LIMNOLOGY 101

Courtesy of Lake Partnerships

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

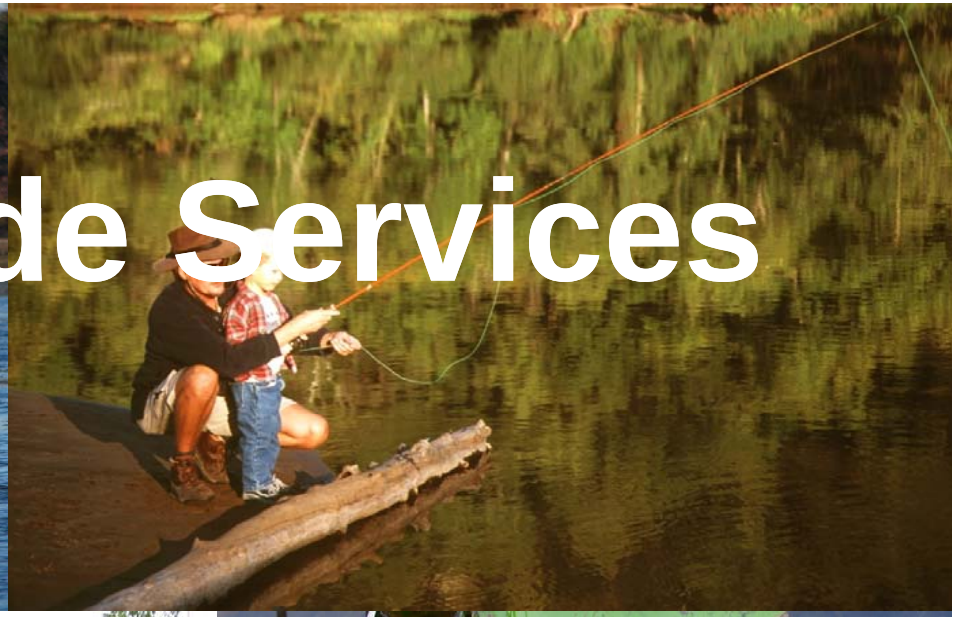
Wisconsin Water Resources

Wisconsin has the 3rd largest concentration of fresh water glacial lakes on the planet.

