Kalamazoo River PCB Fate and Transport Modeling Study

Model Workshop

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Who Will Develop and Apply the Model?

- **Quantitative Environmental Analysis (QEA)**
  - Firm specializing in environmental science and engineering
  - Most of our work focuses on PCB fate & transport
  - Our primary specialty is the development and application of computer models

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QEA Experience

- **QEA personnel have worked on most of the high-profile contaminated sediment sites in the U.S., including:**

Site	Contaminant	Client
Fox River & Green Bay, WI	PCBs	Wisconsin DNR
S. California Bight	DDT, PCBs	NOAA/U.S. DOJ
New Bedford Harbor, MA	Metals/PCBs	U.S. EPA
Hudson River	PCBs	General Electric
Lavaca Bay, TX	Mercury	Alcoa
Housatonic River, MA	PCBs	General Electric
Grasse River, NY	PCBs	Alcoa

Key QEA Personnel

- **C. Kirk Ziegler**
  - 20 years of experience
  - Managed ~25 projects
  - Nationally recognized expert in sediment transport and sediment stability
  - Over 15 peer-reviewed publications

- **David Glaser**
  - 20 years of experience
  - Nationally recognized expert in bioaccumulation
  - Numerous peer-reviewed publications as well as presentations at national conferences

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Why a Modeling Study for the Kalamazoo River?

- **To answer the question:**

What improvement are we likely to see in PCB levels in fish, if we:

- **Remove all or some of the river sediments?**
- **Remove all of some of the impoundment soils?**
- **Cap all or some of the impoundment soils?**
- **Stabilize the banks?**
- **Do nothing and let the river recover naturally?**
- **Use other remedial approaches?**

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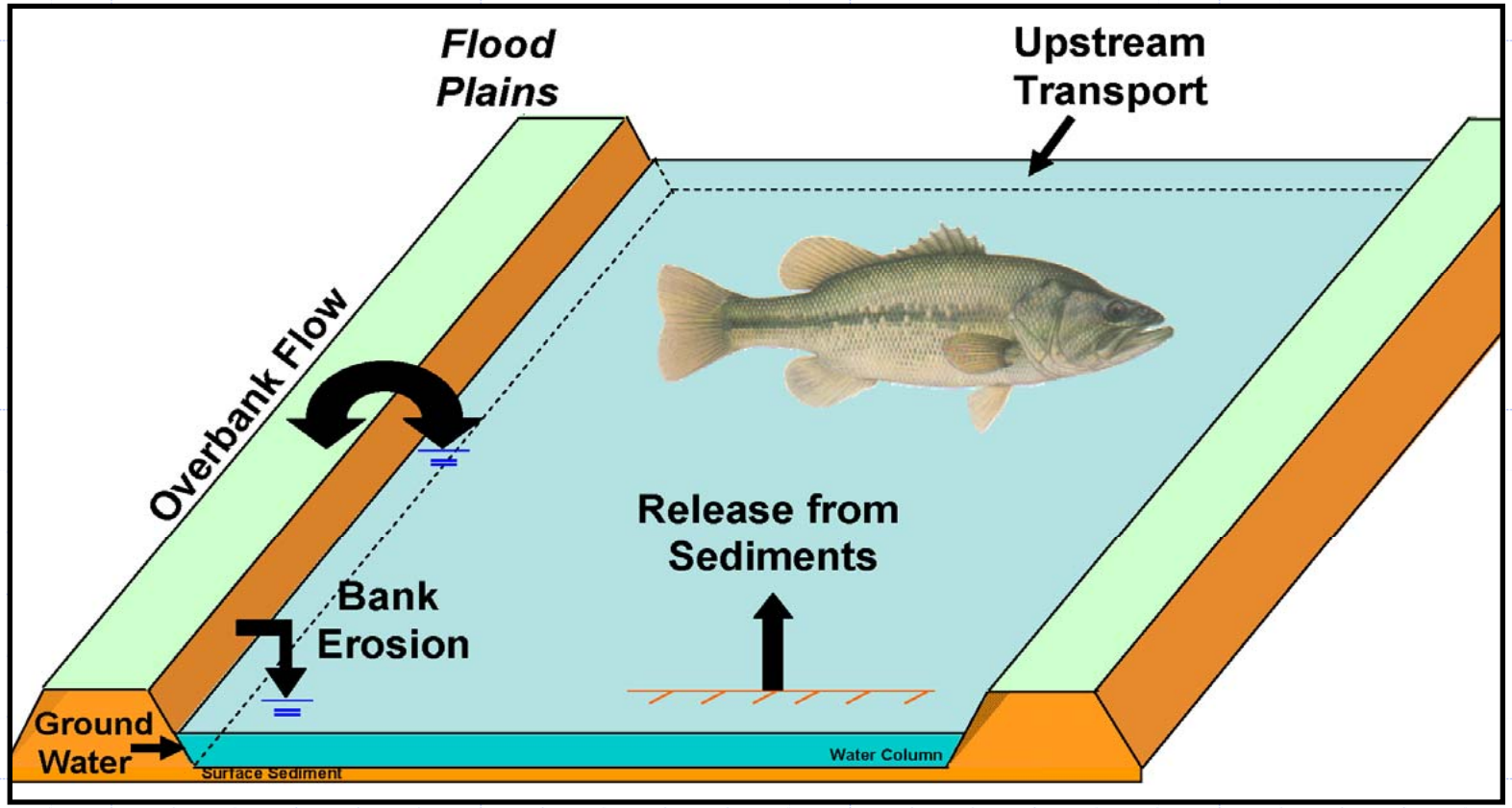
Correctly Answering These Questions is Not Easy

- Fish accumulate their PCBs from several sources

- We want to remediate the correct source(s) to permanently reduce PCB levels in the fish
  - To reduce human health risks
  - To reduce ecological risks

