# Linking Atmospheric Mercury Deposition to Human and Wildlife Exposure (Source to Receptor) by Coupling VELMA and WASP to BASS to Simulate Fish Tissue Concentrations

**Christopher D. Knightes**,[1] Heather E. Golden,[2] Gary M. Davis[1], M. Craig Barber,[1] Karen Riva-Murray,[3] Barbara C. Scudder Eikenberry,[4] Celeste A. Journey,[5] Paul A. Conrads,[5] and Paul M. Bradley.[5]

*[1] US EPA, Office of Research and Development, National Exposure Research Laboratory, Athens, Georgia, USA*
*[2] US EPA, Office of Research and Development, National Exposure Research Laboratory, Cincinnati, Ohio, USA*
*[3] US Geological Survey, Troy, New York, USA*
*[4] US Geological Survey, Middleton, Wisconsin, USA*
*[5] US Geological Survey, South Carolina Water Science Center, Columbia, South Carolina, USA*

Wetlands in a Complex World
Ninth INTECOL International Wetlands Conference
June 3 - 8, 2012 ● Orlando, Florida

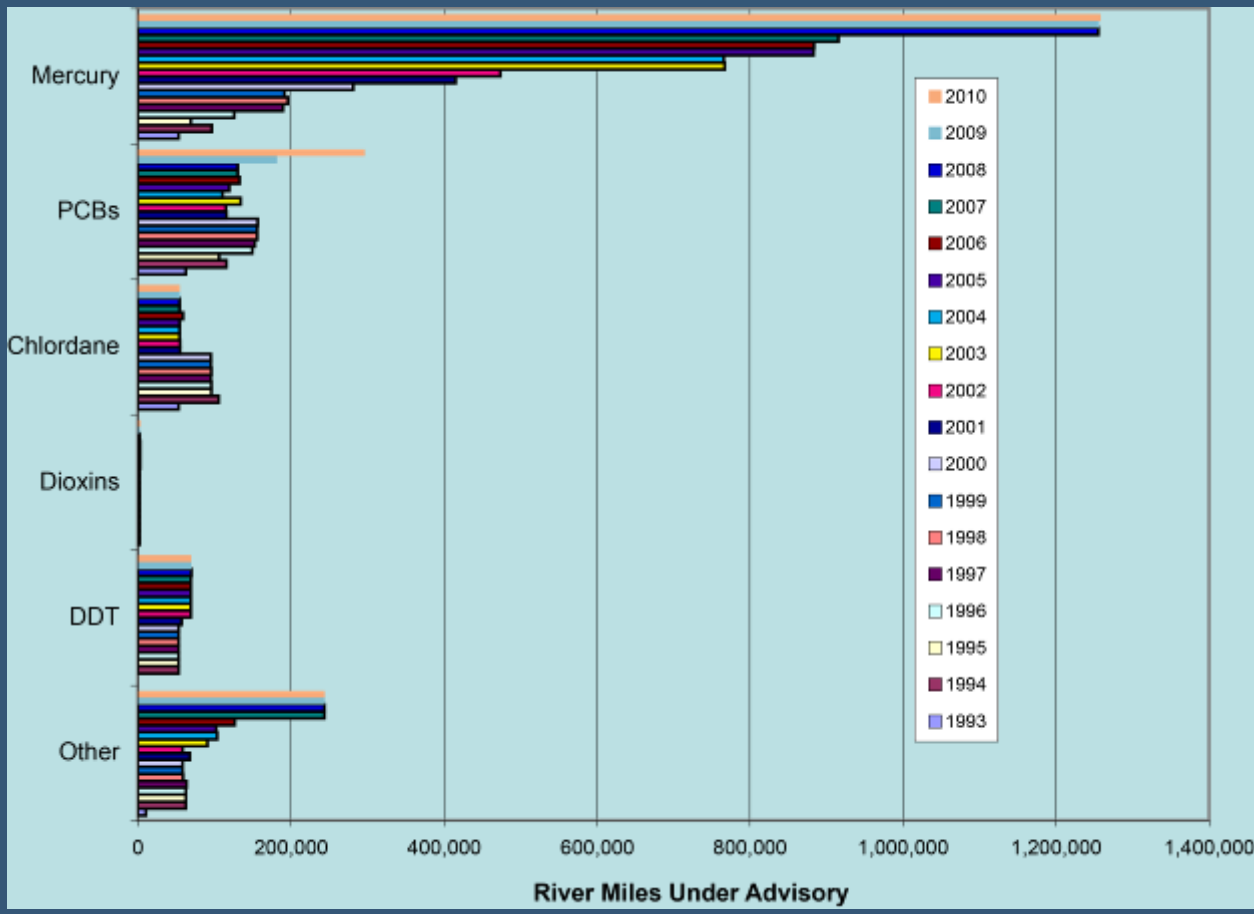
**US EPA, Office of Research and Development**
National Exposure Research Laboratory, Ecosystems Research Division, Athens, Georgia

# Presentation Outline

- Research Background and Motivation
- Research Questions and Research Approach
- Modeling Framework
- Model Results
- Future Research

# Research Background

- In the USA as of 2010
  - Hg fish advisories
    - 50 states
    - 1 US territory
    - 3 tribes
  - 81% of all fish advisories in US surface waters are at least partially due to mercury
  - 2,100,000 km of rivers
  - 3,710 Hg Advisories




http://water.epa.gov/scitech/swguidance/fishshellfish/fishadvisories/technical_factsheet_2010.cfm

# Research Motivation

- US surface waters are impacted by Hg
- > 2,000,000 km of rivers have Hg fish consumption advisories
- Atmospheric deposition is the primary source of Hg to many ecosystems
- **Streams** and **rivers** are intimately linked with their watersheds
- Need to understand factors governing Hg transport, transformation, and bioaccumulation