Over 15,000 Lakes
41.000 miles of Streams

The Wisconsin Lakes Partnership

Lakes Provide Services

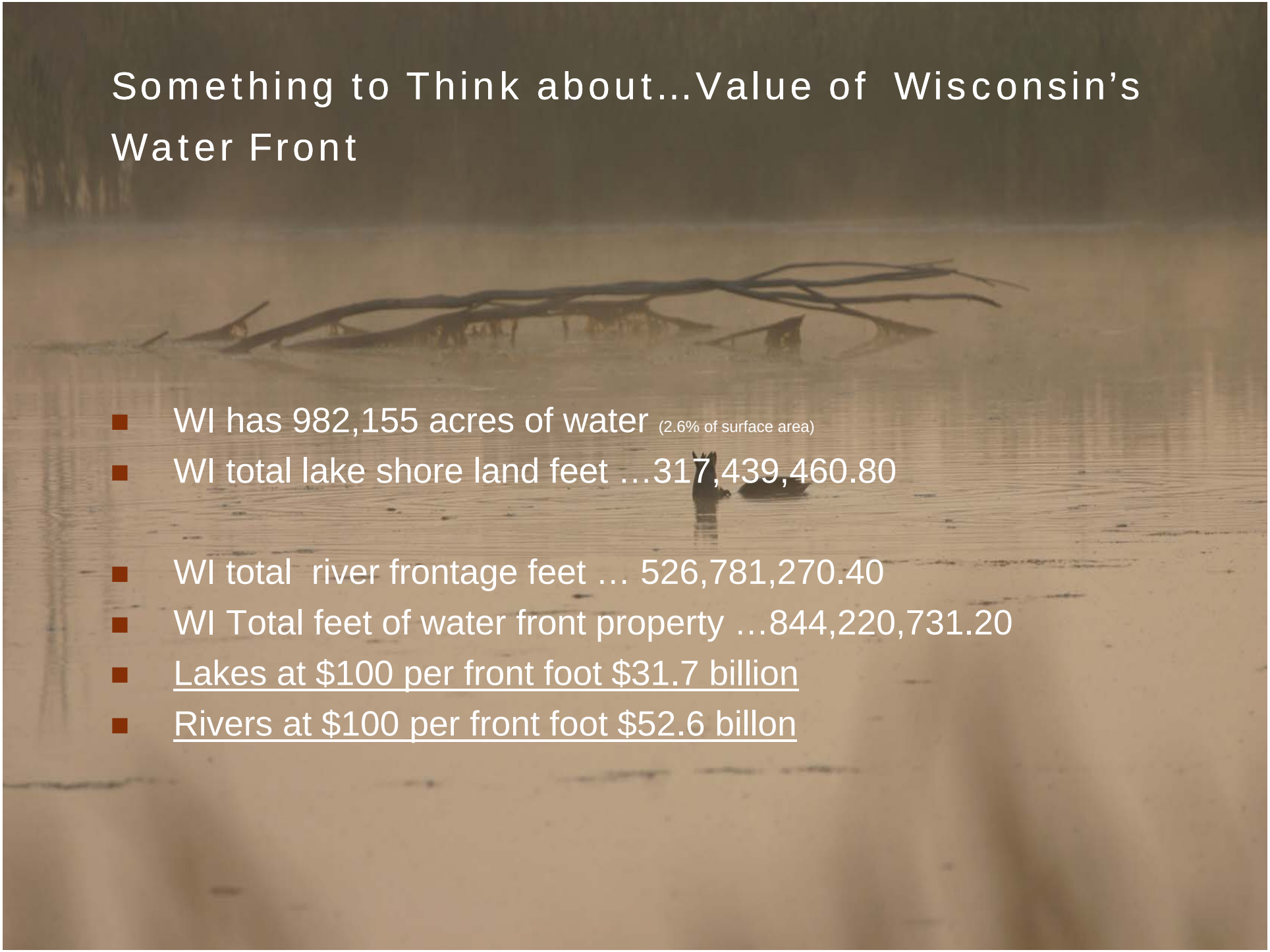


Ecosystem

Cultural

Recreational

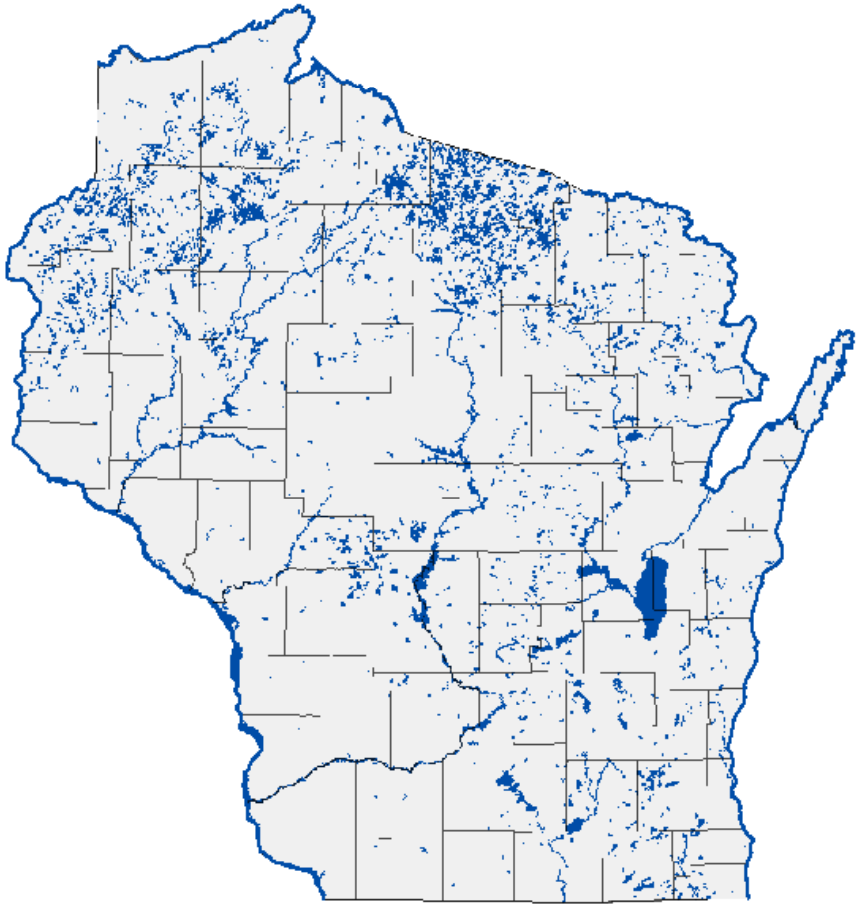
Something to Think about…Value of Wisconsin's Water Front



- WI has 982,155 acres of water (2.6% of surface area)
- WI total lake shore land feet …317,439,460.80

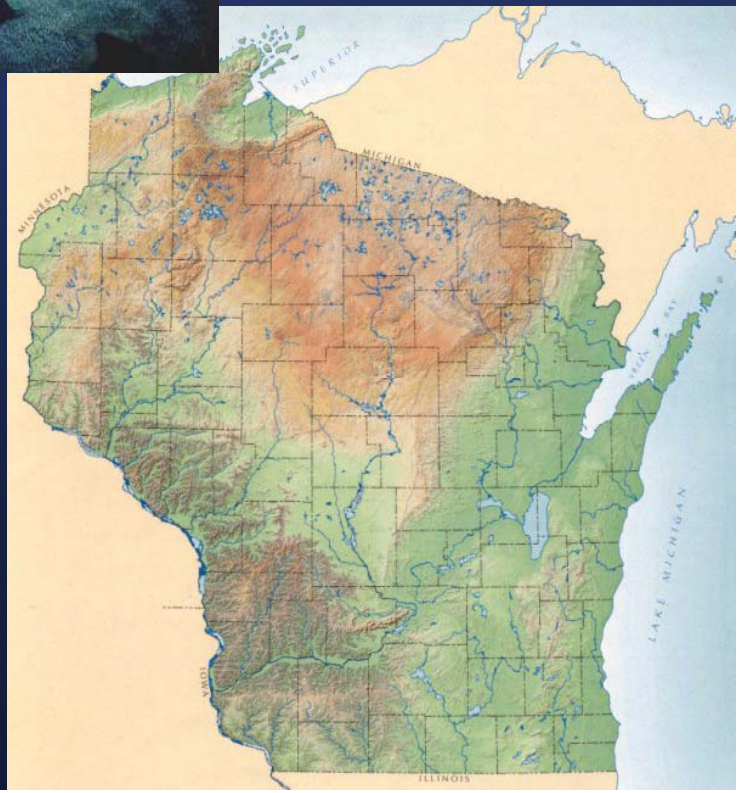
- WI total river frontage feet … 526,781,270.40
- WI Total feet of water front property …844,220,731.20
- Lakes at $100 per front foot $31.7 billion
- Rivers at $100 per front foot $52.6 billon