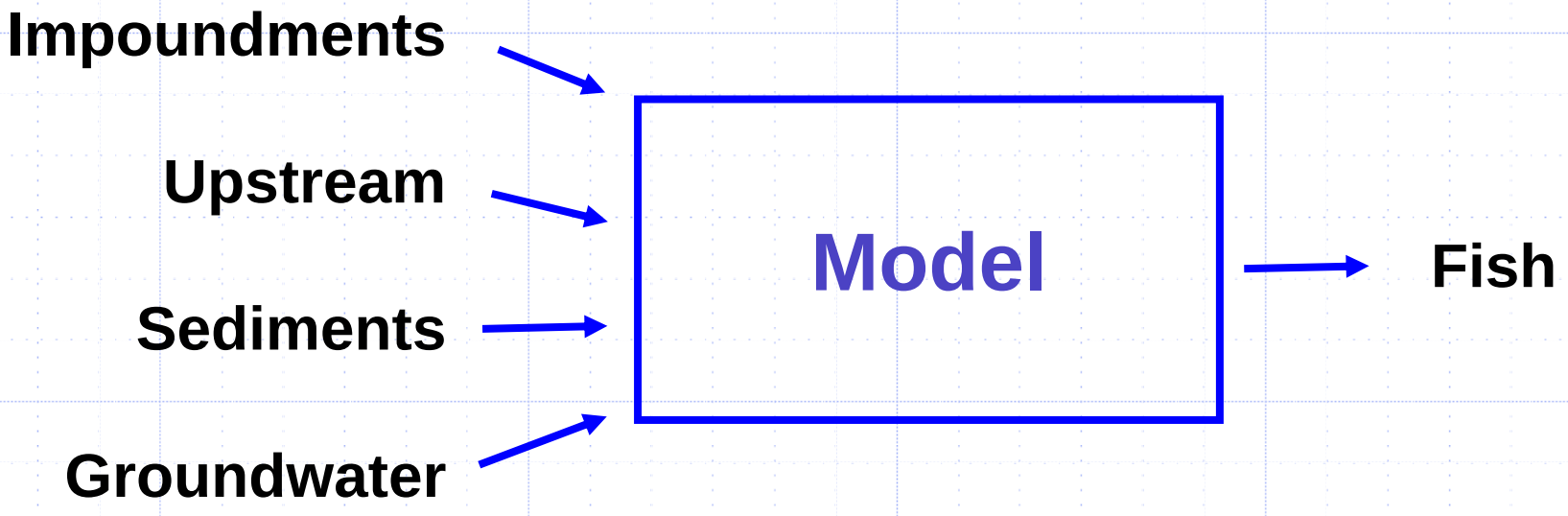
Multiple Sources of PCBs to Fish in the Kalamazoo



We have information on pieces of the puzzle, but we need to integrate them into a coherent, complete picture

How Will a Model Help?

- The model will provide a quantitative link between remediation options and fish PCB levels

