

# A segmented tidal prism flushing model for triplets

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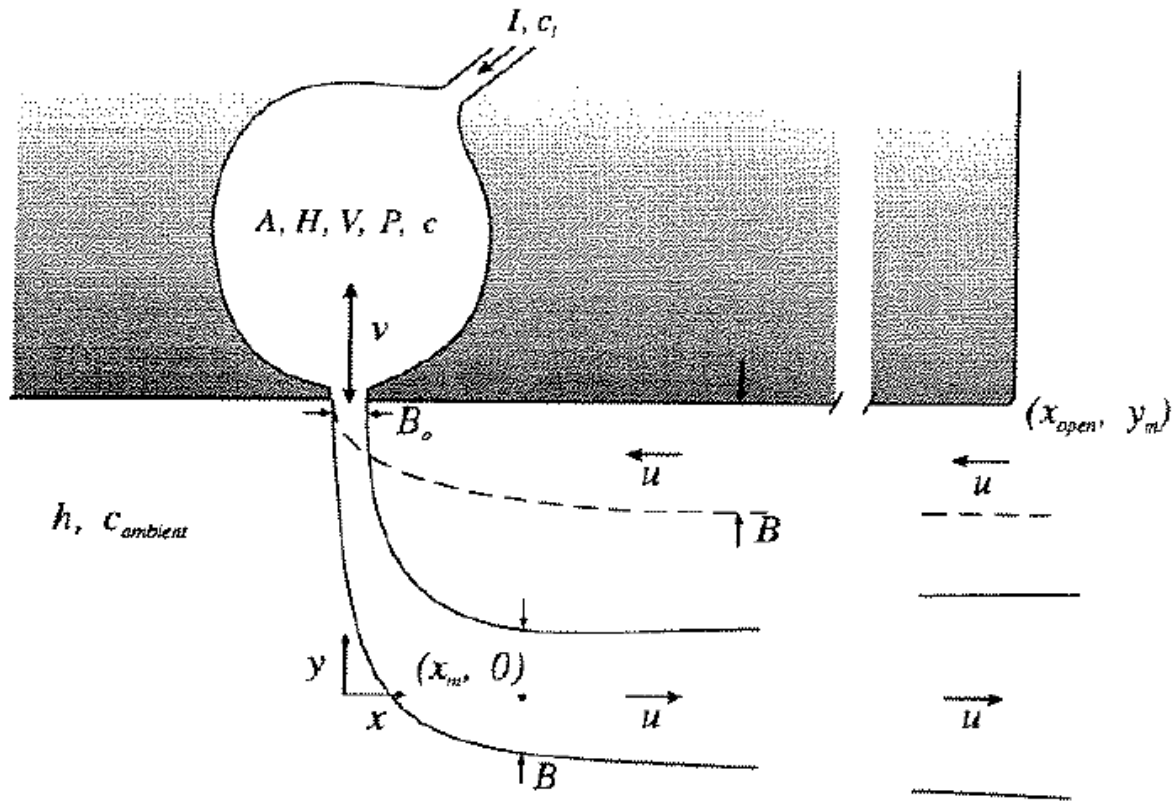
UMCES, Horn Point Laboratory

CBP STAC Workshop on Revisiting Coastal Land-Water Interactions: The Triplet Connection

Hood College, Frederick, MD

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# Tidal Prism Model



- Usually applied to small, well-mixed embayments that are primarily flushed by the rising and falling tide
- Tidal prism  $P$  is the volume of water between low and high tide
- The equivalent steady state flow rate  $Q$  (averaged over a tidal cycle) is  $Q = P/T$ , where  $T$  is the tidal period

Sanford, L. P., Boicourt, W. C., & Rives, S. R. (1992). Model for estimating tidal flushing of small embayments. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, 118(6), 635-654.

