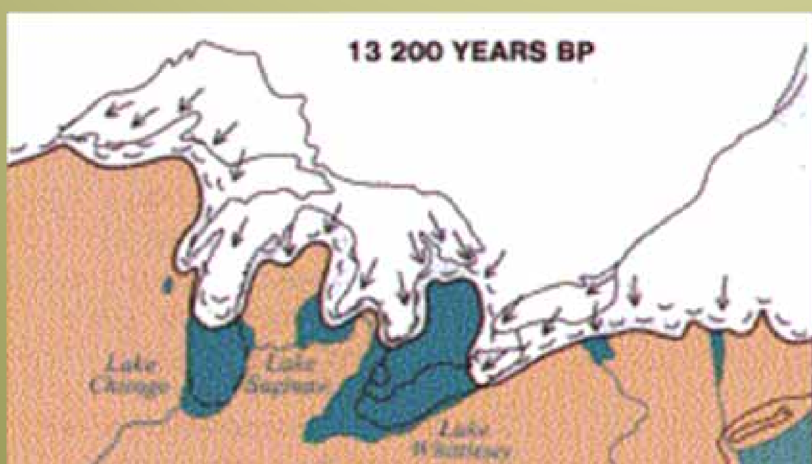
WISCONSIN LAKES

Courtesy of Lake Partnerships

Wisconsin Department of Natural Resources
Wisconsin Association of Lakes
University of Wisconsin Extension

Definitions & Background

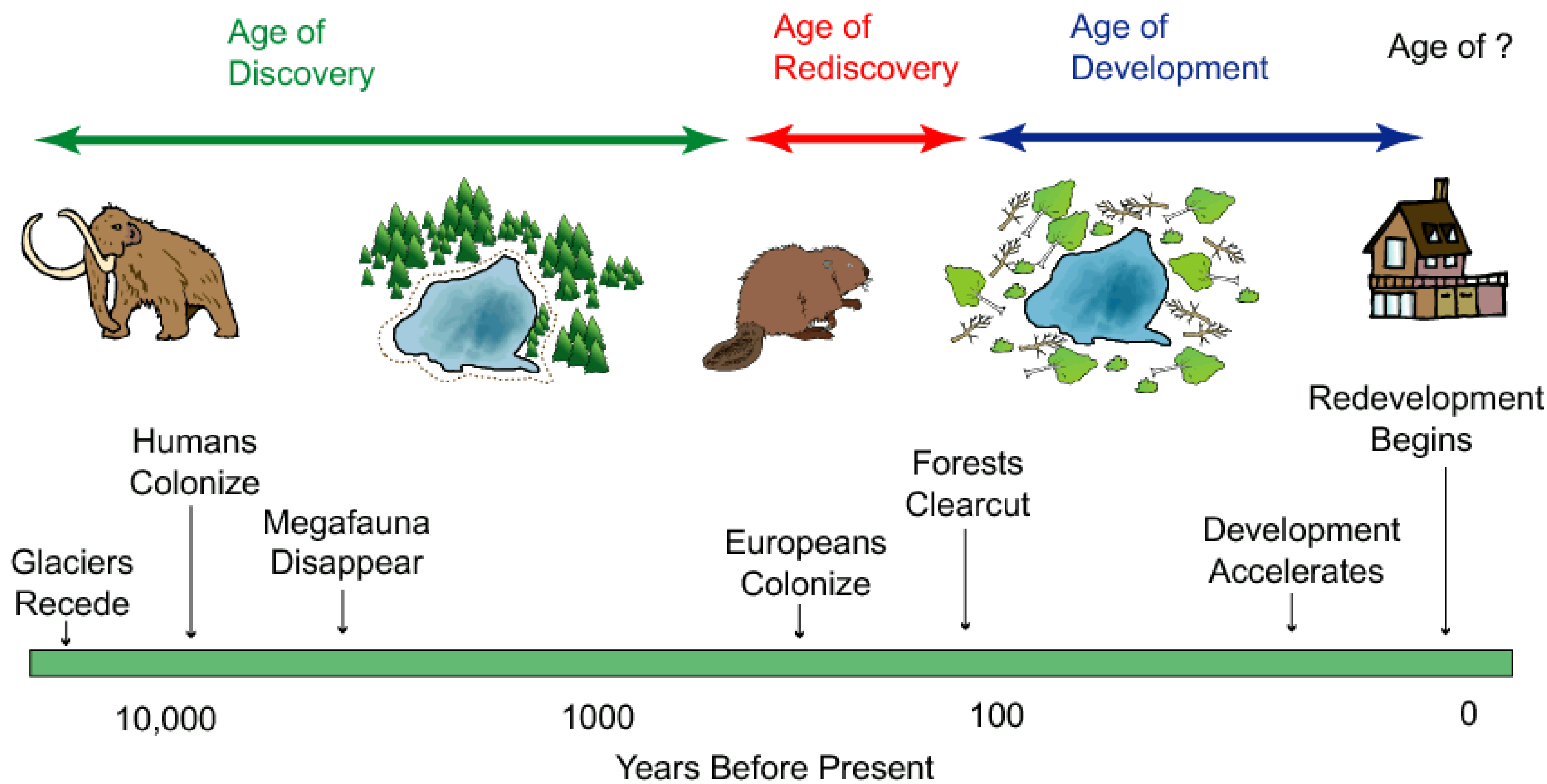
Wisconsin's Glacial Legacy



Wisconsin's lakes

Wisconsin has one of the largest concentration of fresh water glacial lakes on the planet.

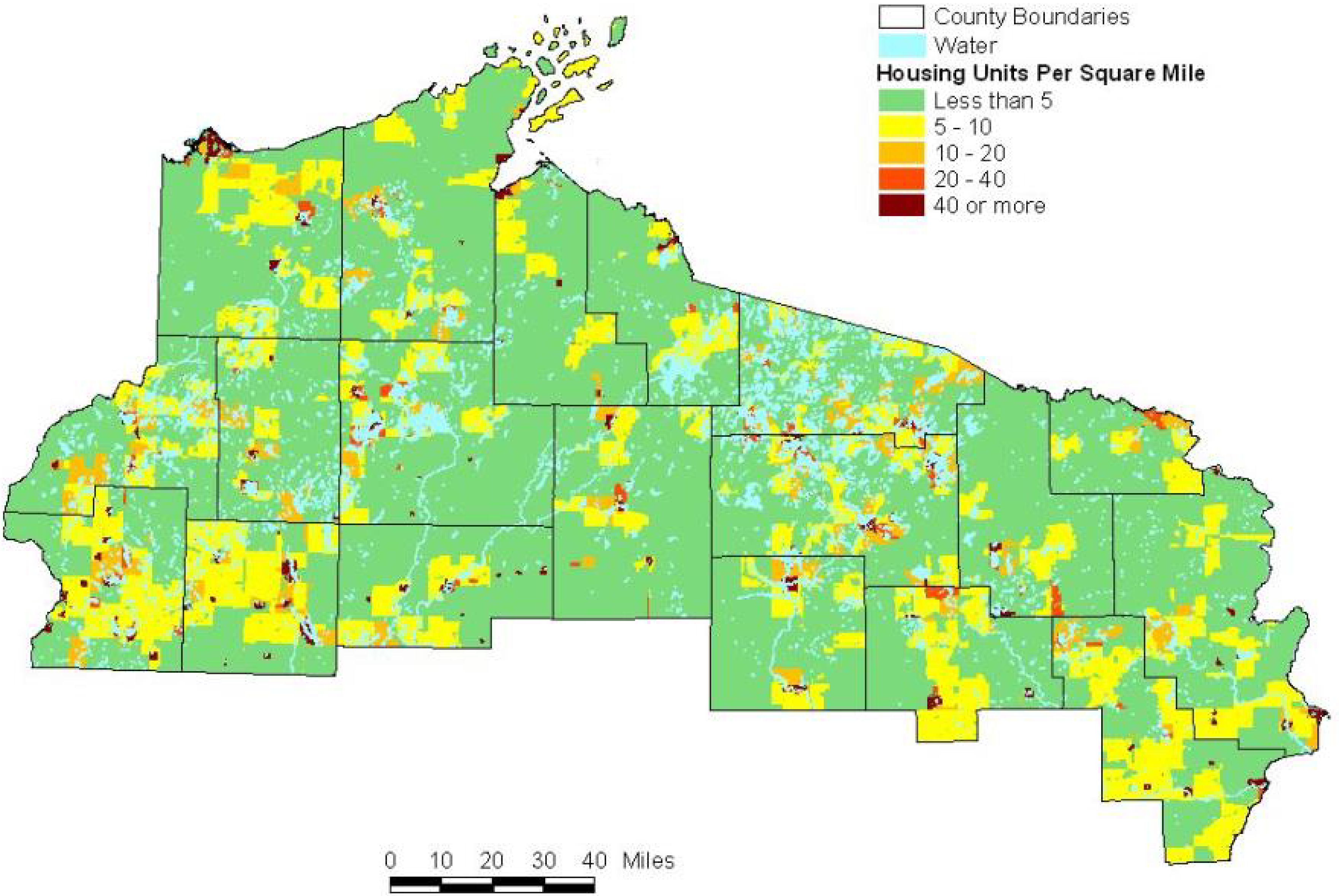
Recent History of Wisconsin's Lakes



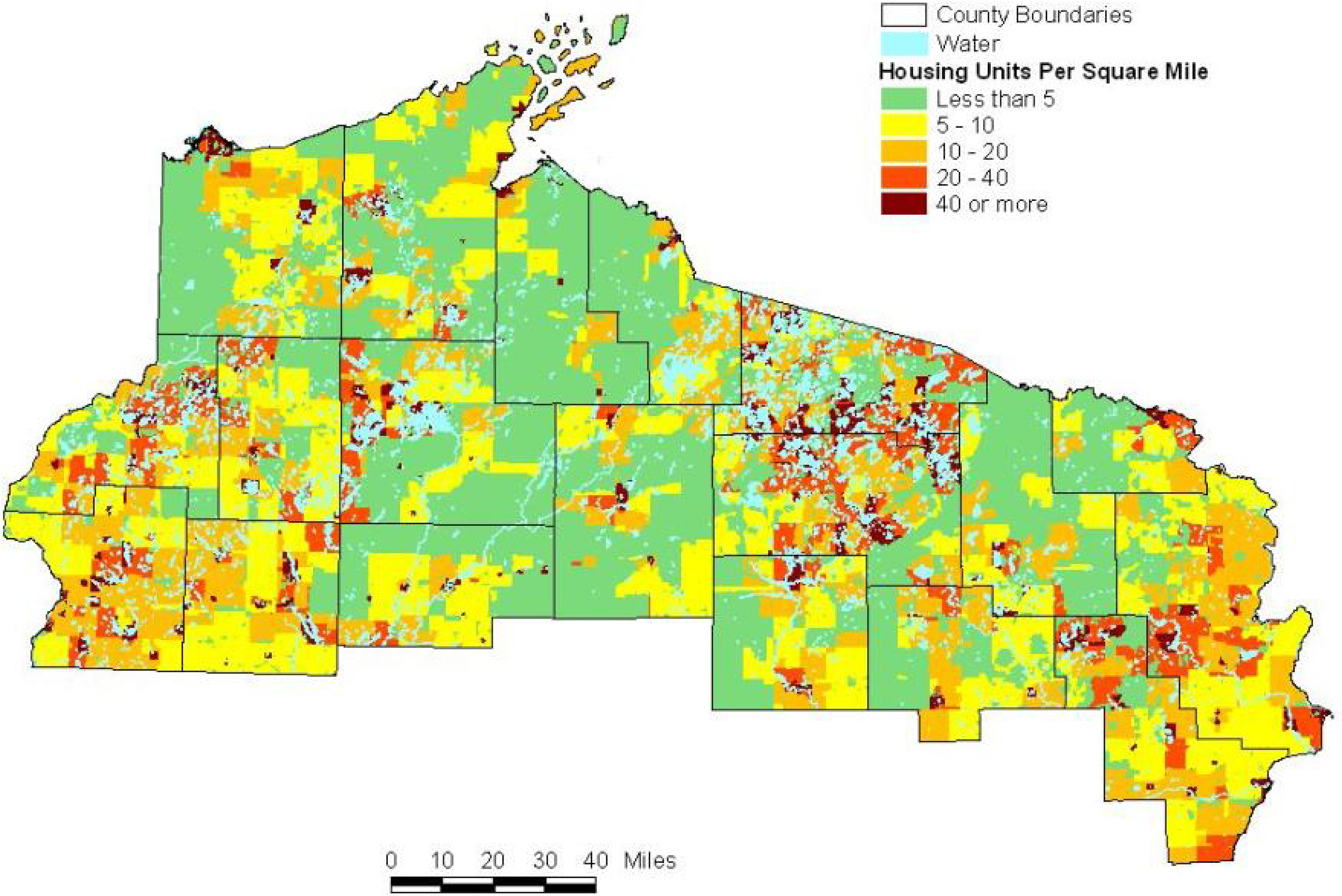
Steve Carpenter


Lakes Provide Services
Ecosystem
Cultural
Societal
Sara Schmidt
07/08/2004
Sara Schmidt

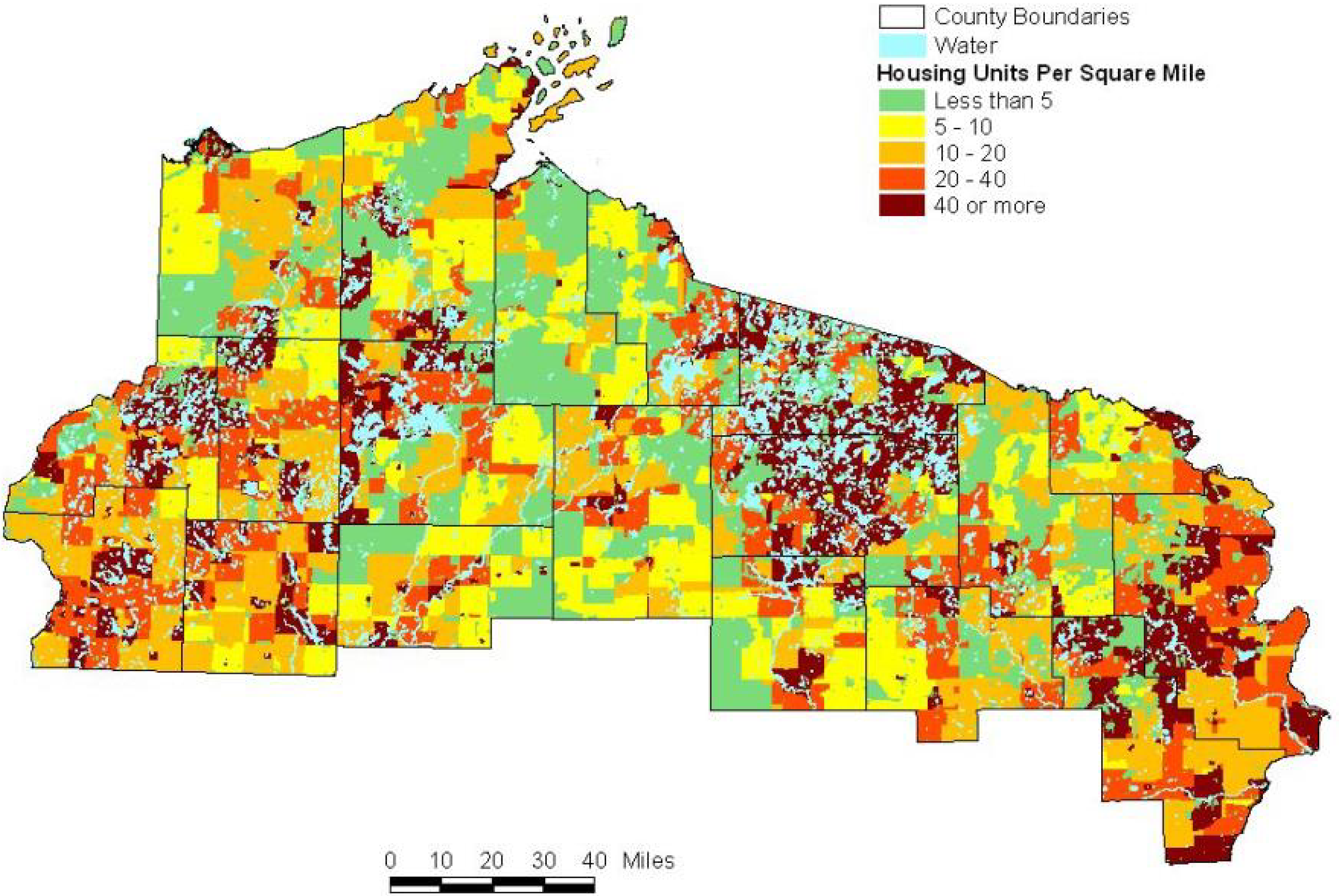
1940 Housing Density by Partial Block Group



1990 Housing Density by Partial Block Group



2010 Housing Density by Partial Block Group
Rural Renaissance Forecast



Wisconsin's Lakes are Changing Faster than Ever:

Algae blooms
(phosphorus pollution)

Destruction of
shoreline habitat

Invading plants and
animals

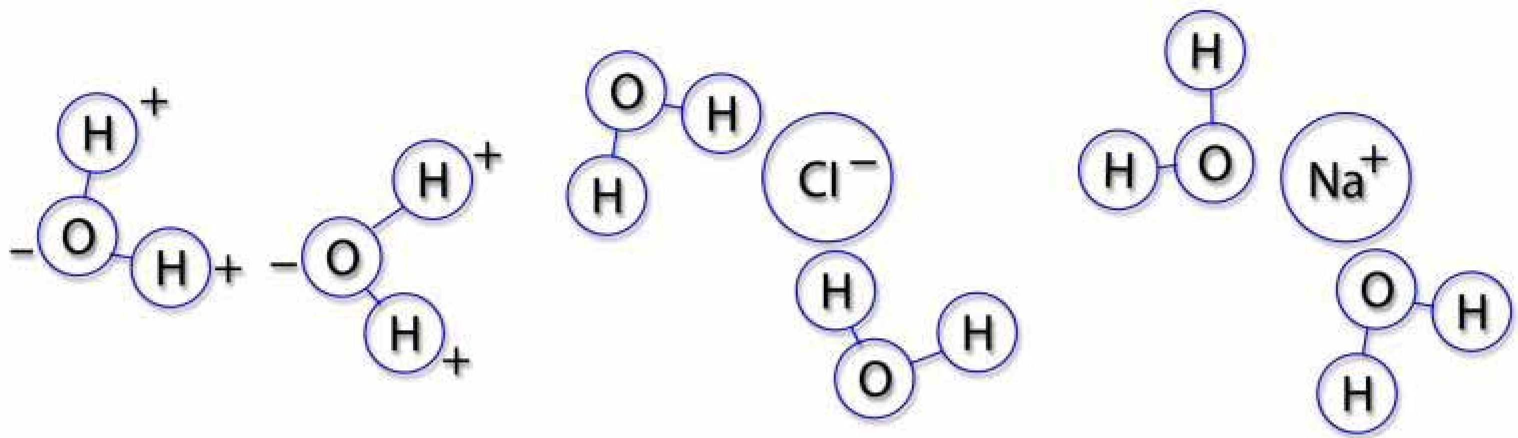
Steve Carpenter

OVERVIEW

- **Unique Properties of Water**
- Lake Types
- Physical, Chemical, Biological and Habitat Characteristics
- Technical Aspects

UNIQUE PROPERTIES OF WATER

- **Universal Solvent**
- **Chemical Molecular Structure H20**
- **Greatest Density at 4º C or 39º F**



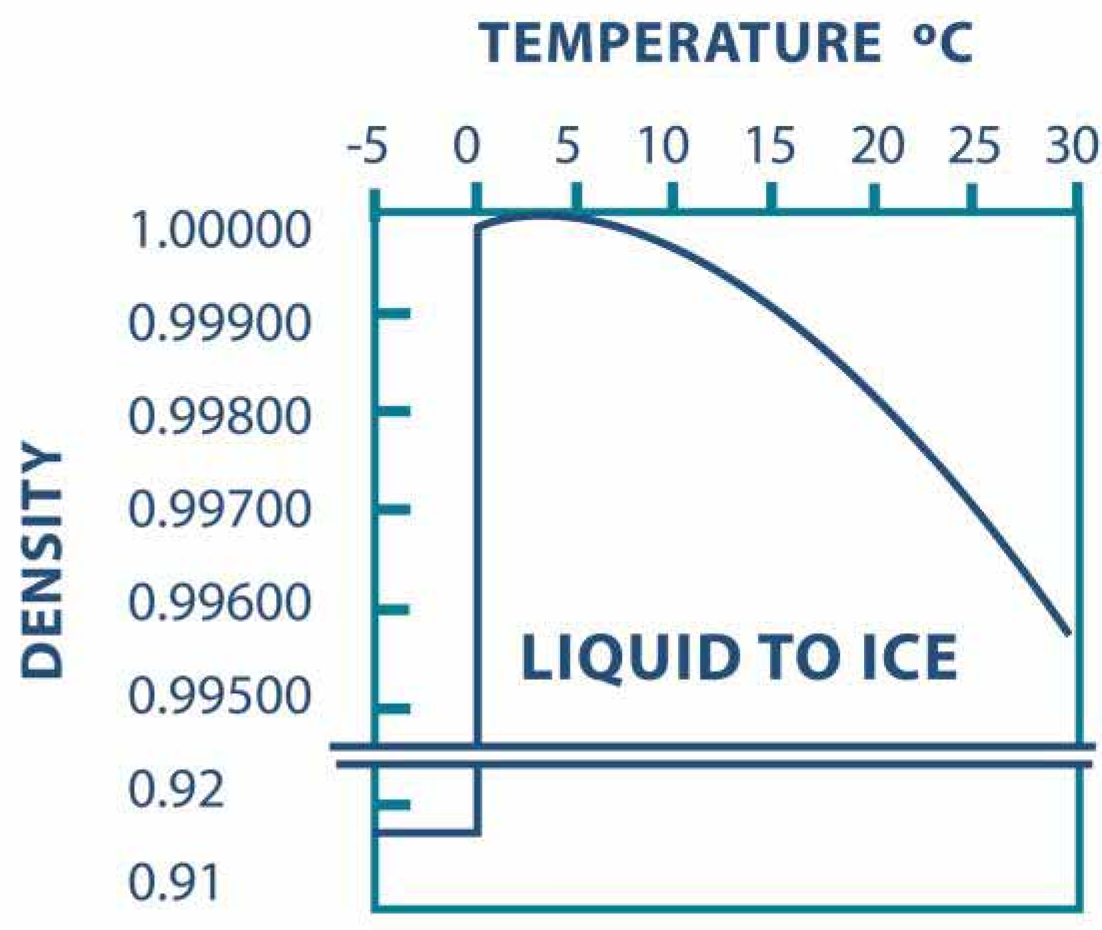
Unique Properties of Water

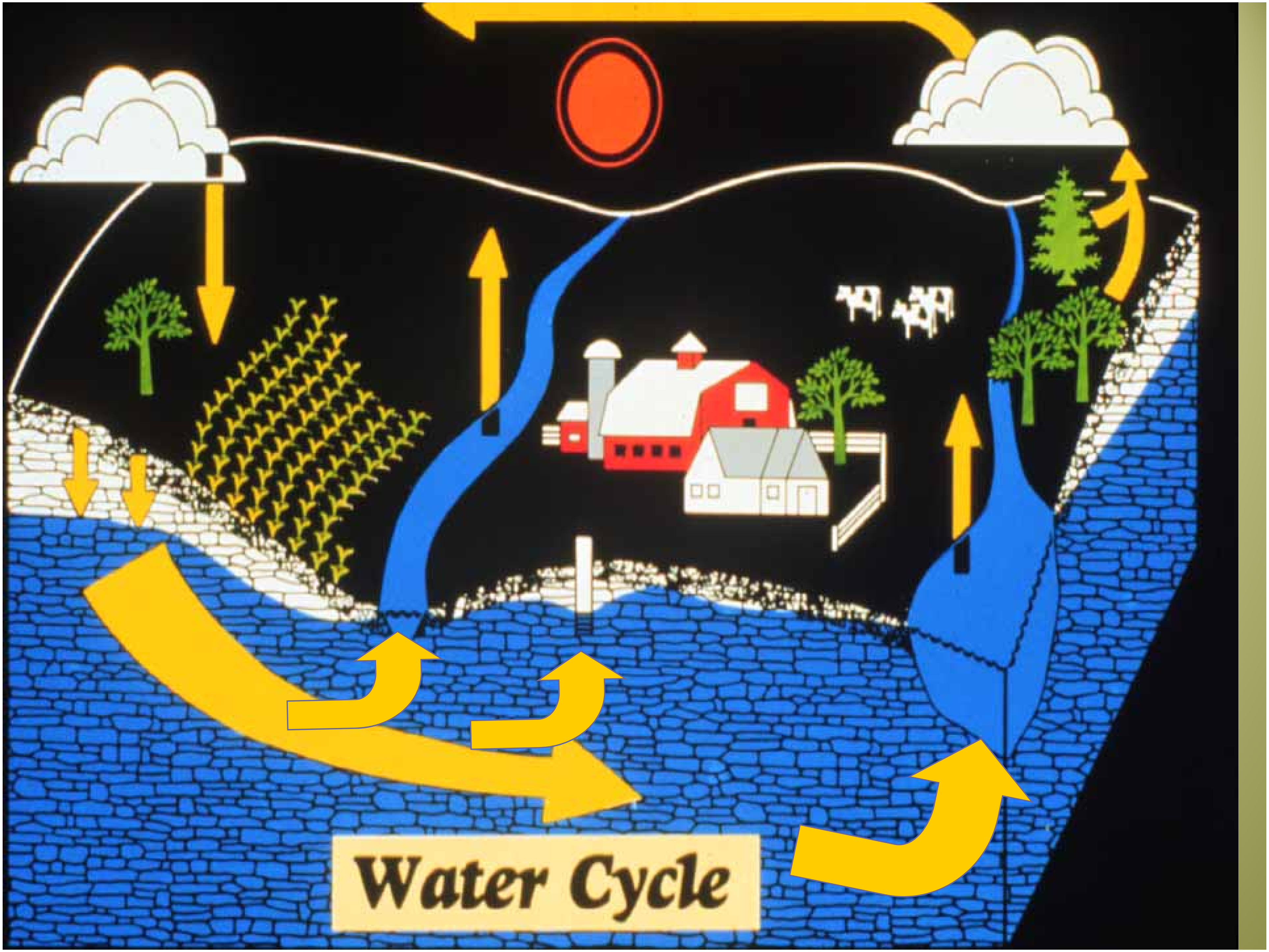
- Living organisms (including us!) are ~70% water
- 71% Earth's surface covered by water
- <1% water on Earth is freshwater
- .009% water on Earth is freshwater lakes

