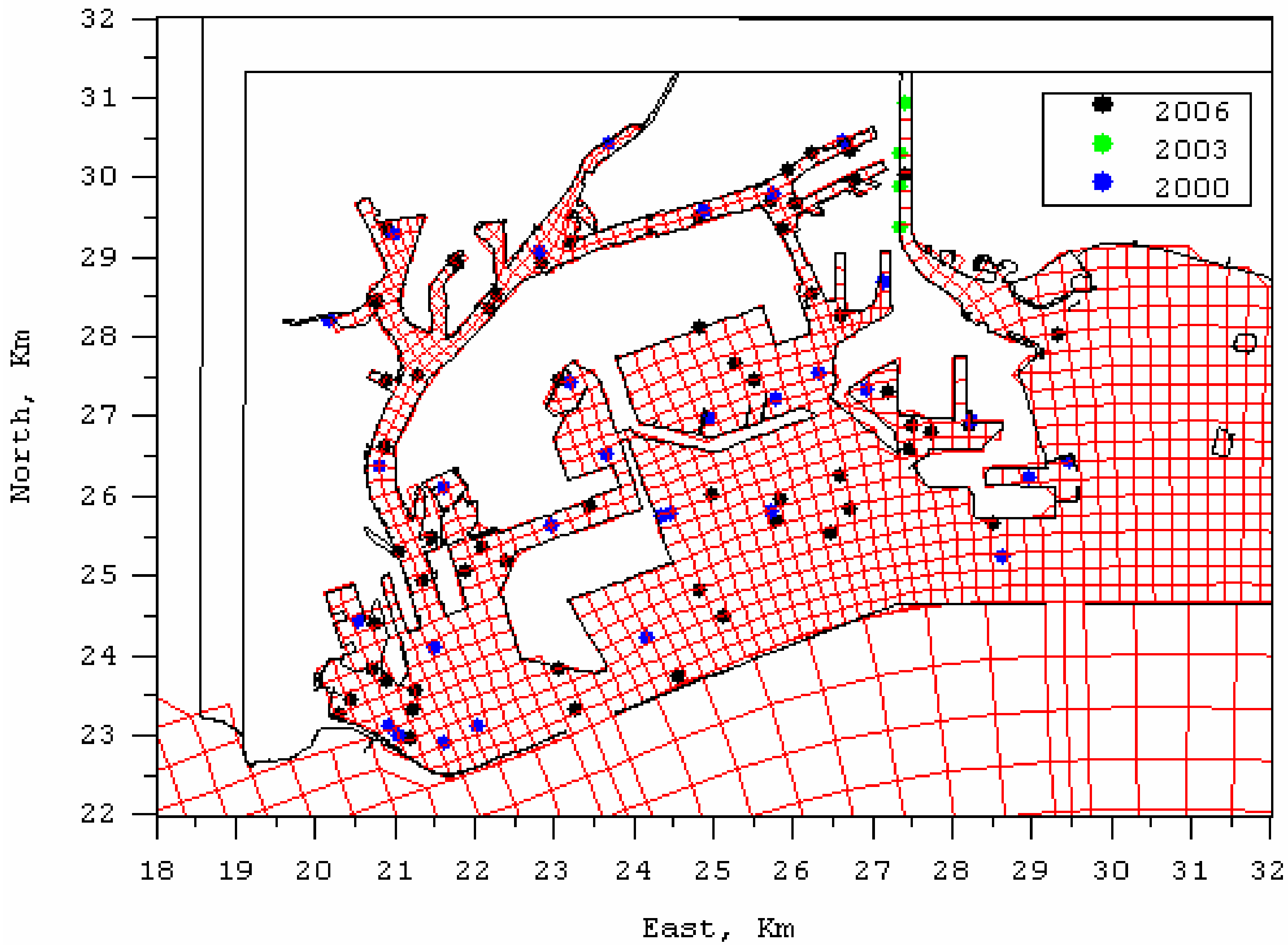
Greater Harbors Grid



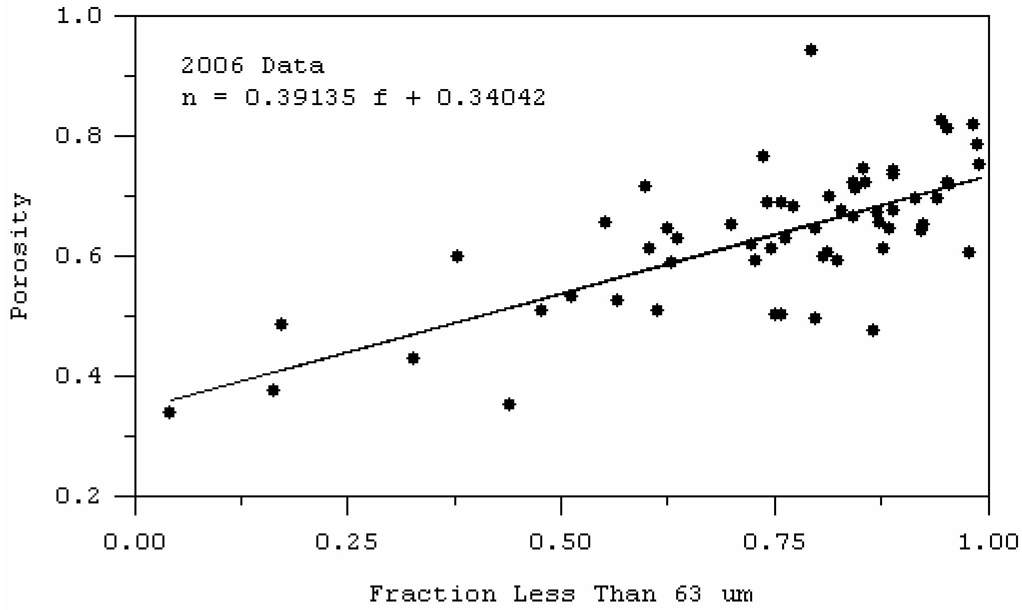
Location of Data Sites Used to Initialize Sediment Bed Physical Properties (300 Sites)



