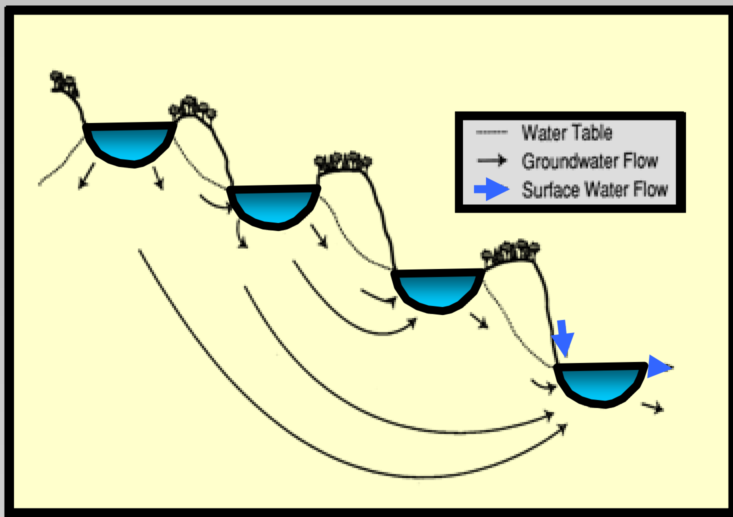
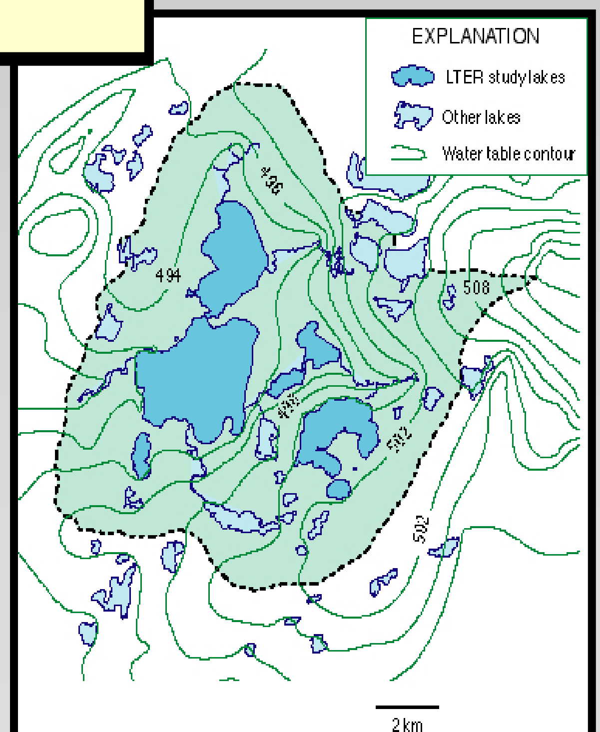
Groundwater-Dominated Systems



Katherine Webster
University of Maine
Katherine.webster@maine.edu



Co-Authors:

NTL-LTER
Tim Kratz

USGS
Randy Hunt
Dave Krabbenhoft
John Walker

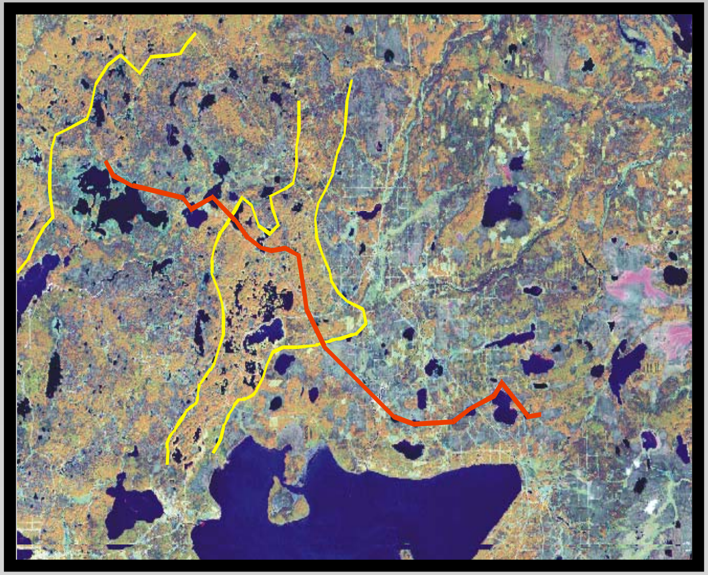
University of Alberta
Kevin Devito

Why are lake-groundwater interactions important?

In Trout Lake area:

- Lakes cover 12% of surface area
- About half of the lakes lake surface water connections
- Lakes only contain about 4% of the water in the whole system. Most is held in groundwater.

Groundwater-dominated systems in contrasting hydrogeologic settings



NTL LTER

- Thick glacial deposits (~50m)
- Low topographic relief
- P>E (0.1 m)
- Low-carbonate till

Boreal Forest, Alberta

- Thick glacial deposits (20-200m)
- Low topographic relief
- P≈E (E slightly higher than P)
- High carbonate drift

Focus on *Hydroecology:*
Links the groundwater flow system with lake ecosystem

- What have we learned?

- What are our challenges?

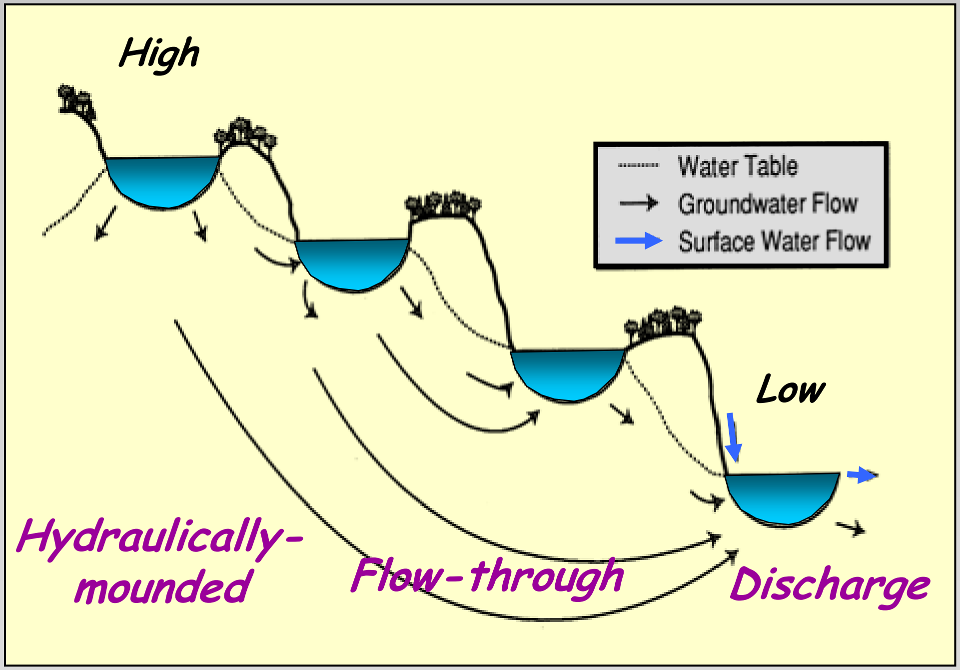
What have we learned?