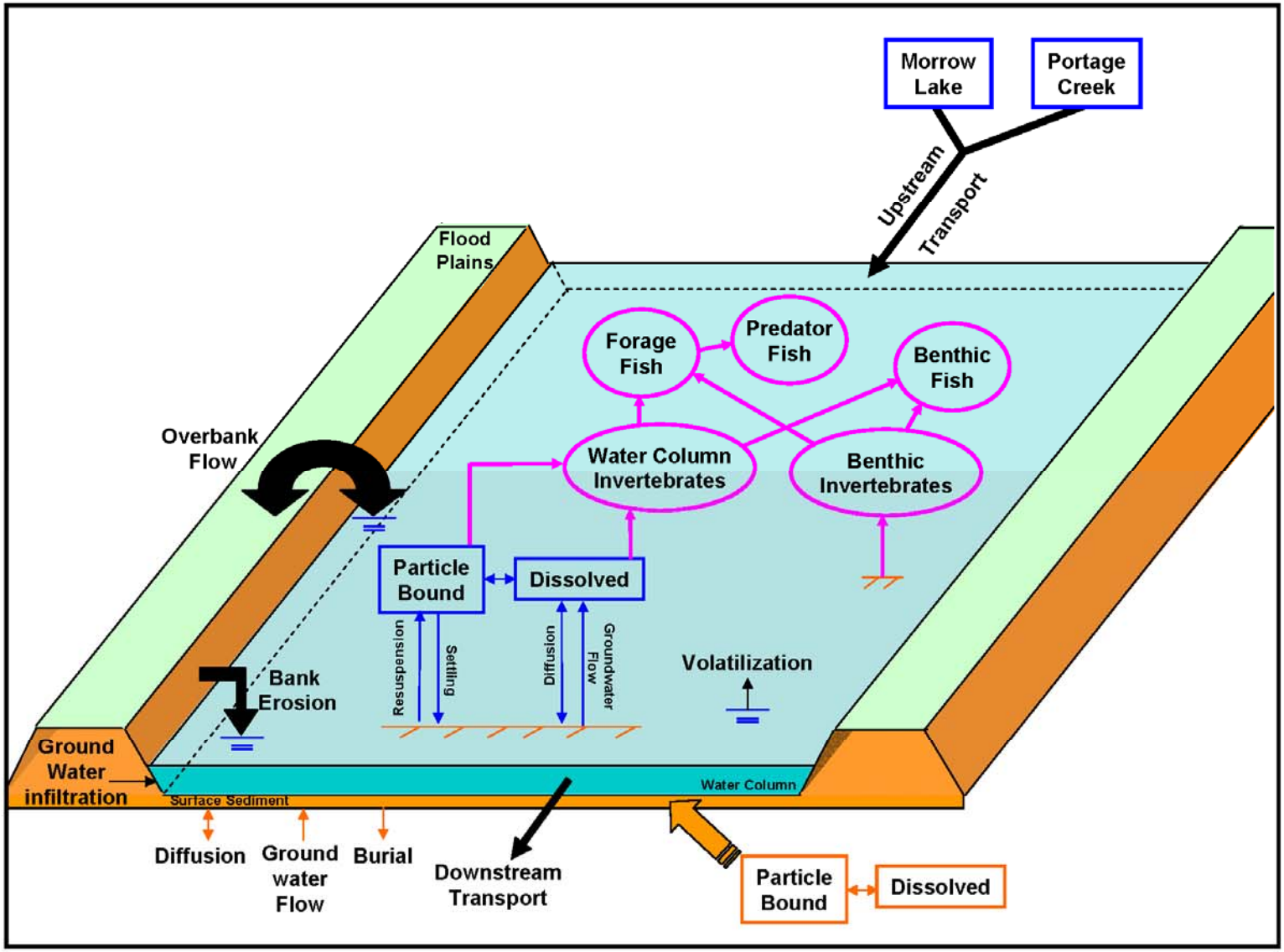


Primary Study Objectives

- What are the relative contributions of the key PCB sources to fish under current conditions?

- How will alternative remedial actions affect future fish levels?

Provisional Conceptual Site Model



Impact of Remediation on Fish Levels

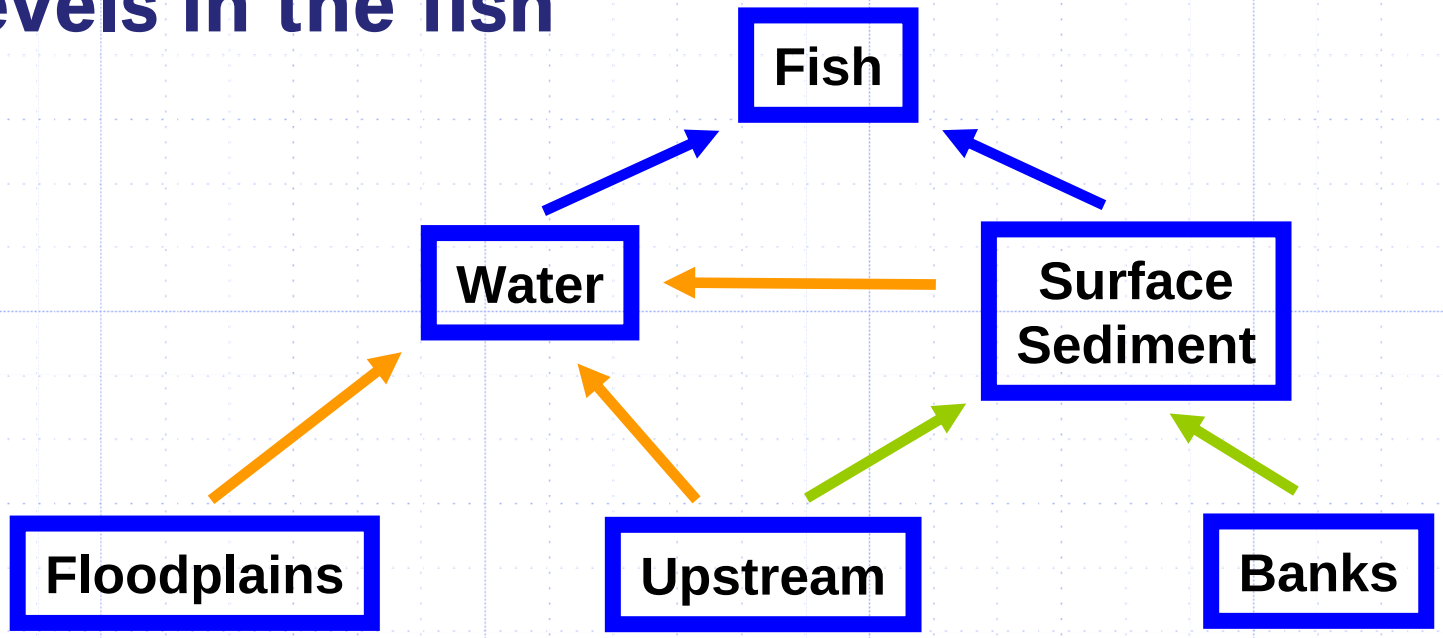
- Natural recovery
- Bank stabilization
- Bank stabilization with partial impoundment removal
- Impoundment hot-spot removal
- Full impoundment removal
- Sediment removal
- Soil capping
- Others?

Fish Response to Remediation: Key Technical Questions

- How much?
- How fast?
- How permanent?
- How extensive (spatially)?

Fish Response: How Much?

