Application of the STIR model to a small river at different river flow rates

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Content

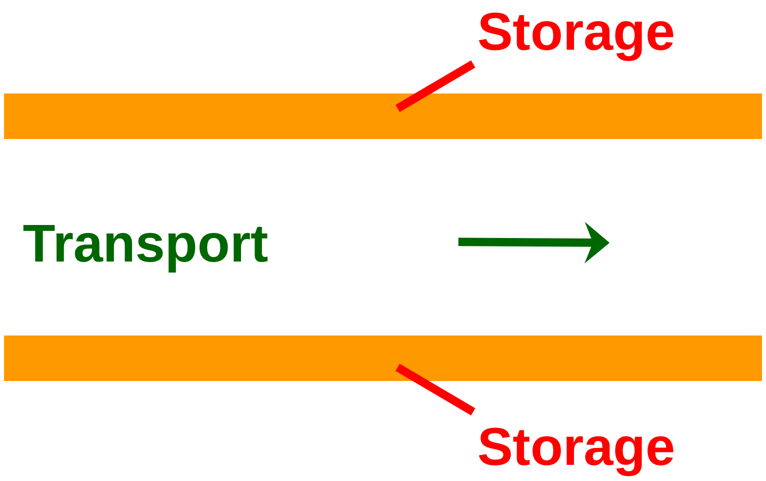
- Background
- STIR model
- Application to Murray Burn tracer data
- Variation of model parameters with flow rate
- Conclusions

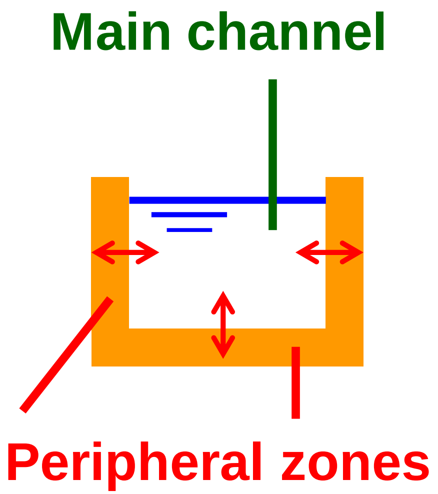
Background

- River pollution modelling
  - Given information on pollutant concentrations at an upstream location, predict future conditions at one or more locations downstream
  - Several approaches developed since 1960s:
    - Advection-dispersion
    - Transient storage
    - Aggregated dead zone
    - Unitized peak
    - Similarity