- Interactions with groundwater drive spatial patterns within and among lakes

Spatial Patterns Within Lakes

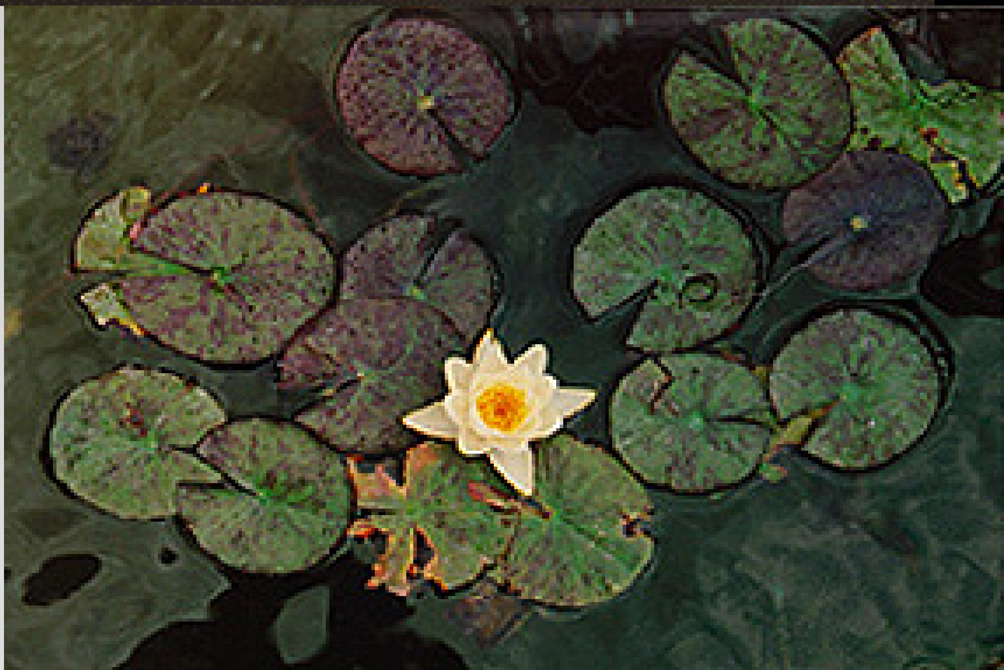
- **Macrophyte beds in areas of groundwater inflow/outflow**
  - *(Lodge et al. 1989)*
- **Benthic algal distributions in areas of groundwater inflow**
  - *(Hagerthey and Kerfoot 1998)*
- **Spring diatom blooms fed by groundwater inputs**
  - *(Hurley et al. 1985)*

Spatial patterns among lakes: landscape position concept



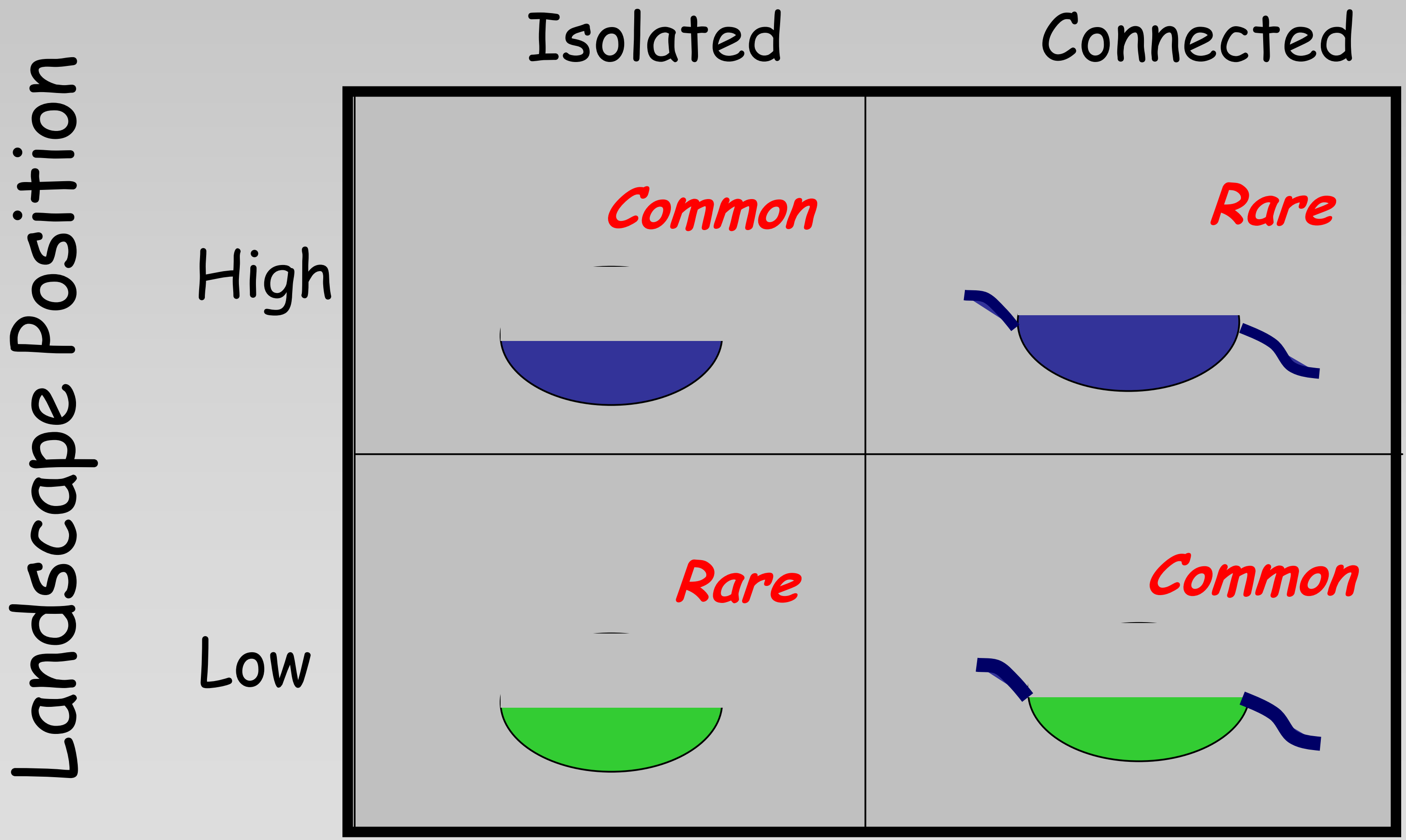
- Organize lakes along hydrologic flowpath
- Distinguish connections to local (short) and regional flowpaths
- Groundwater is enriched in cations, silica, ANC
- Increasing concentrations in lakes from high to low

Landscape Position and Species Richness
(Hrabik et al. in prep.)



