Surface Water Response Modeling

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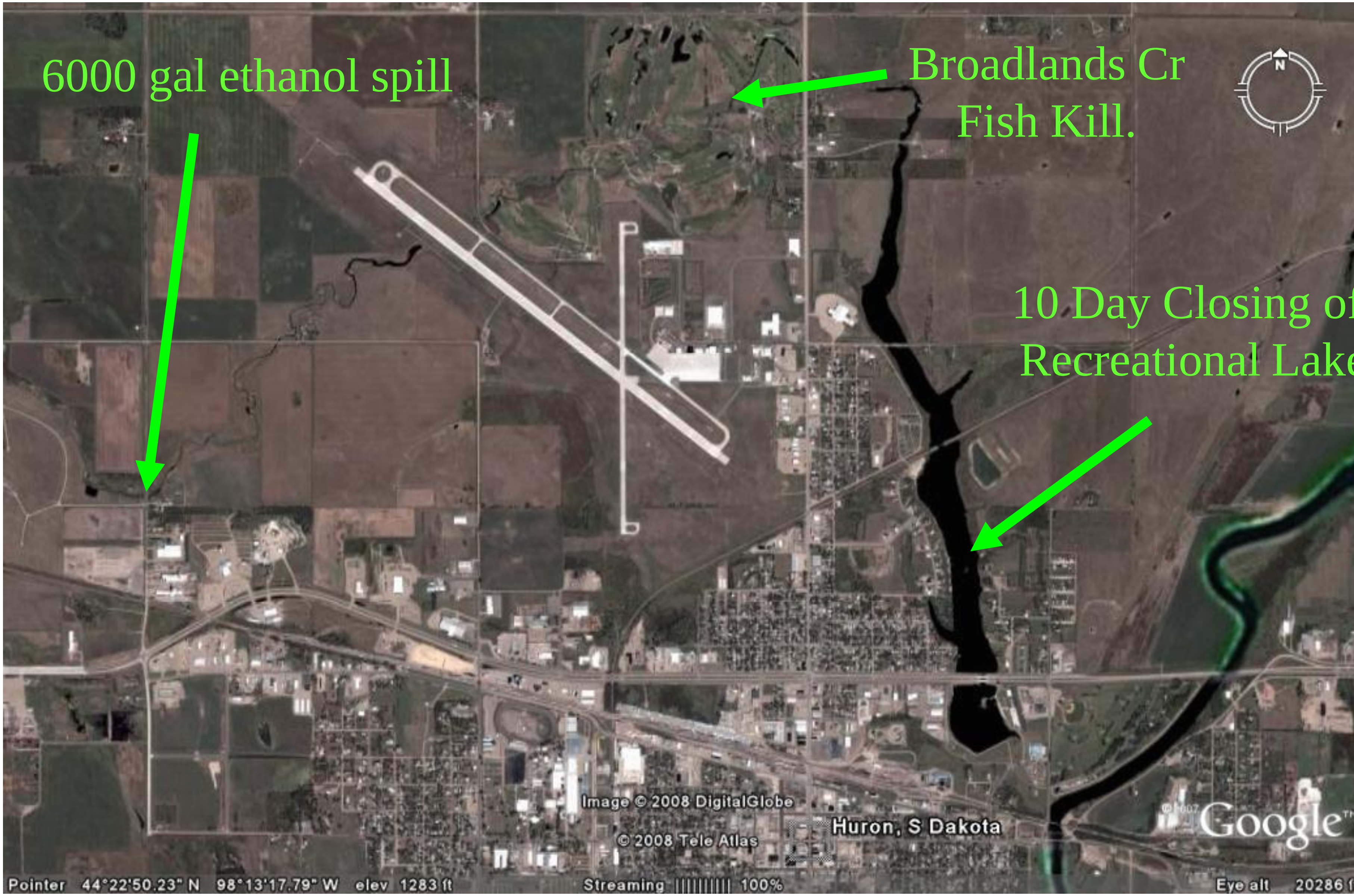


