Developing relations among human activities, stressors, and stream ecosystem responses for integrated regional, multi-stressor models

R. Jan Stevenson[1], M. J. Wiley[2]

D. Hyndman[1], B. Pijanowski[3], P. Seelbach[2]

[1]Michigan State Univ., East Lansing, MI

[2]Univ. Michigan, Ann Arbor, MI

[3]Purdue University, West Lafayette, IN

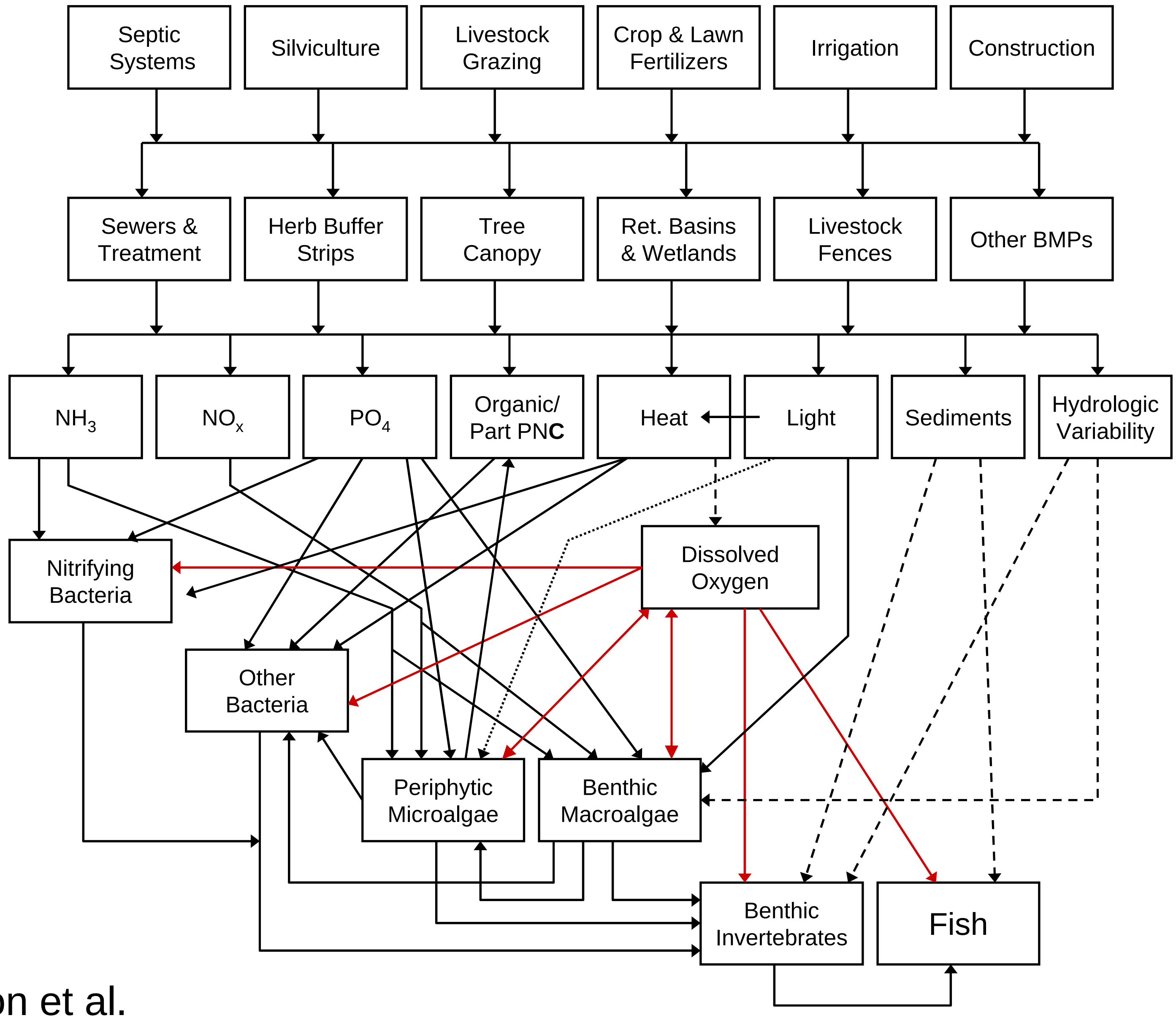
Project Period: 5/1/2003-4/30/2006

Project Cost: $748,527

Goals

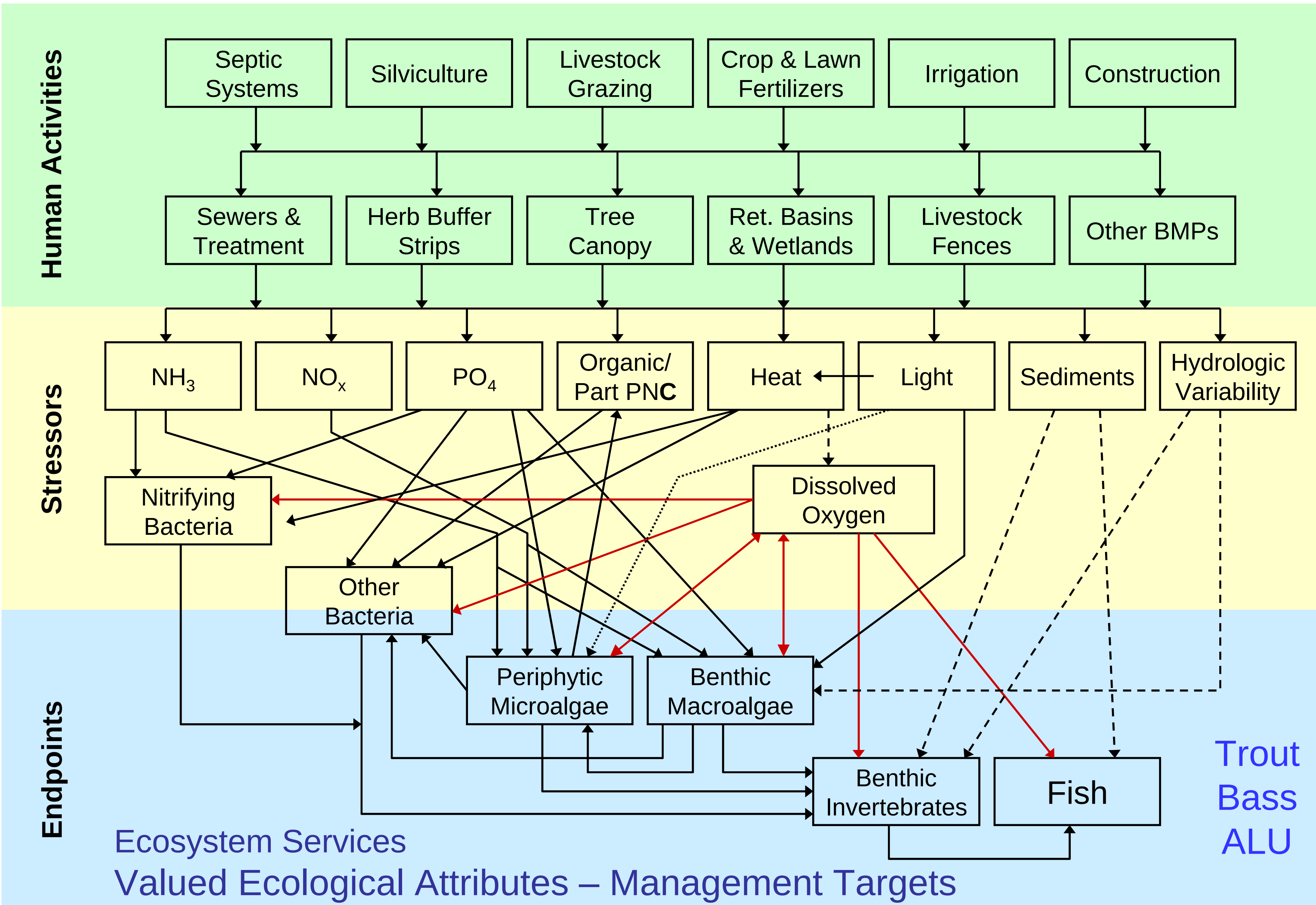
- Relate patterns of human activity to commonly co–varying stressors: nutrients, temperature, sediment load, DO, and hydrologic alterations.
- Relate those stressors to valued fisheries capital and ecological integrity of stream ecosystems.

Natural Ecosystems Are Complex



Stevenson et al.

Natural Ecosystems Are Complex
but can be Organized for Management



Complicating Issues>Opportunities

- Non-linearity and thresholds:
  - graded responses may be rare in complex systems.
  - thresholds complicate management choices.
- Complex causation:
  - multiple actions simultaneously shape biological responses.
  - issues of direct and indirect causation (effects)
- Scale and dynamics:
  - Potential stressors operate at different spatial and dynamic scales
  - Scales complicate the diagnosis of stressor-response relationships
    - obscure causal dependencies through time lags, ghosts of past events, and misidentification of natural spatial/temporal variability.