From waterencyclopedia.com

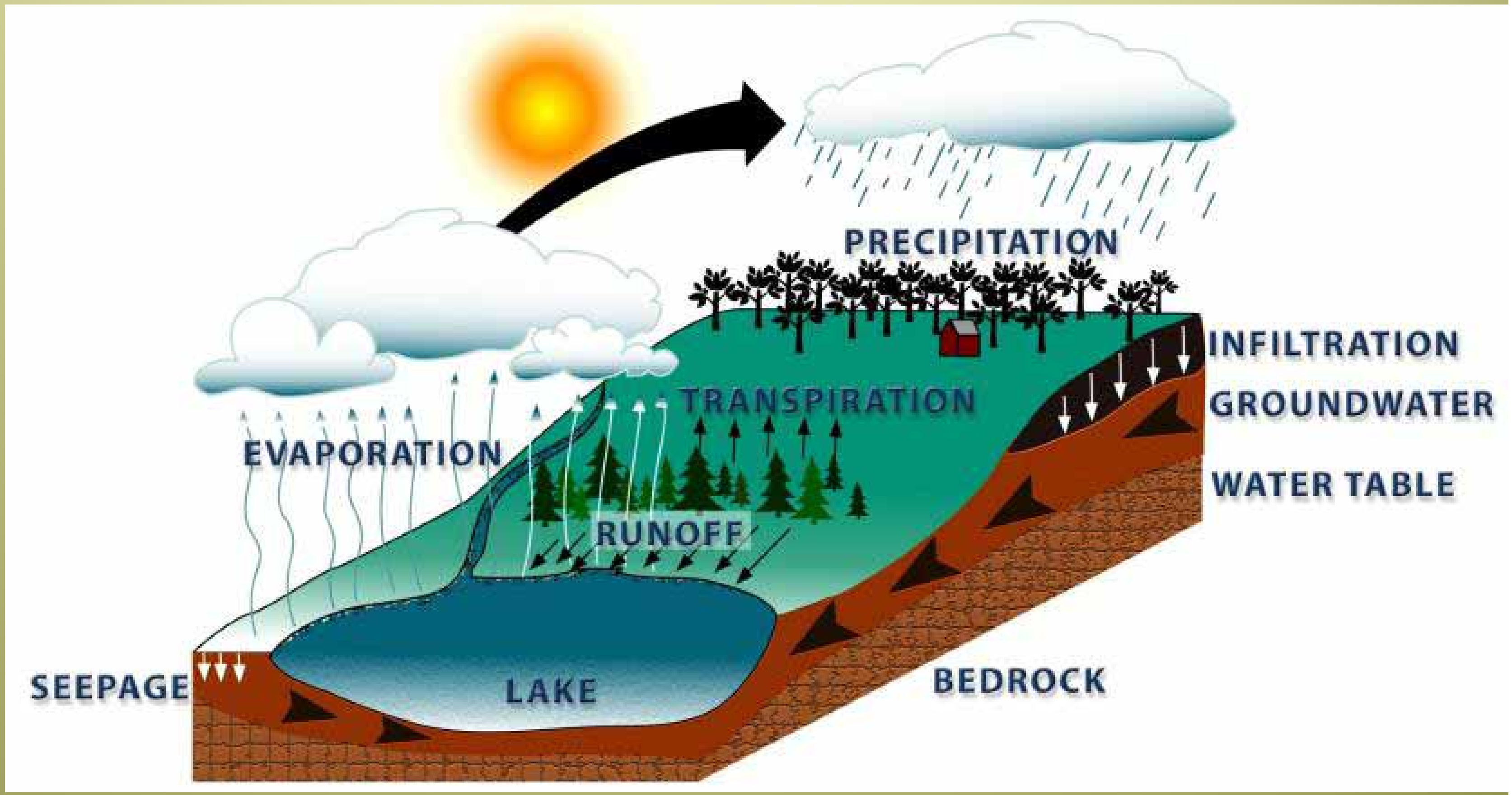
UNIQUE PROPERTIES OF WATER

- Physical Properties
- 71% Earth's Surface Covered by Water
- <1% Water on Earth is Freshwater
- .009% water on Earth is Freshwater Lakes




Water Cycle

HYDROLOGIC CYCLE



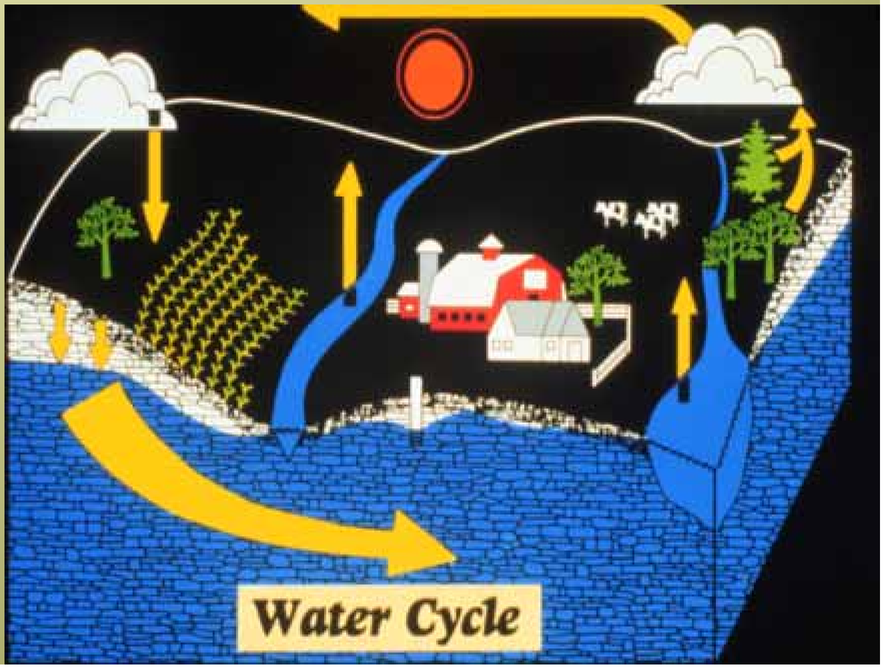

THE WISCONSIN
WATER STORY
32”
32”
20”

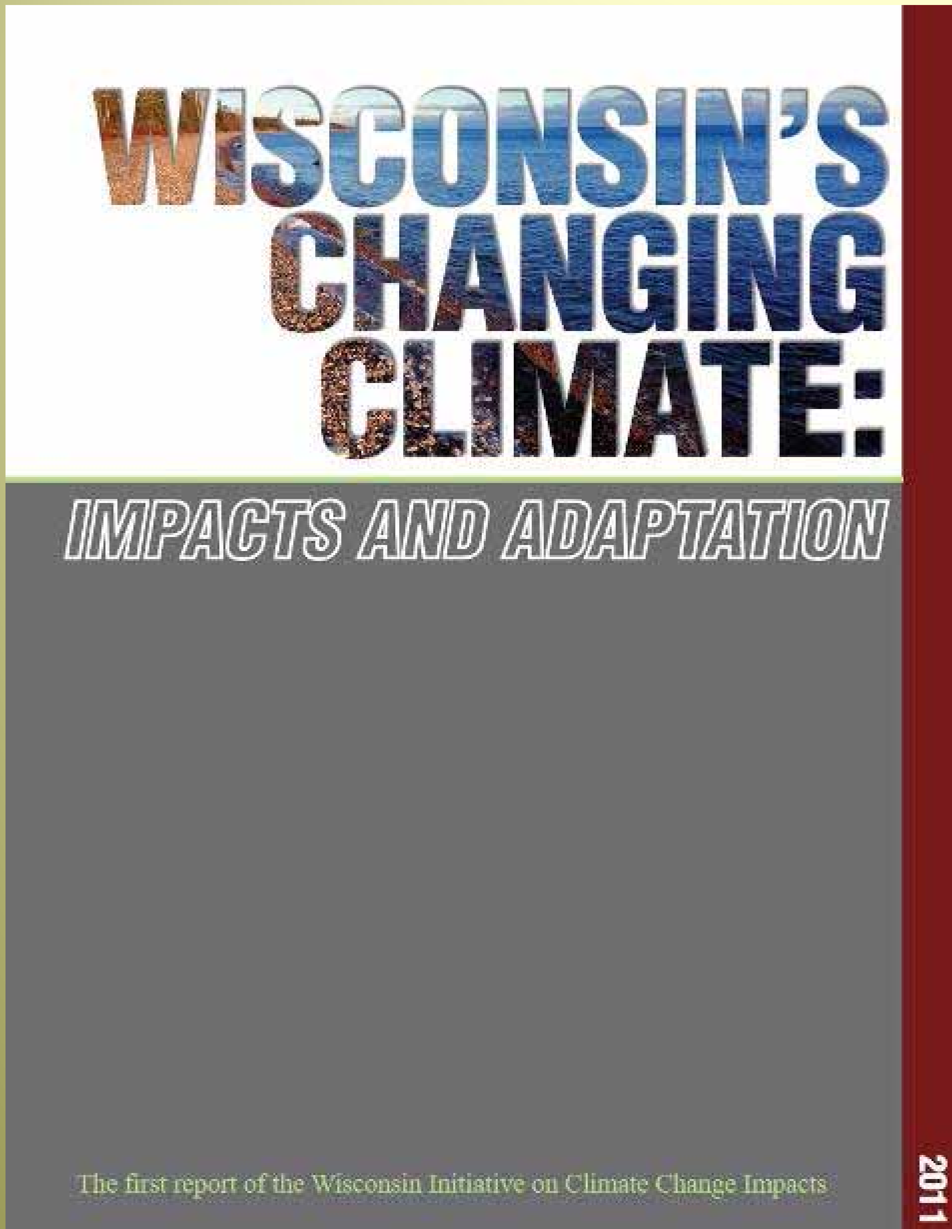
Precip – ***ET*** – ***Runoff***

Change in water table (also lakes and wetlands)

Water In – Water Out = ± Storage

Discharge to streams





WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

WICCI's First Adaptive Assessment Report - released Feb 2011

30+ Authors

10 Editorial Team Members

22 Science Council Members

22 Chairs/Co-Chairs of 15 Working Groups

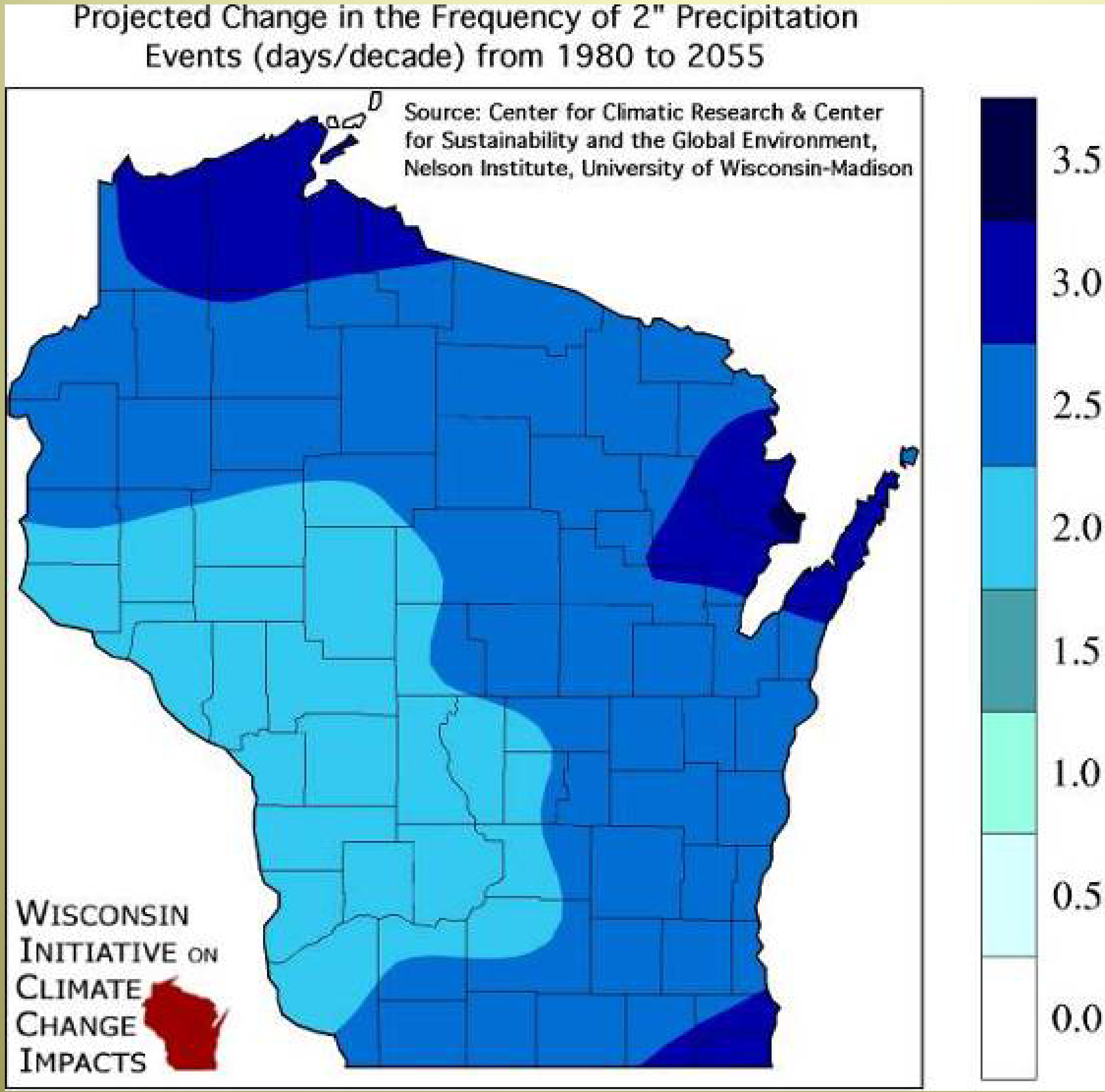
Major Drivers of Climate Change Impacts on Water Resources

- Thermal Impacts (Increased air and water temps, longer ice-free period, more ET)

- Changing rainfall patterns (seasonal and spatial variability, + or – water, less precip in the form of snow)

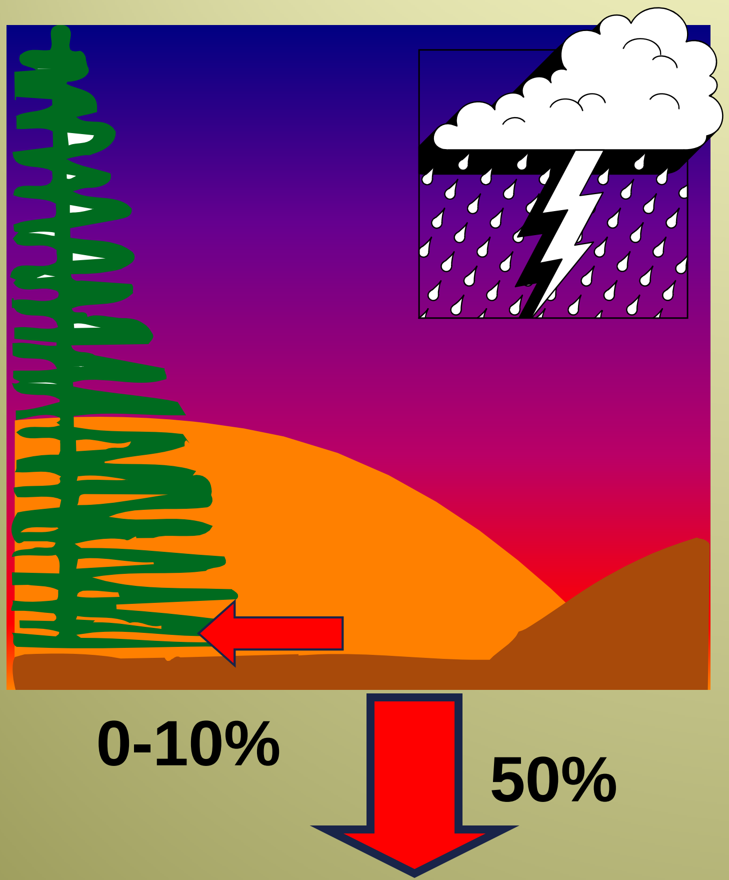
- Increased storm intensity (more frequent large precipitation events)

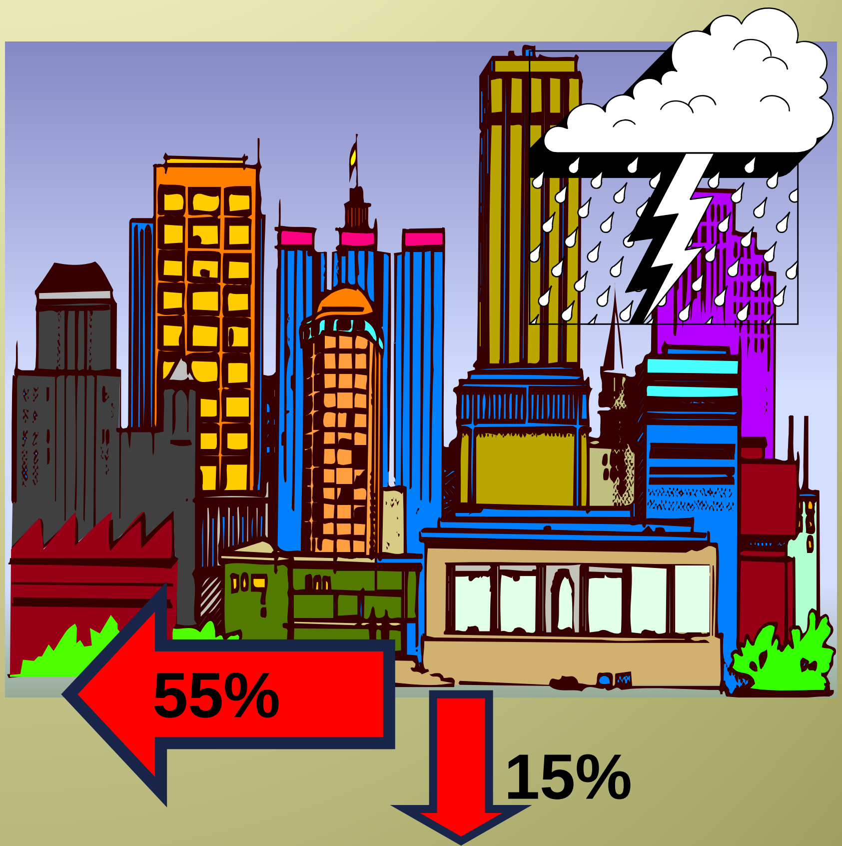
Number of days with intense precipitation is projected to increase across Wisconsin in 21st century.



- Roughly a 25% increase in frequency.
- Recurrence intervals decrease from once every 10 months to once every 8 months in southern Wisconsin

Development Impacts on the Water Cycle

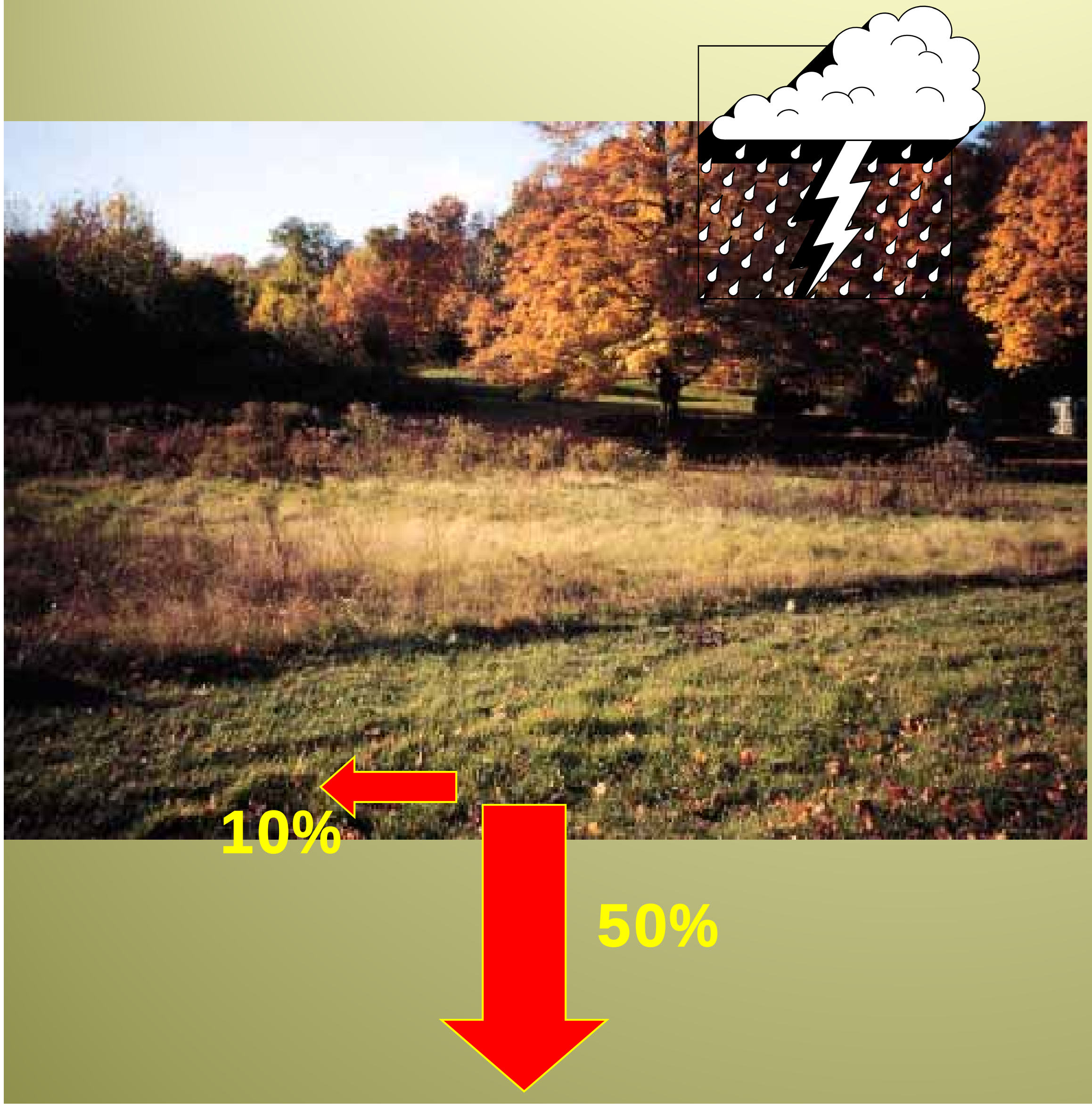




How do you make this…

function like this?