Goals

- Surface water spills:
  - How fast does it get downstream?
  - What will be the concentration when it gets there?
  - Do I need to worry about that drinking water intake?
  - Can I plan a response?
  - Can these questions be answered quickly enough to matter?
- Two approaches:
  - Empirical tracer data
  - Numerical model development

First Approach: USGS Empirical Equations

- Based on hundreds of tracer experiments conducted in all sizes of rivers over the last 40+ years
- No calibration of model needed
  - Otherwise travel time and dispersion coefficients are highly uncertain
- "Unit Peak" concentration concept accounts for variation in
  - Mass loading
  - River discharge
  - Travel distance

Jobson, 1996, USGS
Empirical transport equations:

$$C_{up} = 857 T_p^{-0.760\left(\frac{Q}{Q_a}\right)^{-0.079}}$$

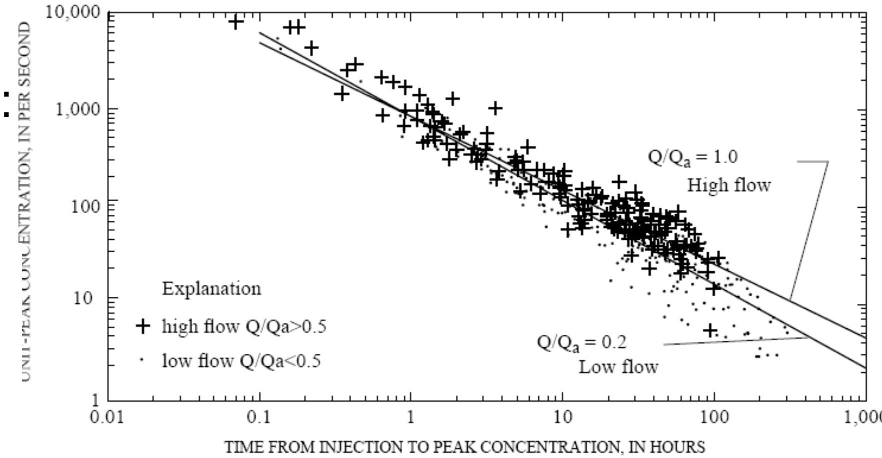


Figure 3. Unit concentrations as a function of traveltime with equation 7 plotted on the figure for two values of Q/Q_a.

$$V_p = 0.094 + 0.0143 \times (D'_a)^{0.919} \times (Q'_a)^{-0.469} \times S^{0.159} \times \frac{Q}{D_a}.$$

Calculations depend on:
Ann. Discharge, Q_a
Discharge, Q
Drainage Area, D_a
Slope, S
Distance