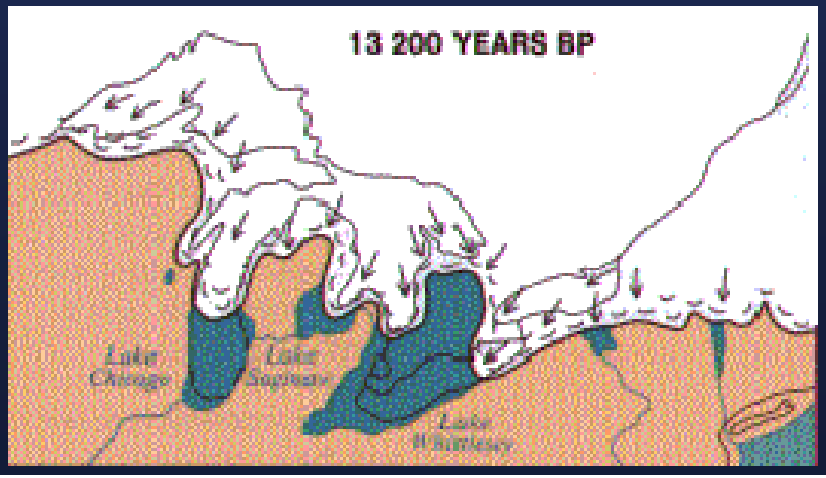
Wisconsin's lakes



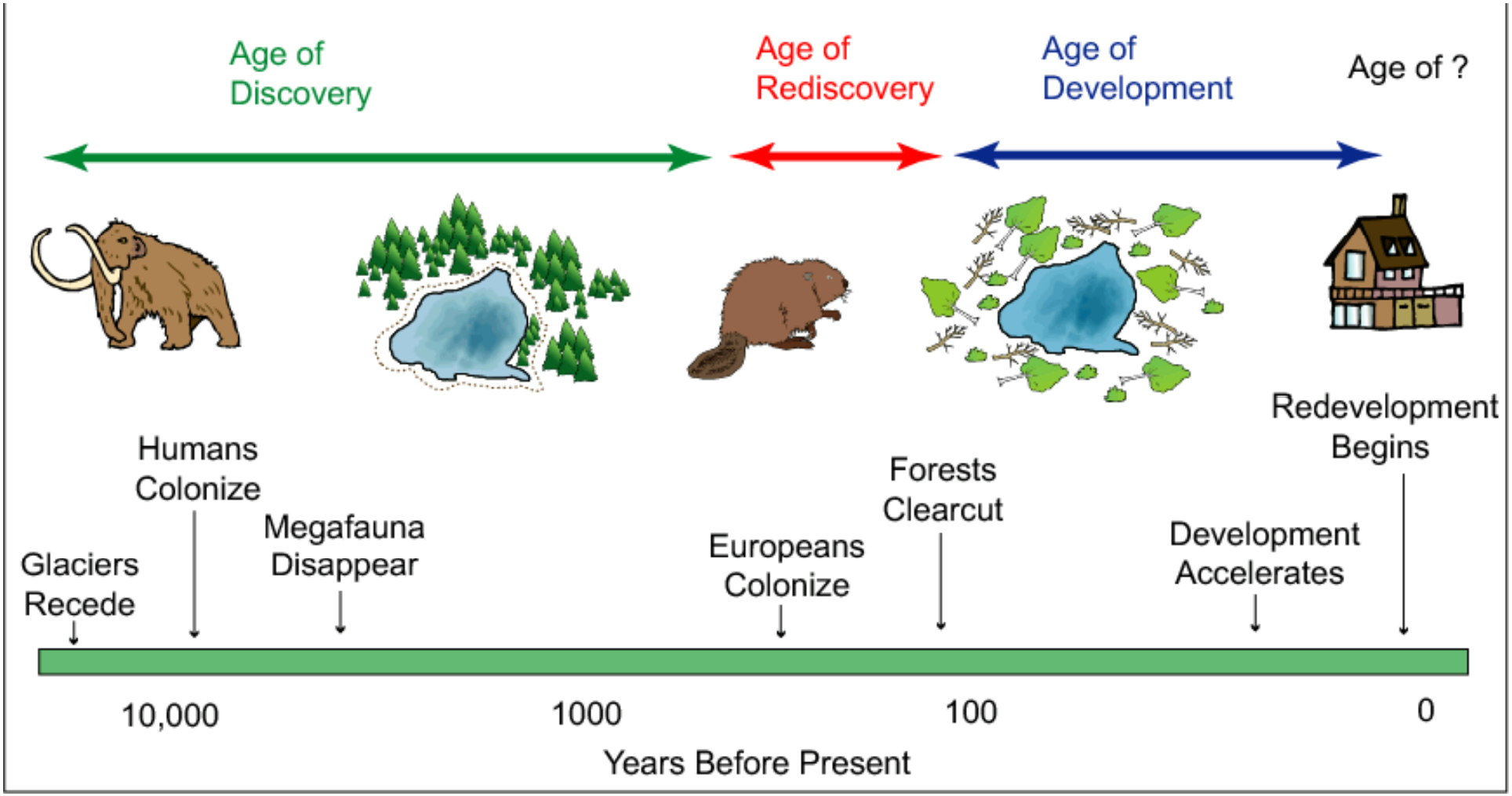
Wisconsin has one of the largest concentration of fresh water glacial lakes on the planet.

Wisconsin's Glacial Legacy





Recent History of Wisconsin's Lakes

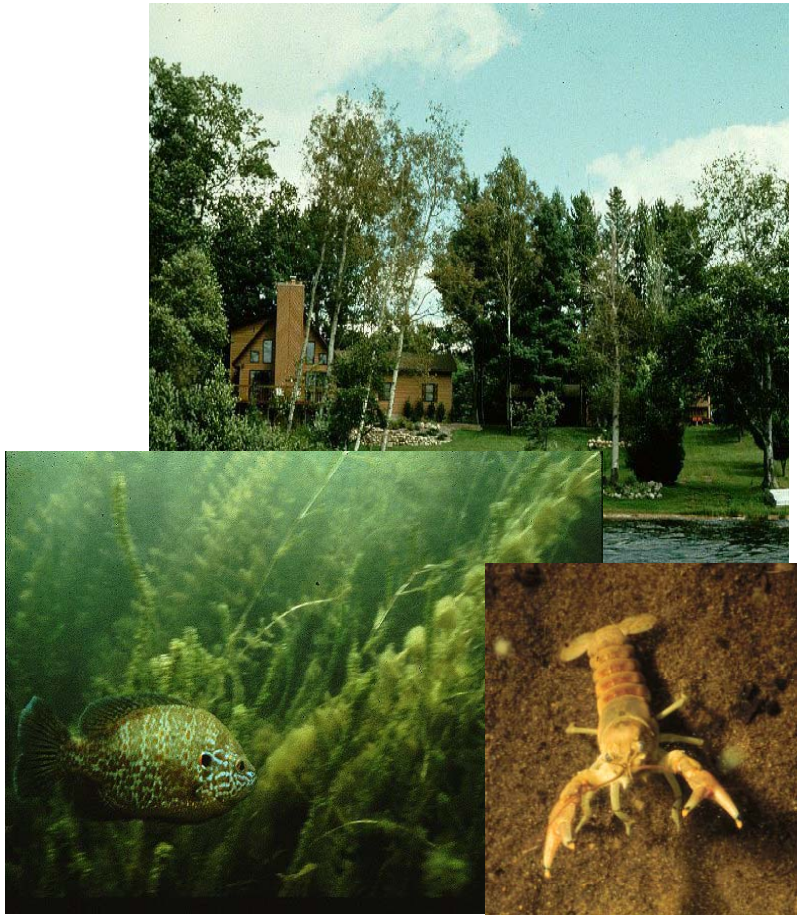


Wisconsin's Lakes are Changing Faster than Ever:

Algae blooms
(phosphorus pollution)