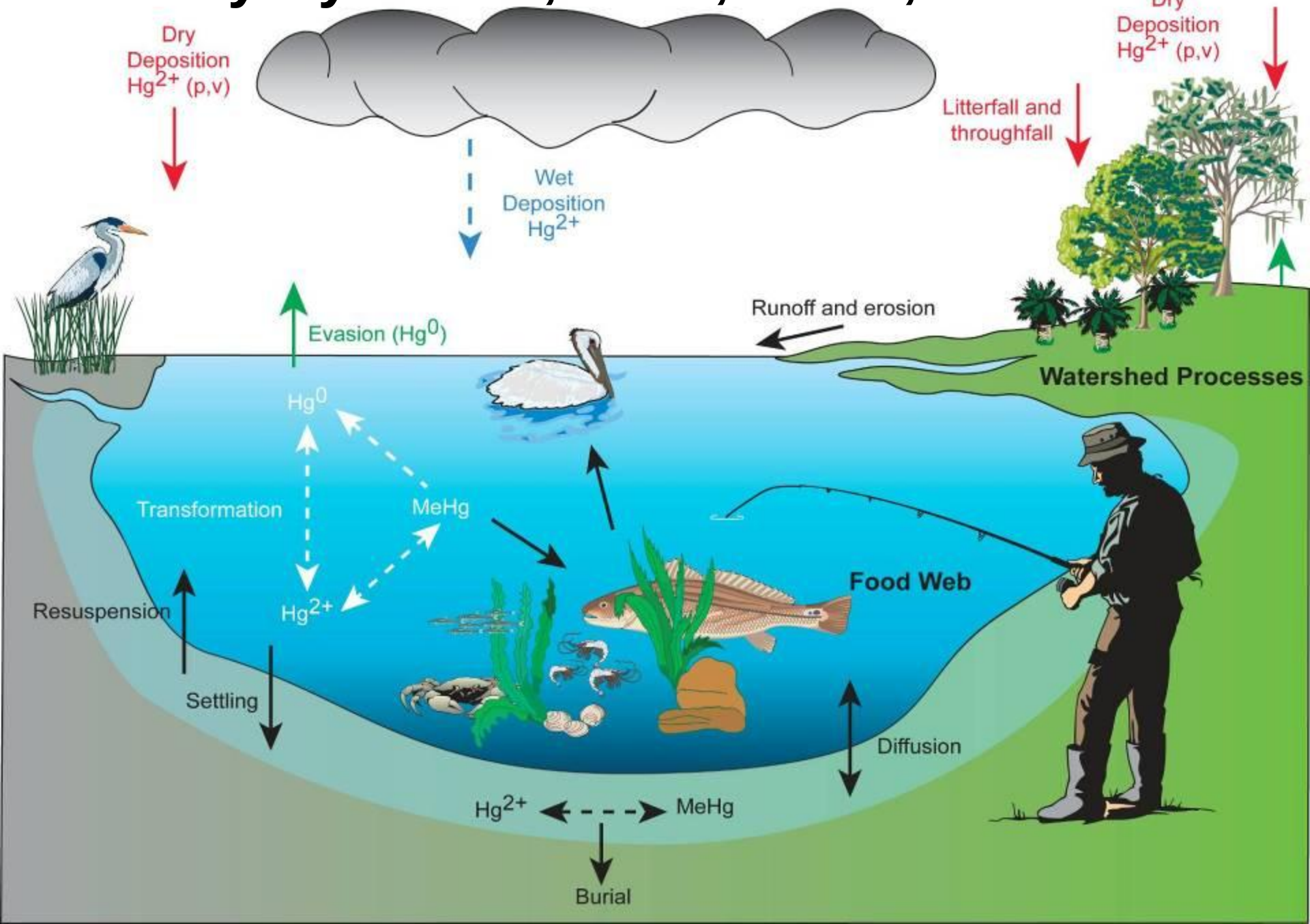
# Research Questions

- What processes and factors govern Hg exposure concentrations in streams and rivers?
- How do we model the link of atmospheric Hg deposition to fish tissue Hg to increase our understanding and ability to predict wildlife/human exposure risk ?
- How can we use focused, site-based (field) research studies to understand Hg exposure at larger scales (regional, national)?

# Research Approach

- Use mechanistic, differential mass balance models to simulate the fate and transport of mercury
  - Land, subsurface, surface water, sediments, fish
- Use linked multi-media framework to simulate Hg exposure concentrations up to larger scale systems
- Use focused reach study to calibrate watershed modeling of Hg
- Use individual models to evaluate governing processes and use linked models as a systems level approach

# Mercury Cycle: Air, Land, Water, Biota



# Research Approach: Mechanistic Models

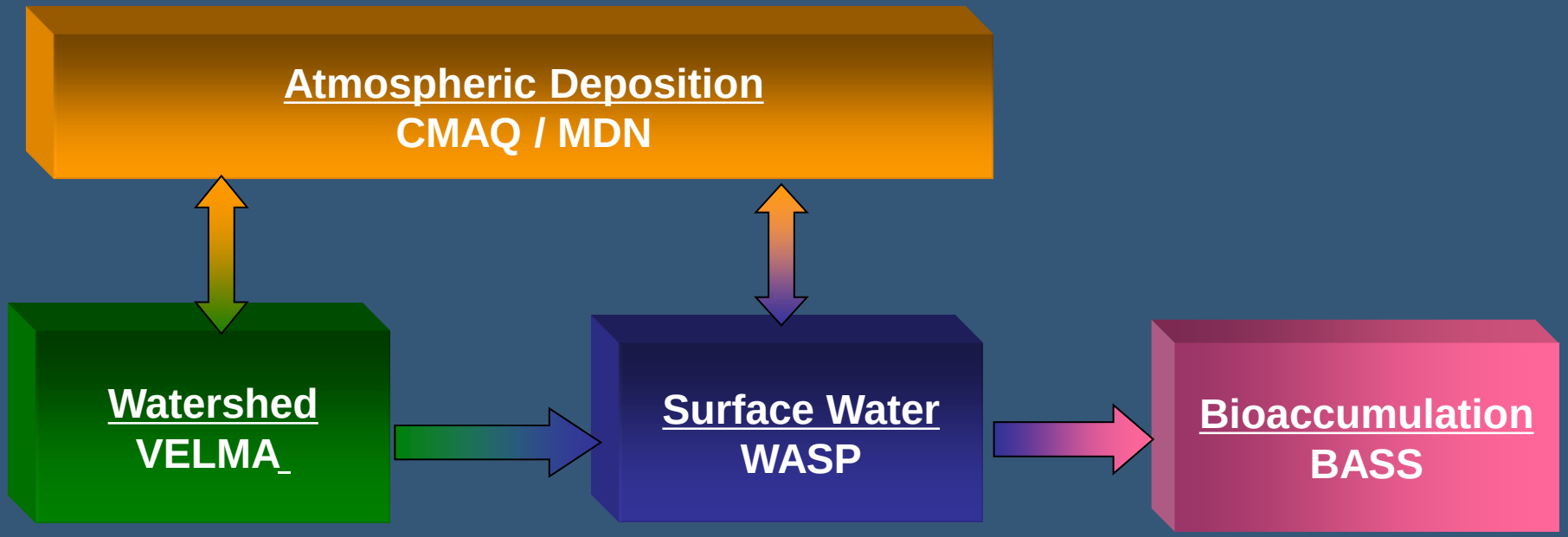
*Why use Mechanistic Models?*

- **Mechanistic Model: Understanding the behavior of a system's components and how they interact**

- **For Understanding**
  - **How well model represents observed data**
  - **How well do we understand governing processes**
  - **Both model success and failure provide insight**

- **For Predictions**
  - **Future exposure concentrations**
  - **Scenario evaluation**
    - **Compare management strategies**
  - **Model scaling**
  - **Modeling different locations and sites**

# Multi-Media Modeling Framework



# Research Approach: Mechanistic Models

## *WATERSHED and GROUND WATER*

- *VELMA: Visualizing Ecosystems for Land Management Assessment*
  - Simulates
    - Hydrology (Runoff, groundwater for 4 soil layers)
    - Carbon: Dissolved Organic and Soil Organic
    - Nitrogen: Ammonium, Nitrate, Dissolved Organic
    - Mercury: MeHg, $Hg^{2+}$
    - Processes: methylation, demethylation, reduction/evasion

# Research Approach: Mechanistic Models

## *SURFACE WATER and SEDIMENTS*

- *WASP: Water quality Analysis Simulation Program*
  - Simulates
    - Media: Water Column and Sediments
    - Stream Flow Hydrology
    - Fines, Sands, Particulate Organic Matter
    - Mercury: MeHg, Hg(II), Hg(0)
    - Processes: methylation, demethylation, oxidation, reduction, sorption, settling, resuspension