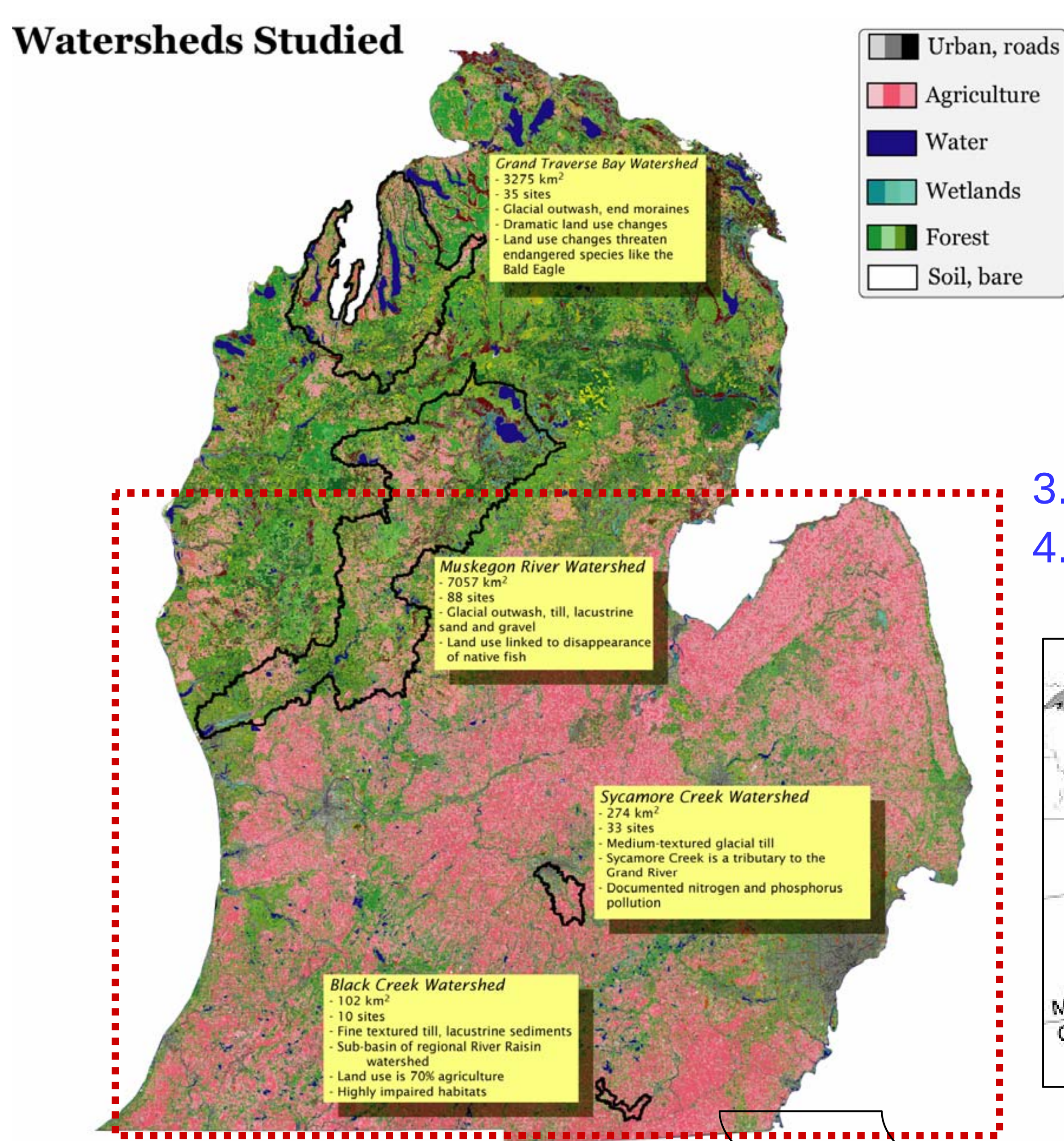
Approaches

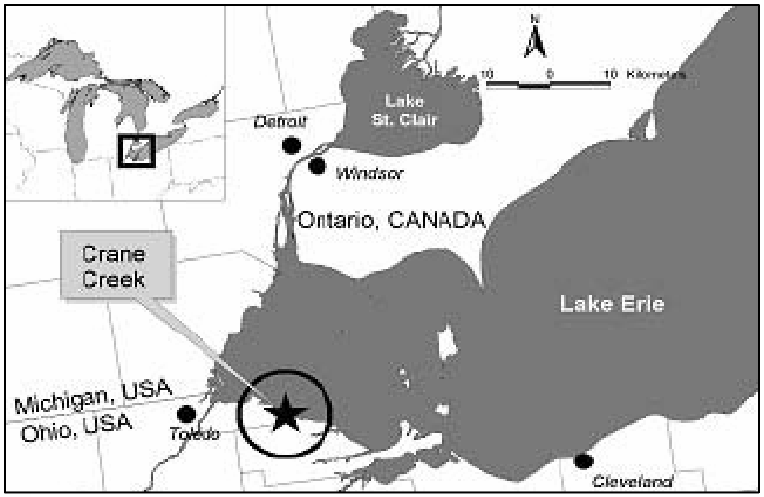
1. Building on other assessment & modeling by team (MI, IN, KY, OH, IL, WI)
2. Multi-scale approach:
   1. reach scale vs watershed
   2. regional vs intensive site
3. Modeling
   1. empirical (statistical) models
   2. process-based (mechanistic) models

      using existing platforms and an integrated modeling system

Where We Are Working (New Data)

1. Early morning DO surveys
2. Reach metabolism models
3. Watershed LULC (MRW & all MI)
4. Watershed modeling

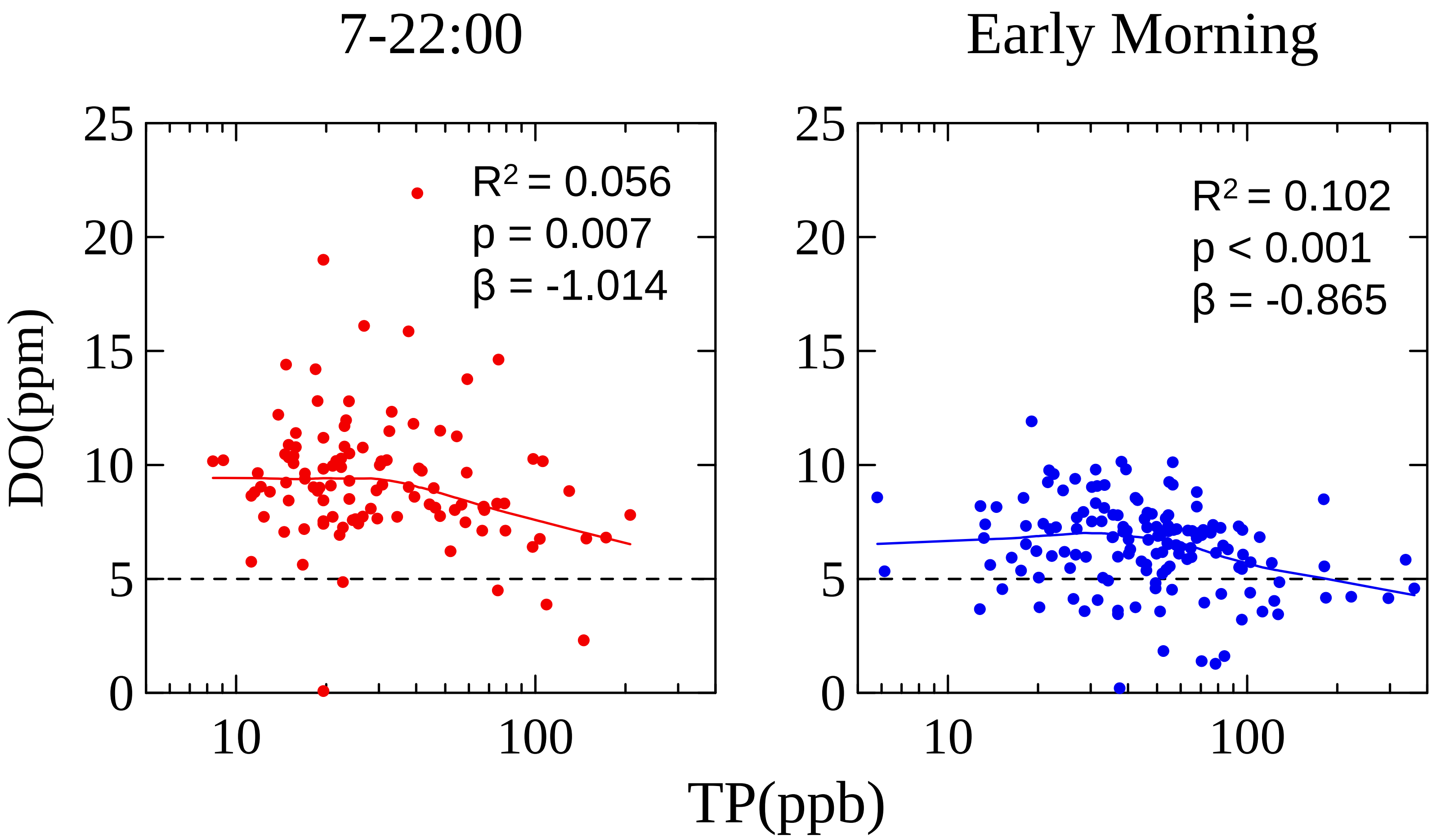




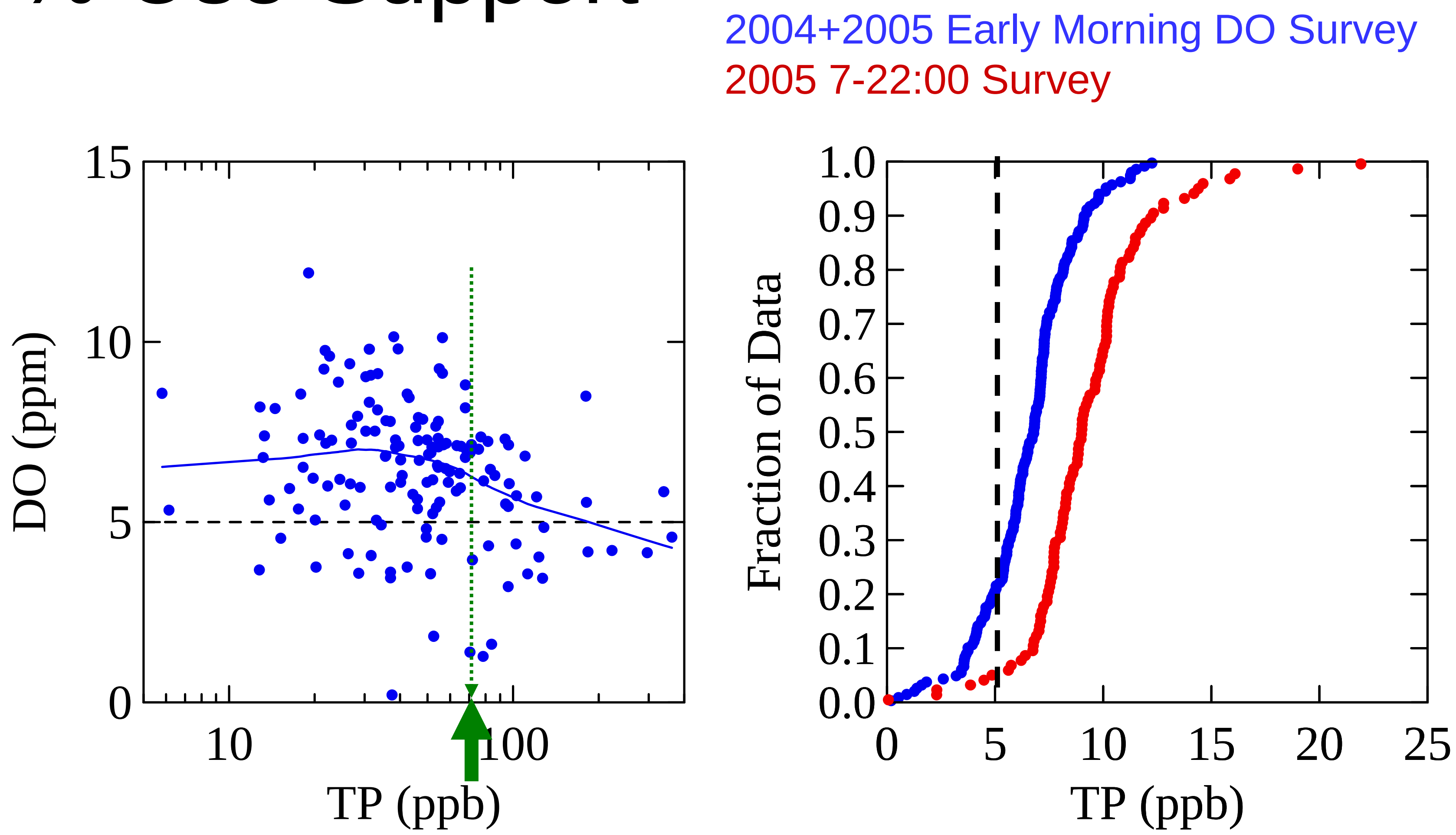
Regional, Reach Scale Statistical Models

