

# LAKE HEALTH

*Courtesy of Lake Partnerships*

Wisconsin Department of Natural Resources

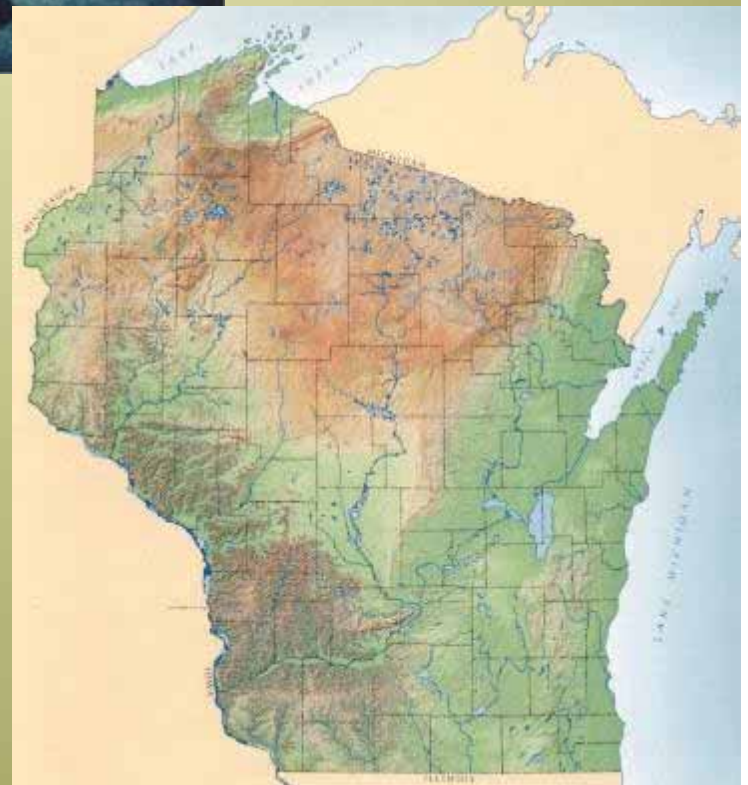
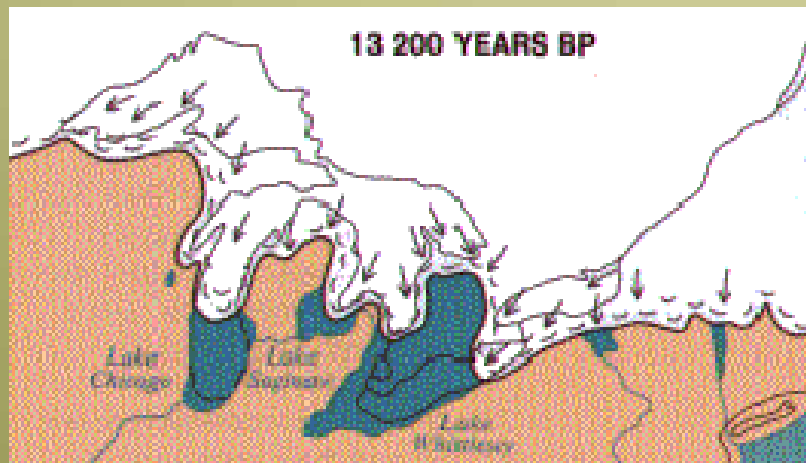
Wisconsin Association of Lakes

University of Wisconsin Extension

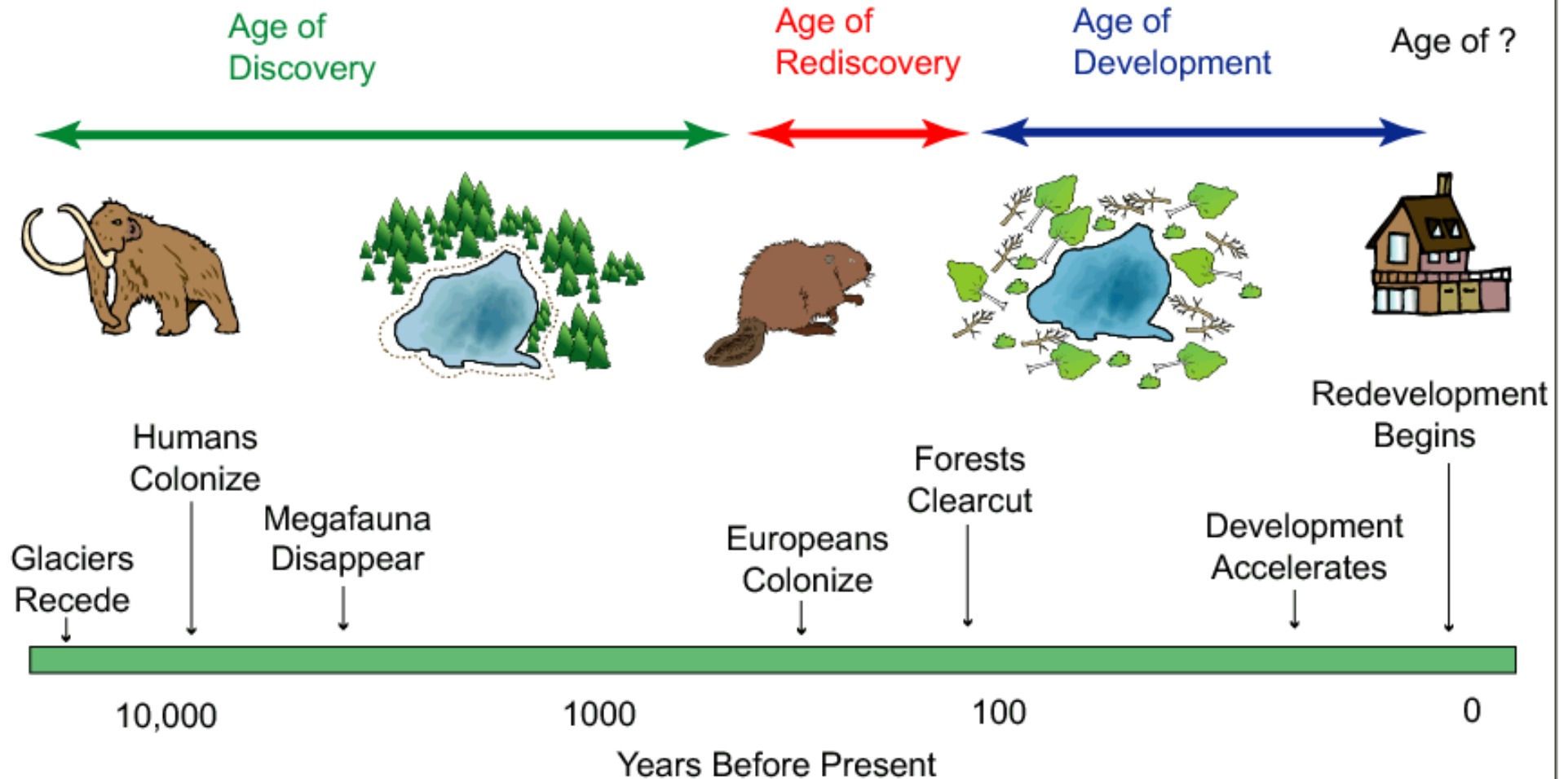


## Definitions & Background

# Wisconsin's Glacial Legacy



# Recent History of Wisconsin's Lakes





# Lakes Provide Services



Sara Schmidt

Sara Schmidt



# Wisconsin's Lakes are Changing Faster than Ever:

Algae blooms  
(phosphorus pollution)

Destruction of  
shoreline habitat

Invading plants and  
animals



# WISCONSIN'S CHANGING CLIMATE:

*IMPACTS AND ADAPTATION*

The first report of the Wisconsin Initiative on Climate Change Impacts

2011

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)

