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Reservoir management to minimize mercury in fish: lessons from a hydropower storage basin

Charleston, South Carolina

September 7, 2011

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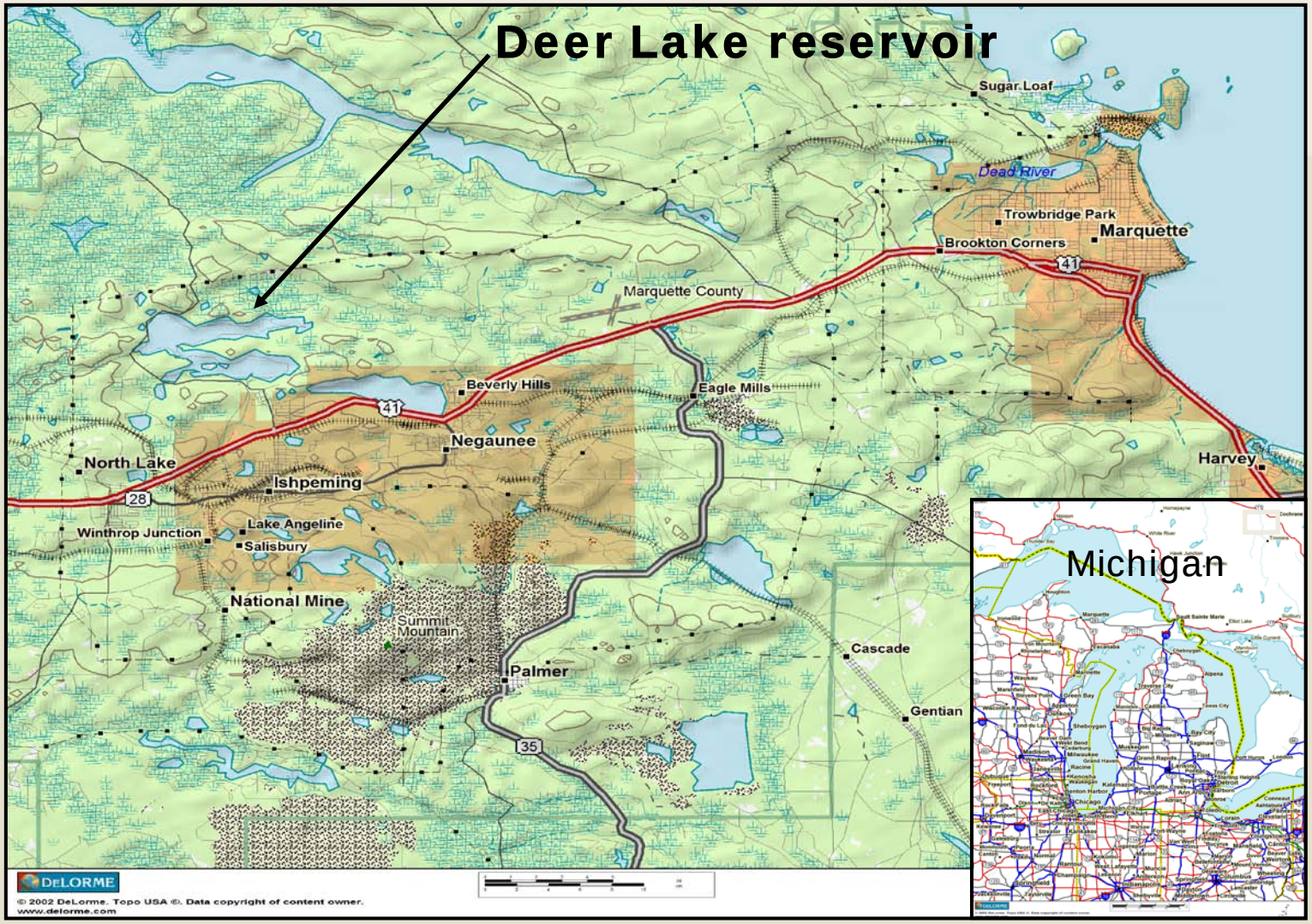
Deer Lake is a Great Lakes Area of Concern (AOC)