- Multiple sources contribute to PCB levels in the fish

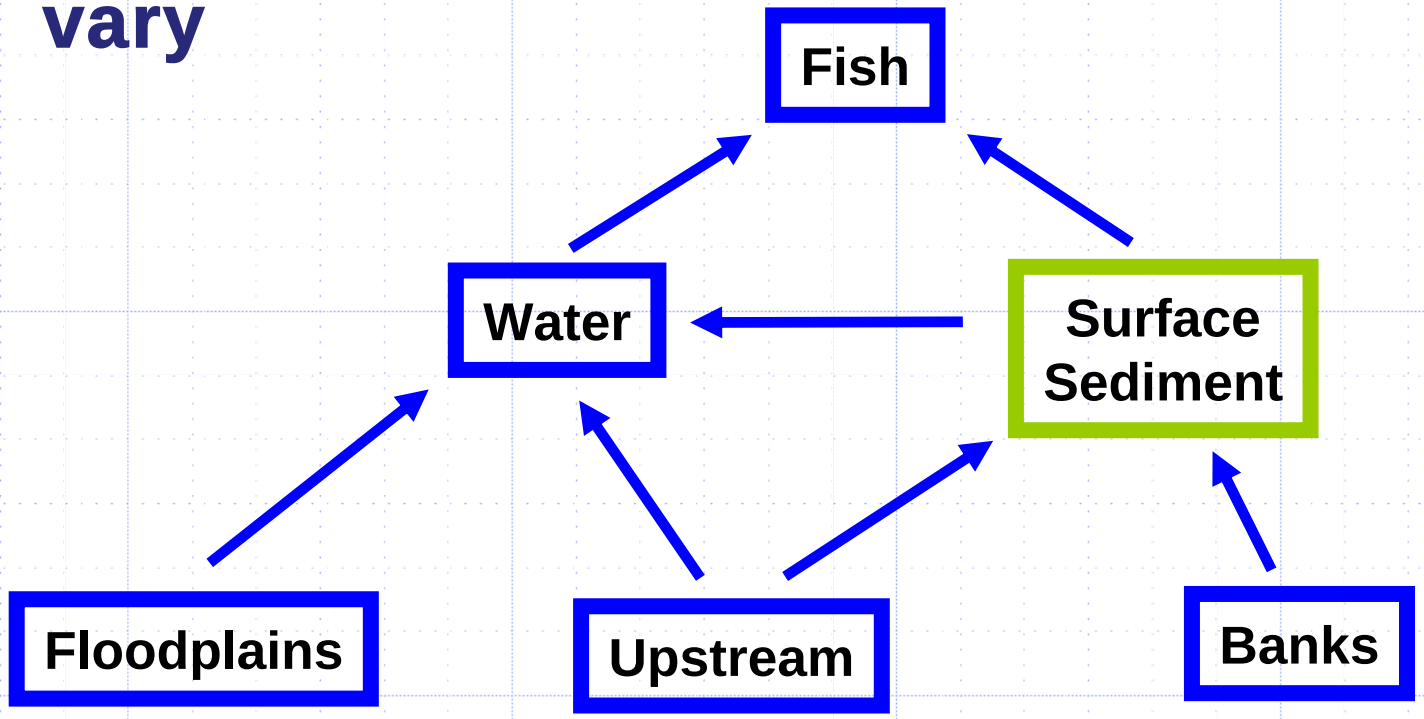


- Source impacts depend on flow rates

Reduction of an external PCB source may not translate into a proportional reduction in fish

Fish Response: How Fast?

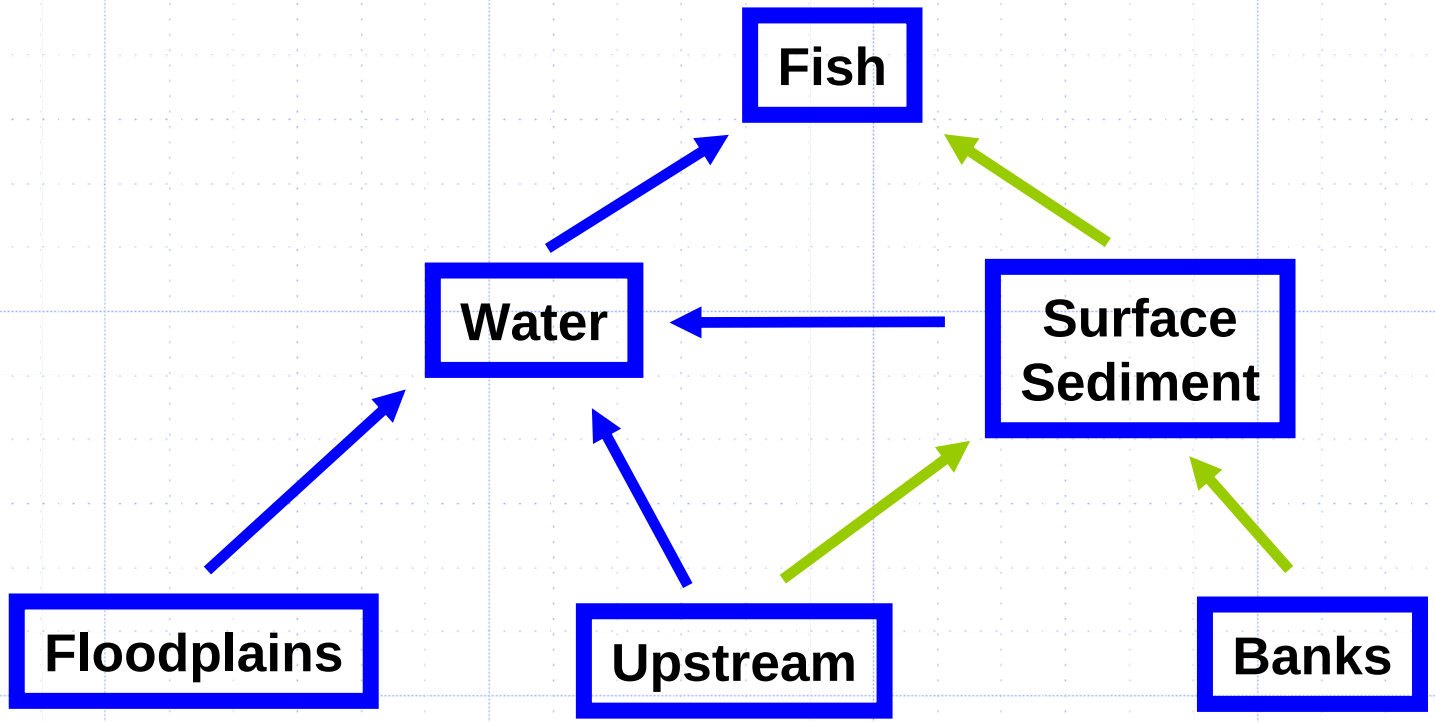
- Time-constants of system components vary



Temporal response of system will depend on which PCB source is targeted for remediation

Fish Response: How Permanent?