# 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**



Photo: <http://photogallery.nrcs.usda.gov/>



Photo: R. Lathrop

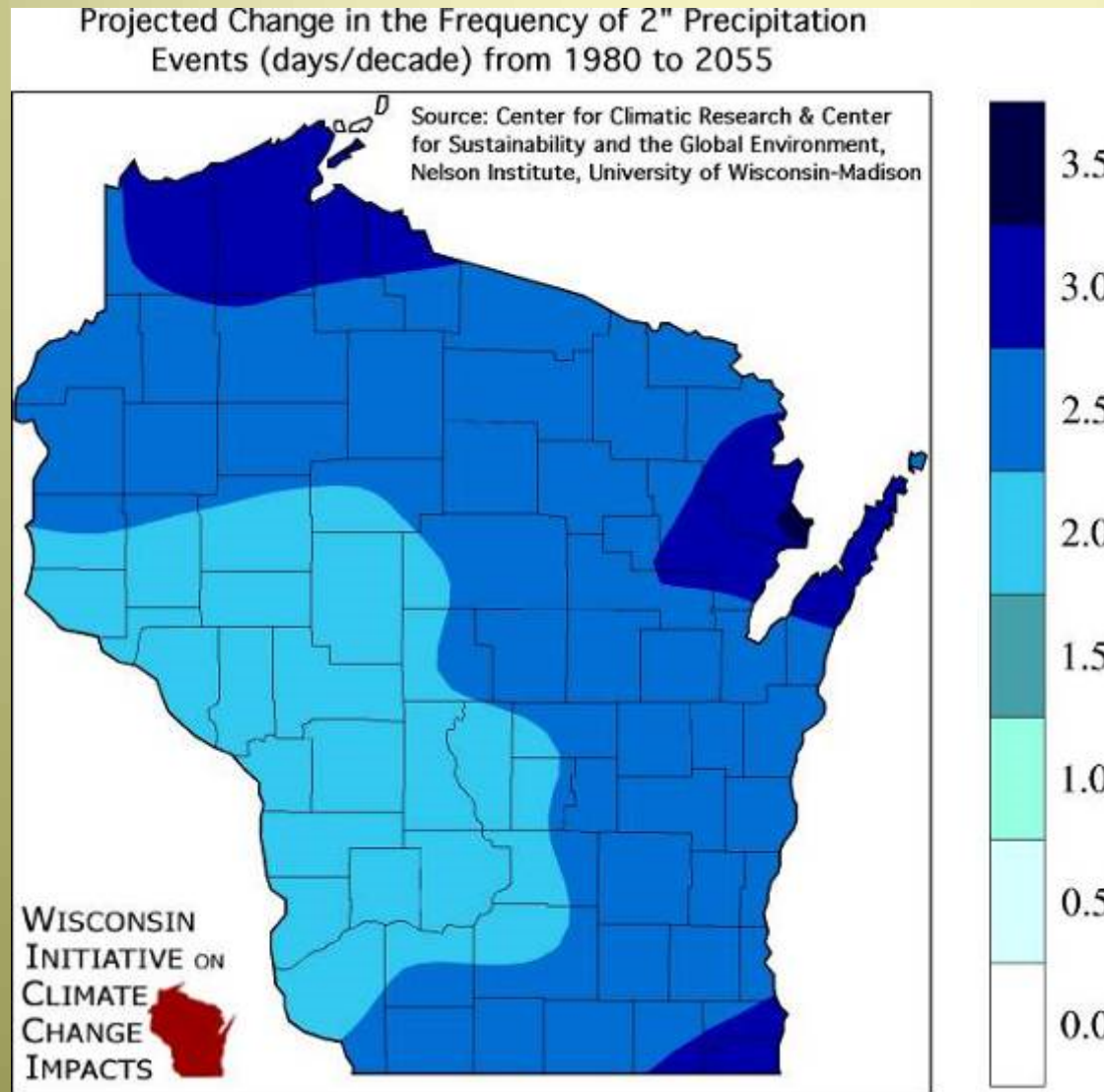


Photo: R. Lathrop

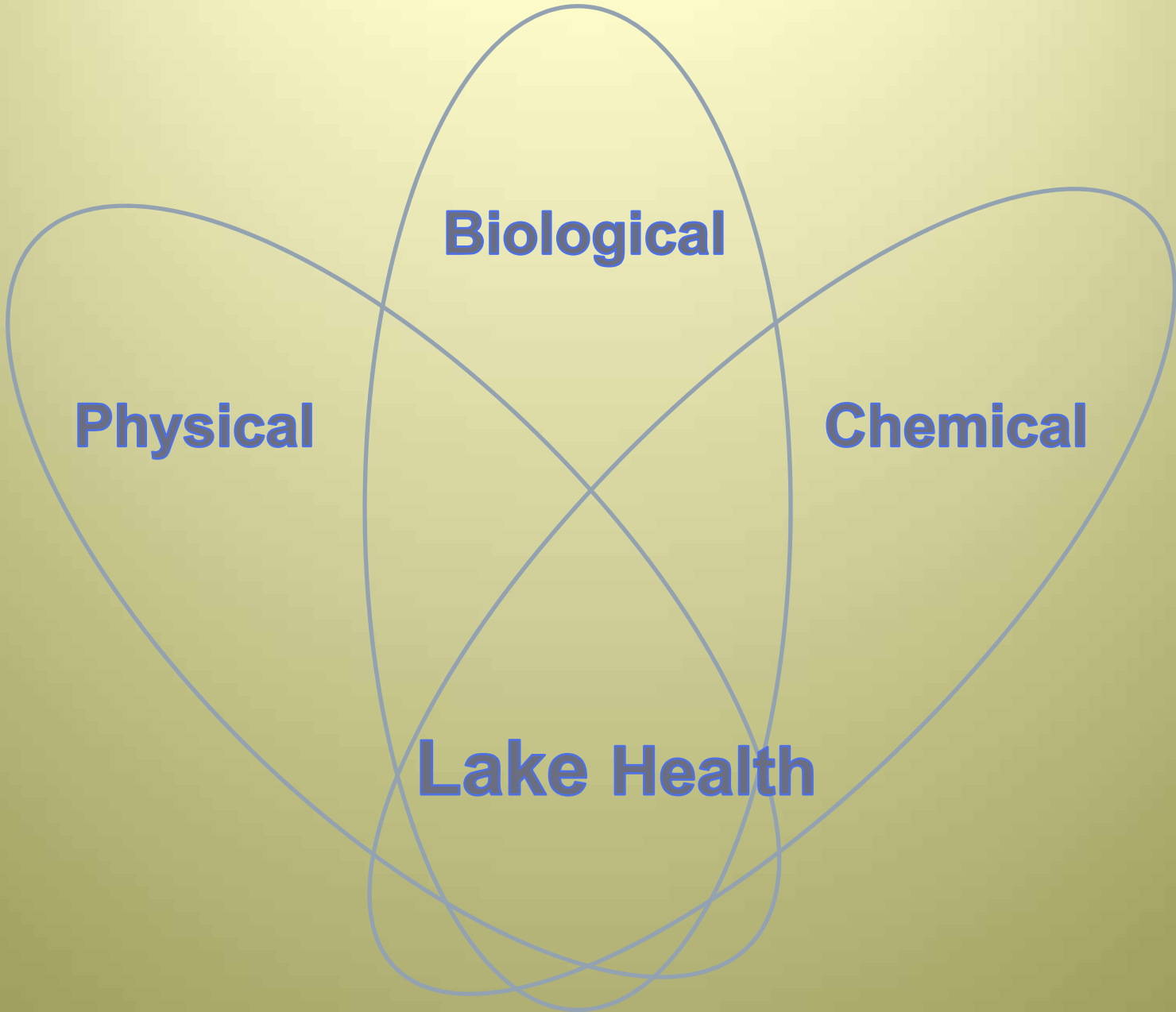


Photo: Melvin McCartney, Lake Monona, June 2006

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



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



**Physical**

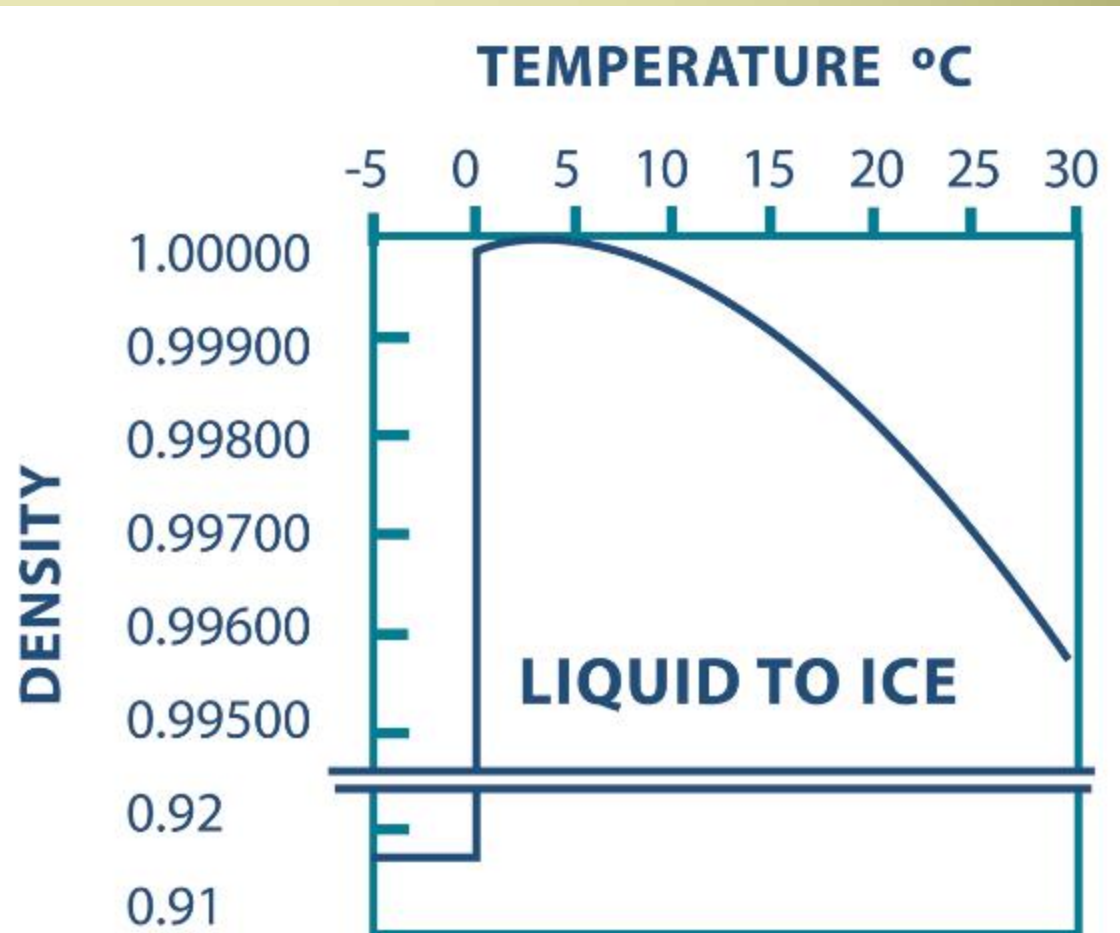
**Biological**

**Chemical**

**Lake Health**

# 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





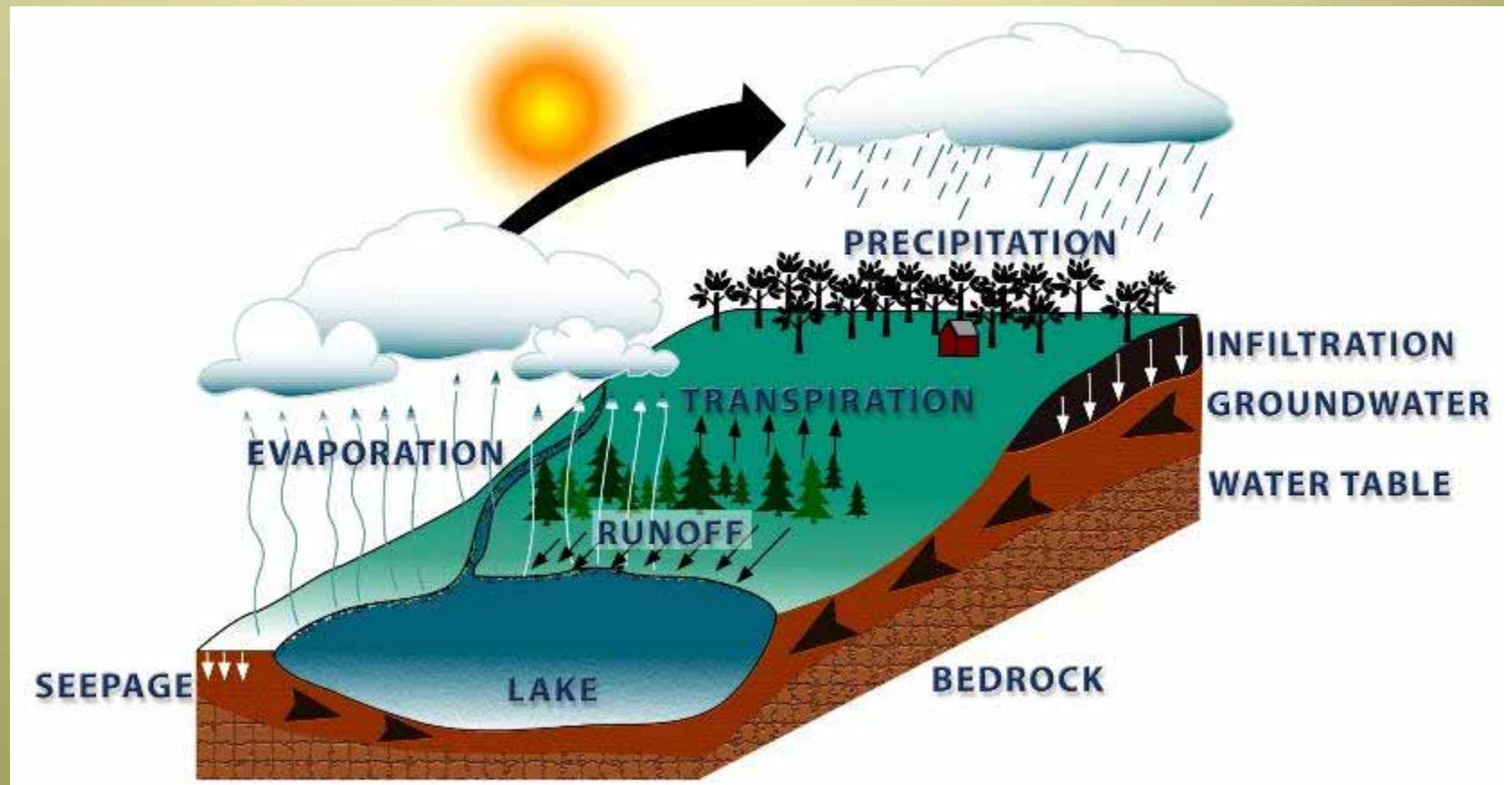
# THE WISCONSIN WATER STORY

32"

32"

20"