Deer Lake AOC is connected to Coastal Lake Superior

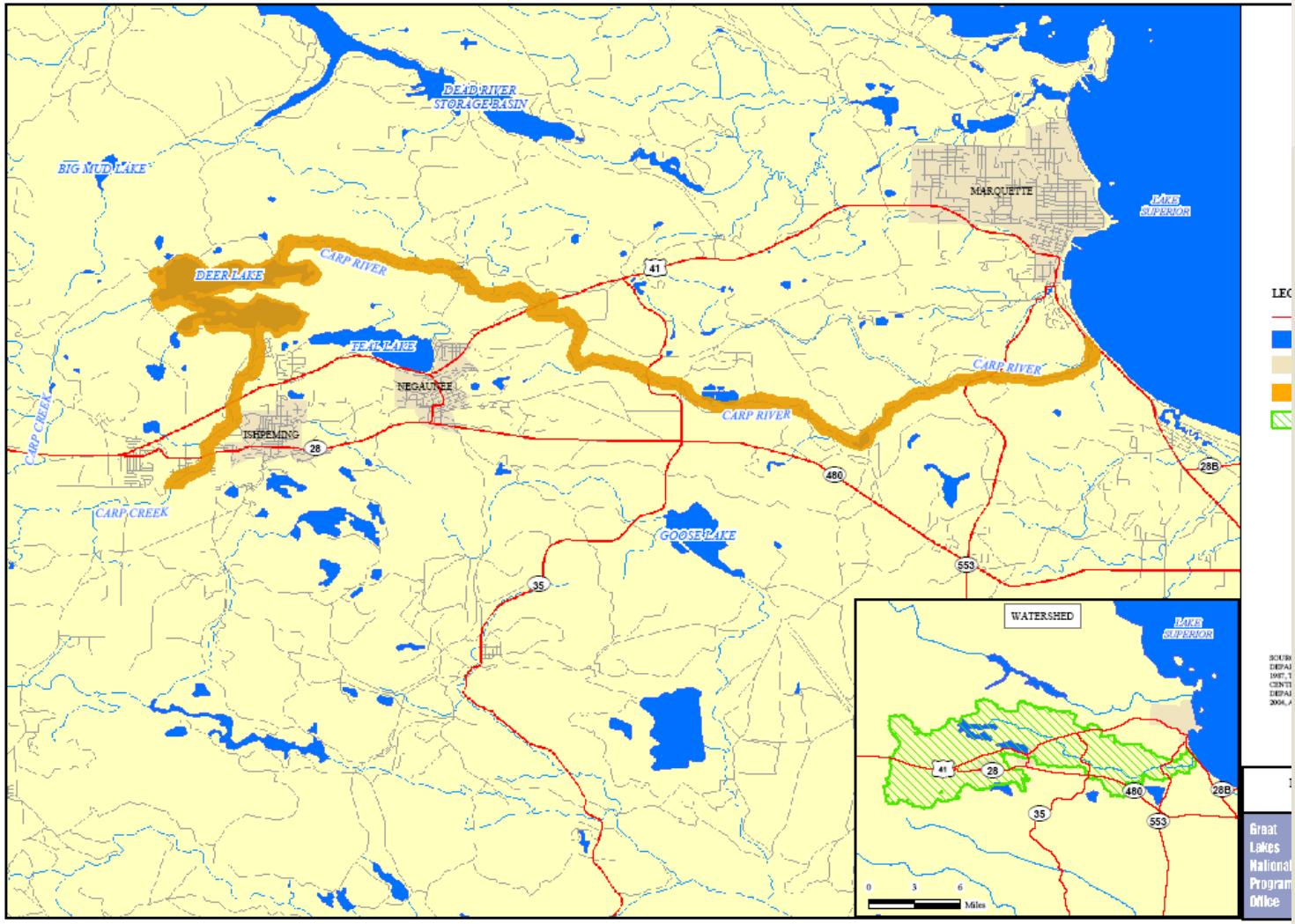
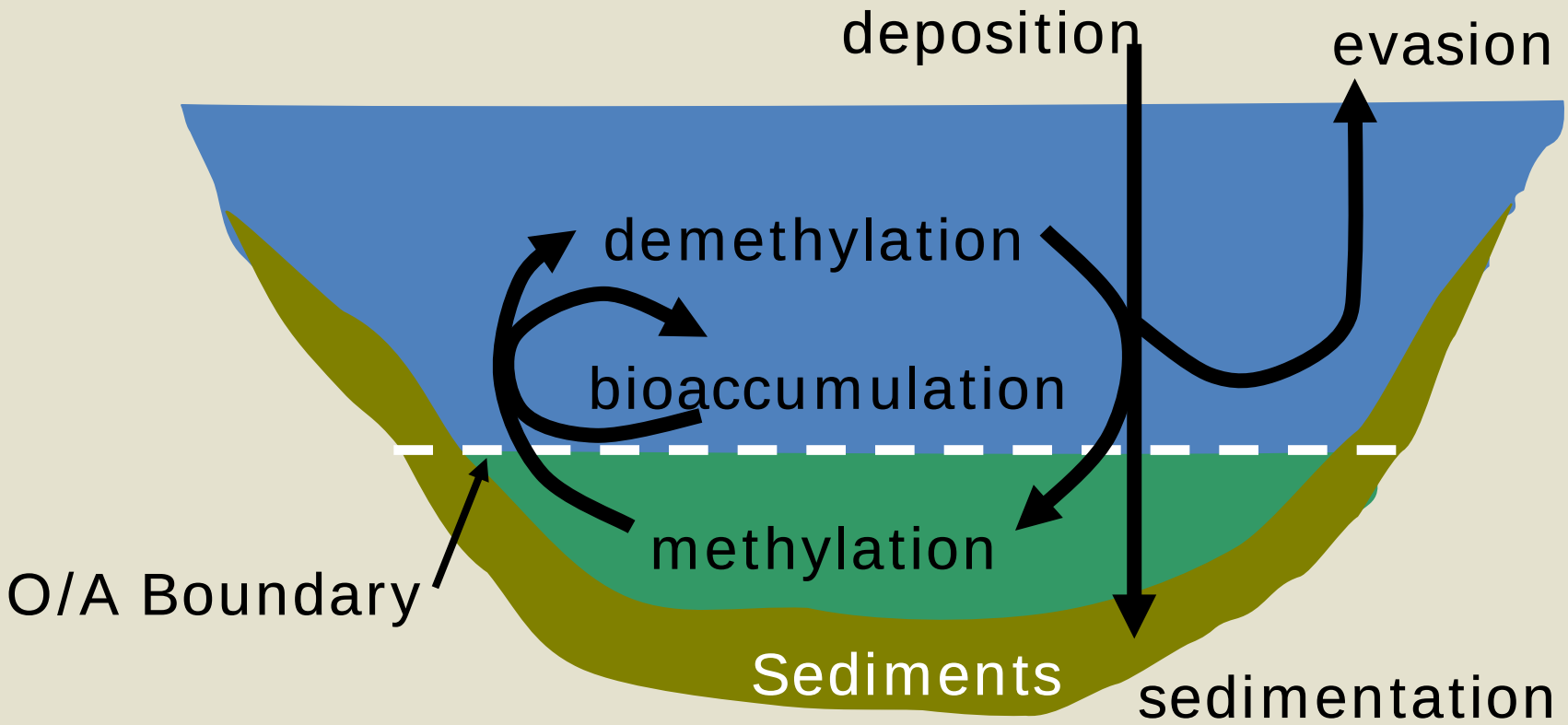
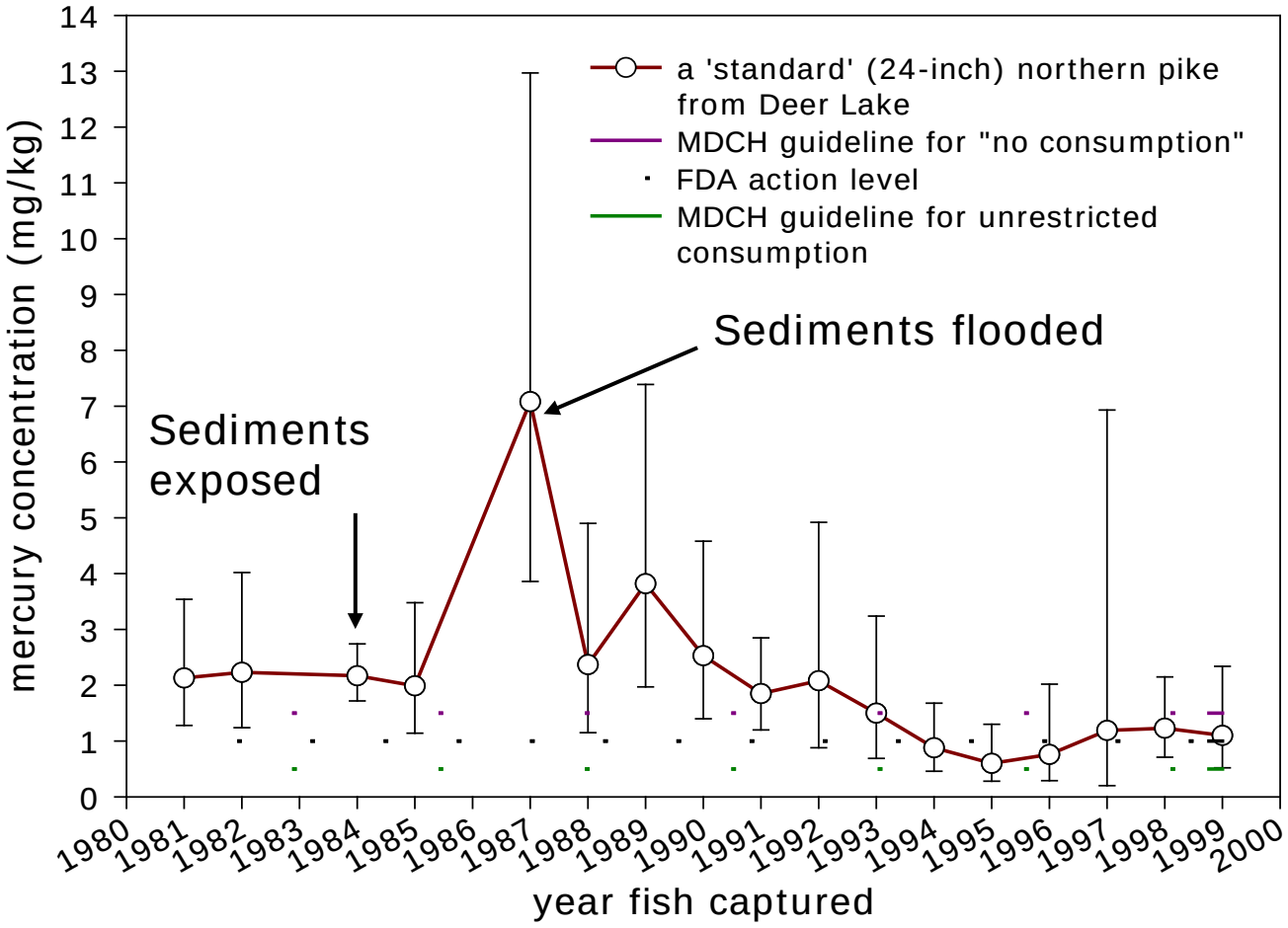