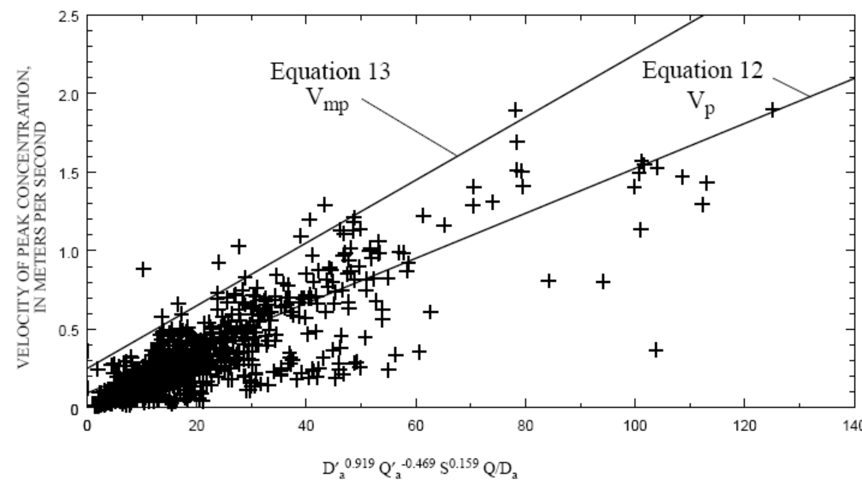
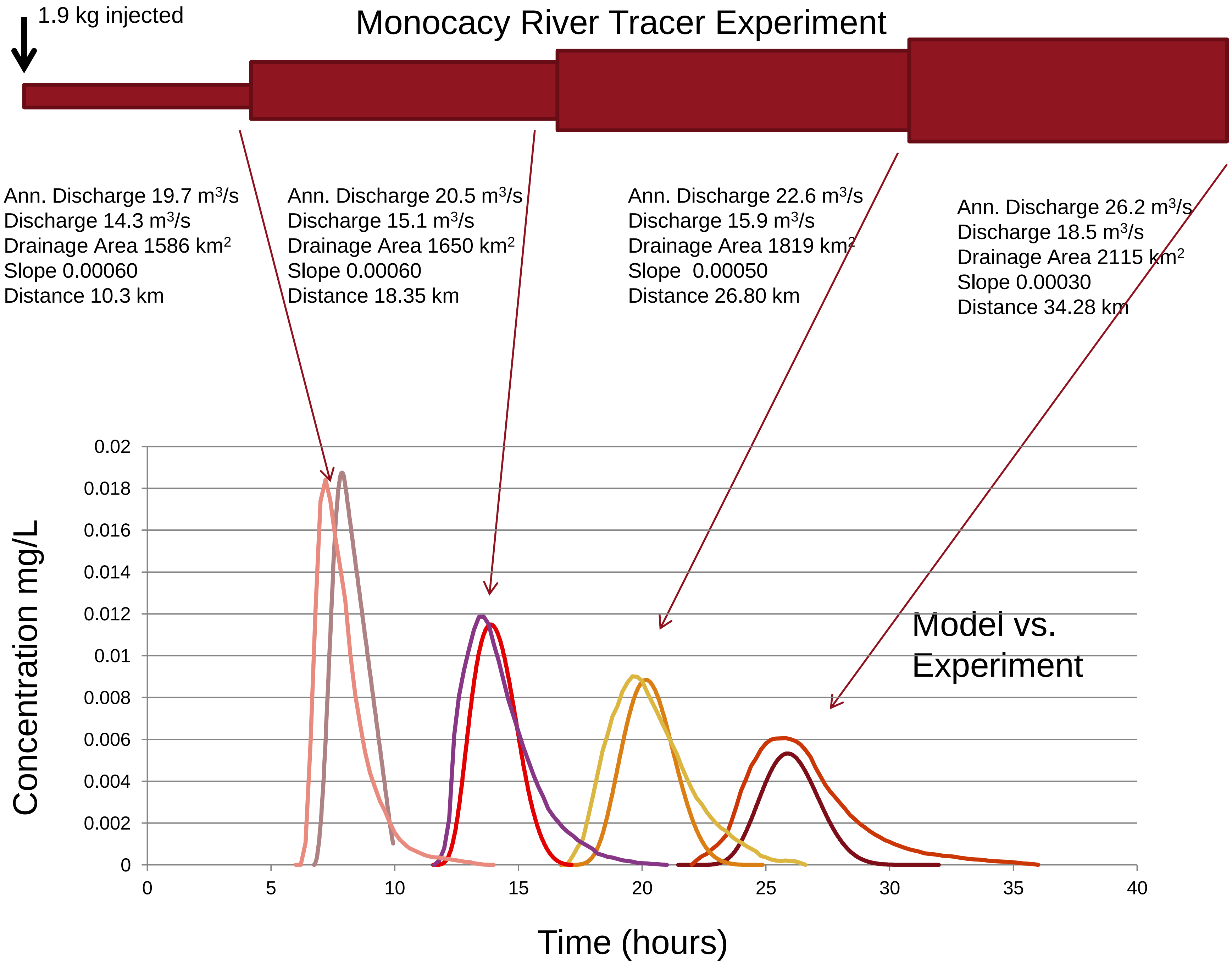


Figure 9. Plot of velocity of the peak concentration as a function of dimensionless drainage area, relative discharge, slope, local discharge, and drainage area.