Destruction of
shoreline habitat

Invading plants and
animals



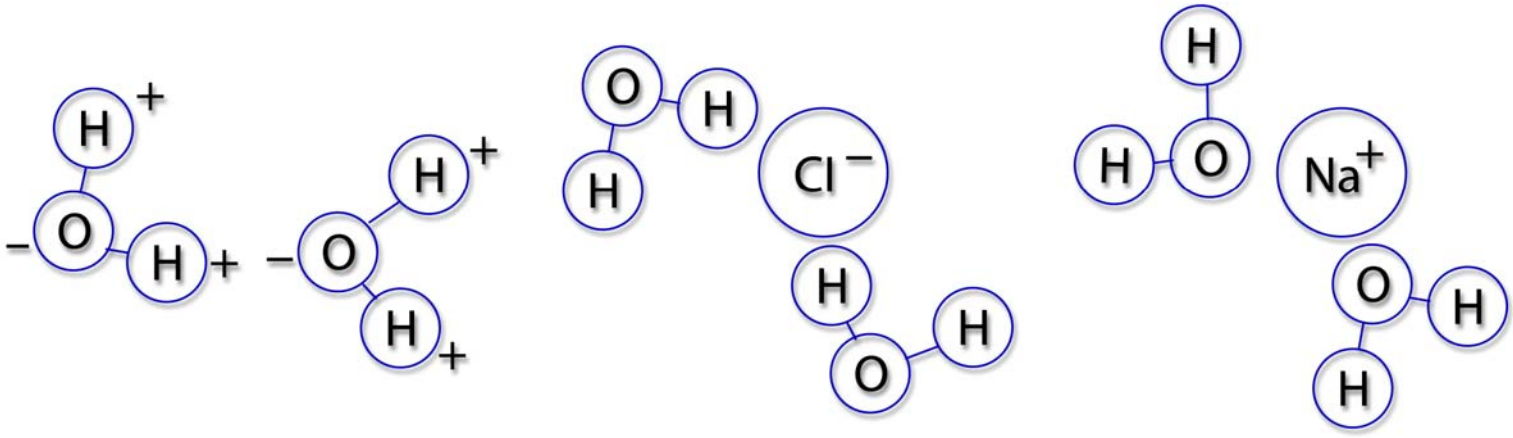
Steve Carpenter

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**



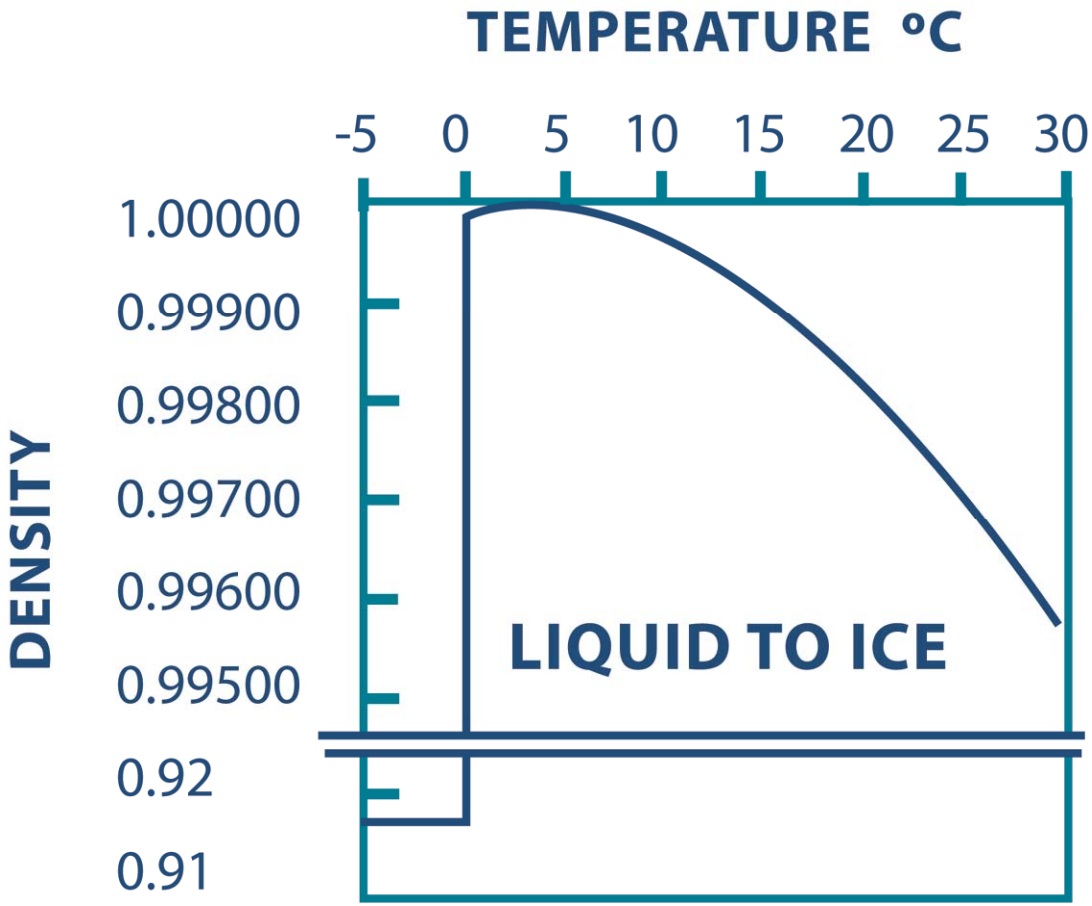
Unique Properties of Water

- 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

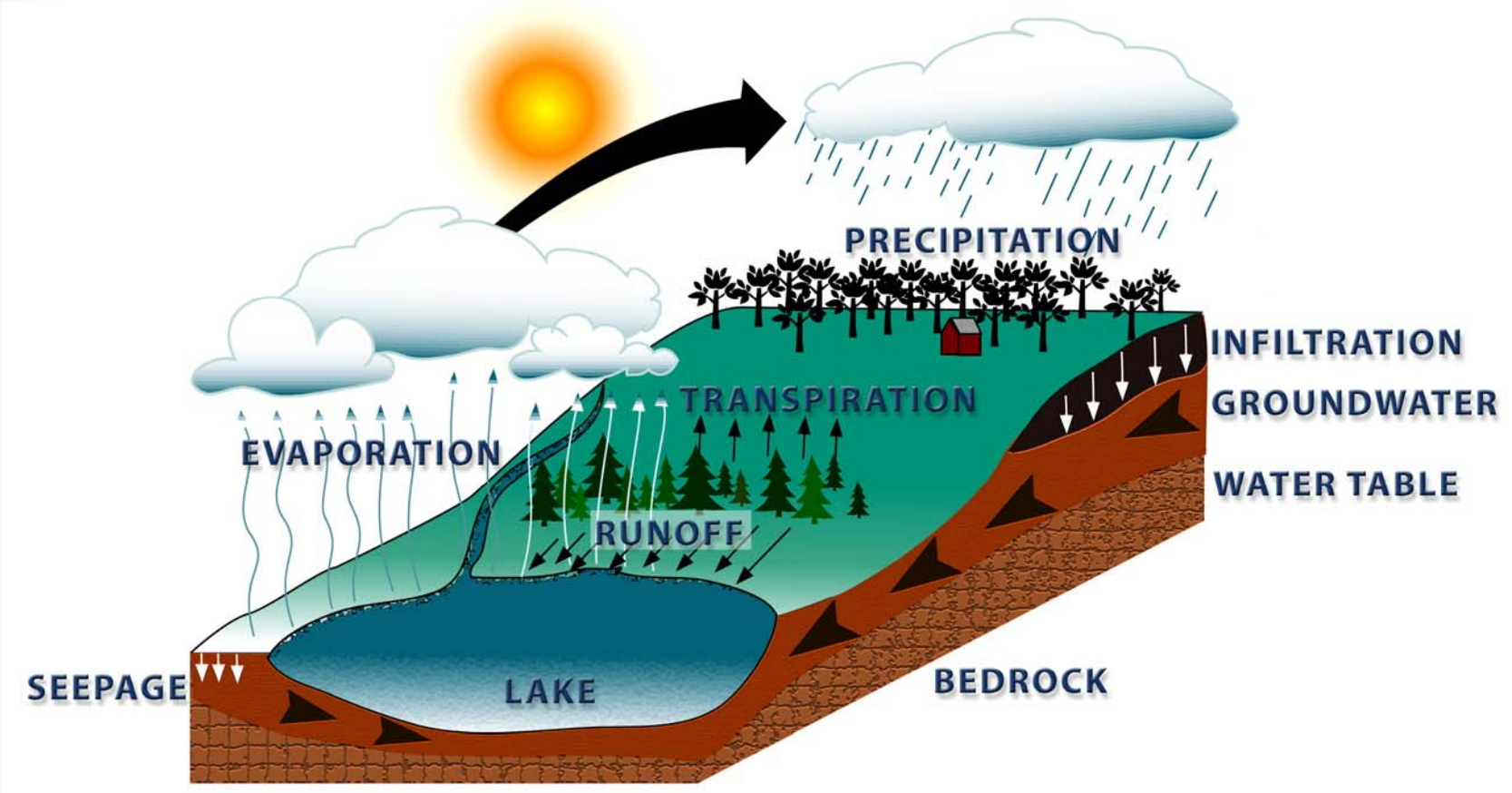
From waterencyclopedia.com

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



HYDROLOGIC CYCLE



OVERVIEW

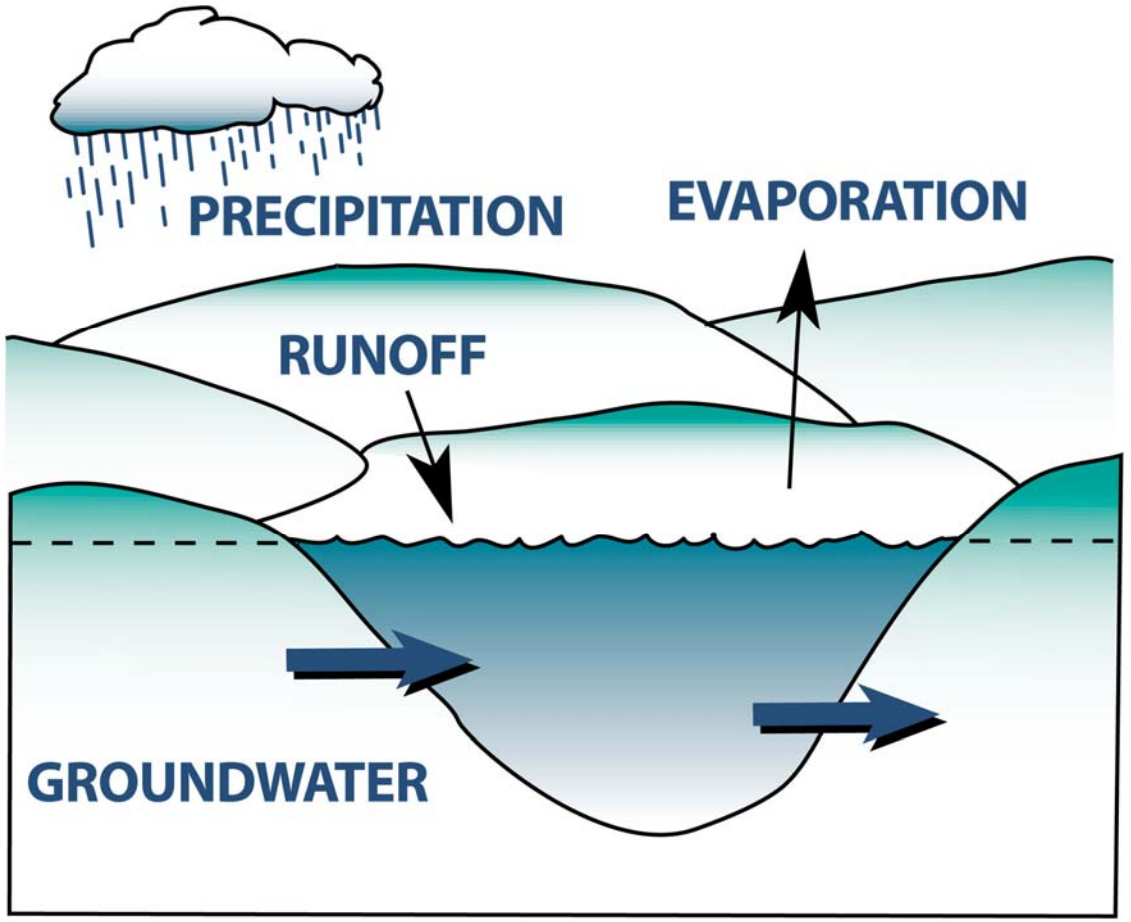