Zoom Show Most Recent Bed Physical Data Sites

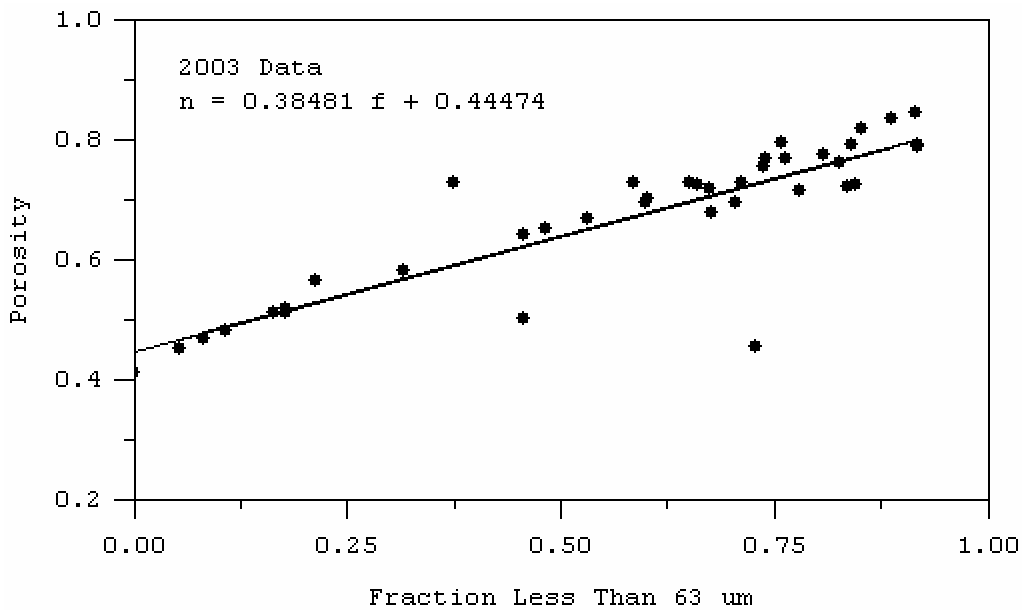


2006 Data

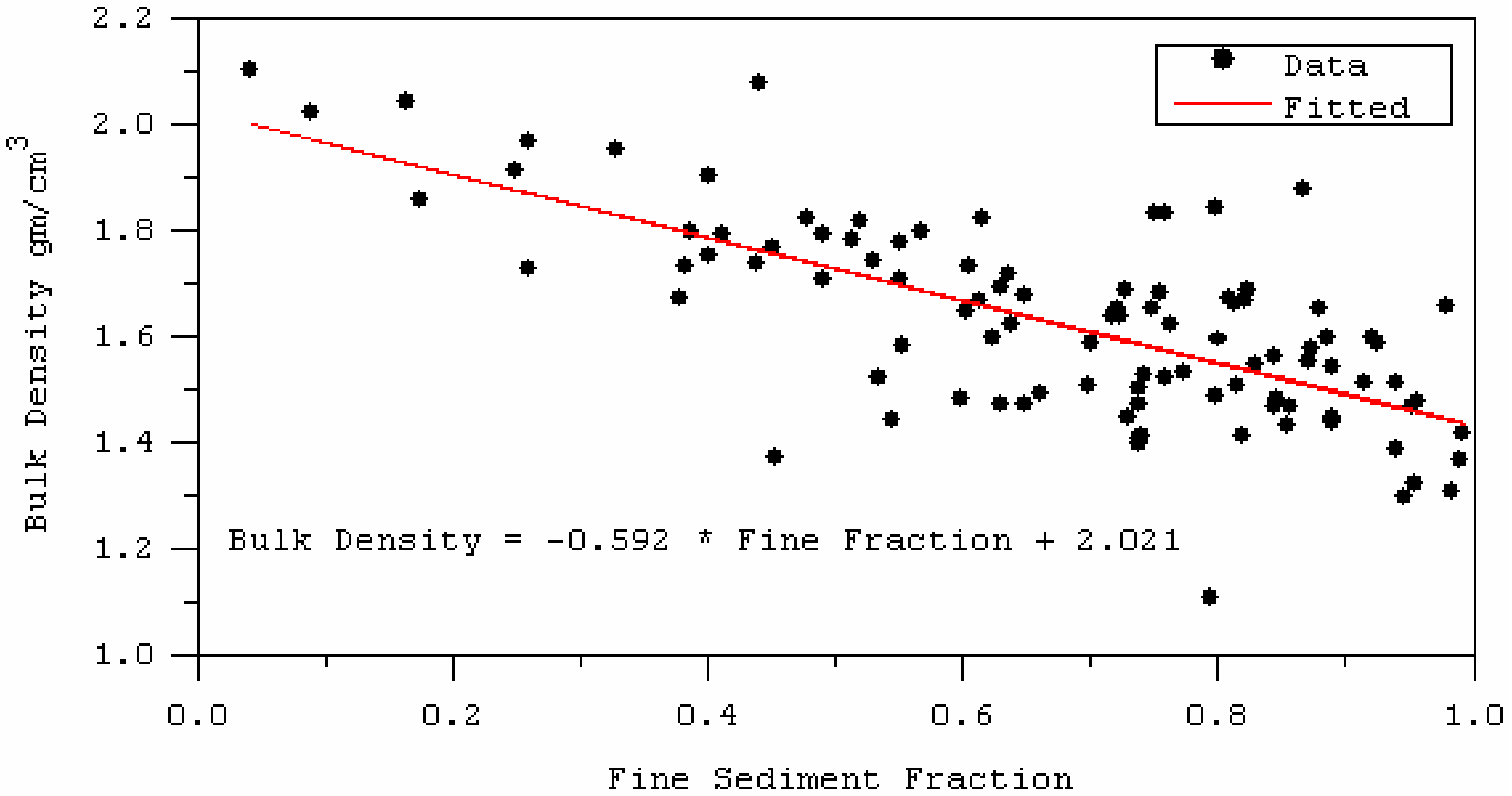


Estimating Bed Porosity

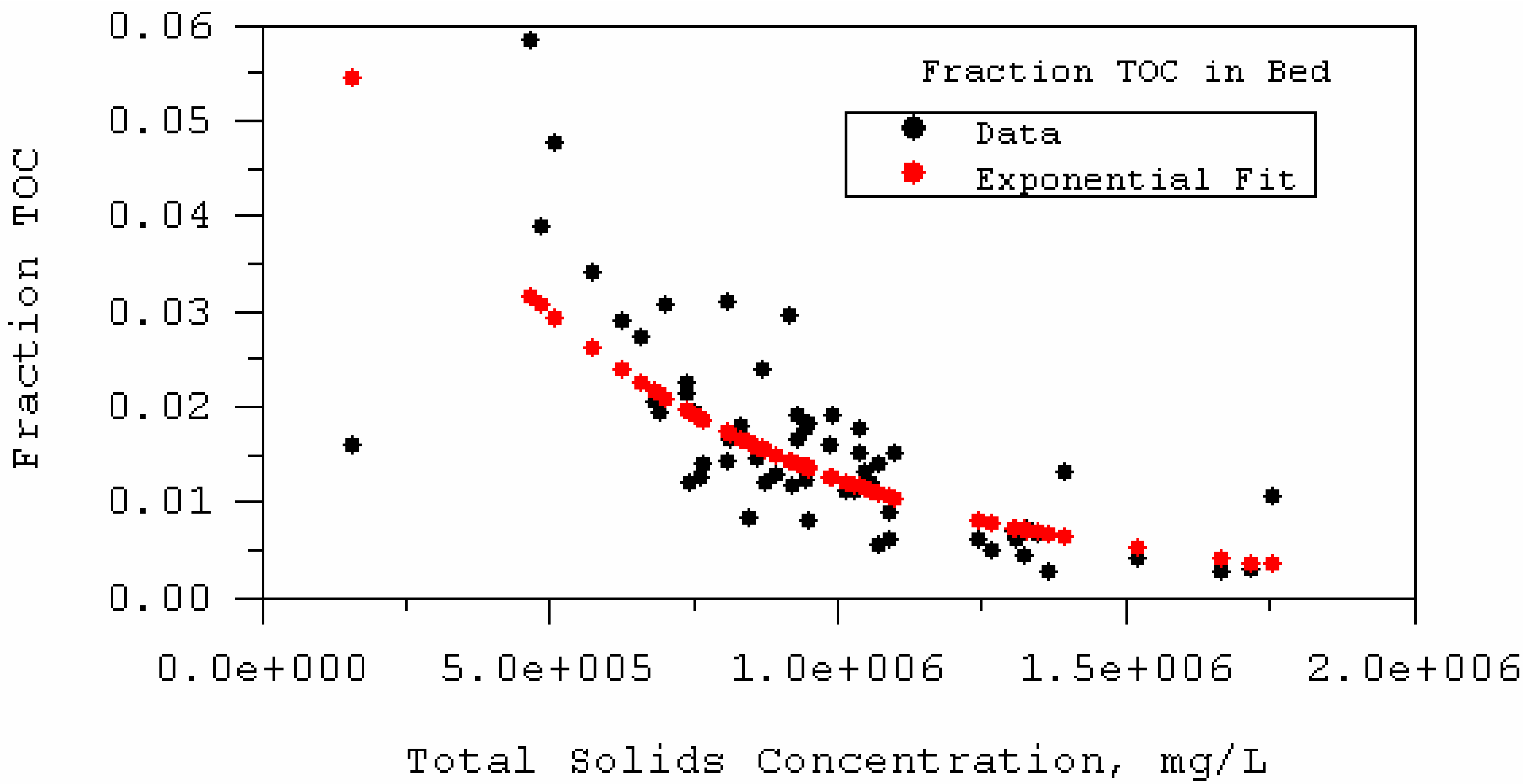
2003 Data



Estimating Bed Bulk Density



Fraction TOC Correlation Using 2006 Bed Data



Sediment Transport Configuration: Other Parameters

- Internal Widely Accepted Parameterizations for Settling, Deposition and Erosion of Noncohesive Sediment Size Classes Are Used
  - Based on Effective Diameter of Size Class
  - Number of Classes and Effective Diameters Can Be Calibrated
- Initial Estimate of Fine Size Class Settling Velocity and Critical Stress for Deposition
  - Literature Values
  - Subject to Calibration
- Initial Estimate of Fine Size Class Critical Stress for Erosion and Erosion Rate
  - Literature Values
  - Sed Flume Test
  - Subject to Calibration

Estimating Sediment Erosion

- UC Santa Barbara Study (Jepson et al 1997)
- Sediment Flume Testing of Field Cores
  - 2 Cores Queen's Way, 5 Cores Queen's Gate
  - "there is no obvious correlation between erosion rate and any of the bulk properties listed" Jepson et al
- Sediment Flume Testing of Composite Cores
  - 4 Cores reformed form Queen's Gate Sediments
  - Allowed to Consolidate for 2, 6, 20, and 60 days
  - Testing Results Showed Significant and Well Defined Bulk Property Dependence

Grain Size Distribution of Composite Samples

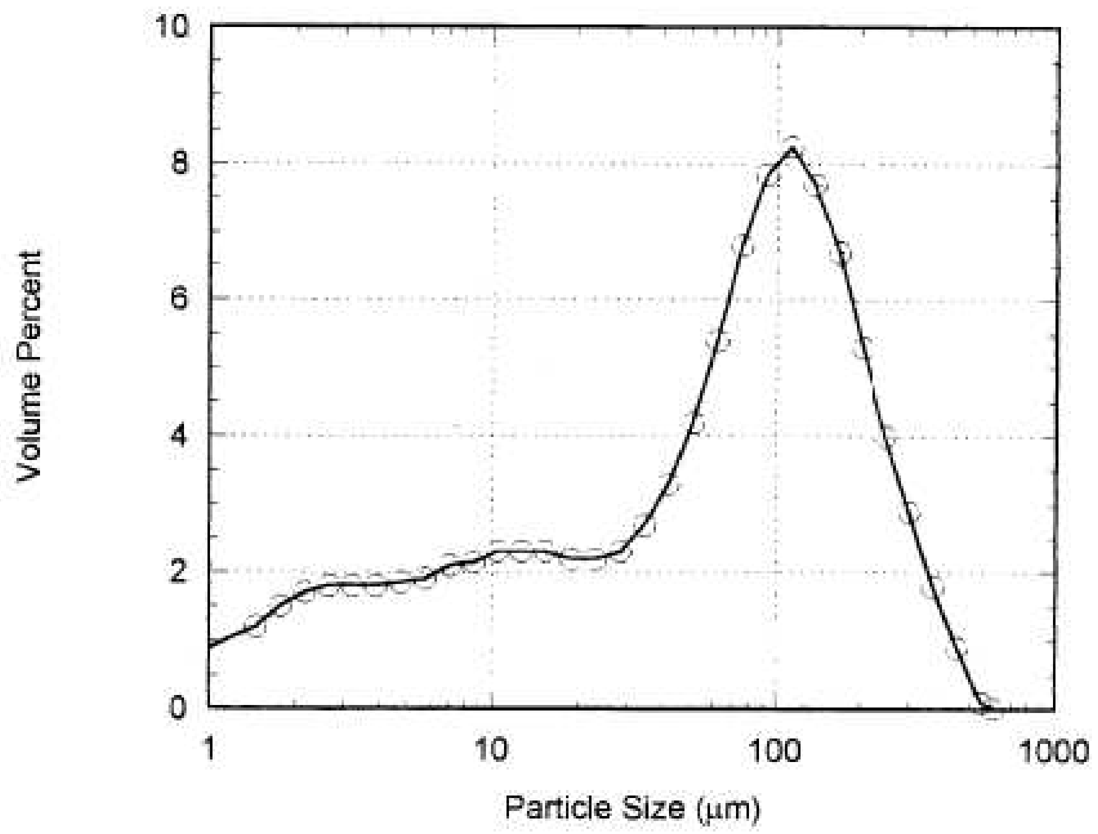


Figure 10. Dissaggregated particle size distribution for the composited sediments from the entrance to the Long Beach Harbor. The median particle size is 70 μm.