Design Principles



Retain & Restore the Natural Landscape

WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

Key Water Resource Impacts

- *Increased flooding*
- *Increased frequency of harmful blue-green algal blooms*
- *Conflicting water use concerns*
- *Changes in water levels*
- *Increased sediment and nutrient loading*
- *Increased spread of aquatic invasive species*

Warmer temperatures and increased runoff from large storm events causes water quality problems, blue-green toxins, eutrophication, etc

OVERVIEW

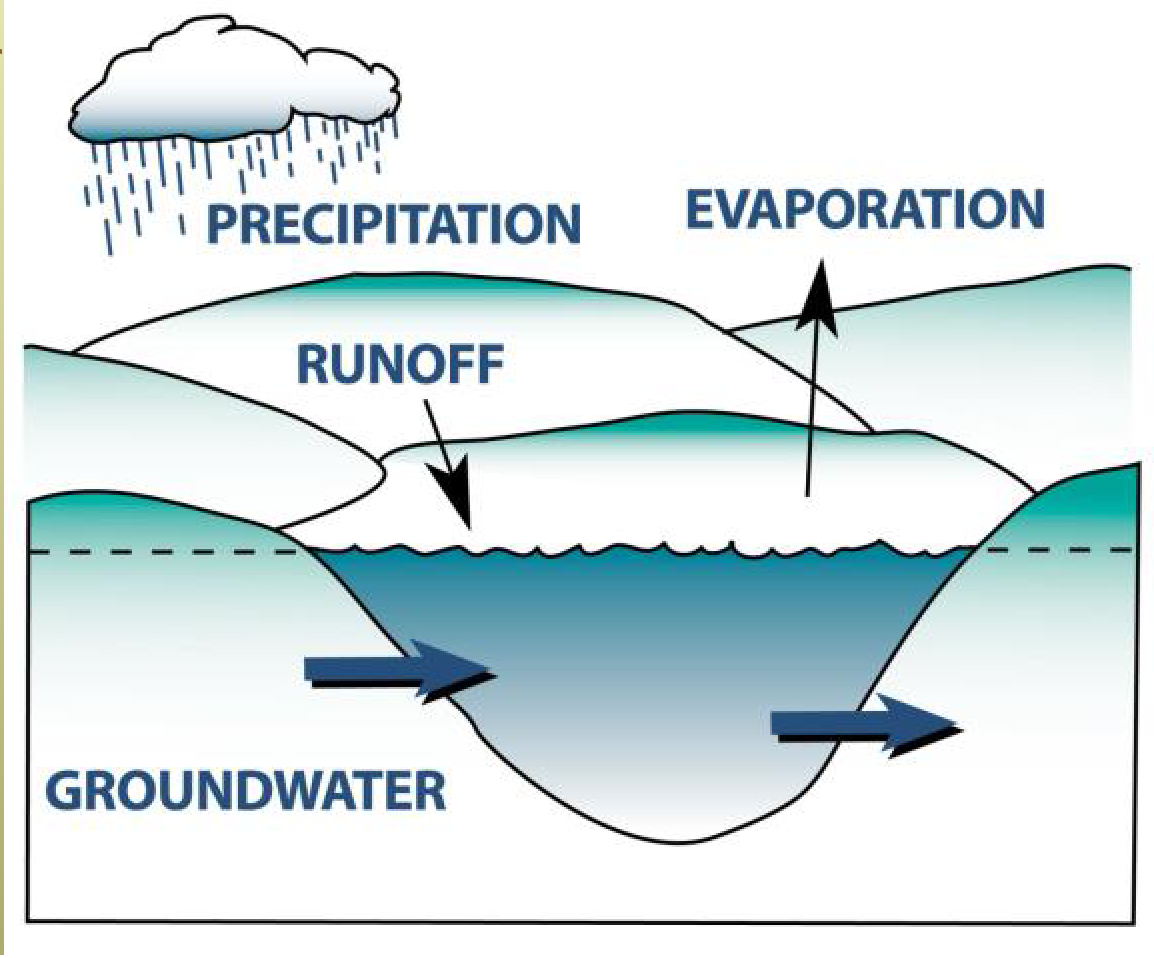
- Unique Properties of Water
- **Lake Types**
- Physical, Chemical, Biological and Habitat Characteristics
- Technical Aspects

LAKE TYPES

- Seepage
- Groundwater Drainage
- Drainage
- Impoundments
- Oxbow

SEEPAGE LAKE

- Natural Lake
- Water Source
  - Groundwater
  - Precipitation
- No Stream Outlet/ Inlet

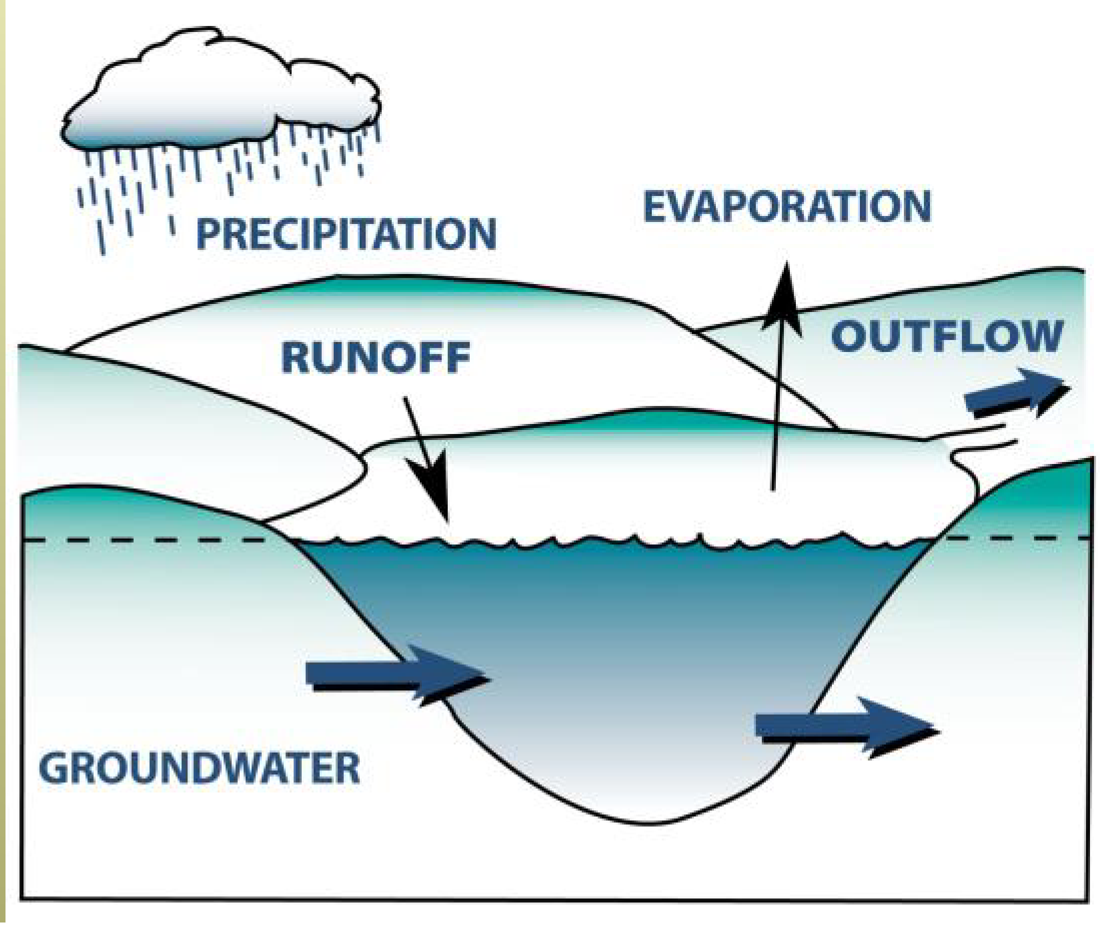


SEEPAGE LAKE

- ***Long & Des Moines Lakes, Burnett Co.***
- Shell Lake, Washburn Co.
- Whitefish Lake, Douglas Co.,
- Potowotomi Lakes, Bayfield Co.

GROUNDWATER DRAINAGE

- Natural Lake
- Water Source
  - Groundwater
  - Precipitation
  - Limited Runoff
- Has Stream Outlet

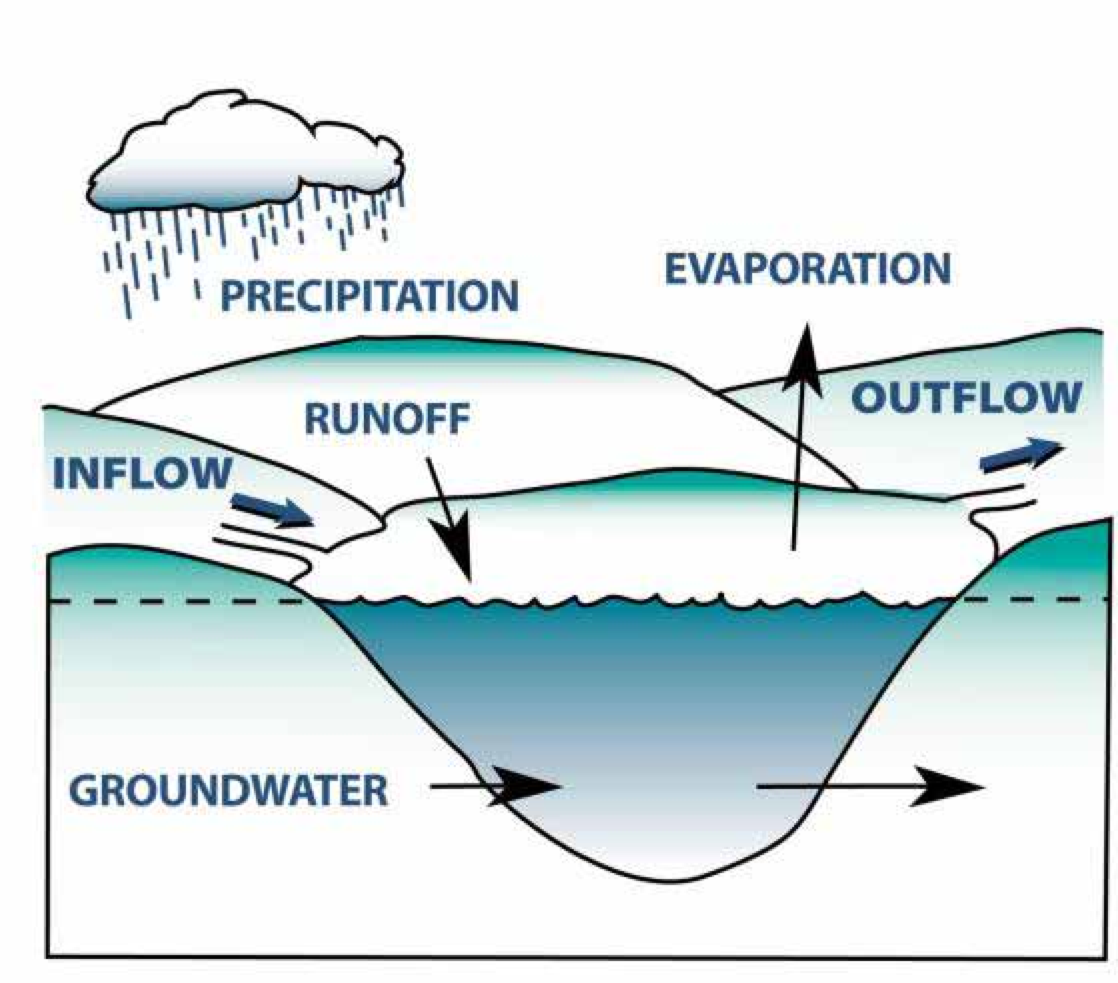


GROUNDWATER DRAINAGE LAKE

- Sand Lake, Chippewa County

DRAINAGE LAKE

- Water Source
  - Streams
  - Groundwater
  - Precipitation
  - Runoff
- Stream Drained

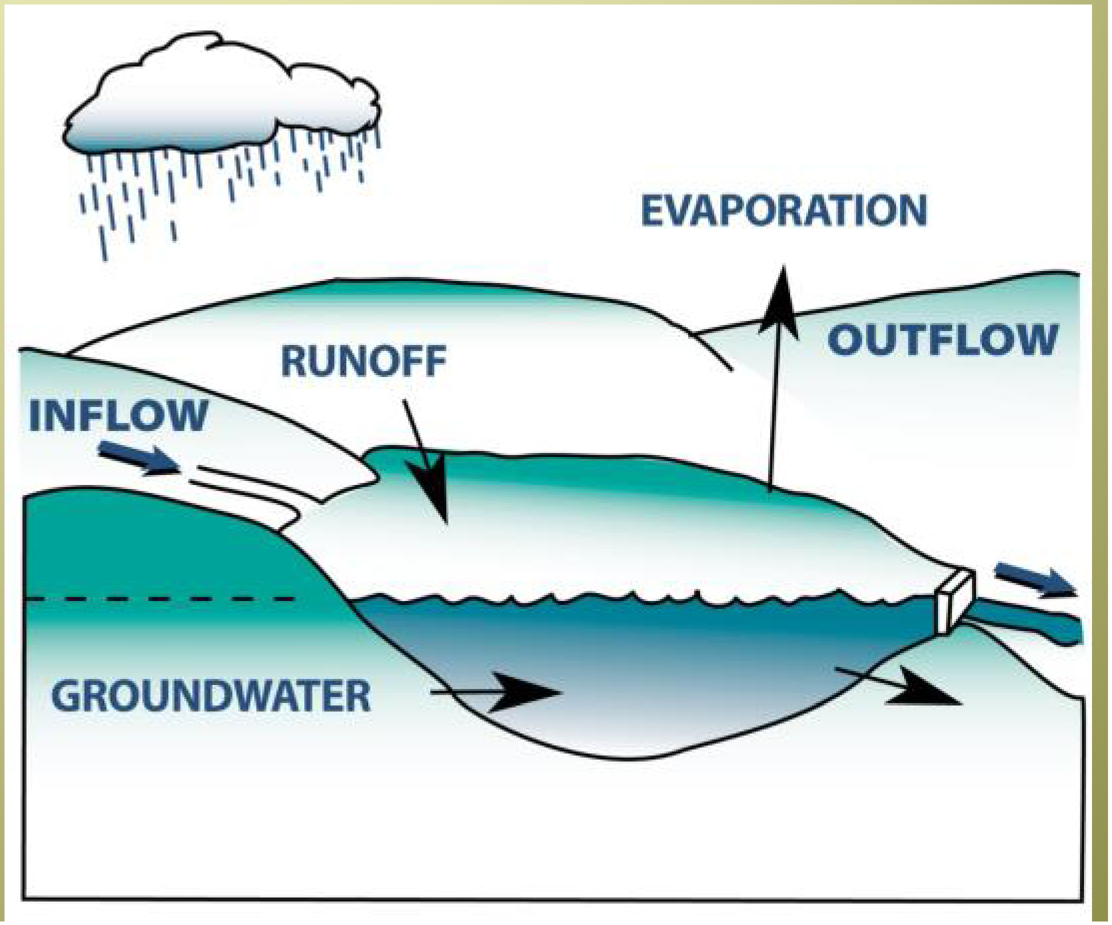


DRAINAGE LAKE

- Long Lake, Chippewa County

IMPOUNDMENT

- A manmade lake
- Dammed River or Stream



- Lake Hallie, Chippewa County

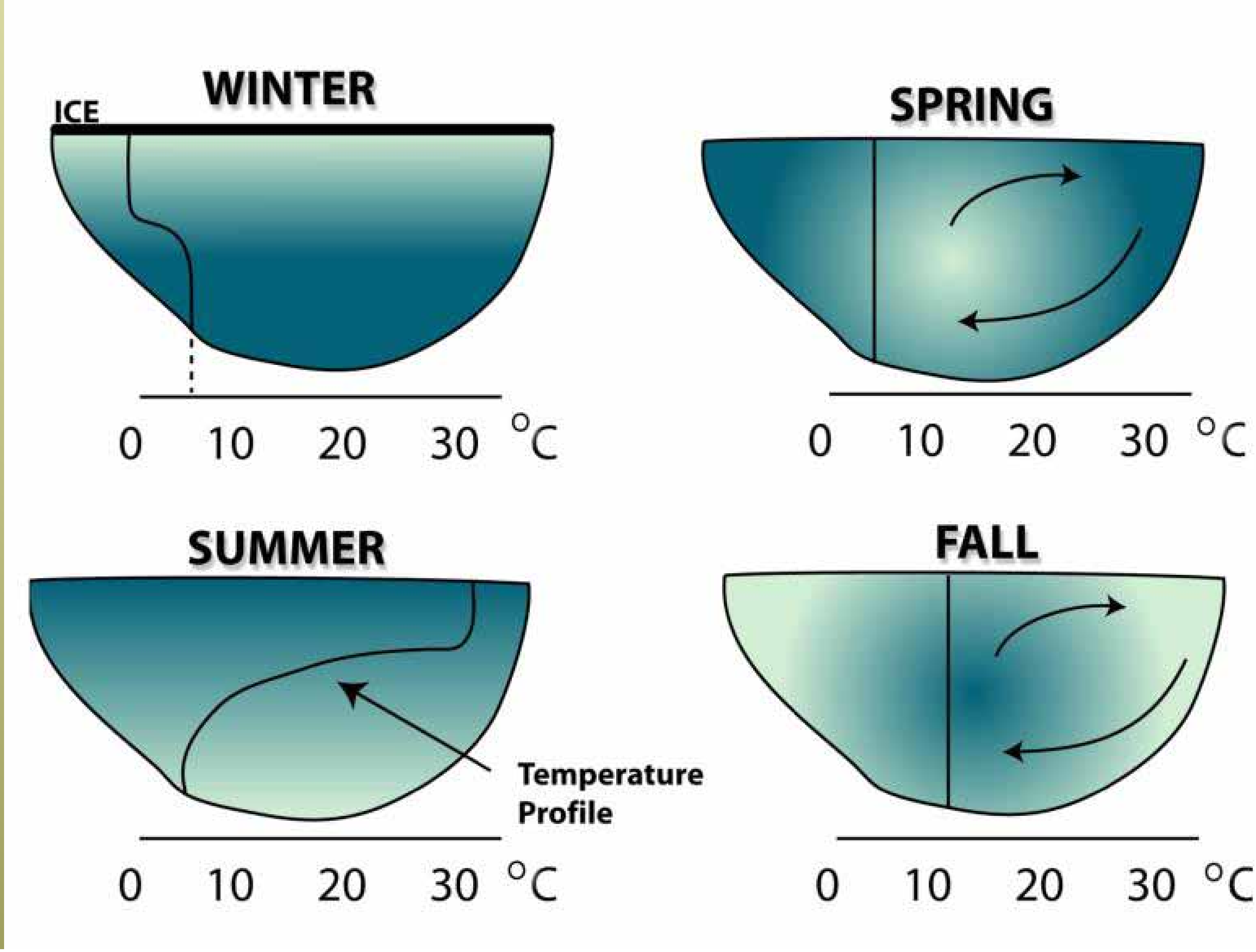
OVERVIEW

- Unique Properties of Water
- Lake Types
- Physical, Chemical, Biological and Habitat Characteristics
- Technical Aspects

PHYSICAL CHARACTERISTICS

- Mixing / Stratification
- Lake Depth
- Retention Time / Flushing Rate
- Drainage Basin/ Lake Area Ratio
- Landscape Position
- Influence of Watershed Runoff