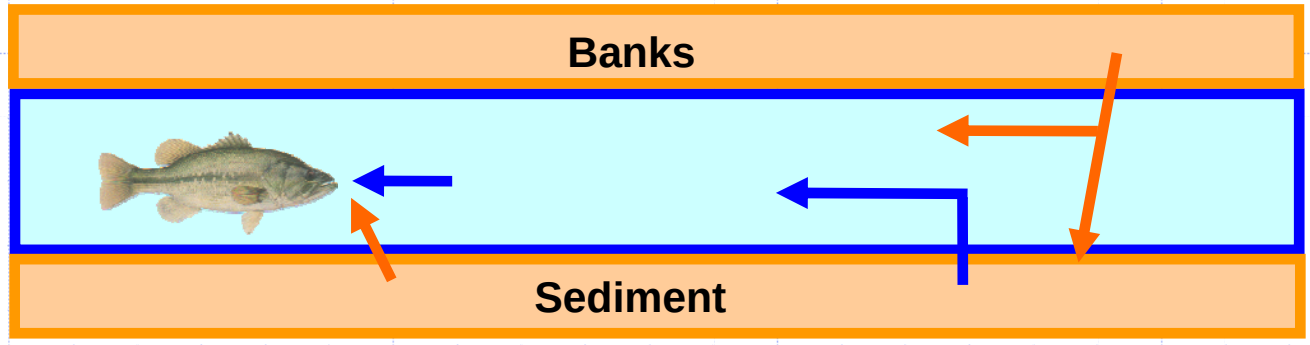
- PCB sources are direct or indirect



If ultimate sources are not remediated, there will remain the potential for recontamination

Fish Response: How Extensive?

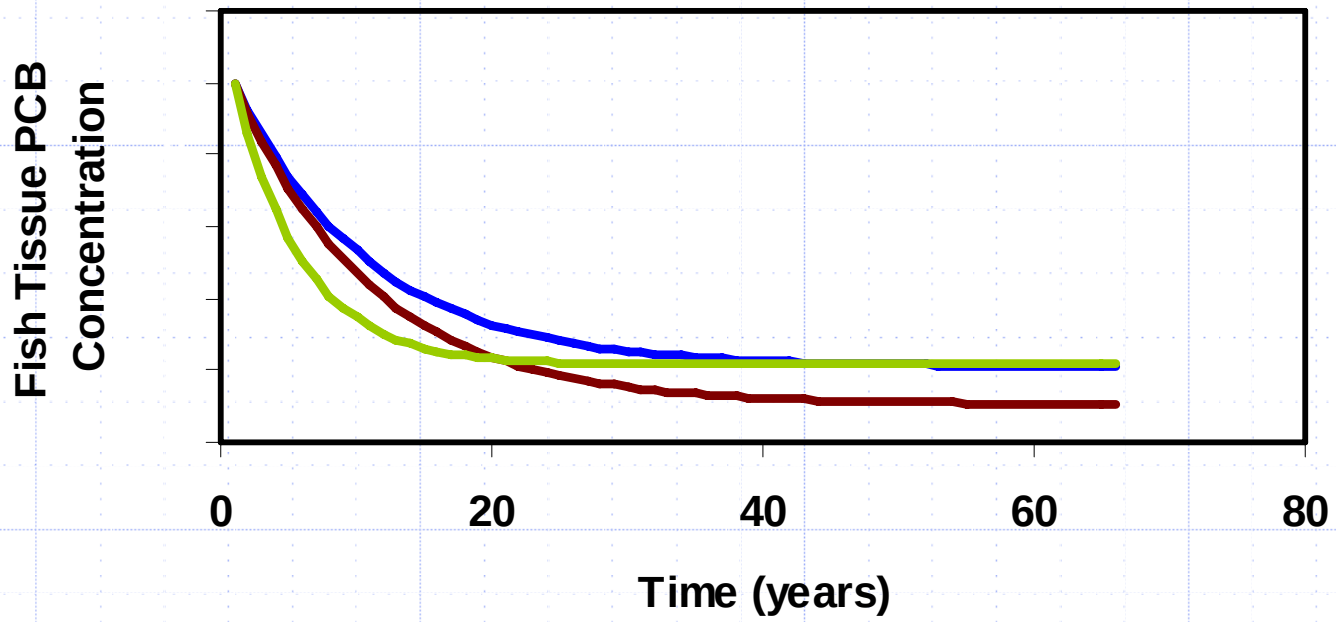
- Fish accumulation
  - From local sediments
  - From waters impacted by upstream sediments



Downstream extent of response to remediation depends on both biological and physical processes

Fish Response: Role of Natural Recovery

- **Remediation may:**
  - **Increase rate of recovery**
  - **Reduce the long-term steady-state level**



Assessment of natural recovery provides the basis for evaluation of remedial alternatives

Decision-Making Tools

- A computer model, *in conjunction with data analyses*, can <u>potentially</u> be used to quantitatively answer the primary study questions

- Use of a model to guide the remedial selection process <u>may</u> decrease the uncertainty in the effectiveness of the preferred remedy

Utility of a PCB Fate Modeling Framework

- **Benefits**
  - Constrain, synthesize and interpret data
  - Quantify effects of different transport processes
  - Make quantitative predictions
    - Compare remedial alternatives

