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The Application of TOPMODEL to Assess Mercury Fluxes in the McTier Creek Watershed

Overall Investigation Objectives

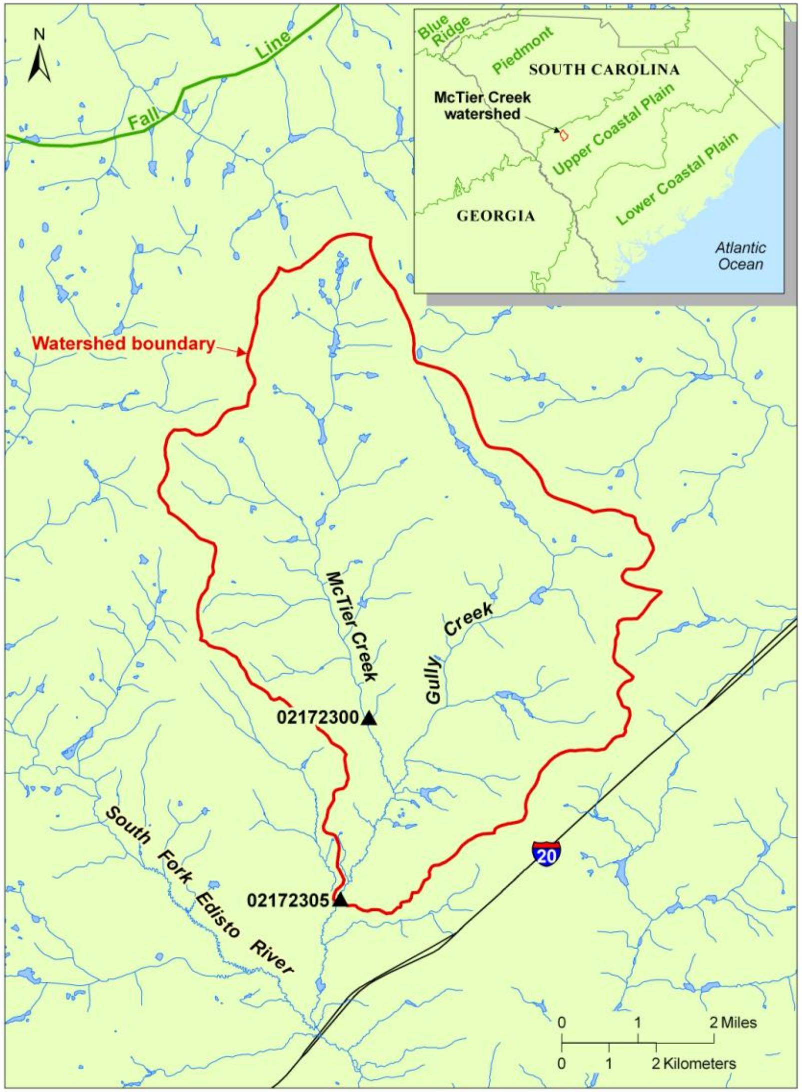
• As part of the U.S. Geological Survey National Water Quality Assessment Program (NAWQA), investigations are ongoing to improve the understanding of key processes that affect storage, transport, and transformations of mercury in stream ecosystems.

• Currently, these investigations are focused on two watersheds, McTier Creek in the Edisto River Basin of South Carolina, and Fishing Brook, in the Upper Hudson River Basin, in the central Adirondack region of New York.

• These two basins provide contrasting and complementary settings for the study of mercury cycling and bioaccumulation in headwater streams with close connectivity to out-of-channel wetlands.

• Atmospheric deposition is the dominant source of mercury in both of these mostly forested watersheds.