Bulk Density as Function of Depth in Sediment Bed (UCSB Study) (void ratios 0.95 to 1.35)

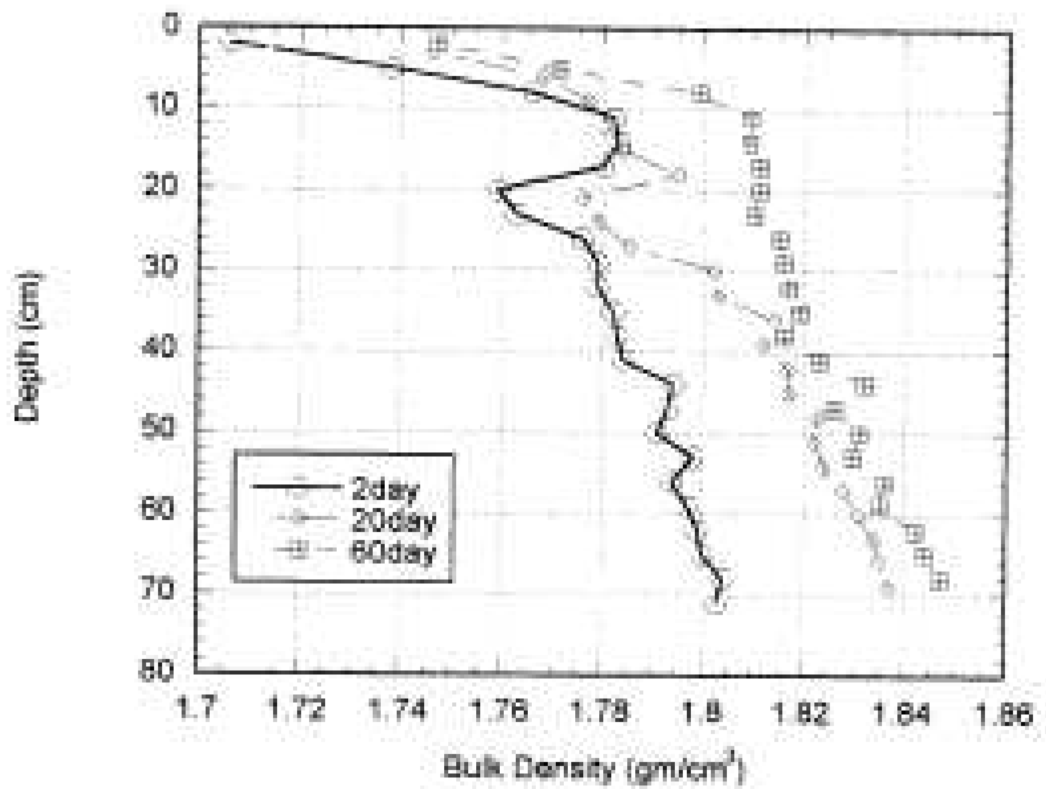


Figure 13. Bulk density as a function of depth for the 80 cm composited sediment cores at consolidation times of 2, 20, 60 days.

Erosion Rate As Function of Bed Stress and Bulk Density (UCSB Study)

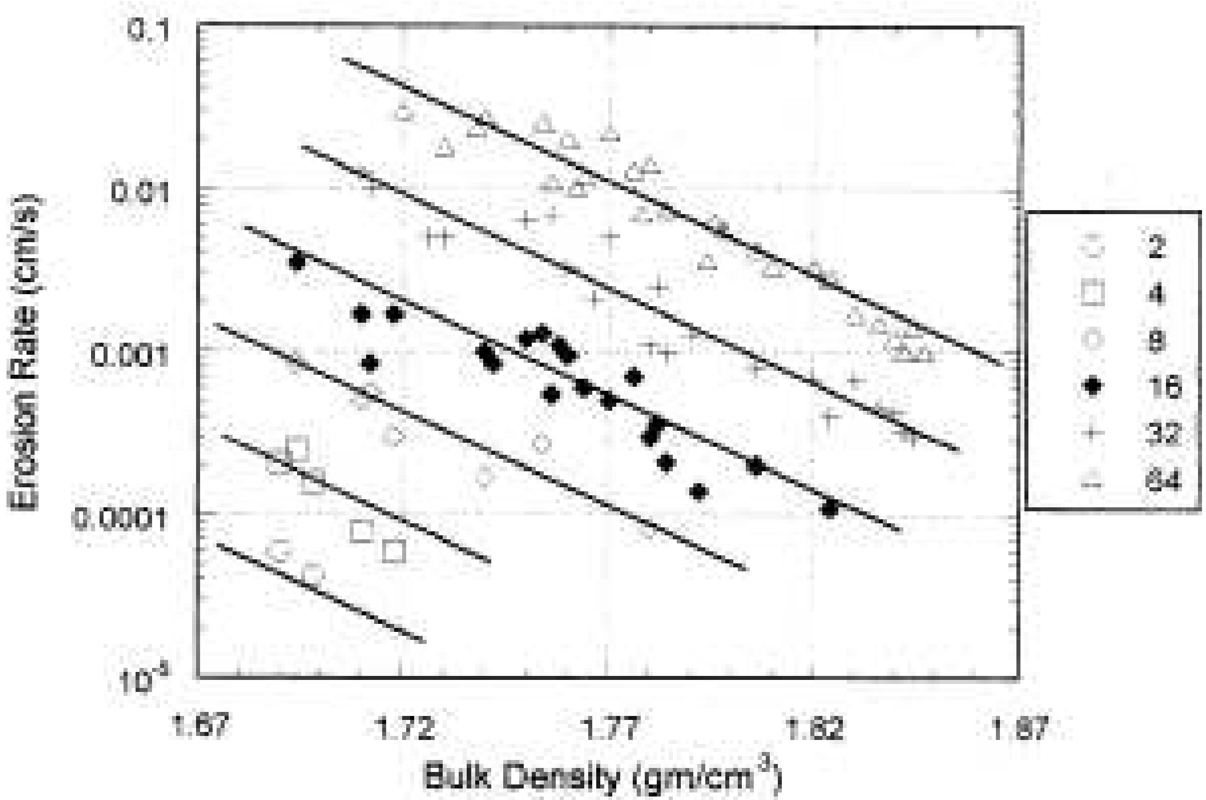


Figure 19. Erosion rates as a function of bulk density for the composited sediments. Erosion rates for shear stresses of 2, 4, 8, 16, 32, and 64 dynes/cm^2 are shown.

Erosion Rate As Function of Applied Stress and Void Ratio (as solids volume fraction)

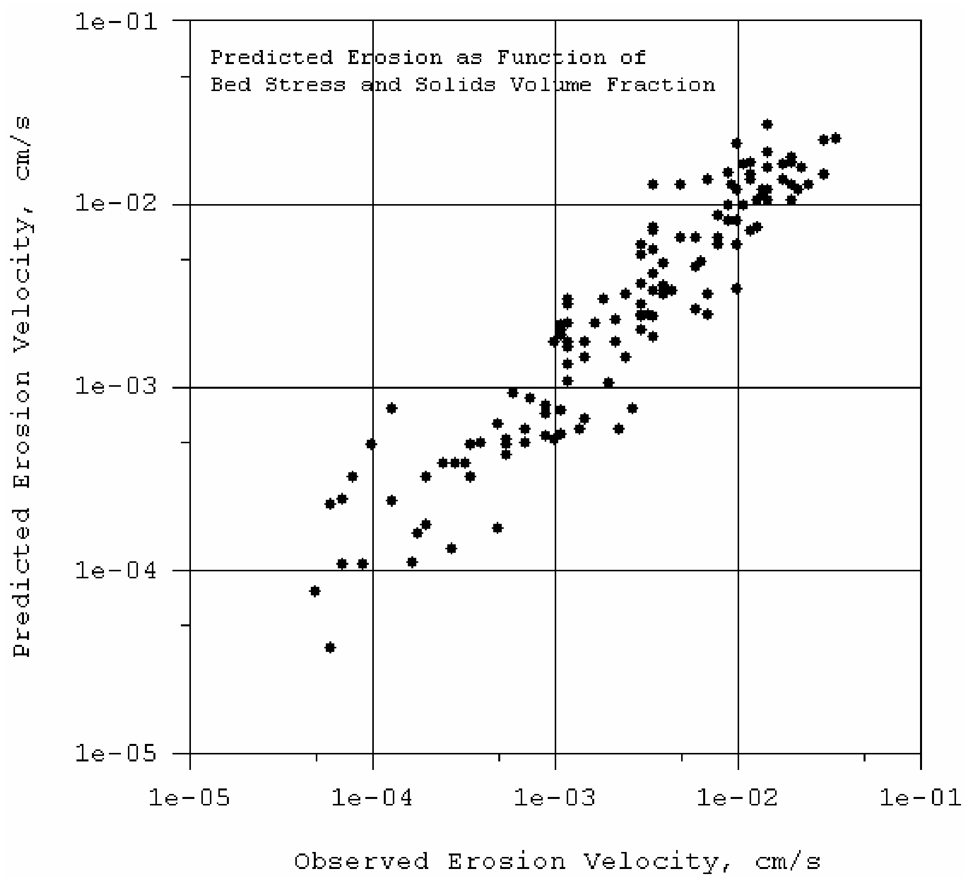
$$\frac{E}{V} = \alpha \left(\frac{\tau}{V^2} \right)^{\beta} \exp\left(\frac{\gamma}{1+\varepsilon} \right)$$