Extended Approach

- We are extending the original approach:
  - Multiple reaches of rivers – differing properties
  - Branching river networks
  - Continuous loadings
  - Loadings on different parts of network

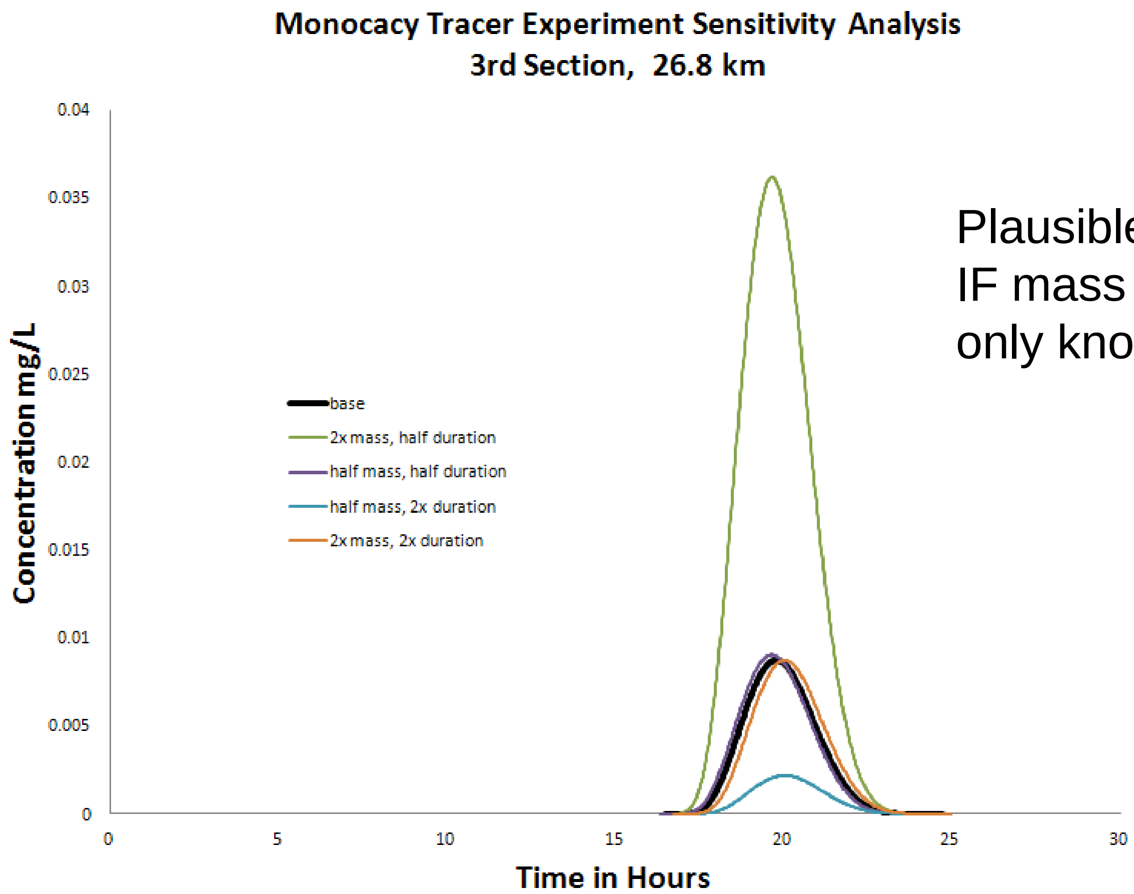
Monocacy River Tracer Experiment



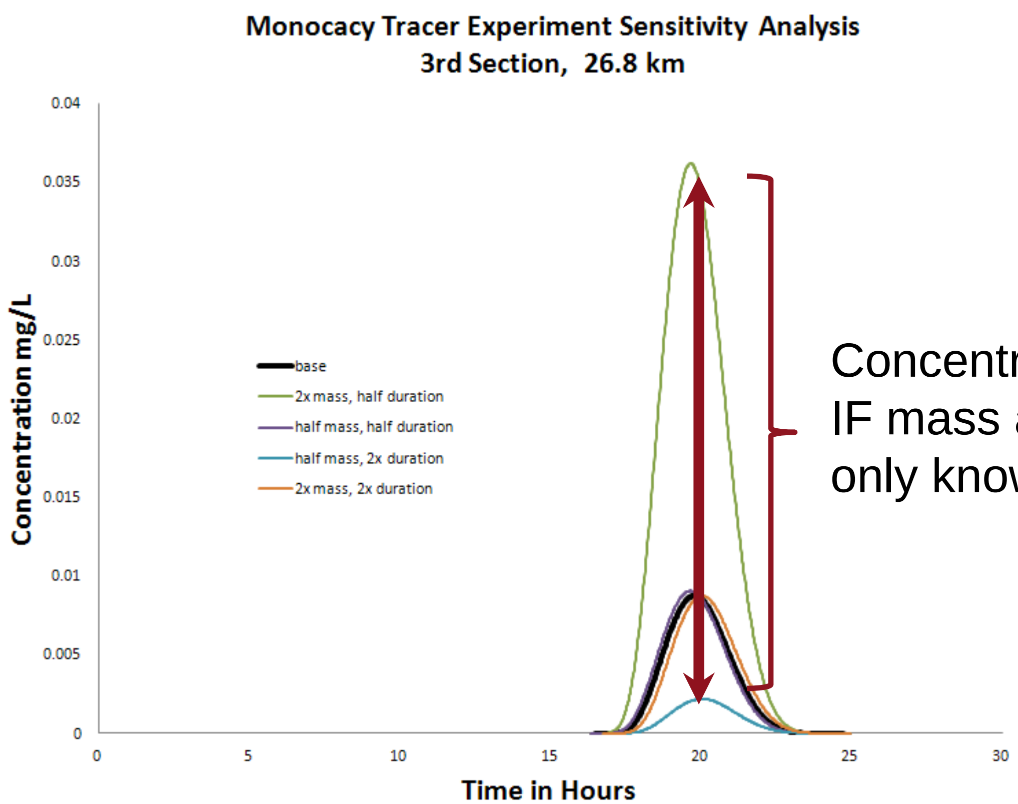
Empirical Approach

- Limitations exist
  - Empirical equations do not include initial mixing
  - Do not include lakes, impoundments
  - Only simple (first order reaction) can be included
- Data needed:
  - River mile distance
  - Average annual discharge
  - Today's discharge
  - Drainage Area
  - Mass/volume of spill
  - Duration

Uncertainty in Mass and Duration



Plausible predictions
IF mass and duration
only known to factor of two



Concentration range
IF mass and duration
only known to factor of two

Numerical Transport in Rivers

- Direct Solutions of partial differential equations
- Travel times
  - Not well estimated by simple point estimates of flows
  - Alternatively: use USGS regression equations
- Turbulent dispersion
  - Recent work has provided better estimates of dispersion coefficients
  - Alternatively: perform a tracer experiment
- Reactions
  - Flexible, but must characterize