McTier Creek Basin



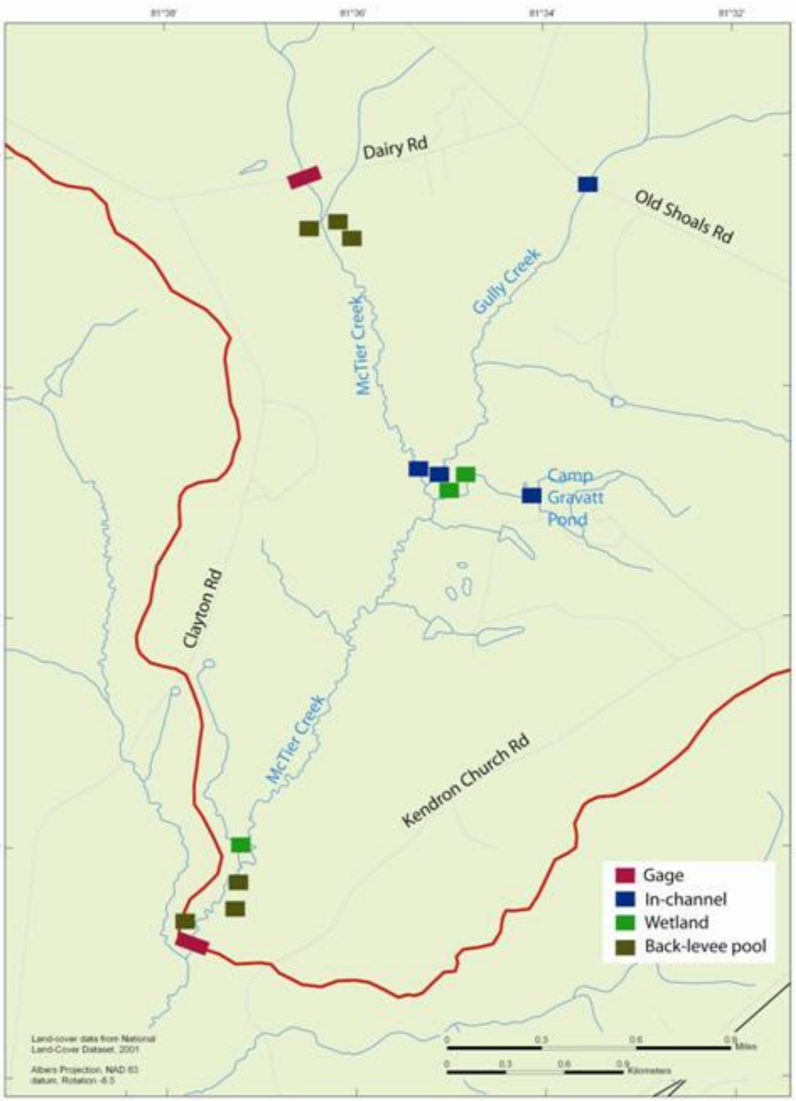
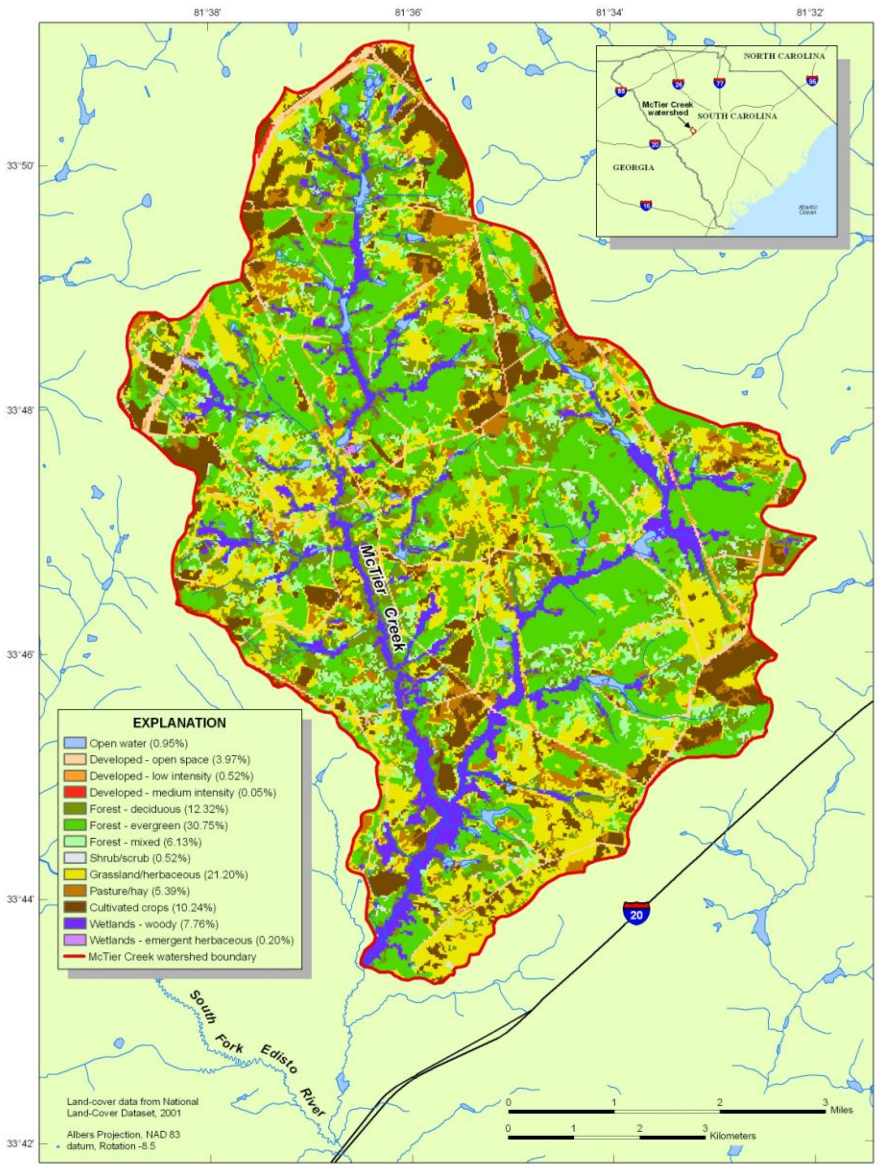


Figure 6. McTier Creek catchment sampling locations.

McTier Creek Basin



- **McTier Creek near New Holland**
  - **USGS Station 02172305**
  - **30.7 mi^2**
  - **50% Timber Forest**
  - **20% Grassland/Herbaceous**
  - **16% Agricultural**
  - **8% Wetland**
  - **5% Developed**
  - **1% Open Water**
  - **Sand Hills Topography**
  - **Wetland Habitats:**
    - **Perennial wetlands.**
    - **Transient back-levee pools.**

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McTier Creek

To assess the hydrologic controls on the transport of mercury in the watershed, the watershed model TOPMODEL is being applied.

TOPMODEL Overview

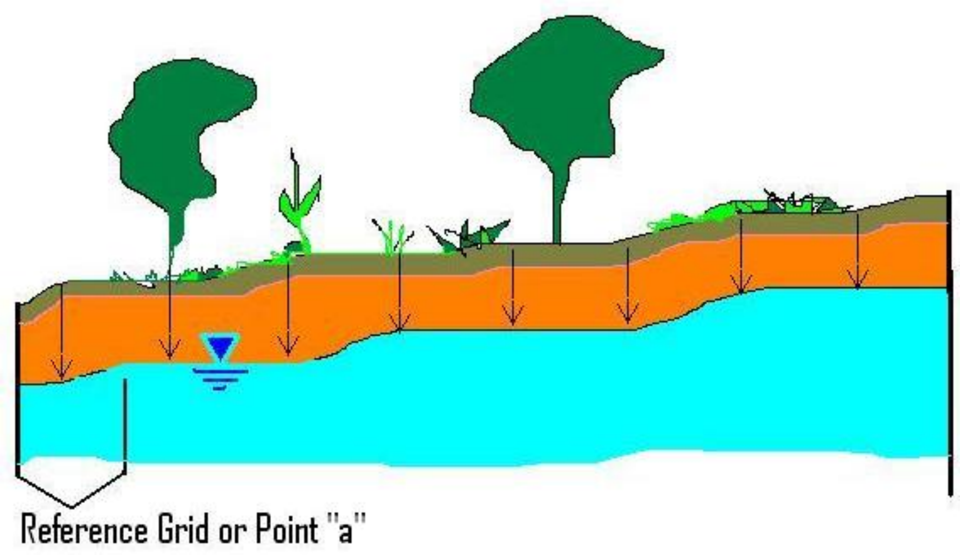
- TOPography-based hydrological MODEL
- Developed by Beven and Kirkby, 1979
- "Physically-based watershed model that simulates the variable-source-area concept of streamflow generation." (Wolock, 1993)
- Many variations/improvements to the original model since 1979
- Three fundamental assumptions