# HYDROLOGIC CYCLE





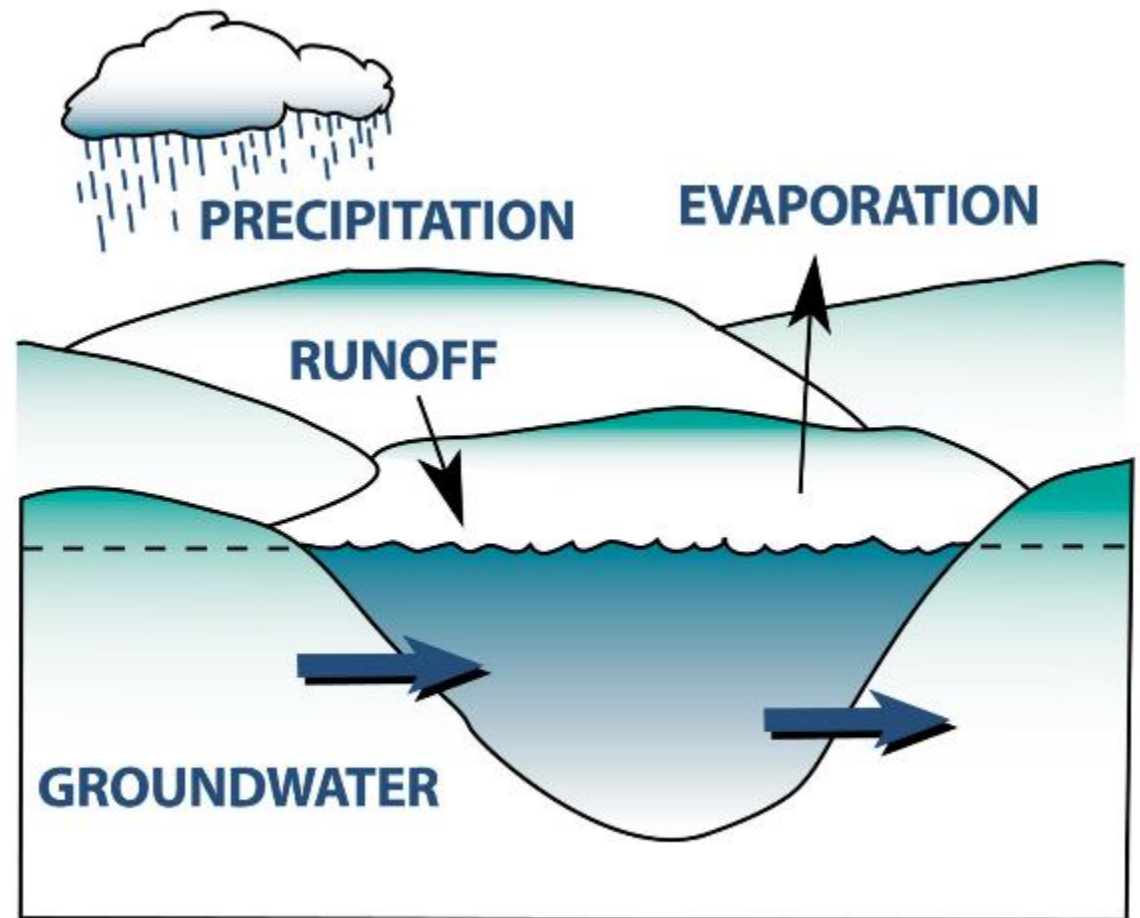
# LAKE TYPES

- Seepage
- Groundwater Drainage
- Drainage
- Impoundments
- Oxbow



# SEEPAGE LAKE

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

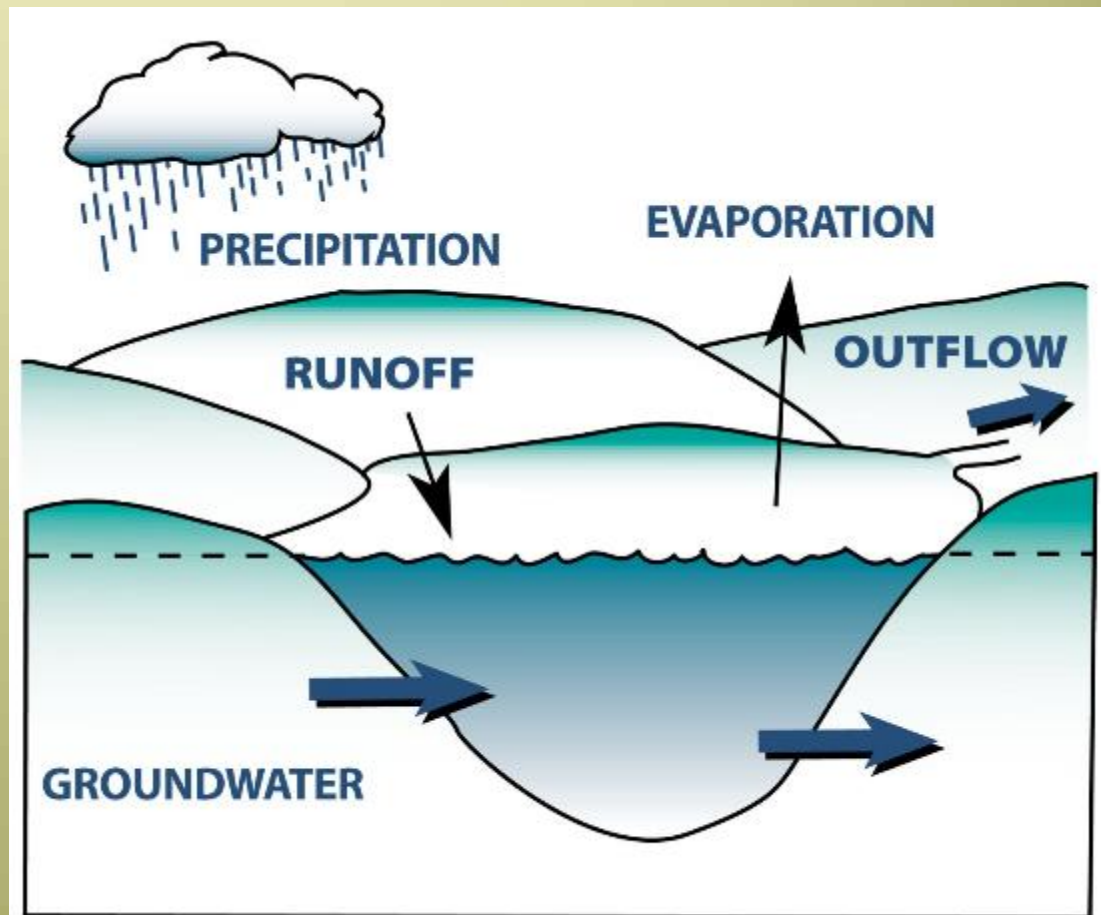






# GROUNDWATER DRAINAGE

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

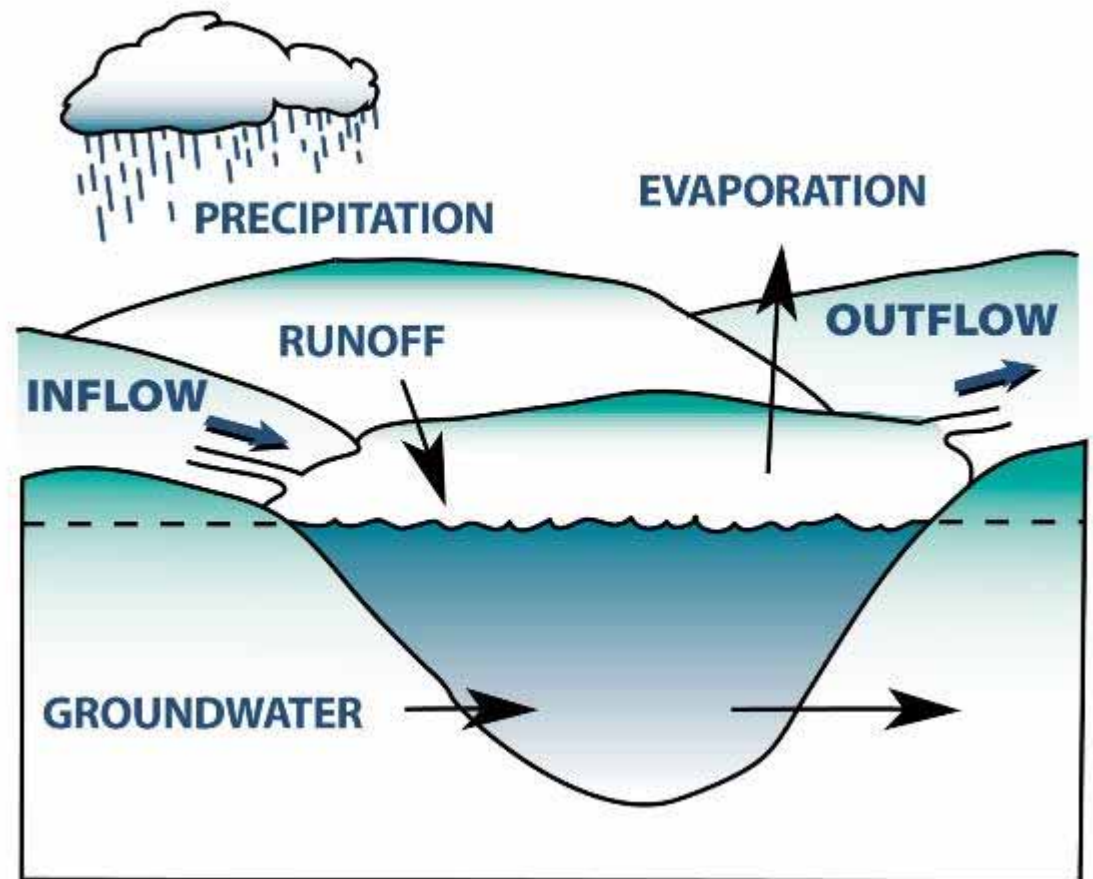


# GROUNDWATER DRAINAGE LAKE

■ Sand Lake, Chippewa County

# DRAINAGE LAKE

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





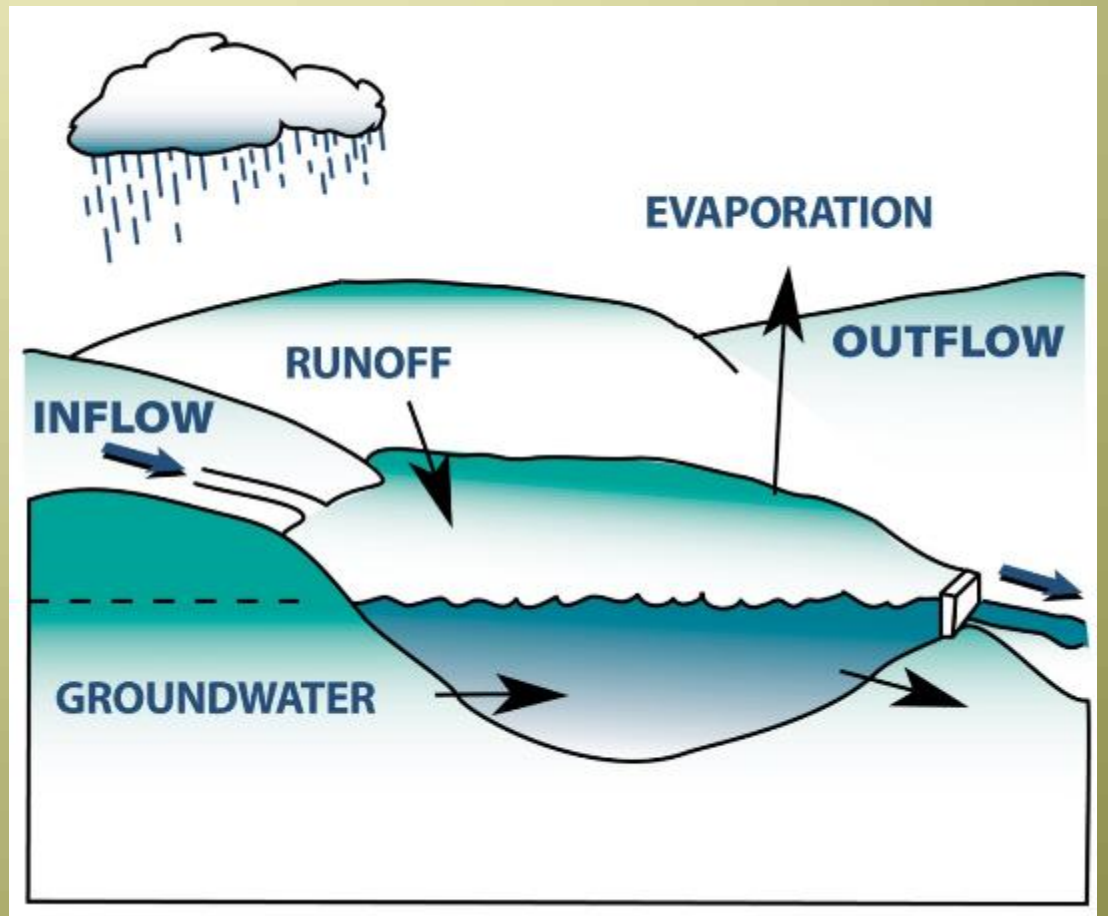
# DRAINAGE LAKE



■ Long Lake, Chippewa County

# IMPOUNDMENT

- A manmade lake
- Dammed River or Stream









■ Lake Hallie, Chippewa County

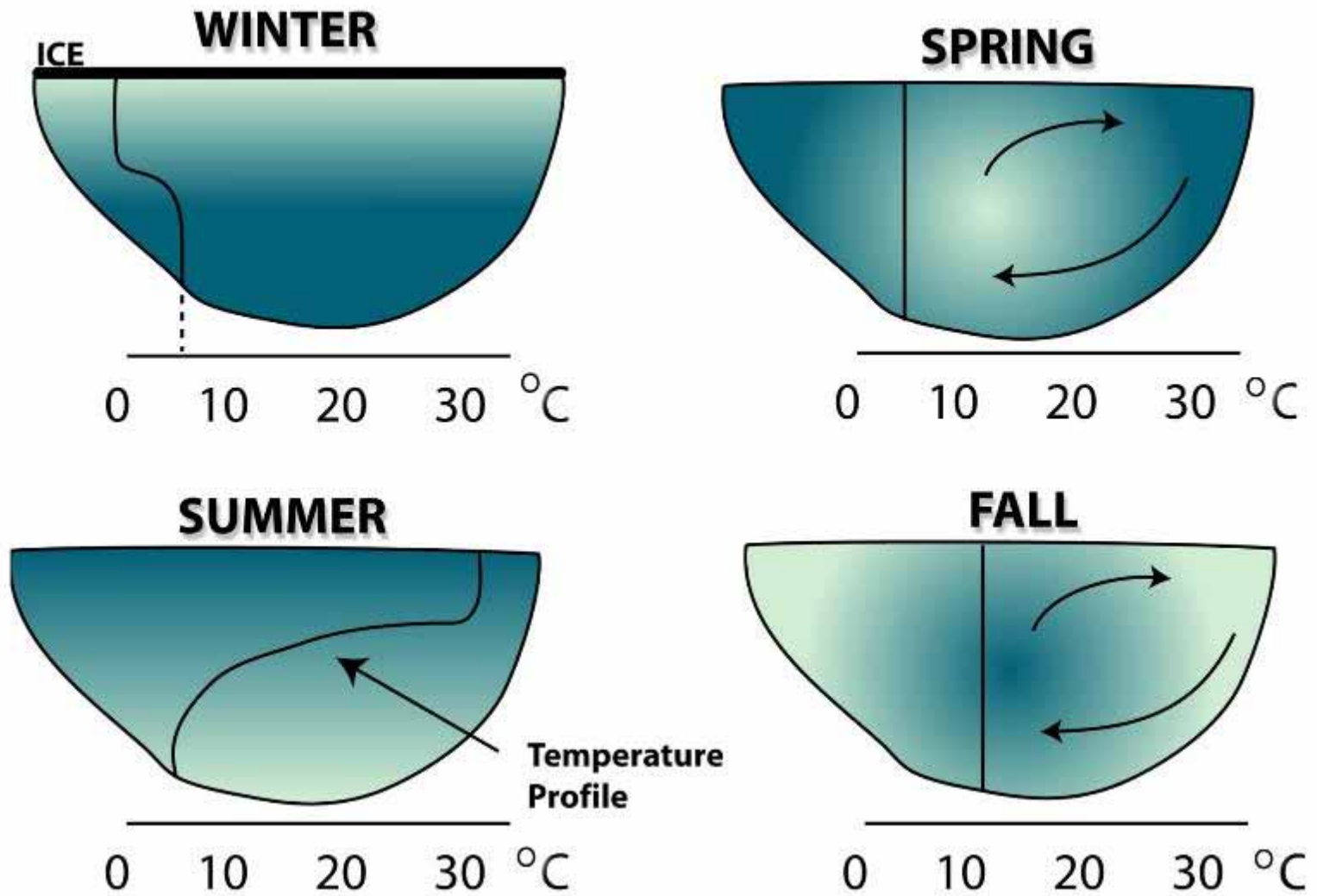


# PHYSICAL CHARACTERISTICS

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

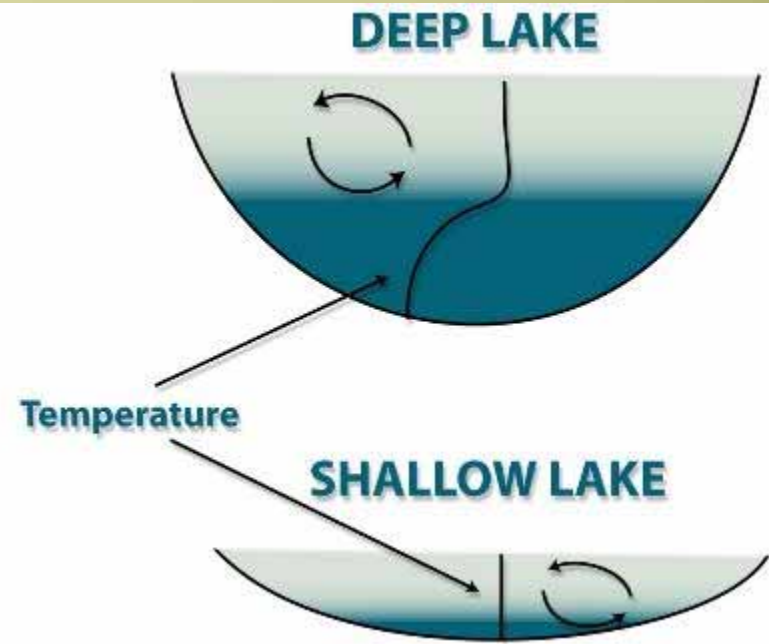


# MIXING/ STRATIFICATION



# LAKE DEPTH MATTERS

- **Deep Lakes**  
Stratify
- **Shallow Lakes**  
Continuous Nutrient  
Recycling



Sections 26, 27, 34, 35  
Alden Township  
in Polk County

Sections 2 and 3  
Star Prairie Township  
in St. Croix County

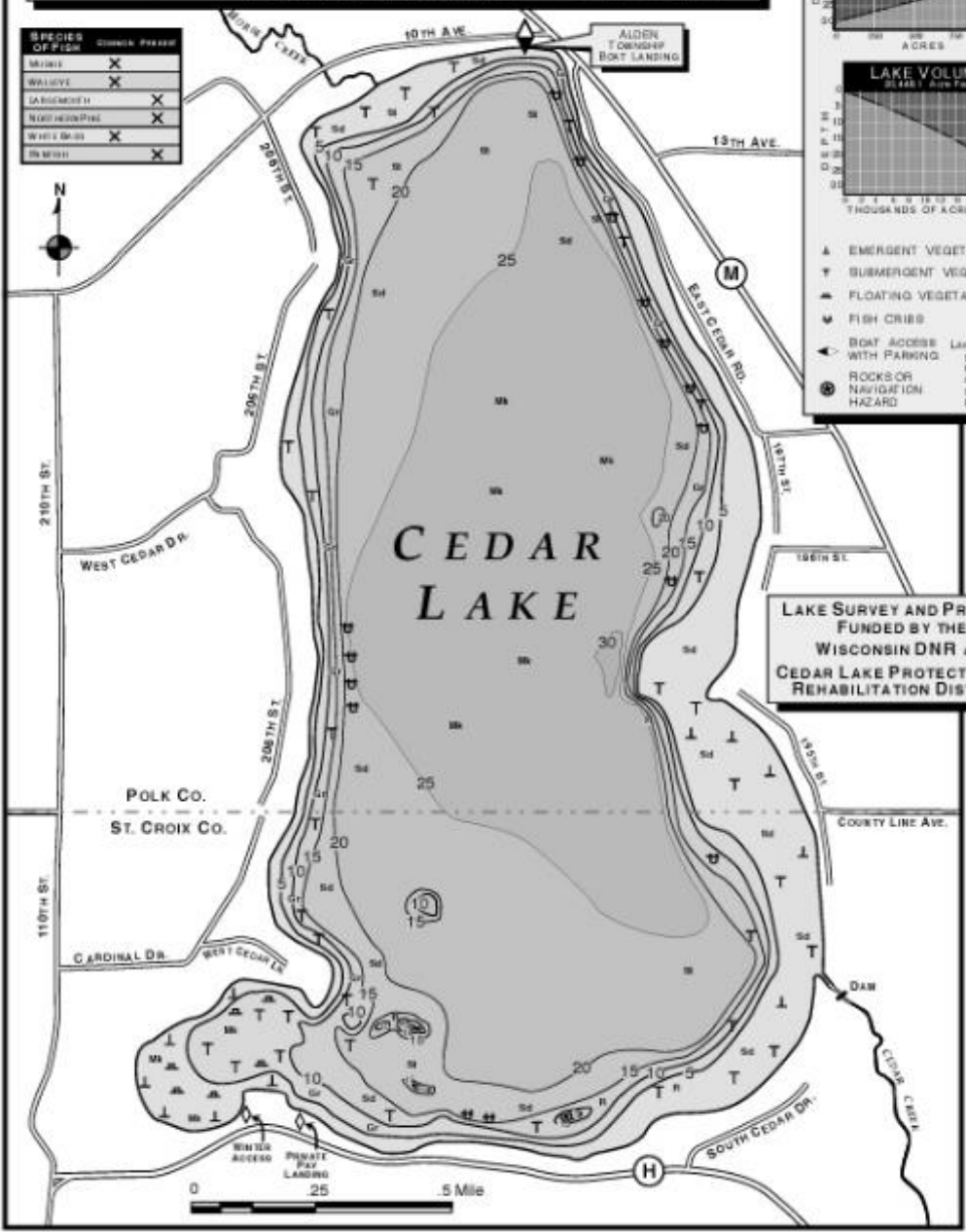
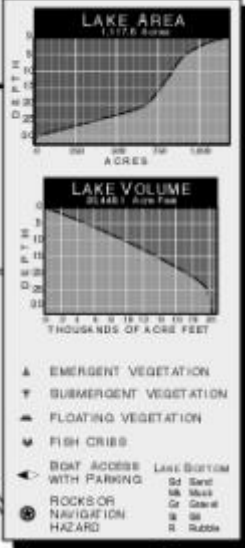
# CEDAR LAKE BATHYMETRIC MAP

1998 Survey Integrating Sonar with GPS  
SEAN HARTNETT • GEOGRAPHER  
UNIVERSITY OF WISCONSIN - EAU CLAIRE

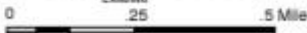
AREA: 1,117.6 Acres  
Under 5 Feet: 189.0 Acres  
Over 20 Feet: 875.8 Acres

VOLUME: 20,448.1 Acre Feet  
MAXIMUM DEPTH: 34 Feet  
SHORELINE: 6.40 Miles

| SPECIES OF FISH | COMMON PRESENT |
|-----------------|----------------|
| MUSKIE          | X              |
| WALLEYE         | X              |
| LAKELINE        | X              |
| NORRHEEDFISH    | X              |
| WHITE BASS      | X              |
| BASS            | X              |



LAKE SURVEY AND PRINTING  
FUNDED BY THE  
WISCONSIN DNR and  
CEDAR LAKE PROTECTION and  
REHABILITATION DISTRICT



$$20448/1117.6=18$$



*Precip* – **ET** – *Runoff*

Change in water table (also lakes and wetlands)

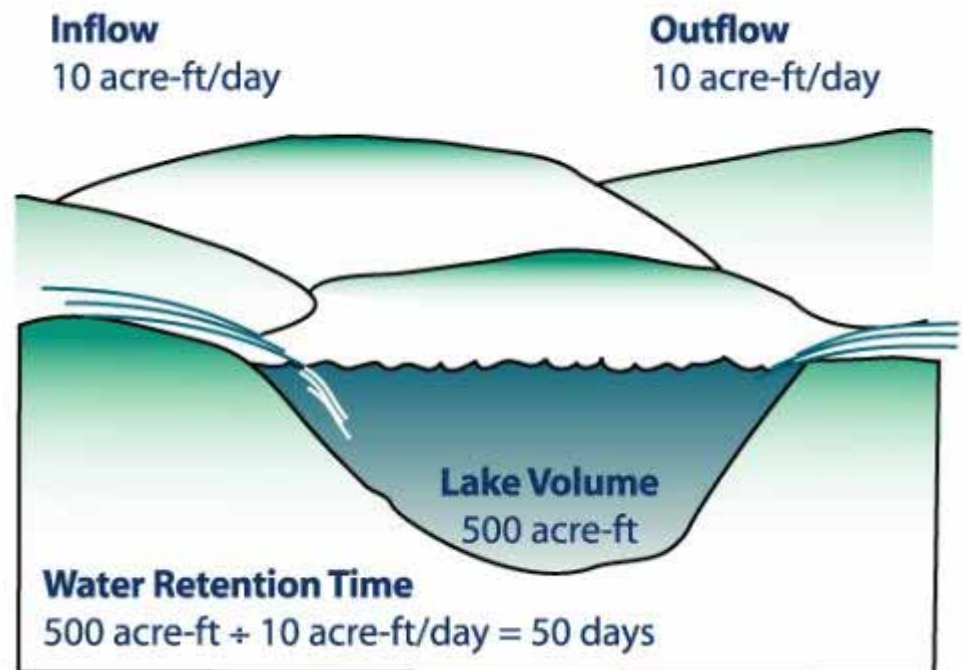
$$\text{Water In} - \text{Water Out} = \pm \text{Storage}$$

Discharge to streams



# 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

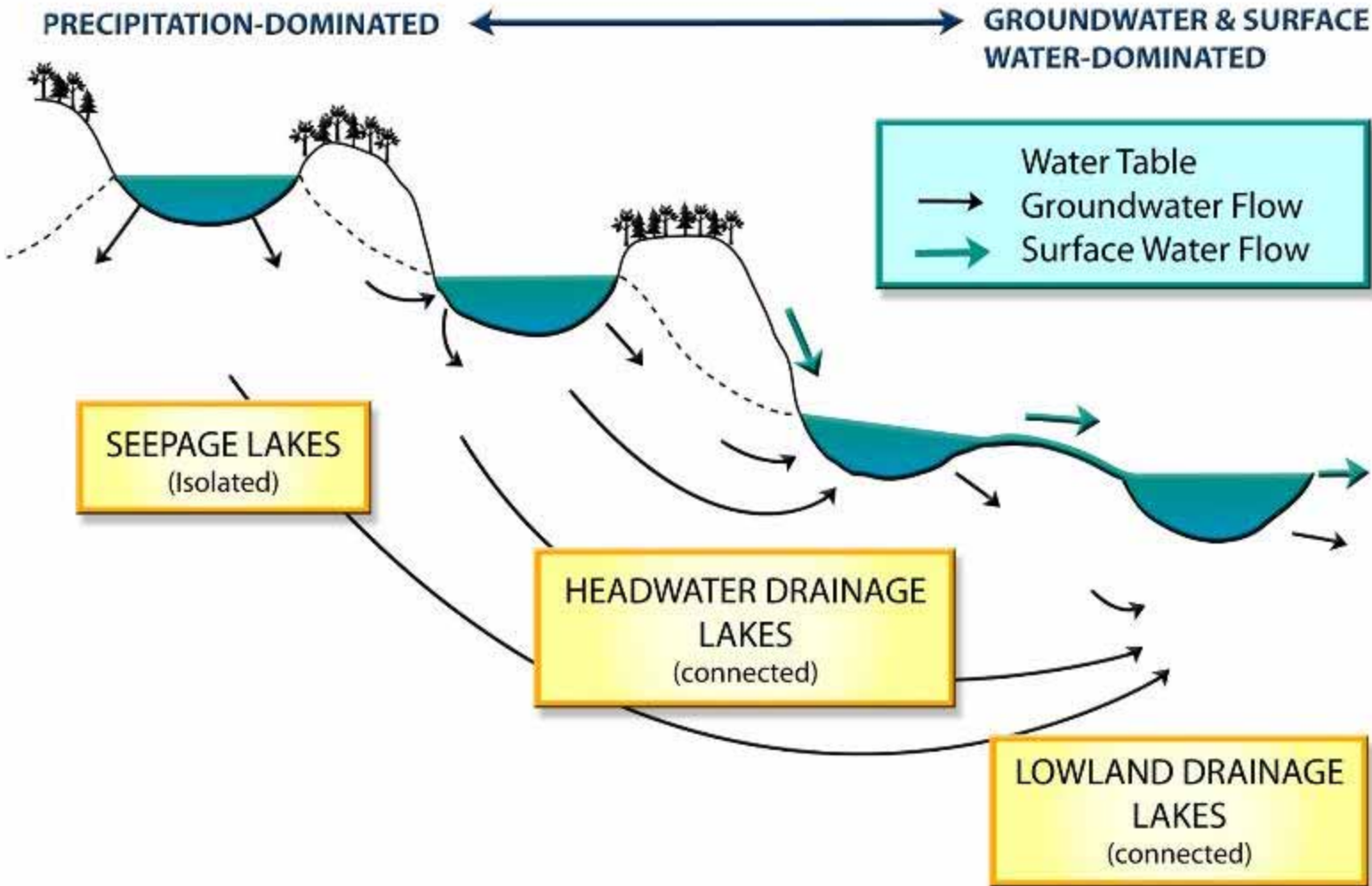


# DRAINAGE BASIN/ LAKE AREA RATIO

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



# LANDSCAPE POSITION





# CHEMICAL CHARACTERISTICS

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

## NUTRIENT FUNCTIONS

| ELEMENT | AVAILABILITY | DEMAND | AVAILABILITY<br>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                      |