Image of Deer Lake reservoir

Mercury Cycling Model (Watras & Huckabee 1994)

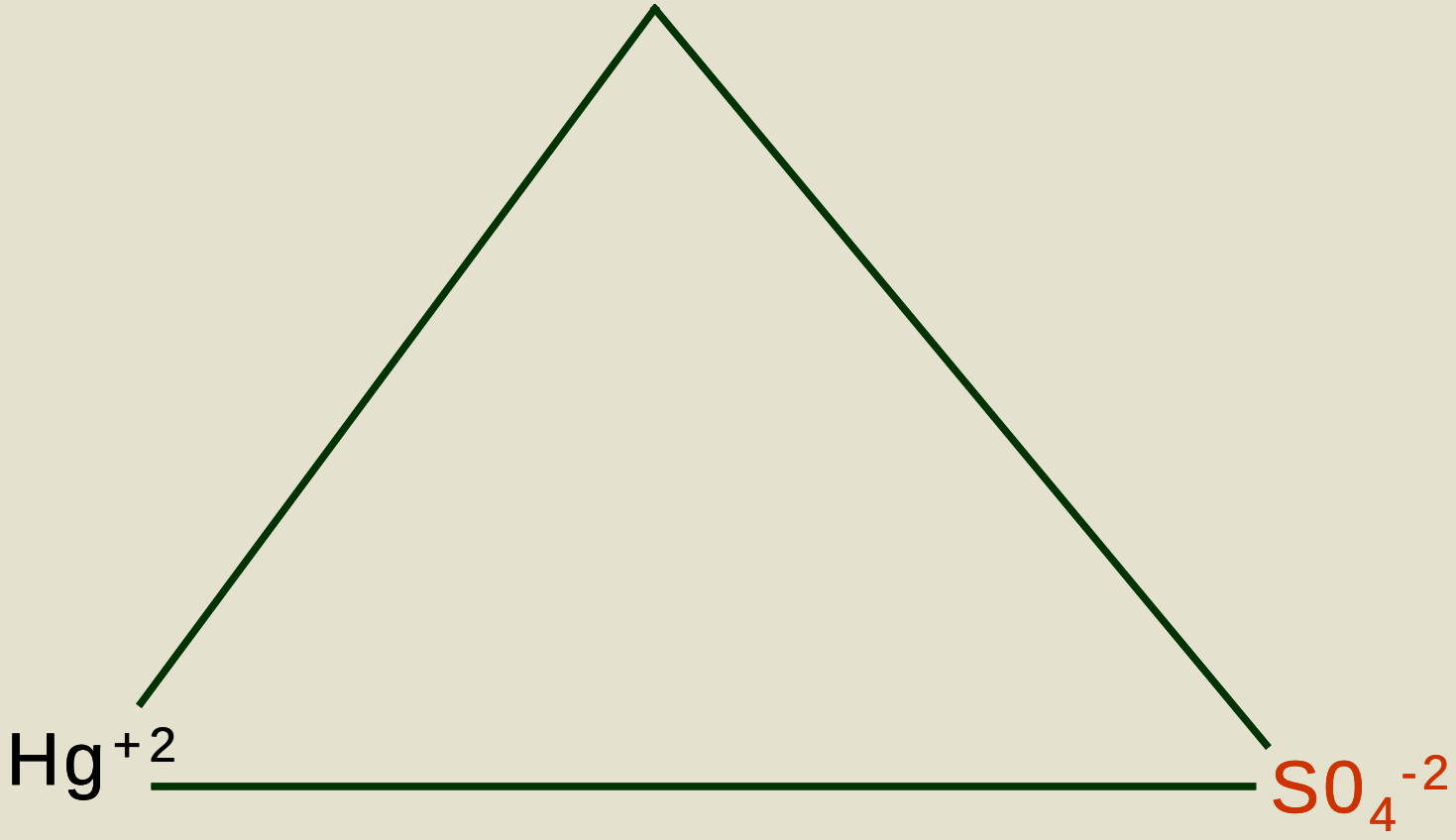


New flooding increases mercury methylation



3 critical requirements for mercury methylation

Anaerobic (sulfate-reducing) bacteria

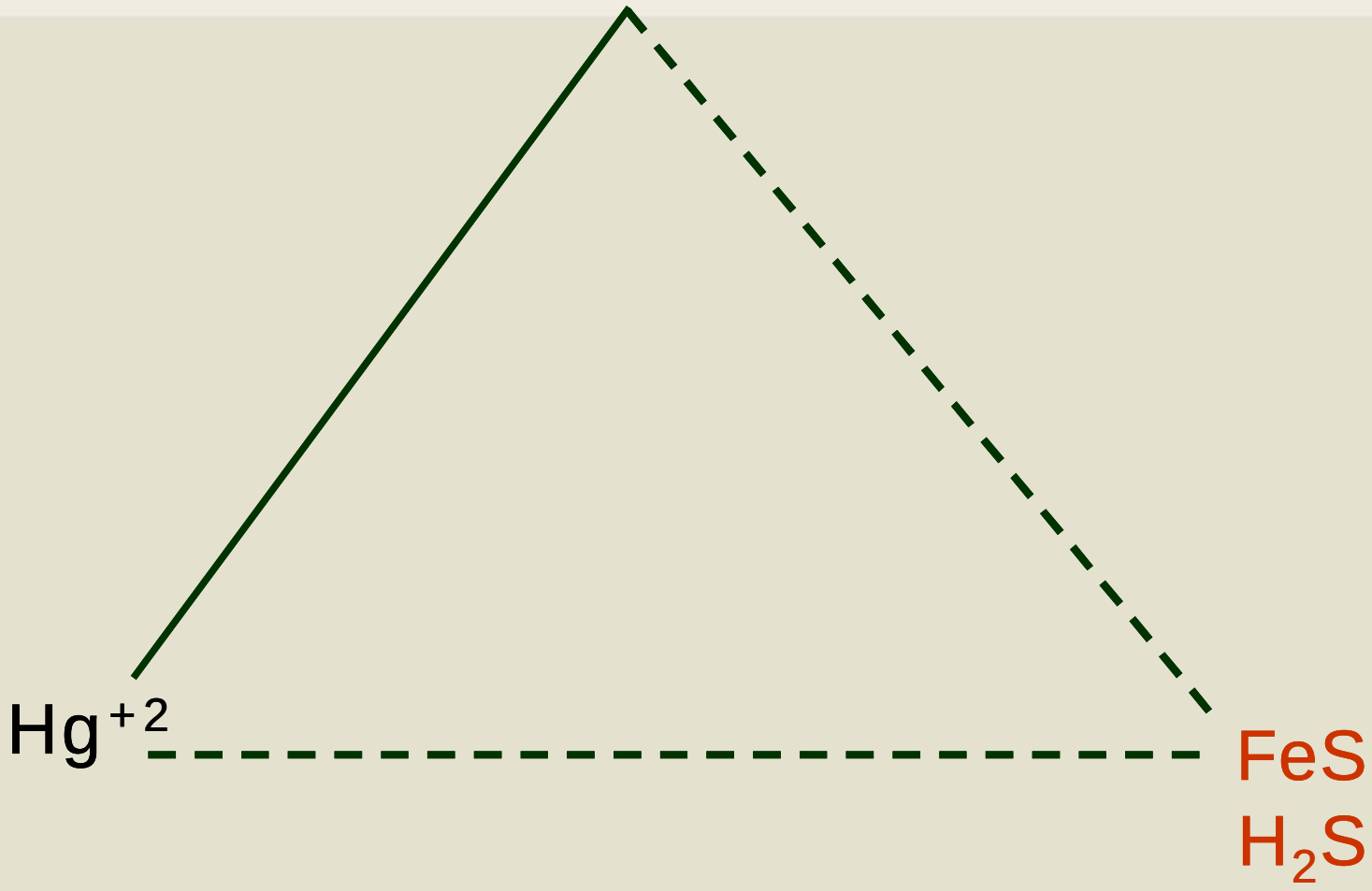


Objective was to minimize net mercury methylation

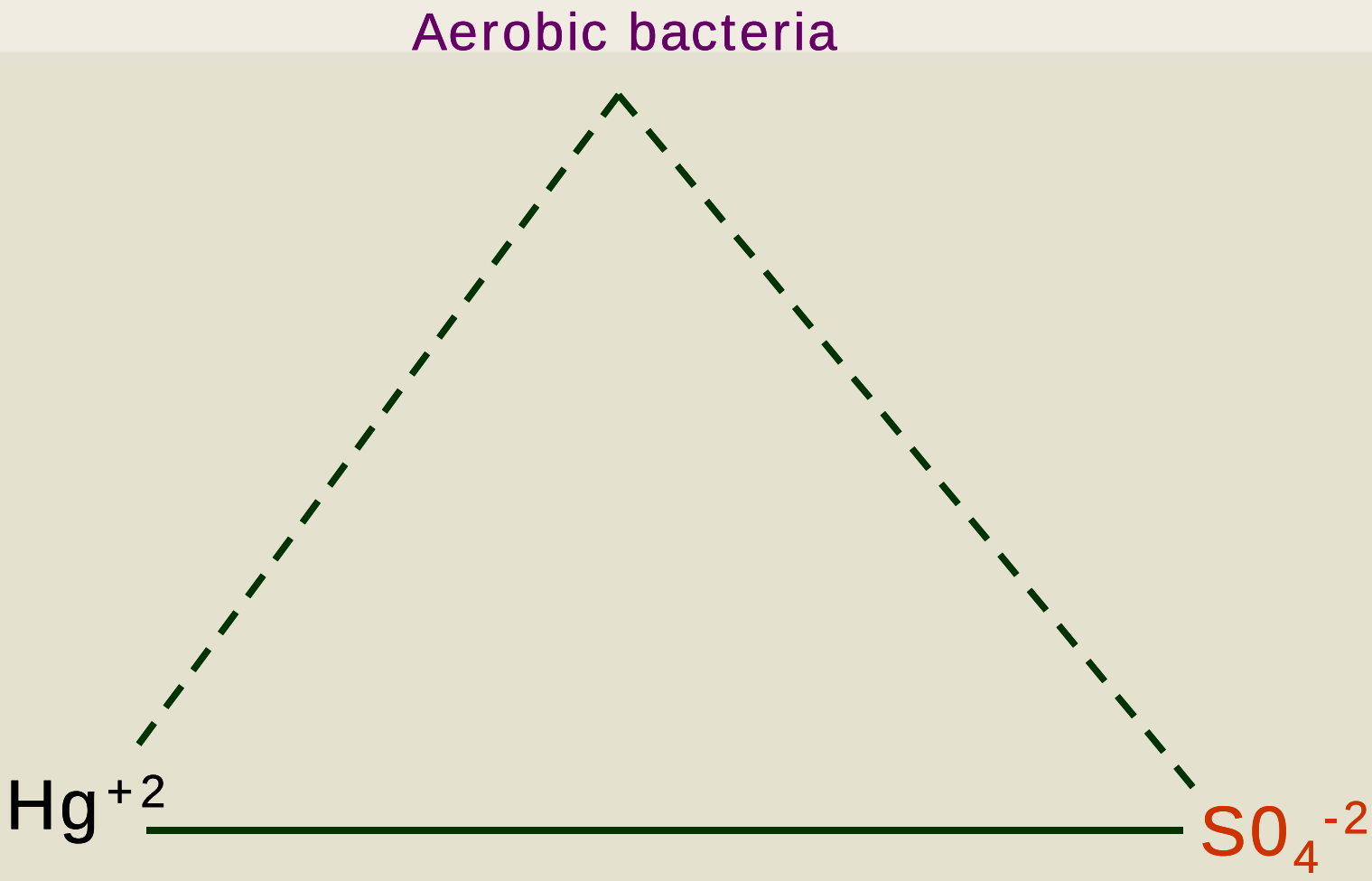
- Sediment - Maintain a “full” reservoir condition to minimize sediment-based nutrients (sulfate) for mercury-methylating bacteria
- Water Column - Release cold water through the valve before oxygen is consumed (anaerobic)
  - Higher oxygen content minimizes the growth of methylating bacteria
  - Higher oxygen content maximizes the growth of de-methylating bacteria