Beven, K.J. and M.J. Kirkby. 1979. A physically based, variable contributing area model of basin hydrology. *Hydrological Sciences Bulletin*, v. 24, pp. 43-69.

Wolock, David M. 1993. Simulating the variable-source-area concept of streamflow generation with the watershed model TOPMODEL. *USGS WRI 93-4124.*

TOPMODEL Assumption #1

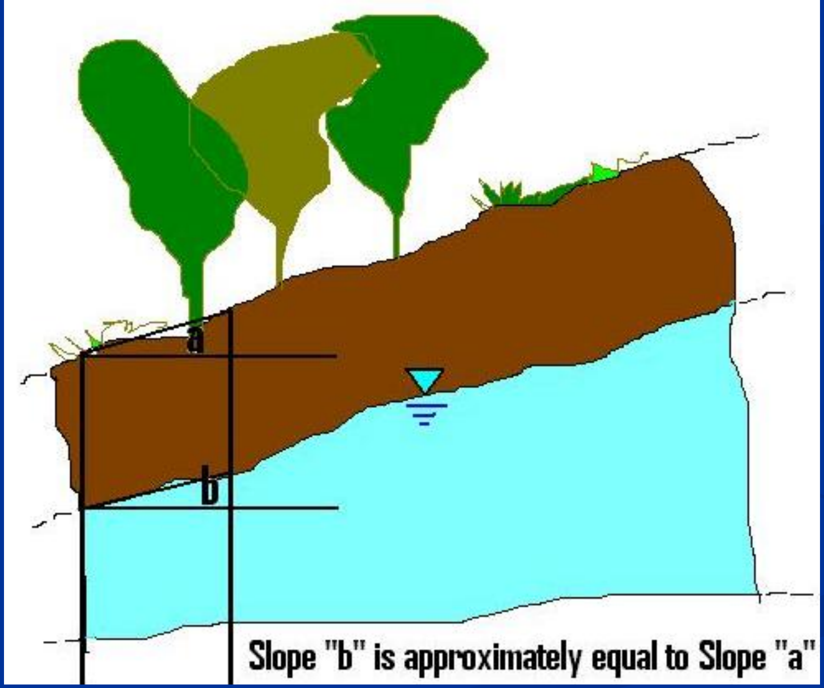
"The dynamics of the water table can be approximated by uniform subsurface runoff production per unit area (or successive steady states compatible with areally averaged rates of recharge) over the area, a, draining through a point." (Beven 1997)



Beven, Keith. 1997. TOPMODEL: A Critique. *Hydrological Processes.* v. 11, pp. 1069-1085.

TOPMODEL Assumption #2

"The hydraulic gradient of the saturated zone can be approximated by the local surface topographic slope, tan β." (Beven 1997)



Beven, Keith. 1997. TOPMODEL: A Critique. *Hydrological Processes.* v. 11, pp. 1069-1085.

TOPMODEL Assumption #3

"The transmissivity profile may be described by an exponential function of storage deficit, with a value of T_O when the soil is just saturated to the surface (zero deficit)." (Beven 2001)

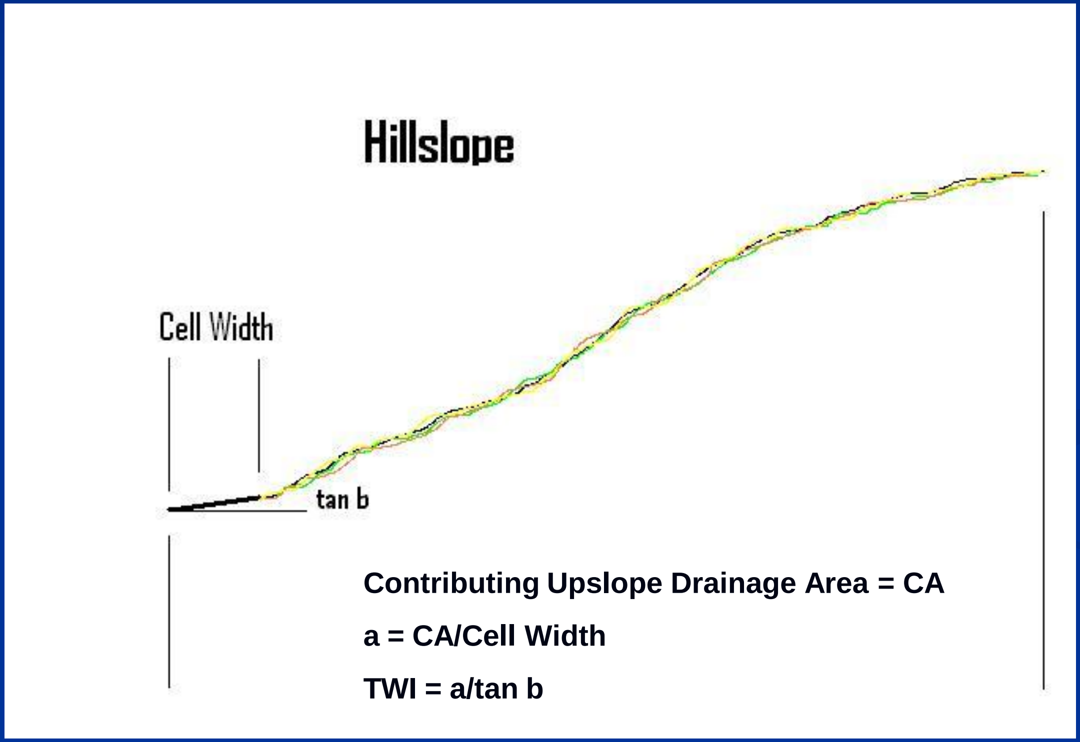
$$T = T_0 e^{-\frac{S_x}{m}}$$

Where S_x = saturation deficit at location x

m = scaling parameter that is a function of porosity and rate of decrease of hydraulic conductivity with depth