- E.g. DO = f (TP), DO = f (TP, stream gradient)
- Early morning, baseflow sampling
  - 2004, 74 sites
  - 2005, 98 sites
- Endpoint: dissolved oxygen minima
- Stressors
  - Direct: water column algae, benthic algae
  - Indirect: nutrients, temperature, land use, hydrologic features
- Classification variables: e.g. watershed gradient
- Used in MDEQ Nutrient Criteria Development

Comparison of DO = f(TP) for surveys without and with early morning sampling constraint



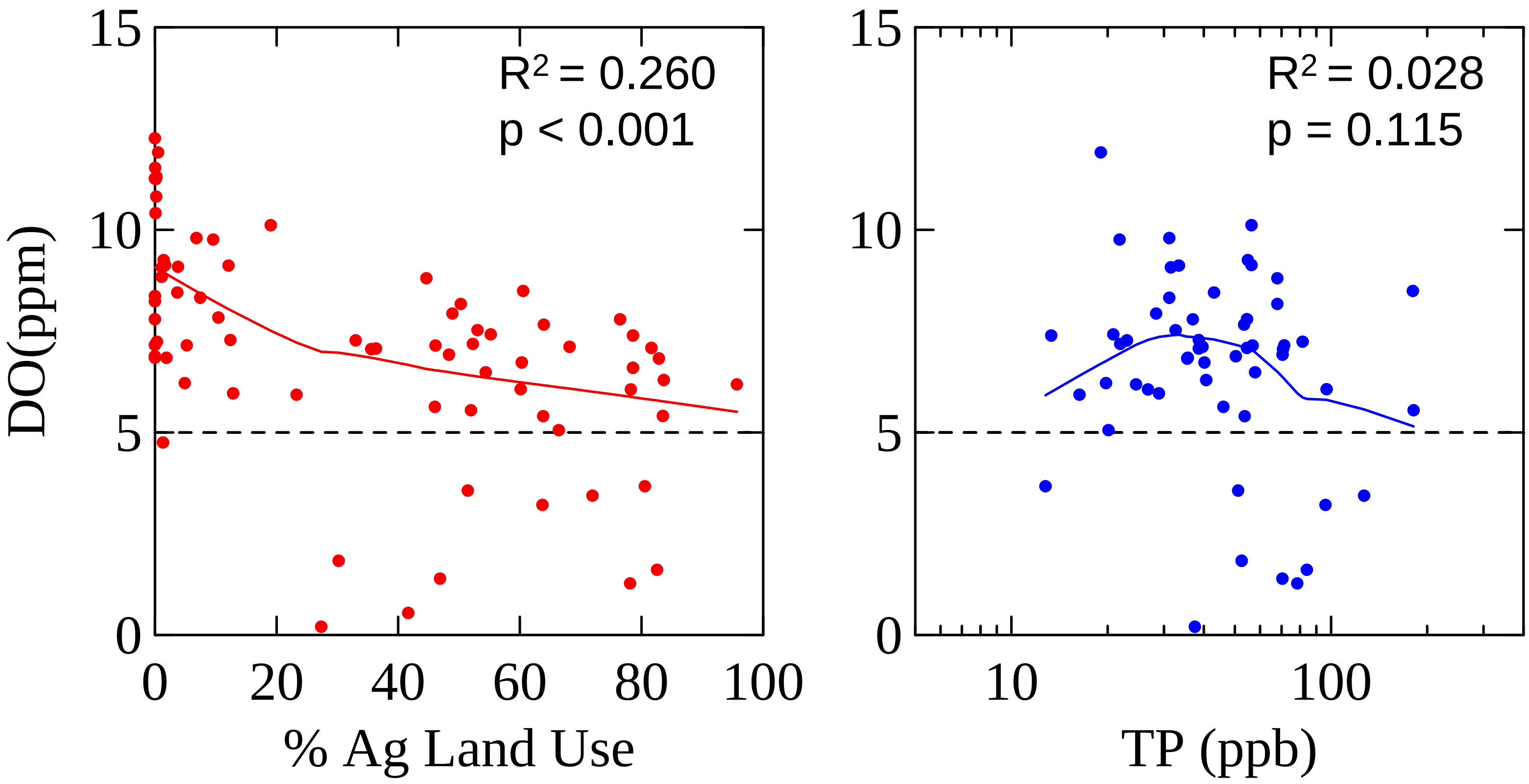
Thresholds, Nutrient Criteria & % Use Support



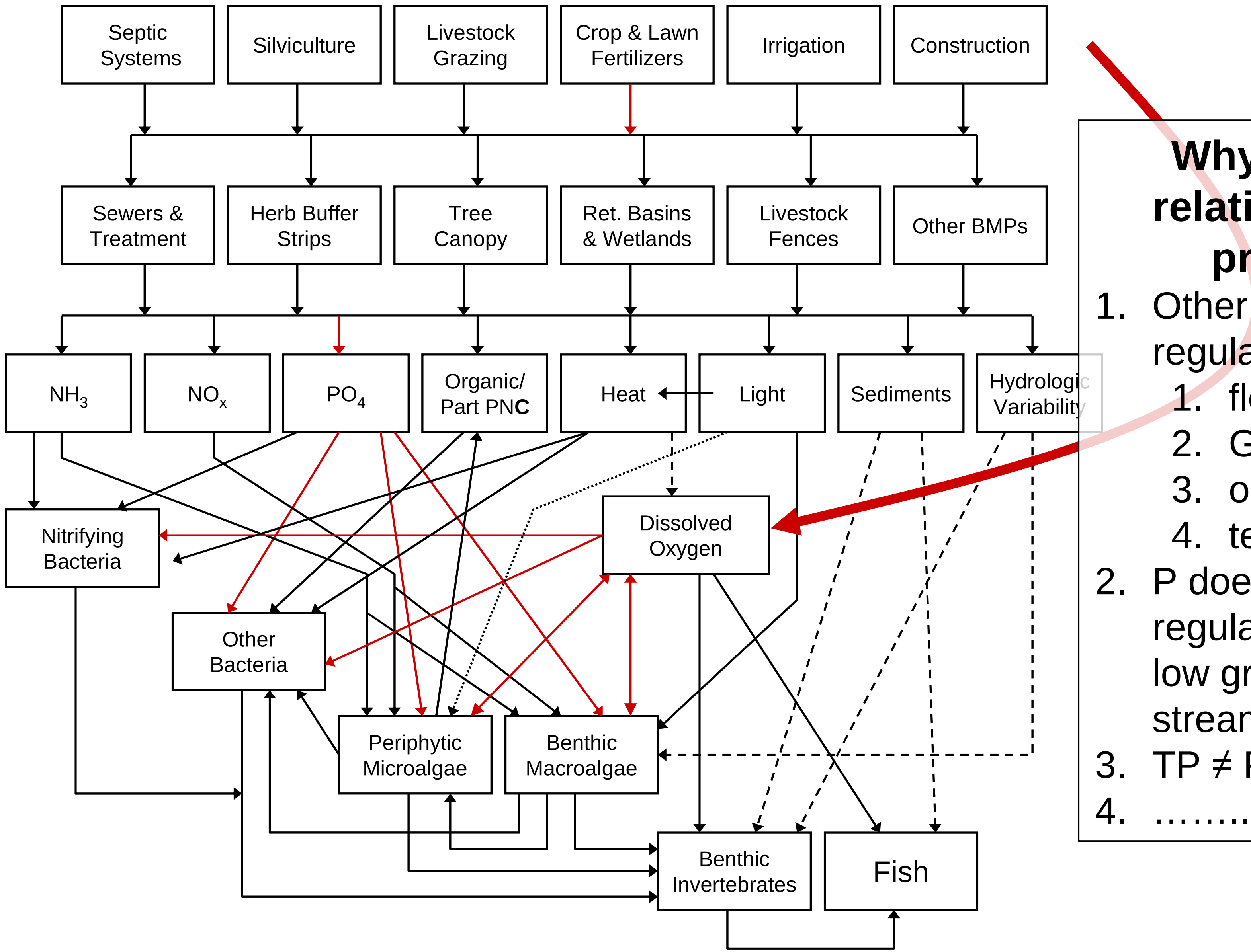
Potential covarying factors: gradient, flow, GW input

Indirect indicators of nutrient availability often better than direct measures

(2004 survey data only)