Conductivity vs. Connectivity

Lakes were sampled within each of these categories, keeping lake area relatively constant, to test whether landscape position (conductivity) or lake isolation (connectivity from surface connections) determined species richness of a range of aquatic organisms. (Hrabik et al. in prep)

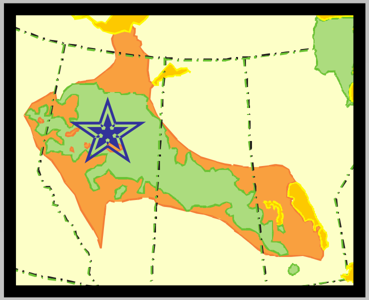


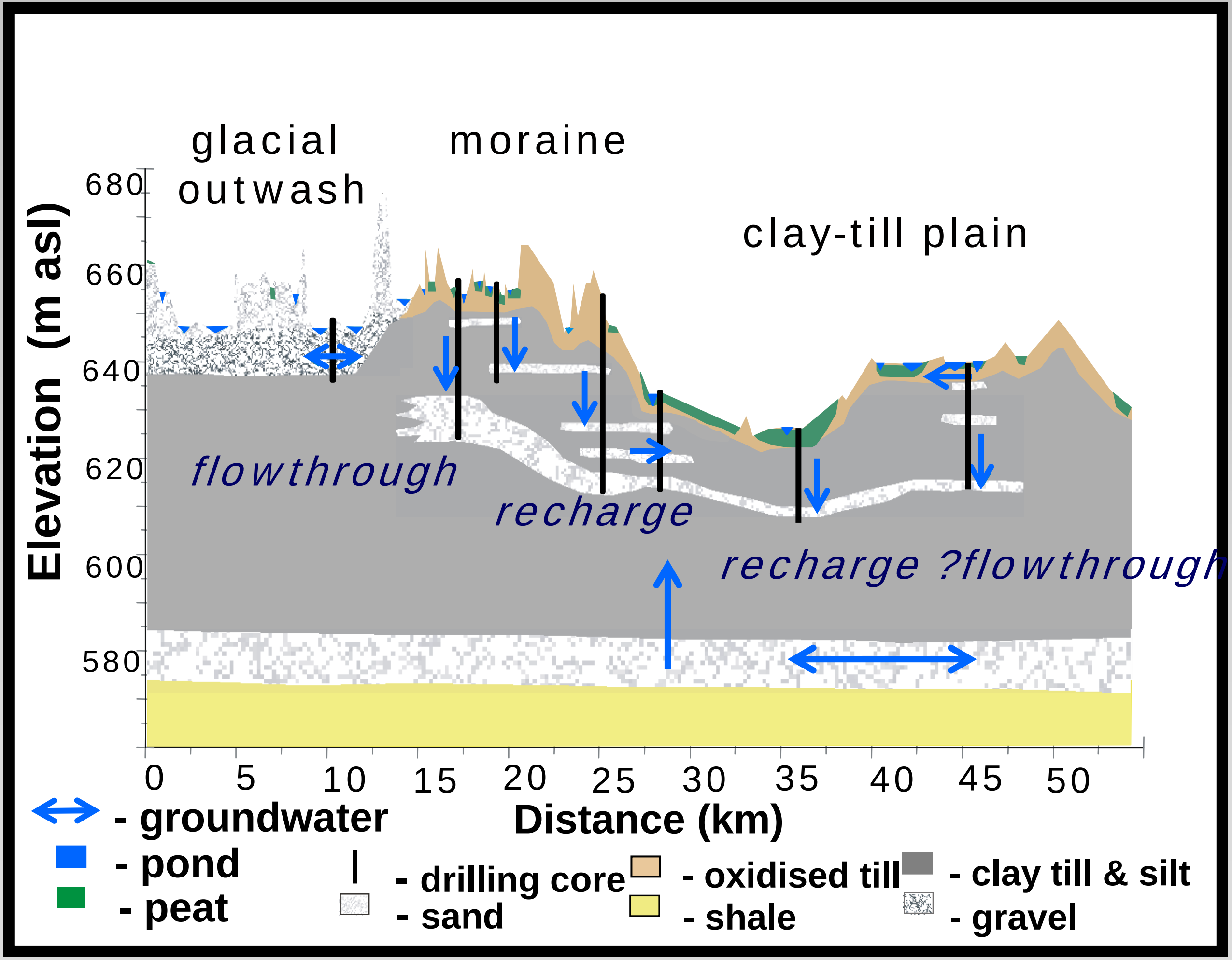
❖Species richness was correlated with conductivity, an indicator of landscape position.

❖Stream connectivity was of secondary importance.

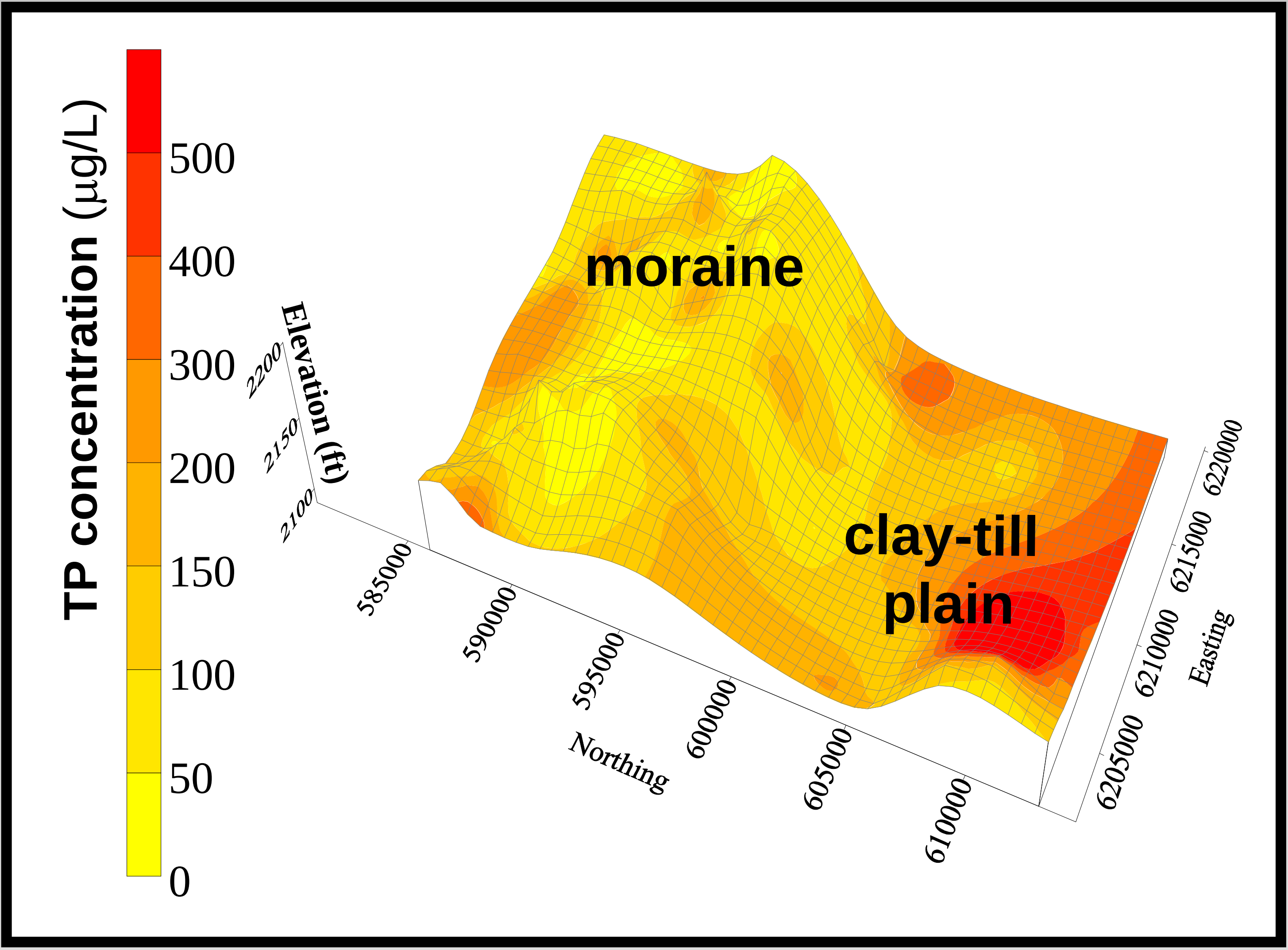
(Hrabik et al., in prep)