Beven, Keith. 2001. *Rainfall – Runoff Modelling – The Primer*. John Wiley & Sons. p. 208.

TOPMODEL topographic wetness index (TWI)



High values of TWI
High potential for saturation

Low values of TWI
Low potential for saturation

Grid cells with the same TWI are hydrologically similar

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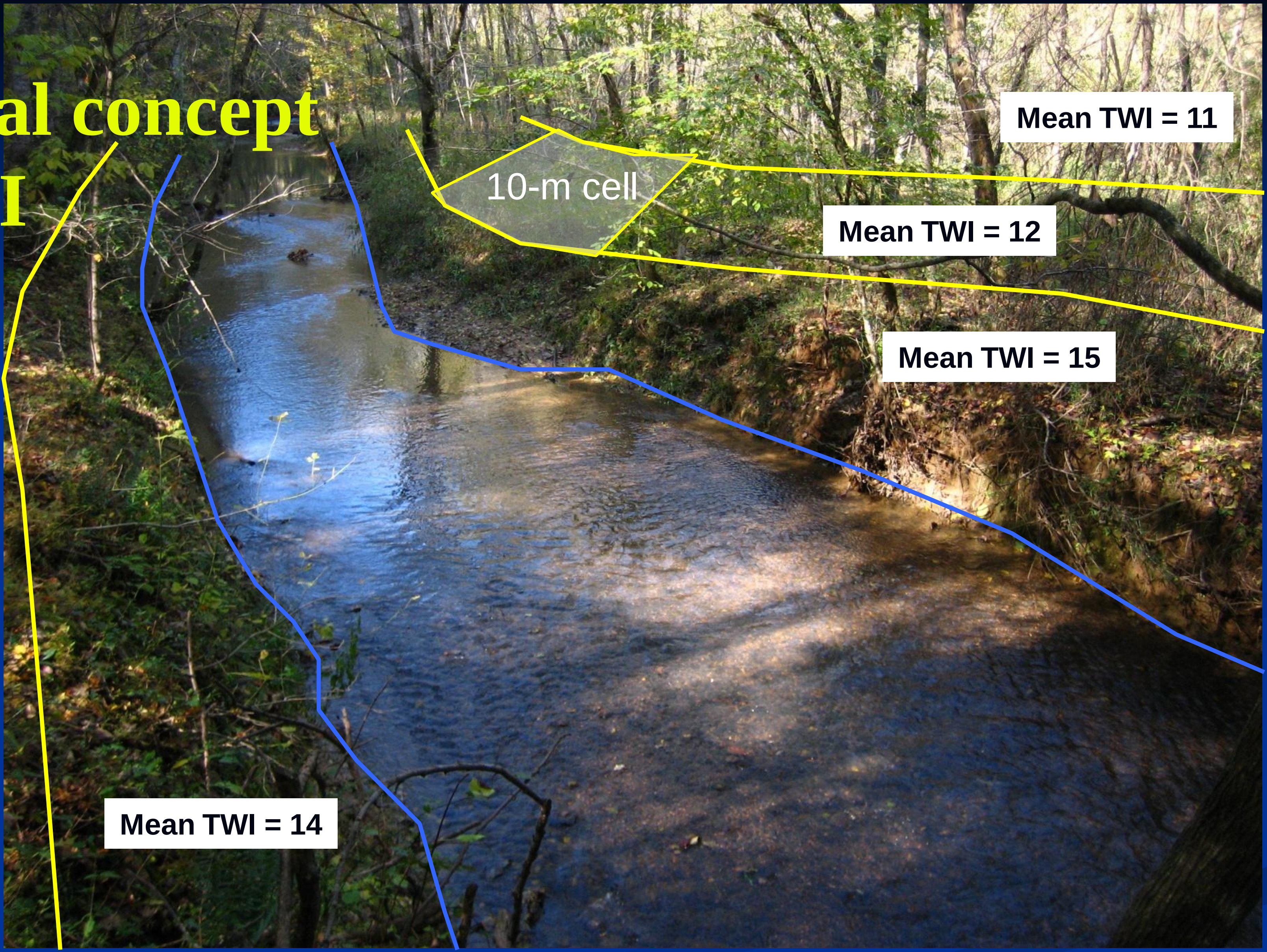
General concept of TWI