Background

- **Transient storage**



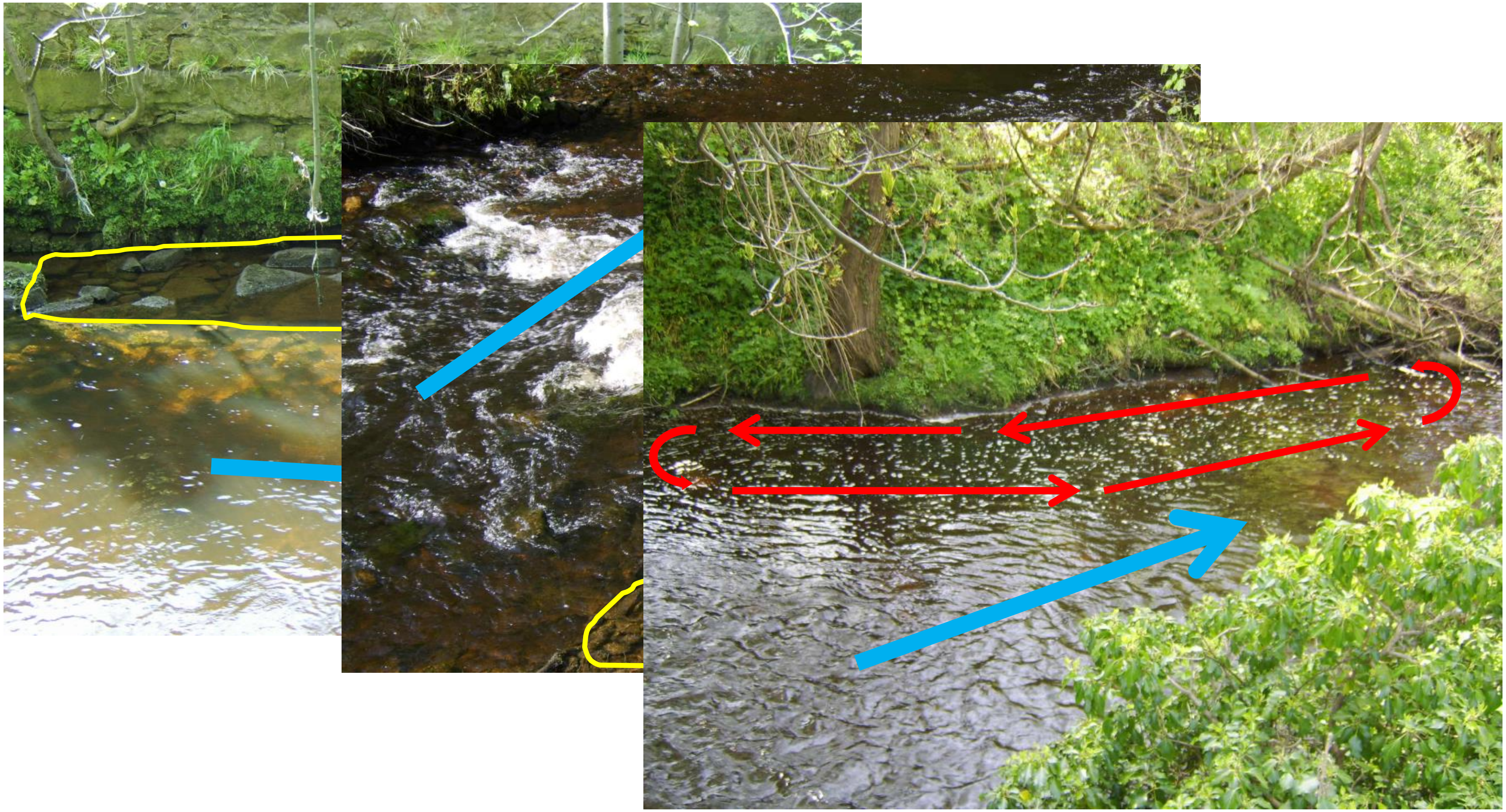


Plan view **Cross-section**

- **Transport: advection-dispersion in main channel**
- **Storage: trapping in, and exchange with, peripheral zones**

Background

- **Reality check**



Background

- **Aims of presentation**

  - **Introduce STIR (solute transport in rivers) model**

  - **Illustrate how the model's parameters vary with river flow rate using Murray Burn tracer data**

  - **Compare results with previous analysis of Murray Burn tracer data**

STIR Model

- **Commonly used transient storage model**

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = D\frac{\partial^2 C}{\partial x^2} + k_1(S - C)$$

$$\frac{\partial S}{\partial t} = -k_2(S - C)$$

- **C – pollutant concentration in main channel**
- **S – pollutant concentration in storage zones**
- **U – flow velocity in main channel**
- **D – dispersion coefficient in main channel**
- **k_1 – pollutant exchange rate (main channel to storage zones)**
- **k_2 – pollutant exchange rate (storage zones to main channel)**
- **x – longitudinal space co-ordinate, t – time**

STIR Model

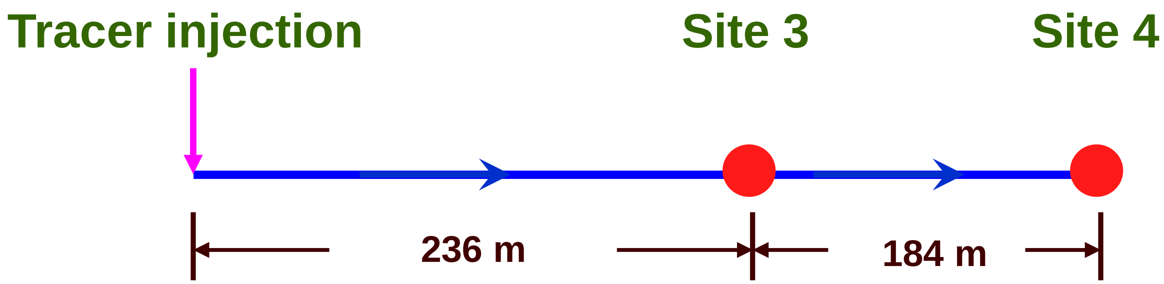
- **Model equation**

$$\frac{\partial C}{\partial t} + U\frac{\partial C}{\partial x} = D\frac{\partial^2 C}{\partial x^2} - \sum_{i=1}^{N}\left\{\alpha_i C - \int_0^t \alpha_i C \varphi_i(t-\tau)d\tau\right\}$$