## 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

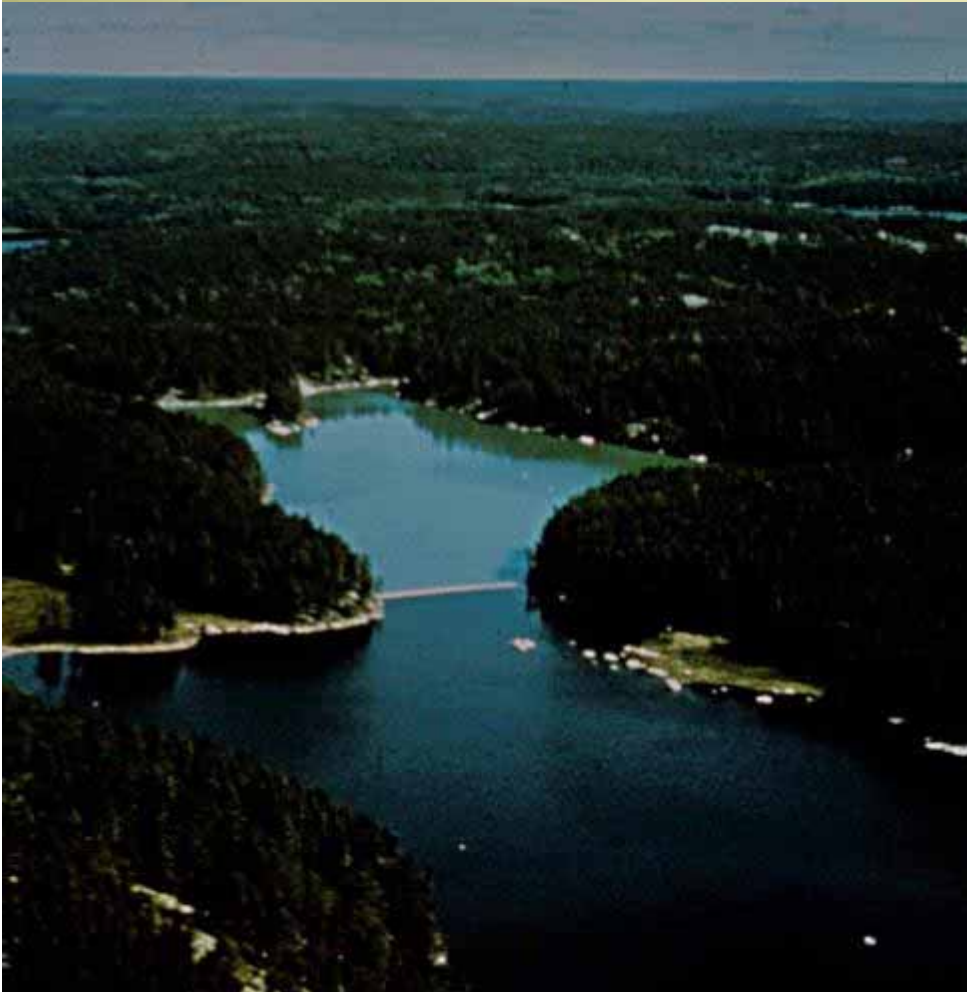
N:P Ratio in plant Tissue 10:1

If the Ratio of N:P in Water is  
<10:1 Nitrogen Limited

>15:1 Phosphorus Limited



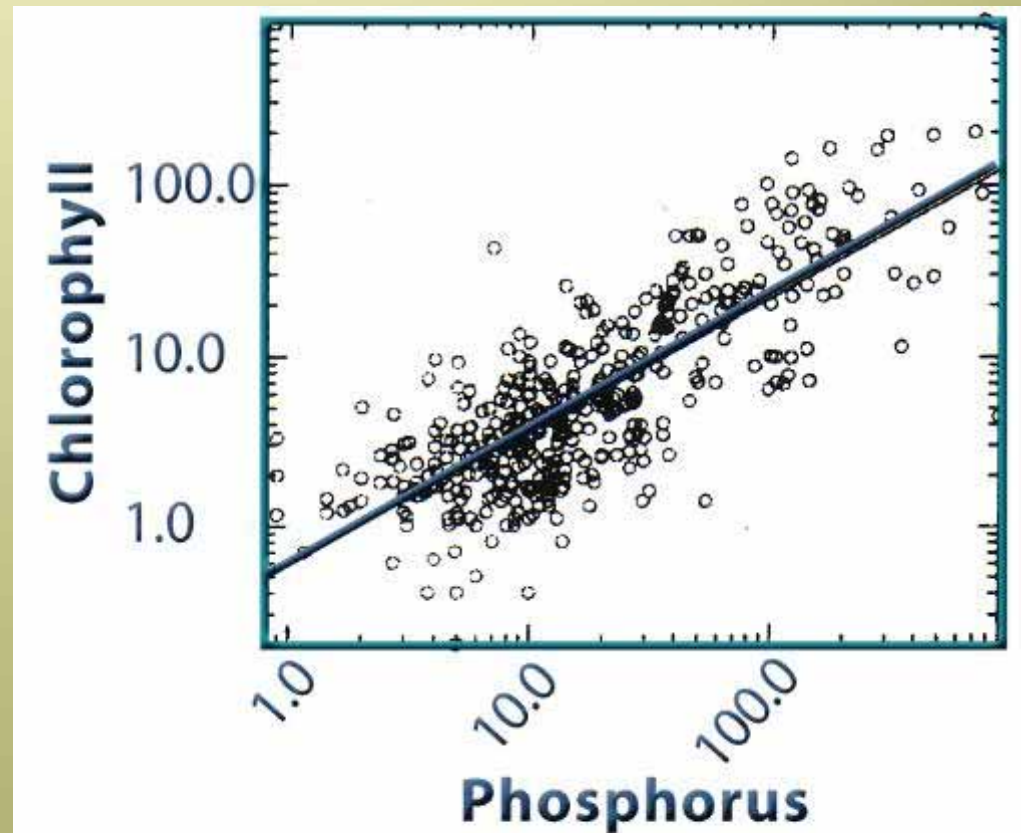
# PHOSPHORUS LIMITATION LAKE 227





# TOTAL PHOSPHORUS/ CHLOROPHYLL a RELATIONSHIP

- Phosphorus causes algae to grow



# Why Develop the Criteria?

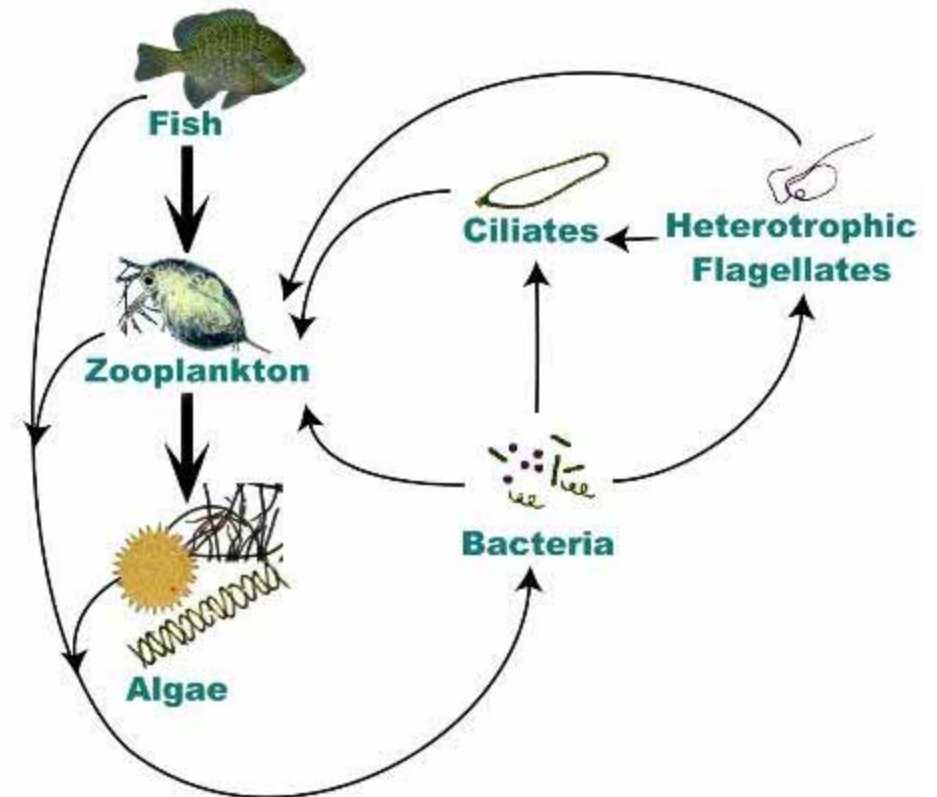
- Obvious water quality problems in state caused by excess nutrient loading
- Numeric goals for protecting or restoring Recreational and Fish and Aquatic Life Uses
- EPA requirement

## 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

# BIOLOGICAL CHARACTERISTICS

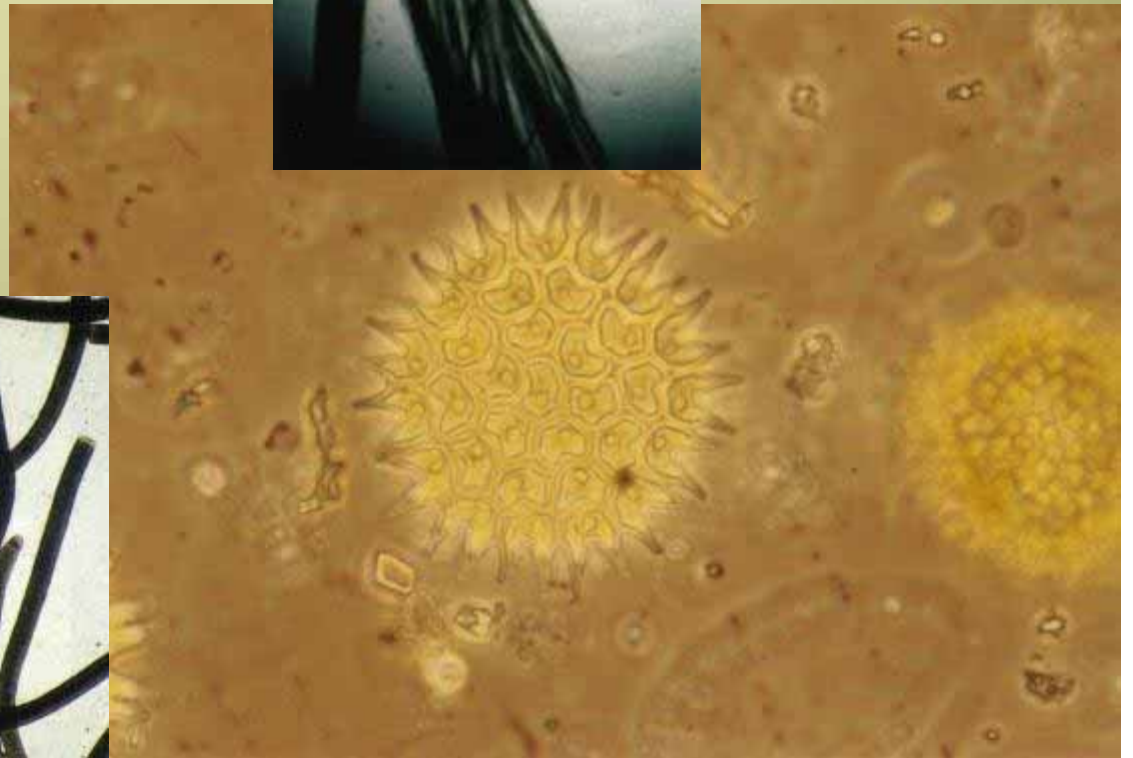
- Viruses/ Bacteria/ Fungi
- Primary - Producers  
Algae/ Macrophyte
- Zooplankton/ Inverts
- Fish

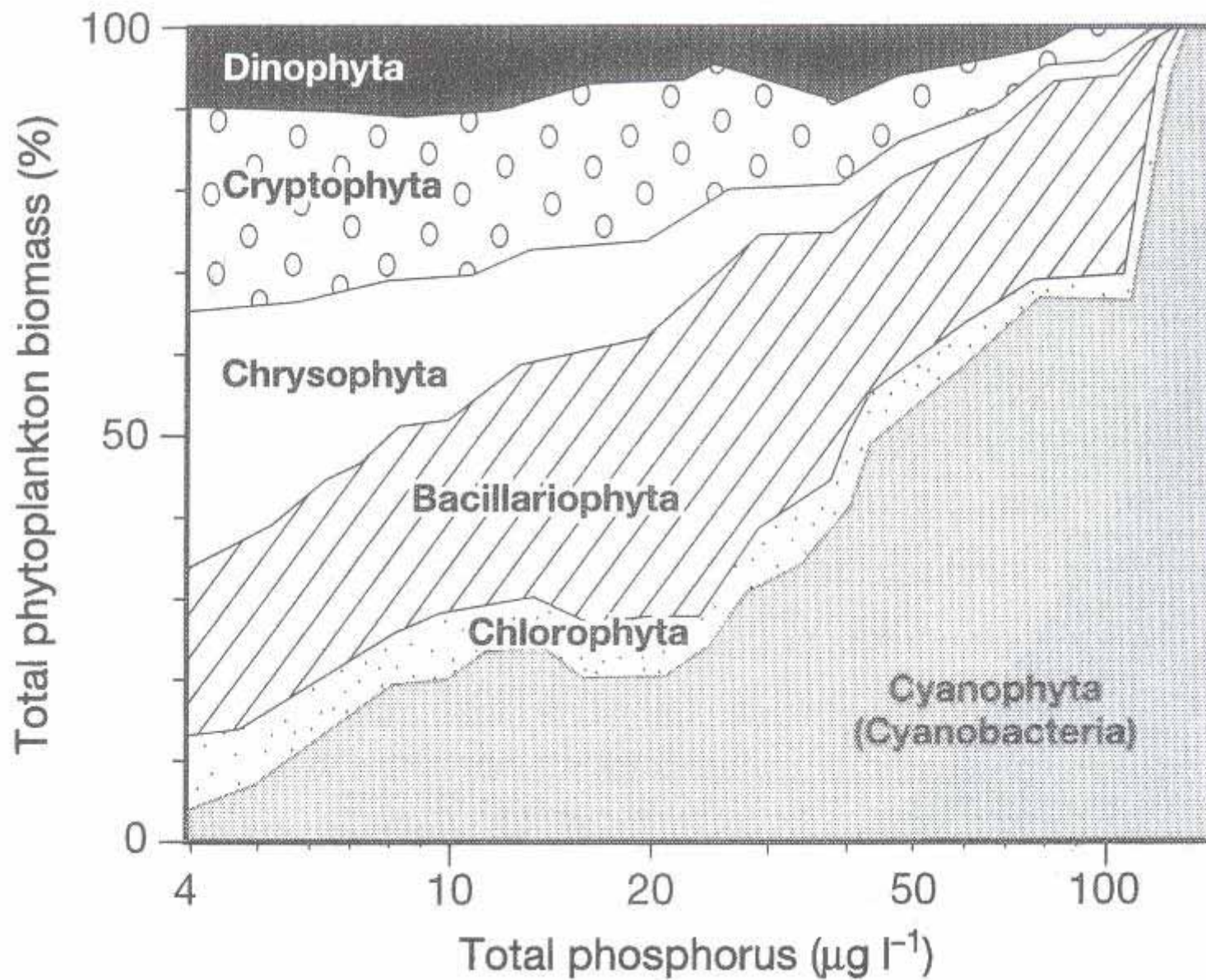




# ALGAE

- Primary Energy Source for Invertebrates
- Can be Nuisance and Human Health Issue
- Produce O<sub>2</sub>





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



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

| <b>Common <i>animal</i> symptoms associated with blue-green algae exposure:</b>             |
|---|
| Lethargy<br>Vomiting<br>Diarrhea<br>Convulsions<br>Difficulty breathing<br>General weakness |