$$\alpha = 0.237$$

$$\beta = 2.18$$

$$\gamma = -32.05$$

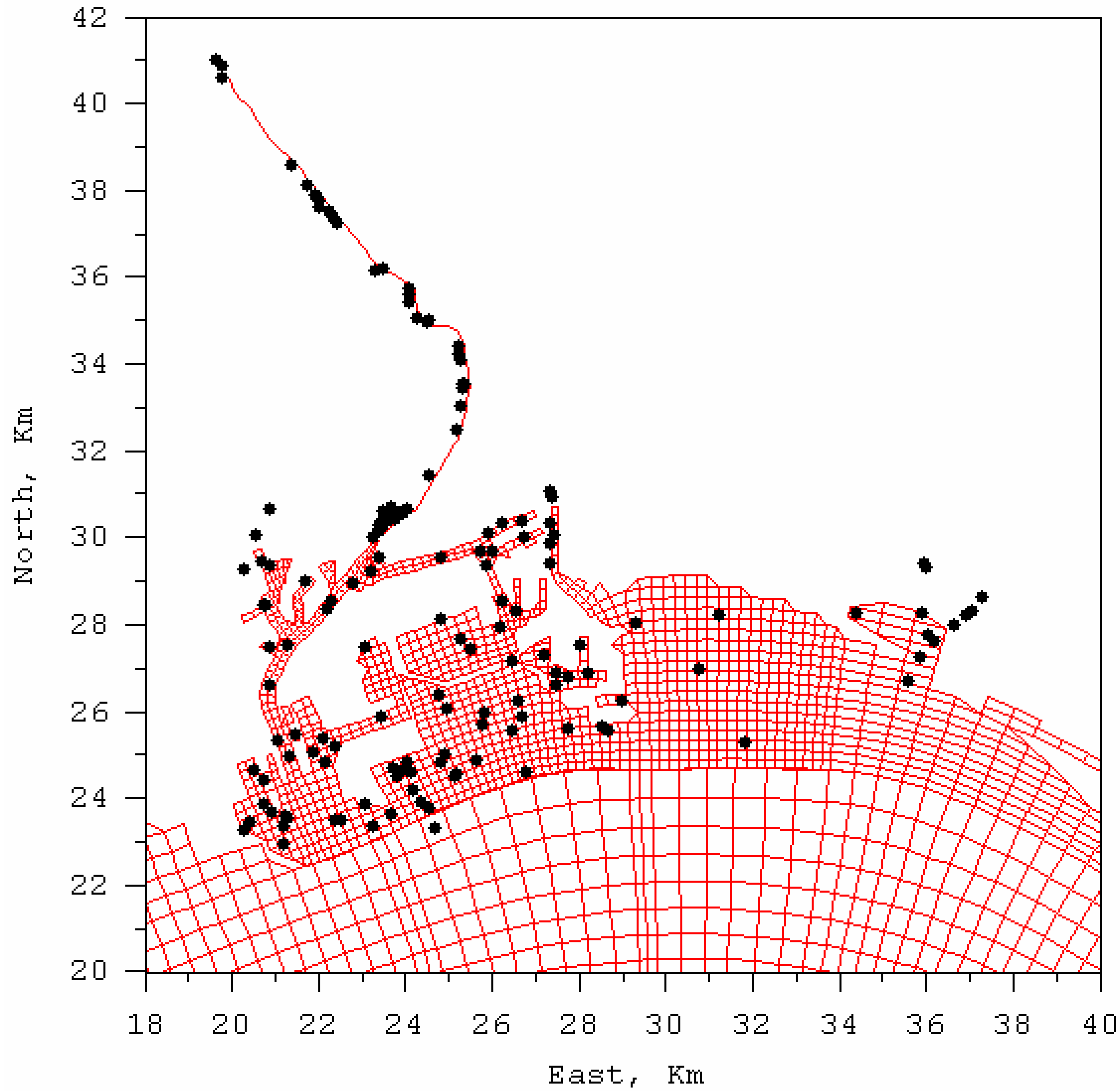
$$V = (\nu g)^{1/3}$$



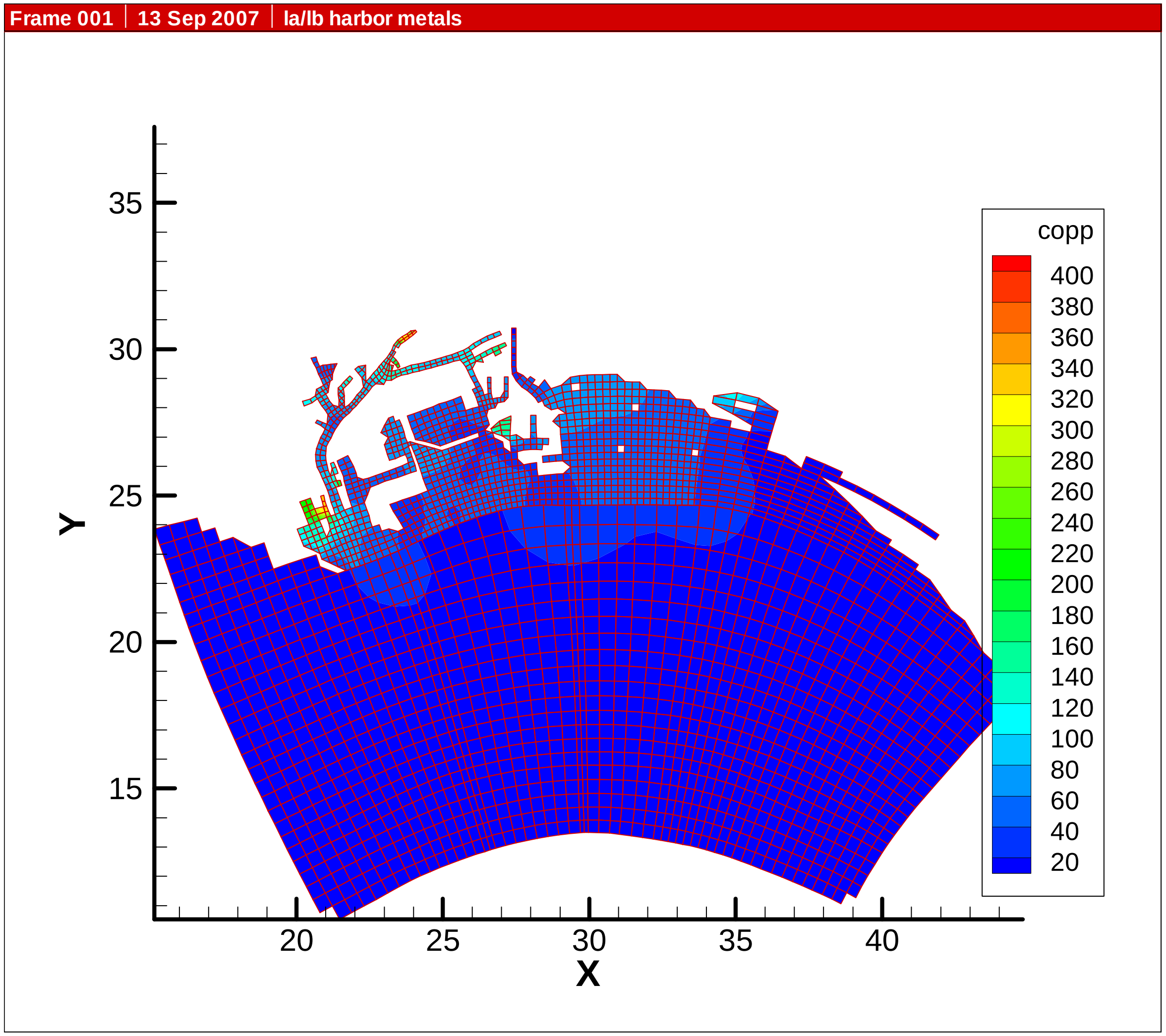
Initialization of the Bed Contaminant Concentrations

- Bed Is Major Reservoir of Contaminants
- Model Needs Total Concentration or Mass per Sed Mass Concentration
- Depending on Partitioning Option, POC, FPOC, and/or Pore Water DOC May Be Needed
- Best Data Has Dissolved and Particulate Concentration and Appropriate OC Data
- Worst Data Has Total or Mass/Mass Concentration
- No Data In San Pedro Bay (except DDT)