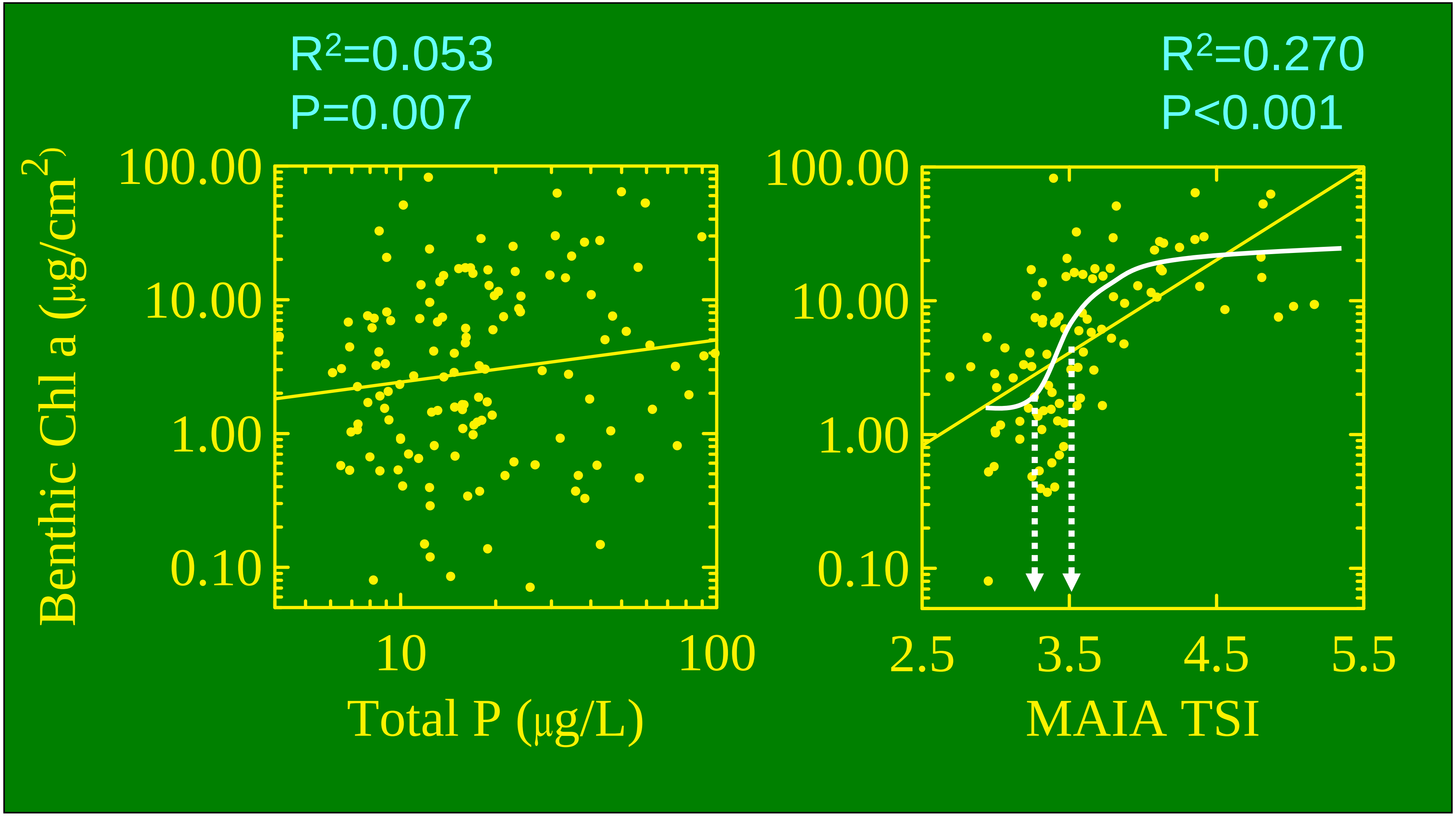
Interpretation of Indirect Relationships



Why indirect relations more precise?

1. Other factors regulate DO, too
   1. flow,
   2. GW flow,
   3. org matter,
   4. temp…
2. P does not regulate BOD in low gradient streams
3. TP ≠ PO4
4. ……..

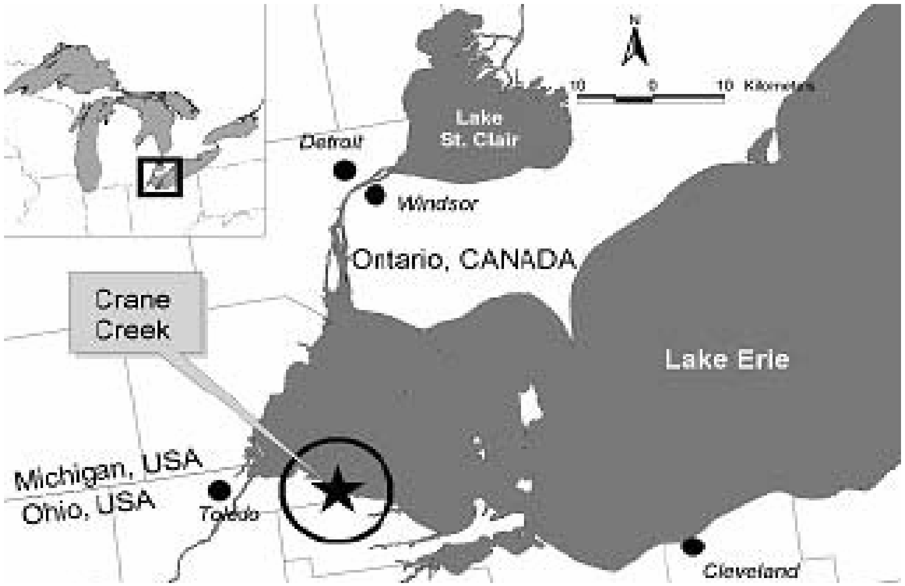
Chl a/Nutrient Model Improves with Diatom Inferred TSI

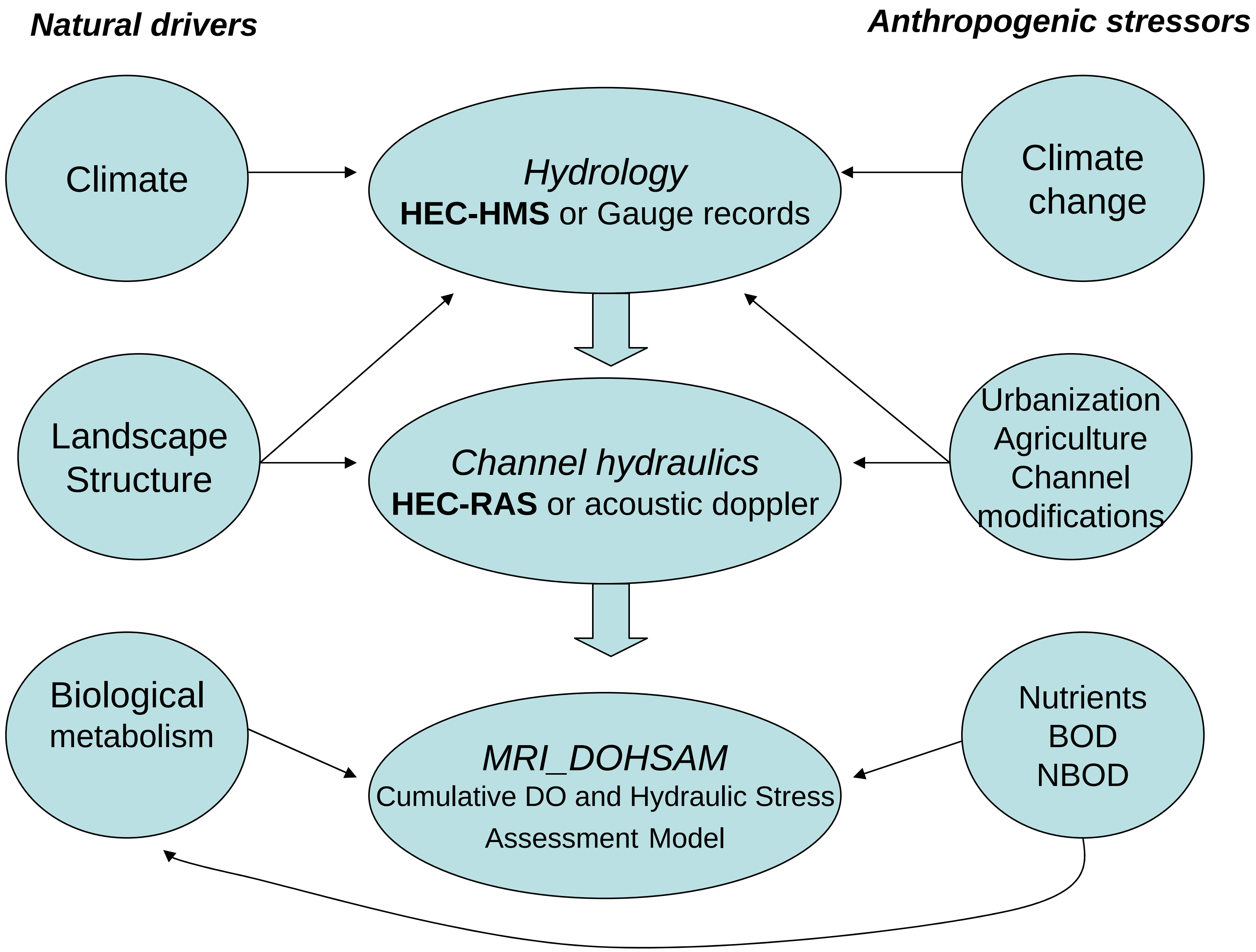


Site-Intensive, Reach Scale Process Based Modeling

1. Refine processed based models
2. Test hypothesis that cause-effect relations in regional, statistical models are plausible