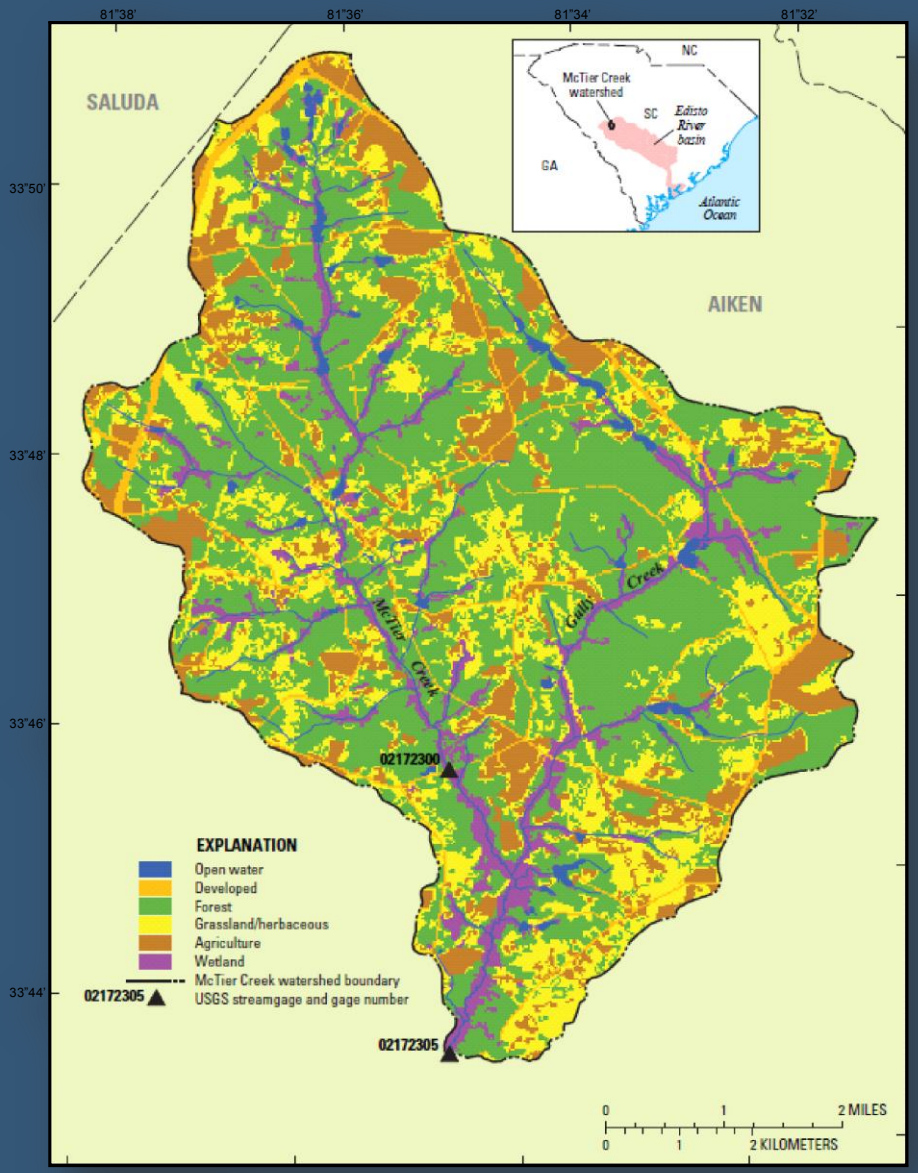
# Research Approach: Mechanistic Models

## *FISH COMMUNITY and BIOACCUMULATION*

- *BASS: Bioaccumulation and Aquatic Simulations Simulator*
  - Simulates
    - Population dynamics of age-structured fish communities
    - Hg in fish tissue for each age cohort of fish species present

# Study Site: McTier Creek Watershed, SC, US

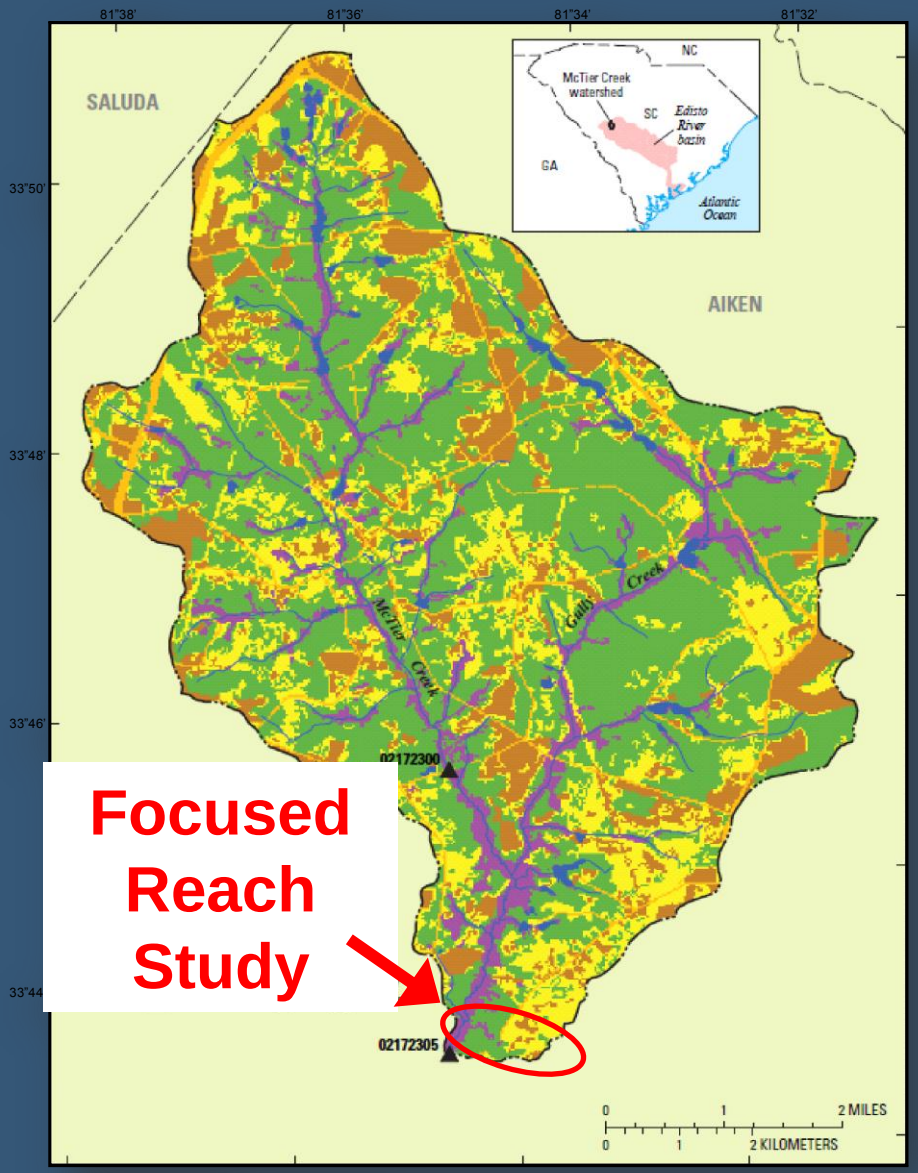
- Sand Hills region of Upper Coastal Plain, SC
- 79 km$^2$ drainage area
- Mixed land cover: 49% forest, 21% grassland and herbaceous, 16% agriculture, 8% wetland, 5% developed, 1% open water
- Shallow groundwater system
  - Low – normal flow: toward stream channel
  - High flow: same with increased area of groundwater-surface water exchange