- Unique Properties of Water
- **Lake Types**
- Physical, Chemical, Biological and Habitat Characteristics
- Technical Aspects

LAKE TYPES

- Seepage
- Groundwater Drainage
- Drainage
- Impoundments
- Oxbow

SEEPAGE LAKE

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



SEEPAGE LAKE

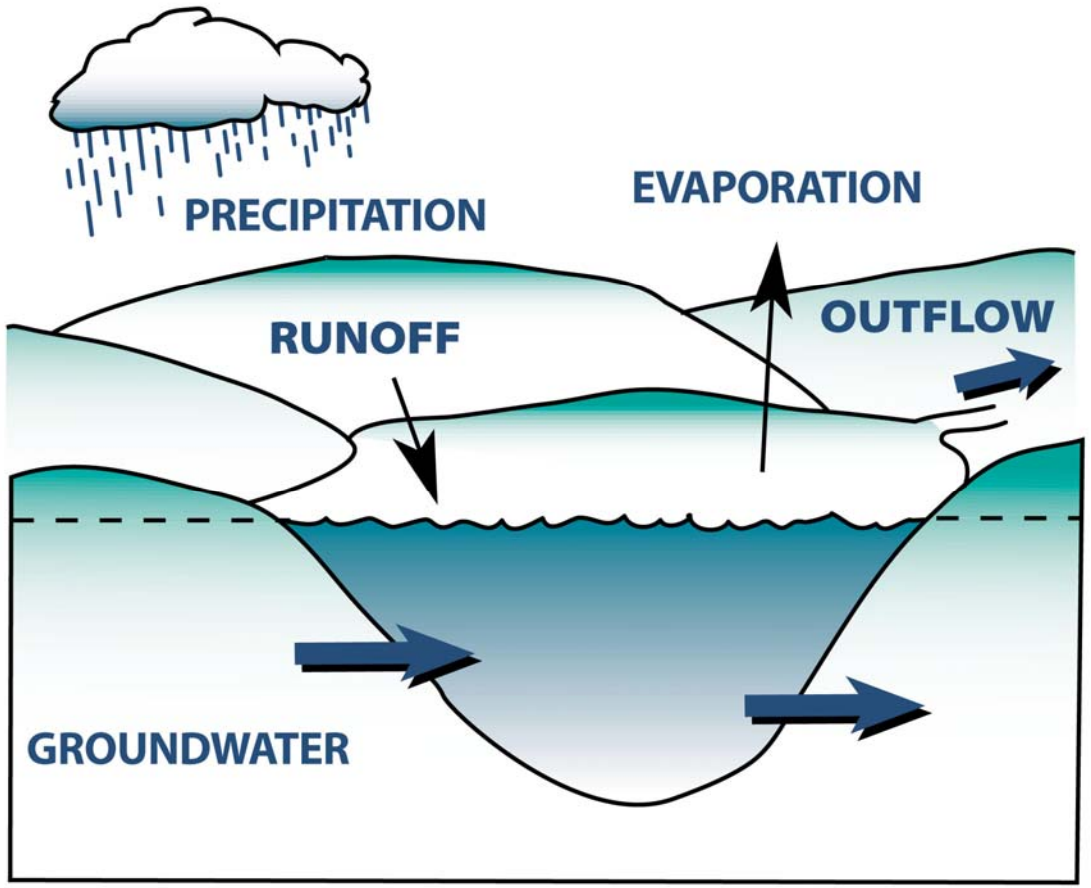
- ***Long & Des Moines Lakes, Burnett Co.***
- Shell Lake, Washburn Co.
- Whitefish Lake, Douglas Co.,
- Potowotomi Lakes, Bayfield Co.