Landscape patterns in the Utikuma Study area in Northern Alberta (Devito et al. in prep)





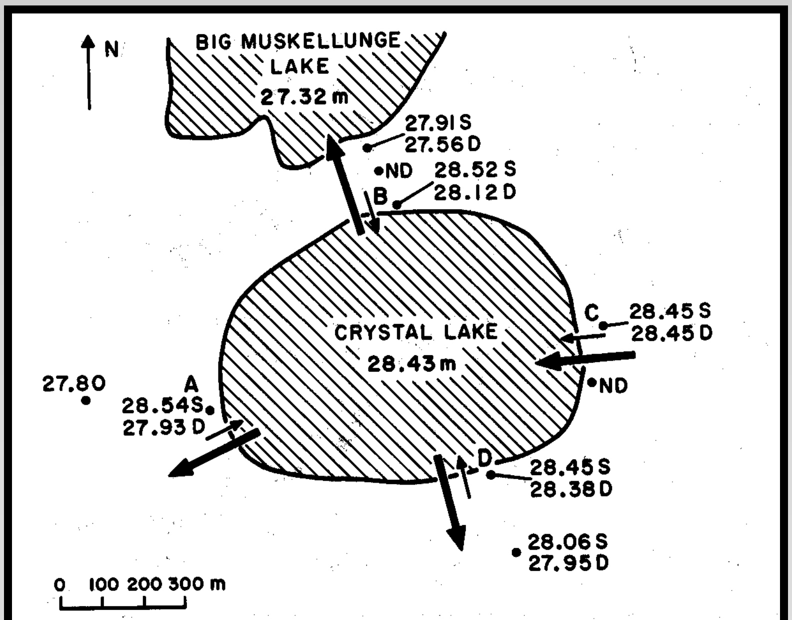
Spatial Patterns in pond chemistry: Isolines of TP concentration relative to elevation of 118 ponds surveyed in 1998 and 1999 *(Devito et al. in prep)*



What have we learned?

- Interactions with groundwater drive spatial patterns within and among lakes
- **Lake-groundwater interactions are dynamic**

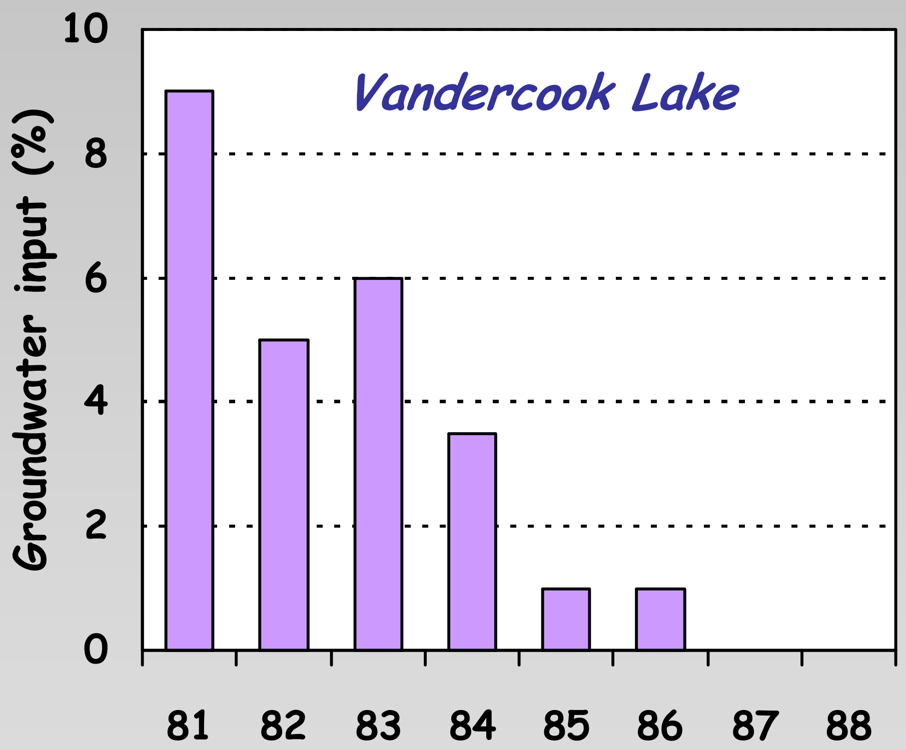
Seasonal Variation: Nearshore groundwater mounds at Crystal Lake



- Mounds form when GW flowpaths reverse
- Seasonally transient
- Did not form in dry years
- Can occur in deep flow systems (heavy arrows) but are more usual in shallow flowpaths

(Anderson and Cheng 1993)

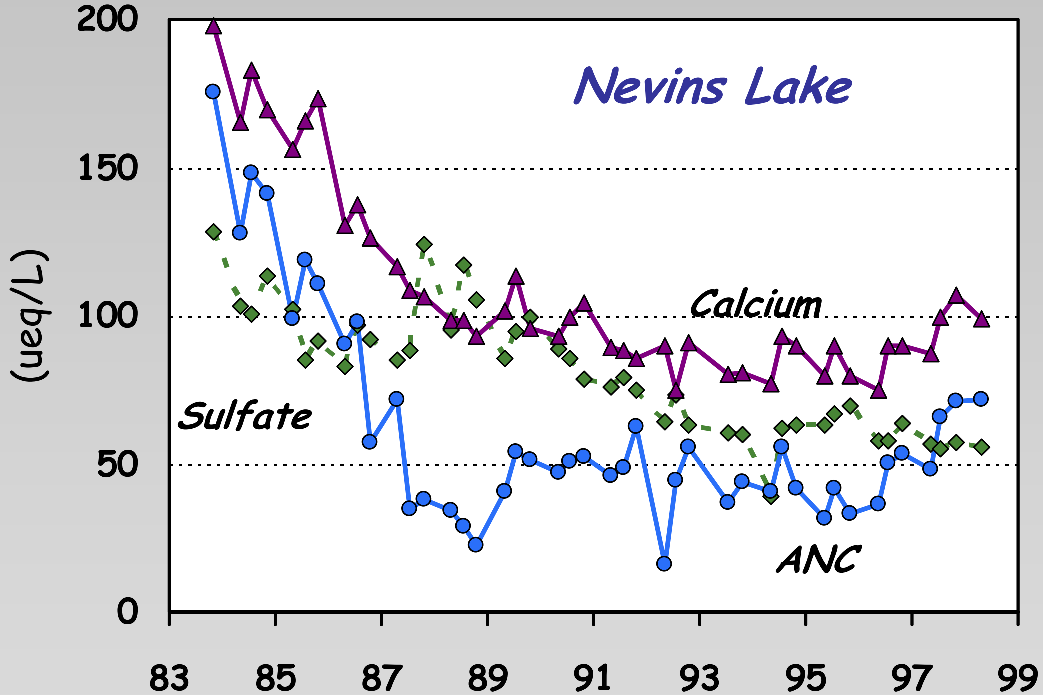
Interannual variation in groundwater inputs



(Wentz et al. 1995)

- Groundwater inputs vary widely on an interannual basis
- Switch in hydrology from flow-through to mounded during drought
- Temporal context is important