Land-cover data from 2001
National Land Cover Dataset (Homer and others, 2004)
Albers projection, NAD83 datum,
Central Meridian - 95 00 00

# Study Site: McTier Creek Watershed, SC, US

- Sand Hills region of Upper Coastal Plain, SC
- 79 km$^2$ drainage area
- Mixed land cover: 49% forest, 21% grassland and herbaceous, 16% agriculture, 8% wetland, 5% developed, 1% open water
- Shallow groundwater system
  - Low – normal flow: toward stream channel
  - High flow: same with increased area of groundwater-surface water exchange



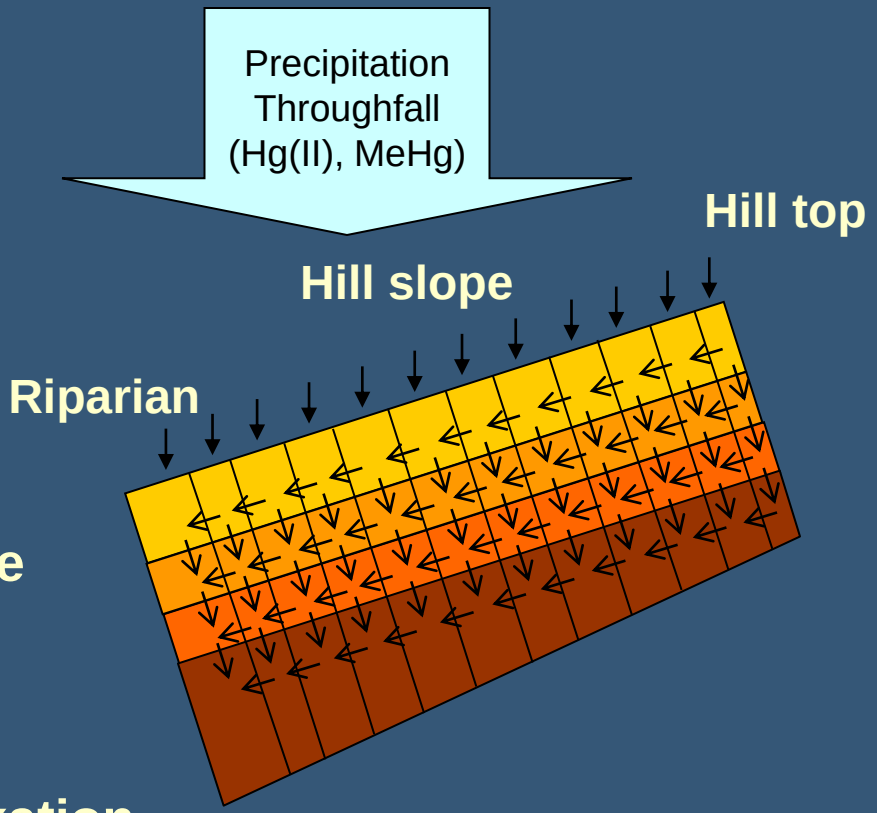
# Focused Reach Study:

**Watershed spatially explicit**
- **3 dimensions**
- **4 soil layers**
- **30m x 30 m area**

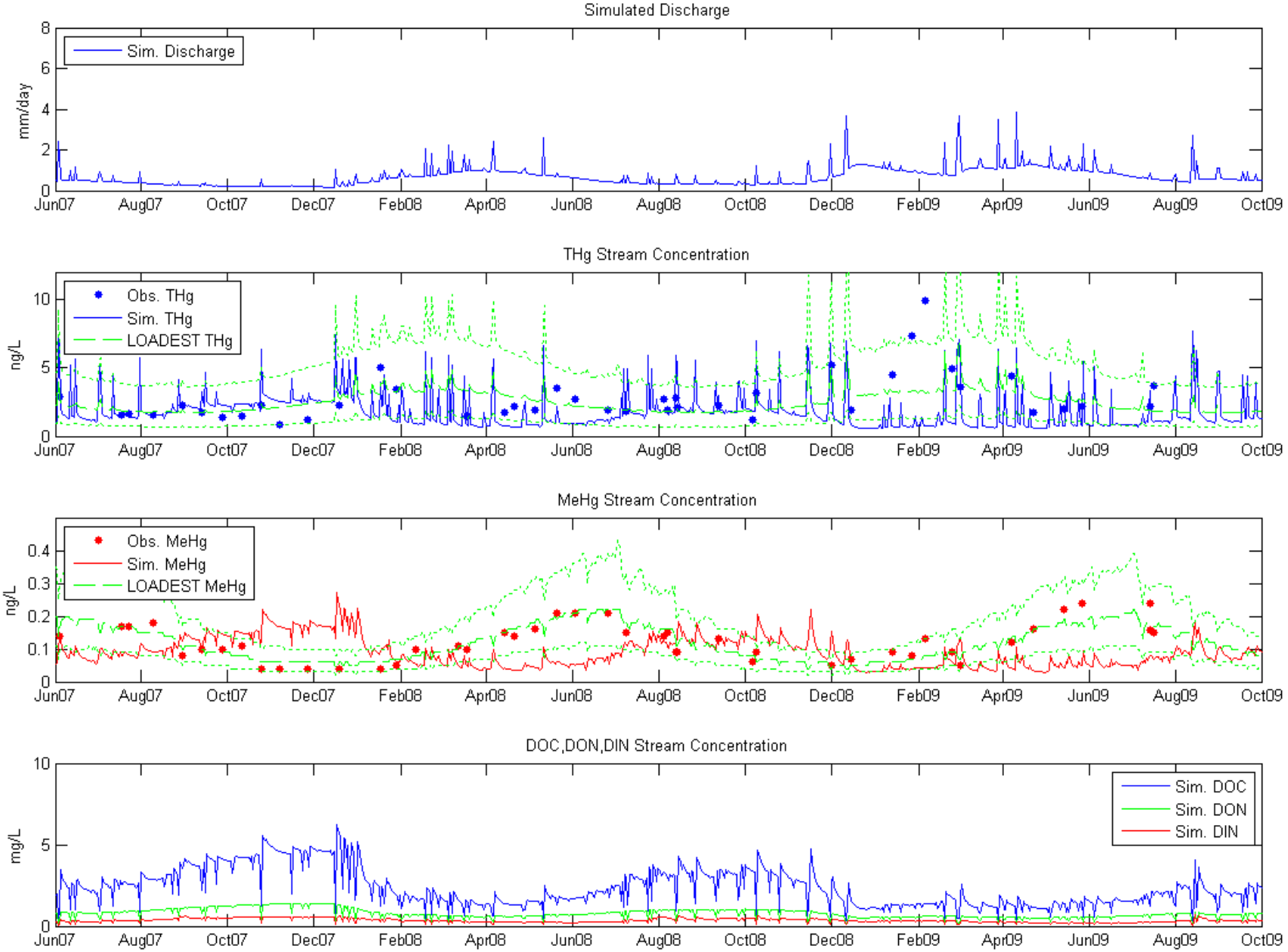
**Processes in Each Soil Cell**
- **Methylation / Demethylation**
- **rates = function of T and soil moisture**