SEEPAGE LAKE

- Round Lake, Chippewa County

GROUNDWATER DRAINAGE

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

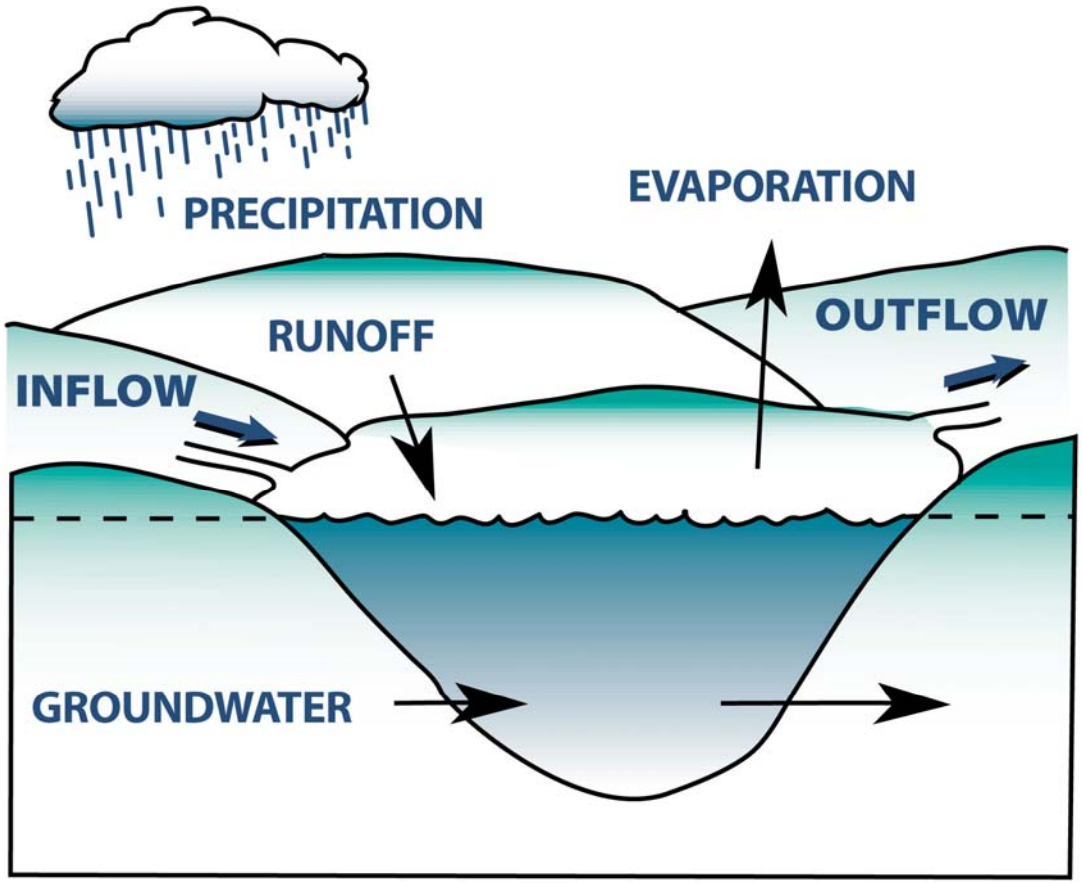


GROUNDWATER DRAINAGE LAKE

- Sand Lake, Chippewa County

DRAINAGE LAKE

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

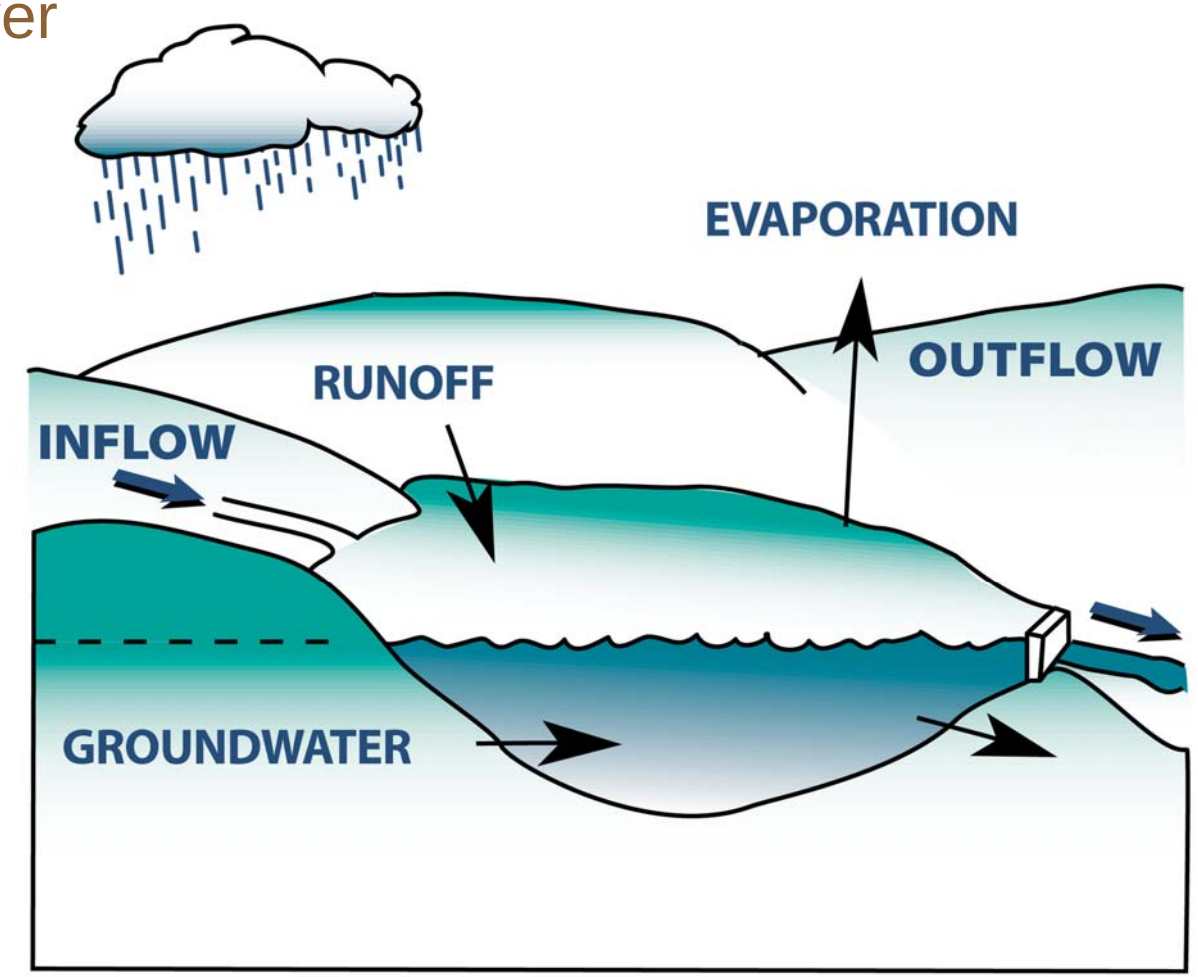