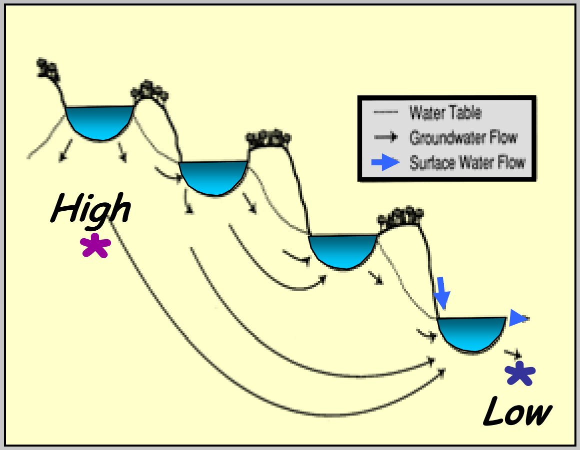
Consequences of Groundwater Shifts



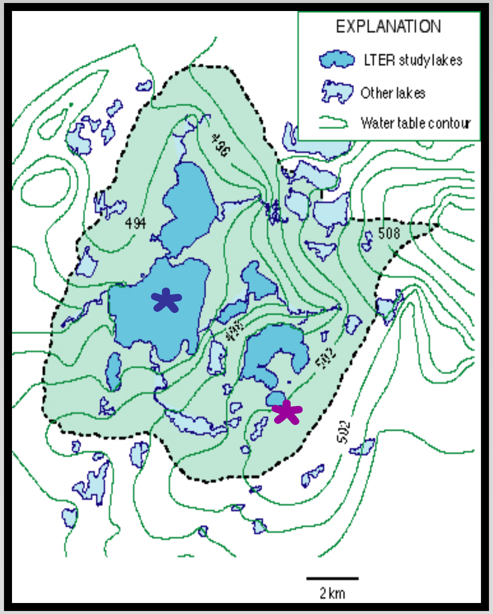
(Webster et al. 1990;
Webster unpublished data)

- Rapid acidification following reversals in groundwater inflow
- Response depends on lake water residence time relative to time of disturbance

Groundwater fluxes in lakes low and high in the flow system



Feature	High	Low
Importance of GW inputs	Less	More
Dominant flowpaths	Local	Regional
Transience in GW inputs	More pronounced	Less pronounced



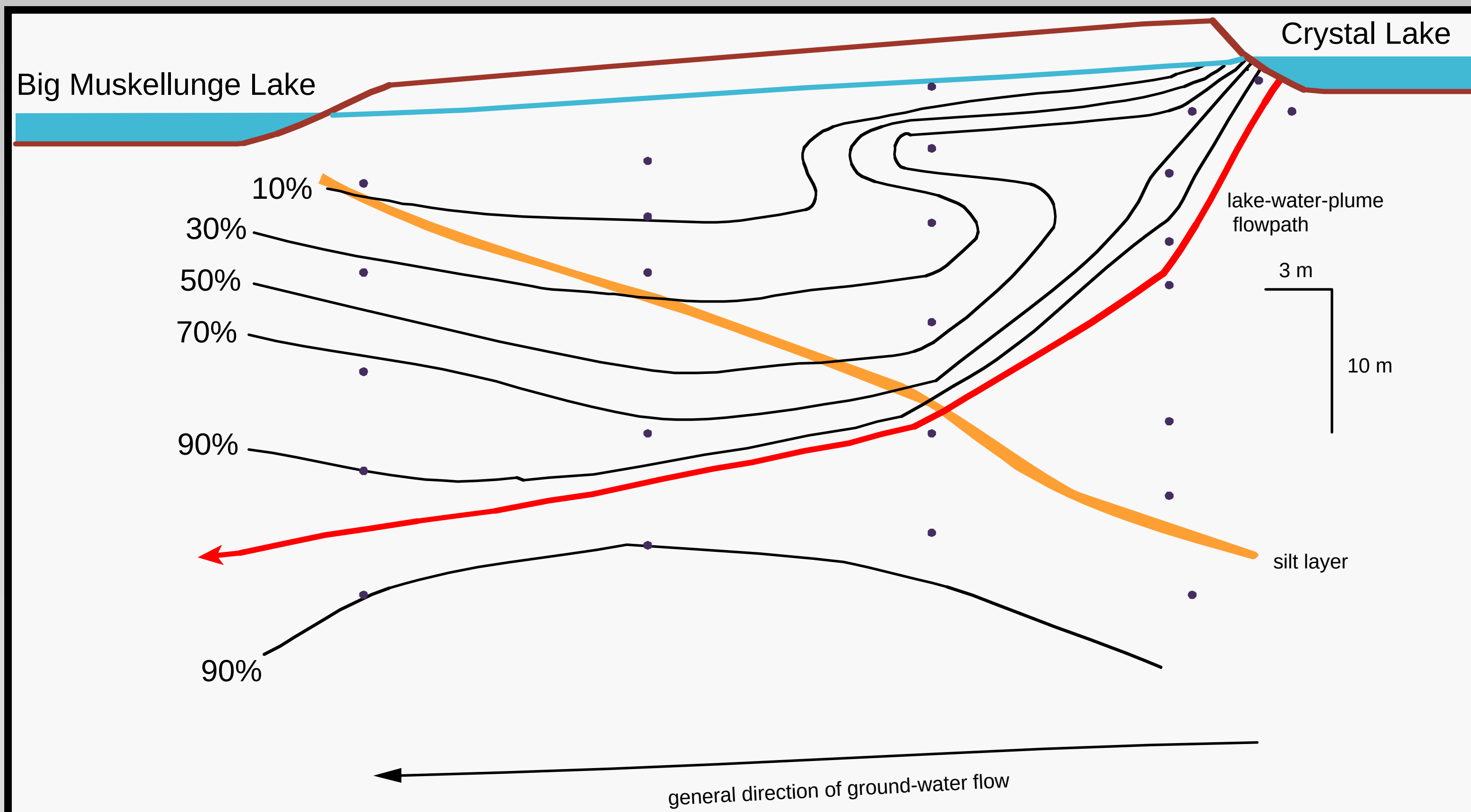
(Cheng and Anderson 1994)

What have we learned?

- Interactions with groundwater drive spatial patterns within and among lakes
- Lake-groundwater interactions are dynamic
- Lake-groundwater interactions are complex!