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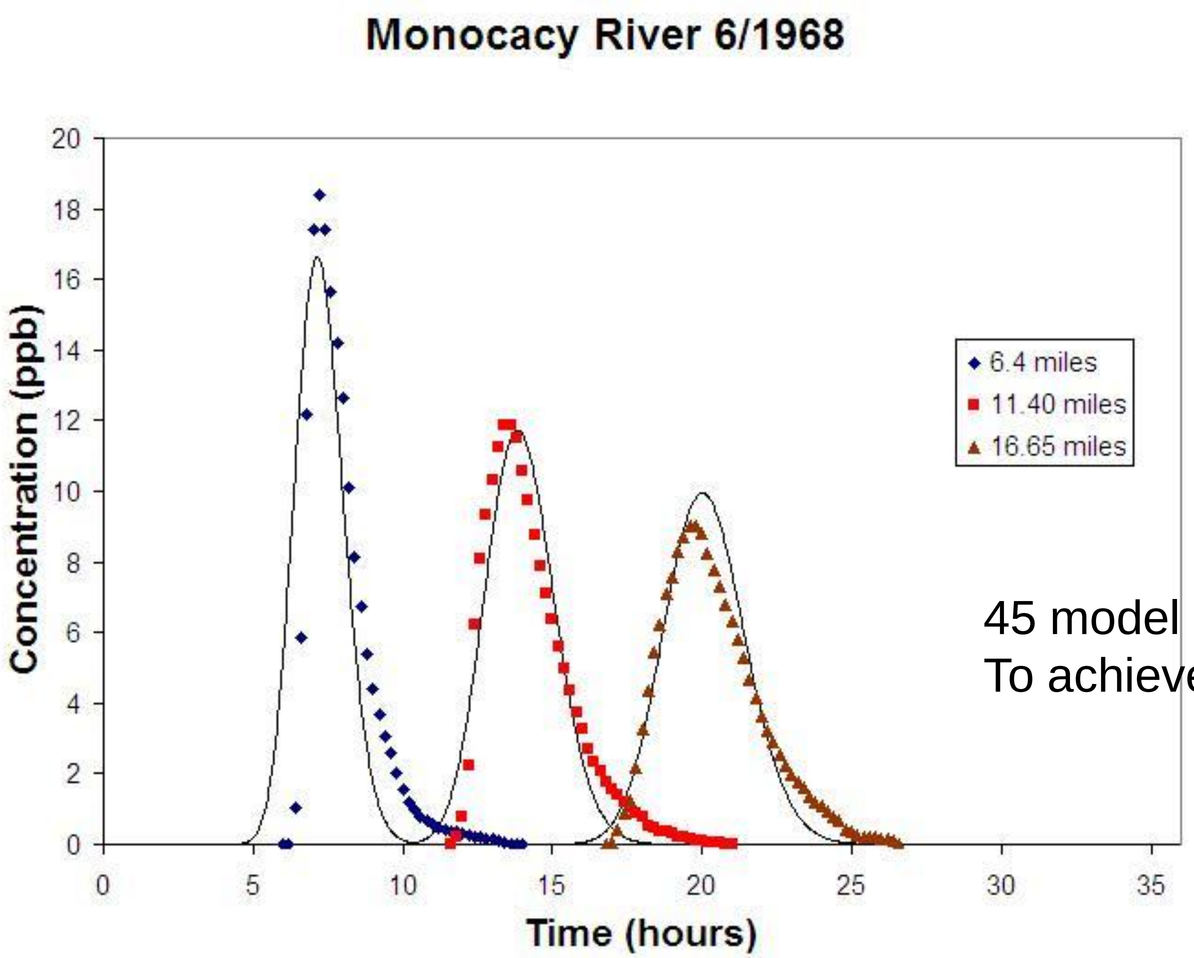