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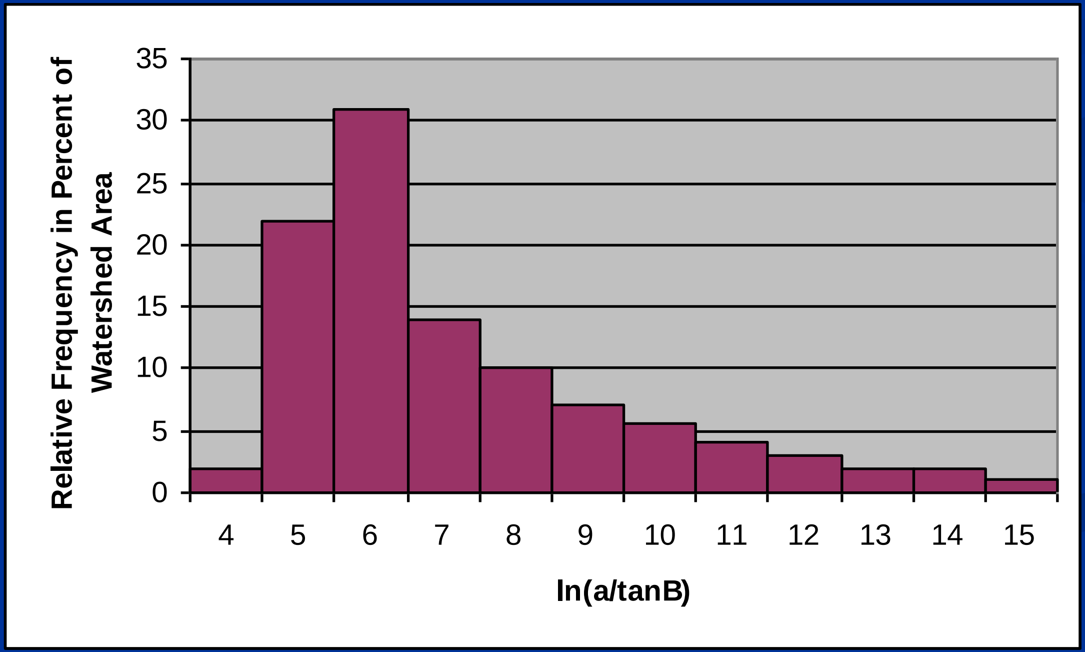
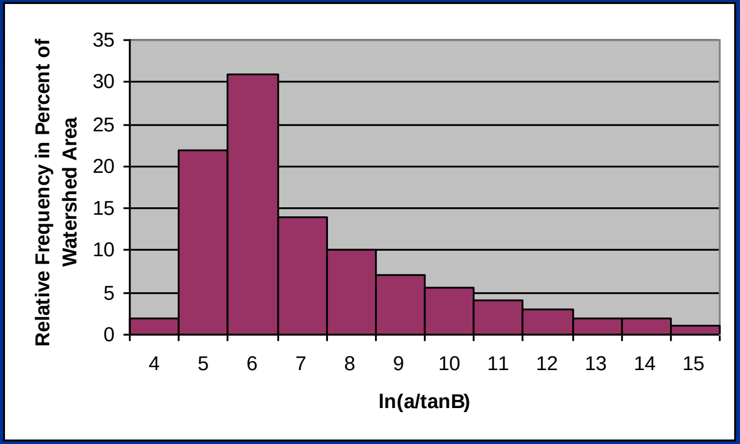
TOPMODEL topographic wetness index

Calculations need not be performed on every single grid cell. Grid cells with approximately the same TWI have similar hydrologic response



TOPMODEL flow equations derived from the continuity equation



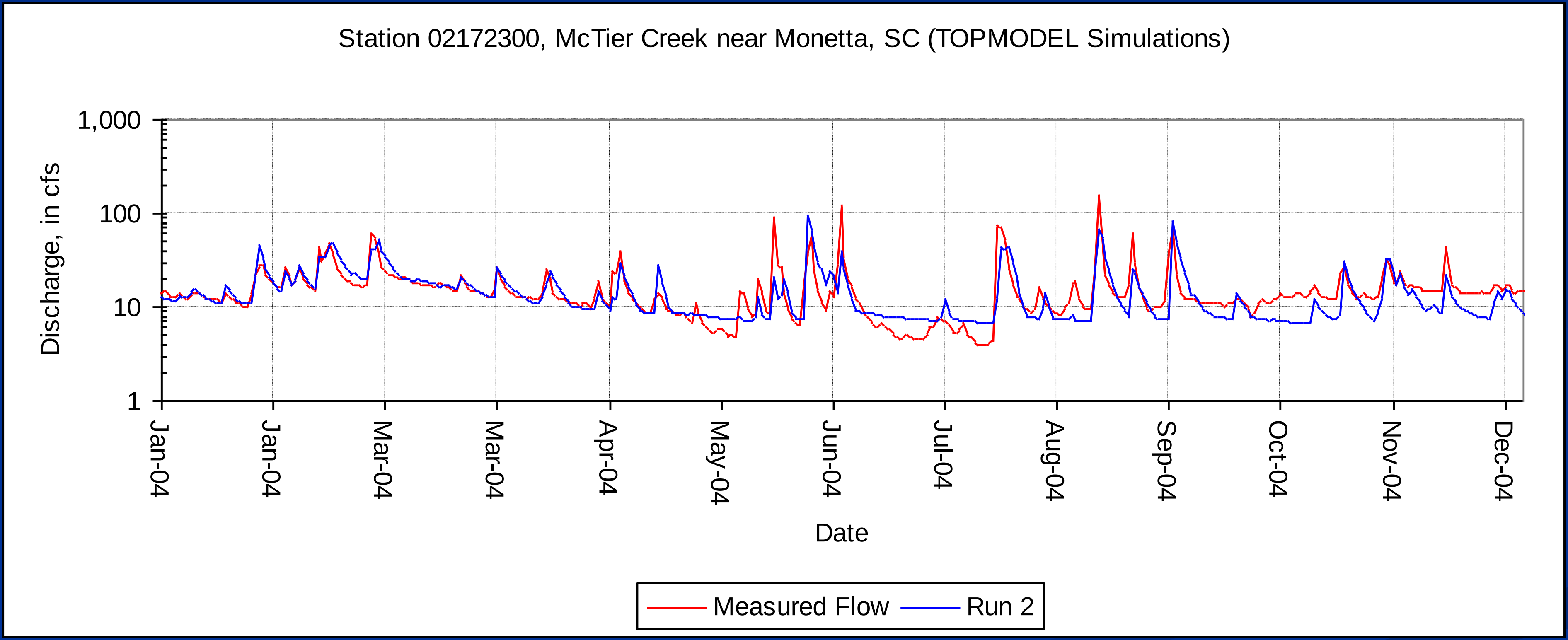
$$q_{direct} = \frac{\frac{\sum a_x i}{A}}{A} \quad where\, S_x \leq 0$$