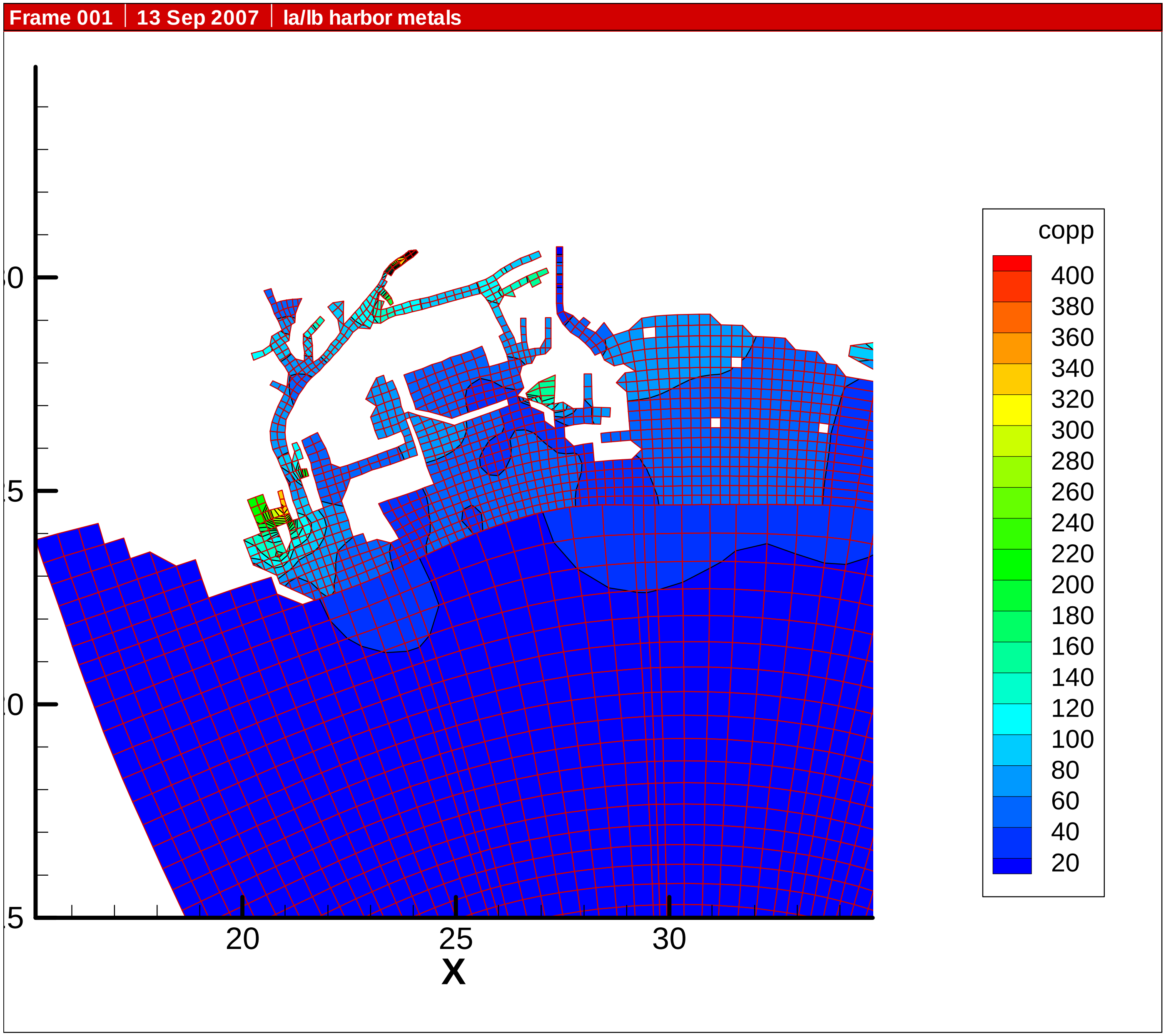
All Data Sites Used to Initialize Sediment Bed Metals and Organics Concentrations (Includes 2006 Sites)



Bed Copper Initial Condition



Bed Copper Initial Condition



Contaminant Transport Configuration: Other Parameters

- Requires Partition Coefficients for Metals and Organics
- Choice Between 2 or 3 Phase Partitioning
- 2 Phase: Particulate and Free Dissolved
  - POC/TOC Can Be Particulate Phase or FPOC/FTOC Associate With One or More Sediment Size Classes
- 3 Phase: Particulate, DOC Adsorbed Dissolved, and Free Dissolved
  - Requires Specification of Sediment Pore Water and Water Column DOC
- 2006 Bed Data Used to Estimate Partition Coefficients

Simplified Equilibrium Partitioning

$$C_d = \left(\frac{n}{n + S \bullet K_p} \right) C = \textit{dissolved per total volume}$$

$$C_p = \left(\frac{S \bullet K_p}{n + S \bullet K_p} \right) C = \textit{particulate per total volume}$$

$$C = \textit{contaminant concentration per total volume}$$

$$n = \textit{porosity}$$

$$S = \textit{sediment concentration per total volume}$$

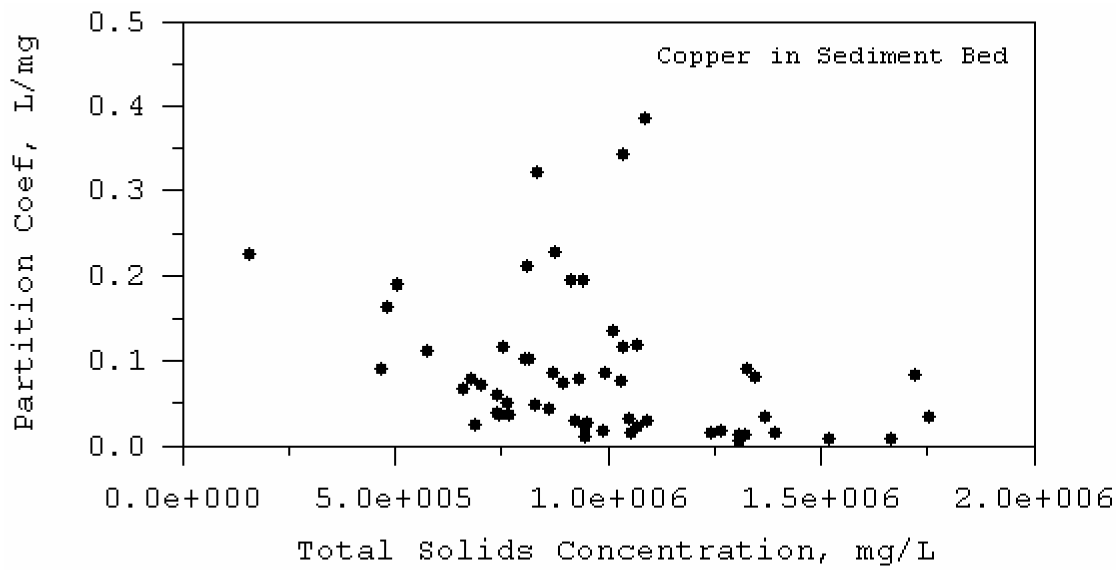
$$K_p = \textit{partition coefficient}$$

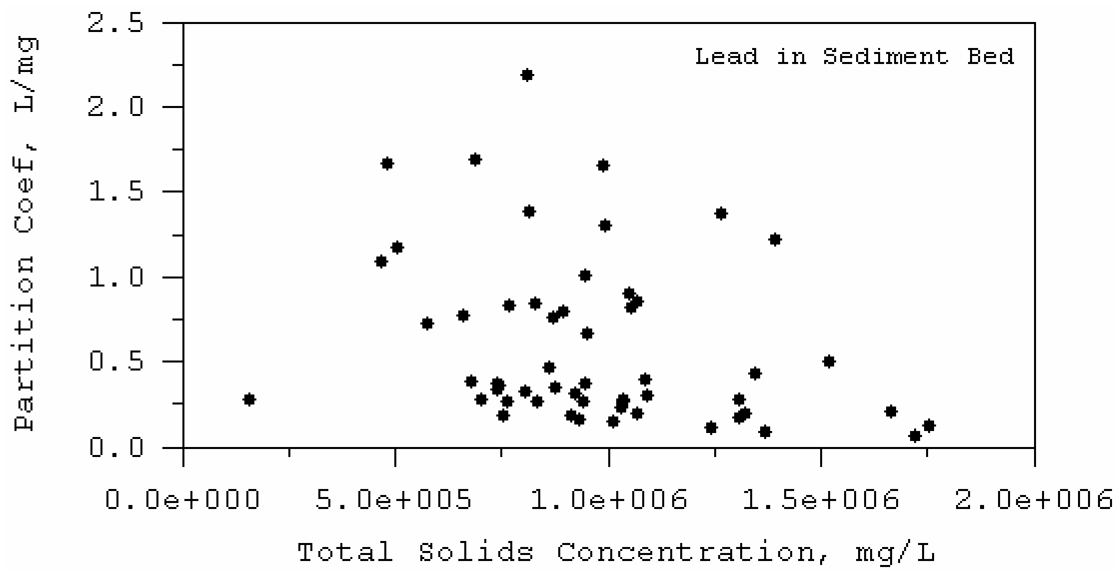
$$K_p = \frac{C_p}{S} \bullet \frac{n}{C_d}$$