**Mercury flows with water**
- **Competing processes of**
  - **Dissolved Organic Carbon complexation**
  - **sorption to soil matrix**

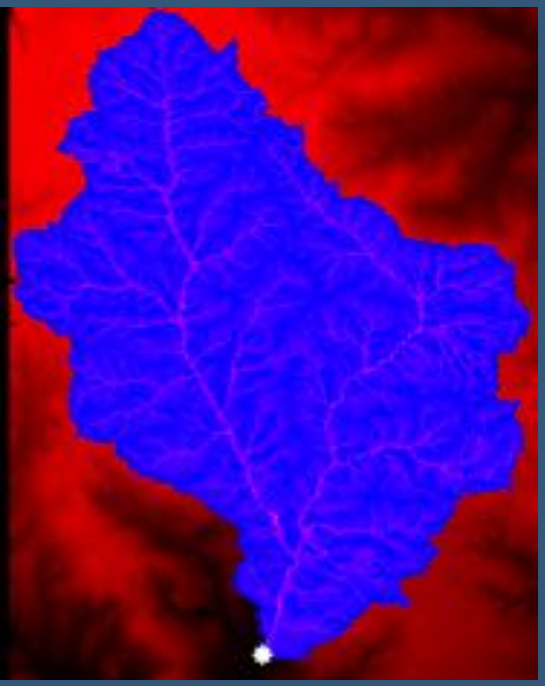
**Water can move in any direction**



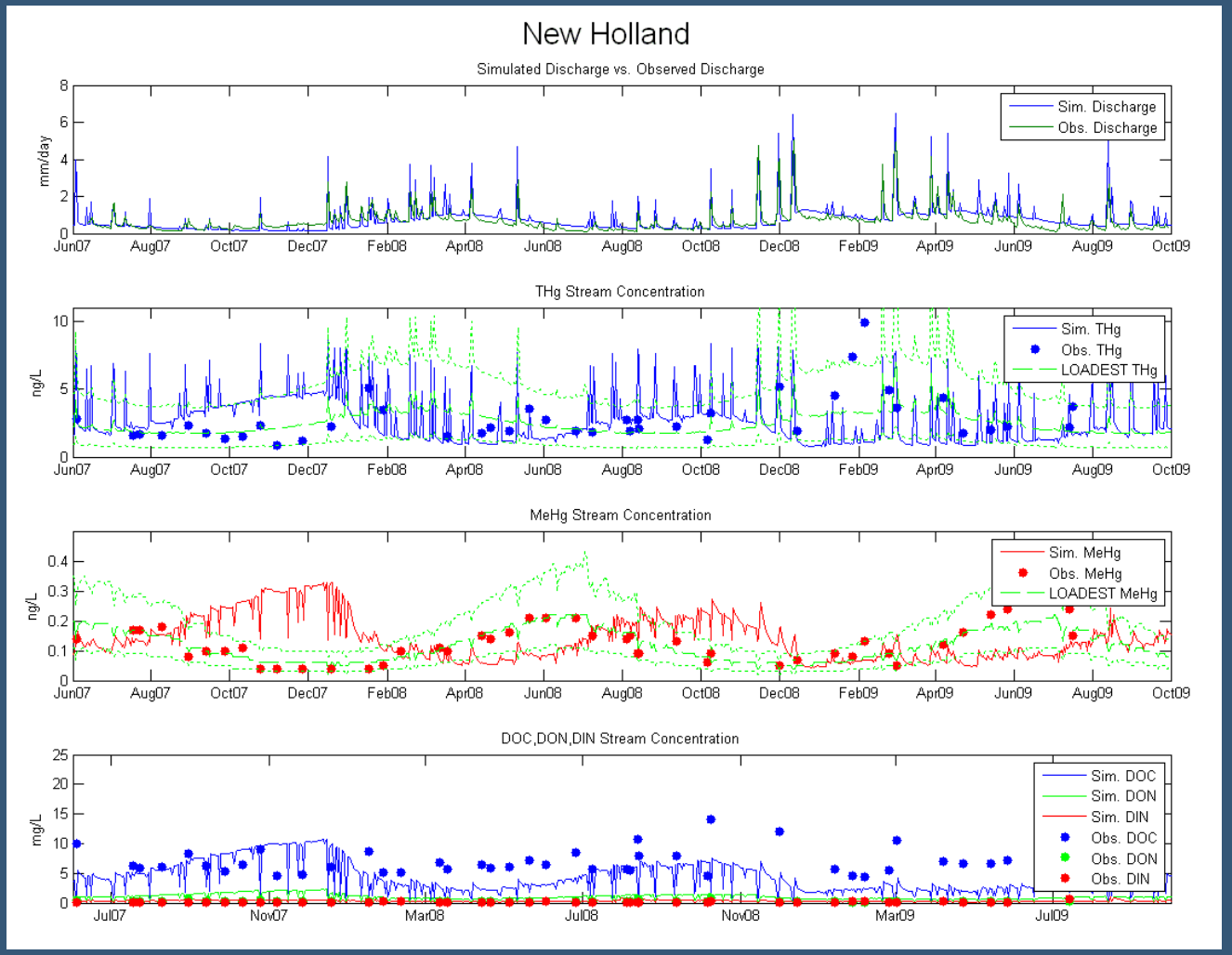
# Focused Reach Study



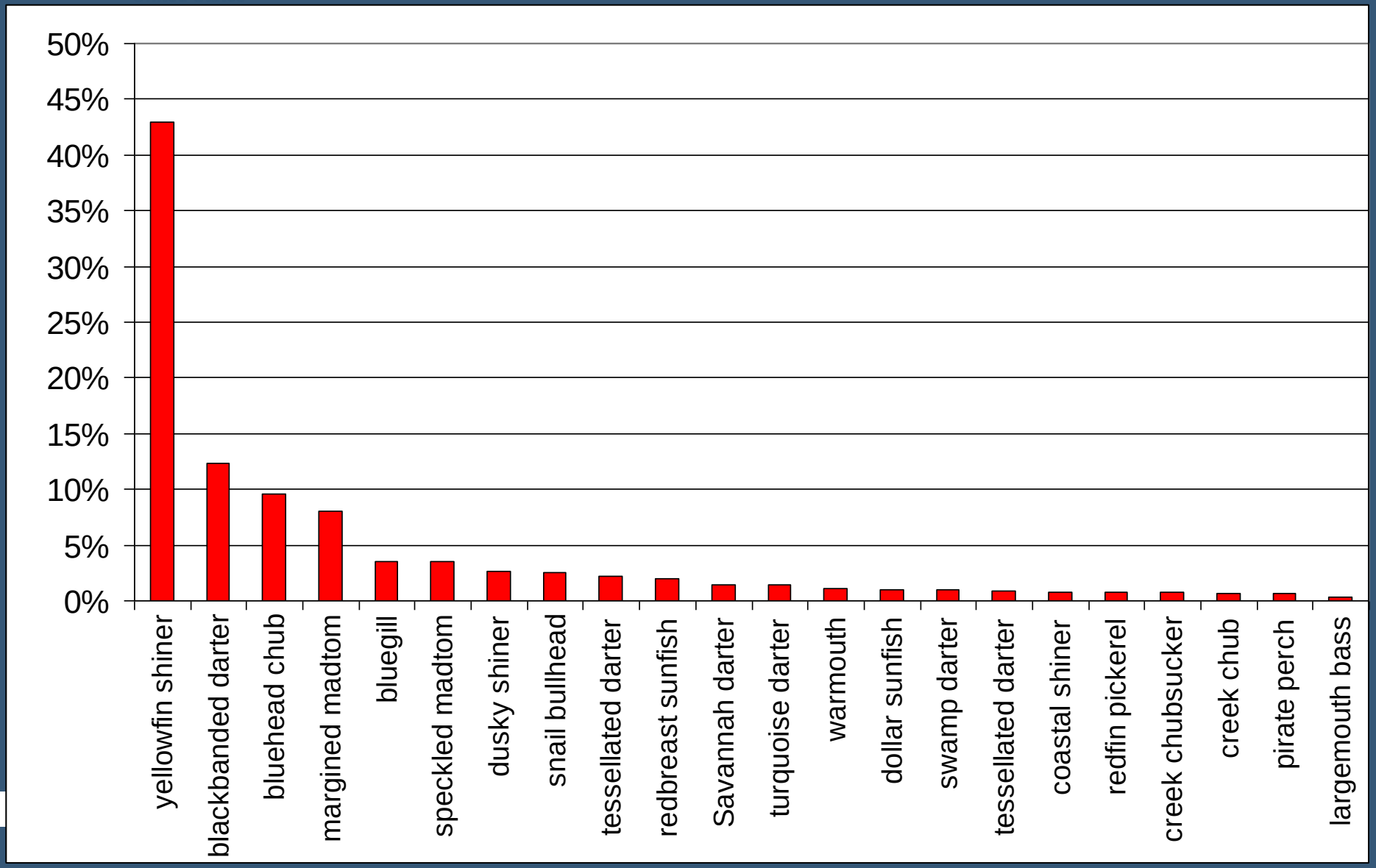
# McTier Creek Watershed Modeling: VELMA