- **α_i – solute mass exchange rate for the ith storage zone**
- **φ_i – residence time function for the ith storage zone**
- **τ – dummy time variable**
- **N – number of storage zones**

Application to Murray Burn tracer data

- **Reach details**



Reach	Length (m)	Mean width (m)	Mean slope	Description
I3	236	3.5	0.021	Upper 100 m: natural channel, meandering, boulders Lower 136 m: modified channel, straight, cobbles
I4	420	3.0	0.016	Upper 100 m: natural channel, meandering, boulders Lower 320 m: modified channel, straight, cobbles
34	184	2.4	0.009	Throughout: modified channel, straight, cobbles

Application to Murray Burn tracer data

- **Reach details**

upper part of reach I3

lower part of reach I3

reach 34

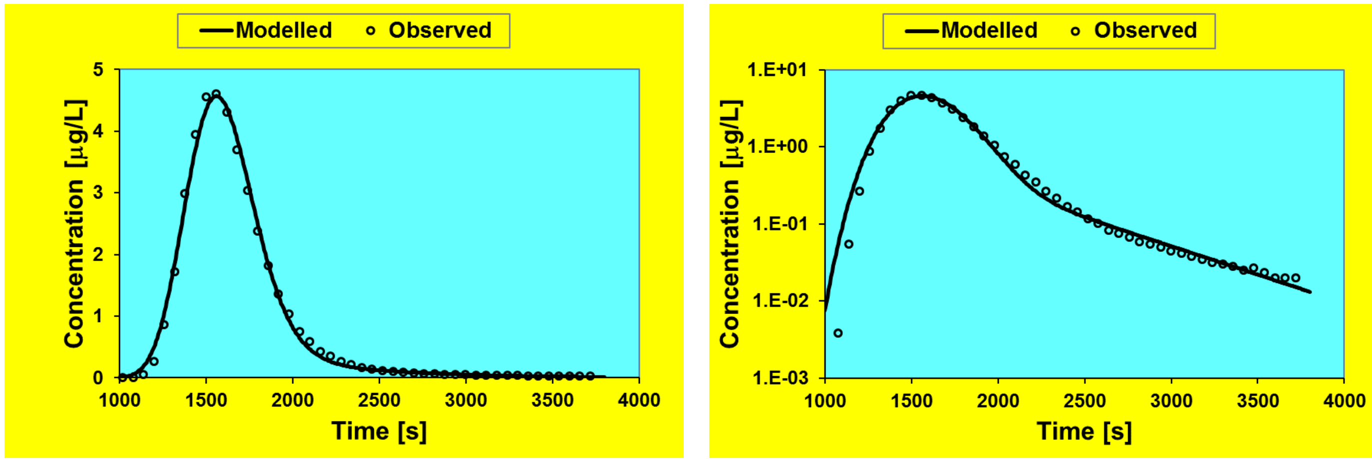
Application to Murray Burn tracer data

- **Model calibration**
  - One storage zone with an exponential residence time distribution
  - Nine experiments; flow rates 15 – 400 L/s
  - Temporal concentration data interpolated to time step of 2.5 s
  - Temporal concentration data truncated at 4tp where tp is time delay between first rise above background and peak
  - 4 model parameters optimised using linear fitting around the peak and logarithmic fitting on the tail
  - Model applied to three reaches: I3, I4 and 34