MIXING/ STRATIFICATION



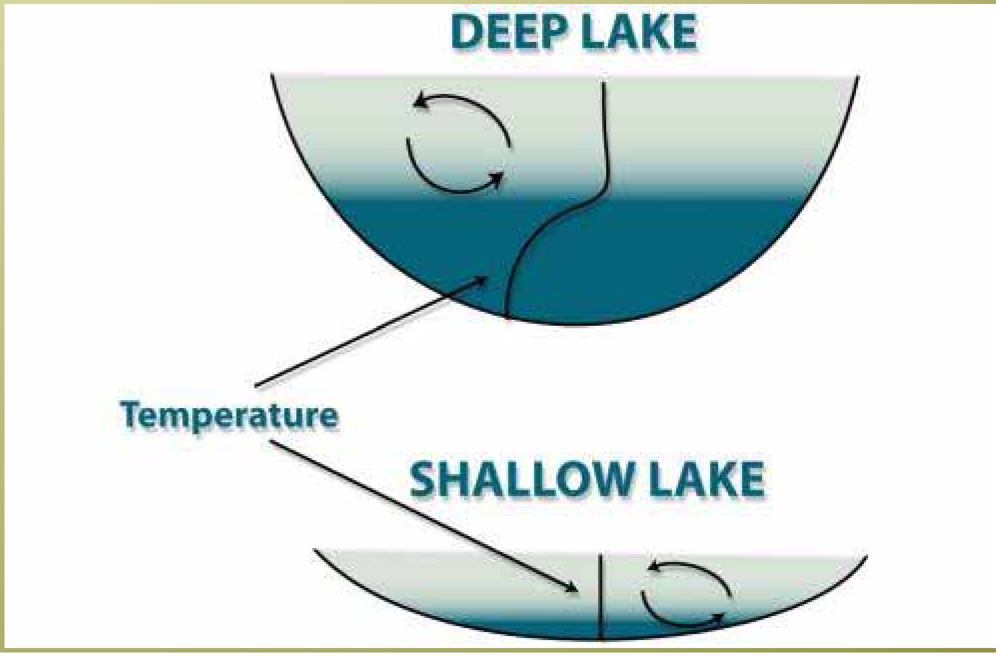
LAKE DEPTH MATTERS

- **Deep Lakes**

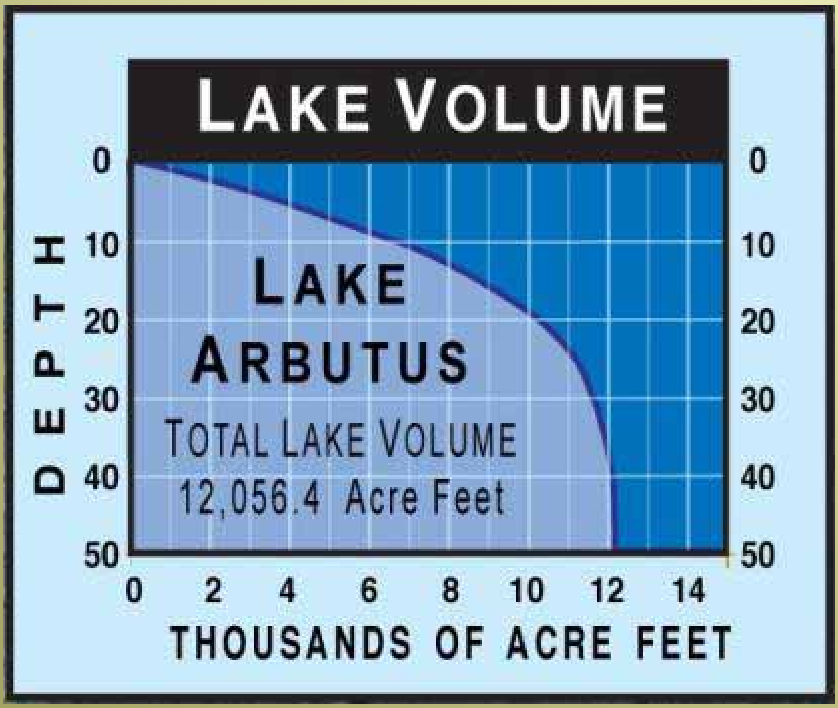
  Stratify

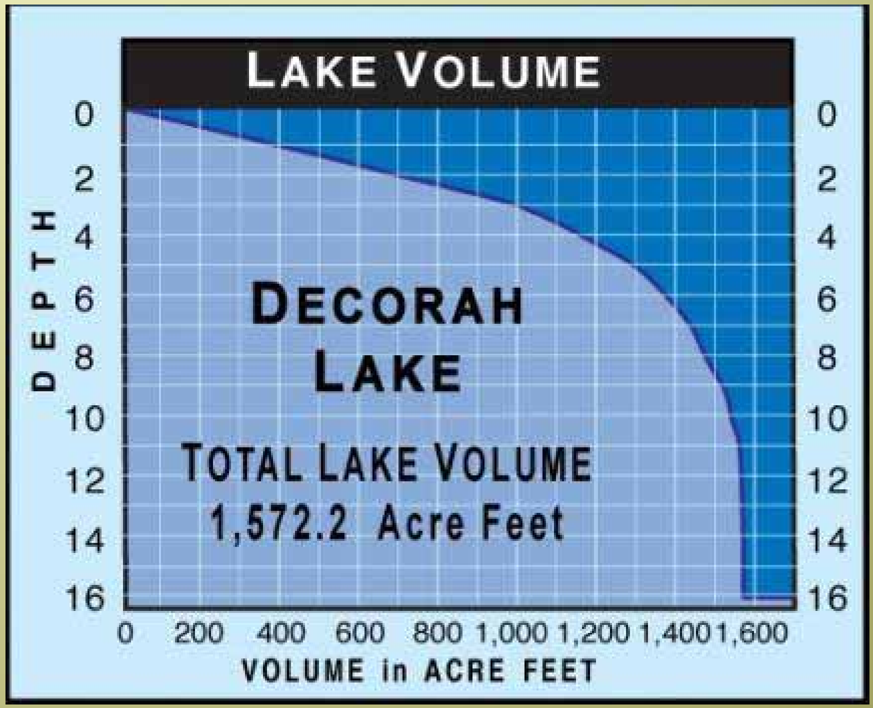
- **Shallow Lakes**

  Continuous Nutrient Recycling



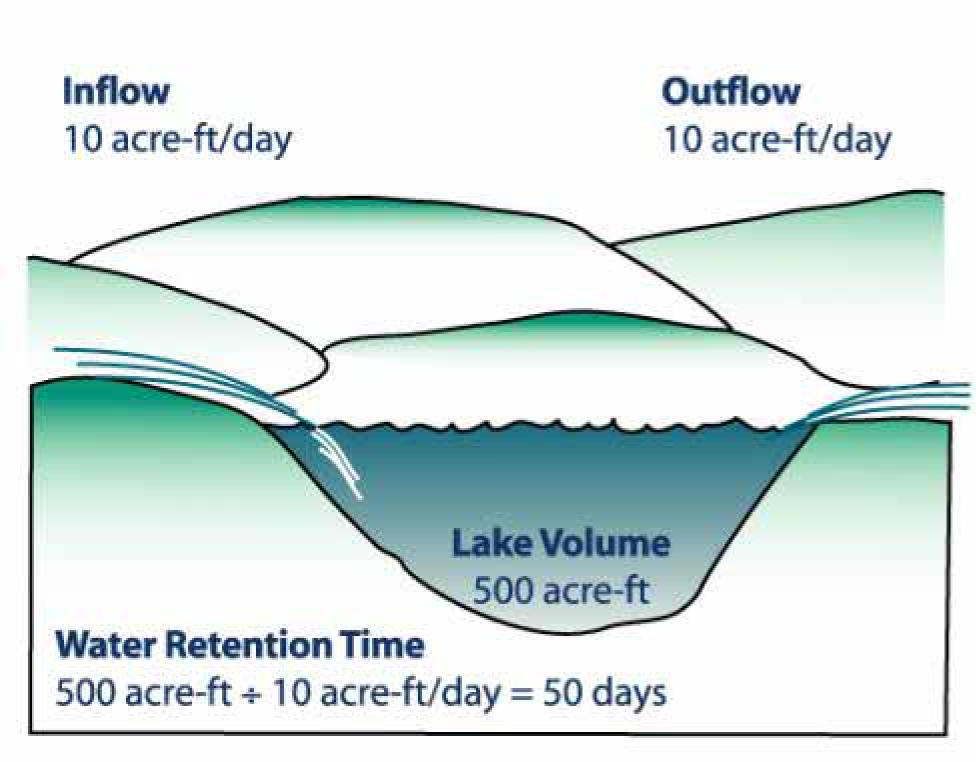
Lake Level vs Lake Volume





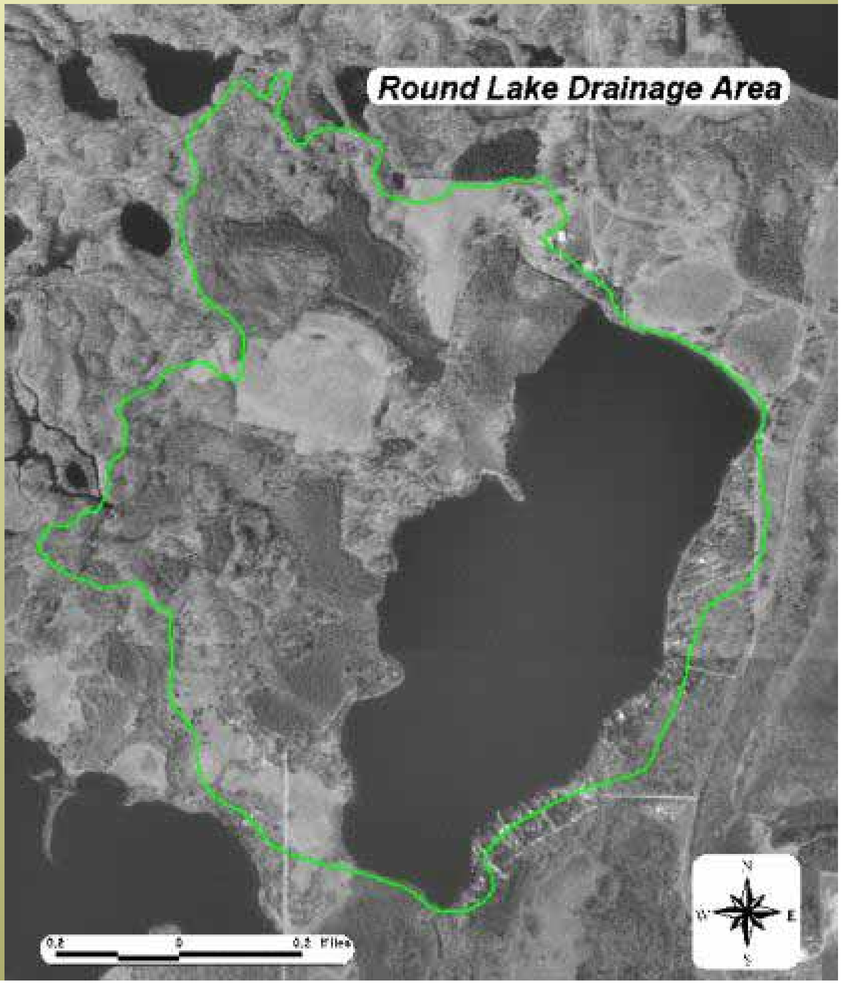
RETENTION TIME/ FLUSHING RATE

- How long would it take to fill a drained lake?
- Retention Time Matters
- Long Lake & Altoona
  - Long Lake, 7years
  - Lake Altoona, 22days

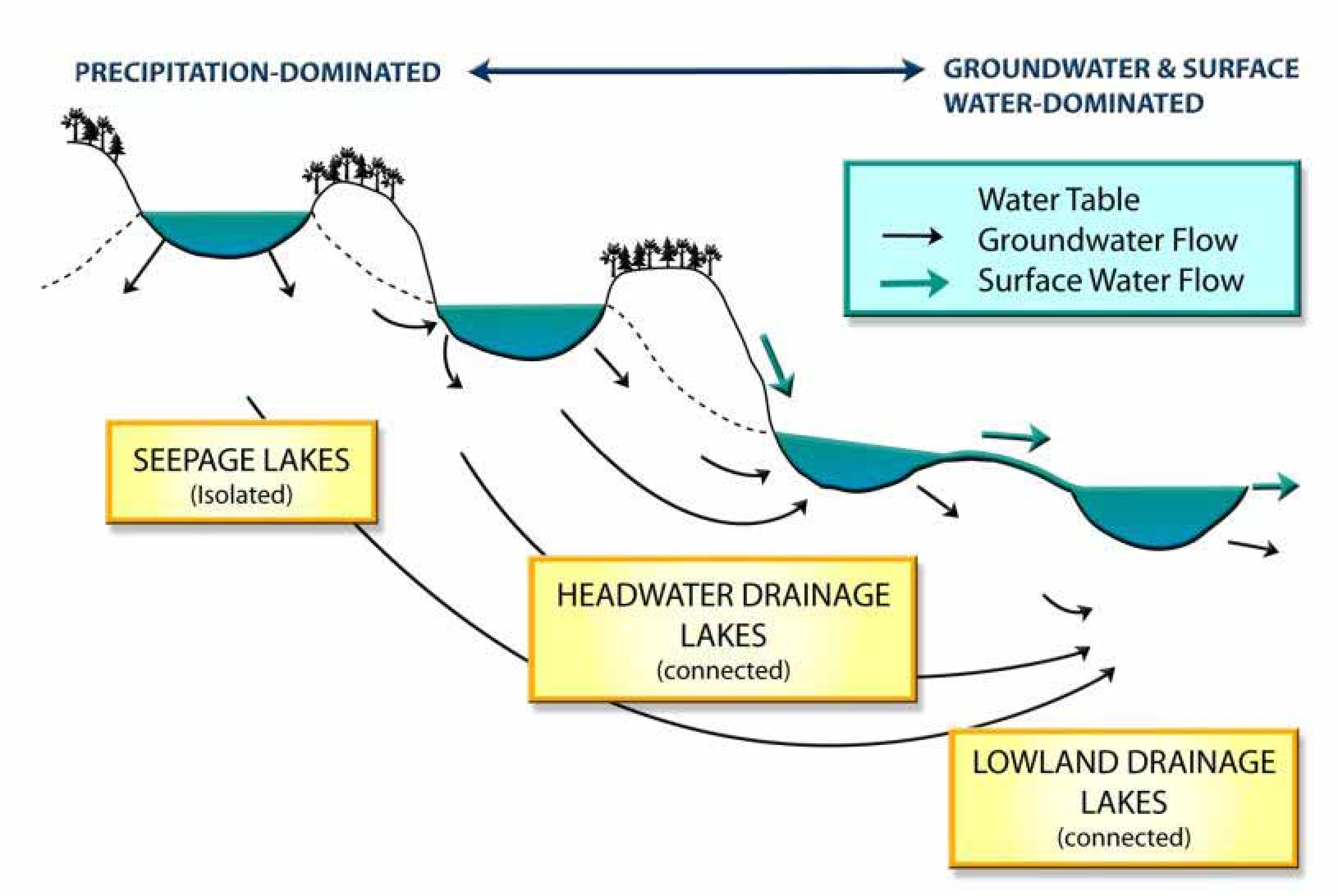


DRAINAGE BASIN/ LAKE AREA RATIO

- Seepage Lake- small
- Drainage Lake- large watershed
  - Seepage Lake w/ drainage area mapped Round Lake



LANDSCAPE POSITION



CHEMICAL CHARACTERISTICS

- Chemical Characteristics
- Limiting Nutrient Concept P vs N
- Lake 227

CHEMICAL CHARACTERISTICS

- Nutrients
  - P
  - N
- pH
- Hardness/ Alkalinity
- Dissolved Oxygen (optimum 5 ppm)

NUTRIENT FUNCTIONS

ELEMENT	AVAILABILITY	DEMAND	AVAILABILITY DEMAND	FUNCTION
Na	32	0.5	64	Cell membrane
Mg	22	1.4	16	Chlorophyll, energy transfer
Si	268	0.7	383	Cell wall (diatoms)
P	1	1	1	DNA, RNA, ATP, enzymes
K	20	6	3	Enzyme activator
Ca	40	8	5	Cell membrane
Mn	0.9	0.3	3	Photosynthesis, enzymes
Fe	54	0.06	900	Enzymes
Co	0.02	0.0002	100	Vitamin B12
Cu	0.05	0.006	8	Enzymes
Zn	0.07	0.04	2	Enzyme activator
Mo	0.001	0.0004	3	Enzymes

CHEMICAL CHARACTERISTICS

NUTRIENT FUNCTIONS

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Mo	0.001	0.0004	3	Enzymes

Source: The Biology of Lakes and Ponds, by Christer Bronmark and Lars-Anders Hansson

Phactoids: Importance of P to organisms

- **Phosphorus is a critical nutrient**
  - Genetic molecules: DNA, RNA
  - Structural molecules: phospholipids in cell walls
  - Energy metabolism: ATP
  - ***Every living organism needs phosphorus***
- **A little P goes a long way**
  - 1 lb of P can produce 500 lb of algae, and that P can be recycled many times
- **Phosphorus is less abundant than most other nutrients**
  - Both N and P tend to be high in demand by organisms, relative to their supply in the environment
  - N is often the limiting nutrient in terrestrial and marine ecosystems (with P close behind...)
  - ***But in lakes, P is nearly always the principal limiting nutrient***

LIMITING NUTRIENT PRINCIPLE

…That Nutrient in Least Supply
Relative to Plant Needs

N:P Ratio in plant Tissue 10:1

If the Ratio of N:P in Water is

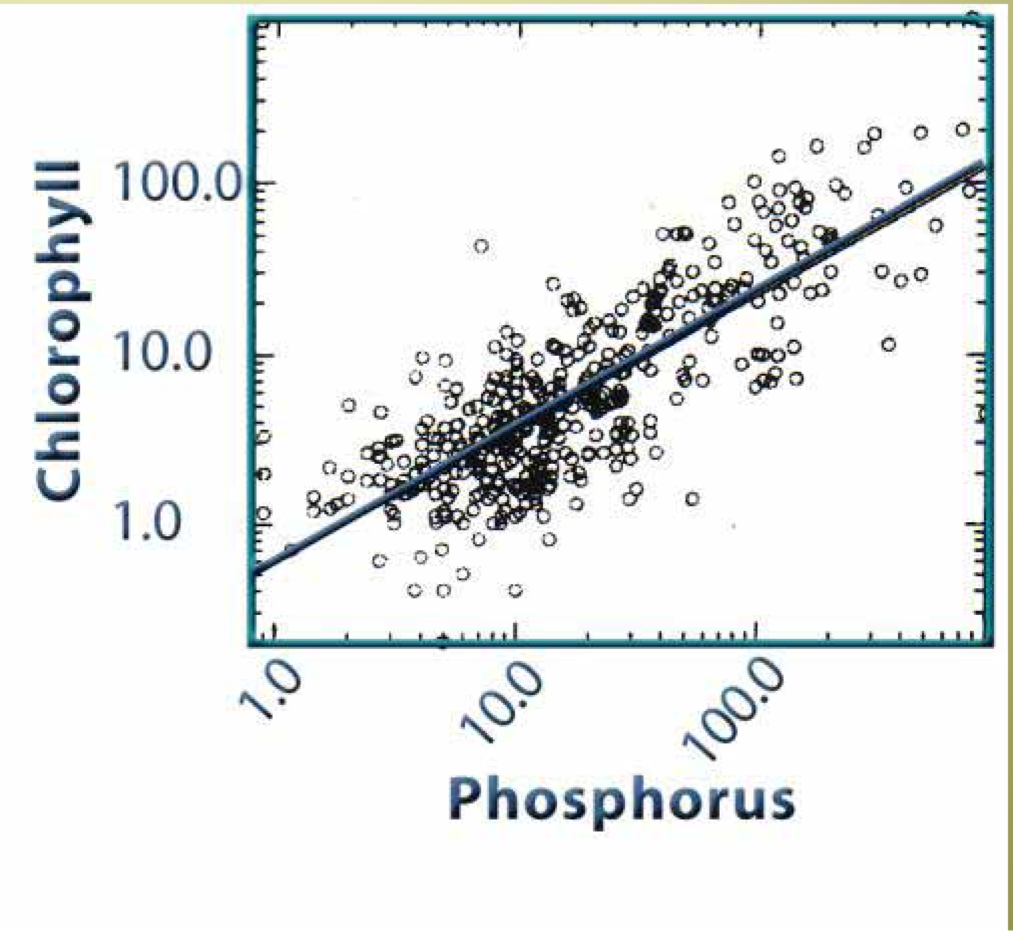
<10:1 Nitrogen Limited

>15:1 Phosphorus Limited

PHOSPHORUS LIMITATION
LAKE 227

TOTAL PHOSPHORUS/ CHLOROPHYLL a RELATIONSHIP

- Phosphorus causes algae to grow



Why Develop the Criteria?

- Obvious water quality problems in state caused by excess nutrient loading

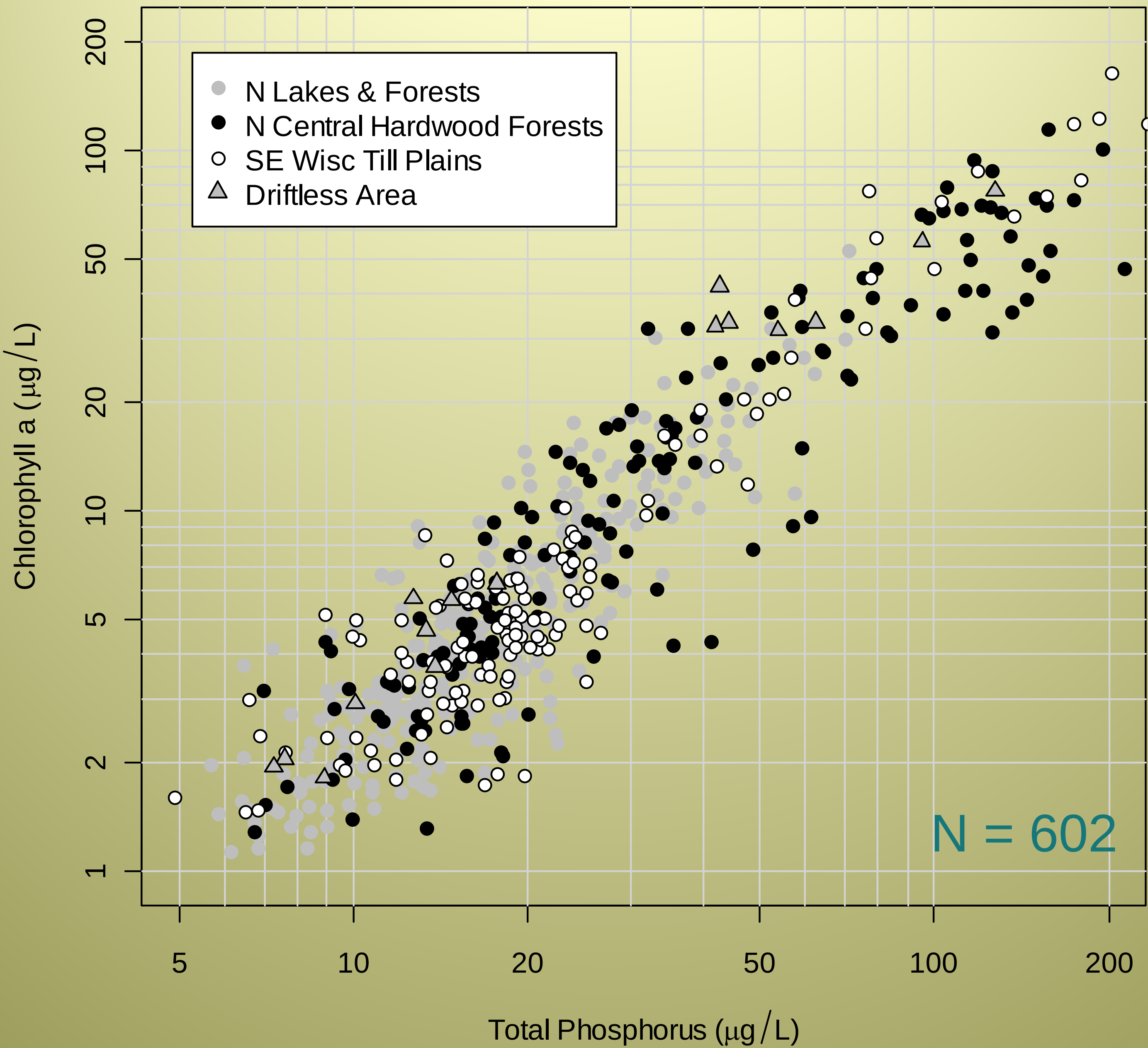
- Numeric goals for protecting or restoring Recreational and Fish and Aquatic Life Uses

- EPA requirement

Specific Lake Criteria

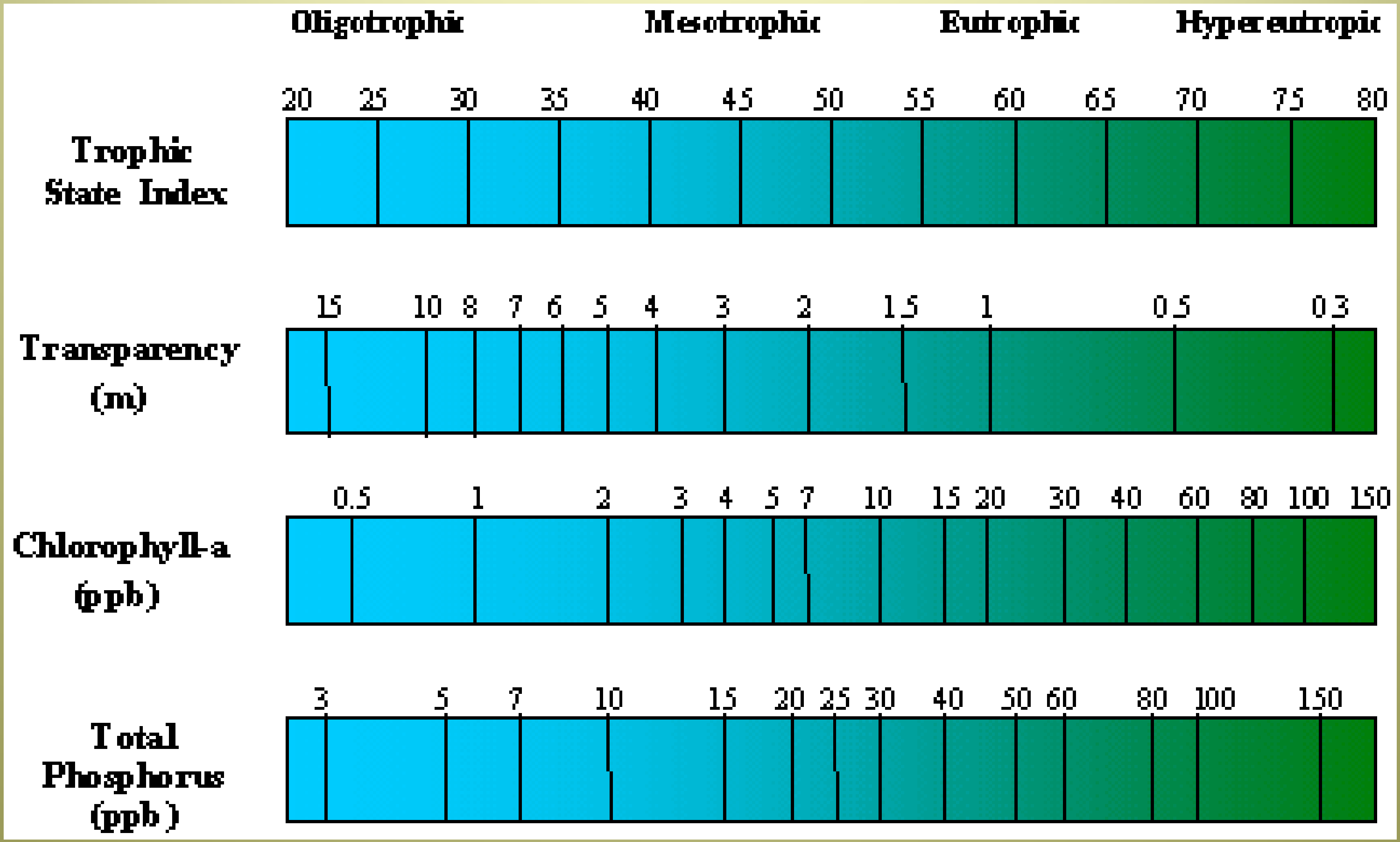
- 2-story fishery lakes – 15 ug/l
- Stratified seepage lakes – 20 ug/l
- Stratified drainage lakes – 30 ug/l
- Stratified reservoirs – 30 ug/l
- Non-stratified lakes – 40 ug/l
- Non-stratified reservoirs – 40 ug/l

Ecoregions



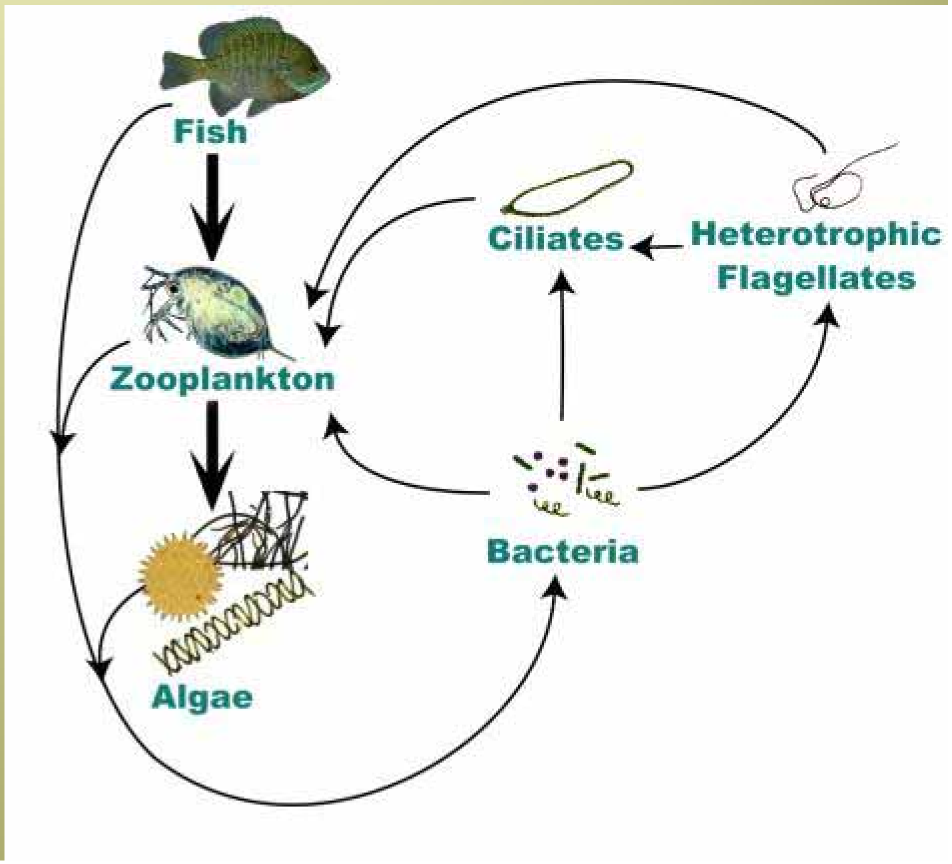
N Lakes & Forests
N Central Hardwood Forests
SE Wisc Till Plains
Driftless Area
N = 602
Chlorophyll a (µg/L)
Total Phosphorus (µg/L)
1
2
5
10
20
50
100
200
5
10
20
50
100
200