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



# ZOOPLANKTON & AQUATIC INVERTEBRATES

Zooplankton

Dragonfly



# AQUATIC PLANTS

- Habitat
- Energy Dissipation
- O<sub>2</sub> Producers



# FISH

Planktivore

Piscivore

Benthivore



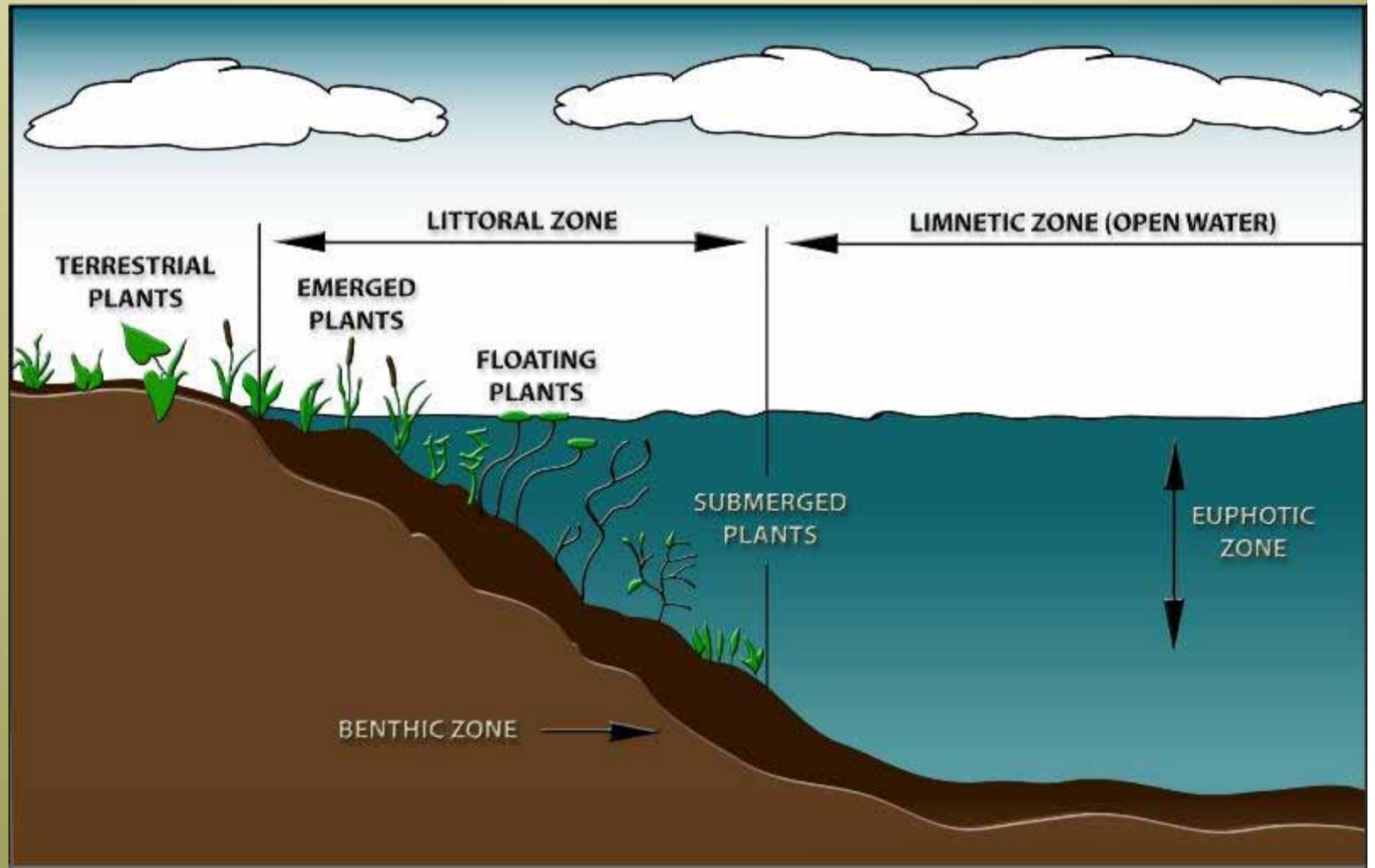


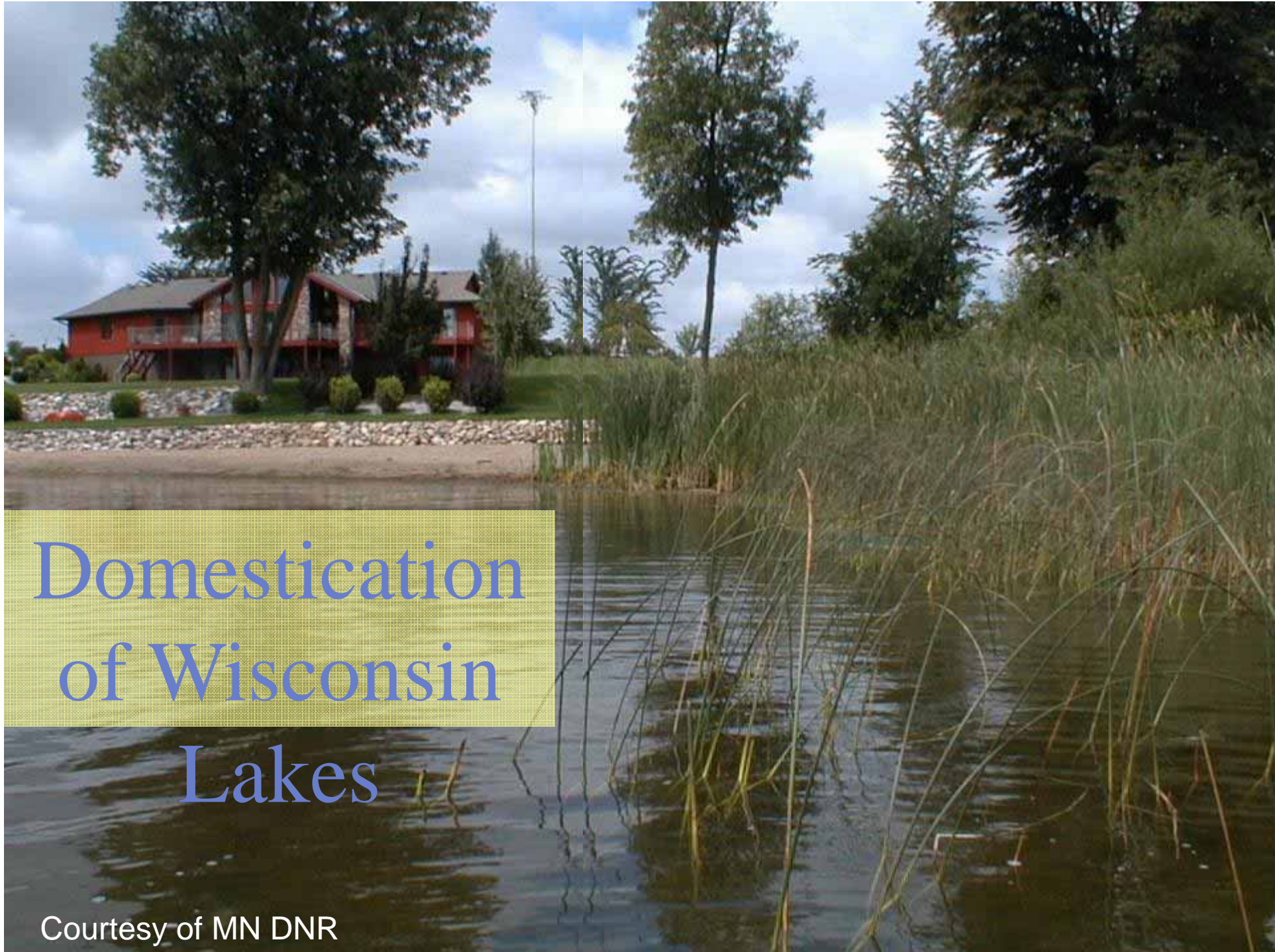
Without habitat, they are gone





# LAKE HABITAT ZONES



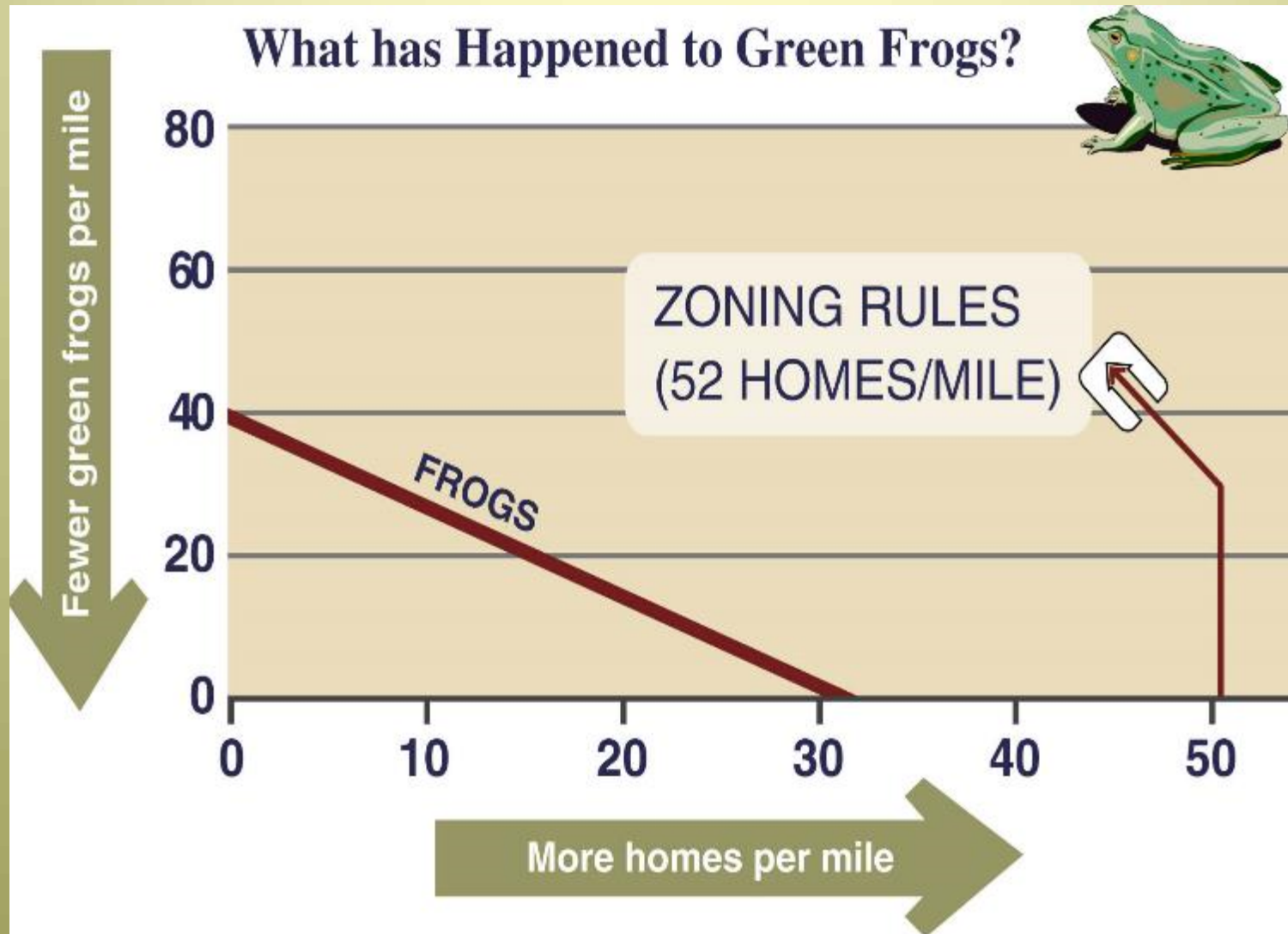


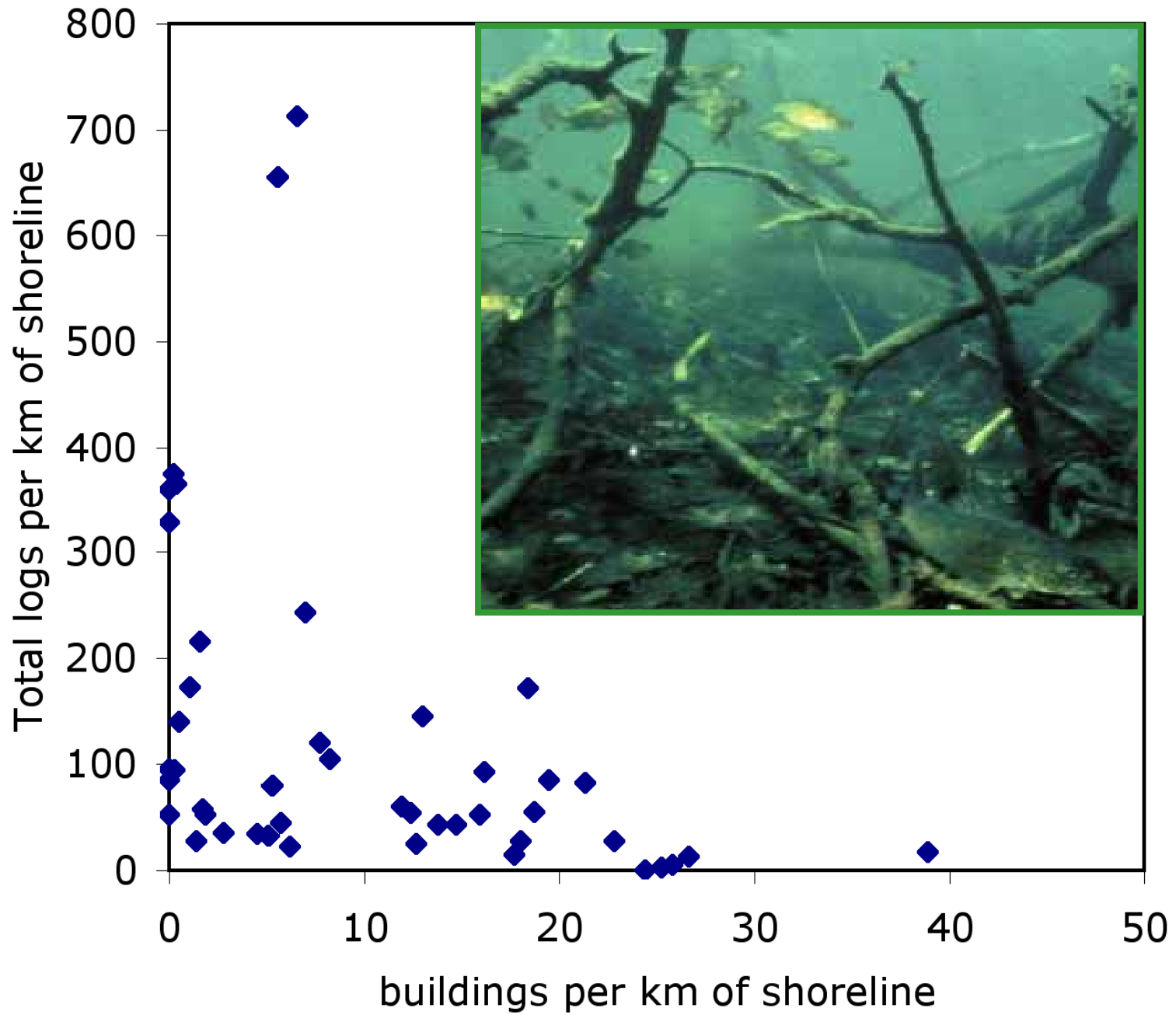
Domestication  
of Wisconsin  
Lakes

Courtesy of MN DNR



# Shoreland green frog trends

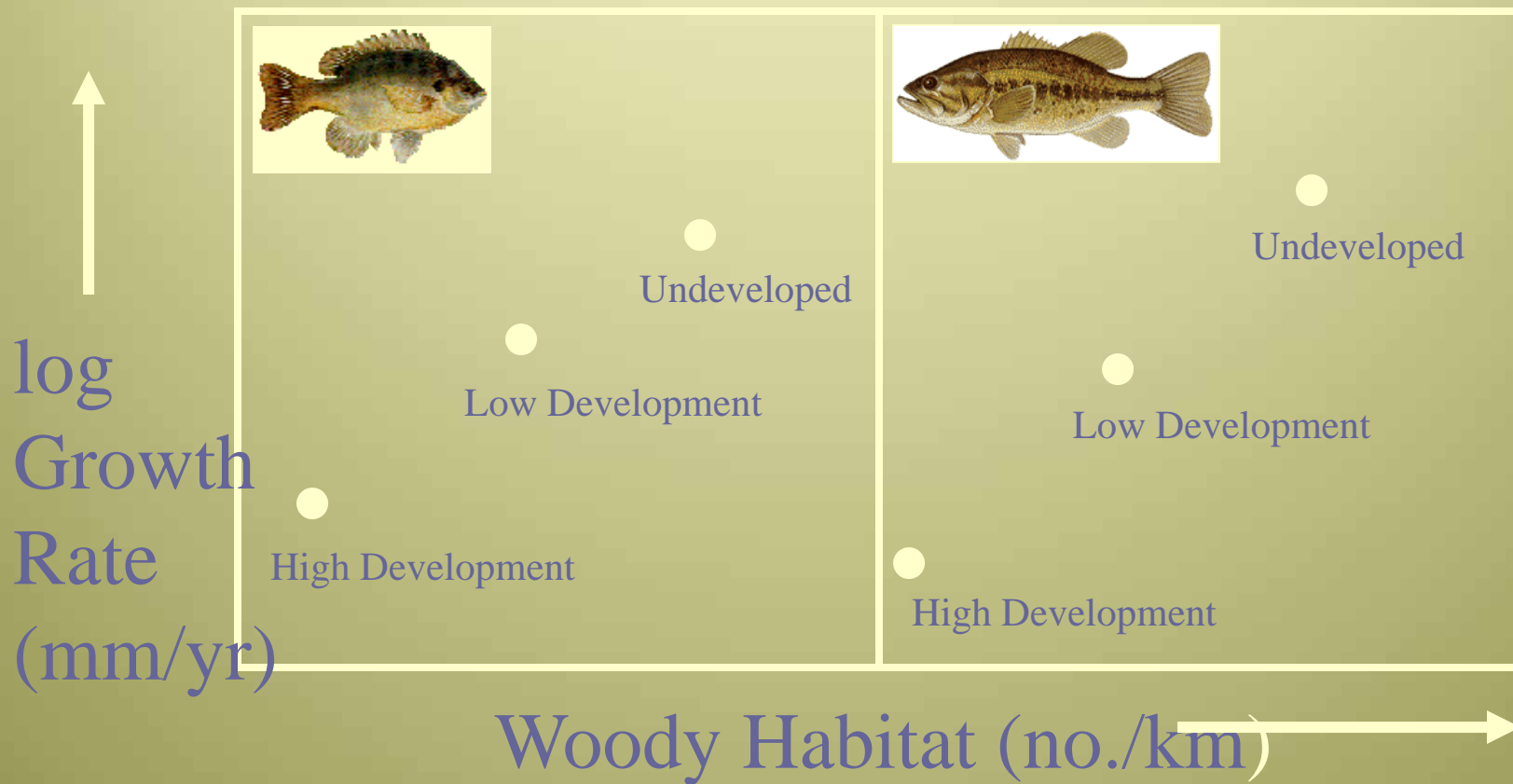




Data: U.W. BioComplexity project



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

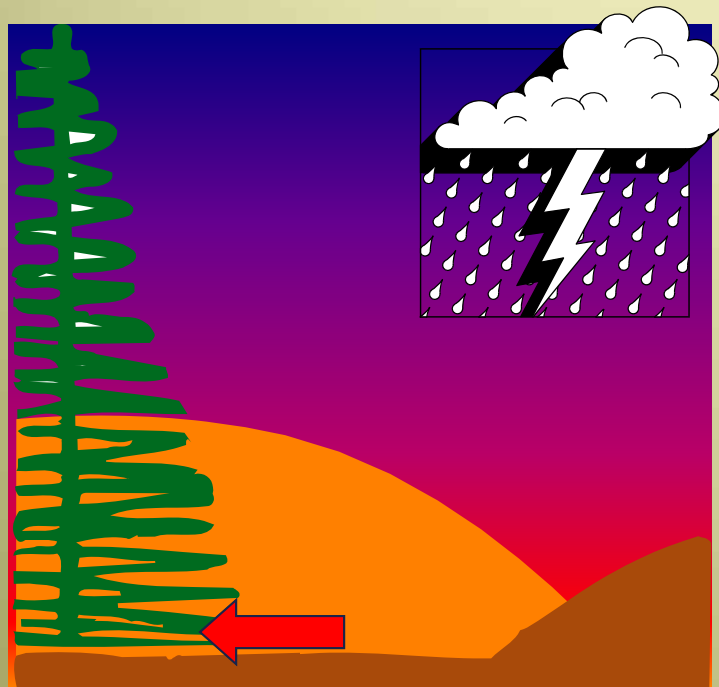


From Schindler et al. 2000

# LAND USE AND WATERSHED IMPACTS



# Land Use Impacts on the Water Cycle



0-10%

50%



55%

15%





How do you make this...

300-600 ppb TP

function like this?



20-50 ppb TP



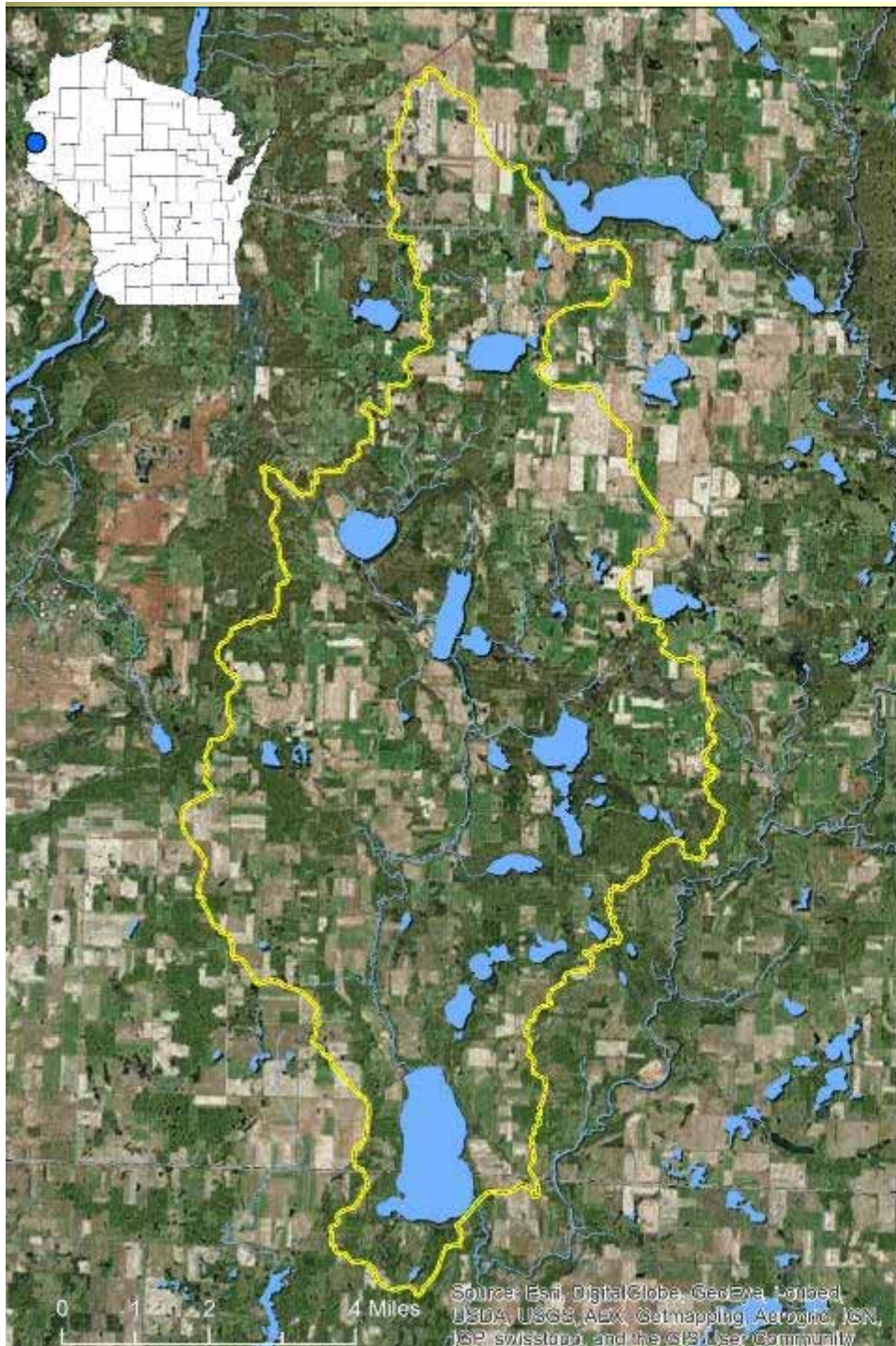


# Empirical Watershed Models

Phosphorus export coefficients - developed based using monitoring data.