- **Drawbacks**
  - Level of uncertainty in results may be unacceptable

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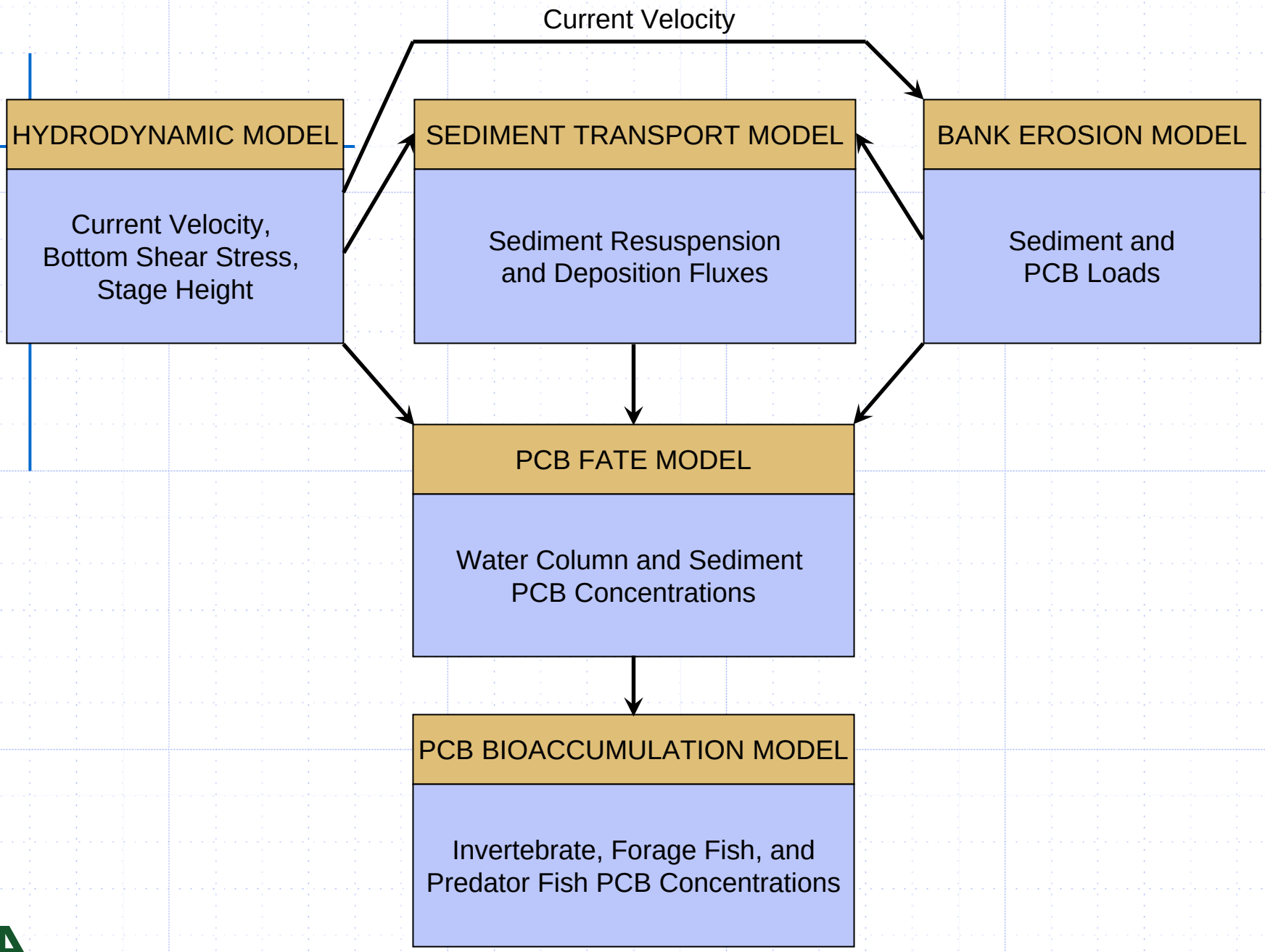
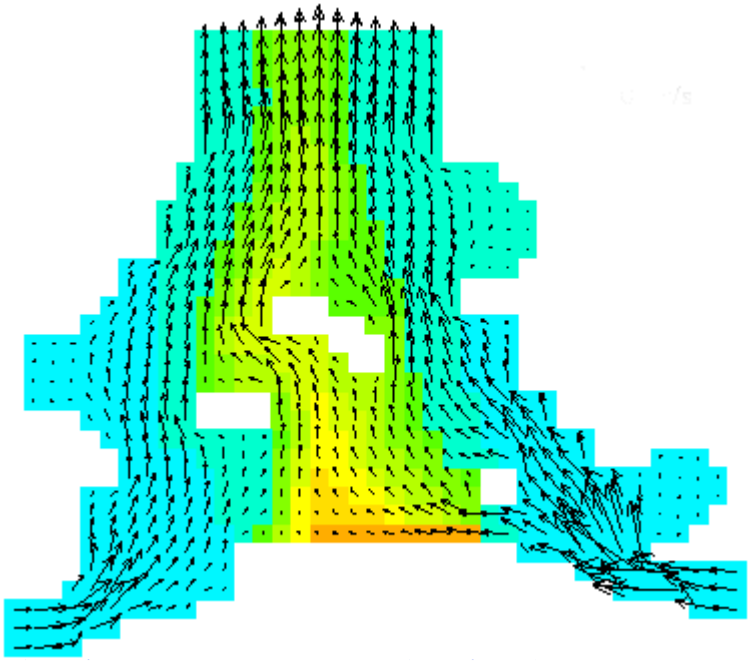

Current Velocity
HYDRODYNAMIC MODEL
Current Velocity, Bottom Shear Stress, Stage Height
SEDIMENT TRANSPORT MODEL
Sediment Resuspension and Deposition Fluxes
BANK EROSION MODEL
Sediment and PCB Loads
PCB FATE MODEL
Water Column and Sediment PCB Concentrations
PCB BIOACCUMULATION MODEL
Invertebrate, Forage Fish, and Predator Fish PCB Concentrations

Sub-Model Overview: Hydrodynamics

- Using enhanced version of EFDC
  - EPA-approved model
- Sub-model characteristics
  - 2-D, vertically-averaged
  - Curvilinear, boundary-fitted grid
  - Wetting and drying of floodplains