TROPHIC STATE INDEX



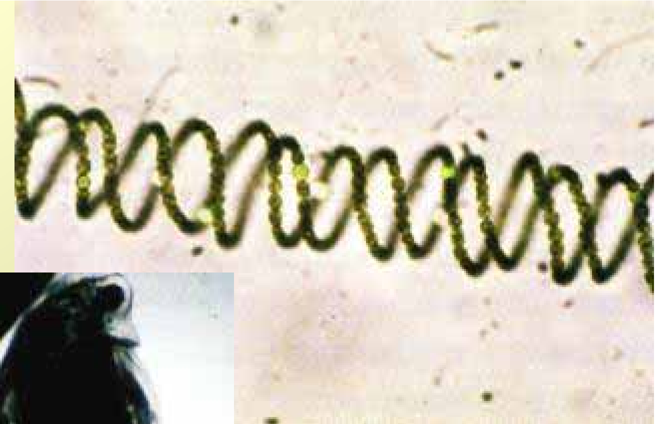
BIOLOGICAL CHARACTERISTICS

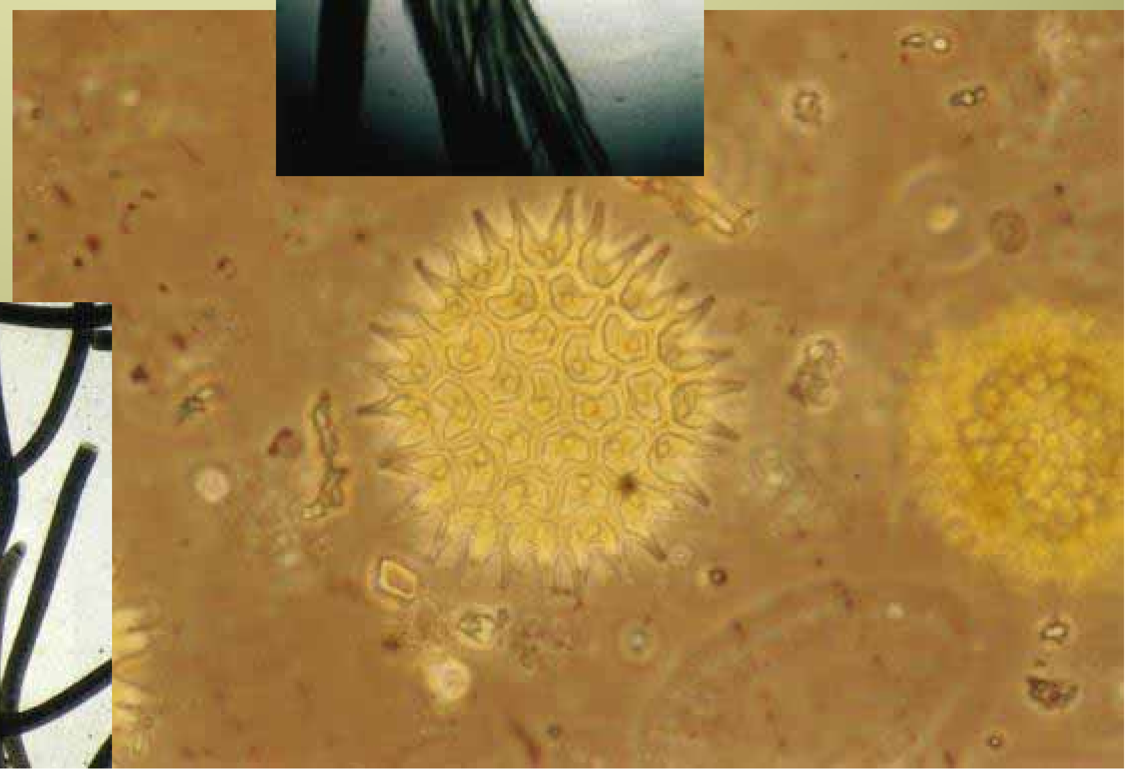
- Viruses/ Bacteria/ Fungi
- Primary - Producers Algae/ Macrophyte
- Zooplankton/ Inverts
- Fish

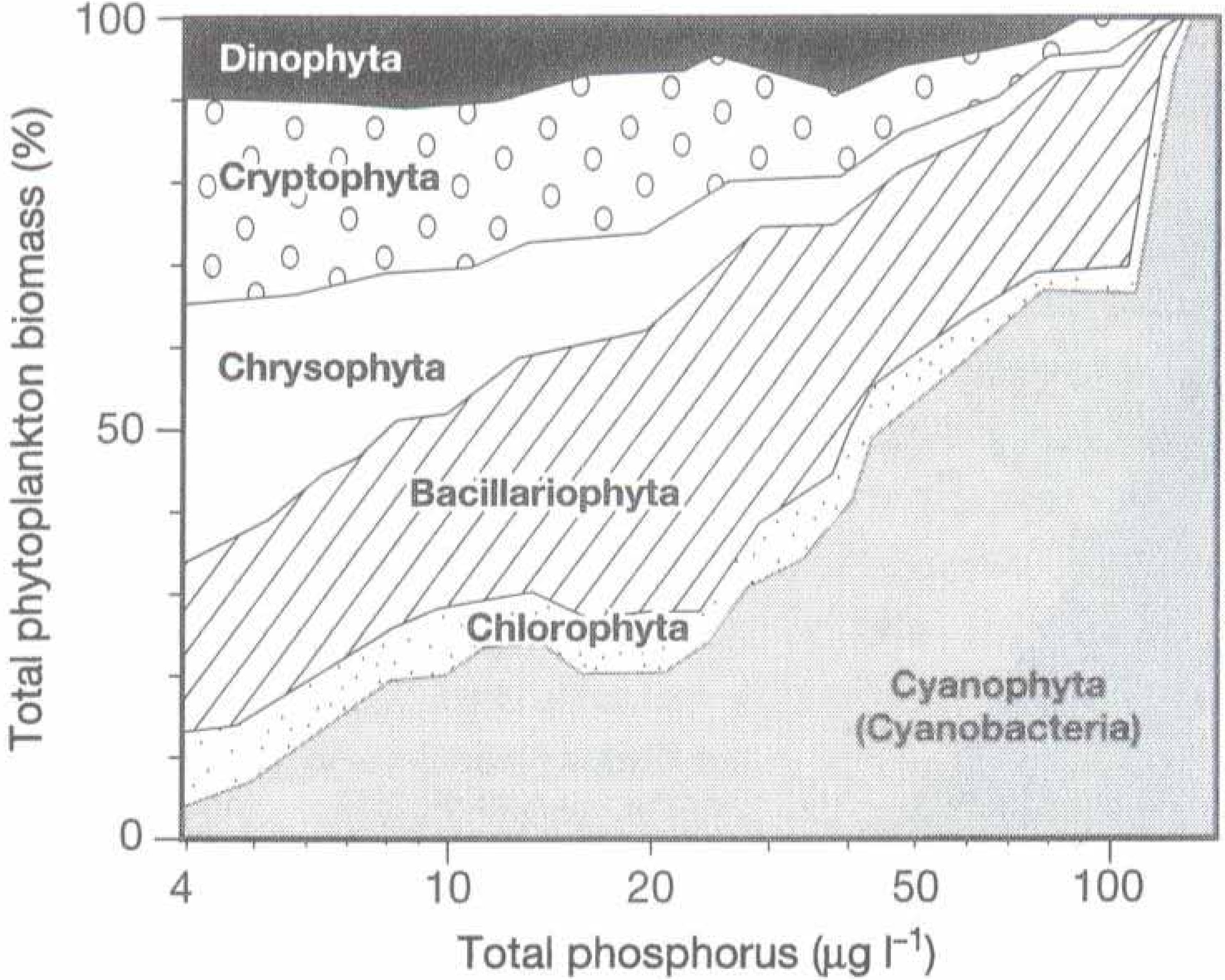


ALGAE

- Primary Energy Source for Invertebrates
- Can be Nuisance and Human Health Issue
- Produce O_2







Watson SB, McCauley E, Downing JA. 1997. Patterns in phytoplankton taxonomic composition
Across temperate lakes of differing nutrient status. Limnol Oceanog 42:487-495

Human Health Concerns

- **Toxic algae**

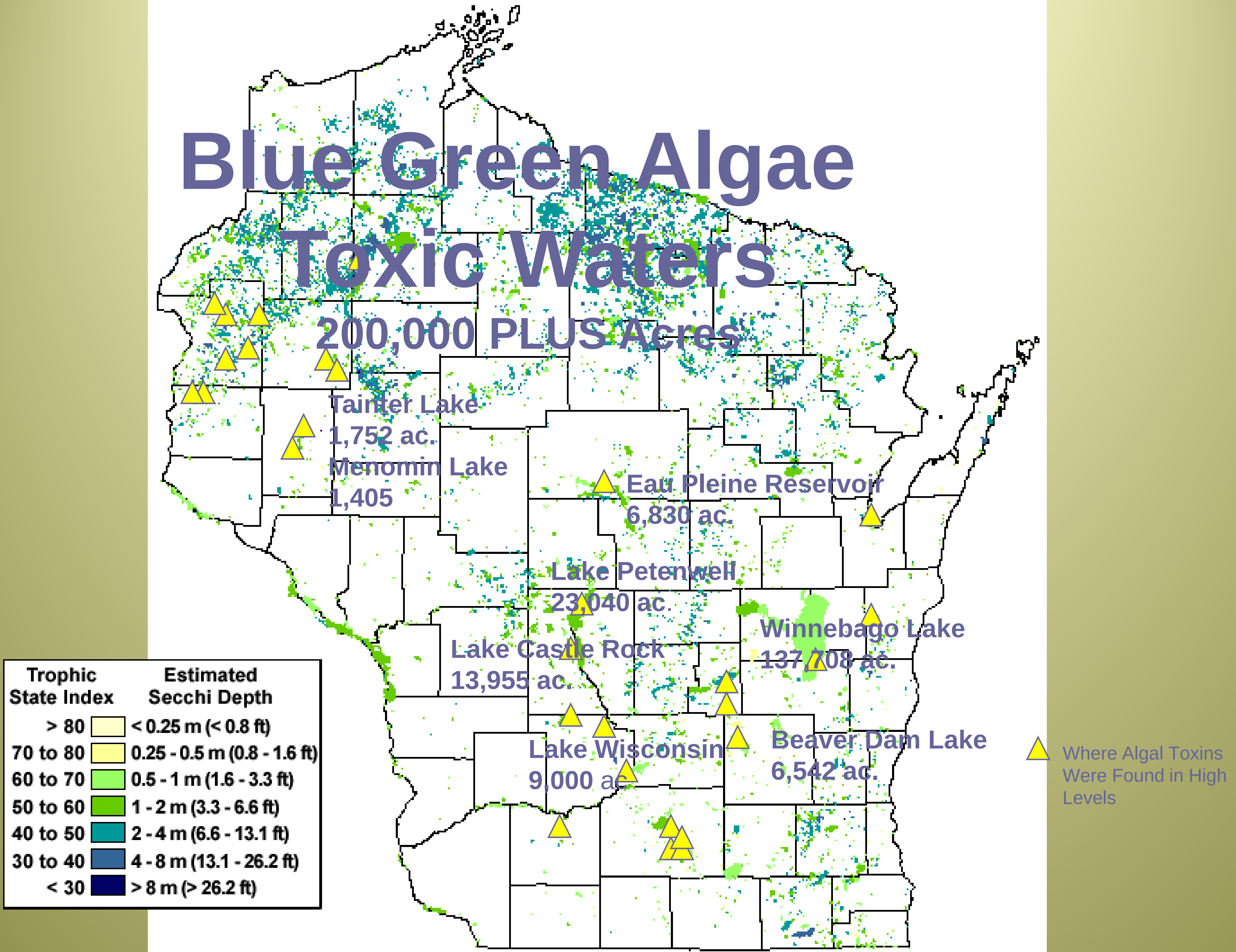
Common *human* symptoms associated with blue-green algae exposure include:		
Respiratory	**Dermatologic**	**Other**
Sore throat	Itchy skin	Earache
Congestion	Red skin	Agitation
Cough	Blistering	Headache
Wheezing	Hives	Abdominal pain
Difficulty breathing	Other Rash	Diarrhea
Eye irritation		Vomiting
		Vertigo

Common *animal* symptoms associated with blue-green algae exposure:
Lethargy
Vomiting
Diarrhea
Convulsions
Difficulty breathing
General weakness