- Crane Creek
  - > Severe DO problems

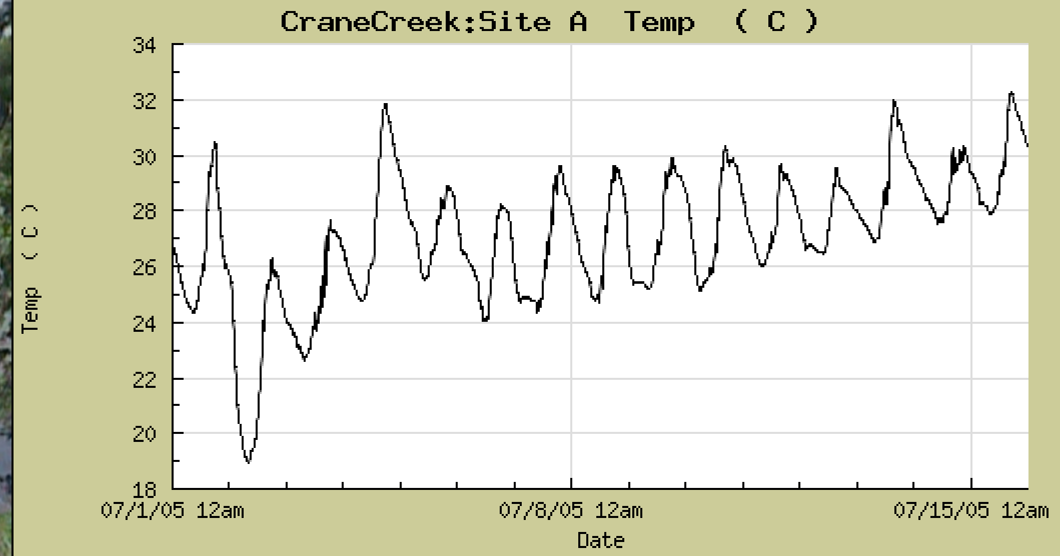


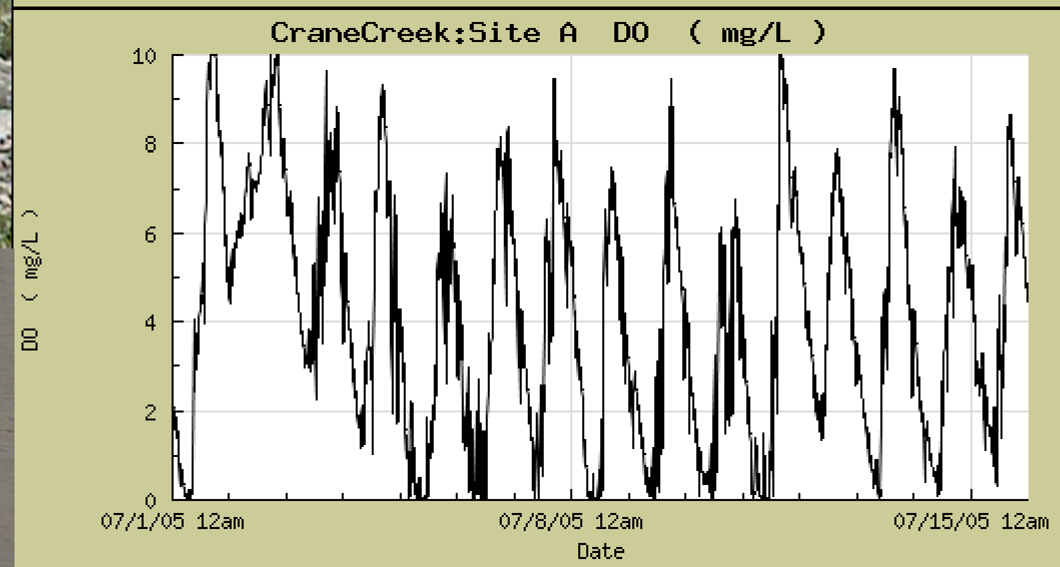


Coupling Reach-specific modeling to explore Multi-stressor dynamics

High resolution oxygen and flow monitoring at Crane Creek

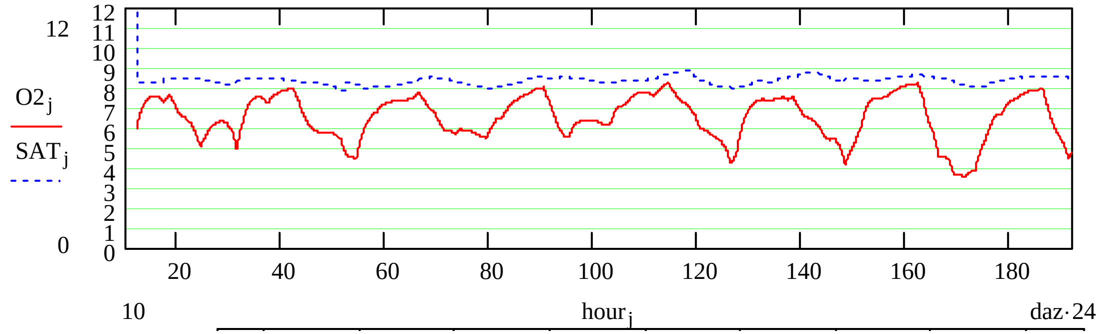
http://www.wqdata.com/

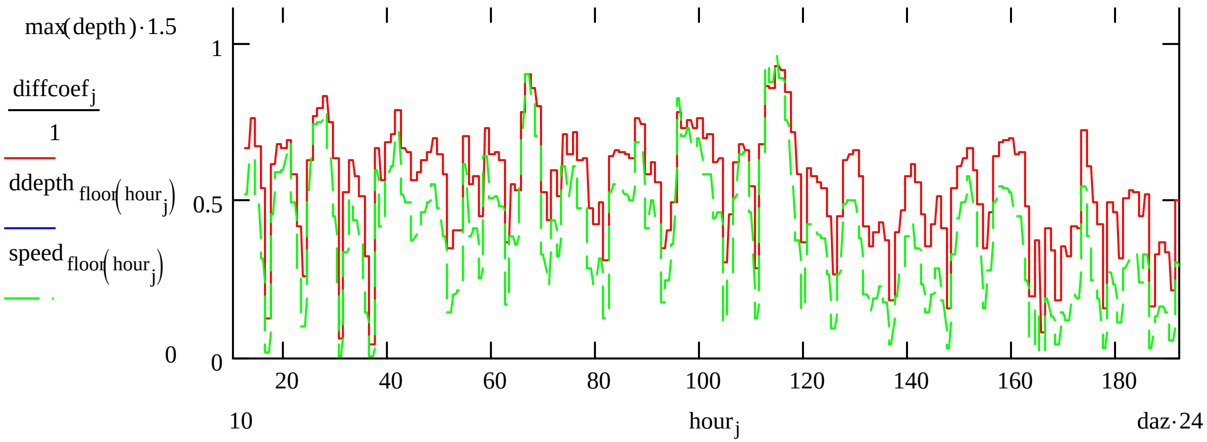




In collaboration with USGS & USFWS, high resolution data are being generated in Crane Creek (a watershed of the Ottawa National Wildlife Refuge) using a combination of (2) fixed station, telemetered YSI 6000 sondes; short-term mobile platforms with recording doppler sonar units (Sontek PC-ADP, ADP, and shallow-water Argonaut units) and YSI 600 series sondes; and an array of digital water level recorders.

MRI_DOHSAM
cumulative DO & Hydraulic Stress Assessment Model
{under development}





8 day simulation for Crane Creek Outlet channel using observed flow temp, depth and velocity data from an up-looking doppler sensor.

Loading parameters
BOD = 8 ppm, NH4=.2 ppm

<u>Stress summary: as % of period</u>

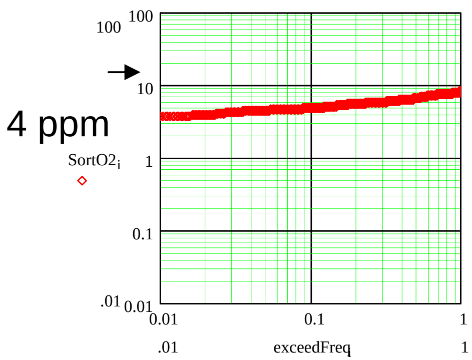
Scour_stress = 56.8

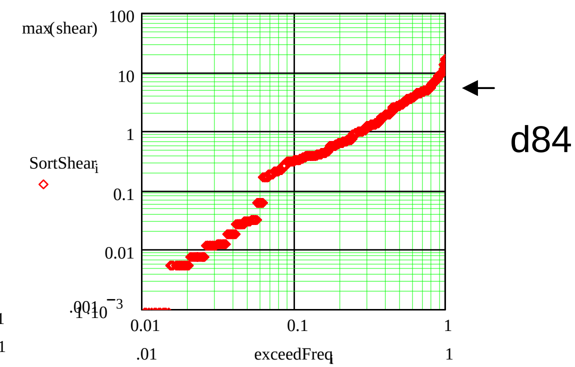
O_2 stress = 2.5

Combined = 59.1

Simultaneous = <.1

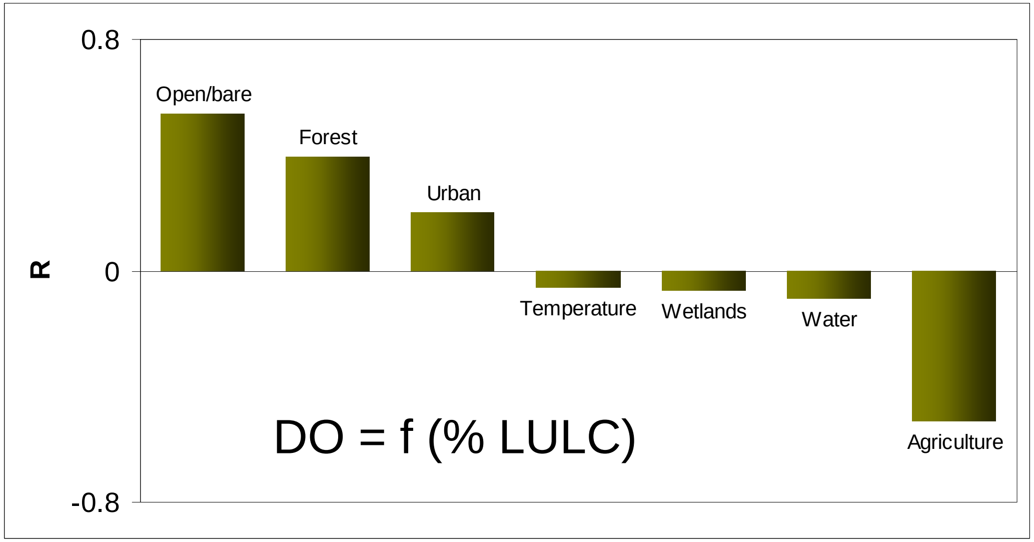
Exceedence frequencies for Dissolved oxygen and bed mobilization



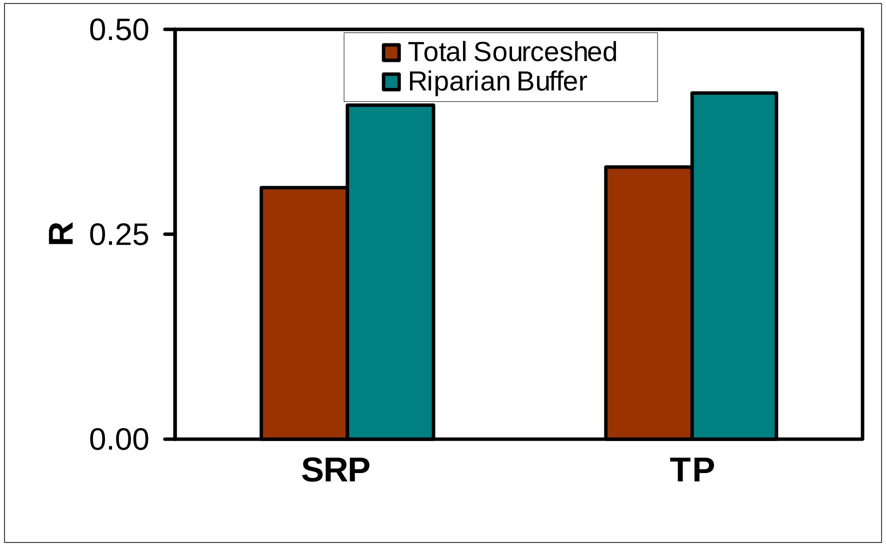


Specified stress thresholds:
O2 : 4 ppm
Incipient Bed mobilization : ratio of ave. shear to $D84_{critical\ shear}/5$