Copper

Metals Partition Coefficients

Lead

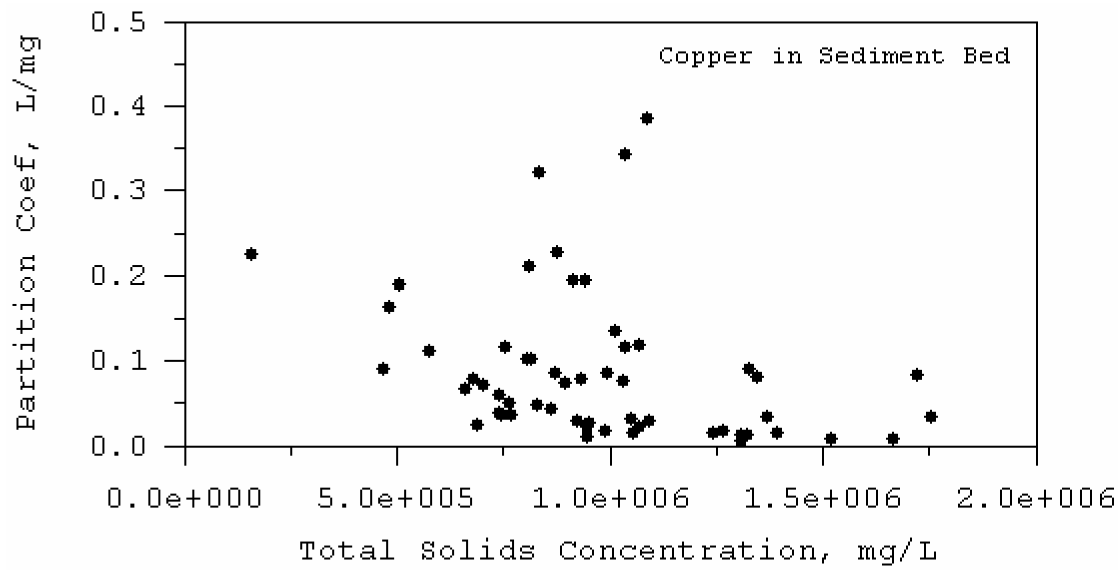


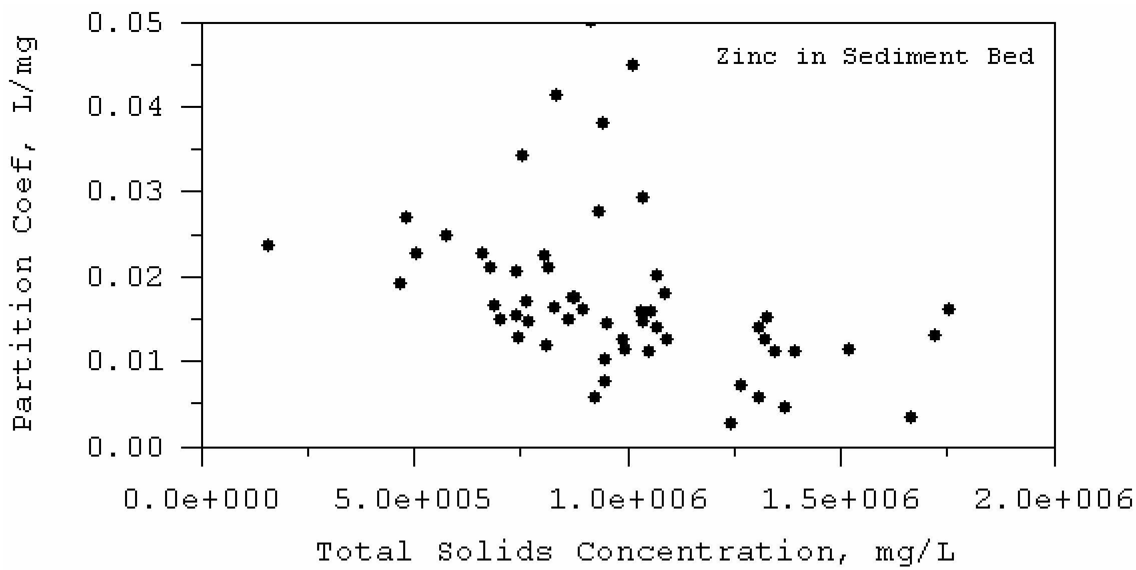


Copper

Metals Partition Coefficients

Zinc

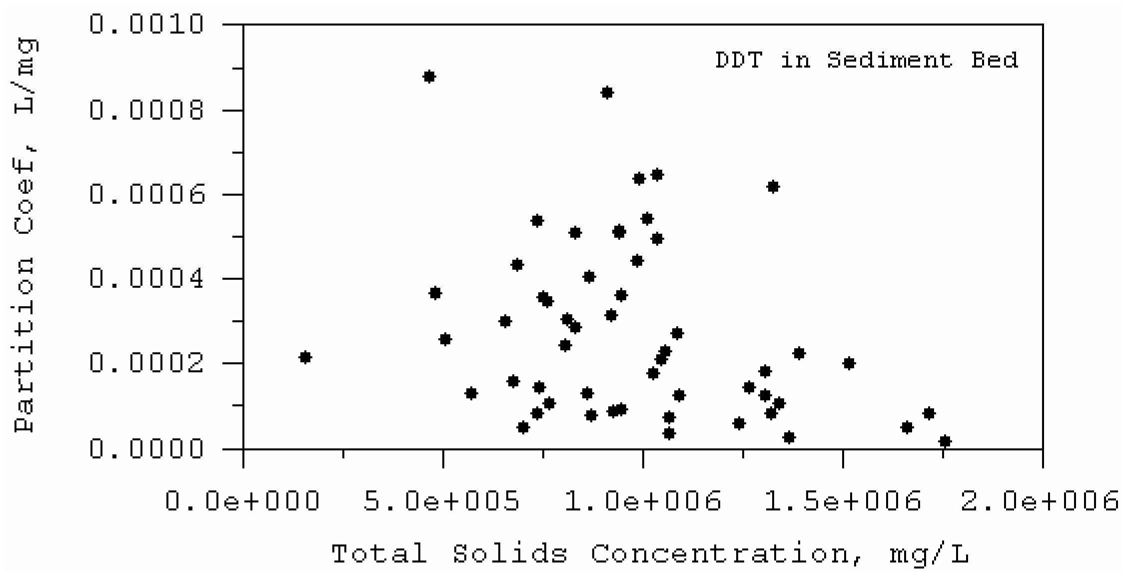


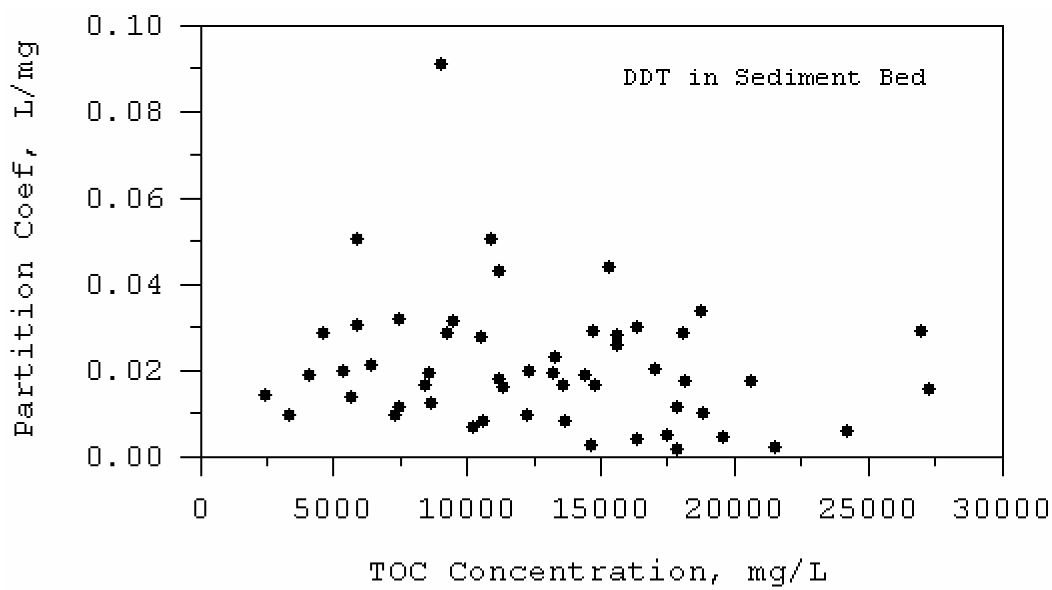


Total Solids

DDT Partition Coefficient

TOC

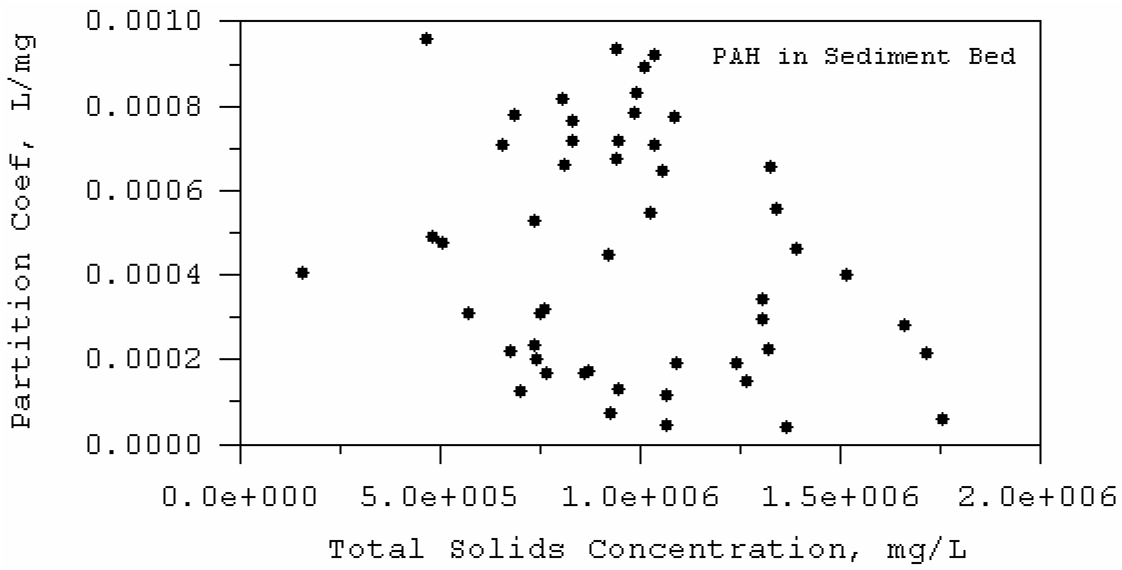


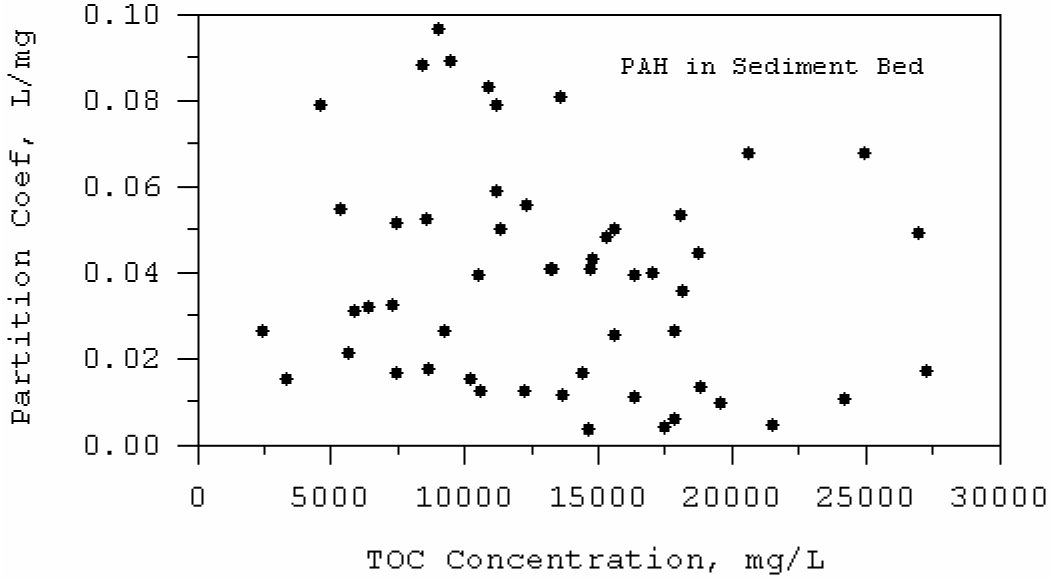


Total Solids

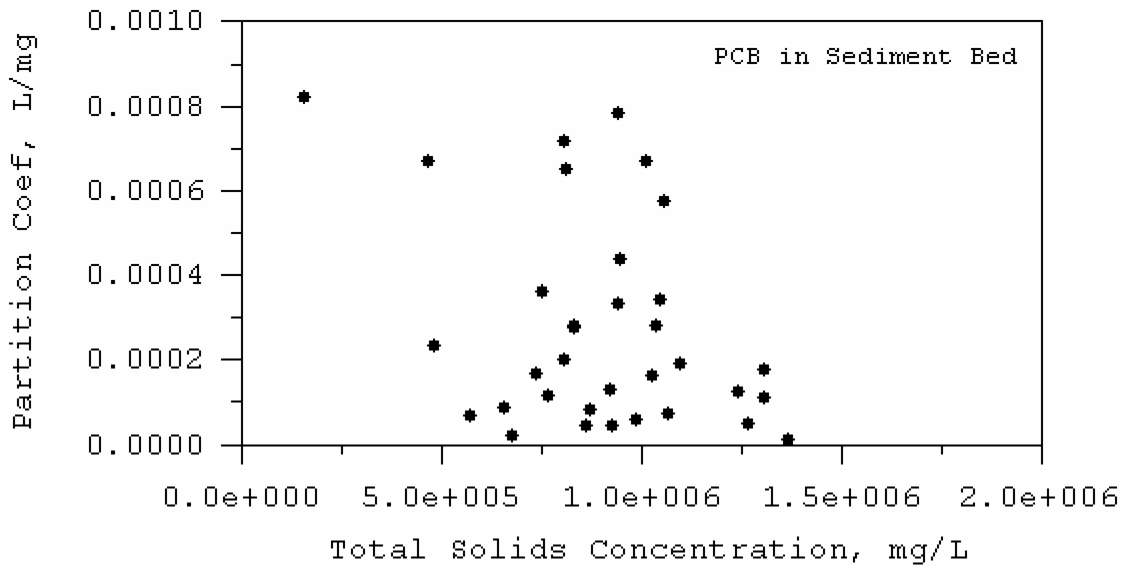
PAH Partition Coefficient

TOC



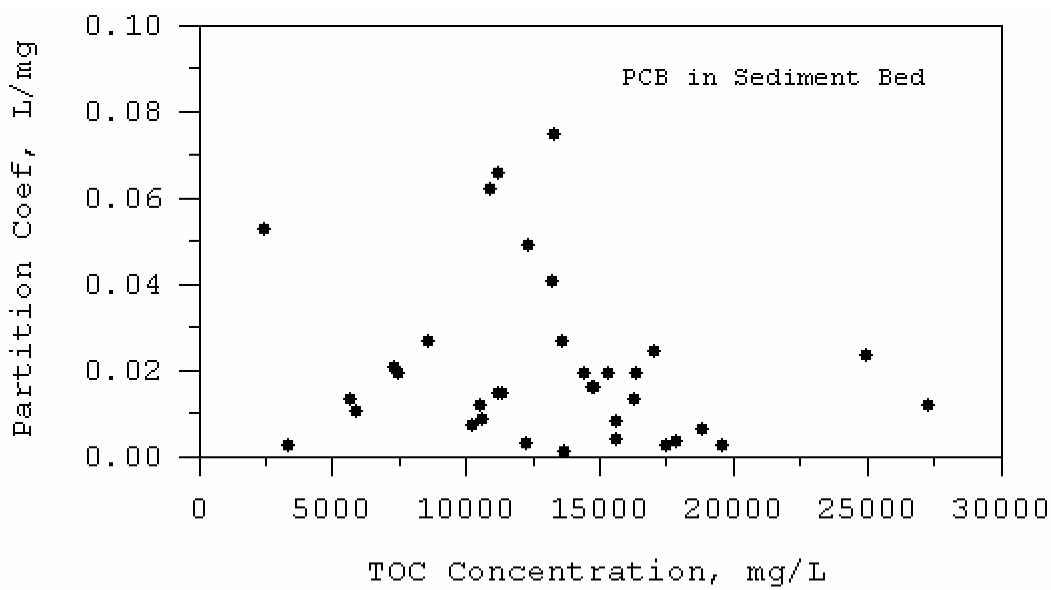


Total Solids



PCB Partition Coefficient

TOC



Partition Coefficients, L/mg
(Multiply by 1E+6 for L/Kg)

Variable	Bed Solids	Bed TOC	Water Solids	Water TOC
Copper	0.05		0.25	
Lead	0.25		1.25	
Zinc	0.01		0.05	
DDT	0.0002	0.02		0.02
PAH	0.0004	0.04		0.04
PCB	0.0002	0.02		0.02