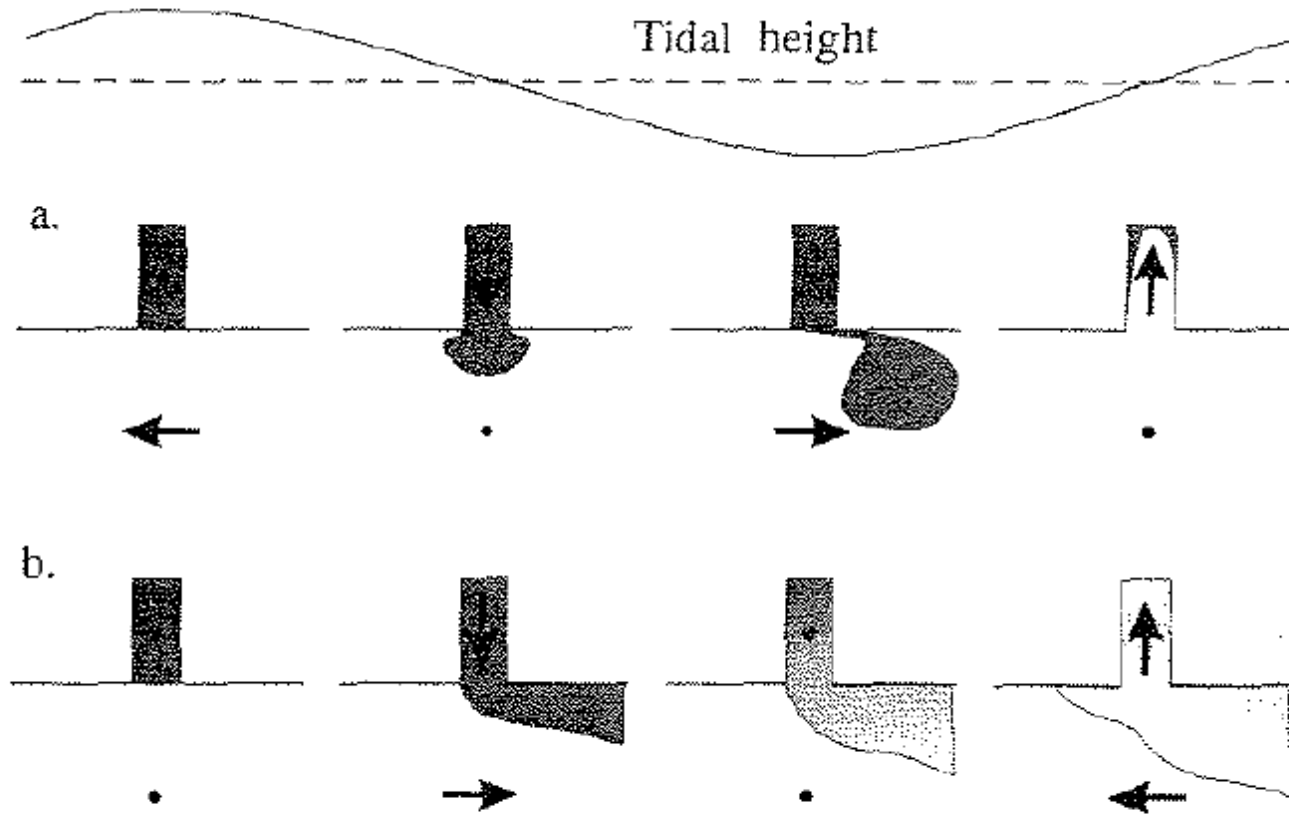
# Governing equations for a single basin

$$\frac{dc}{dt} = \frac{S}{V} - kc - \frac{1}{T_f} (c - c_{out}) - \frac{I}{V} (c - c_I) \text{ where}$$

$$T_f = \frac{V}{(1-b)\frac{P}{T} + (1+b)\frac{I}{2}} \text{ or } T_f = \frac{V}{(1-b)\frac{P}{T}} \text{ for } I = 0$$

Most of these parameters are prescribed inputs or are determined from the geometry of the system, tidal range, and watershed inputs. A key, often undetermined parameter is the return flow factor  $b$ , which is the fraction of embayment water exiting during ebb that returns during flood. If  $b = 0$ , the embayment is maximally flushed by the tide. If  $b = 1$ , there is no tidal flushing. SO  $b$  DETERMINES TIDAL INTERACTION BETWEEN A BASIN AND ITS RECEIVING WATERS.