Persistence of lake water plumes

% of Crystal Lake Water based on isotope analysis

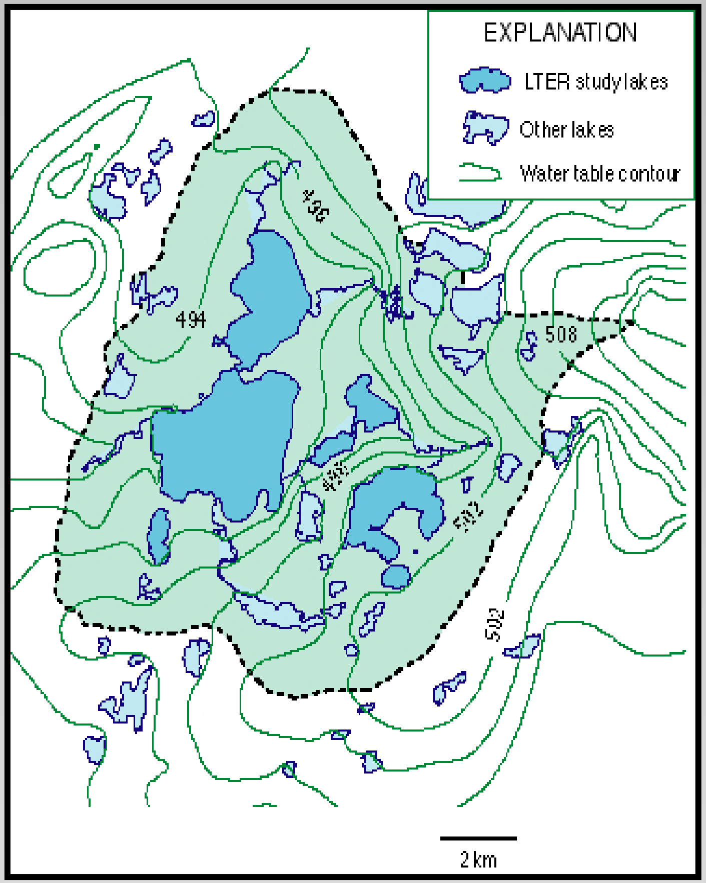


(USGS WEBB project: Walker and Bullen 2000)

What are our challenges?

- Improve spatial resolution in models of lake-groundwater interactions

Lake-groundwater models

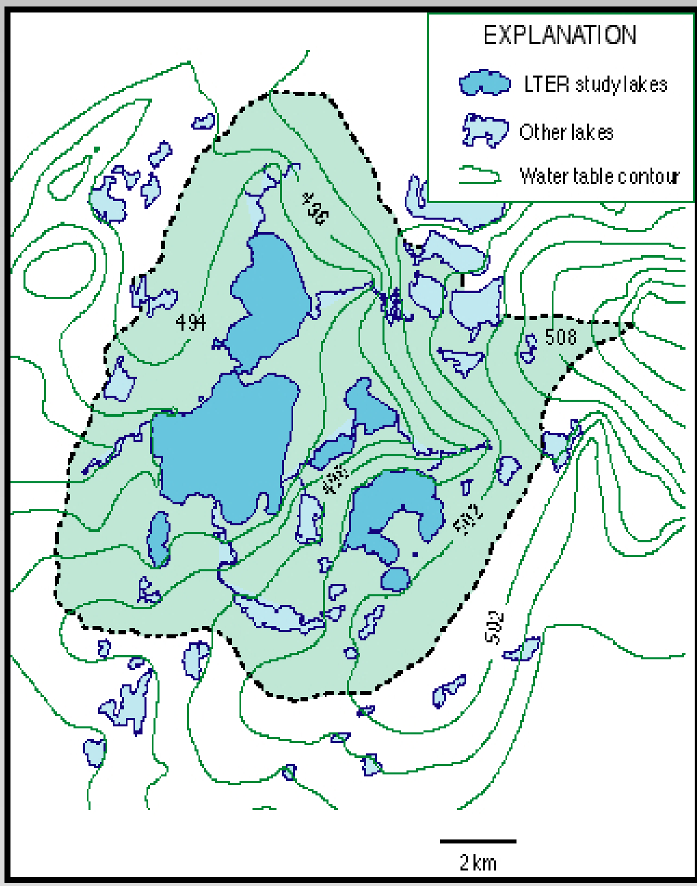


- At basin scale - dynamic models have greatly improved, but are complicated
  - Need detailed field data to constrain models
- Spatial resolution at smaller scales still problematic

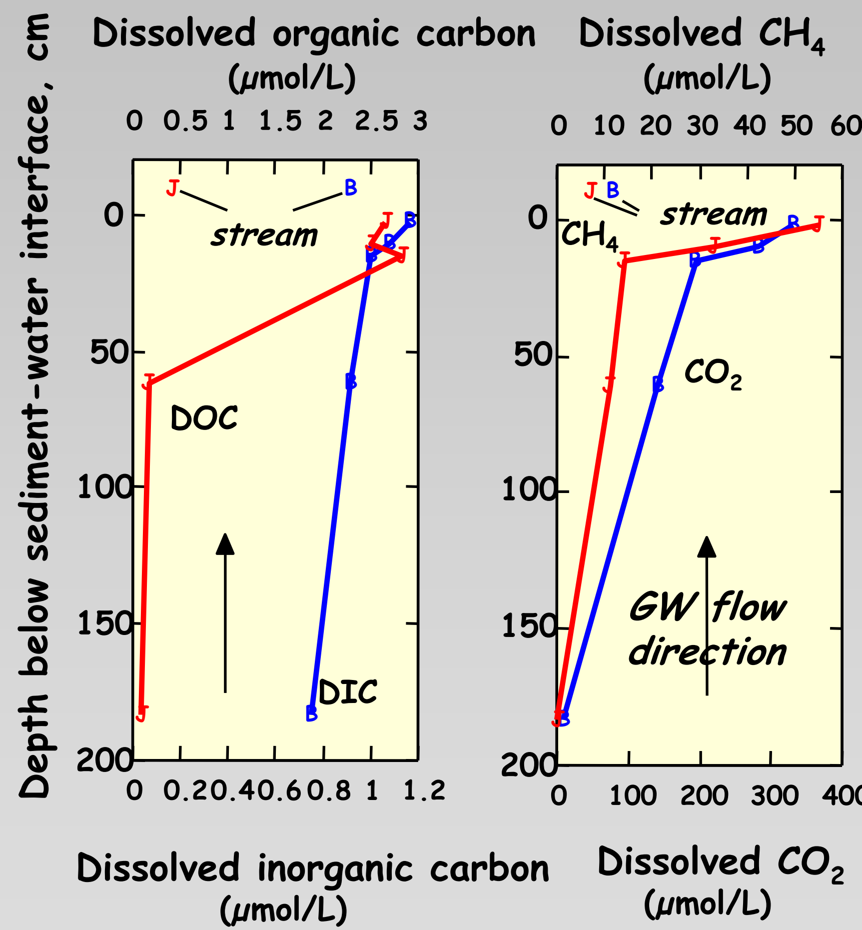
What are our challenges?

- Improve spatial resolution in models of lake-groundwater interactions (water flow)
- Integrate hydrologic models with small-scale biogeochemical studies (solutes)