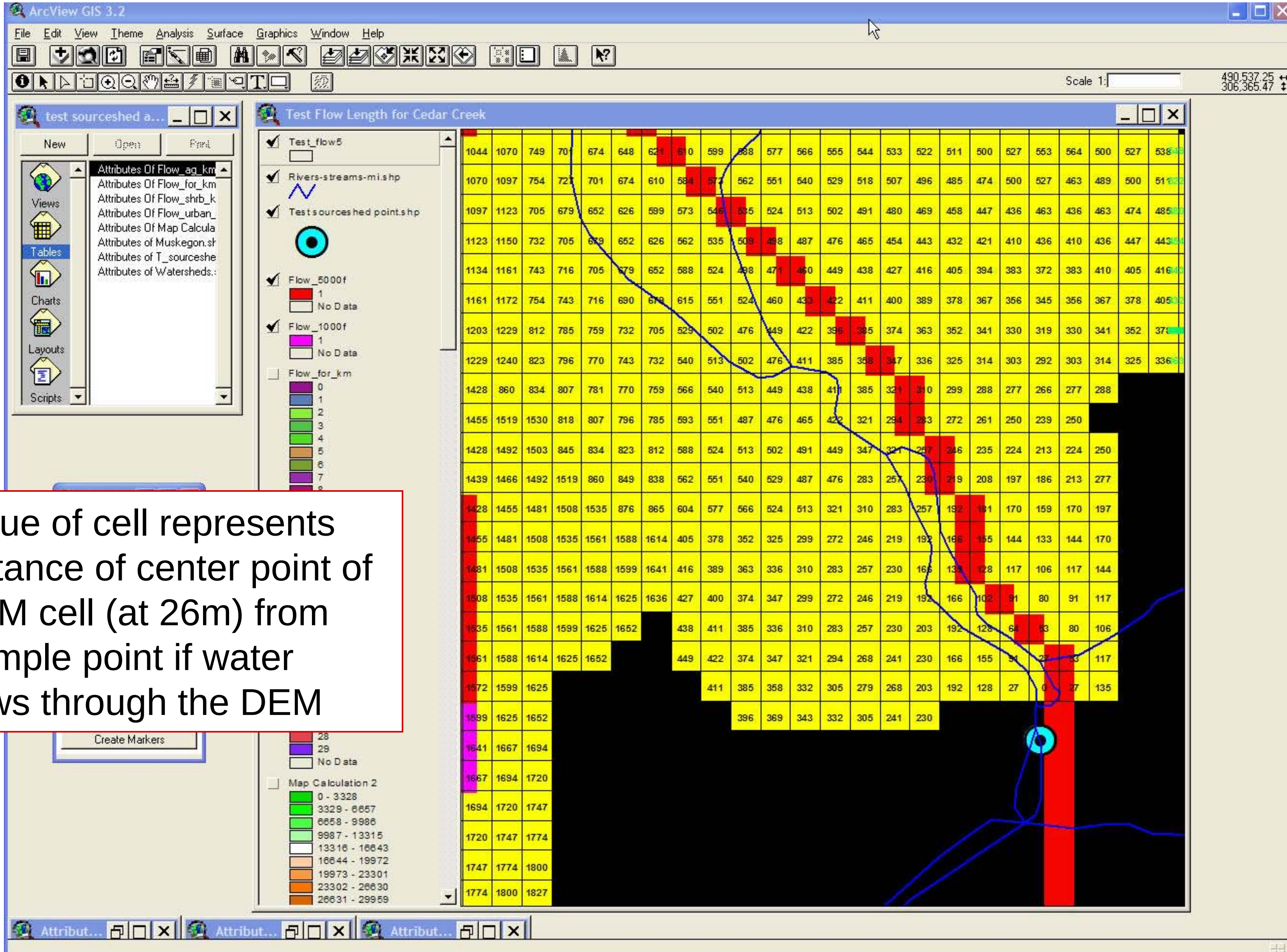
Regional, Watershed Scale Statistical Models



- Endpoints & Stressors
  = f (land use/cover, natural landscape features)
- Refine inference models for watershed contamination based on flow-path weighted “routes of exposure/transport”

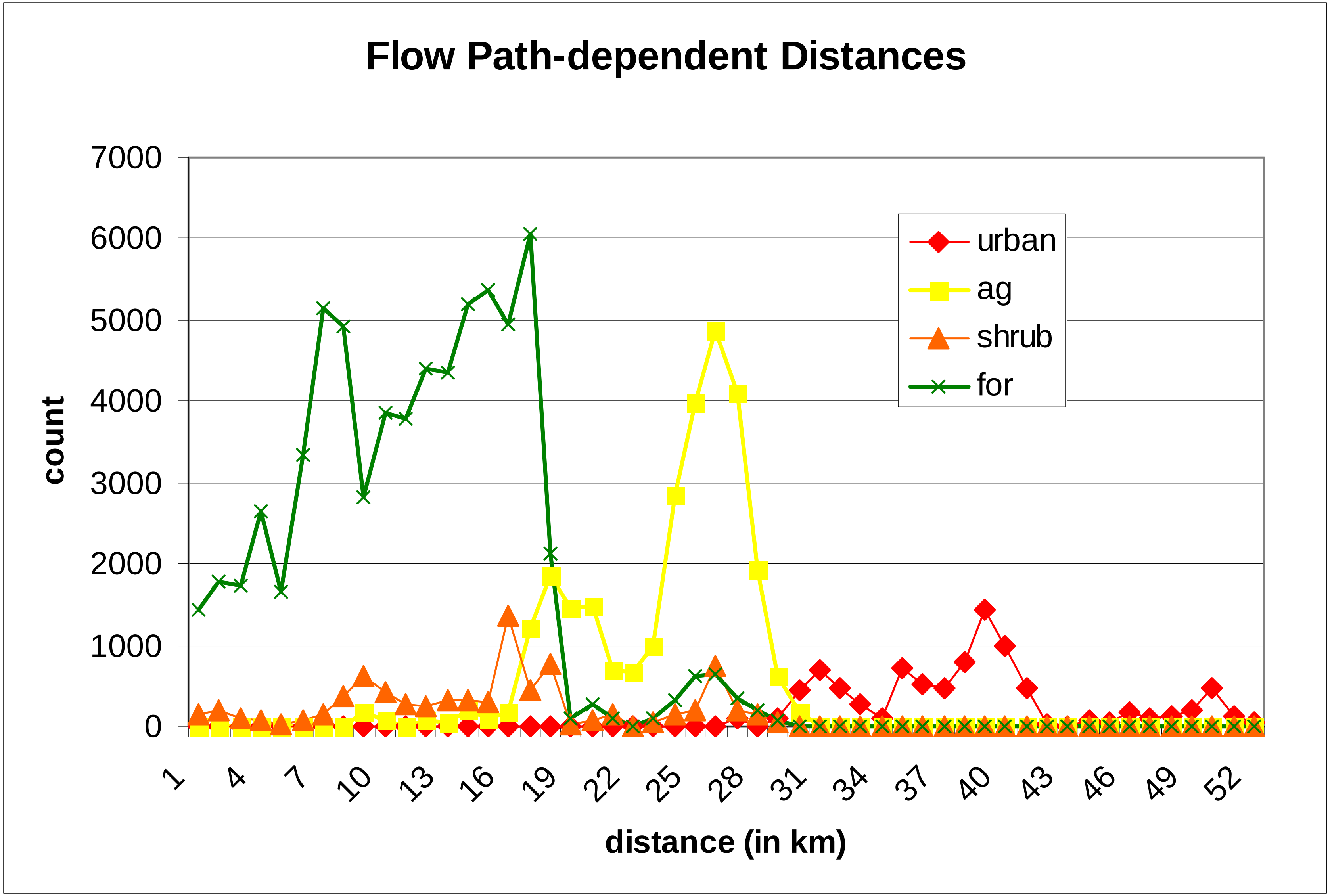


Flow-path Weighted LULC Watershed Characterizations



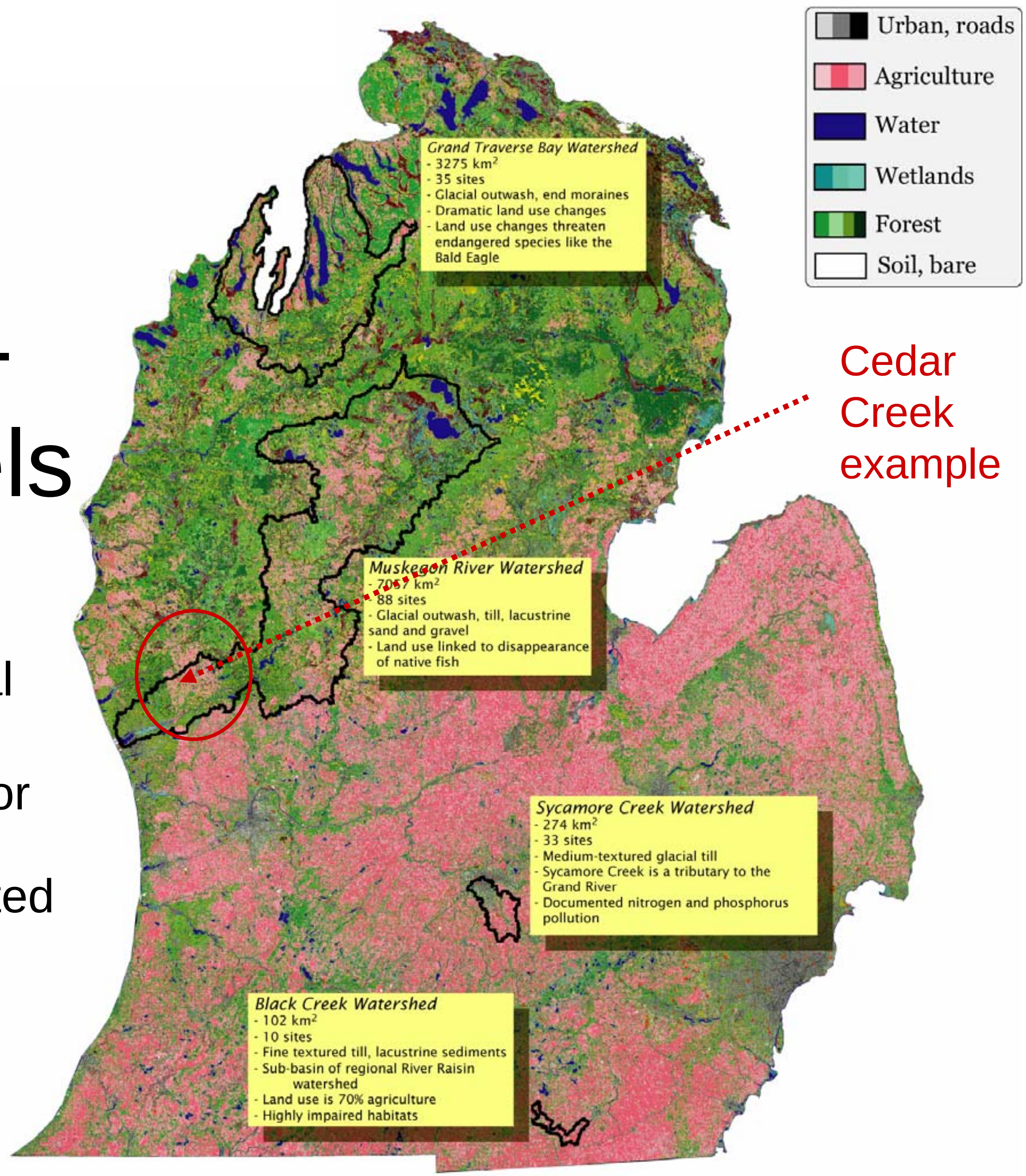
Value of cell represents distance of center point of DEM cell (at 26m) from Sample point if water flows through the DEM