http://dhs.wisconsin.gov/eh/bluegreenalgae/#NewProg

Blue Green Algae Toxic Waters

200,000 PLUS Acres



ZOOPLANKTON &
AQUATIC INVERTEBRATES

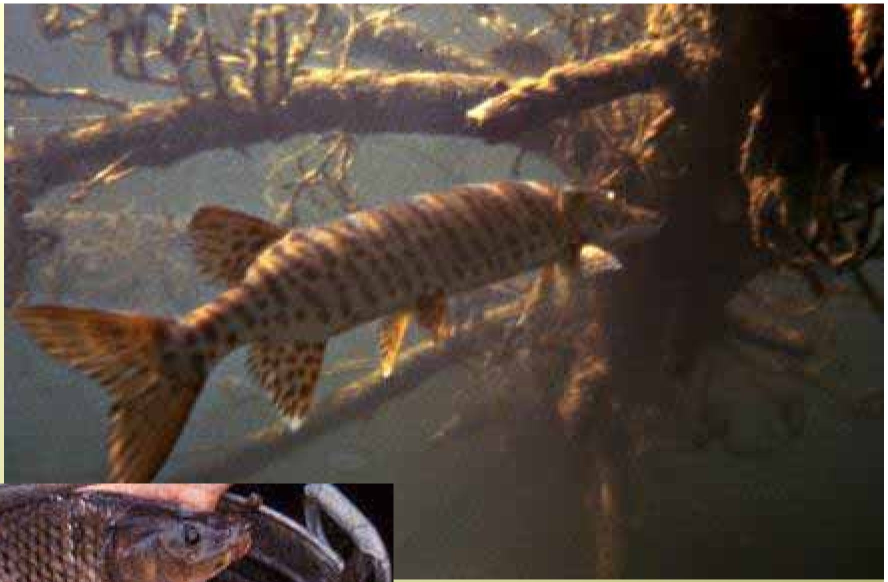
- Zooplankton
- Dragonfly

AQUATIC PLANTS

- Habitat
- Energy Dissipation
- O_2 Producers

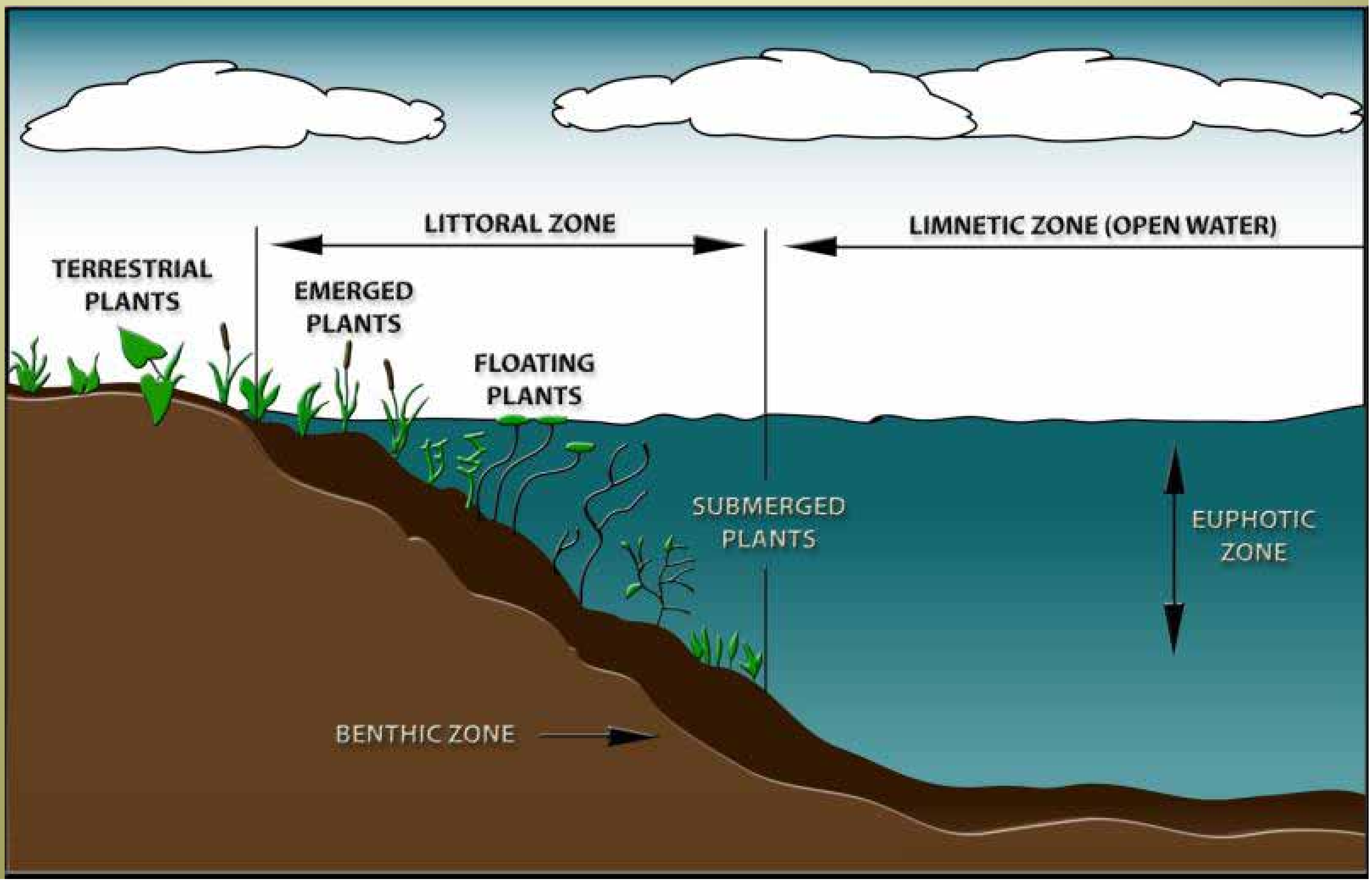
FISH

- Planktivore
- Piscivore
- Benthivore



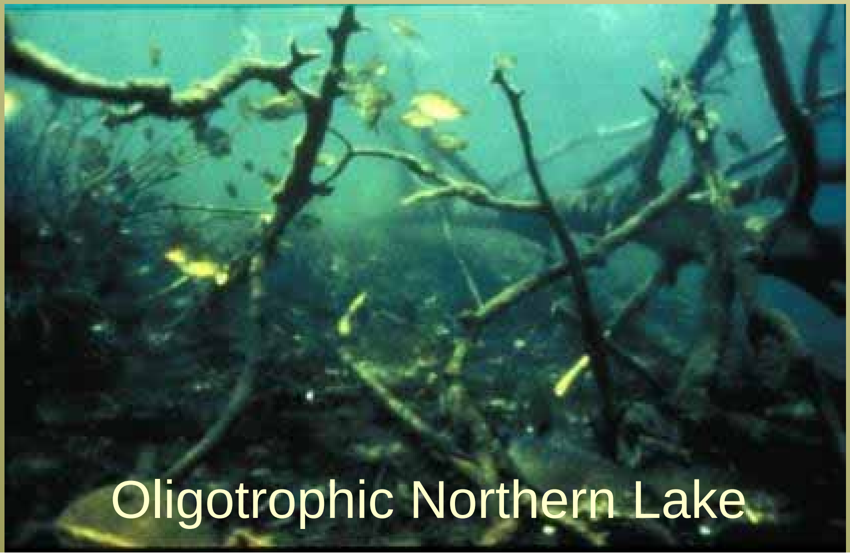
Without habitat, they are gone

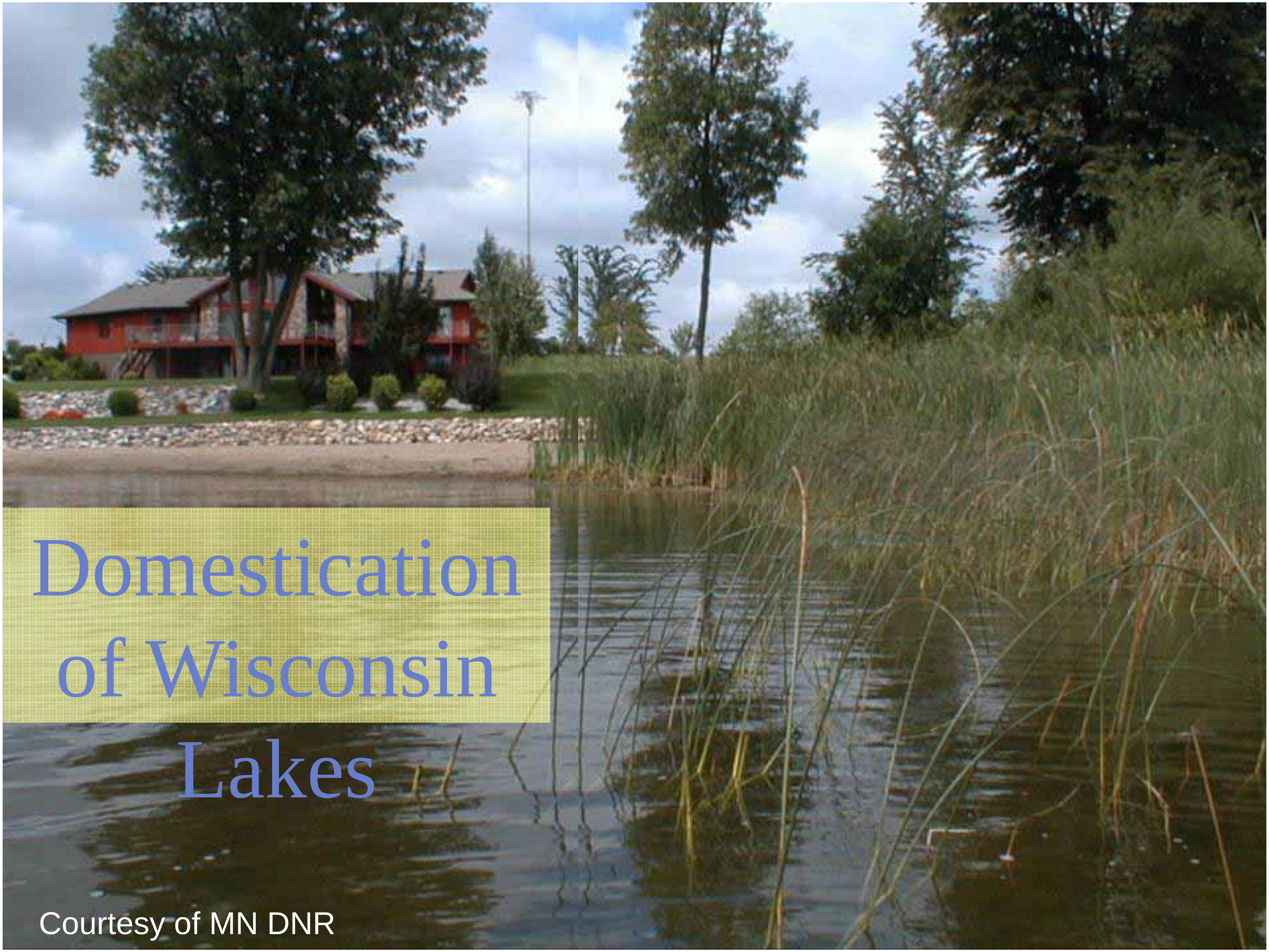
LAKE HABITAT ZONES



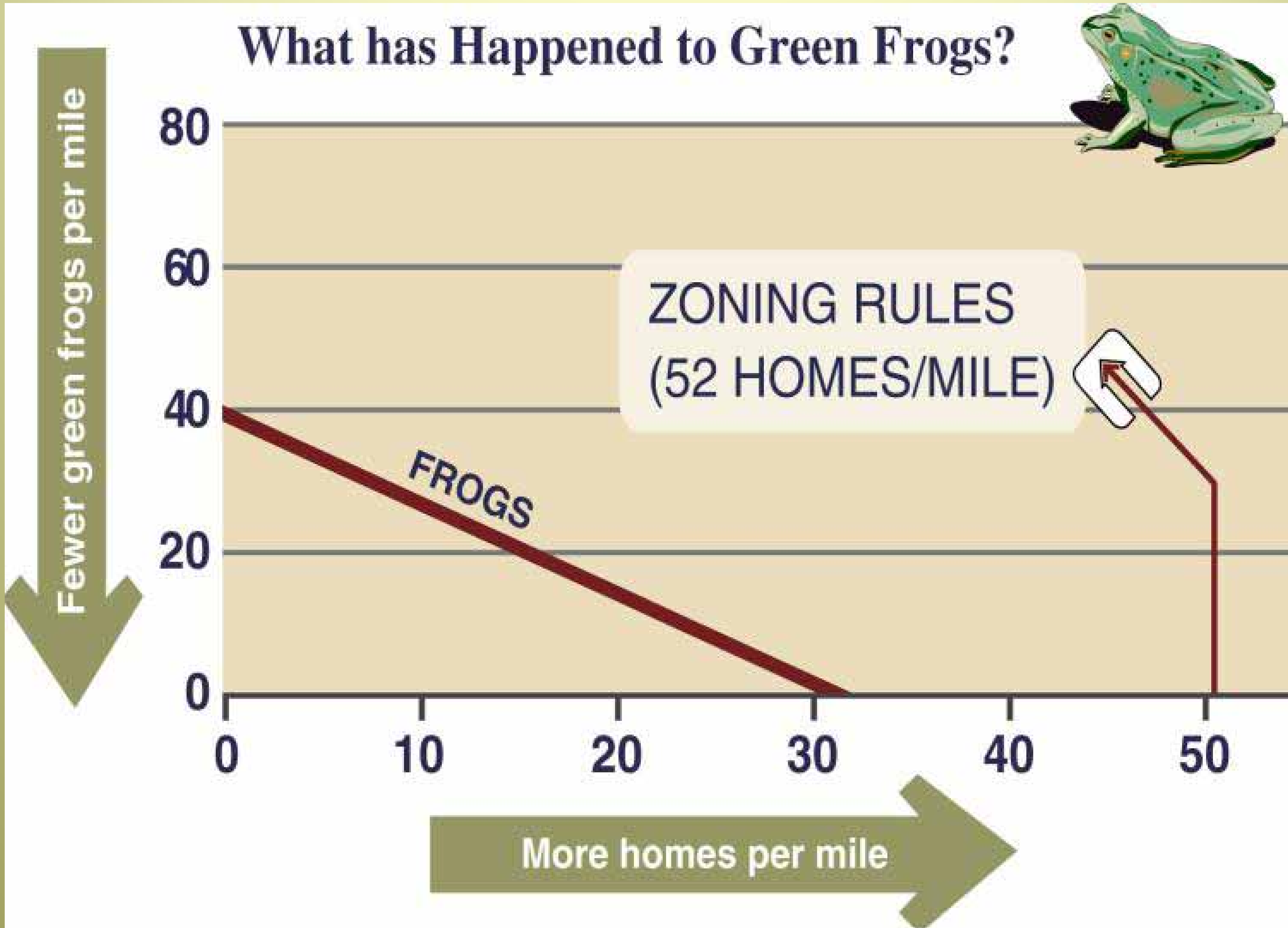
LAKE LITTORAL ZONE

- Functions
  - Intercepts Nutrients
  - Refuge from Predators
  - Nursery for Fish



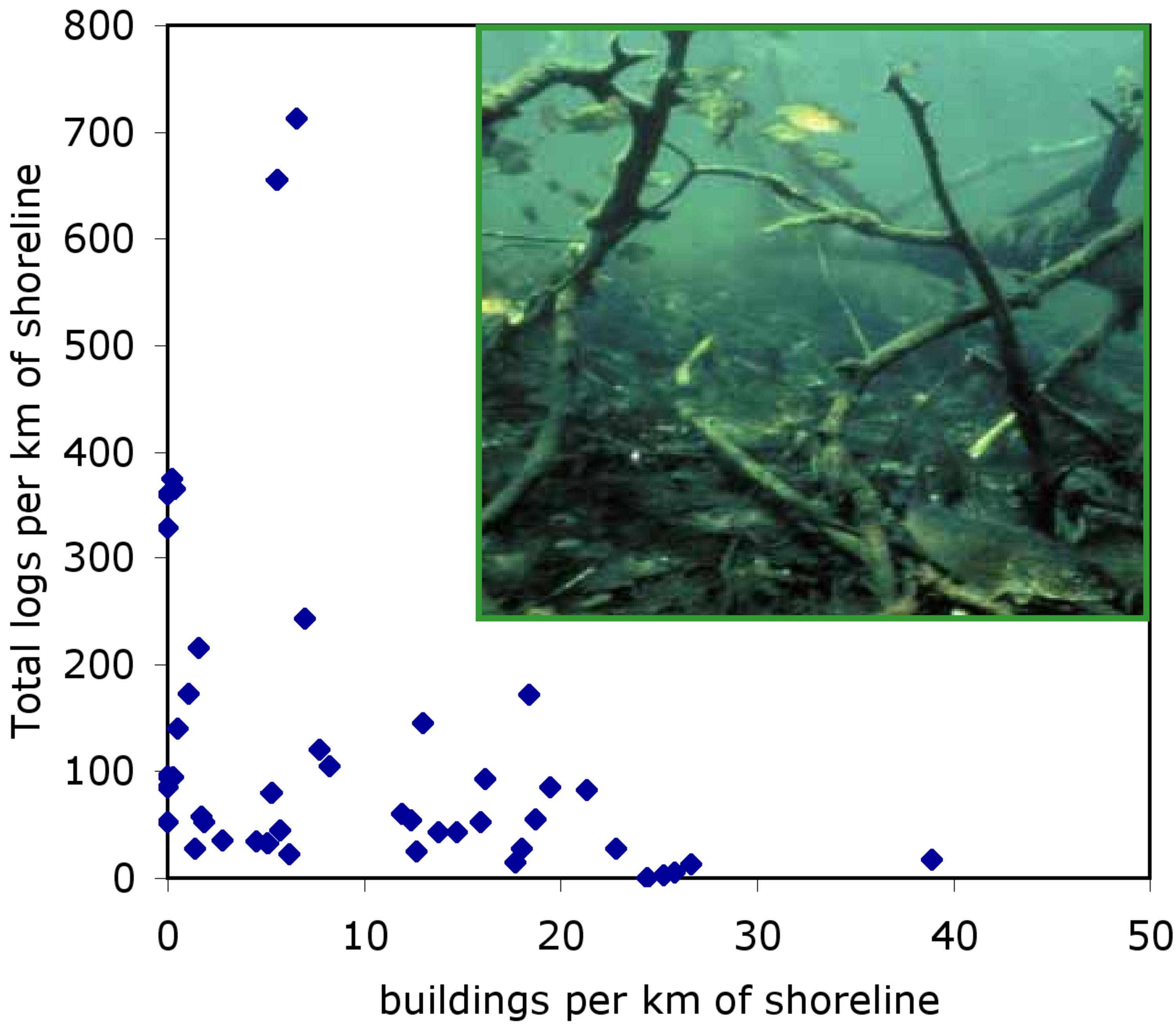

Domestication
of Wisconsin
Lakes
Courtesy of MN DNR

Shoreland green frog trends



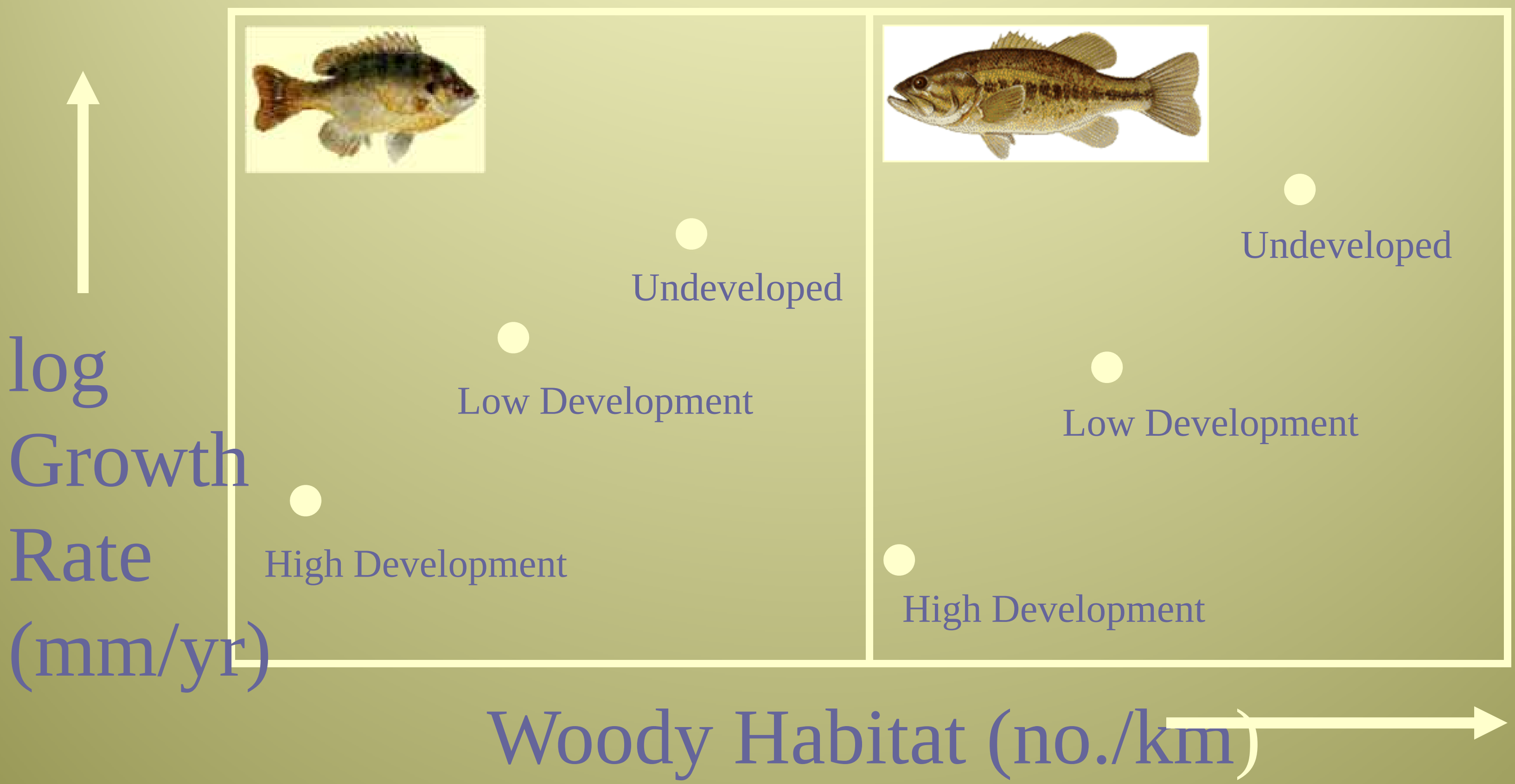
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership



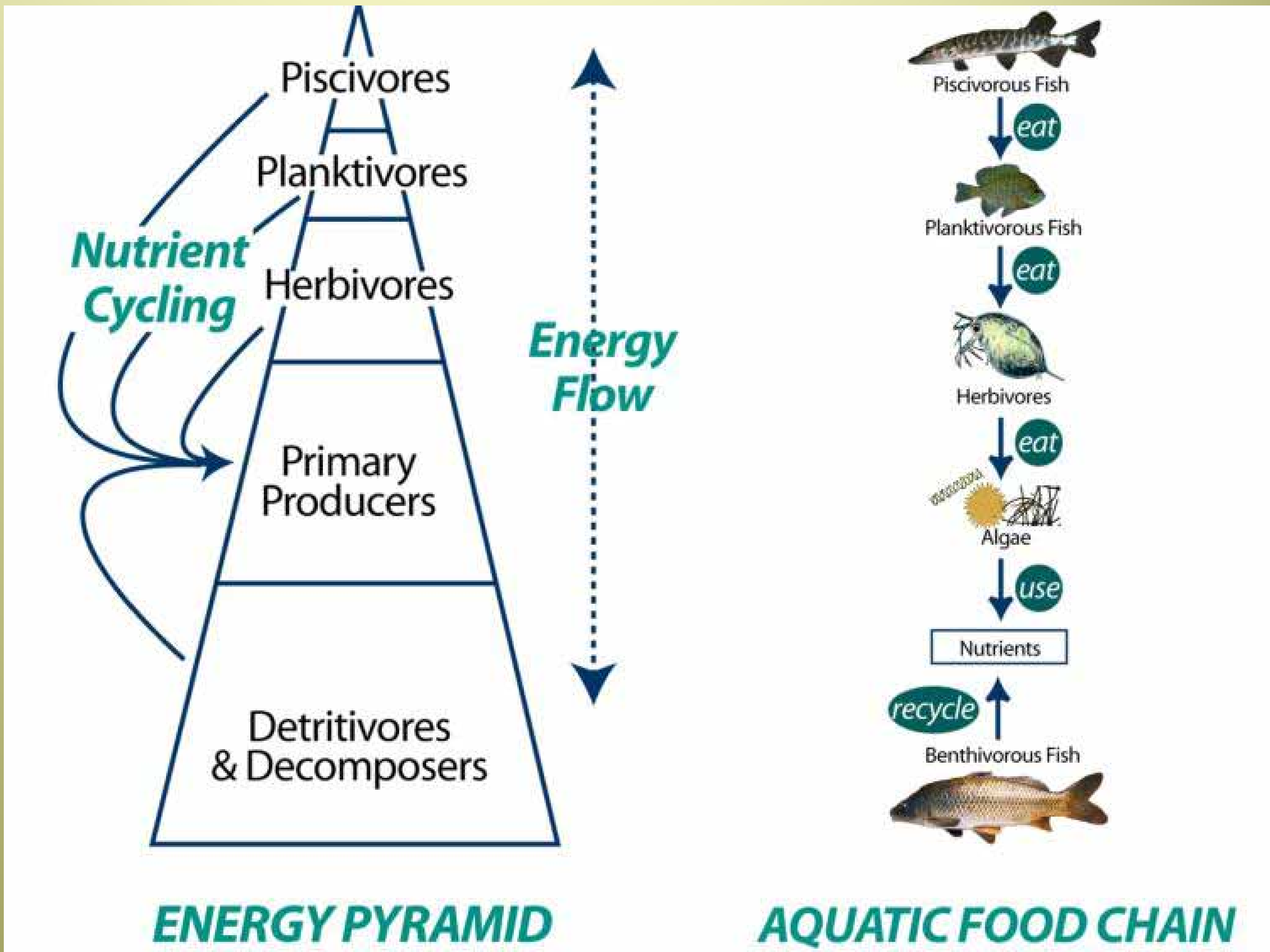
Data: U.W. BioComplexity project

Fish grow ~3X faster in lakes with lots of woody habitat

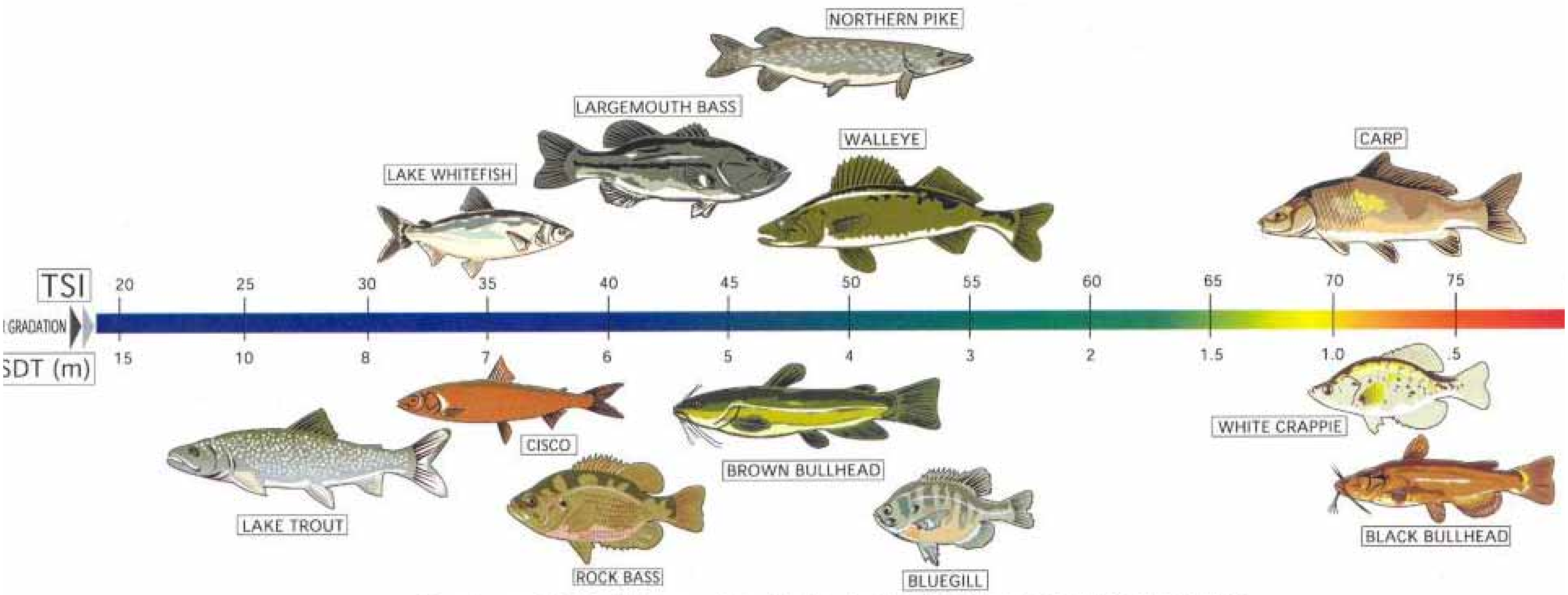


From Schindler et al. 2000

TROPHIC PYRAMID



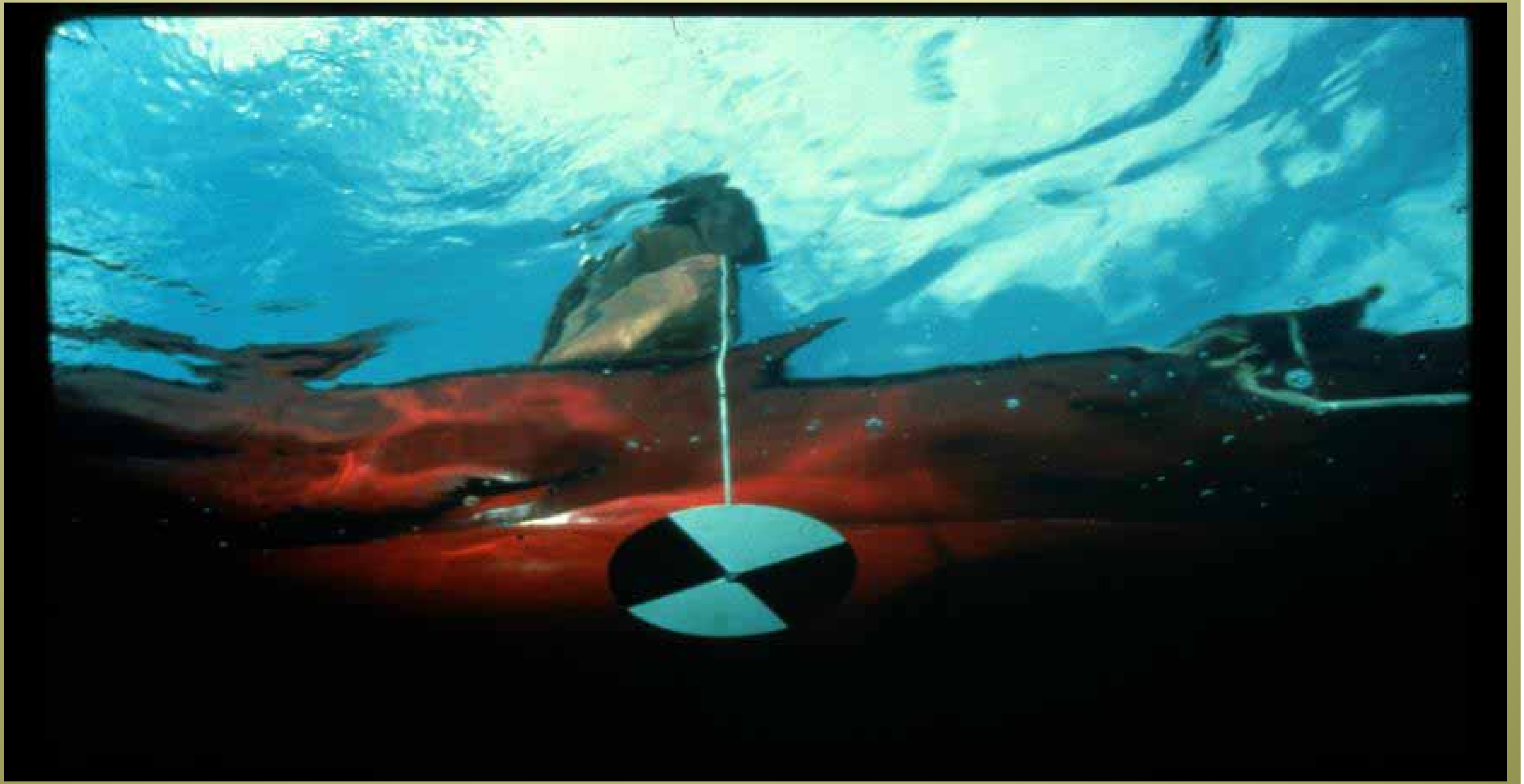
Fish species vary relative to lake trophic status



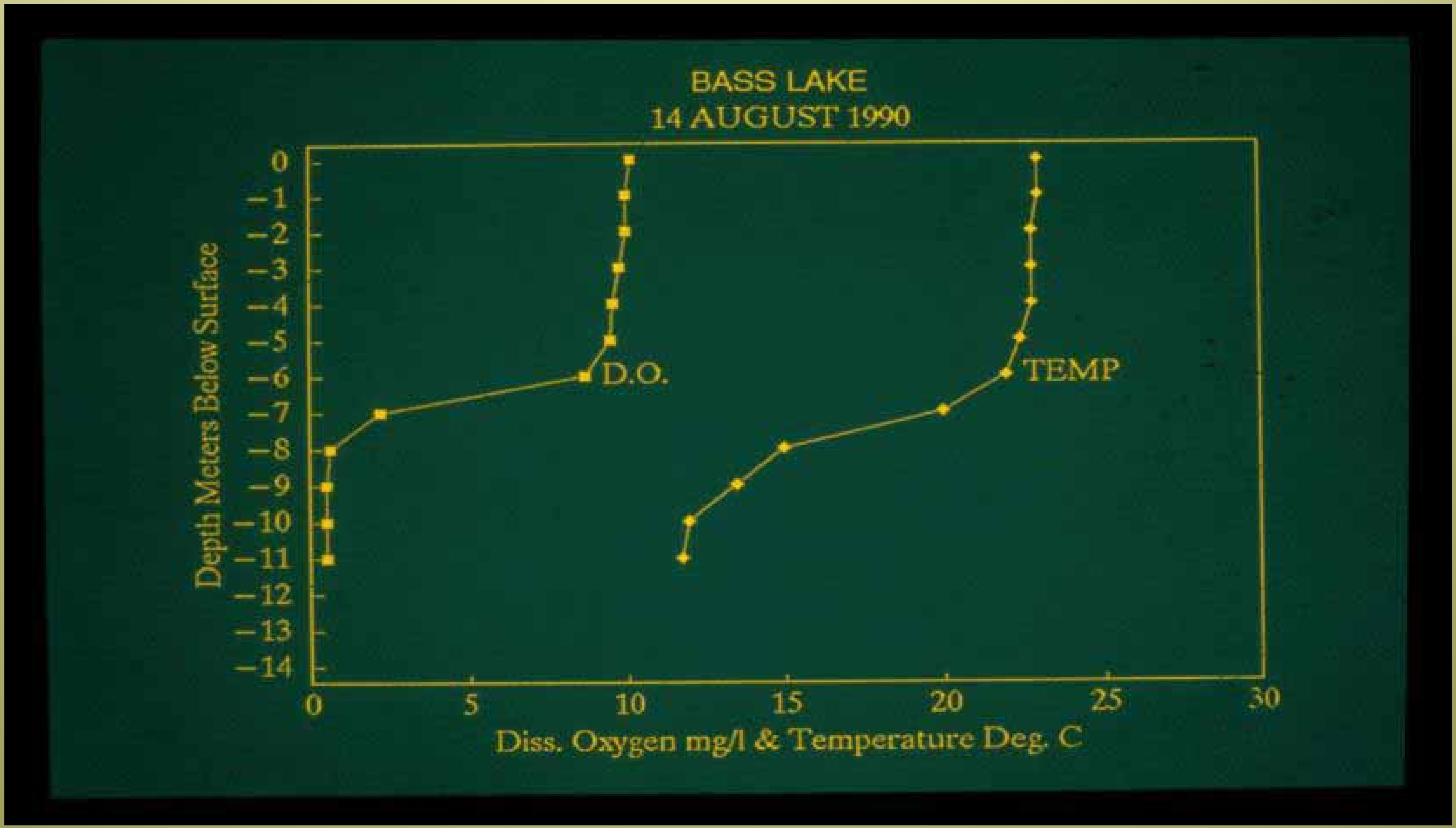
Every change of 10 in the TSI corresponds to a doubling of a lake's algae biomass and a halving of water clarity.