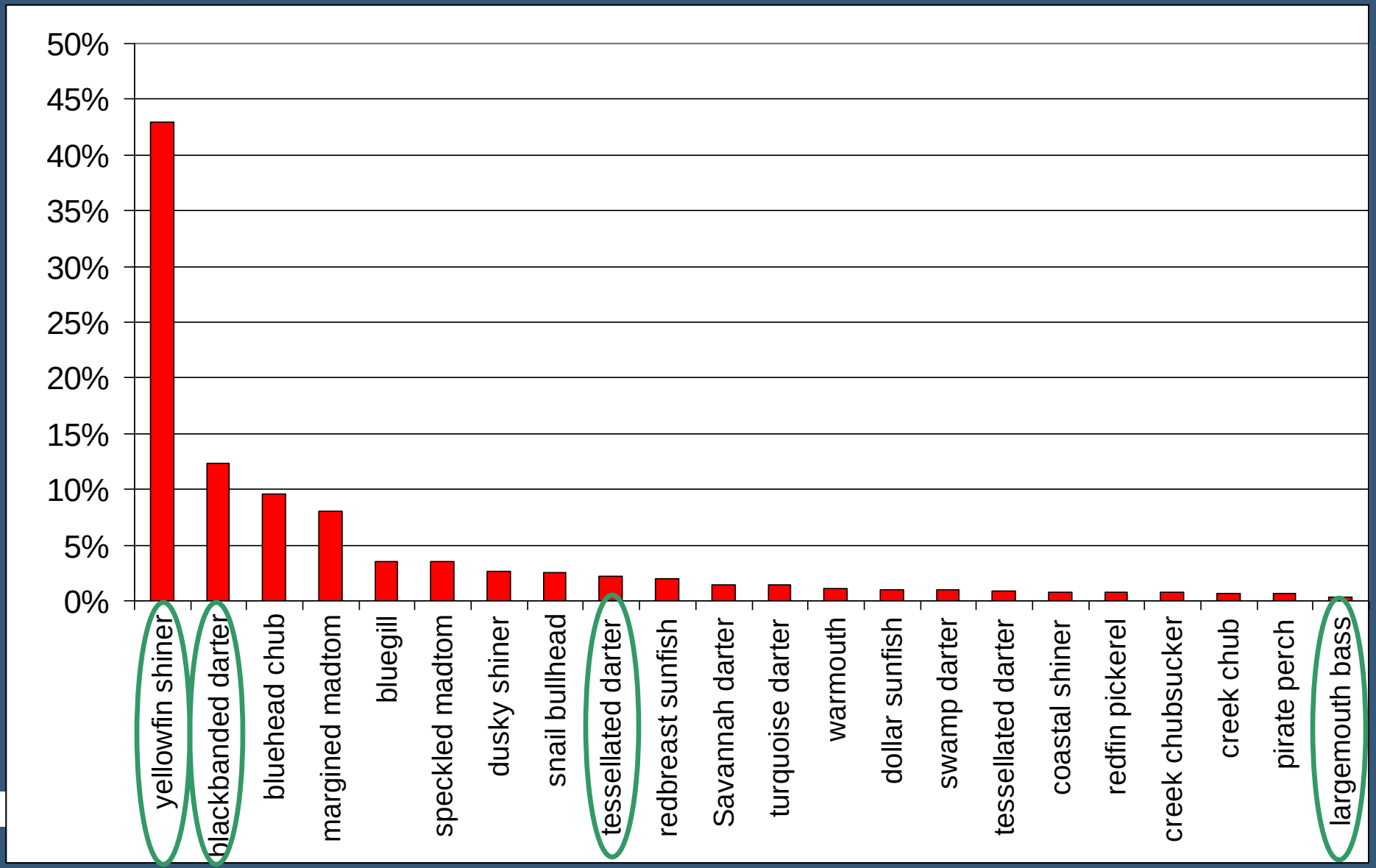
**New Holland, 79.4 km²**



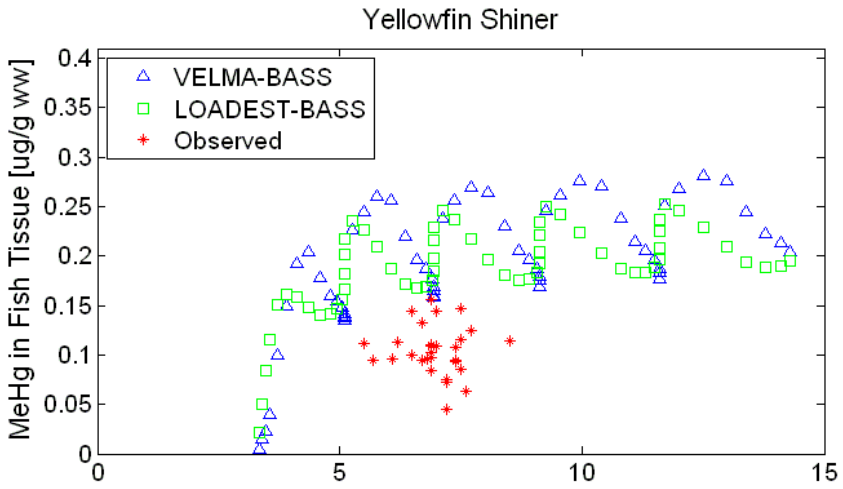
# Linking VELMA Output to BASS McTier Creek Fish Community