What determines  $b$ ? The relative phase of the tide inside:outside and diffusion of the plume when it is outside.



**FIG. 2. Extremes of Phase between Channel Tidal Current and Coastal Tidal Current. (a) 90° Out of Phase, Coastal Tide is Progressive Wave; (b) in Phase, Coastal Tide is Standing Wave**

# Residence Times of Small Chesapeake Bay Tributaries

Thomas Wazniak, William Boicourt, and Elizabeth North  
University of Maryland Center for Environmental Science  
Horn Point Laboratory

July 16, 2009

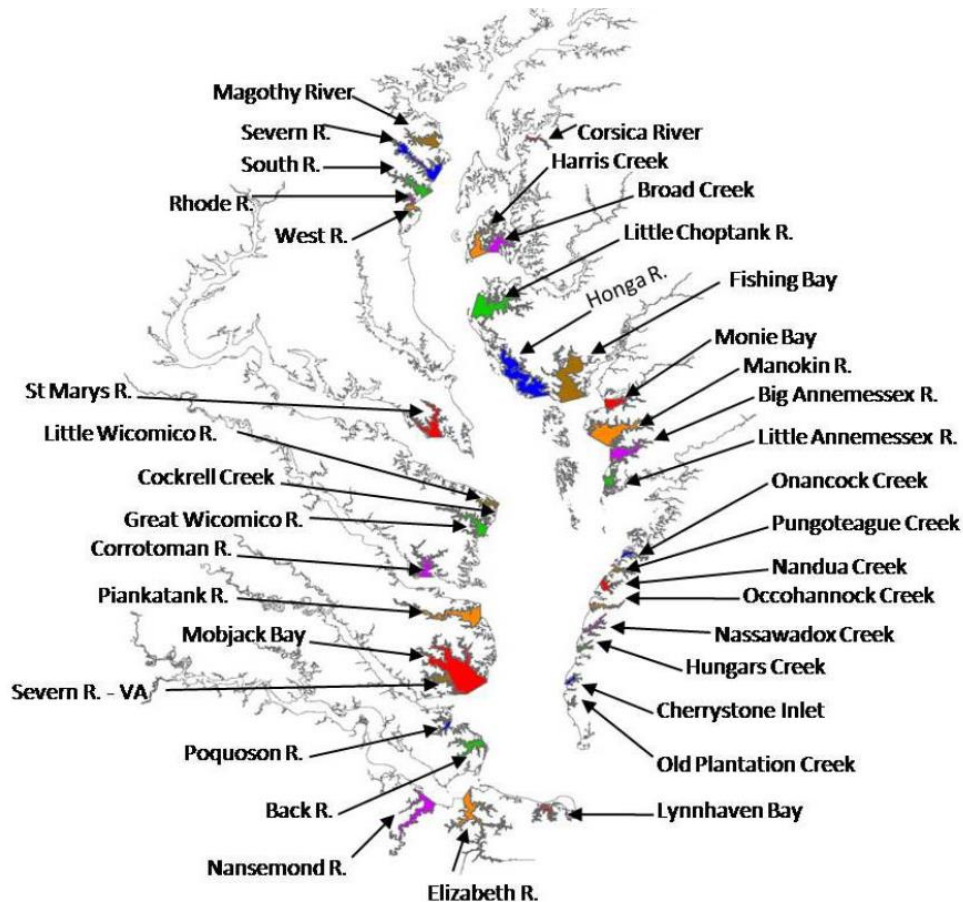


Fig. 1. Tributaries for which flushing times were calculated.