Sediment Transport Model Calibration Approach

- Calibrate Sediment Transport First
  - Water Column Sediment Concentrations Strongly Influence WC Contaminant Concentrations
- Calibrate to Observed Water Column Sediment Concentrations
  - Not Much Observational Data to Do This, Particularly During Events
  - 2006 Overlying Water Observation Significant In Determining Near Bottom Sediment Dynamics

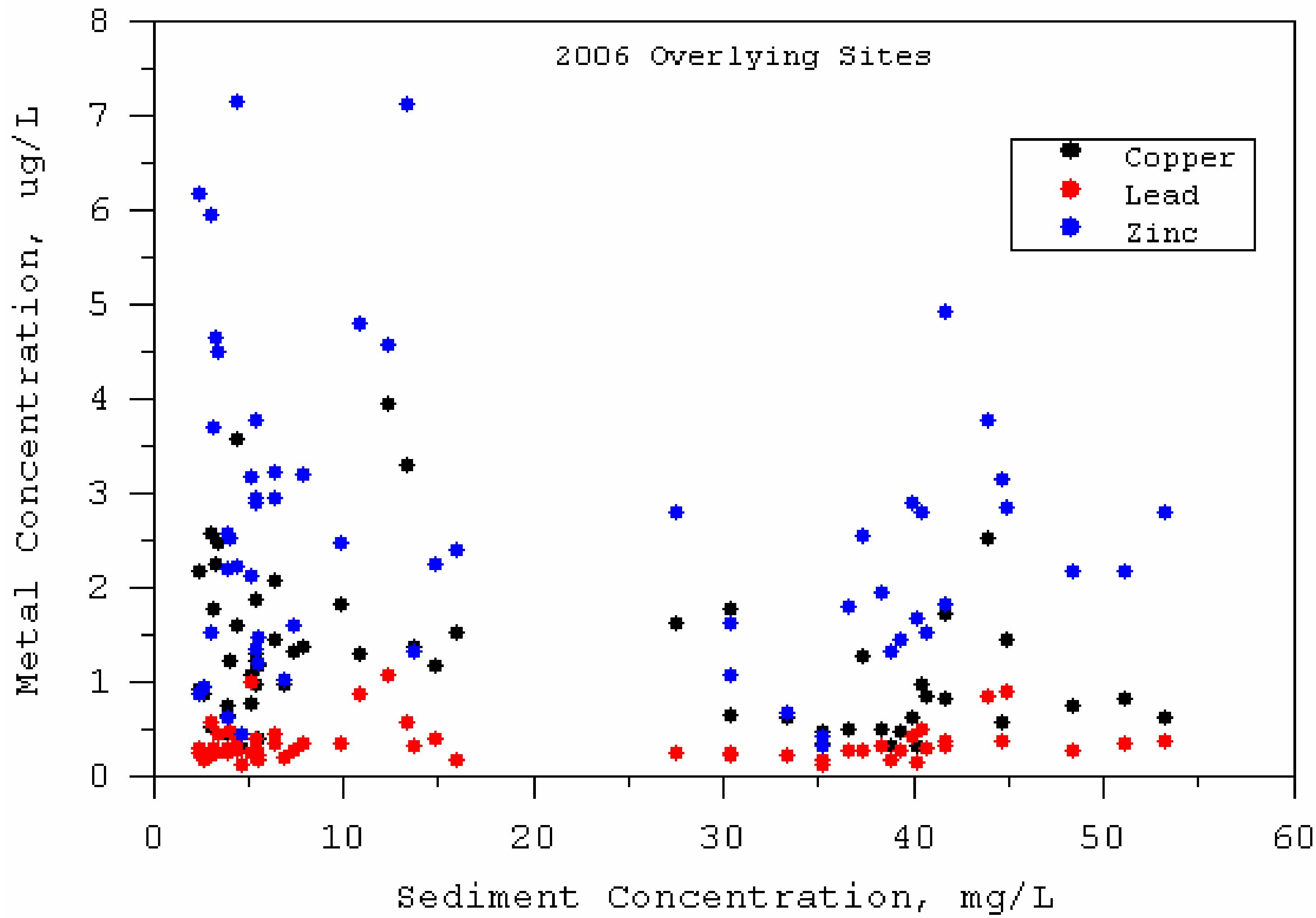
Sediment Transport Model Calibration Approach

- Watershed Sediment Loads Can Be Adjusted for Calibration
- Calibration Parameters for Fine or Cohesive Behaving Sediment
  - Settling Velocity and Critical Stress for Deposition
  - Critical Stress for Erosion and Erosion Rate (and Formulation)
  - Splits of Watershed Sediment Loads Between Sand, Silt, and Clay