DRAINAGE LAKE

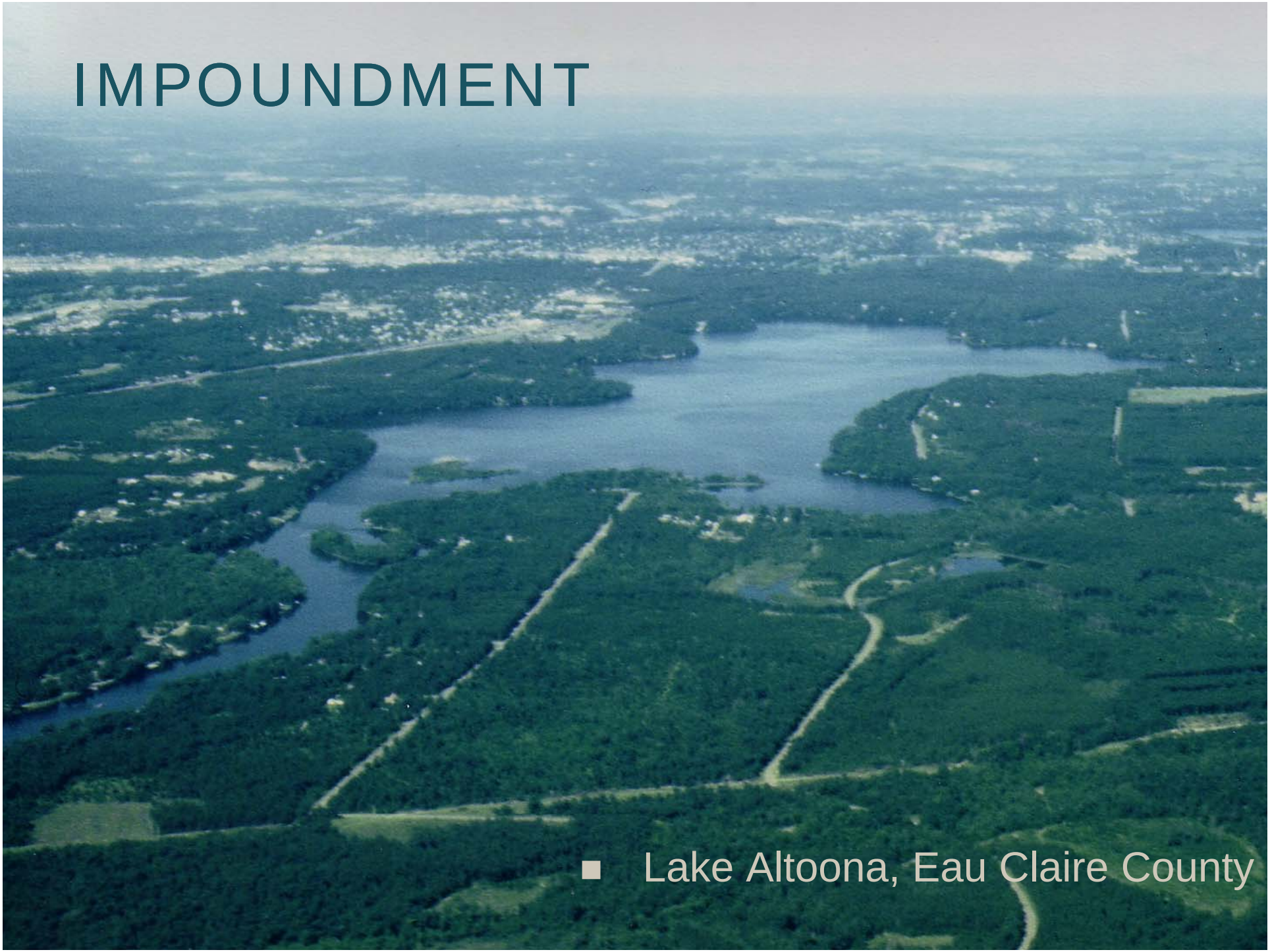
- Long Lake, Chippewa County

IMPOUNDMENT

- A manmade lake
- Dammed River or Stream



IMPOUNDMENT



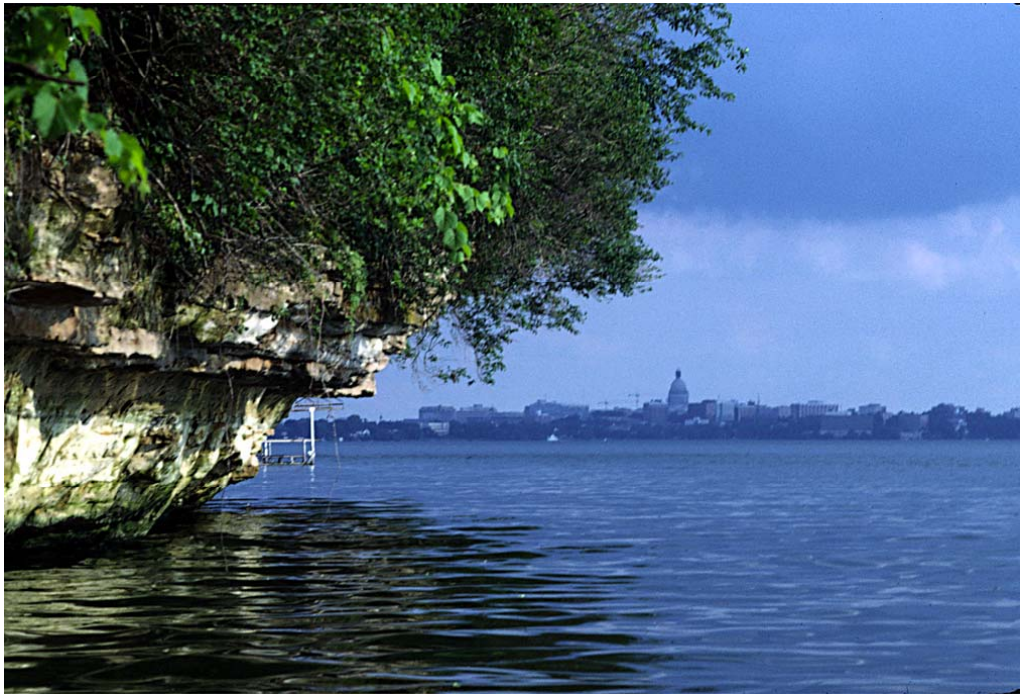
- Lake Altoona, Eau Claire County

OXBOW

- Lake Hallie, Chippewa County

OVERVIEW