Sub-Model Input/Output: Hydrodynamics

- **The model uses (input):**
  - River geometry and bathymetry
  - Upstream and tributary flow rates
  - Stage height at dams
  - Effective roughness of sediment bed

- **The model produces (output):**
  - Water depth (stage height)
  - Current velocity (depth-averaged)
  - Bottom shear stress

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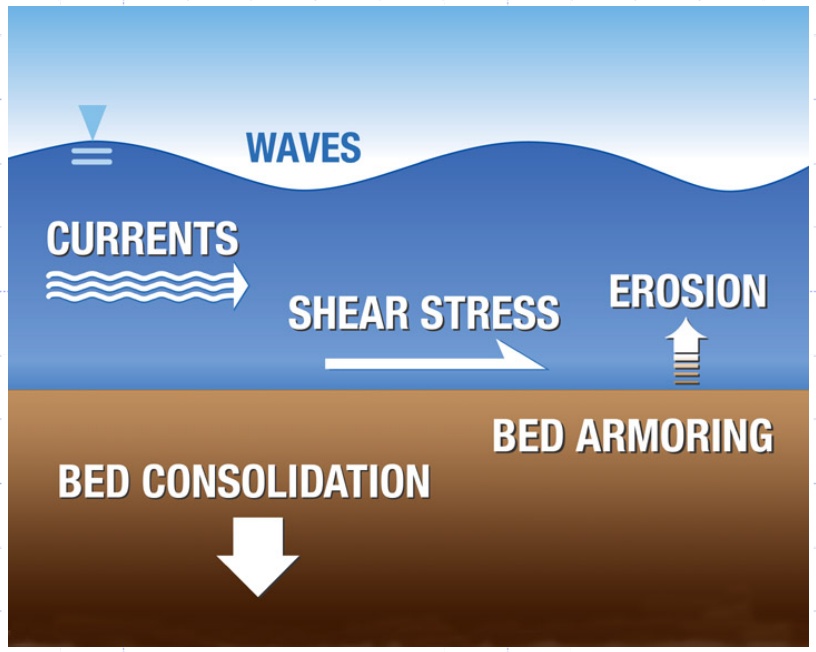
Critical Technical Issues: Hydrodynamics

- Numerical grid design
  - Sufficient resolution
  - Ability to conduct 75-year simulations

- Wetting and drying of floodplain areas

Sub-Model Overview: Sediment Transport

- Using SEDZLJ model
  - Sophisticated algorithm
- Sub-model characteristics
  - Suspended load transport of cohesive sediment
  - Suspended and bed load transport of non-cohesive sediment



Sub-Model Input/Output: Sediment Transport

- **The model uses (input):**
  - Sediment loads (magnitude & composition)
    - Upstream and tributary sources
    - Bank erosion
  - Sediment bed properties
    - Erosion rate and critical shear stress
    - Grain size distribution
    - Bulk (dry) density
  - Settling speed of sediment

- **The model produces (output):**
  - Suspended sediment concentration
  - Bed elevation change
  - Erosion and deposition fluxes
  - Sediment mass balance

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Critical Technical Issues: Sediment Transport

- Upstream and tributary sediment loads
  - Magnitude and composition
- Spatial distribution of bed properties
  - Erosion properties of cohesive sediments

Sub-Model Overview: Bank Erosion

- Appropriate bank erosion model will be determined during initial model development

- Results of USGS study will be used to guide model selection and development

Sub-Model Input/Output: Bank Erosion

- The model uses (input):
  - Near-bank shear stress/velocity
  - Bank height
  - Erosion properties
  - Locations of active bank erosion

- The model produces (output):
  - Bank erosion rate
  - Bank erosion mass flux
    - Sediment
    - Particle-bound PCBs

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Critical Technical Issues: Bank Erosion

- Incorporation of USGS study results
  - Direct use of USGS model
  - Use USGS results to develop simplified bank erosion model

Sub-Model Overview: PCB Fate & Transport

- Using QEA-FATE model
  - Enhanced version of WASTOX

- Sub-model characteristics
  - The model integrates:
    - Sources (upstream, impoundments, sediments)
    - Sinks (downstream, impoundments, sediment bed, atmosphere)
  - PCB fate & transport processes
    - Settling to the sediment bed
    - Diffusion, groundwater transport, and resuspension from the bed
    - Loss to the atmosphere
    - Attachment (adsorption) to particles in the water column and sediment bed

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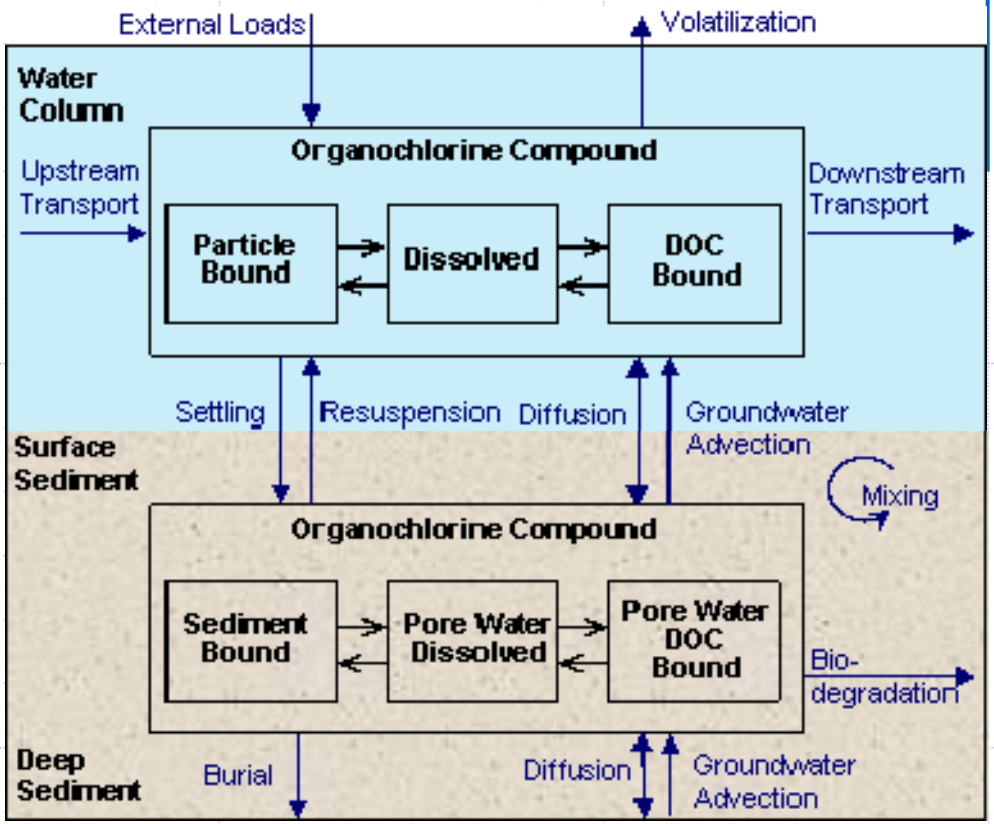
Model Input/Output: PCB Fate & Transport