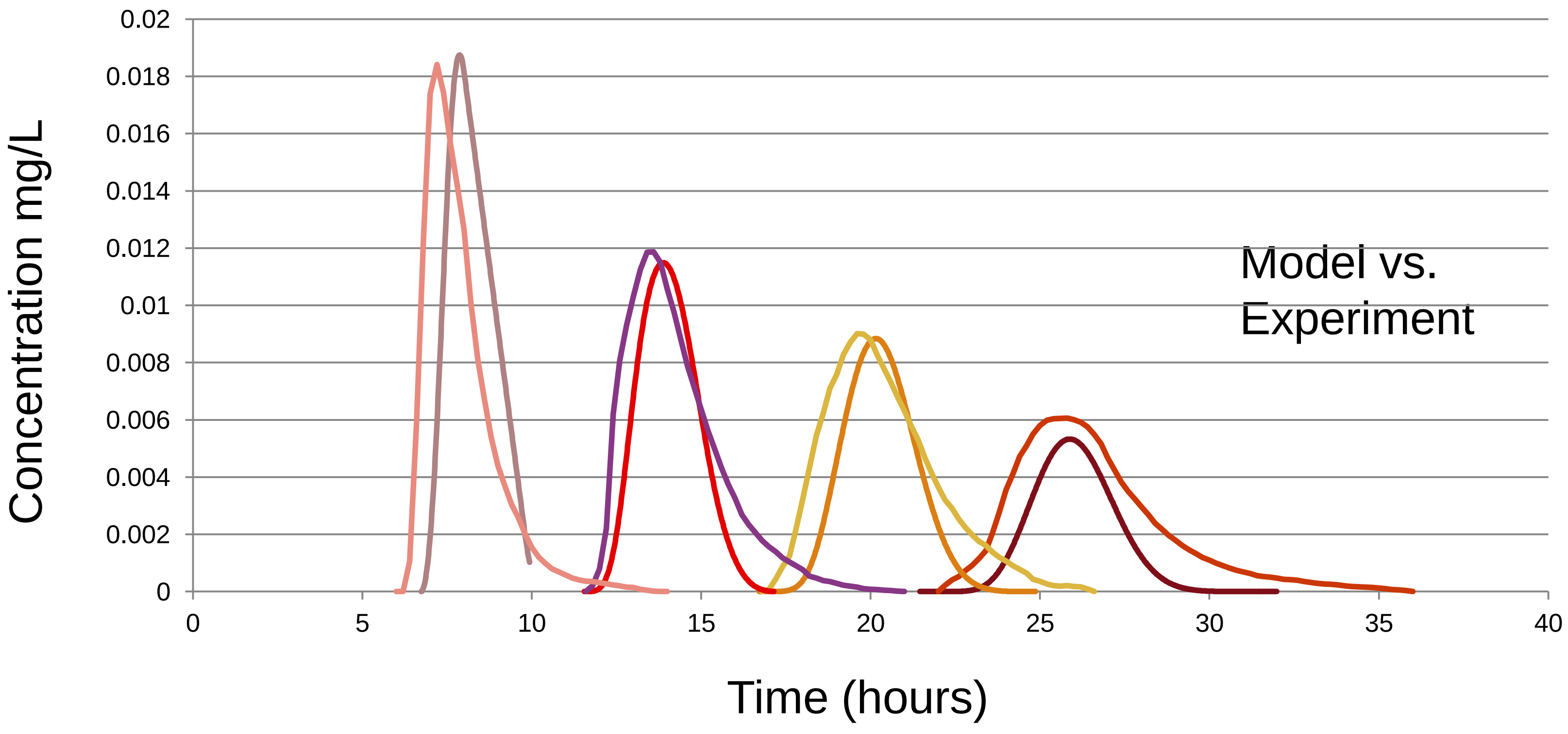
One Dimensional Numerical Model