The amount of uses aggregated by flow length distances in km for total sourceshed in Cedar Creek



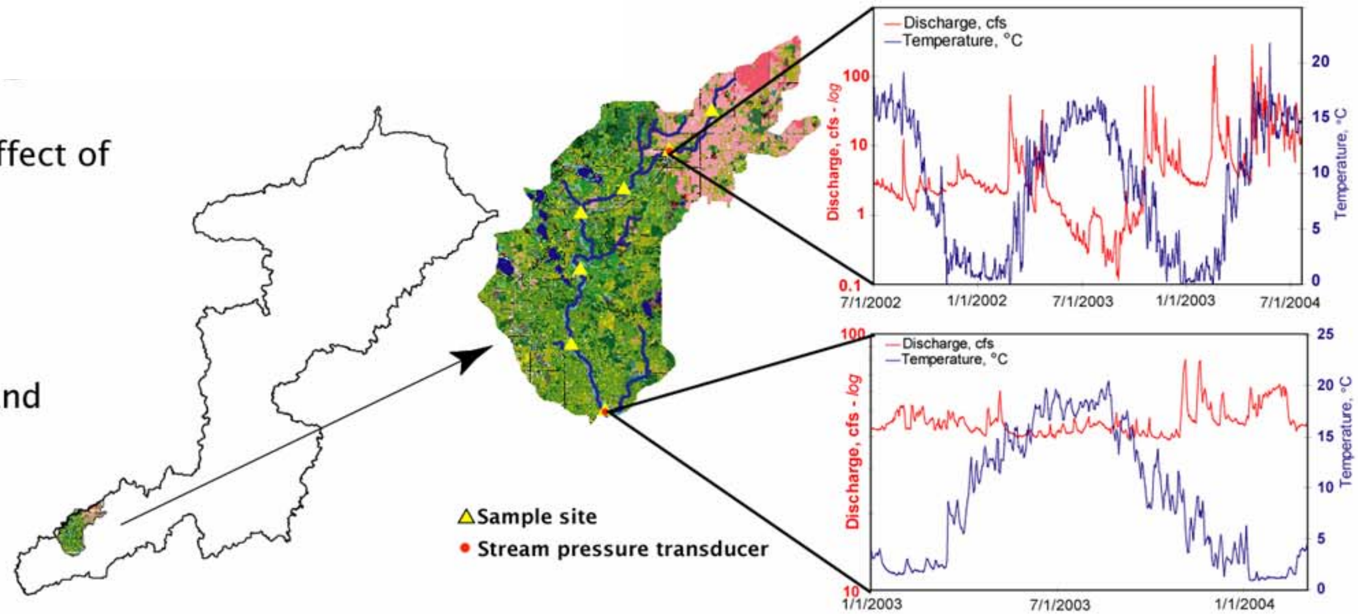
Watershed Scale, & Intensive Processed-Based Models

- Endpoints & Stressors
- = f (land use/cover, natural landscape features)
- Refine inference models for watershed contamination based on flow-path weighted “routes of exposure/transport”



Cedar Creek
(GW influenced watershed)

- Selected to examine the effect of land use on water quality
- Groundwater sourceshed
- Two long-record pressure transducers at upstream and downstream sites

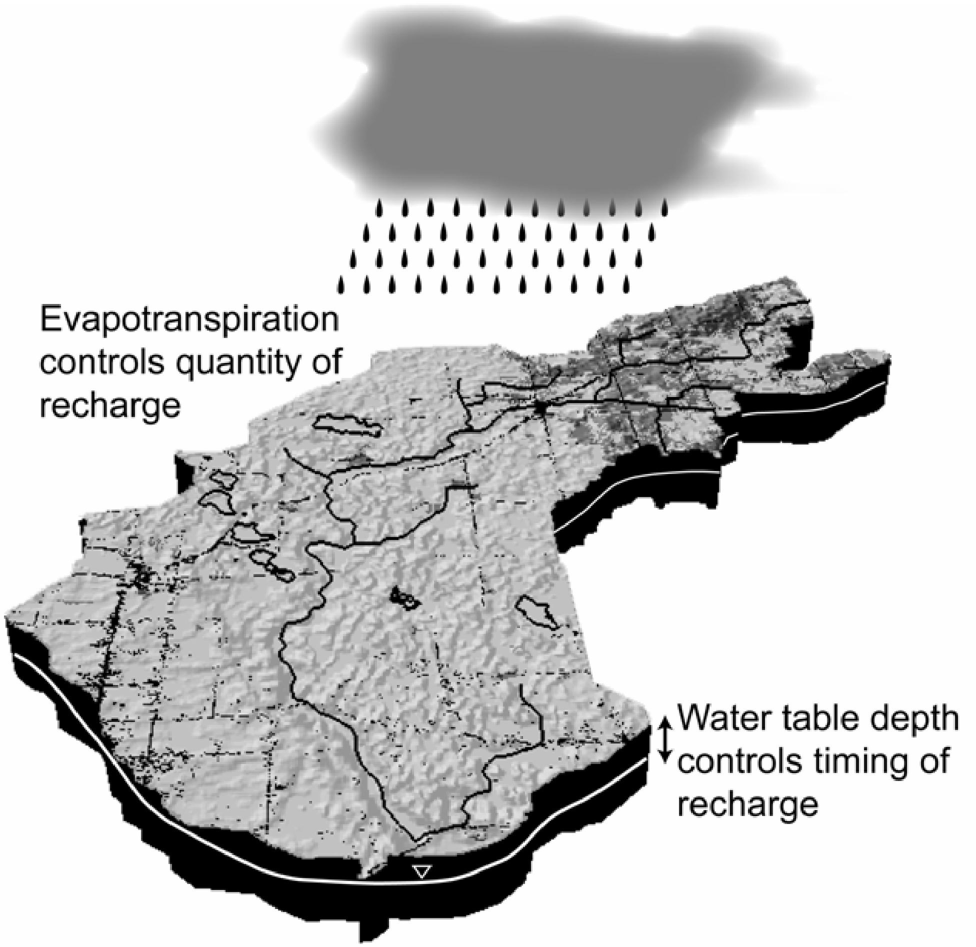


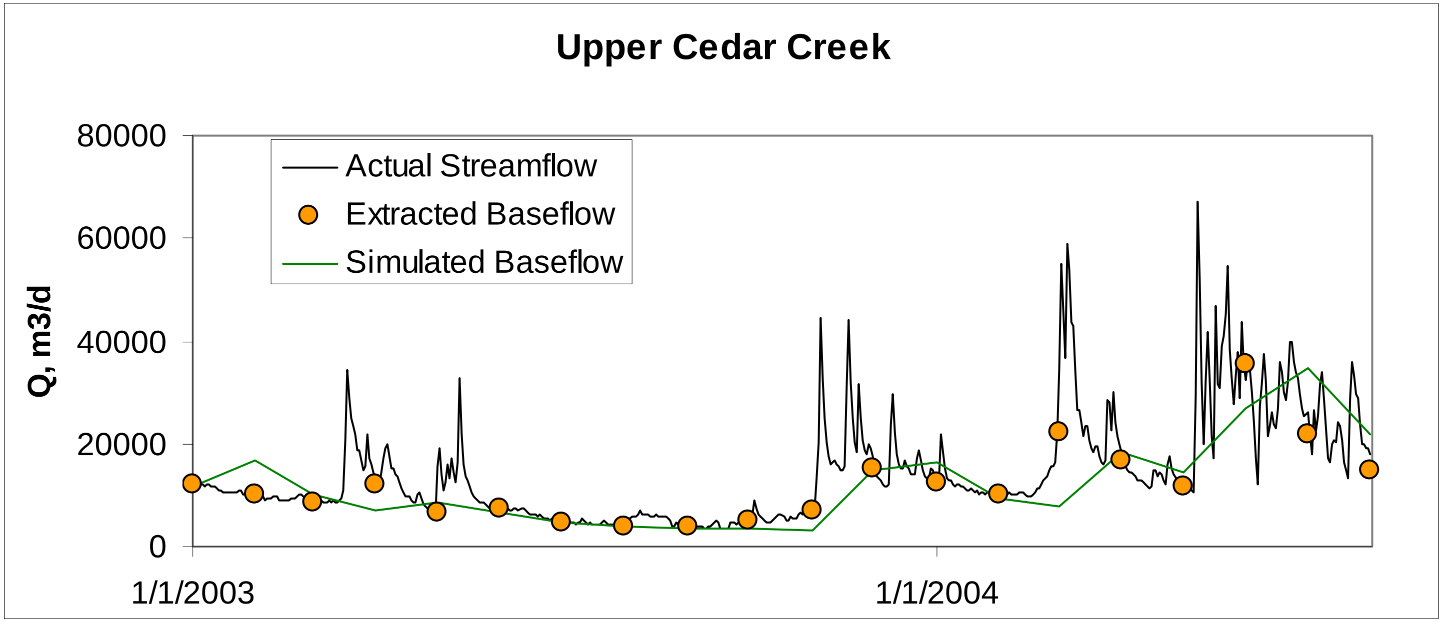
- **Spatially & temporally intensive water chemistry and biological sampling**

Q(cfs)	Conductivity (uS)	NOx-N (pbb)	TP (pbb)
0.0	824	101	120
1.0	670	102	90
1.1	521	522	121
15.9	278	197	53
18.4	293	209	43
24.4	293	156	48
24.5	300	150	10