Sediment - maintain stable sulfides & “starve” SRB

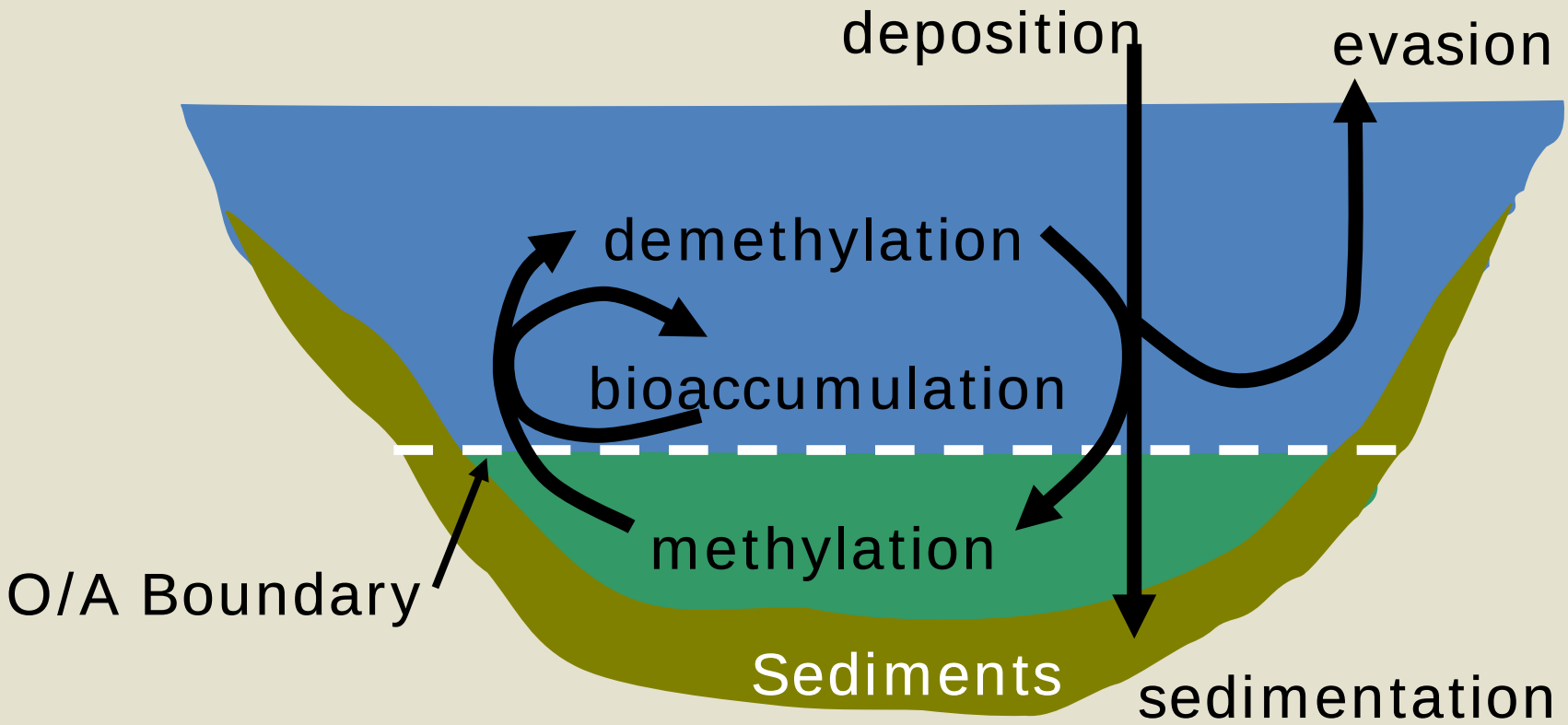
Anaerobic (sulfate-reducing) bacteria



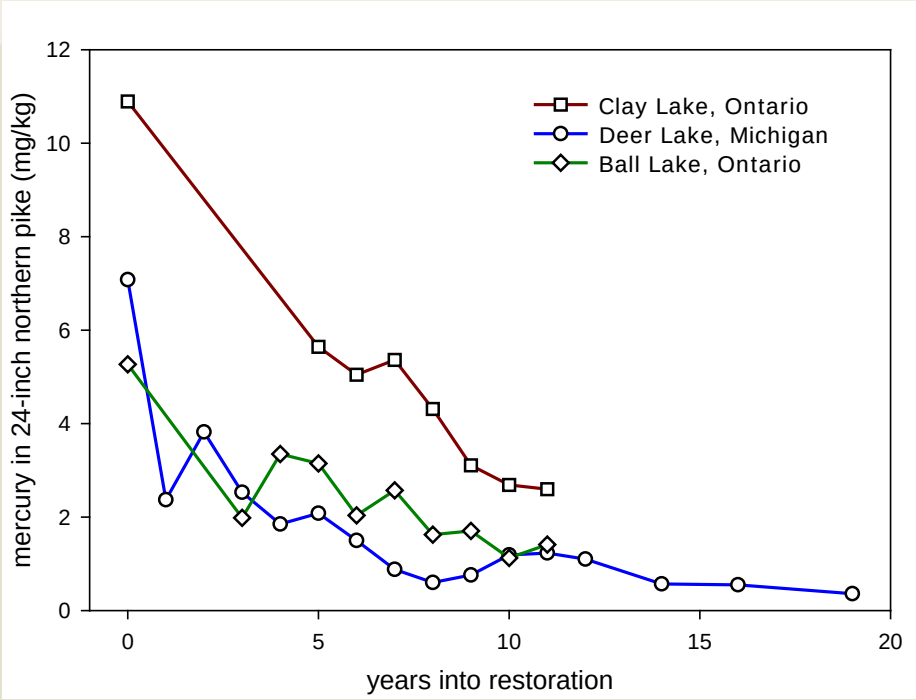
Water - maintain aerobic conditions & SRB cannot compete for carbon