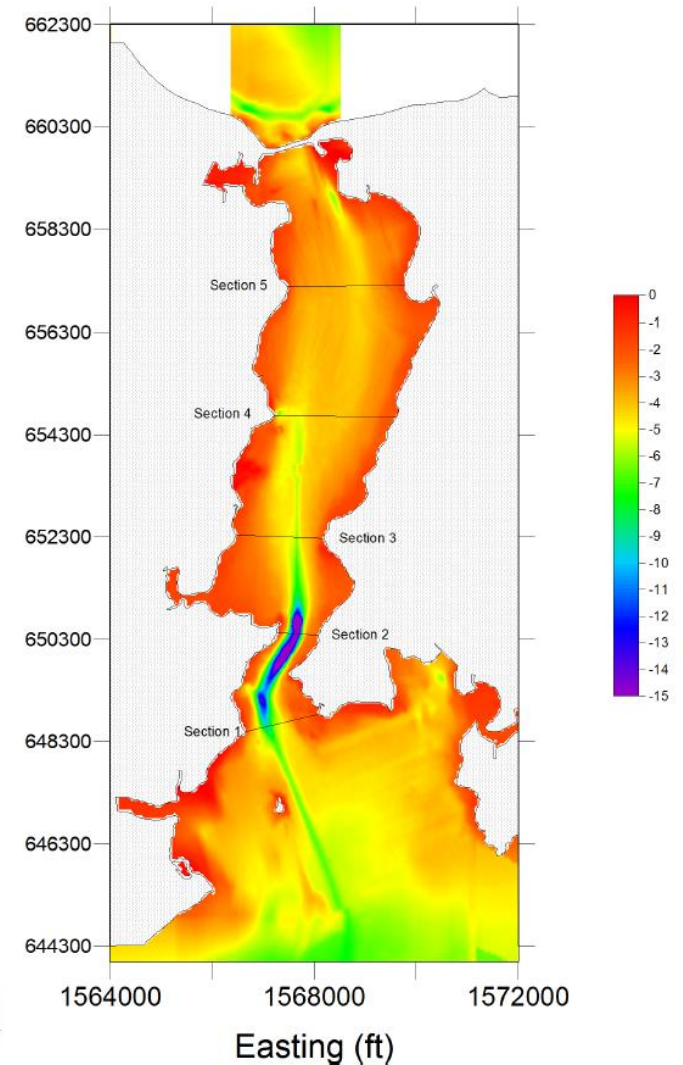
How does single basin tidal prism flushing work in Chesapeake Bay embayments and tributaries?

Wazniak et al. (2009) made careful estimates for 36 small tribs of CB, resulting in flushing times ranging from fractions of a day to several days.