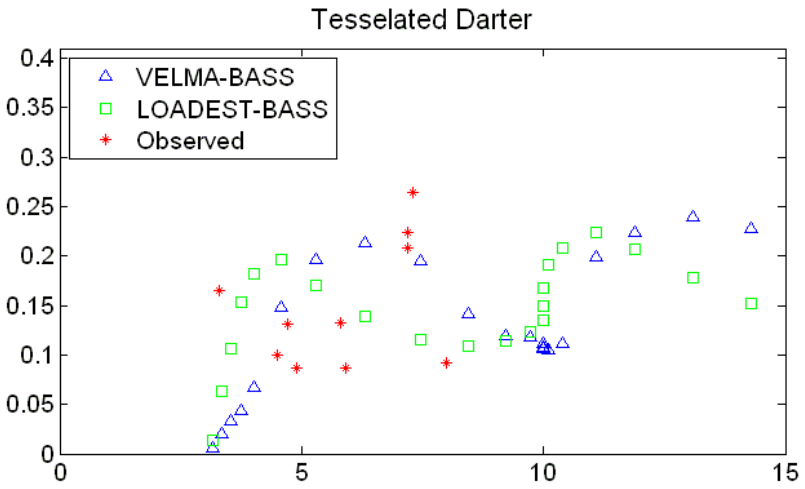


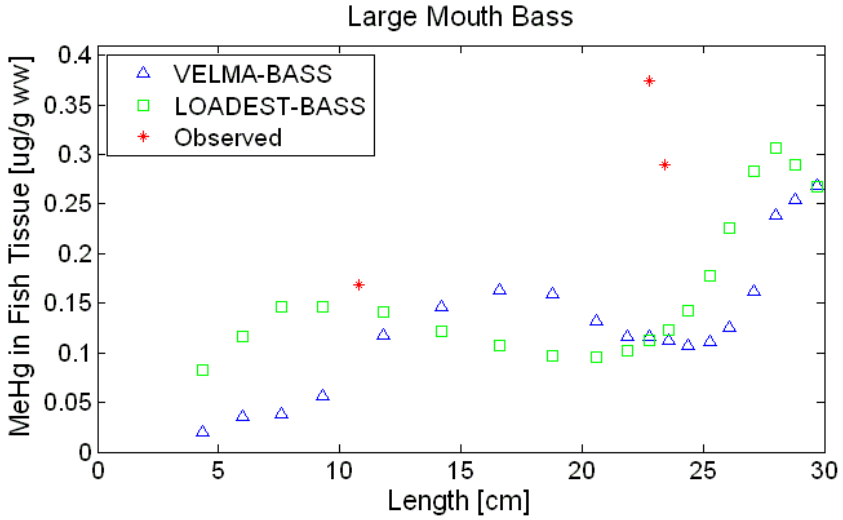
# Linking VELMA Output to BASS McTier Creek Fish Community