Basin-lake scale hydrologic models

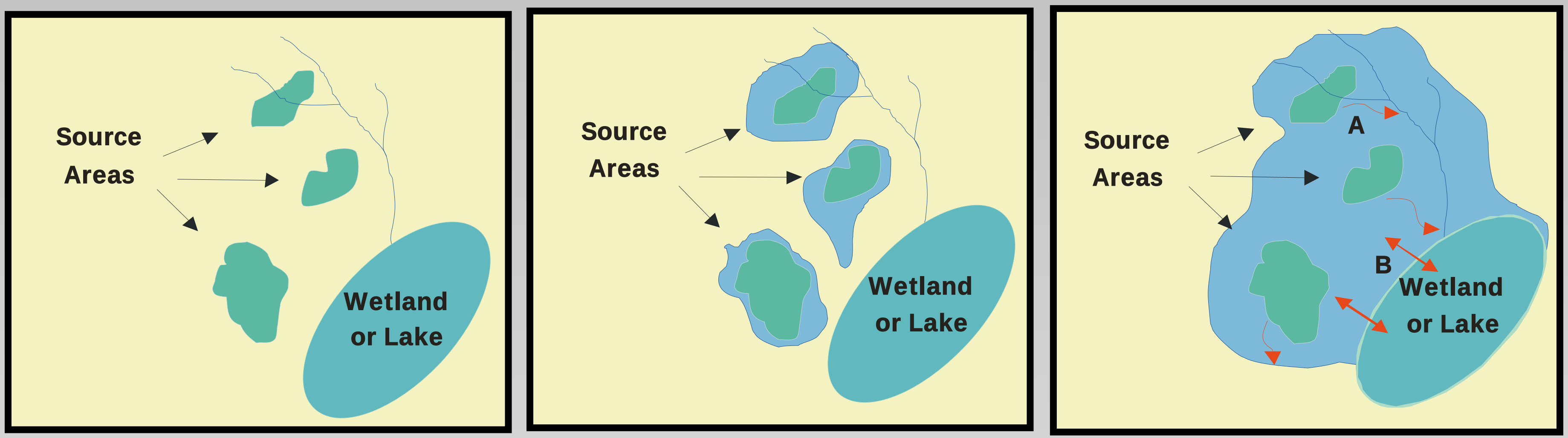


Complex biogeochemical reactions at the sediment-water interface



(USGS WEBB project: Walker and Bullen 2000; Schindler and Krabbenhoft 1998)

Variable Source Area Dynamics



Isolated source areas

Expansion of source areas

Further expansion of source areas that results in:

A. flow reversals;

B. hydrologic connections to the lake

(Devito et al. 2000. Can. J. Fish. Aquat. Sci. 57:1977-84)

What are our challenges?

- Improve spatial resolution in models of lake-groundwater interactions (water flow)

- Integrate hydrologic models with small-scale biogeochemical studies (solutes)

- Link terrestrial, groundwater and lake ecosystem models

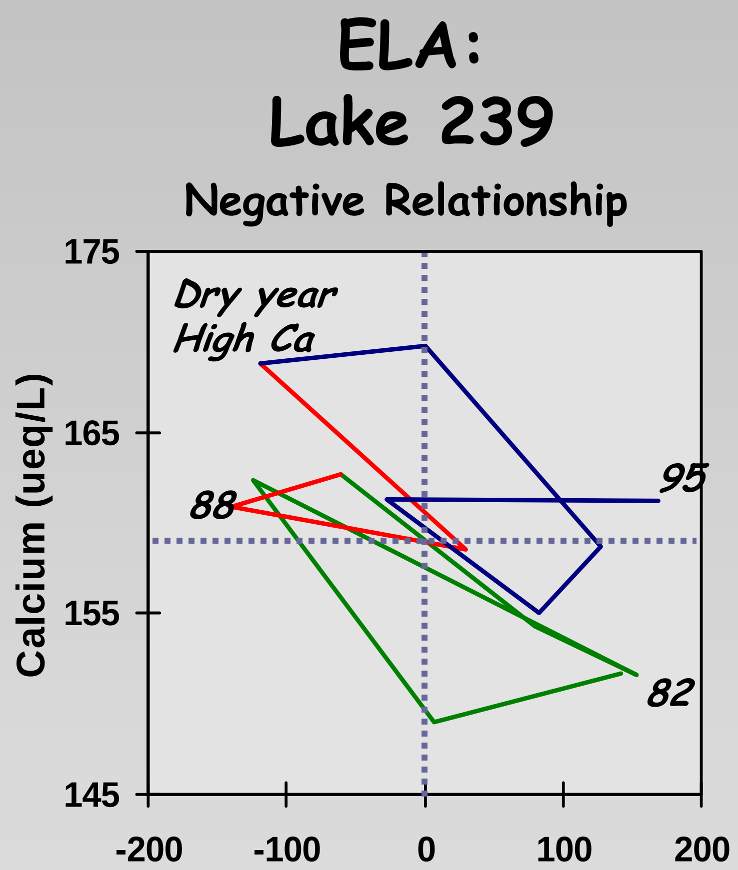
Link terrestrial, groundwater and lake ecosystem models

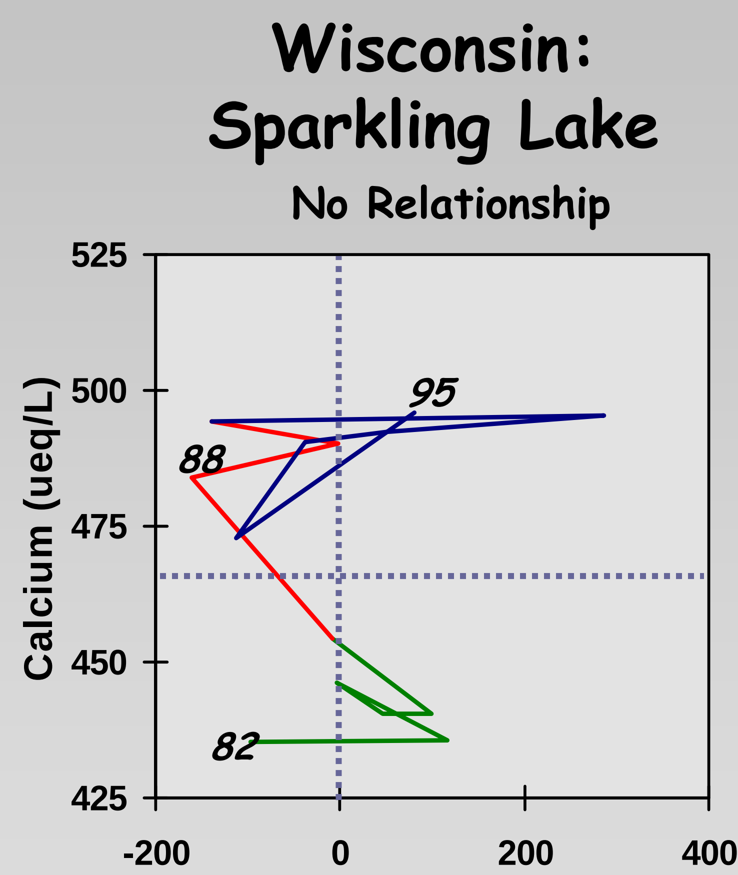
- Existing, discipline-specific models don't link up at present
  - Different spatial and temporal resolution
- Key to understanding --
  - external drivers like (land use or climate change)
  - biogeochemical cycles (like carbon budgets)

What are our challenges?

- Improve spatial resolution in models of lake-groundwater interactions (water flow)
- Integrate hydrologic models with small-scale biogeochemical studies (solutes)
- Link terrestrial, groundwater and lake ecosystem models
- Improve understanding of key drivers influencing groundwater dominated systems