ENVIRONMENTAL SIGNS OF DEGRADATION

LOSS OF WATER CLARITY



HYPOLIMNETIC DO DEPLETION



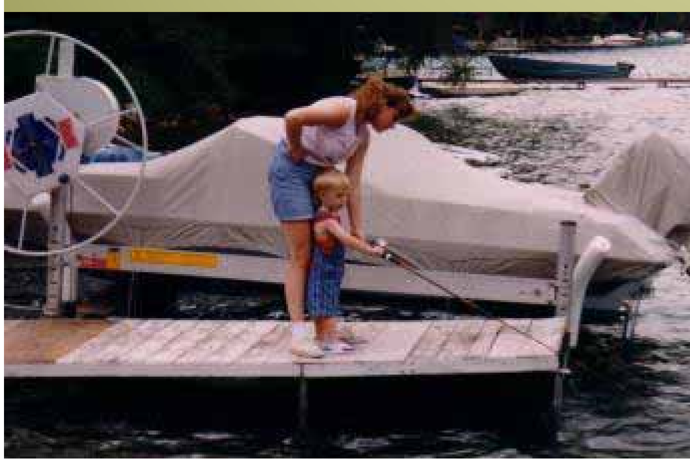
HARMFUL ALGAE BLOOMS

FISHERIES DEGRADATION

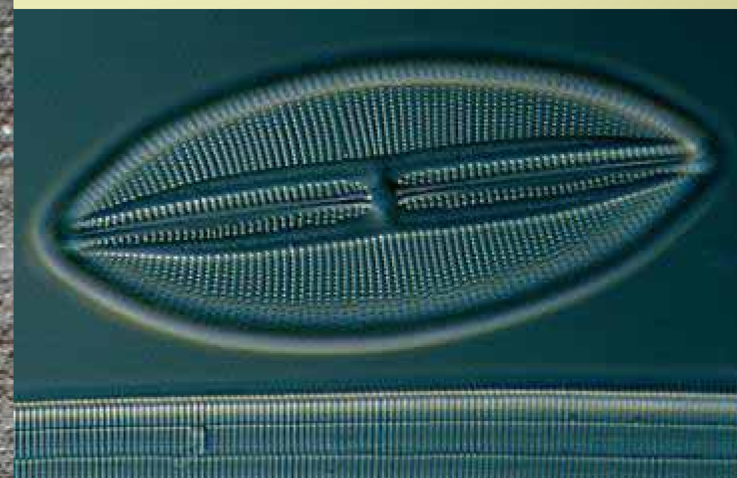
LEAVING A LEGACY

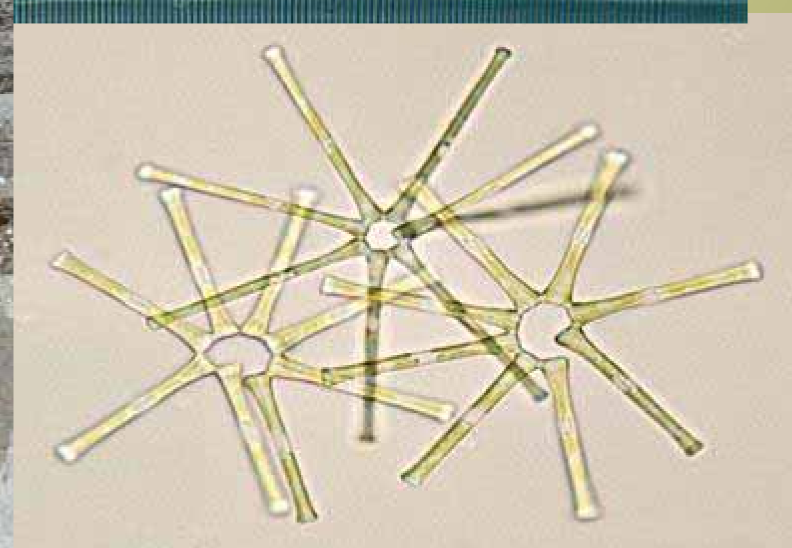
Help Protect Wisconsin's…

WATER RESOURCES.

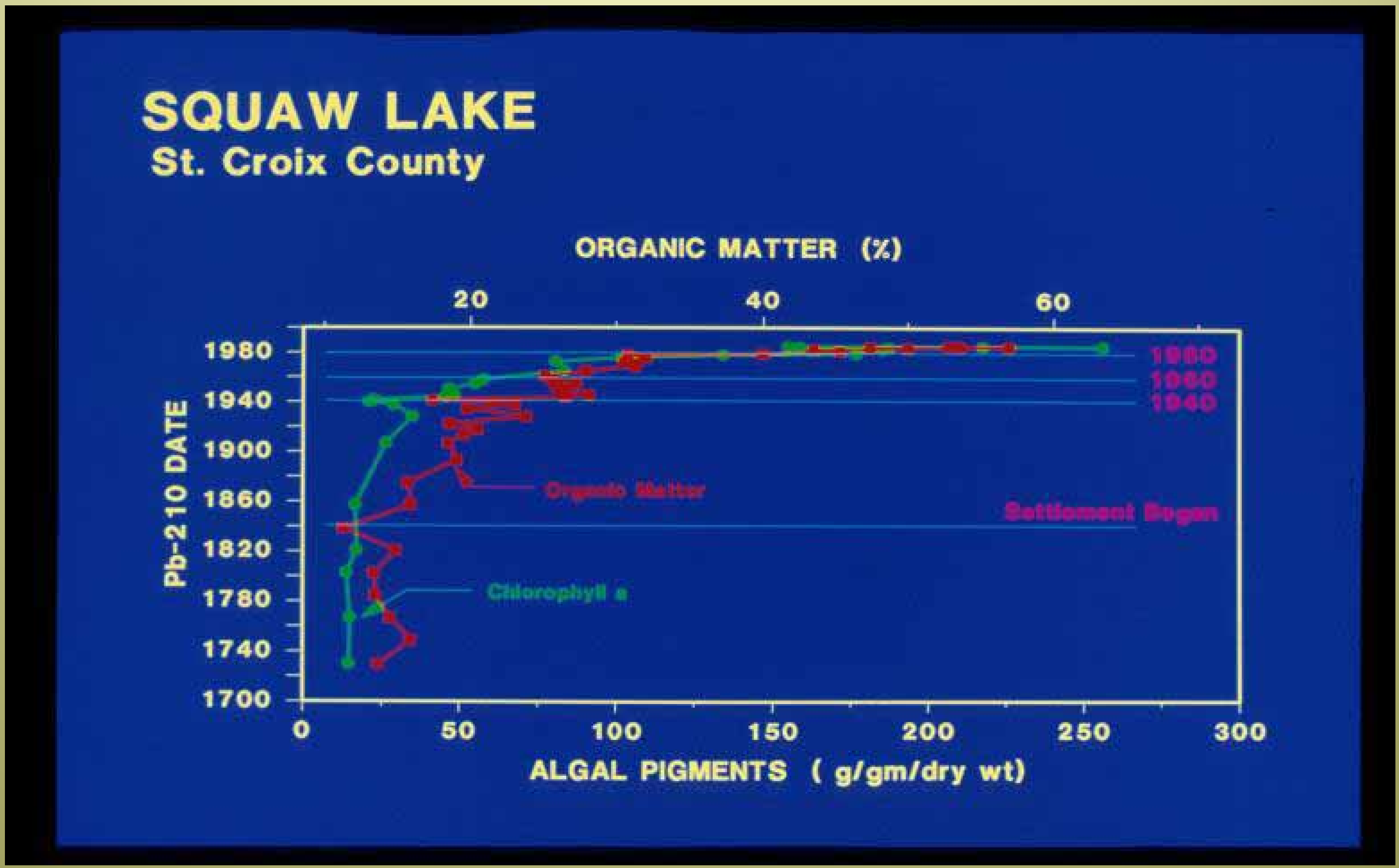


PALEOLIMNOLGY





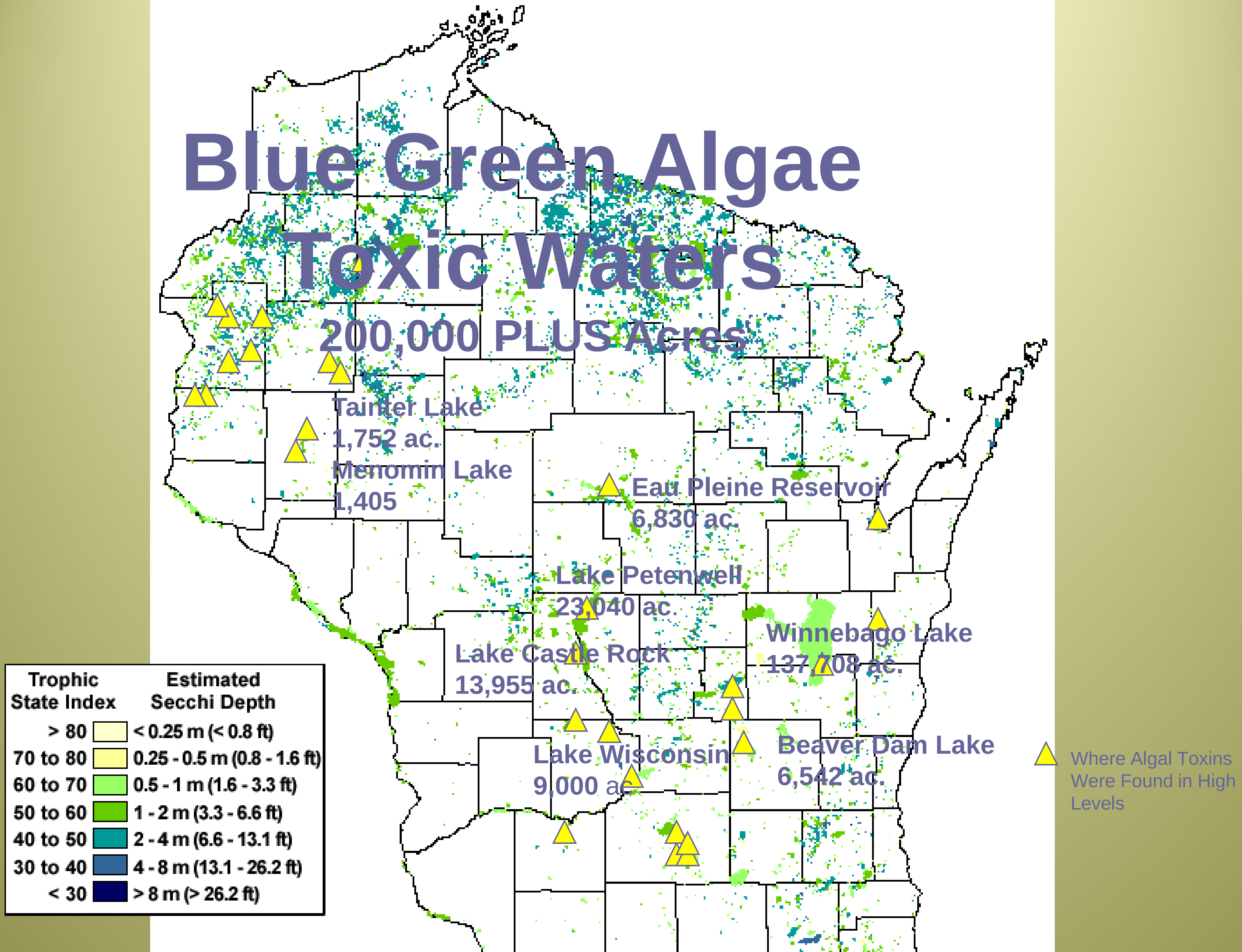
PALEOLIMNOLGY




Despite all this…..
HONDA

Blue Green Algae Toxic Waters

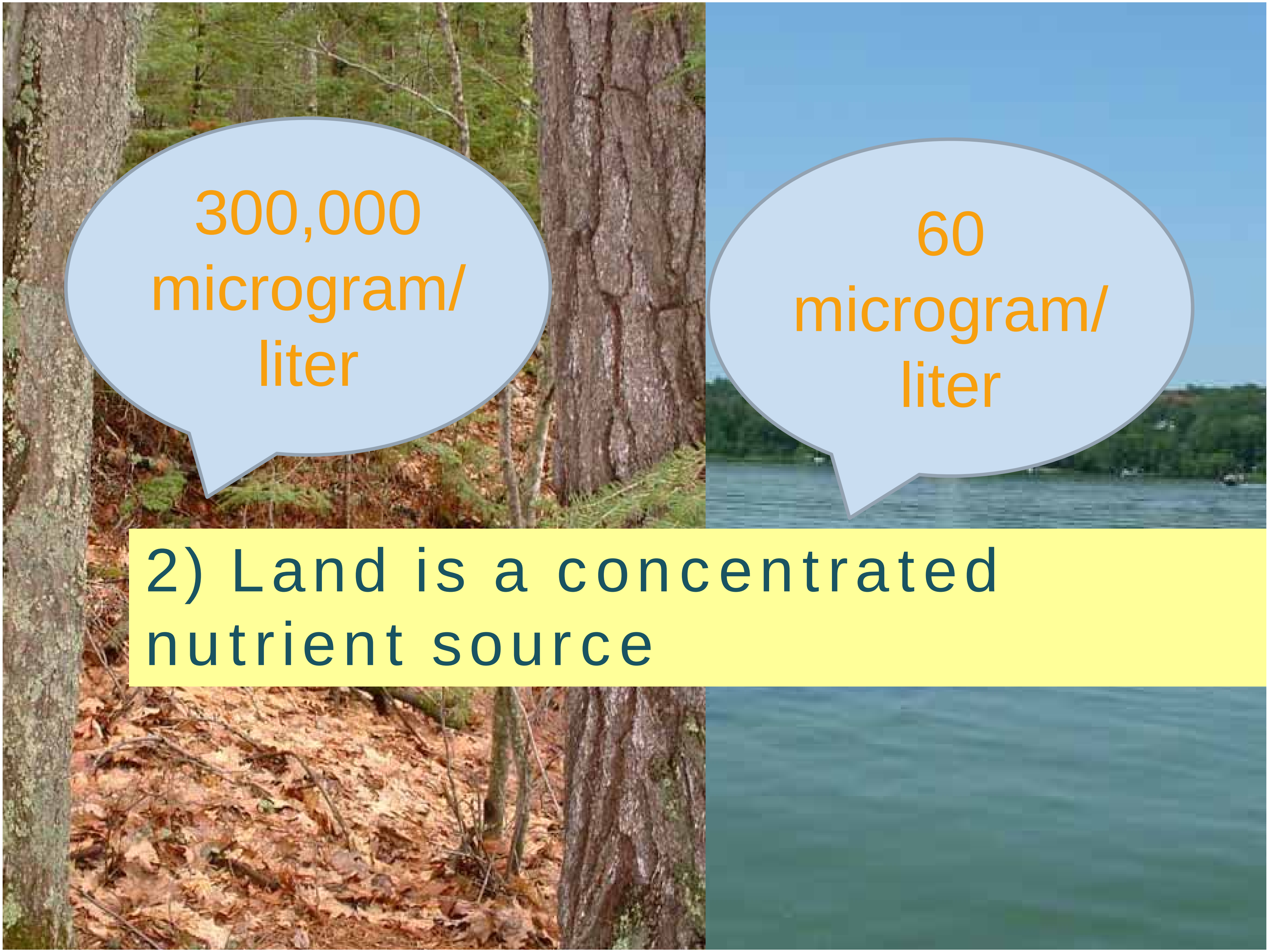
200,000 PLUS Acres



Algal toxins

A threat to both human and animal health

LAND USE AND WATERSHED IMPACTS



2) Land is a concentrated nutrient source

Empirical Watershed Models

Phosphorus export coefficients - developed based using monitoring data.

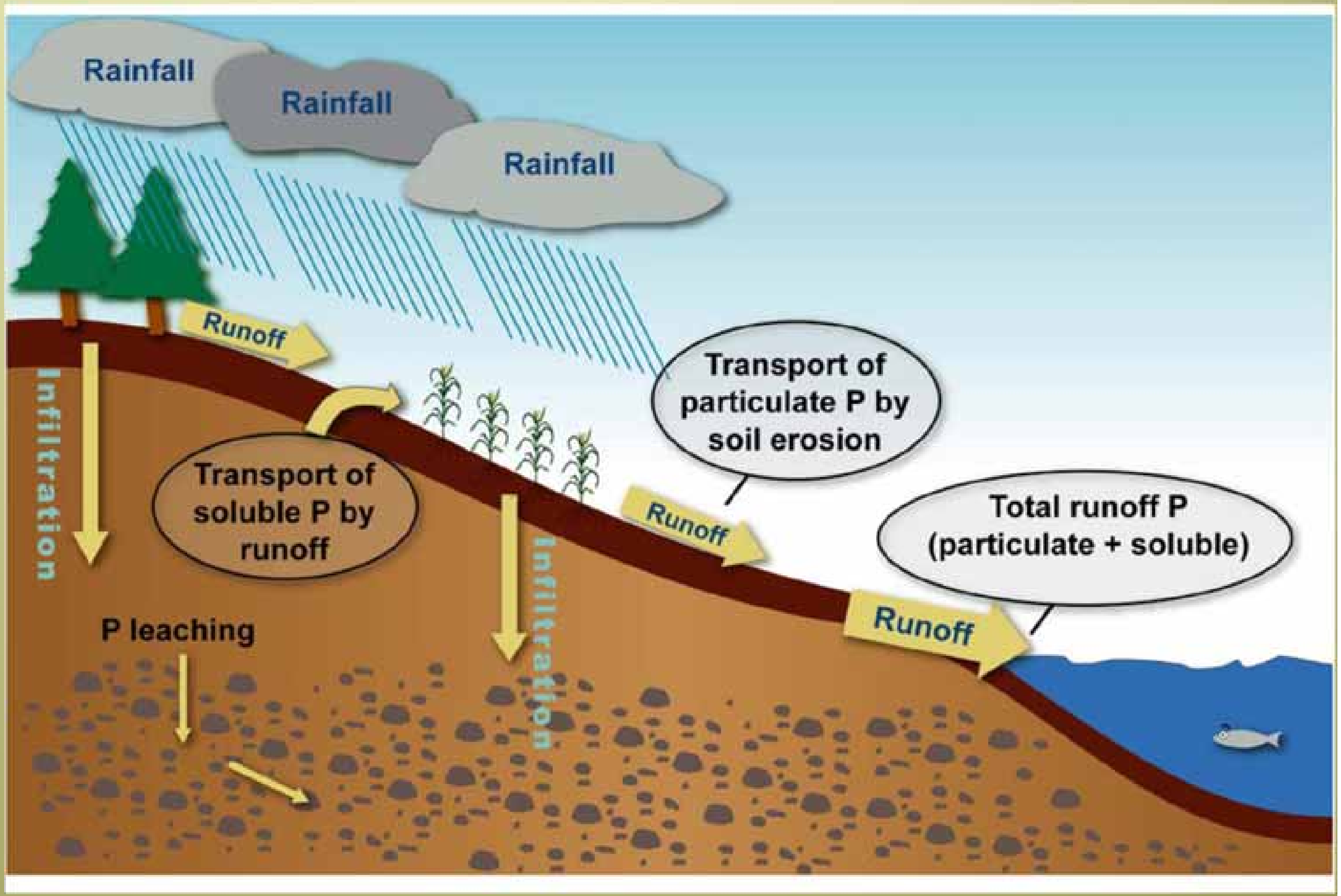
WISCONSIN VALUES

Land Cover	TP Export kg/ha/yr
High Density Urban	1.5
Row Crop Agriculture	1.0
Mixed Agriculture	0.8
Grass / Pasture	0.3
Medium Density Urban	0.5
Low Density Urban	0.1
Forested	0.09

Phosphorus transport

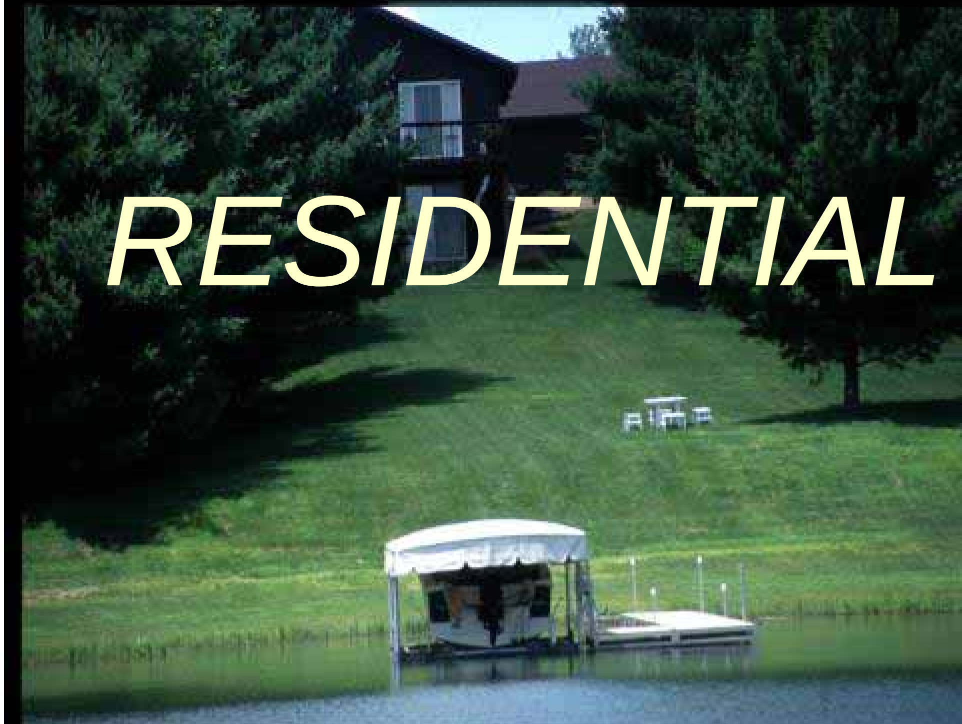
-- P is transported by runoff in both (1) dissolved [DP] and (2) particulate forms [PP].