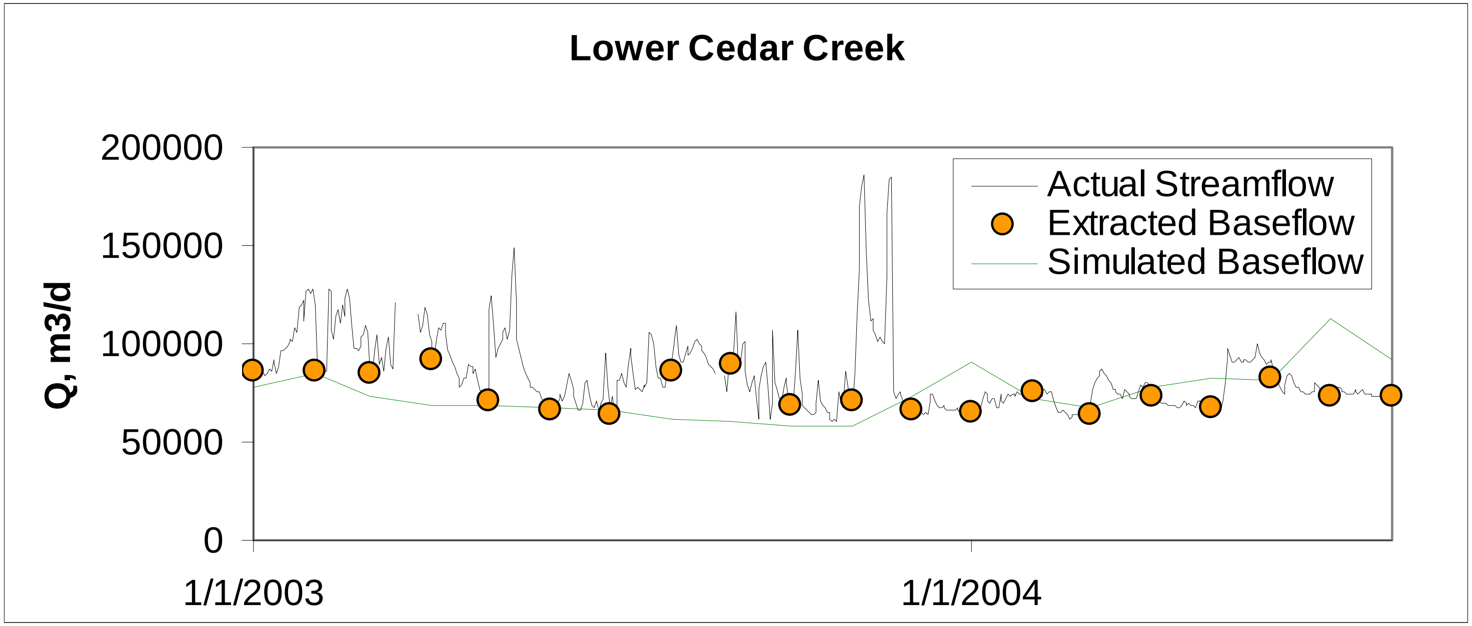
Groundwater Modeling:
Simulate Transient Fluxes to SW

- MODFLOW
- Inputs:
  - Land Use
  - Regional Geology
  - NEXRAD Precipitation
  - NOAA Snow Depth
  - MODIS LAI
  - DEM
  - Solar radiation
  - Streamflow (transducer)



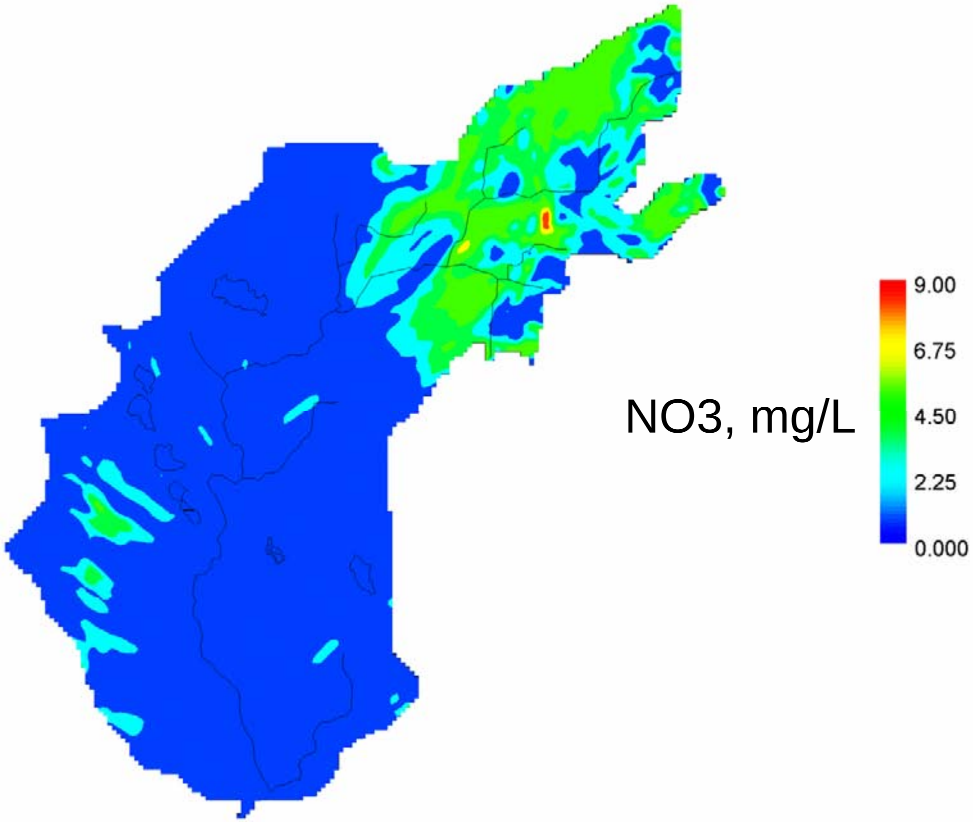


MODFLOW simulates the groundwater component of streamflow well



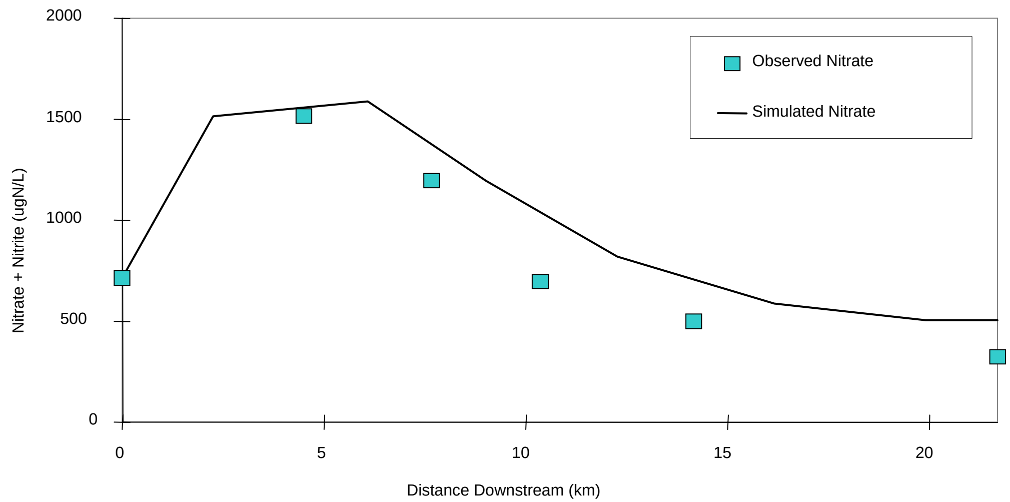
Nitrate Transport Simulation (MT3D)

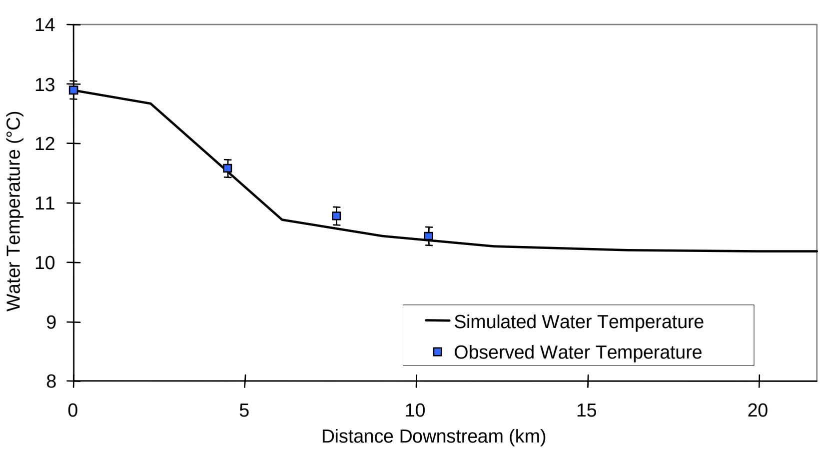
- Used GW model fluxes
- Nitrate sources
  - Atmosphere
  - Agricultural lands
  - CAFOs
  - Septic systems
- Nitrate fluxes exported to stream ecohydrology model

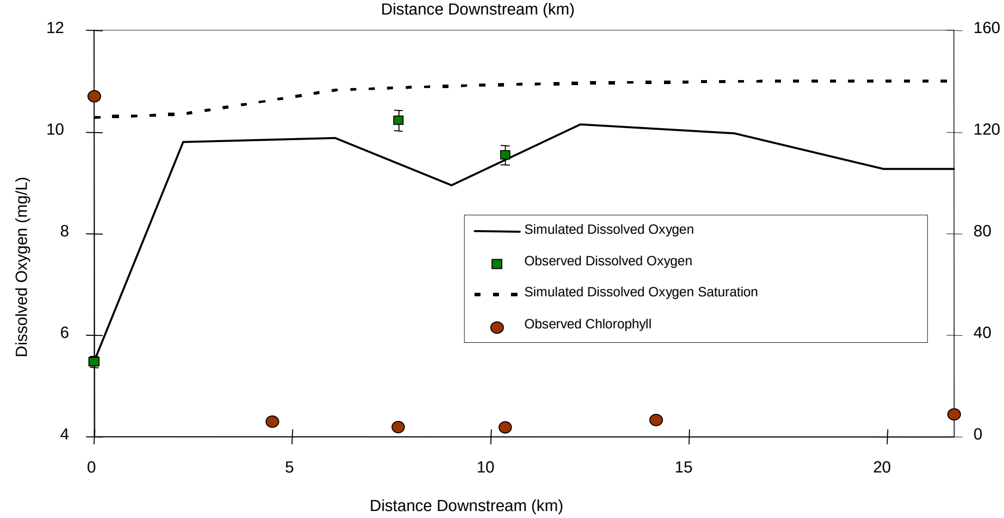


Simulating Water Chemistry and Biological Response in Cedar Creek

- Using nitrate & GW fluxes to Cedar Creek calculated in transport model
- QUAL2K

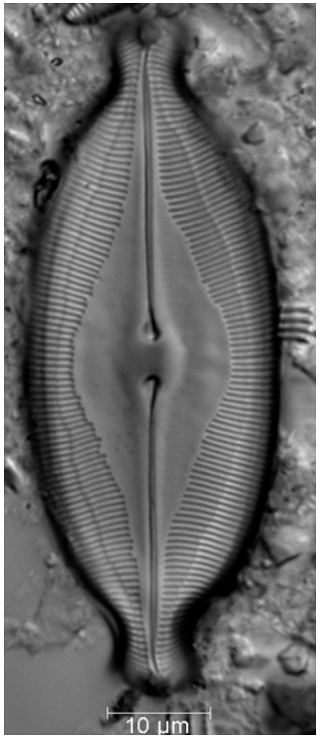






Next Steps

- Model refinements & Synthesis
  - Watershed & reach scale
  - Empirical & processed-based (including P)
- Test models with biological endpoints
  - Small-scale and regional approach



Integrated Assessment/Management Framework