Make Blue Large and Green Small
Move O/A Boundary to Sediment/Water Interface

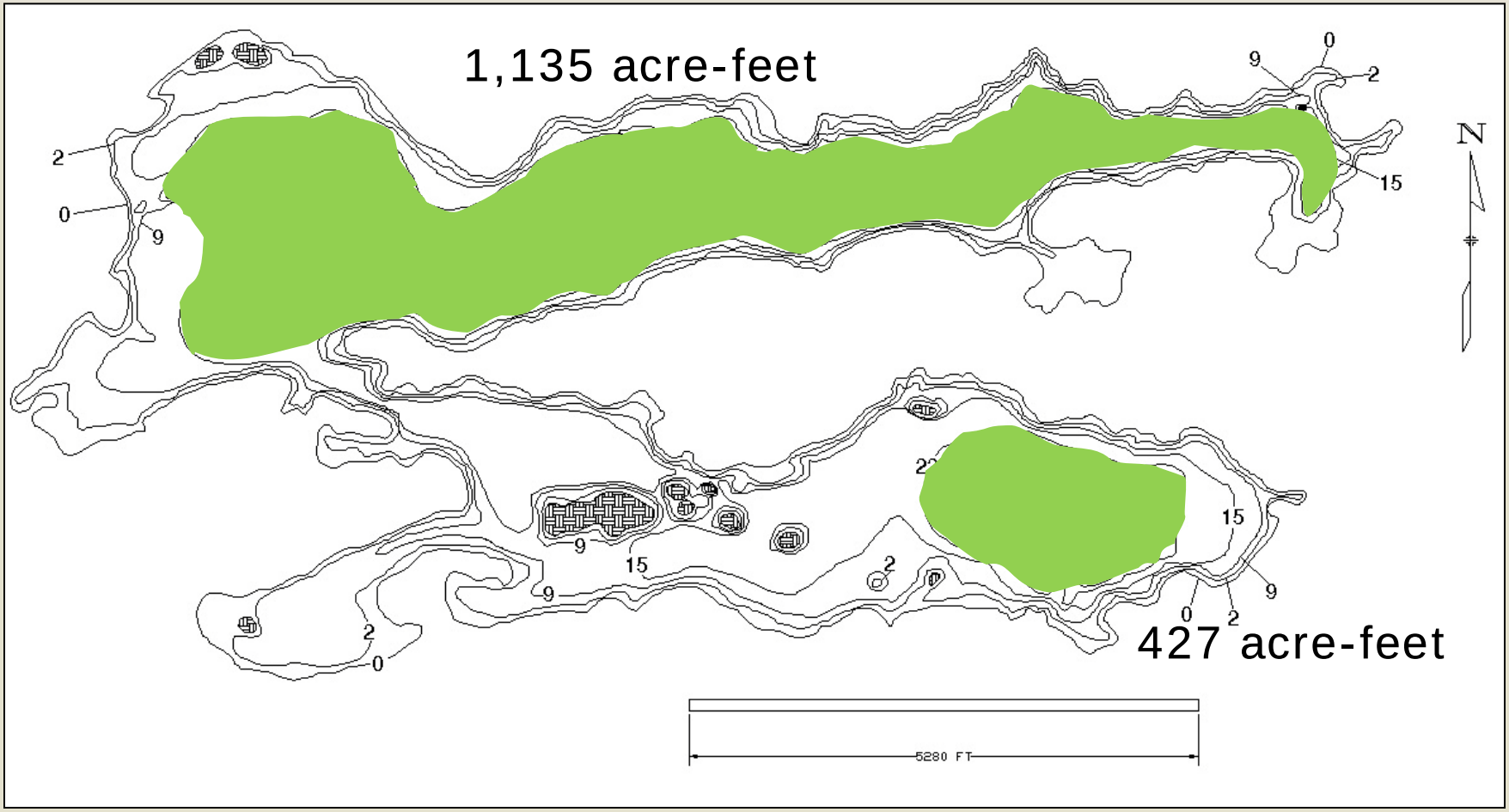


Northern pike say that source control + SRB starvation work quite well

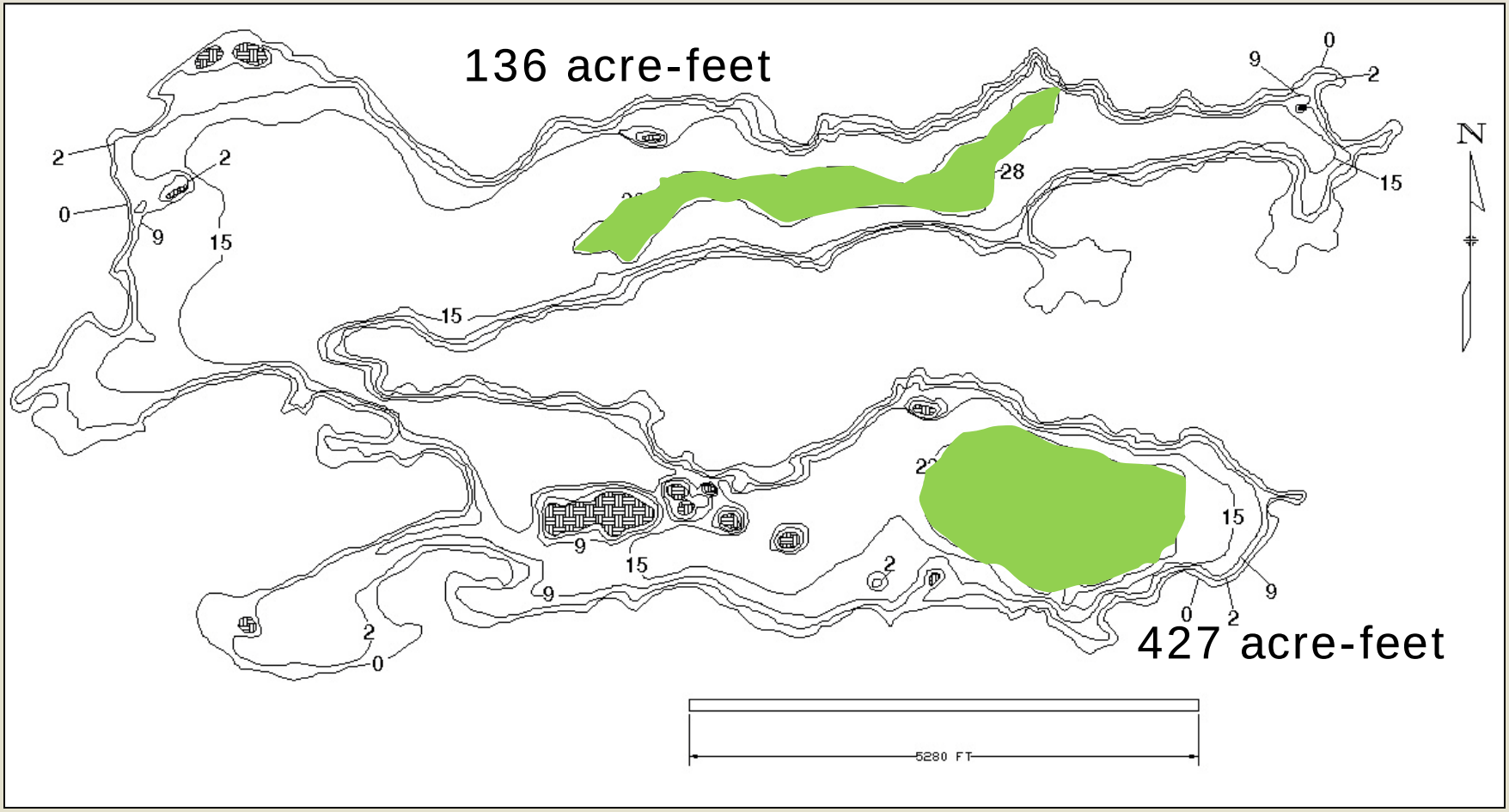


Water Column Management: bottom water release

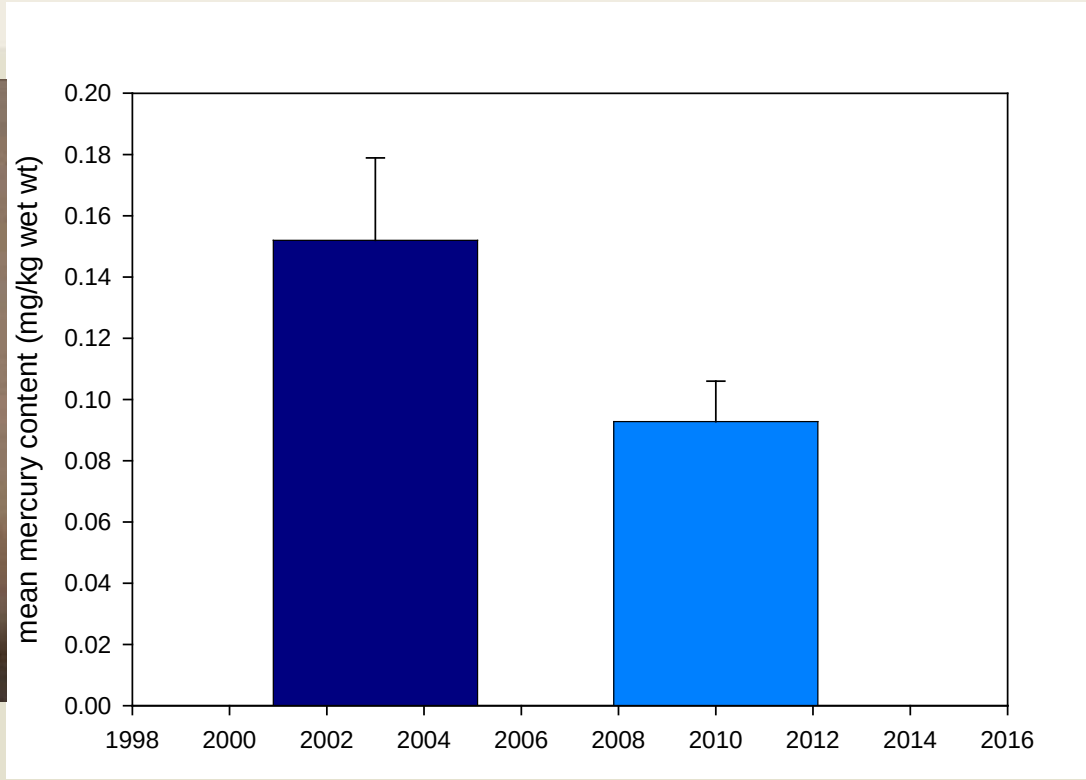
Valve closed: 3,400 mg methyl mercury per year



Valve open: 2,000 mg methyl mercury per year



Yellow perch say that bottom water discharge works quite well



What does Deer Lake tell us that applies elsewhere?

- Flooded soils and wetlands typically generate and export methyl mercury

- Aquatic habitat management can control mercury methylation
  - Microbial habitat (aerobic vs anaerobic)
  - Sulfur cycling (sulfate vs sulfide)
  - Carbon, Nitrogen and Phosphorus loading matter

- If mercury is an issue in sediments and/or fish
  - Recommend a stable water level (run-of-river)
  - Recommend bottom- water discharge

- Reservoirs, if properly managed, are methyl mercury sinks