-- GW-P is usually low, ~10-15 ppb



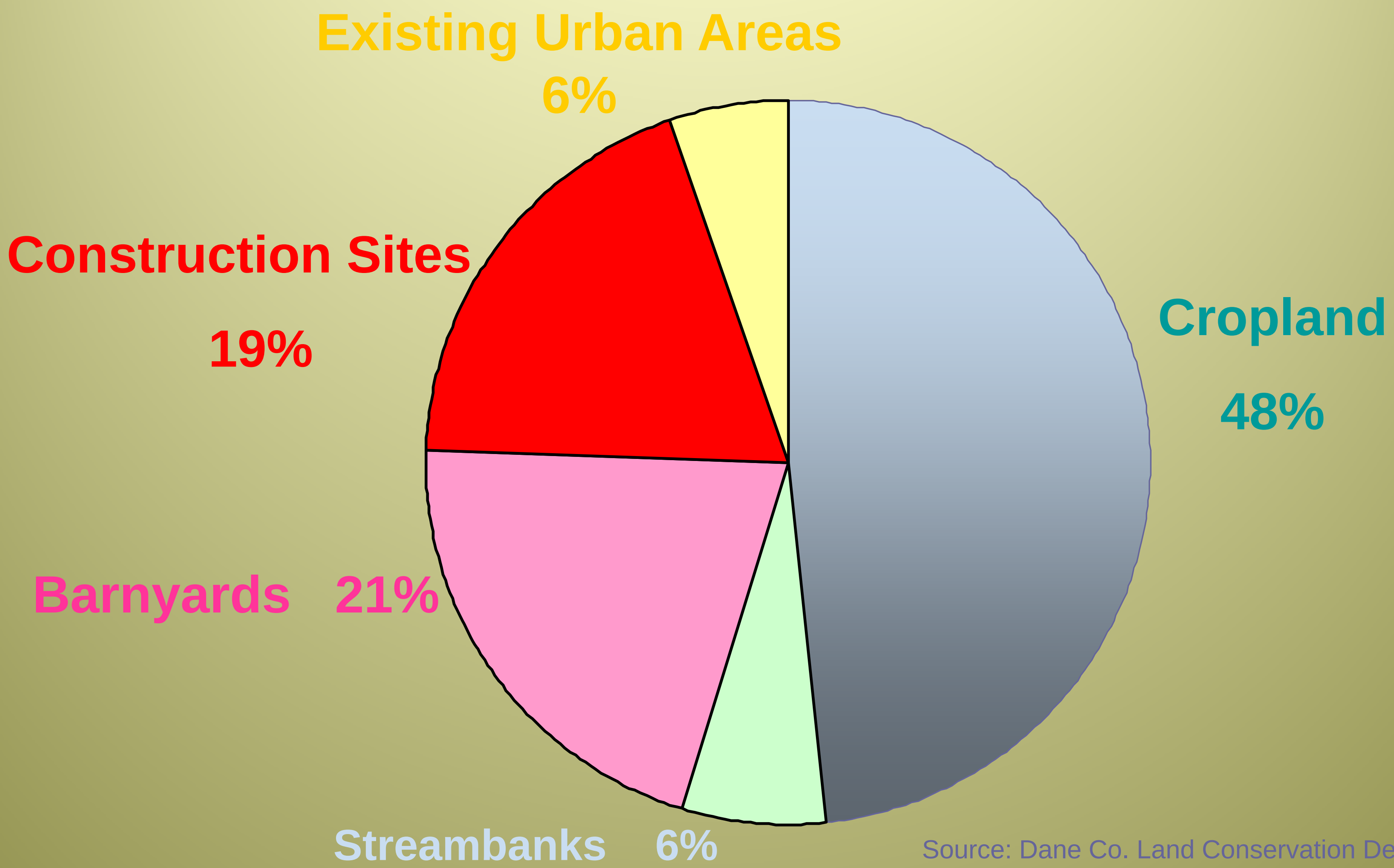
from Sturgul & Bundy 2004; UW-Madison & UW-Extension, Dept. of Nutrient & Pest Mgt.

RESIDENTIAL DEVLOPMENT



AGRICULTURE IMPACTS

P Loading Sources to Lake Mendota



Source: Dane Co. Land Conservation Dept.

Lake Mendota Watershed P Budget

(from Bennett et al. 1999)

P Inputs

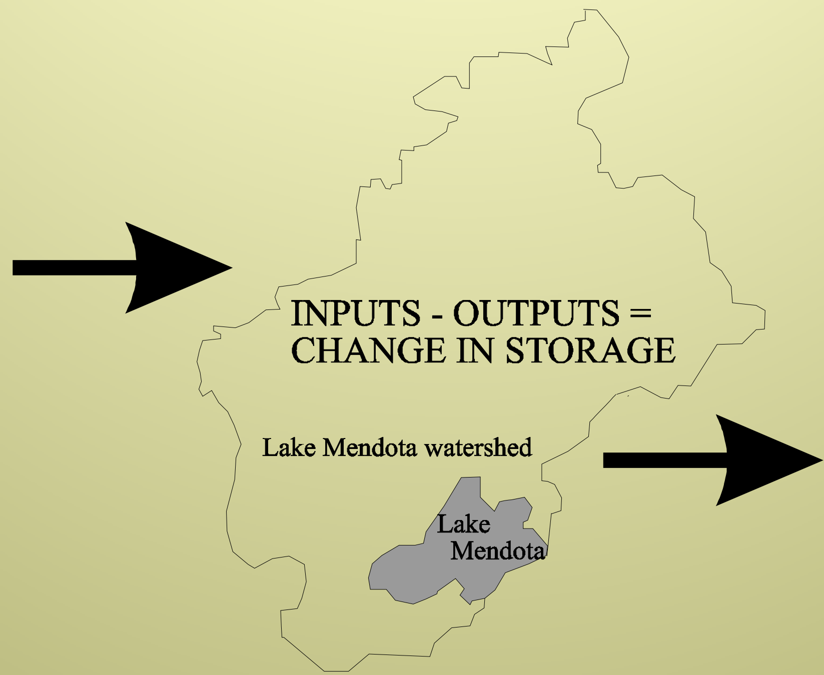
Fertilizer for agricultural crops, including:
- corn
- soybeans
- wheat
- oats
- peas and beans
- barley

Feed supplements for dairy cattle

Fertilizer for urban lawn

Dry and wet deposition

P in = 1,307 MT



P Outputs

Crops harvested, including:
- corn
- soybeans
- wheat
- oats
- peas and beans
- barley
- forage

Animal products, including:
- cattle
- hogs/pigs
- milk and dairy
- eggs

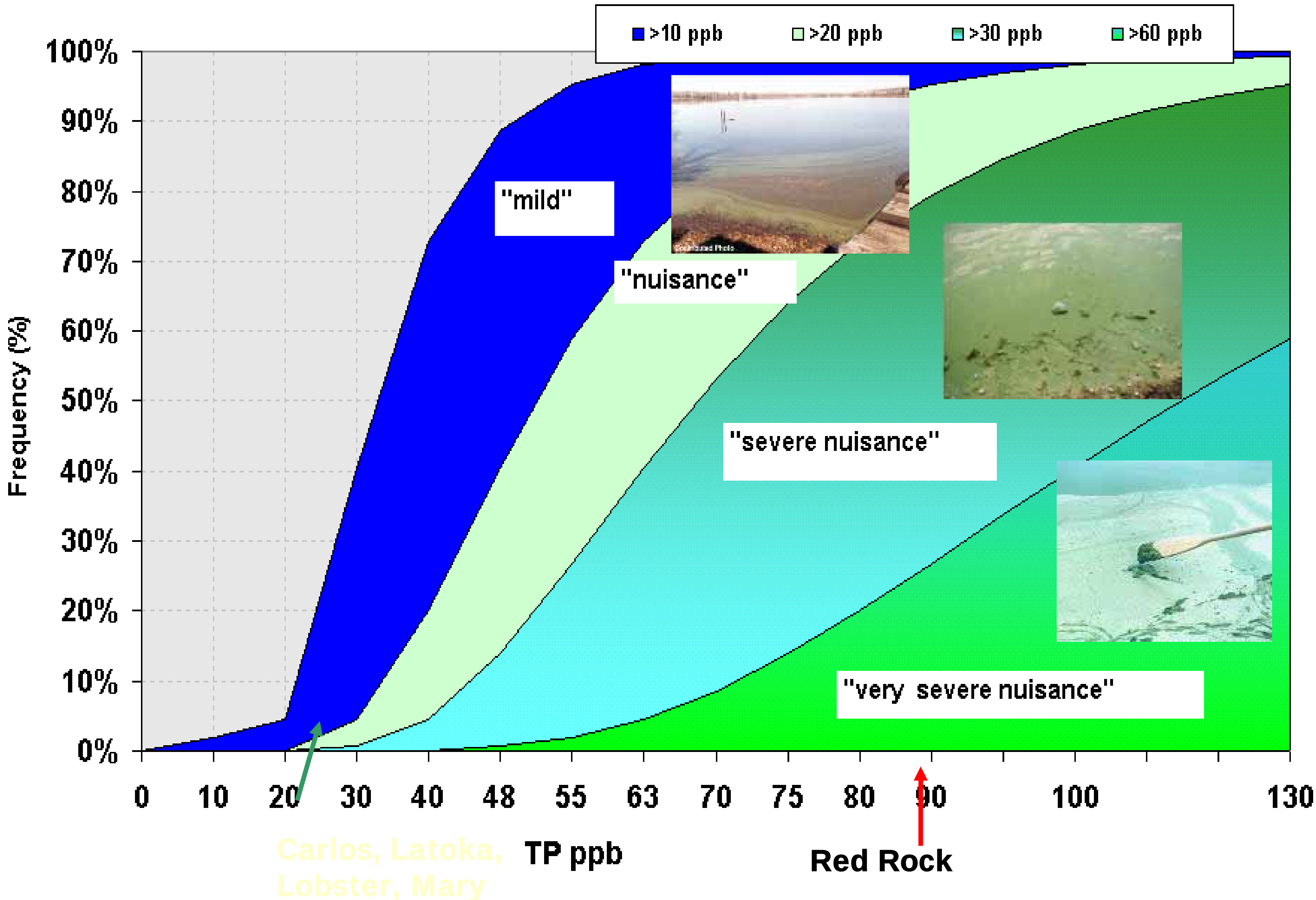
Hydrologic export to Lake Mendota **= 34 MT**

P out = 732 MT

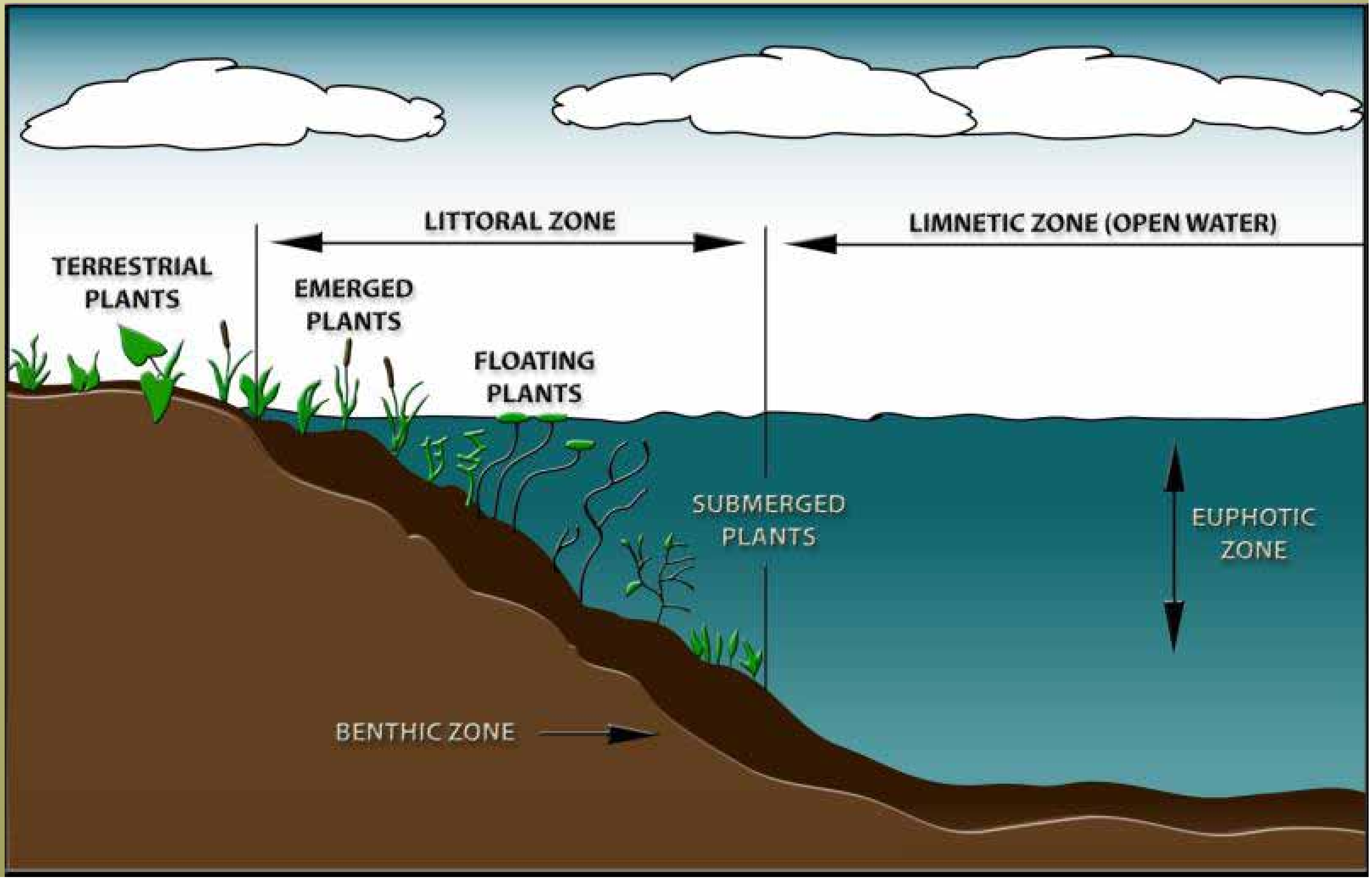
P Storage = + 575 MT !!

Figure 1. Schematic diagram of inputs and outputs used to calculate a P budget for the Lake Mendota watershed for 1995.

Chlorophyll-a interval frequency versus total phosphorus.



LAKE HABITAT ZONES

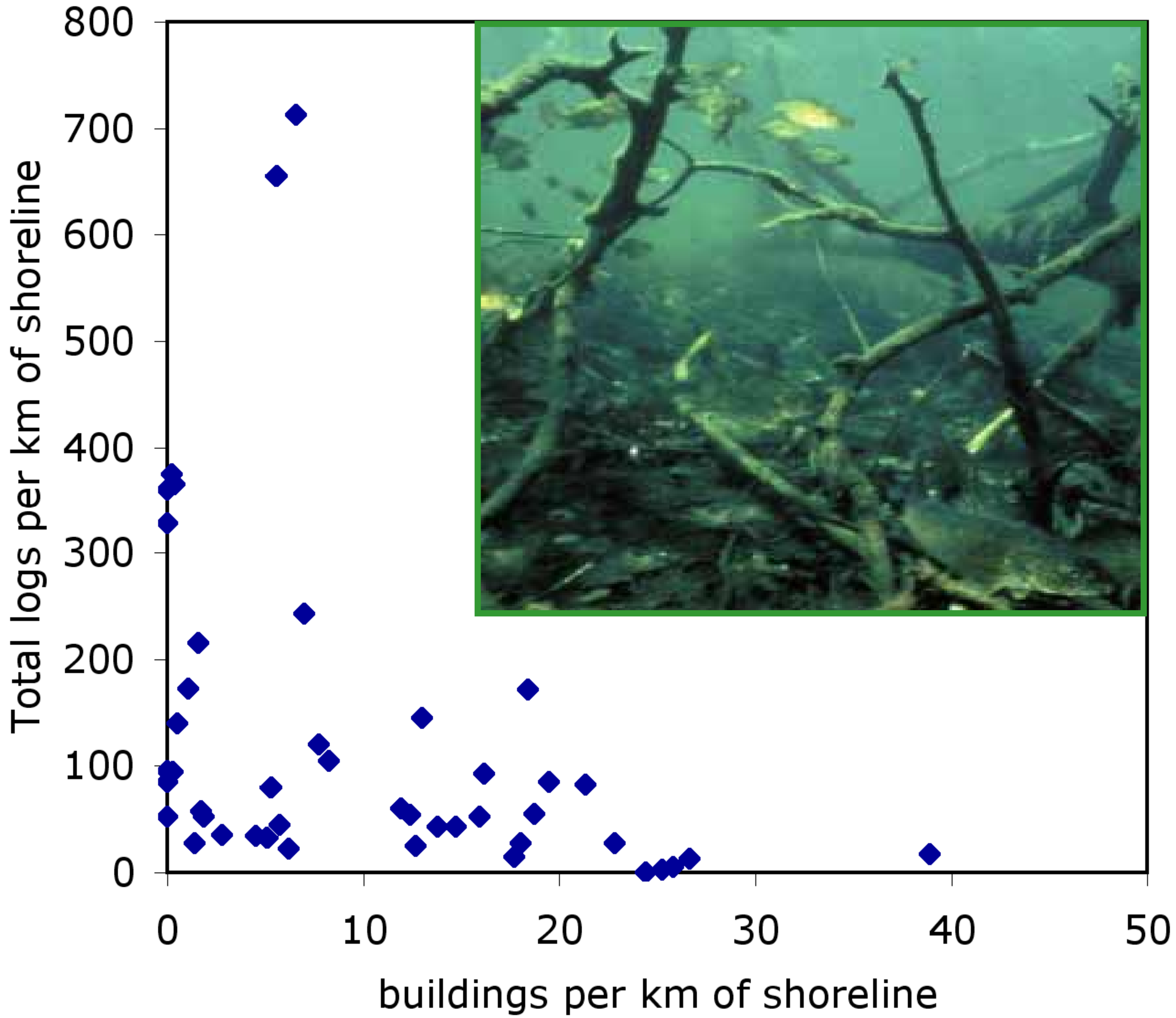


Without habitat, they are gone

Shoreland green frog trends

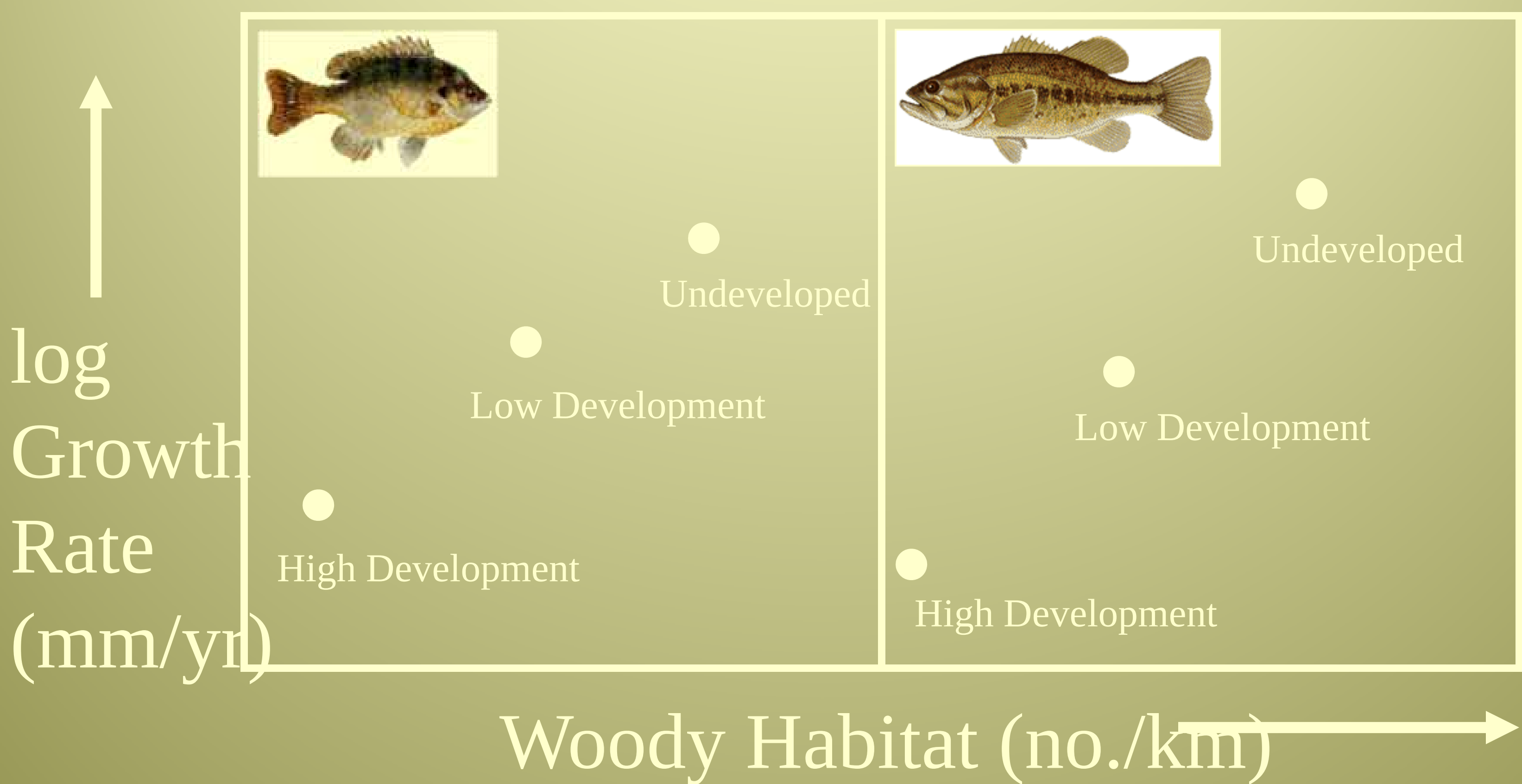
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership



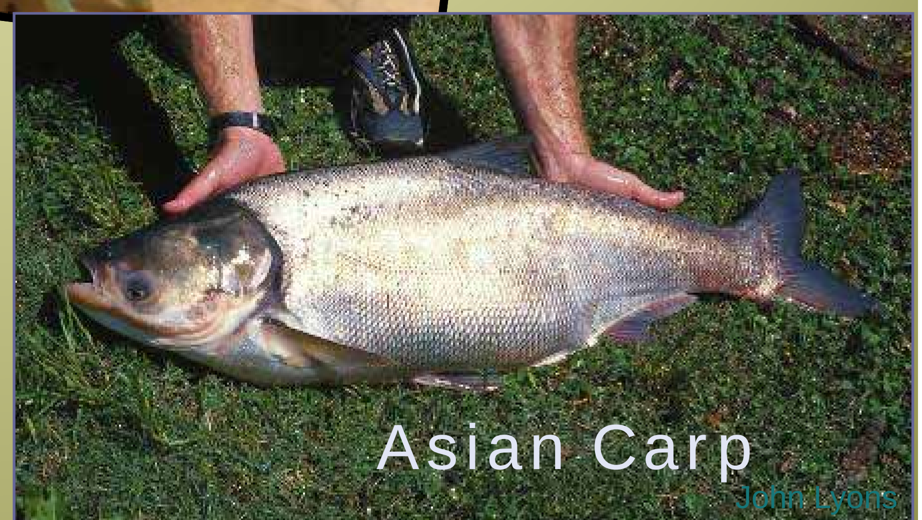
Data: U.W. BioComplexity project

Fish grow ~3X faster in lakes with lots of woody habitat



From Schindler et al. 2000

Aquatic Invasive Species in Wisconsin



How do they get here?

- Ballast water
- Stocking
- Nursery industry
- Bait industry
- Aquarium trade
- Aquaculture

How do they spread?

- Boaters
- Anglers
- Other water users
- Natural dispersal

Why do we care?

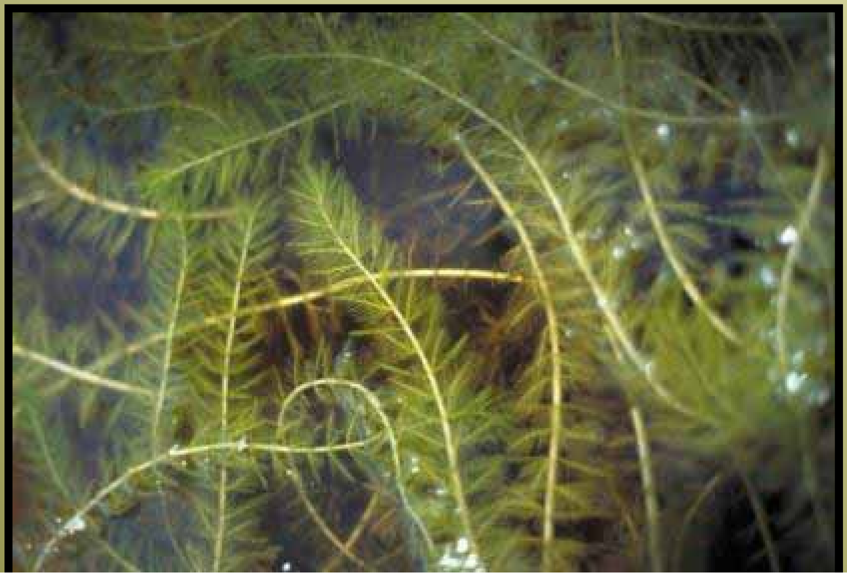
- **Economic impacts**
  - Fishing industry, tourism, property values
- **Ecological impacts**
  - Native fish, invertebrates, plants
- **Recreational impacts**
  - Boating, angling, swimming

Wisconsin’s AIS Program

Prevent introduction and limit the spread of aquatic invasive species

Program Goals

- **Focus on containment**
- **Increase AIS awareness & responsible behaviors**
- **Strengthen partnerships**



AIS Program Elements

- **Education & Outreach**
- **Watercraft Inspection**
- **Citizen Lake Monitoring**
- **Purple Loosestrife Biological Control**
- **Aquatic Invasive Species Grants**
- **Research**
- **Rules to Prevent Spread**

How do you make this…

function like this?