$$q_{return} = \frac{\frac{\sum a_x |S_x|}{A}}{A} \quad where\, S_x < 0$$

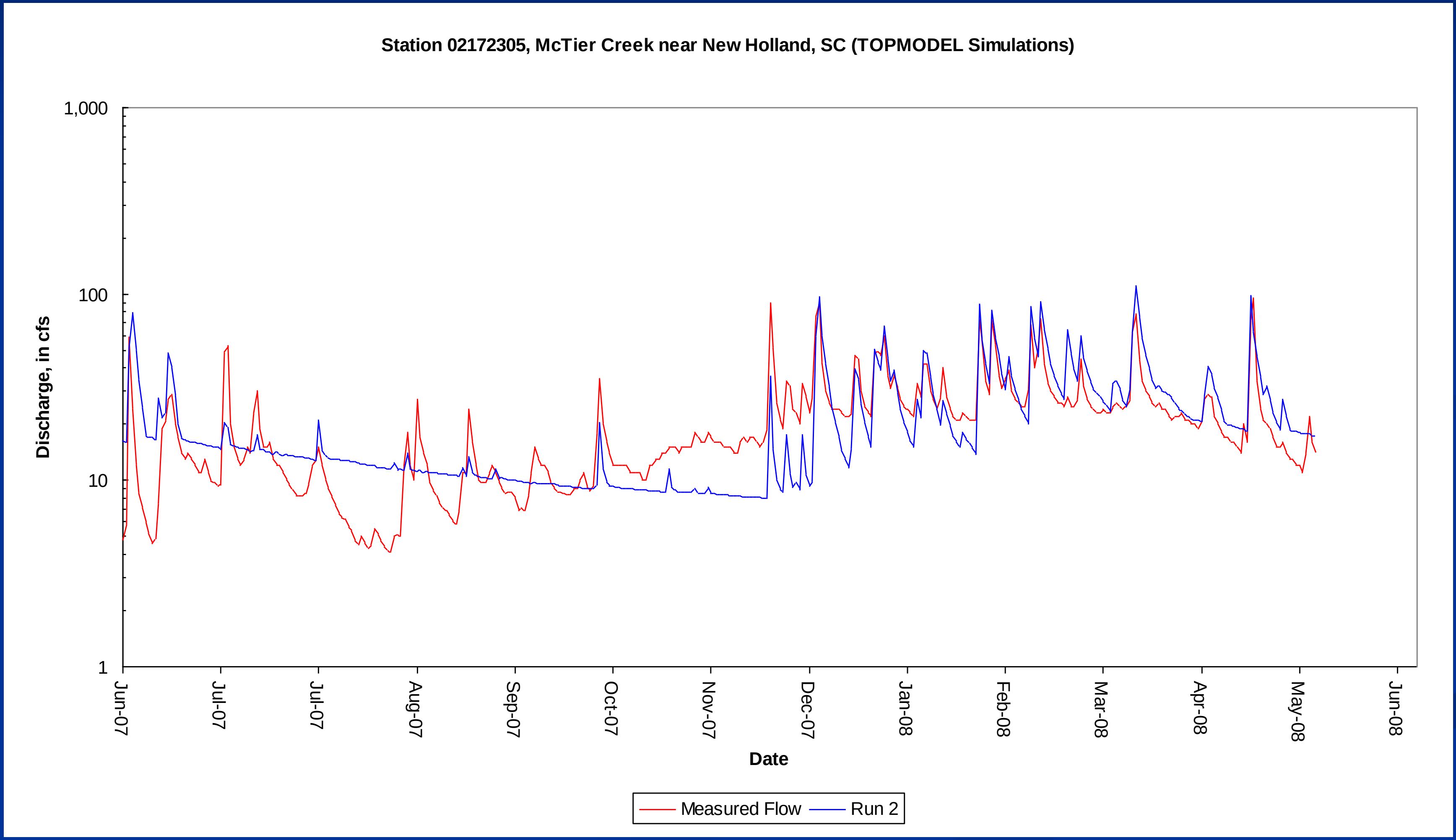
$$q_{subsurface} = T_0 e^{-\lambda} e^{-\frac{\bar{S}}{m}}$$