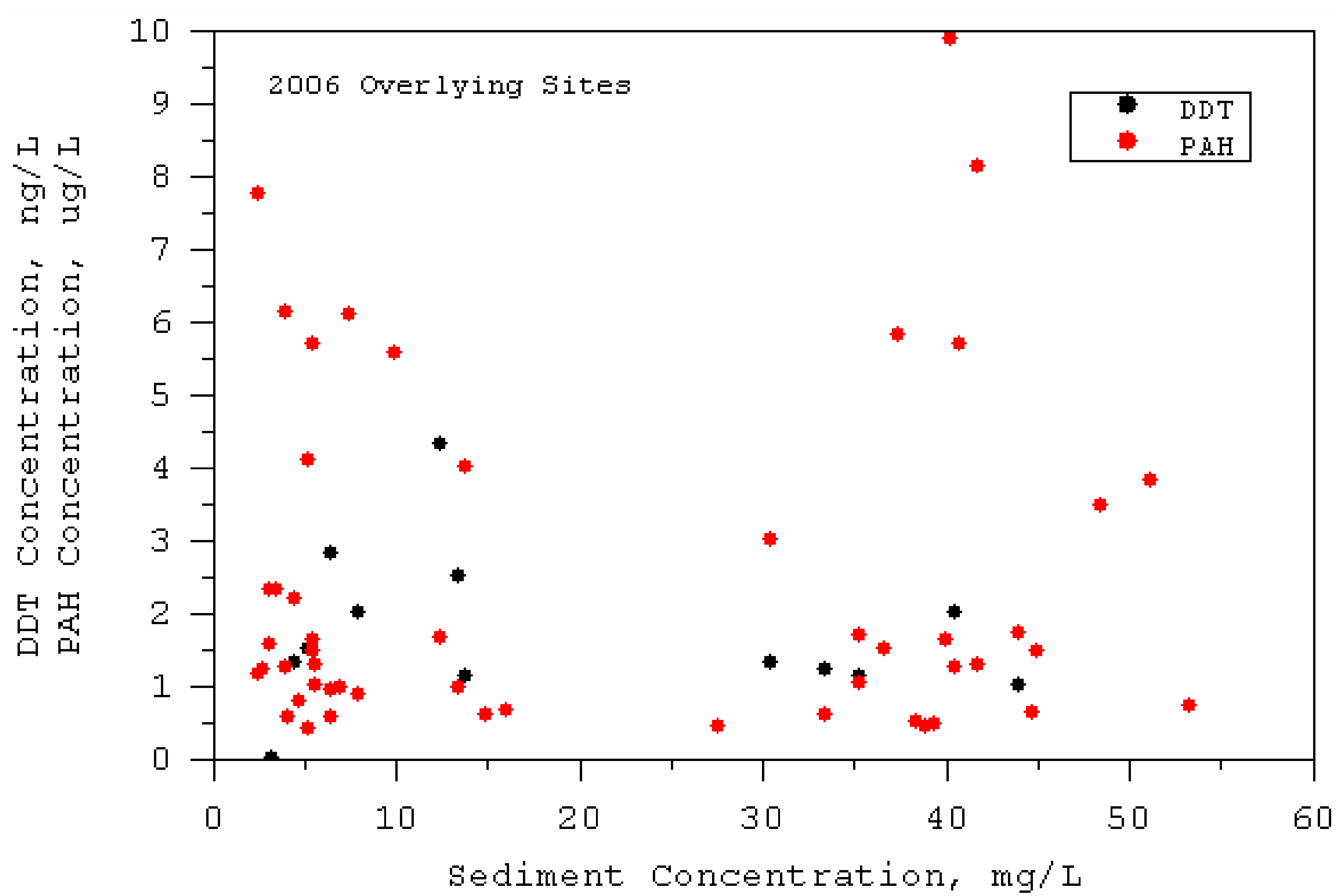
Contaminant Transport Model Calibration Approach

- Calibrate to Observed Water Column Contaminant Concentrations
- Watershed Contaminant Loads Can Be Adjusted for Calibration
- Partition Coefficients Can Be Adjusted for Calibration

Range of Metals and Sediment Concentrations at 2006 Overlying Water Sites



Range of DDT, PAH, and Sediment Concentrations at 2006 Overlying Water Sites



Calibration Measures and Sensitivity Analysis

- Calibration Measures for Sediment and Contaminants
  - Mean, Absolute Mean, and Root Mean Square Error (and Dimensionless or Normalized Counterparts)
  - Regression Measures
  - Consider Sparceness of Data in Space and Time
  - What Are Acceptable Values
- Quantify Sensitivity by Change In Calibration Measures in Response to Change in Calibration Parameters
- Sensitivity Information Accumulated During Calibration

Sediment and Contaminant Calibration

- In Progress
- Sediment Response to Events is Reasonable
- Dry Weather Sediment Concentrations Tend to Be Too Low
  - Increase Cyclic Erosion and Deposition of Fine Sediment
- Low Water Column Contaminant Levels Result form Low Sediment Levels
- Anticipate Completion in October

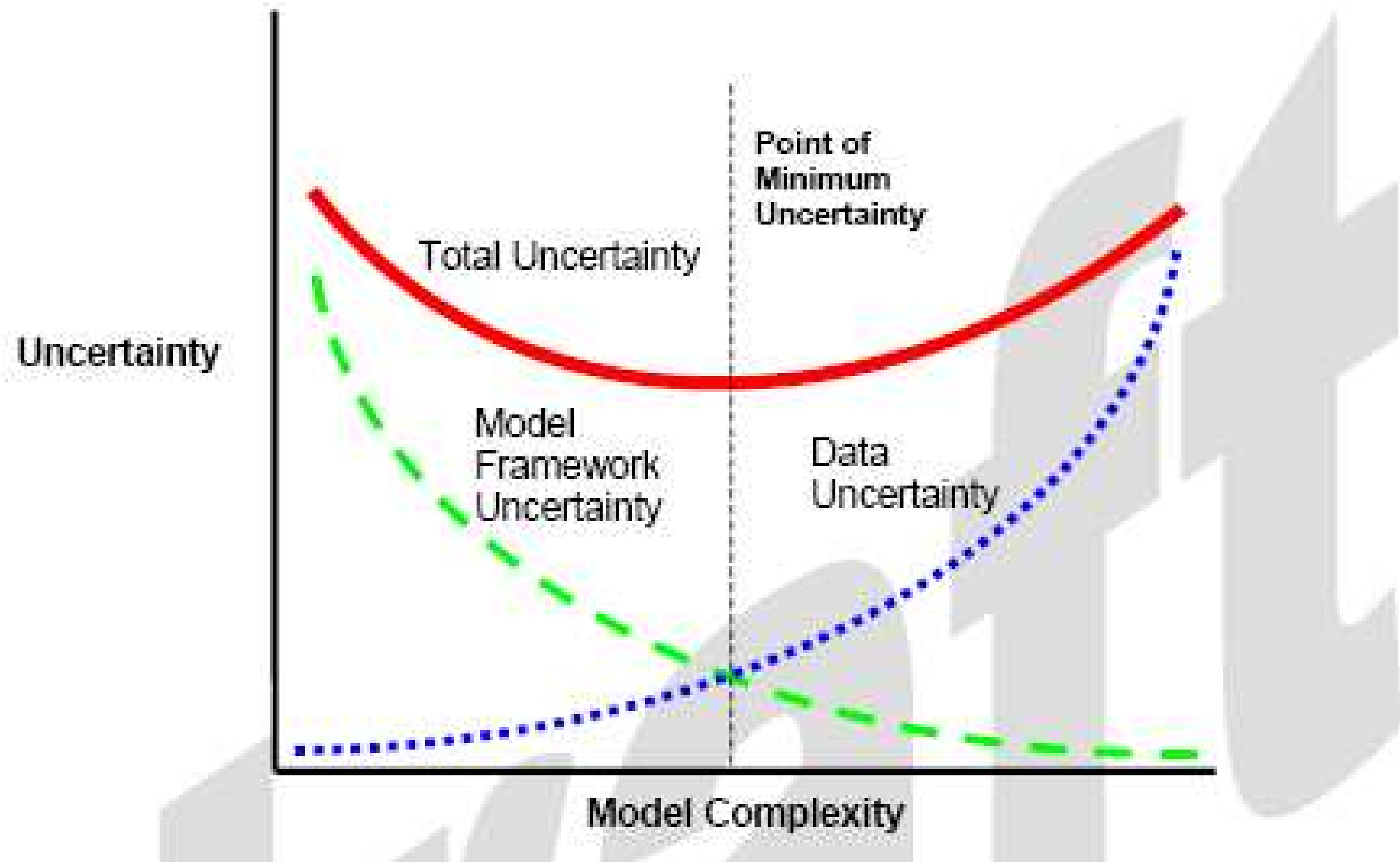
Using the Model for TMDL Development

- What the Model Cannot Do
  - Make Absolute Predictions at Specific Historical and Future Space and Time Locations
- What the Model Can Do
  - Predict Observed Ranges of Sediment and Contaminant Levels When Calibrated
  - Quantify Uncertainty In Predictions
  - Evaluate Relative Difference Between Scenarios
- What If Scenarios
  - Reduce Watershed Loads
  - Remediate Sediment Hotspots

Sediment and Contaminant Transport Model Uncertainty

- Modeling System Theoretical Formulation
- Software Coding Errors
- Physical Sediment Initial Conditions
- Sediment Loading
- Sediment Deposition and Erosion
- Sediment Contaminant Concentration Initial Conditions
- Contaminant Partition Coefficients
- Sediment and Contaminant Boundary Conditions

Minimizing Uncertainty



Performance Evaluation and QA Issues

- Evaluation of Generic Modeling System
- Evaluation of Data Used to Develop Specific Application
- Evaluation of the Model Application

Evaluation of EFDC

- US EPA ORD Evaluation of EFDC Application
  - Hayter, E.J. 2006. Evaluation of the State-of-the-Art Contaminated Sediment Transport and Fate Modeling System. U.S. Environmental Protection Agency, Athens, GA.Publication No. EPA/600/R-06/108.
- Housatonic River PCB Site
  - High Stakes, Long-Term Study
  - Data Rich
  - PRP's Consultants Failed to Find Major Fault with Model Software and Overall Application
  - Three Stage Scientific Peer Review
  - http://www.epa.gov/ne/ge/thesite/restofriver-reports.html