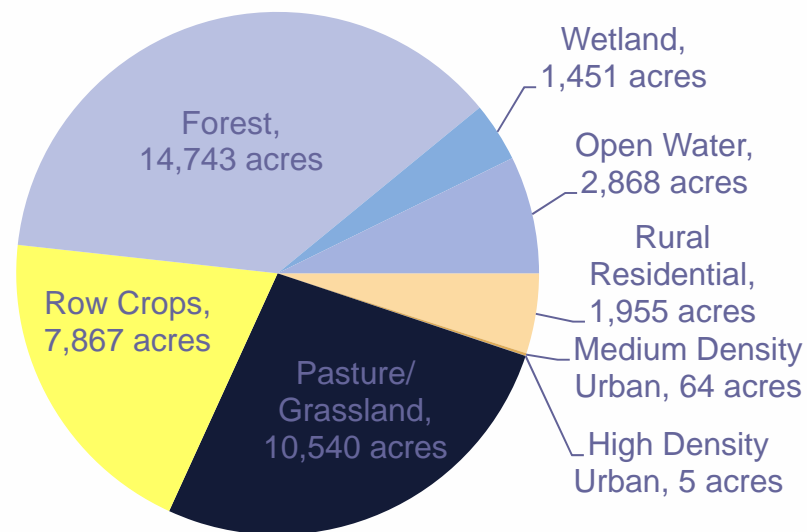
## WISCONSIN VALUES

| <u>Land Cover</u>    | <u>TP Export</u><br><u>kg/ha/yr</u> |
|----------------------|-------------------------------------|
| 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                                |



# Cedar Lake

|                               |                      |
|-------------------------------|----------------------|
| Polk County                   |                      |
| WBIC                          | 2615100              |
| Surface area                  | 1,120 acres          |
| Max depth                     | 32 ft                |
| Mean outflow                  | 33.7 cfs             |
| Summer water residence time   | 280 days             |
| Drainage area                 | 39,495 acres         |
| Phosphorus load (most likely) | 13,600 lb/yr         |
| Phosphorus load (range)       | 6,300 - 35,000 lb/yr |

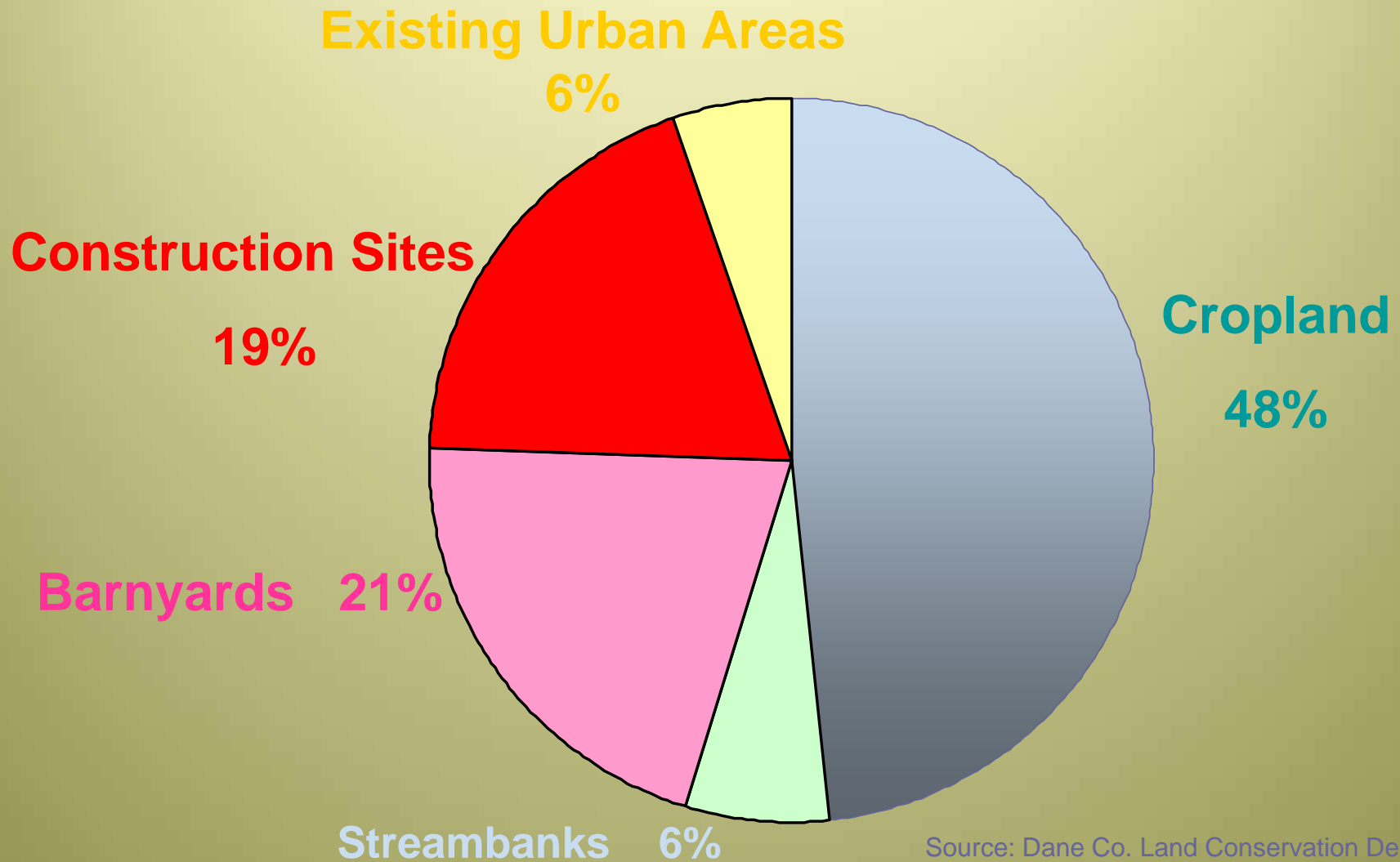




# AGRICULTURE IMPACTS



# P Loading Sources to Lake Mendota



Source: Dane Co. Land Conservation Dept.



## P Inputs

# Lake Mendota Watershed P Budget

## P Outputs

(from Bennett et al. 1999)

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

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 in = 1,307 MT**

**P out = 732 MT**

**P Storage = + 575 MT !!**

INPUTS - OUTPUTS =  
CHANGE IN STORAGE

Lake Mendota watershed

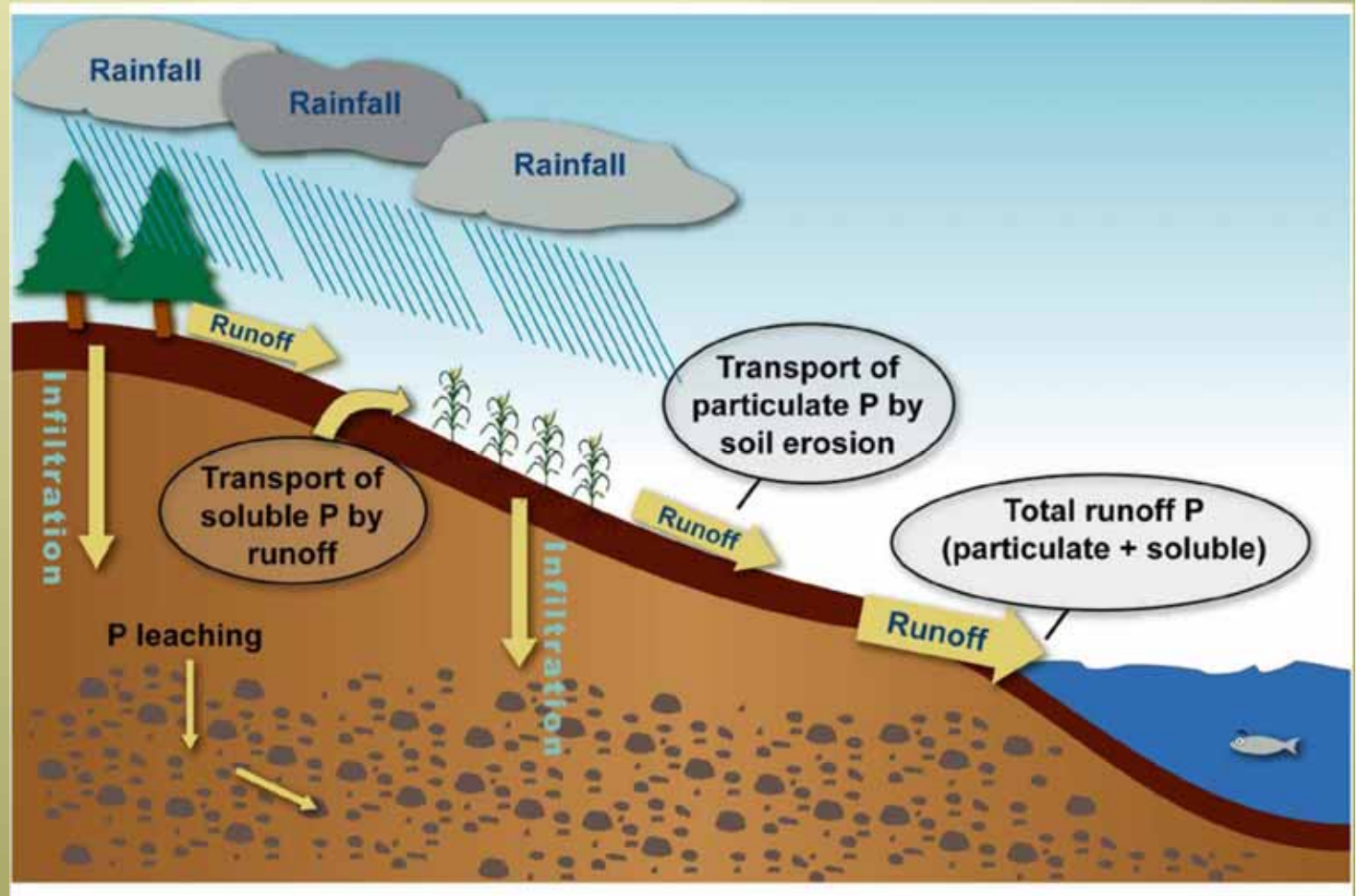
Lake Mendota

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

# 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.

A photograph of a forest with several tree trunks in the foreground and a dense canopy of green and brown leaves in the background.

300,000  
microgram/  
liter

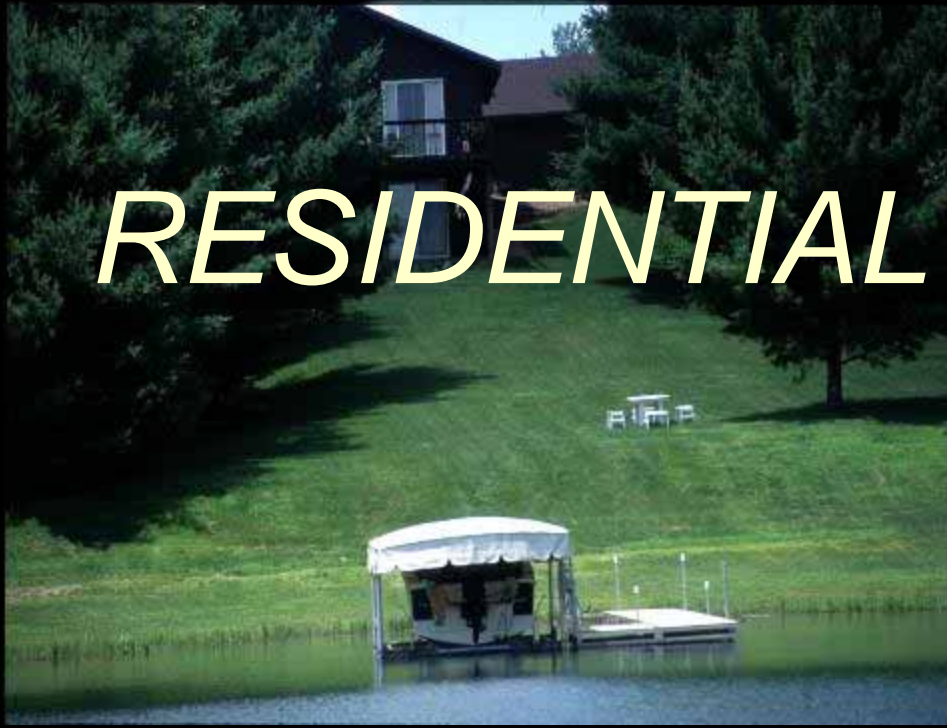
A photograph of a large body of water, likely a lake or reservoir, under a clear blue sky. The water is dark blue with some ripples.

60  
microgram/  
liter

2) Land is a concentrated  
nutrient source



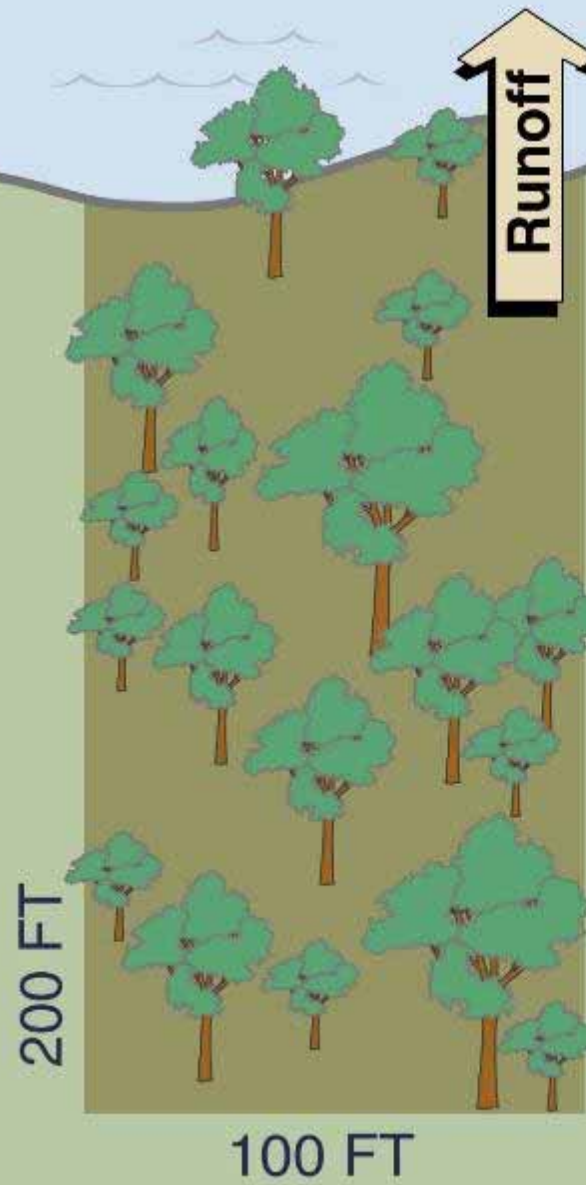
# *RESIDENTIAL DEVELOPMENT*





# Undeveloped – Apr.-Oct. phosphorus/sediment runoff model

- maple-beech forest
- 6% slope to lake
- sandy loam soil



## IMPACT ON LAKE (April - Oct.)

- 1,000 ft<sup>3</sup> runoff to lake
- 0.03 lbs. phos. to lake
- 5 lbs. sediment to lake

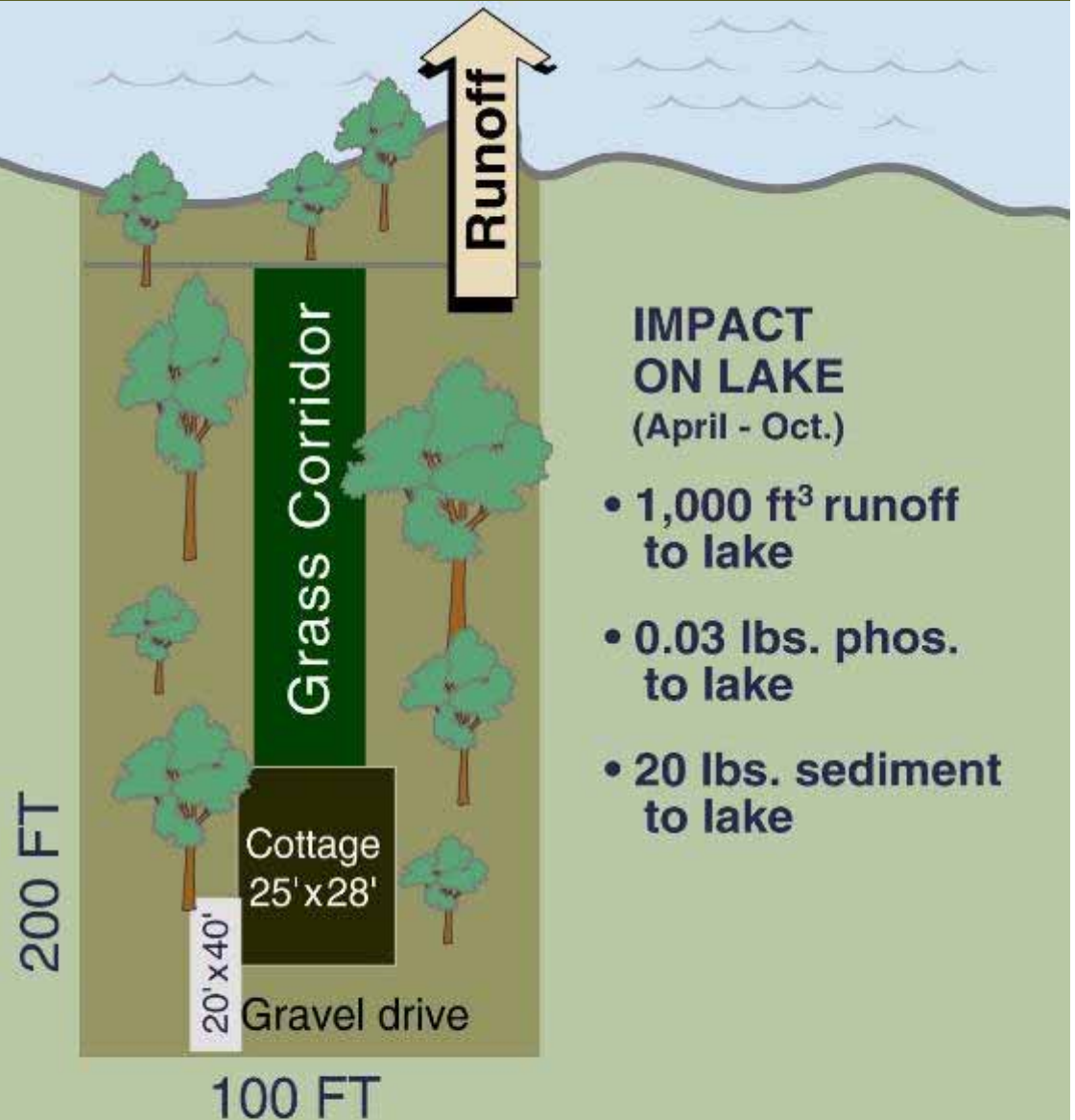


Laine Cabin, Long Lake Chippewa County



# 1940s development – Apr.-Oct. phosphorus/sediment runoff model

- maple-beech forest
- 6% slope to lake
- grass corridor 20'-wide
- cottage 700 ft<sup>2</sup> perimeter
- gravel drive 800 ft<sup>2</sup>
- 35'-wide buffer strip