45 model runs
To achieve calibration

Monocacy River Tracer Experiment 1 run



Mixing Schematic (Jobson, 1996)

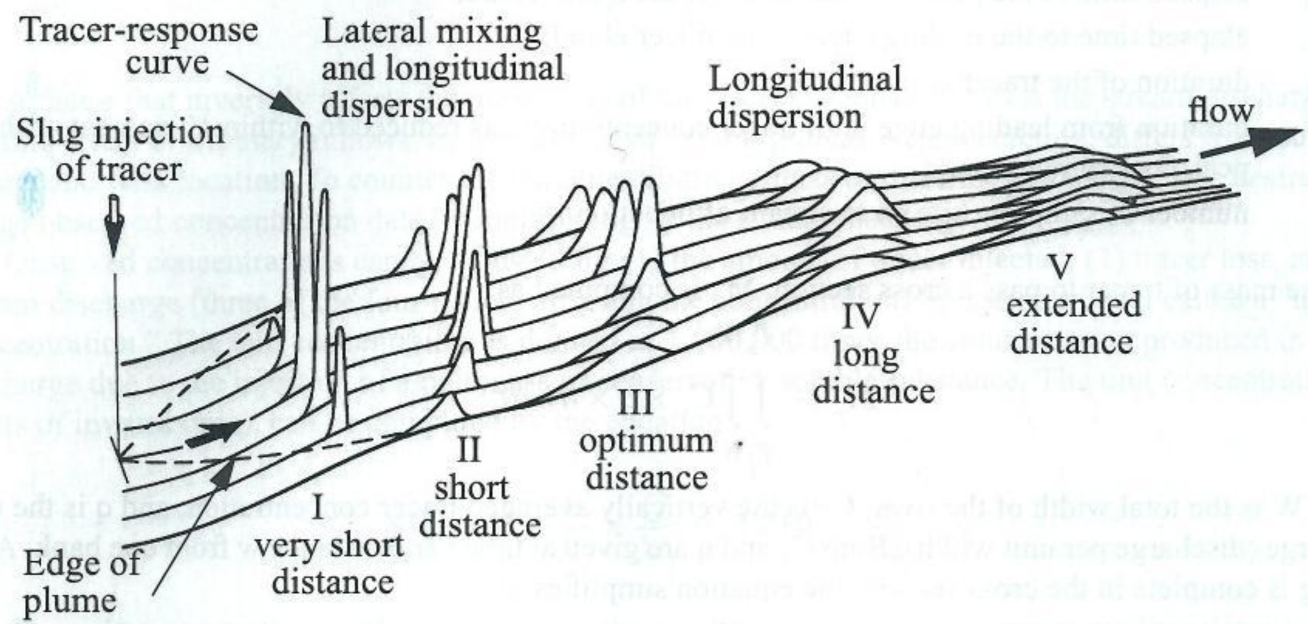


Figure 1. Lateral mixing and longitudinal dispersion patterns and changes in distribution of concentration downstream from a single, center, slug injection of tracer. (Modified from Kilpatrick, 1993, p. 2.)

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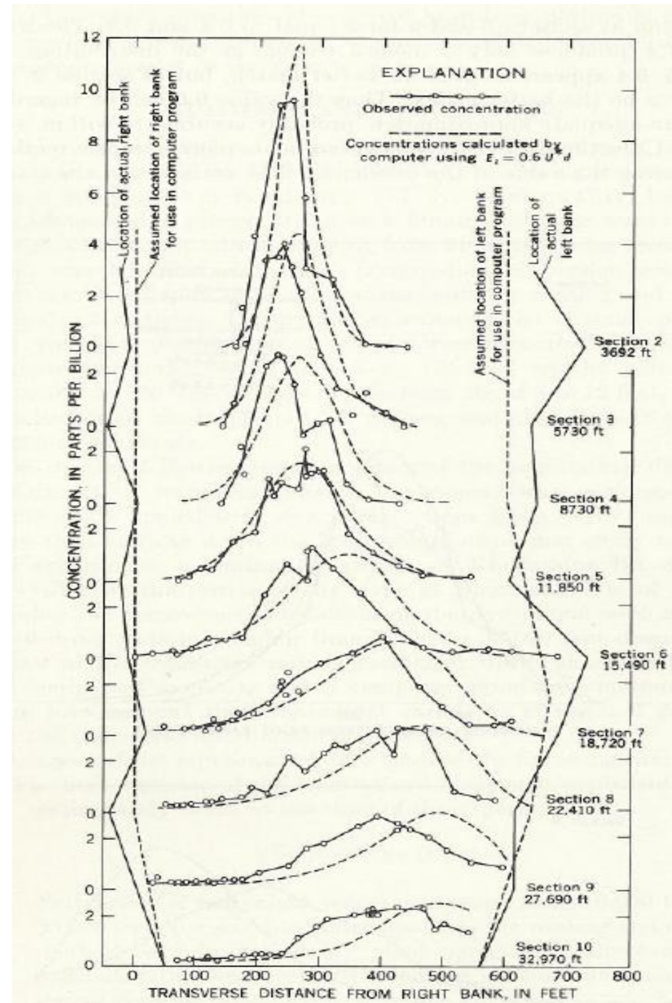
Missouri River Tracer Experiment

- Current numerical transport work focuses on simulating this experiment:
- Extensions:
  - Mixing at tributaries
  - Bubbling air/oxygen at places of refuge



Summary

- Empirical-base model captures transport essentials
  - Data required on rivers
    - Drainage area, slope, discharge, annual discharge
  - We're developing data for a few river networks
  - (Should we do more?)
  - Modeling tool to be made available through web/smart phone
- Numerical models – more powerful, but data/parameter limited

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