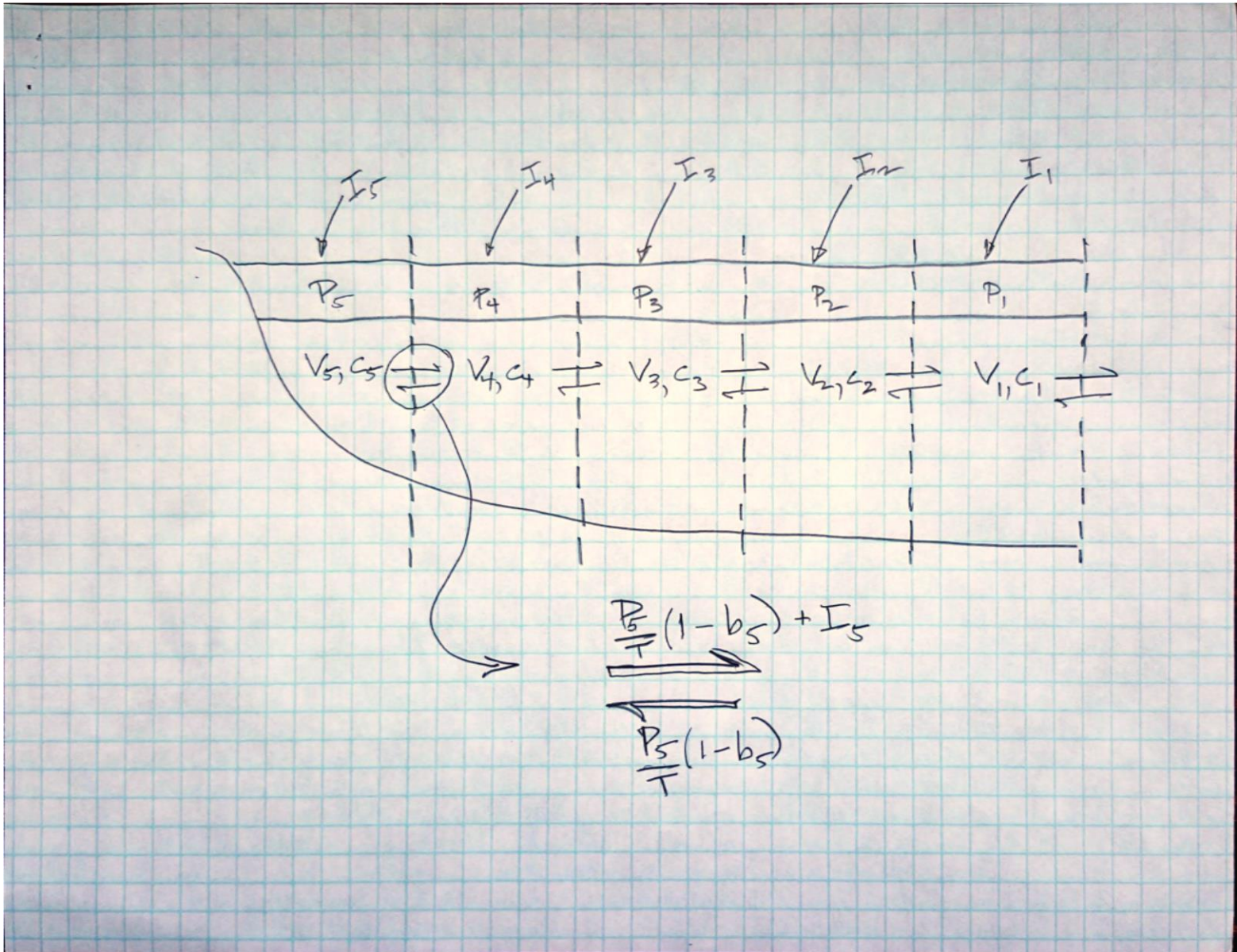
When does single basin Tidal Prism flushing NOT work?  
When model assumptions are not valid.

- Model assumes complete mixing during the flood tide – so there must be rapid connectivity between all parts of the basin.
- Model ignores other mechanisms of flushing such as wind forcing and estuarine circulation.
- This presentation considers extending the tidal prism method to tidal embayments (tributaries and triplets) with incomplete mixing, but still dominated by tidal flushing ( $P/T > 1/2$ )