where T_o is the transmissivity of the soil at the surface

TOPMODEL simulations of total predicted flow at station 02172300



TOPMODEL simulations of total predicted flow at station 02172305



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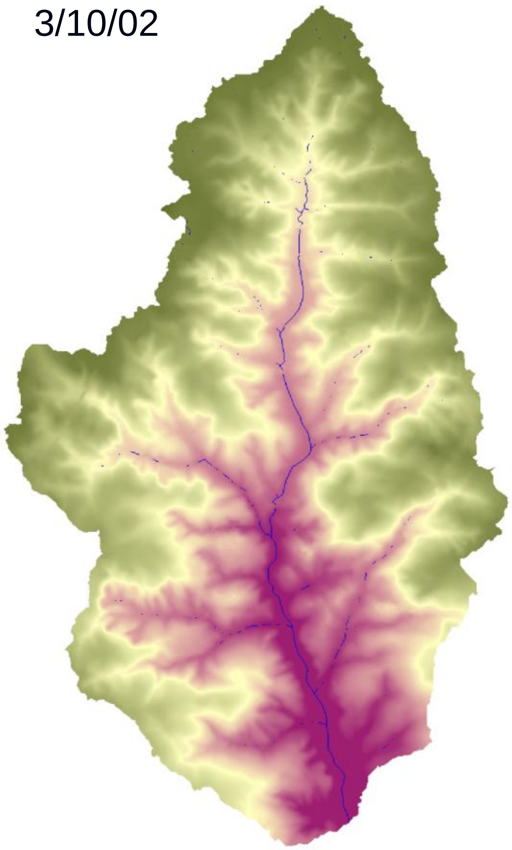
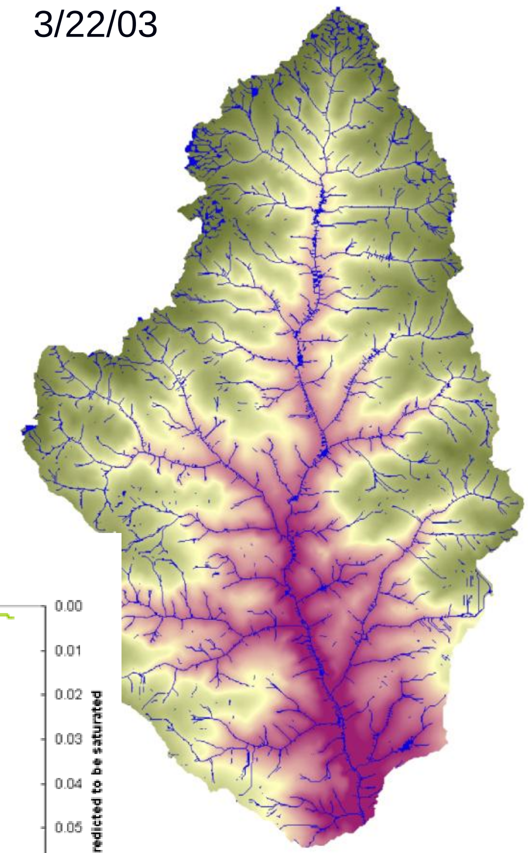
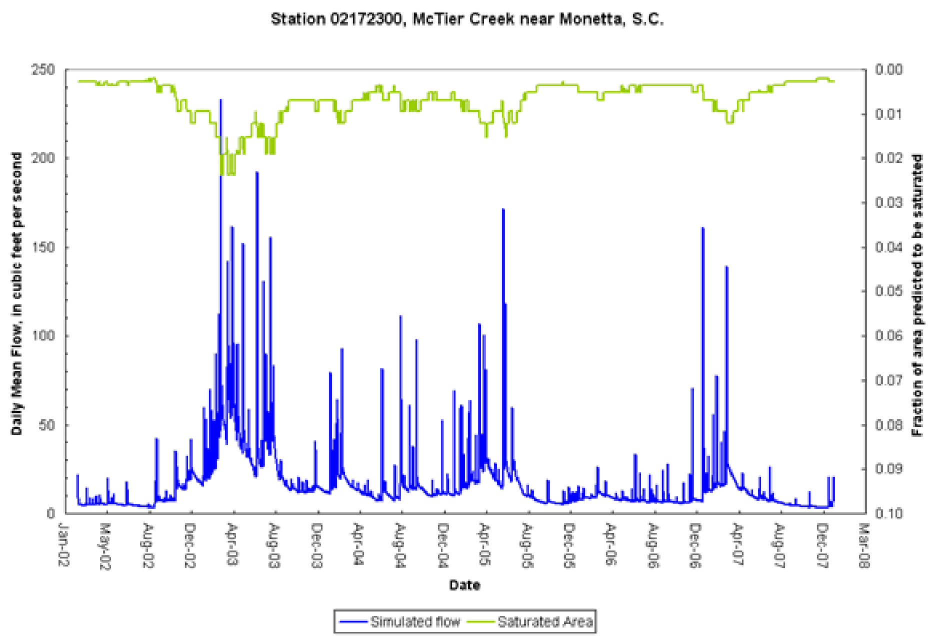
McTier Creek basin saturated areas from simulations