## IMPACT ON LAKE (April - Oct.)

- 1,000 ft<sup>3</sup> runoff to lake
- 0.03 lbs. phos. to lake
- 20 lbs. sediment to lake



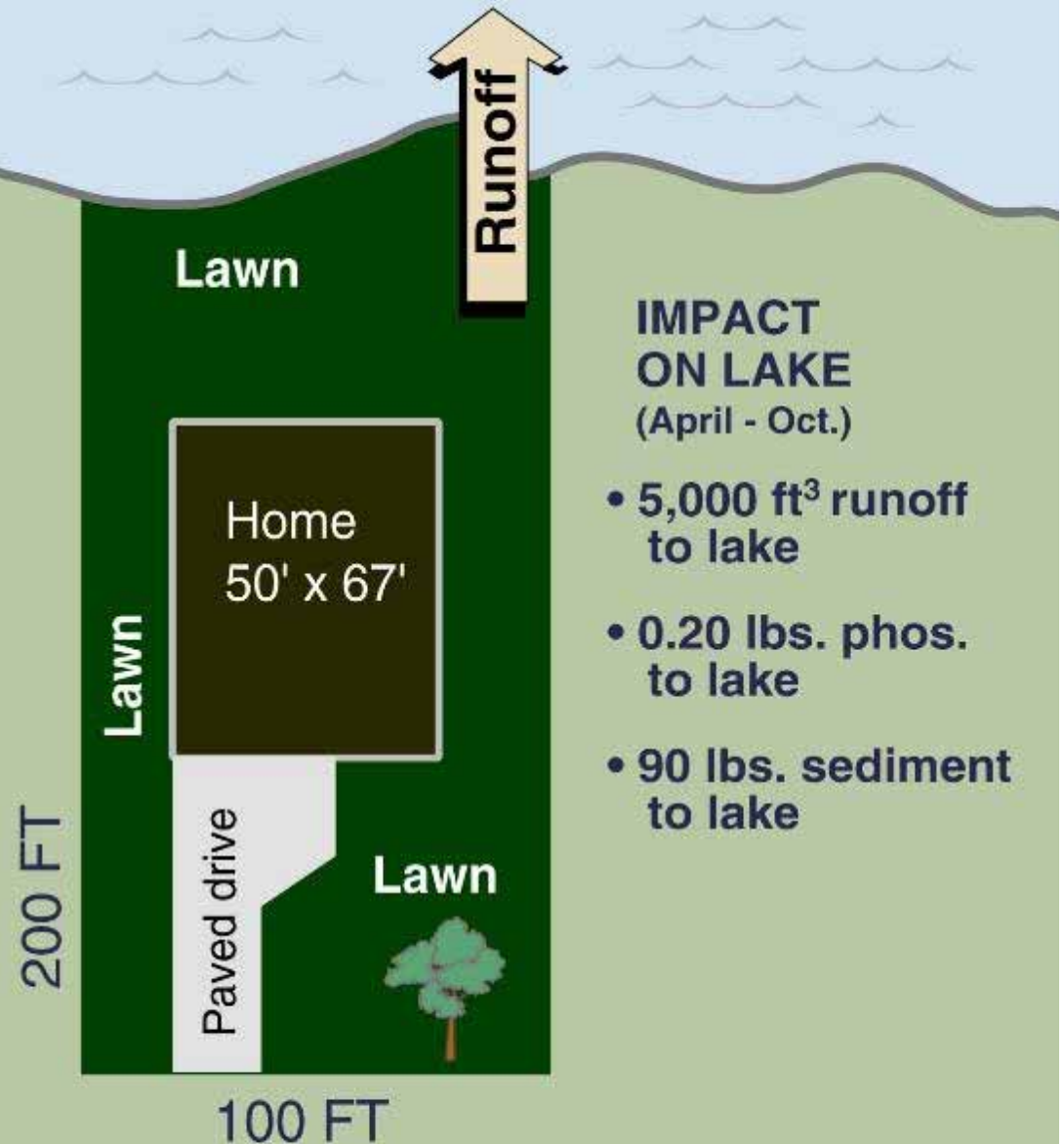
Redevelopment Long Lake Chippewa County

4 28 '04



# 1990s development – Apr.-Oct. phosphorus/sediment runoff model

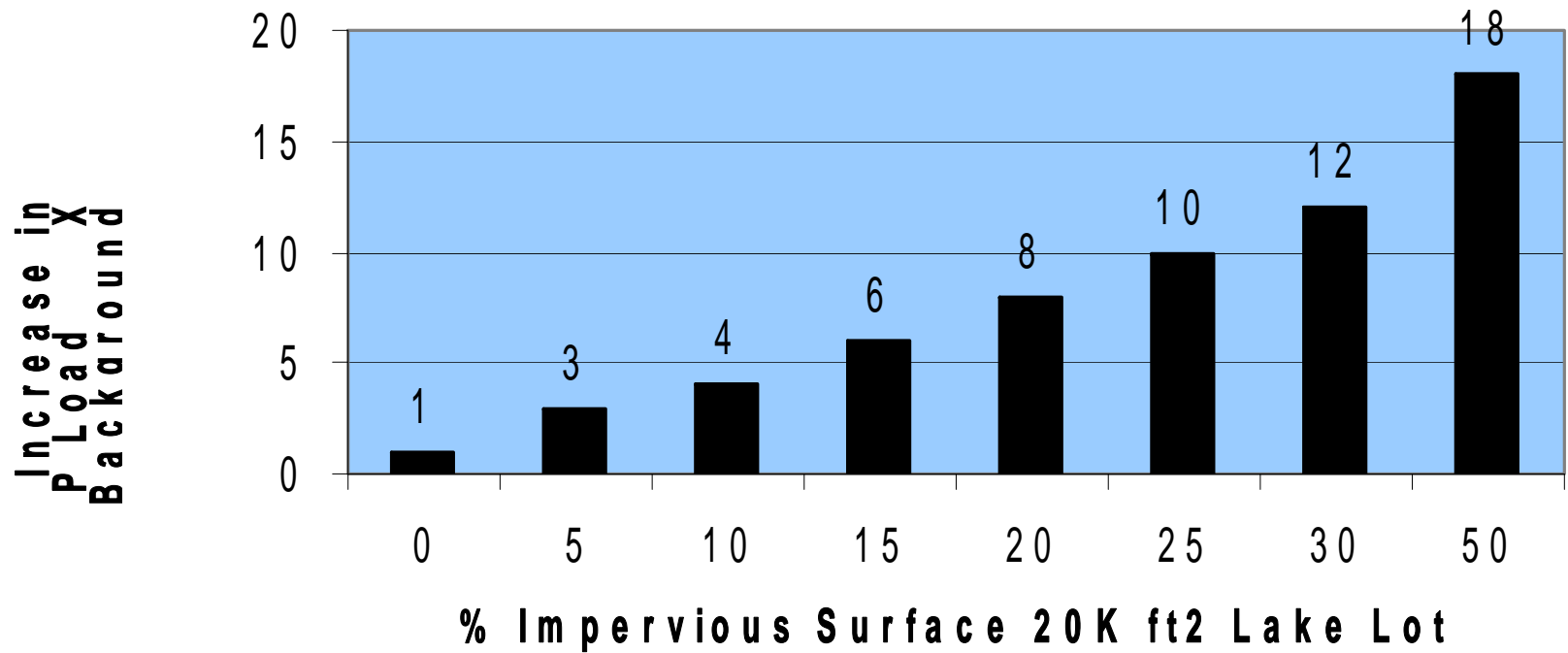
- maintained lawn, soil graded
- 6% slope to lake
- home 3,350 ft<sup>2</sup> perimeter
- paved drive 770 ft<sup>2</sup>



## IMPACT ON LAKE (April - Oct.)

- 5,000 ft<sup>3</sup> runoff to lake
- 0.20 lbs. phos. to lake
- 90 lbs. sediment to lake

## Impacts from Impervious Surfaces on Phosphorous Loading





# LEAVING A LEGACY



*Help Protect Wisconsin's...*

**LAKE HEALTH.**





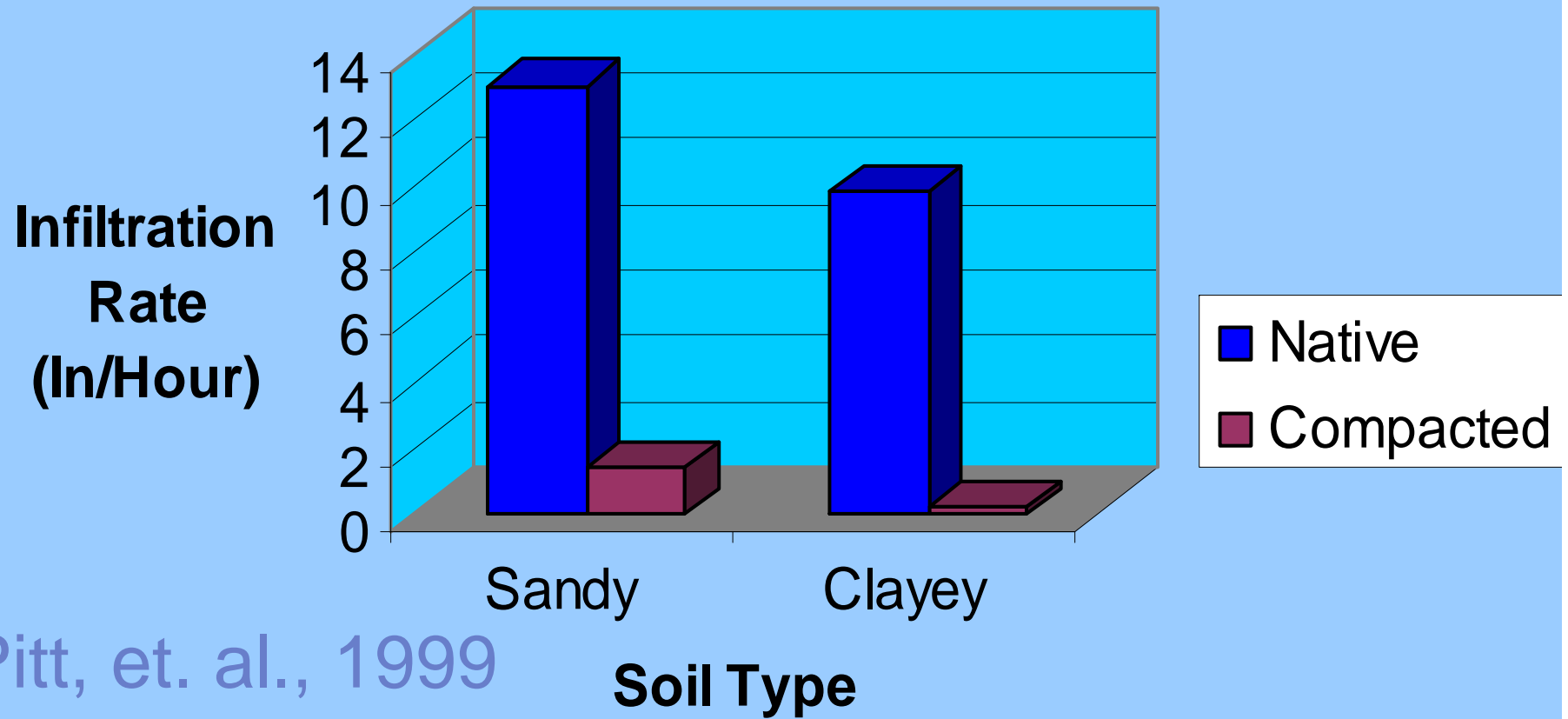


Soil Compaction is increased during building construction

Spoil from basements placed on adjacent soils

Building crews and material suppliers drive on soils

# Effect of Compaction on Infiltration Rate



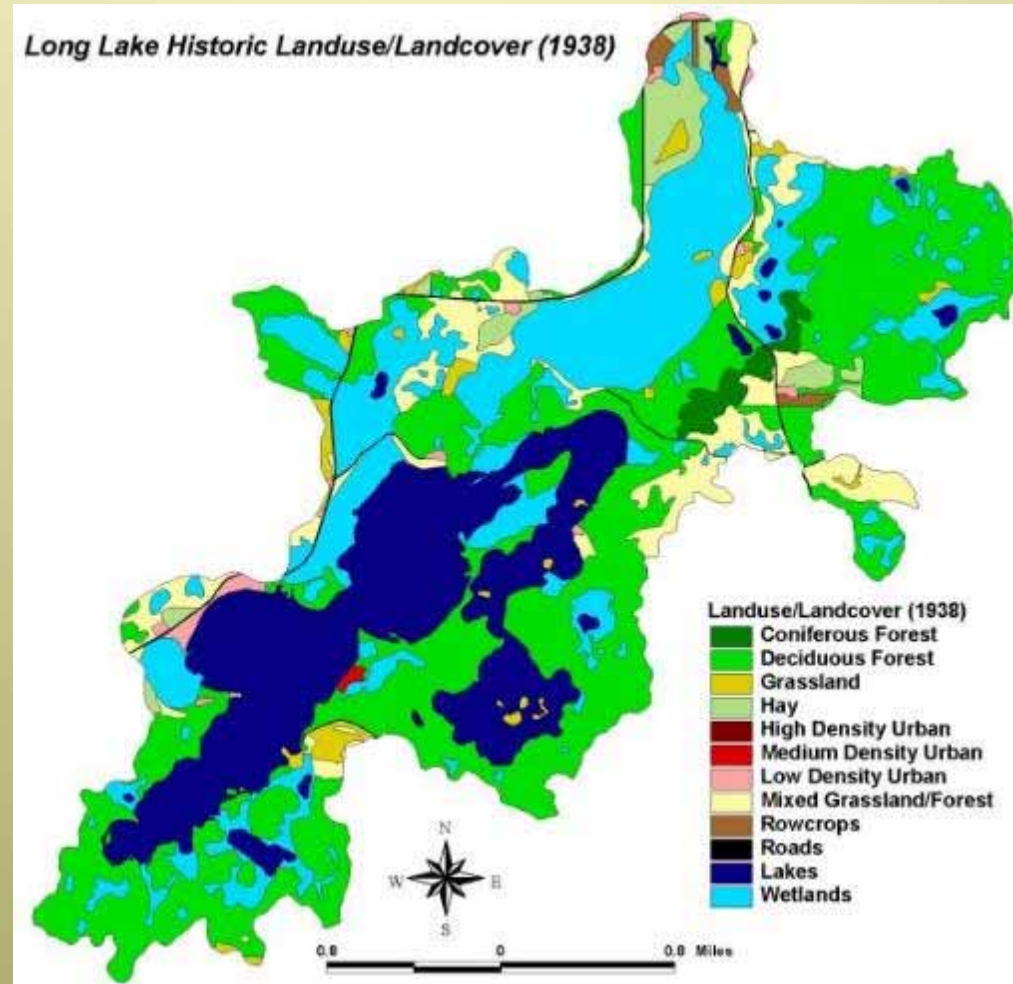
Pitt, et. al., 1999

# Reducing Soil Compaction

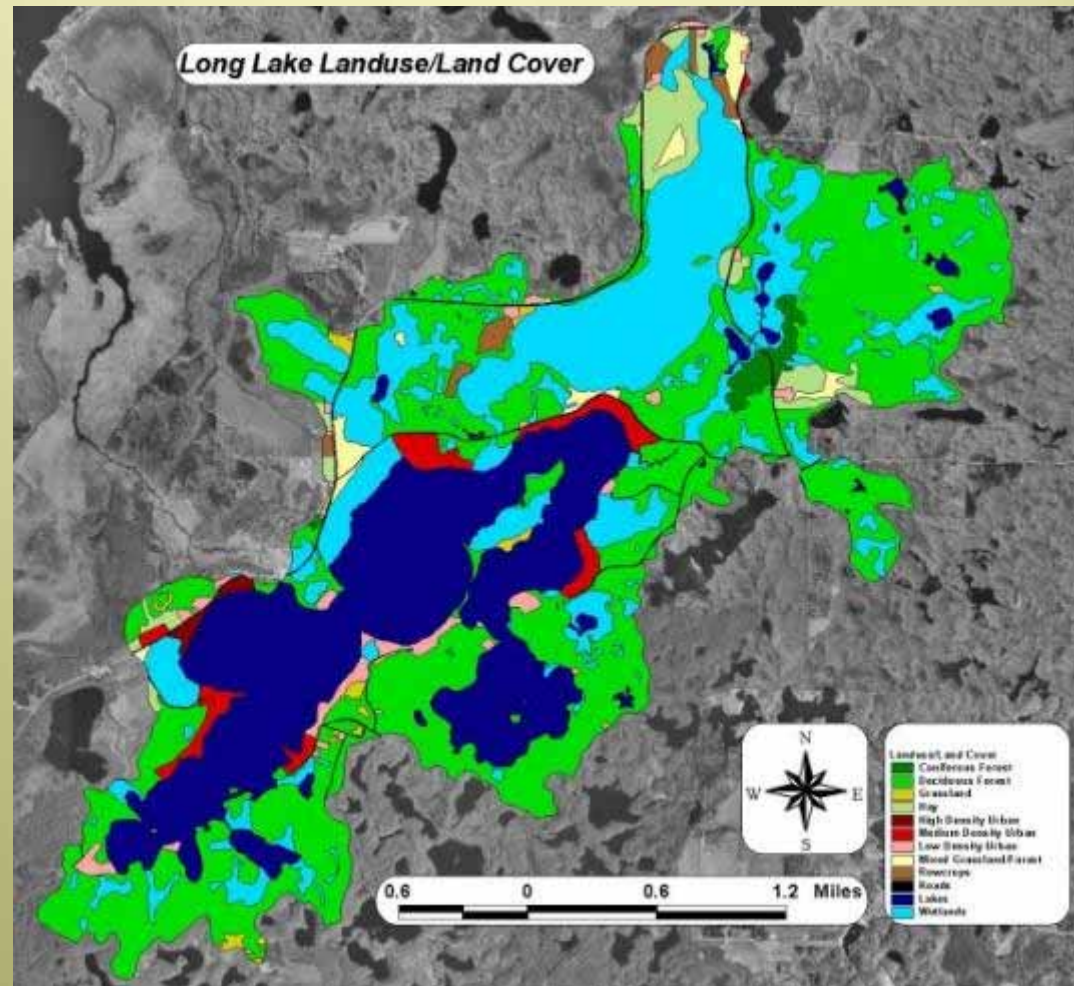
- Avoid during construction - compaction is fore
- Till compacted areas around buildings
- Apply adequate topsoil prior to seeding
- Add organic matter - minimum of 5%
- Aerate turf areas annually



# Watershed Landuse 1938



# Watershed Landuse 2001



Applied Data Consultants, Inc.