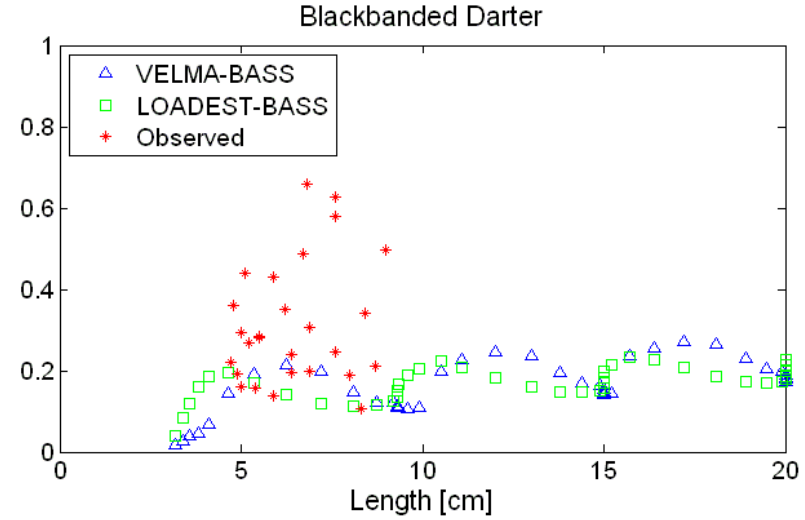


# Linking VELMA Output to BASS



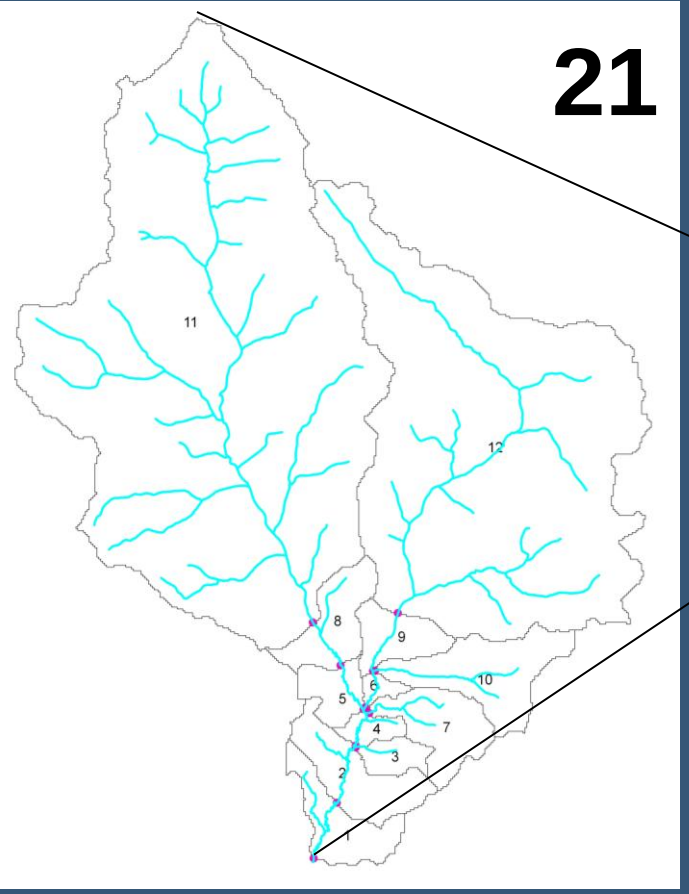
# Future Research Questions

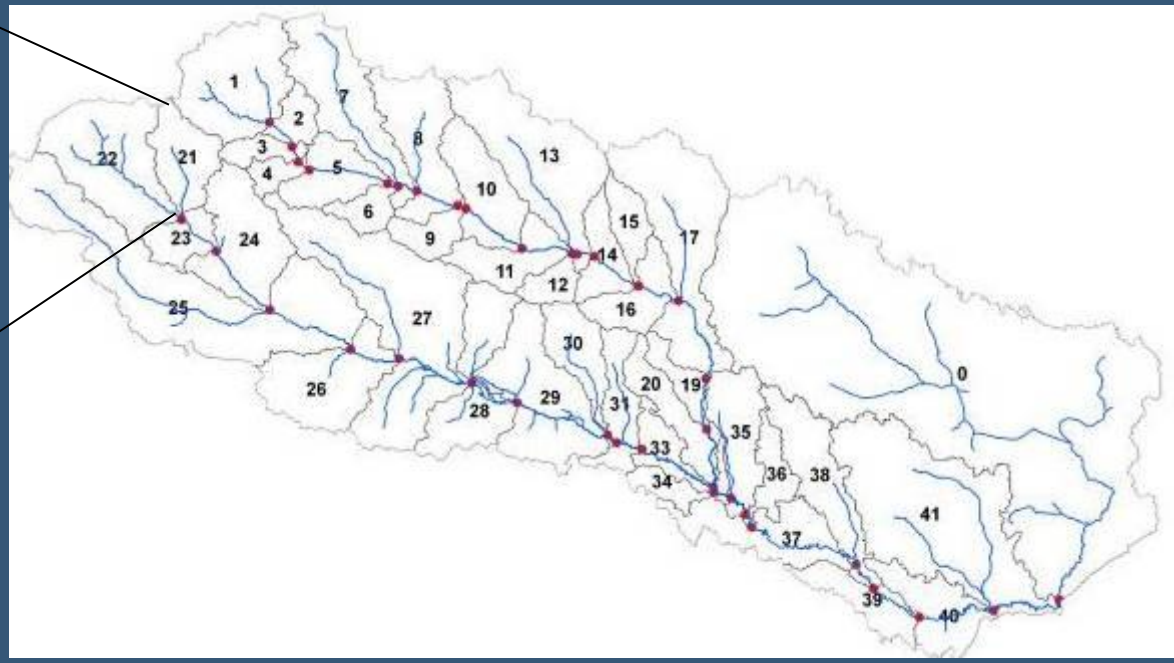
- Linking VELMA and LOADEST MeHg w/BASS predicted relatively well
- Fish Tissue Hg
  - Yellowfin Shiner: Overpredicted
  - Tesselated Darter: Well predicted
  - Large Mouth Bass: n = 3, falls within range
  - Blackbanded Darter:
    - Wide range of observed
    - Simulations on low end of observed

# Future Research Questions

- The phase of VELMA simulated MeHg concentrations are out of phase with the observed and LOADEST
- VELMA having fish Hg out of phase and VELMA slightly higher than LOADEST
- Are flow paths not adequately represented in VELMA?
- Importance of wetlands?
  - How can we represent wetlands in VELMA?
  - Should a water quality model be used?
- Link VELMA to WASP
  - Does this improve predictions of THg and MeHg?
  - Is it worth additional modeling cost/effort?
- Should wetlands be simulated in WASP rather than VELMA?
- Are wetlands a watershed component or a surface water component?

# Future Research



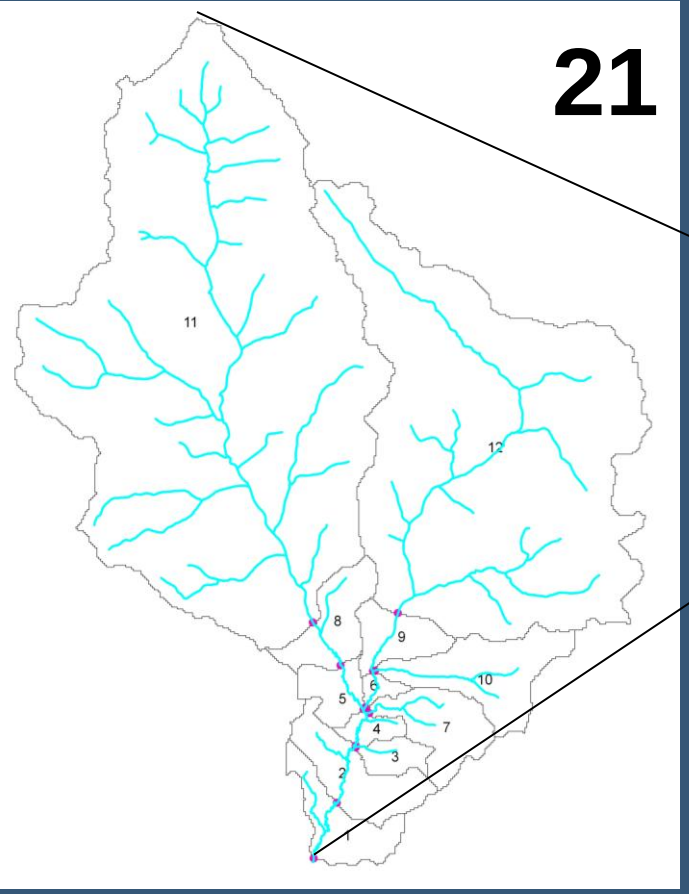



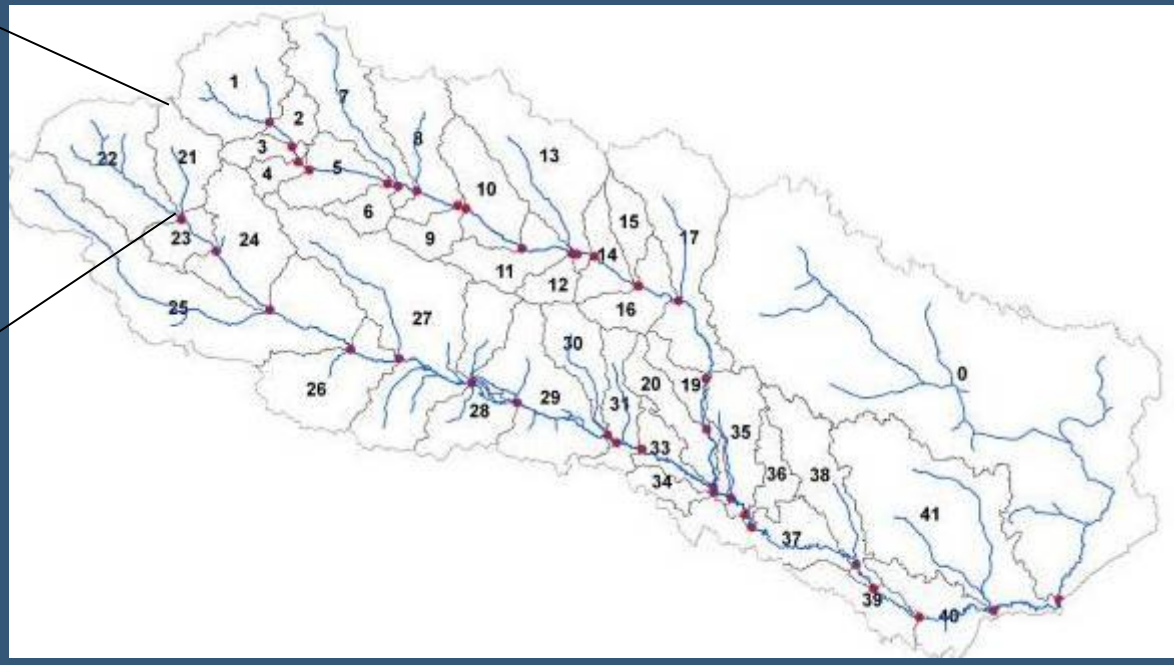

Can we then use McTier Creek to simulate THg, MeHg, and fish tissue Hg on a regional scale?

Continuing linkage of VELMA and BASS?

Do we need to incorporate WASP to link HUC12s together and capture instream processes?

# VELMA + BASS vs VELMA + WASP (?) + BASS




What is the best modeling framework design to simulate regional basins?

Mechanistic model comparison/evaluation.
Is VELMA+WASP+BASS >> VELMA + BASS?