3/10/02

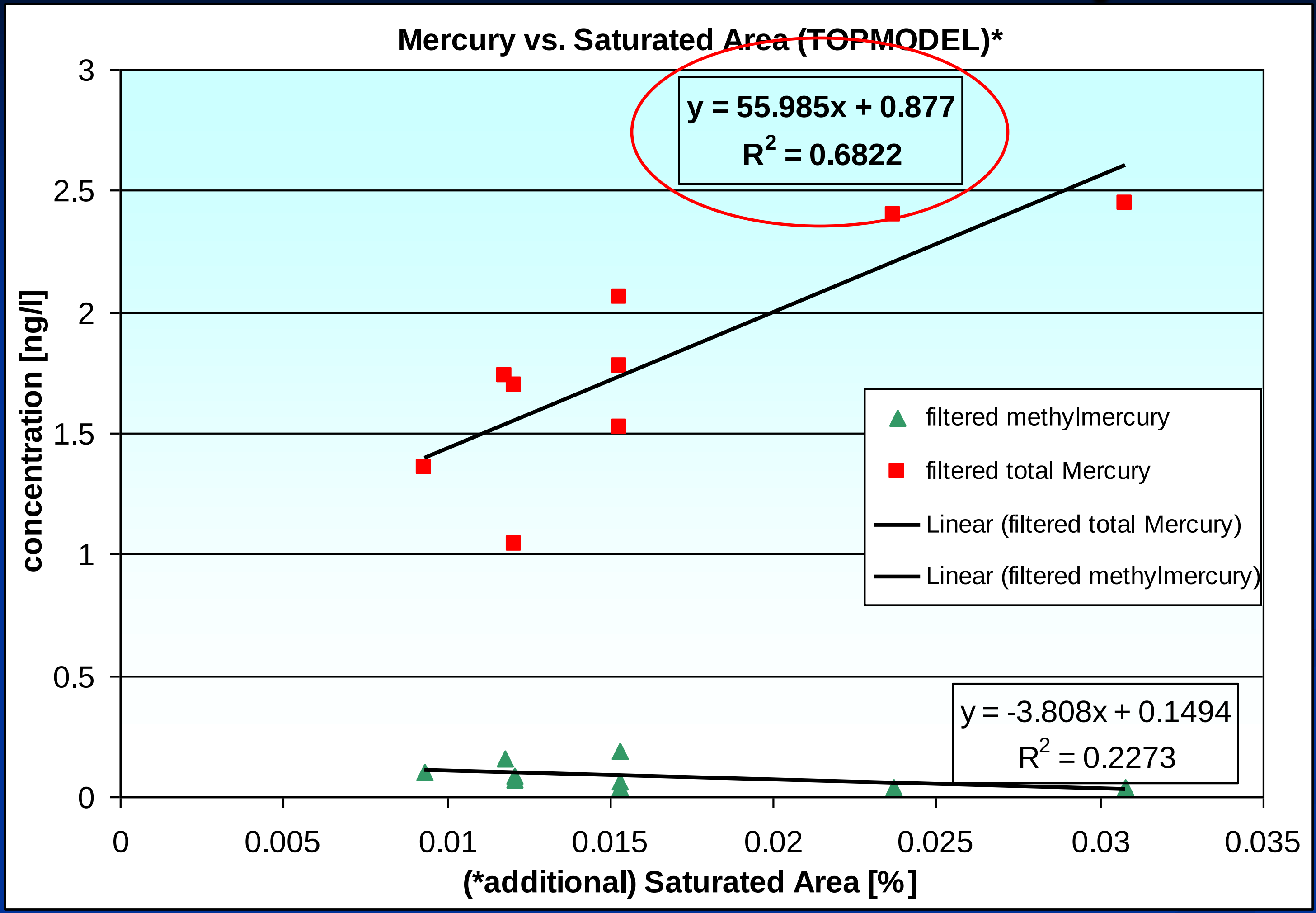


3/22/03





Prediction of Mercury

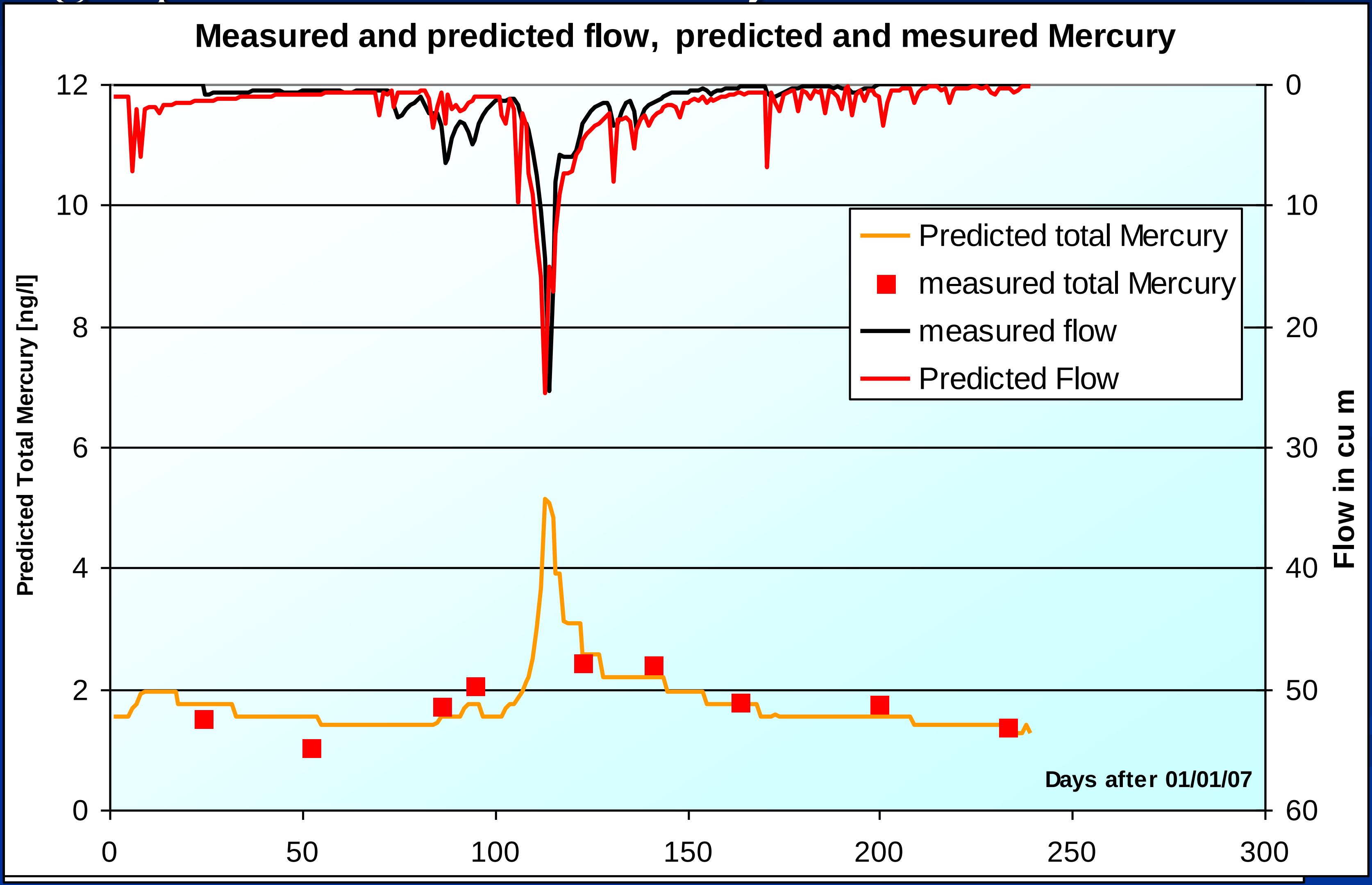


Process: Increasing total Mercury with increasing saturated Area.

→ "Flushing of mercury out of the wetlands with saturation"

Prediction of Mercury

Single-process based Mercury Model:



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Questions?

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