  - Deer Lake keeps 80% of the mercury from its watershed out of the coastal zone of Lake Superior

What is the sustainability message?

- United Nations Brundtland Commission (June 1987) defined Sustainable Development as

"…meets the needs of the present without compromising the ability of future generations to meet their own needs"

- Global Reporting Initiative (GRI)
  - International framework for reporting environmental, social and economic performance (triple bottom line)
  - Developed in response to the EXXON Valdez oil spill in 1989 by Ceres, an association for investors
  - Assumes if we manage for sustainable performance, disasters will be avoided
  - United Nations Environment Programme (UNEP) joined forces with Ceres in 1990
  - GRI spun off as an independent organization in 2001
  - Third generation guidelines (g3) released in 2007

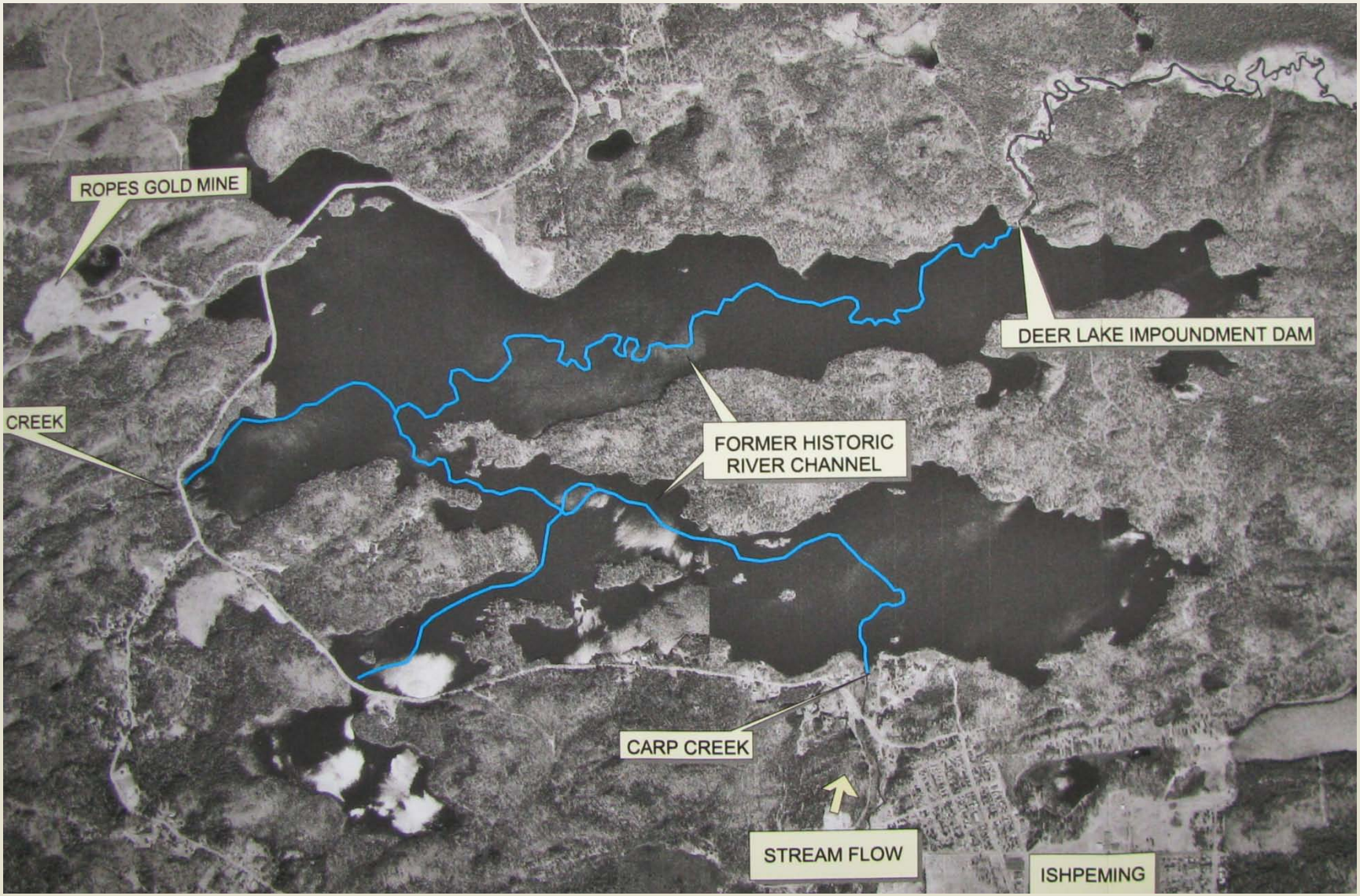
The GRI g3 has six indicator protocols

- Economic & Financial
- Environmental
- Social
- Labor Practices & Human Rights
- Communication & Public Relations
- Product Service & Responsibility