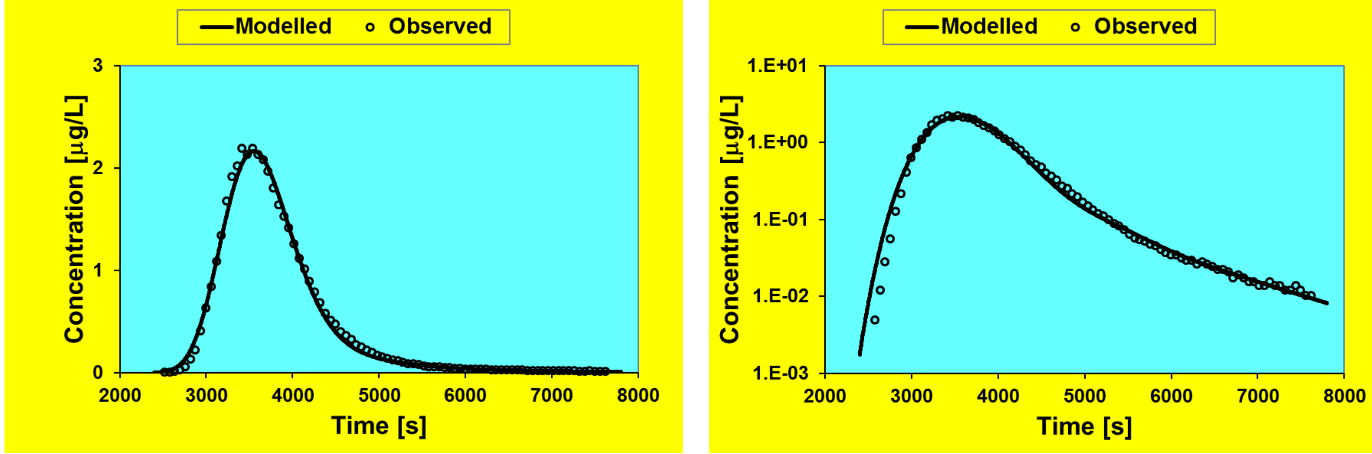
Application to Murray Burn tracer data

- **Example model fits: experiment 7**

Reach I3

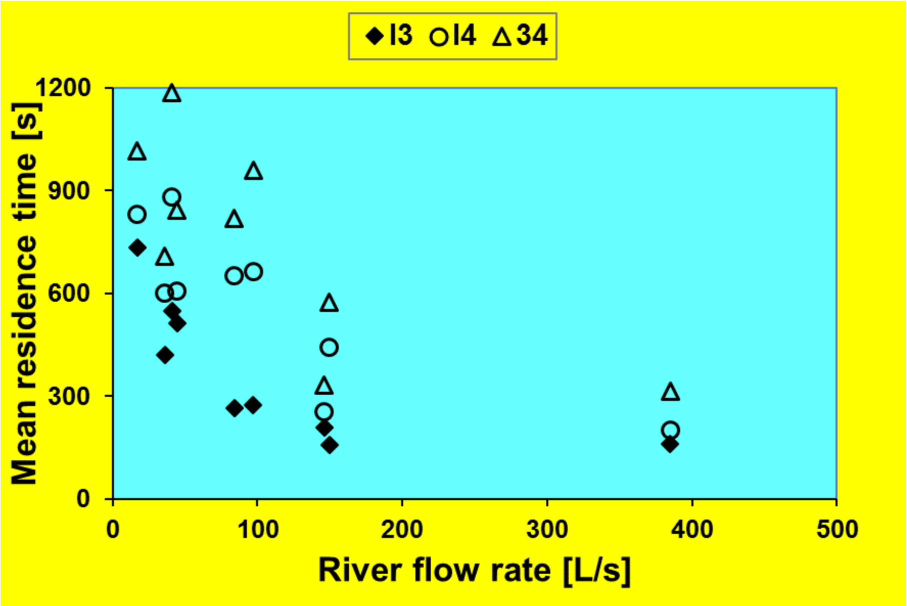


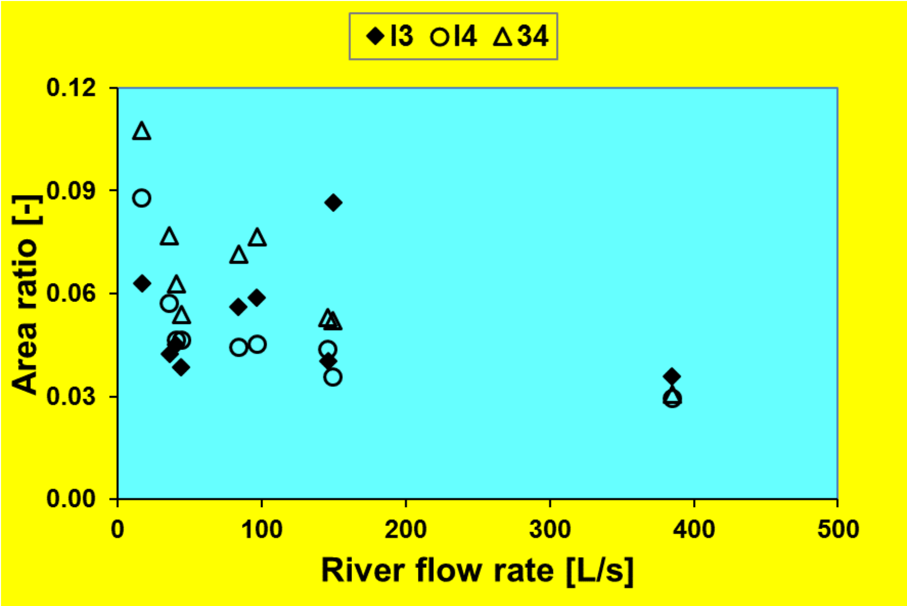
Reach 34



Variation of model parameters with flow rate

- **Transient storage**



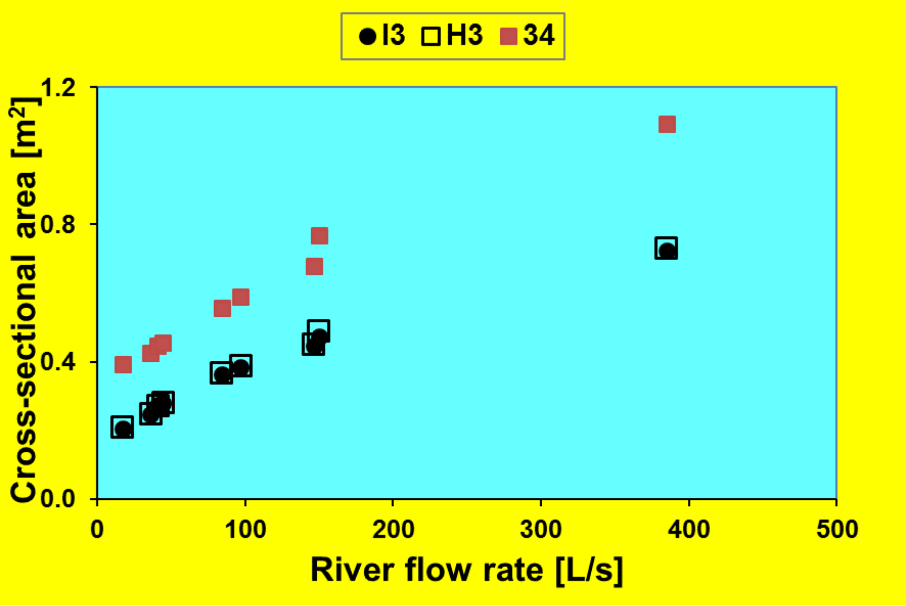


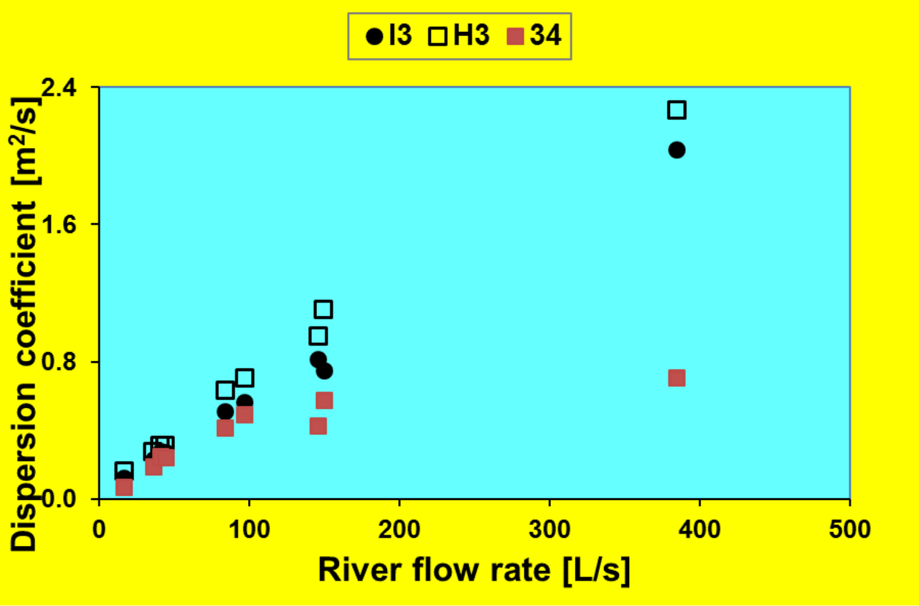
All expts: 34 > I4 > I3
All reaches: reduce with Q

Most expts: 34 > I4 and I3
All reaches: reduce with Q

Variation of model parameters with flow rate

- **Main channel**





Heron > STIR: 1% for I3
(2% for I4; 3% for 34)

Heron > STIR: 22% for I3
(25% for I4; 66% for 34)

Conclusions

- **Optimised STIR model parameters are reliable**
  - **Values are consistent with nature of reaches**
  - **Values vary with flow rate in expected manner**
  - **Values are consistent with independent analysis**