# Segmented Tidal Prism flushing model, developed for a study of Spesutie Narrows in upper CB



# Schematic of segmented box model

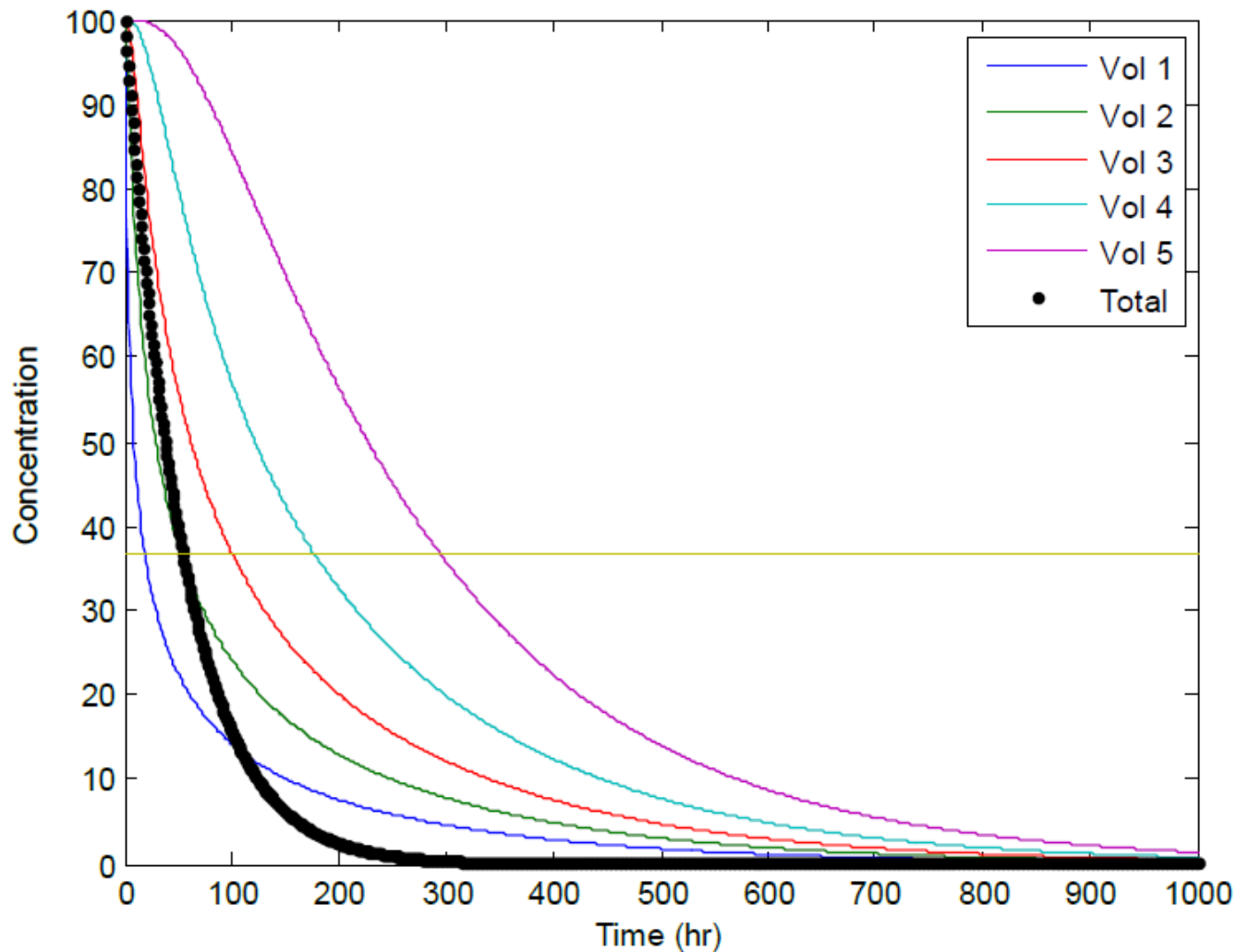


# Solution for tidal flushing only

$$\frac{dc_i}{dt} = M_{ii} * c_i, \text{ where } c_i = \begin{bmatrix} c_1 \\ c_2 \\ c_3 \\ c_4 \\ c_5 \end{bmatrix} \text{ and } M_{ii} = \begin{bmatrix} M_{11} & M_{12} & 0 & 0 & 0 \\ M_{21} & M_{22} & M_{23} & 0 & 0 \\ 0 & M_{32} & M_{33} & M_{34} & 0 \\ 0 & 0 & M_{43} & M_{44} & M_{45} \\ 0 & 0 & 0 & M_{54} & M_{55} \end{bmatrix}$$

Straightforward calculation of the exchange coefficients  $M_{ij}$ , could also add internal sources/sinks, external inputs. More difficult is rigorous assignment of return flow factors  $b_{ij}$ , though for illustrative purposes some reasonable assumptions are adequate.

Could also go back to the governing equation and solve for steady state in each segment – perhaps the more interesting calculation...



**Figure 4.1** – Time histories of concentration changes due to flushing of Spesutie Narrows estimated as a series of 5 sequential sub-basins (eq 6) with realistic interbasin exchange, for comparison to flushing of a single well-mixed volume (eq 2). The horizontal line at  $c=36.8$  denotes the concentration used to define flushing time.