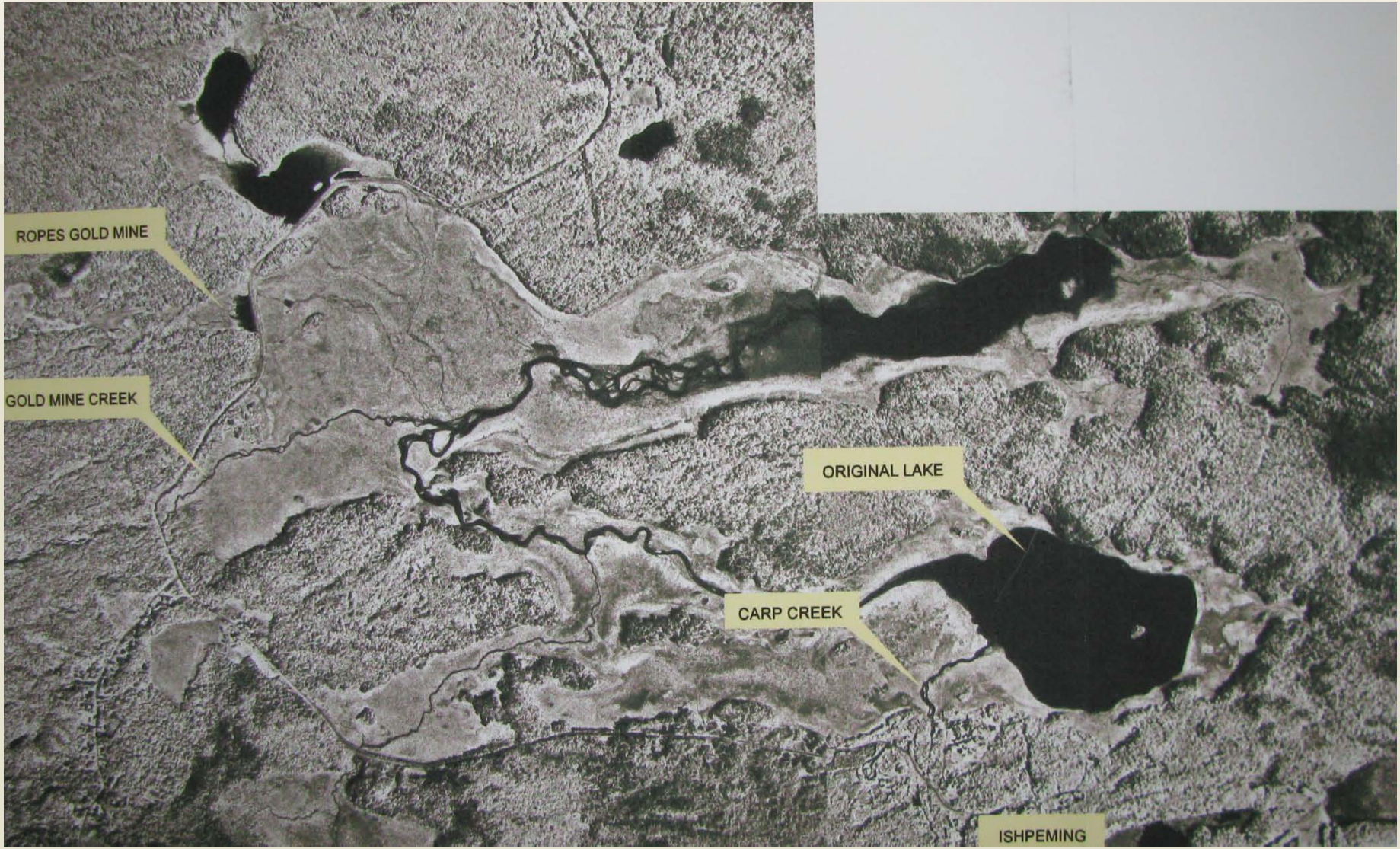
Economic & Financial Performance Comparison

- Managed Reservoir
  - $50,160,000 property value
  - $37,000 annual fishery value
  - Full-time mining jobs maintained
- Drained & Dredged
  - $10,505,500 property value
  - $1,040 annual fishery value
  - Full-time mining jobs lost
  - Part-time construction jobs gained

Deer Lake at normal pool



Deer Lake drawn down



Environmental Performance Comparison

- Managed Reservoir
  - 1,010 acre lake
  - Methyl mercury budget
    - ~9 g input
    - ~2 g in-lake
    - ~2 g to Lake Superior
  - 1,516 acres land protected
    - 34,000 feet shoreline
    - 4.5 river miles
  - 1,645 gallons diesel
  - 10,225 miles driven
  - 16,615 kg CO_2
- Drained & Dredged
  - 90 acre lake
  - Mercury budget (est)
    - ~9 g input
    - ≥2 g in basin
    - ≥ 11 g to Lake Superior
  - No land conservation
    - 4 river miles restored
  - 901,204 gallons diesel
  - 7,389,144 miles driven
  - 9,102,160 kg CO_2

Social Performance Comparison

- Managed Reservoir
  - Human health protected
  - ≤14 miles from population center to excellent walleye fishery
  - Trout stream protected
  - 40 personal vehicle trips of traffic over 30 years
- Drained & Dredged
  - Human health protected
  - 53 miles from population center to excellent walleye fishery
  - Trout stream vulnerable
  - 29,320 semi-truck trips of traffic over 8 years

Summary

- Reservoirs can be managed to control methyl mercury in fish
  - Microbial communities can be managed by manipulating habitat
  - Nutrients are also important
  - Sediment, wetland and water column habitats need to be considered in a comprehensive plan
- Recommendations for methyl mercury management
  - Stable pool preferred over fluctuating water level
  - Run-of-river hydraulic regimens are preferred
  - Bottom water release is generally preferred
- The GRI g3 is a useful sustainability assessment tool
  - Flexible self-reporting method
  - Gaining acceptance in the private sector, used to communicate p
  - Useful for comparing options and communications

Thank You

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