# Watershed Landuse 2001

|                               | Historic    | Current       |
|-------------------------------|-------------|---------------|
| Coniferous Forest             | 59.99       | 43.17         |
| Deciduous Forest              | 1875.29     | 1983.04       |
| Grassland                     | 98.21       | 32.37         |
| Hay                           | 136.01      | 147.08        |
| <b>High Density Urban</b>     | <b>----</b> | <b>14.32</b>  |
| <b>Moderate Density Urban</b> | <b>5.19</b> | <b>104.36</b> |
| Low Density Urban             | 39.05       | 84.01         |
| Mixed Grassland/Forest        | 383.46      | 63.12         |
| Roadways                      | 30.92       | 41.49         |
| Rowcrops                      | 27.61       | 39.27         |
| Water                         | 1041.81     | 1193.75       |
| Wetlands                      | 1193.18     | 11            |

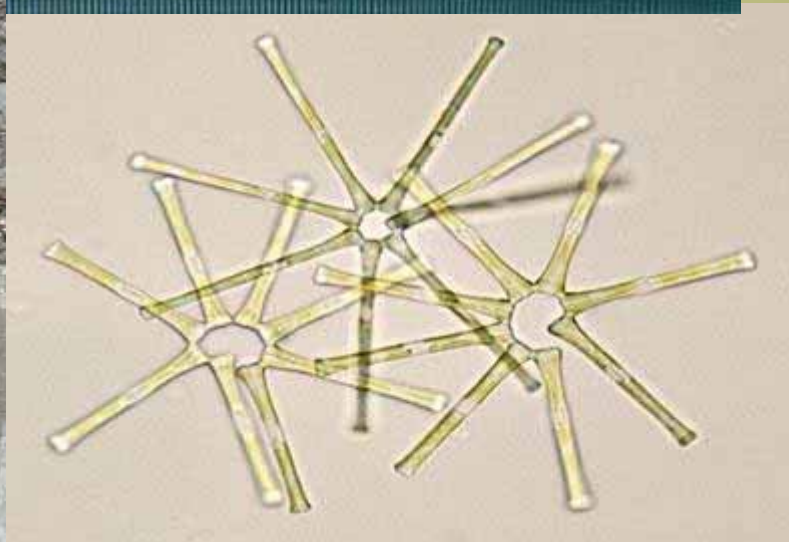
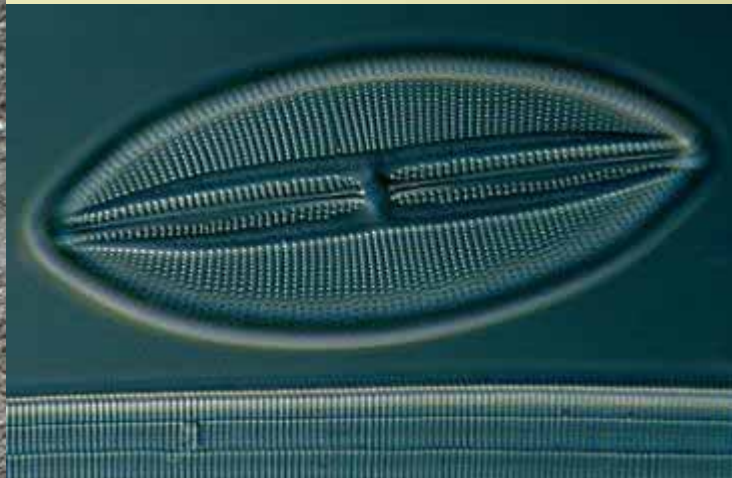




# Landuse Nutrient Loads 2006

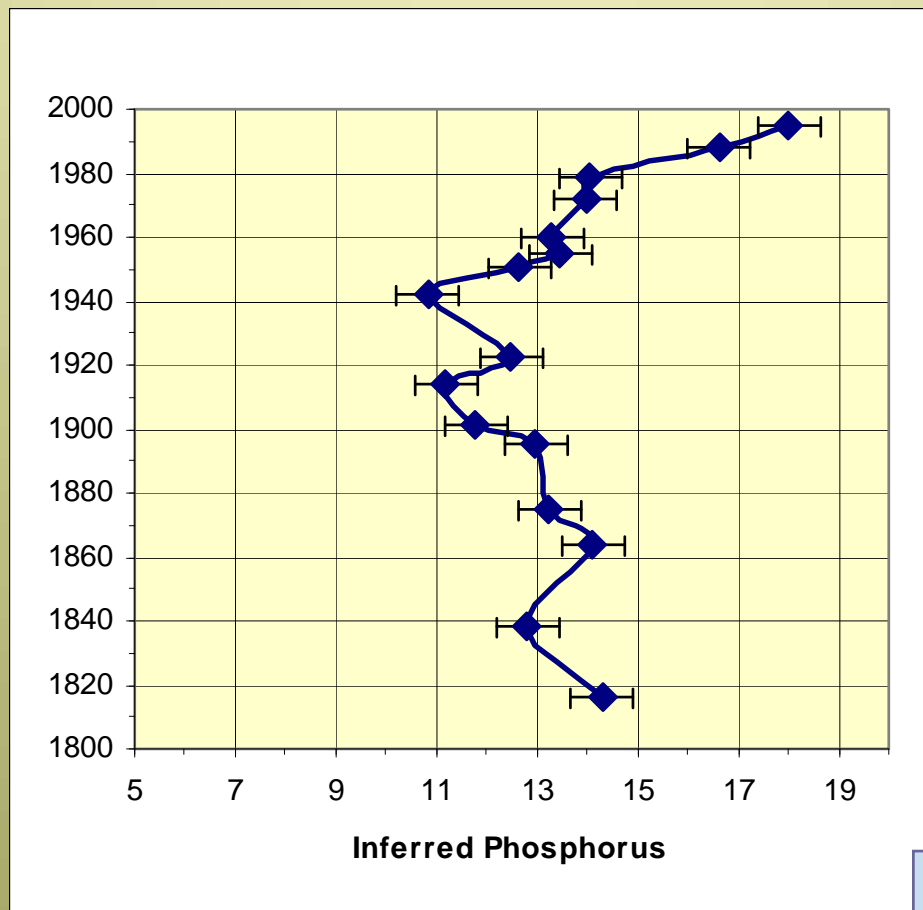
| Landuse                     | Acres        | Kg/Year       | Lbs/Year     |
|-----------------------------|--------------|---------------|--------------|
| <b>High Density Urban</b>   | <b>17.3</b>  | <b>11</b>     | <b>24.3</b>  |
| <b>Medium Density Urban</b> | <b>125.7</b> | <b>25</b>     | <b>55.1</b>  |
| Rural Residential           | 101.2        | 4             | 8.8          |
| Pasture/Grass               | 218.7        | 27            | 59.5         |
| Wetlands                    | 1144.7       | 46            | 101.4        |
| Forest                      | 2089.4       | 76            | 167.6        |
| Atmosphere                  | 1052         | 128           | 282.2        |
| Septics                     |              | 6.25          | 13.8         |
| <b>Total</b>                |              | <b>323.25</b> | <b>712.7</b> |

# PALEOLIMNOLOGY



# LONG LAKE

## Chippewa County

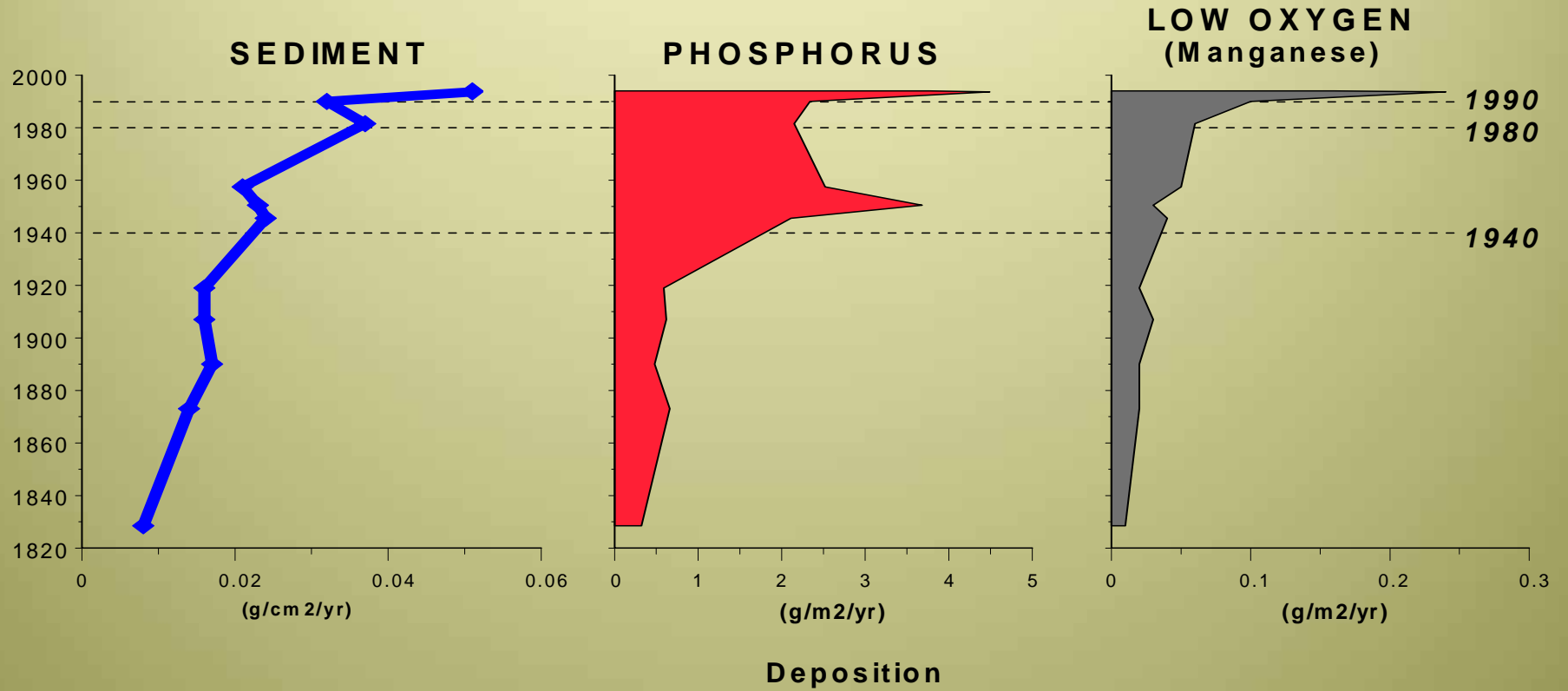


P. Garrison, 1995





# LONG LAKE Chippewa County



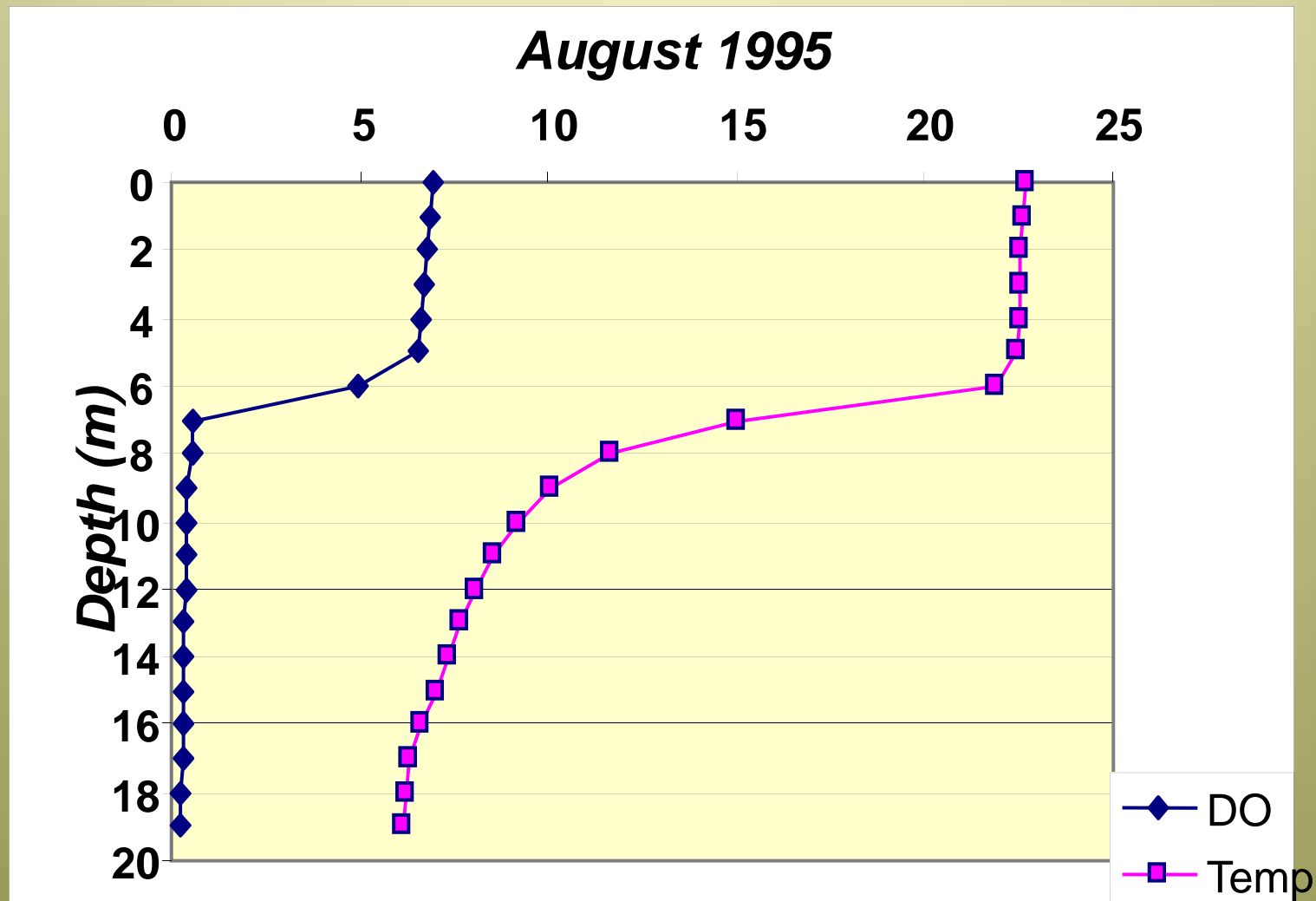
# SUMMARY

- Development during the early twentieth century had a small impact on the lakes.
- Development during the last 30 years has degraded water quality.
- In Long Lake recent development has increased sediment infilling, phosphorus levels in the surface waters, phosphorus loving diatoms, and decreased oxygen levels in the bottom waters.

P. Garrison, 1995

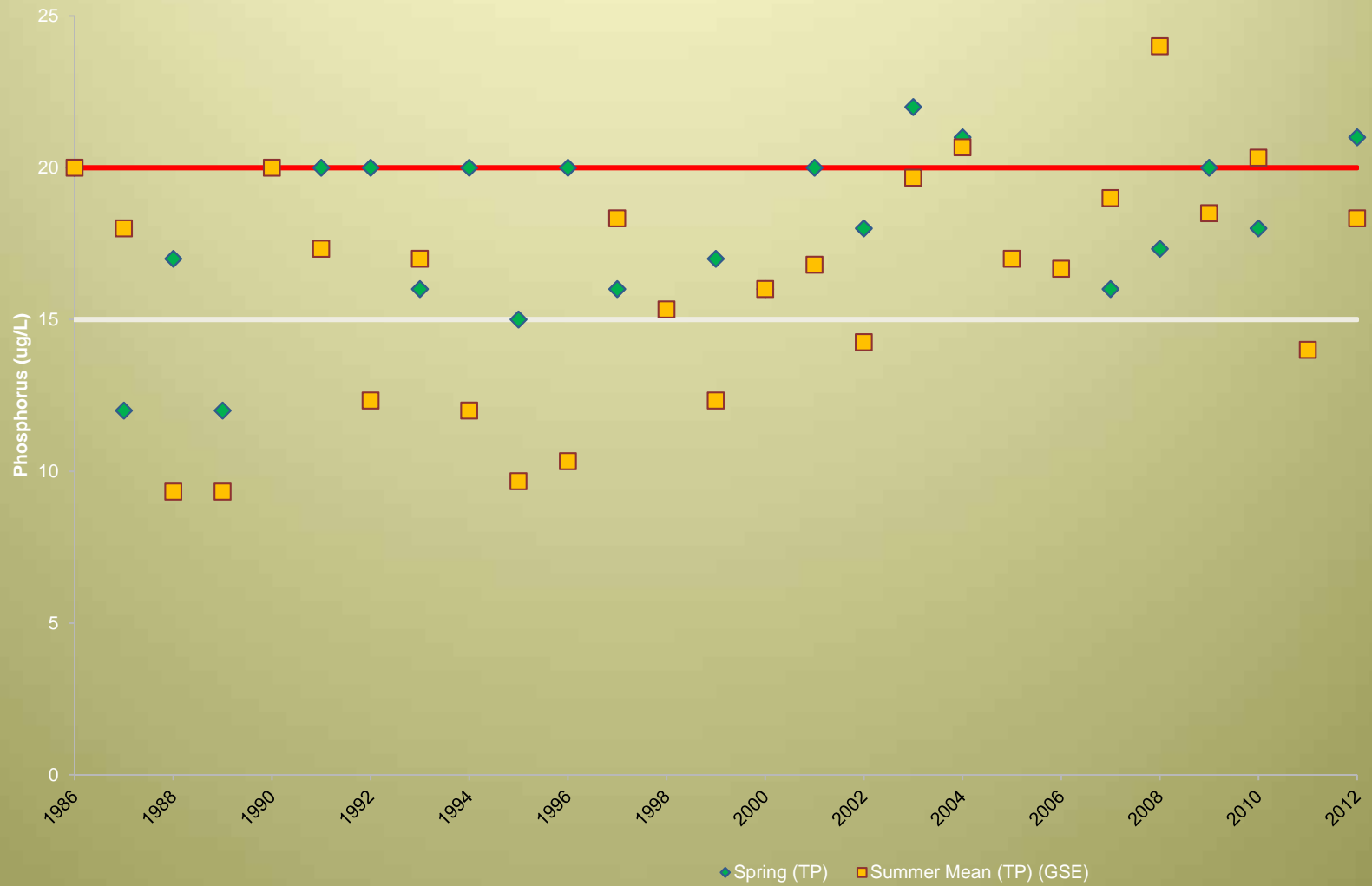


# Dissolved Oxygen Depletion





# Long Lake Spring vs. Summer Mean Total Phosphorus 1986-2012



Goal I. Protect water clarity, prevent the occurrence of algae blooms and reduce nutrient levels in Long Lake.

- ▣ **The families and individuals, particularly our children, deserve to have a lake with clean water to use and enjoy. Protecting water quality will be achieved by reducing the spring turnover total phosphorus concentration to 16-18 ug/l and summer surface total phosphorus concentration to 14-15 ug/l.**

# Semi Shade – Polk County, WI







One year later...





# Rain Garden Depth & Size

Balance between:

- drainage area
- slope
- soil
- desired garden size





# LEAVING A LEGACY



*Help Protect Wisconsin's...*

**WATER RESOURCES.**