Climate: Interactions with groundwater introduce lags in response

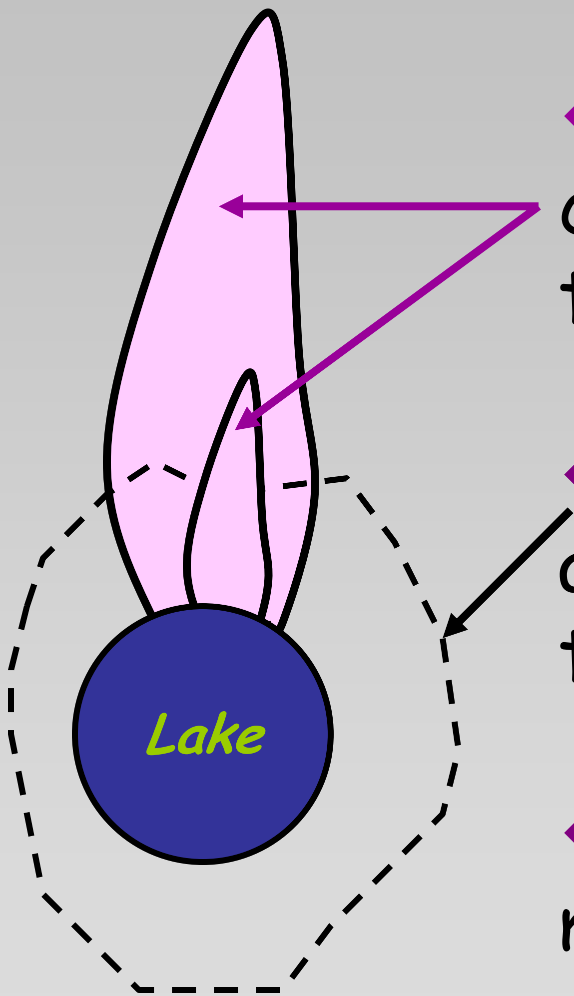




Precipitation - Water Year Anomaly (mm)

(Webster et al. 2000)

Spatial pattern of land use change relative to hydrology



- GW contributing area changes (and can be transient
- Groundwater contributing areas not correspond to topographic watershed
- Areas near lakeshore are more important – less probability of GW underflow

What is the nature of the stressor?

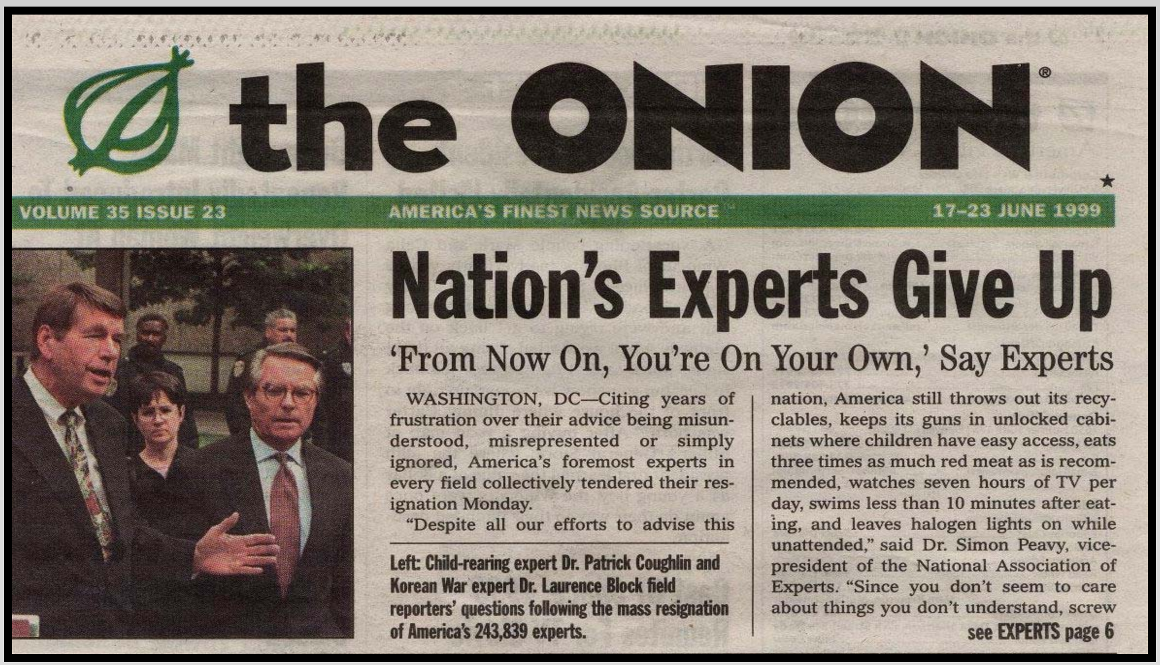
- In post-audits of groundwater model predictions, the main reason model prediction failed was because the modeler had made faulty guess as to what the future stresses to the system would be.

- Stochastic or non-linear? What are the lags?

Interacting Drivers

- What is the interplay between regional and local drivers?

- What is the cumulative influence of multiple stresses?



the ONION®

VOLUME 35 ISSUE 23 AMERICA'S FINEST NEWS SOURCE 17–23 JUNE 1999

Nation's Experts Give Up

'From Now On, You're On Your Own,' Say Experts

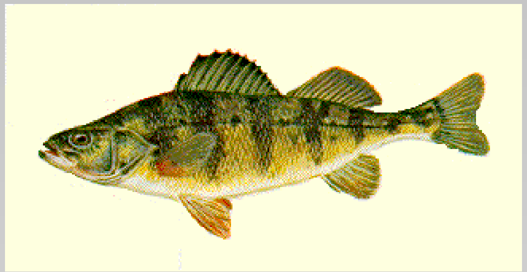
WASHINGTON, DC—Citing years of frustration over their advice being misunderstood, misrepresented or simply ignored, America's foremost experts in every field collectively tendered their resignation Monday.

"Despite all our efforts to advise this nation, America still throws out its recyclables, keeps its guns in unlocked cabinets where children have easy access, eats three times as much red meat as is recommended, watches seven hours of TV per day, swims less than 10 minutes after eating, and leaves halogen lights on while unattended," said Dr. Simon Peavy, vice-president of the National Association of Experts. "Since you don't seem to care about things you don't understand, screw

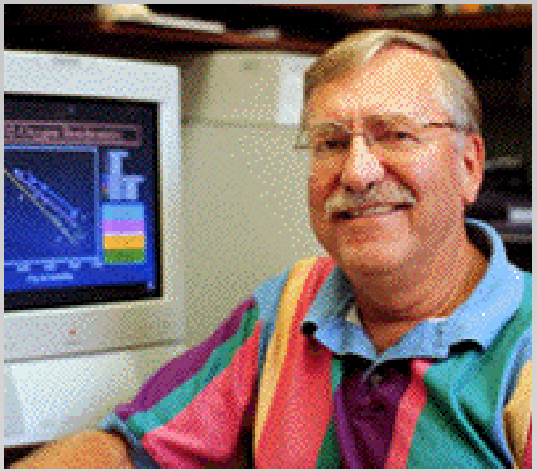
see EXPERTS page 6

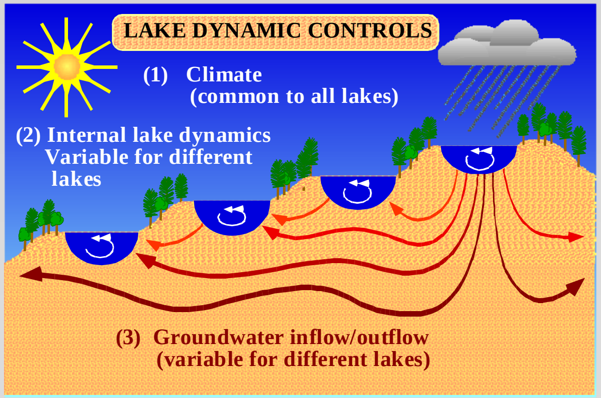
Left: Child-rearing expert Dr. Patrick Coughlin and Korean War expert Dr. Laurence Block field reporters' questions following the mass resignation of America's 243,839 experts.

Ultimate goal to link fish ecology and groundwater
Special thanks to:



Dr. John Magnuson





Dr. Carl Bowser