- The model uses (input):
  - Initial PCB bed concentration
  - External PCB loads
  - Partition coefficients
  - Flows, temperature
- The model produces (output):
  - PCB concentrations
    - Water column
    - Sediment bed
  - PCB mass balance



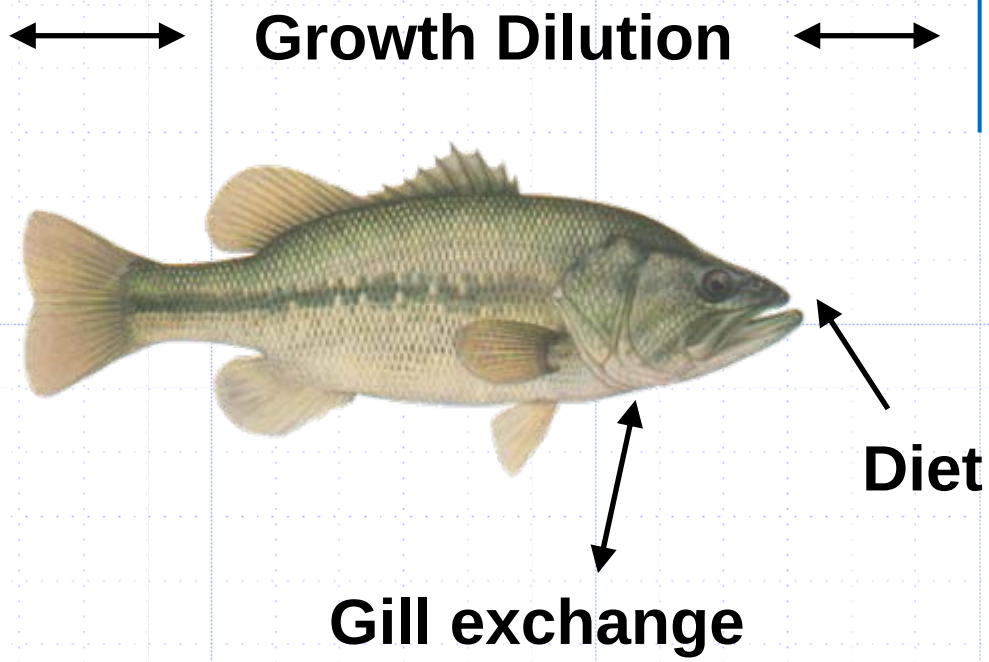
Critical Technical Issues: PCB Fate & Transport

- External PCB sources
  - Upstream and tributaries
  - Flood plains
  - Groundwater
  - Bank erosion

- Spatial distribution of PCB bed concentrations

Sub-Model Overview: Bioaccumulation

- Using QEA-FDCHN model
- Sub-model characteristics
  - Entire food web
  - Growth of fish
  - Movement patterns
  - Bioenergetics
  - Uptake from food and water



Model Input/Output: Bioaccumulation

- The model uses (input):
  - PCB concentrations in sediment and water
  - Growth and respiration rates
  - Lipid contents

- The model produces (output):
  - PCB concentrations in invertebrates and fish
    - Forage fish
    - Benthic fish
    - Predator

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Critical Technical Issues: Bioaccumulation

- Diet/food web structure
- Growth rates
- Movement patterns
- PCB composition

Can a Useful Model Be Developed?

- Are the available data sufficient for development, calibration and validation of the model?
- Is the calibrated model sufficiently constrained for use as a management tool?

Phase 1 → Phase 2 → Phase 3

A phased approach to model development will provide flexibility and reduce project risk

Phase 1

- Compile, analyze and synthesize available data
- Refine CSM
- Initial model development
- Decision point: model calibration meeting
  - Are available data sufficient for model calibration and validation?
  - Decide whether or not to proceed to Phase 2

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Phase 2

- Calibrate and validate 5 sub-models
- Conduct sensitivity and uncertainty analyses
- Decision point
  - Is the model sufficiently constrained for use as a management tool?
  - Decide whether or not to proceed to Phase 3

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Phase 3

- Conduct PCB source analyses
- Evaluate impacts of various remedial alternatives

How Can the Model Be Used to Support Management Decisions?

- Quantitatively evaluate contribution of current PCB sources to fish levels

- Project PCB concentrations in fish, sediment and water for various remedial alternatives
  - Makes it possible to answer "What if …?" questions
  - Provides exposure levels for risk assessment
  - Provides support for remedial design efforts

- Estimate impacts of remedial alternatives on PCB loads over Otsego City Dam
  - Dams-in and dams-out scenarios

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