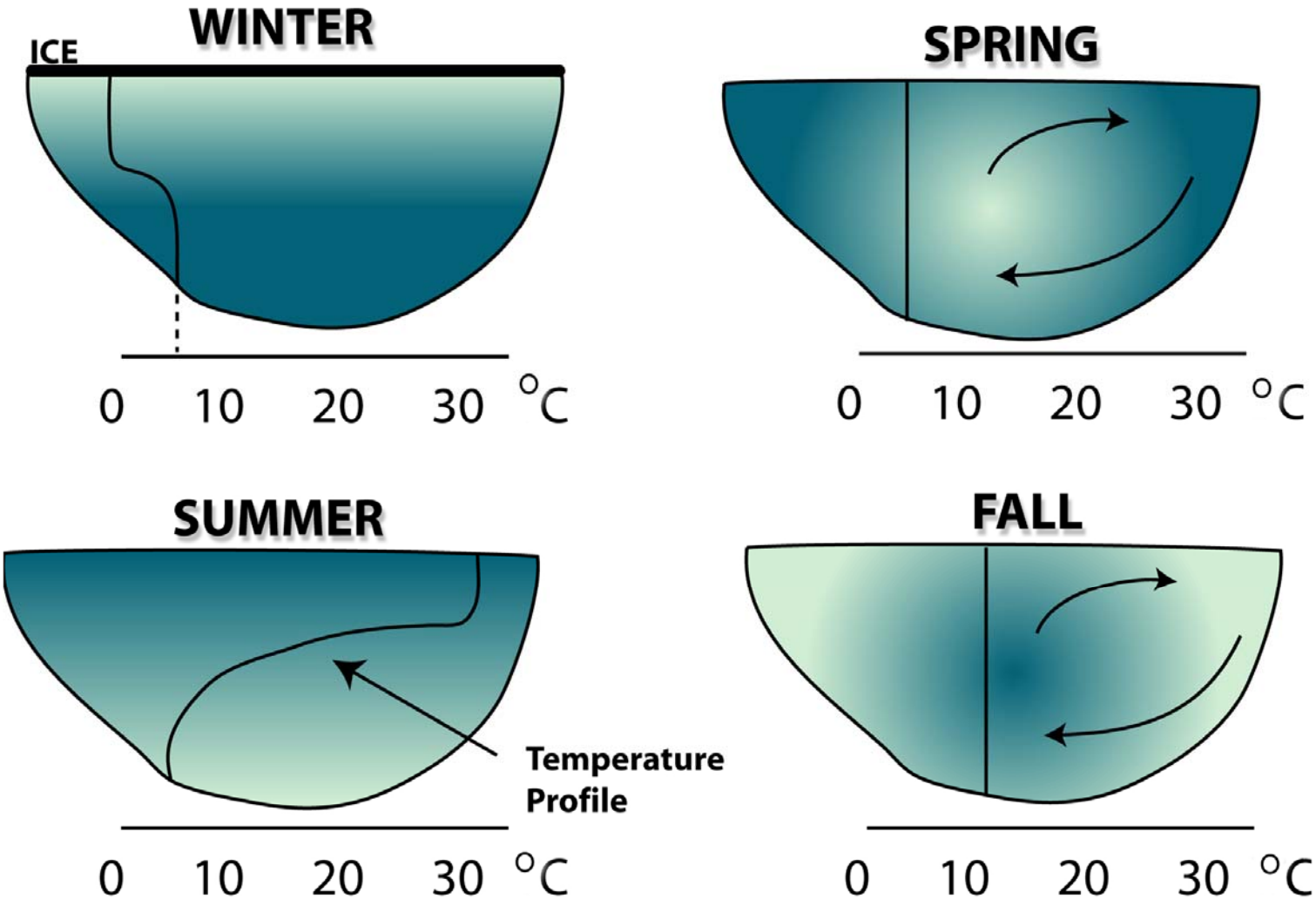
- Unique Properties of Water
- Lake Types
- Physical, Chemical, Biological and Habitat Characteristics
- Technical Aspects



PHYSICAL CHARACTERISTICS

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

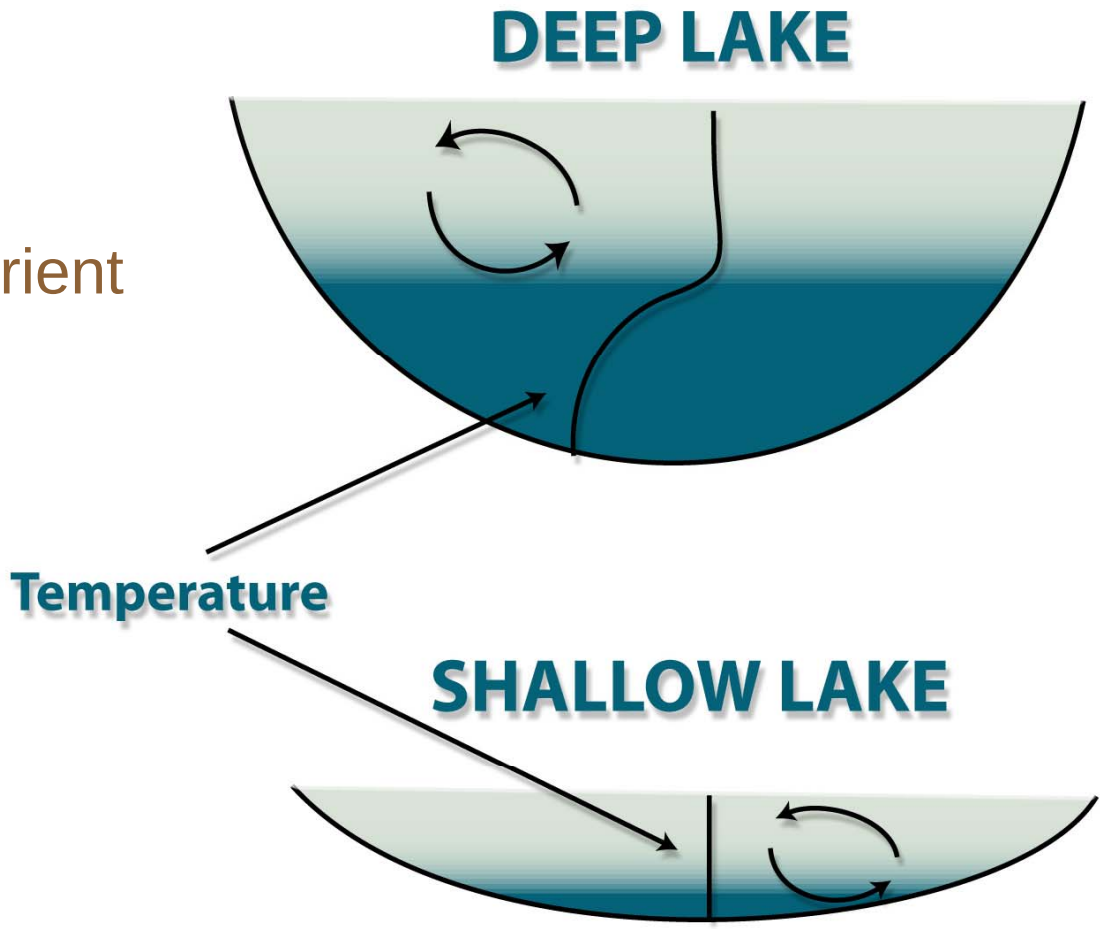
MIXING/ STRATIFICATION



LAKE DEPTH MATTERS

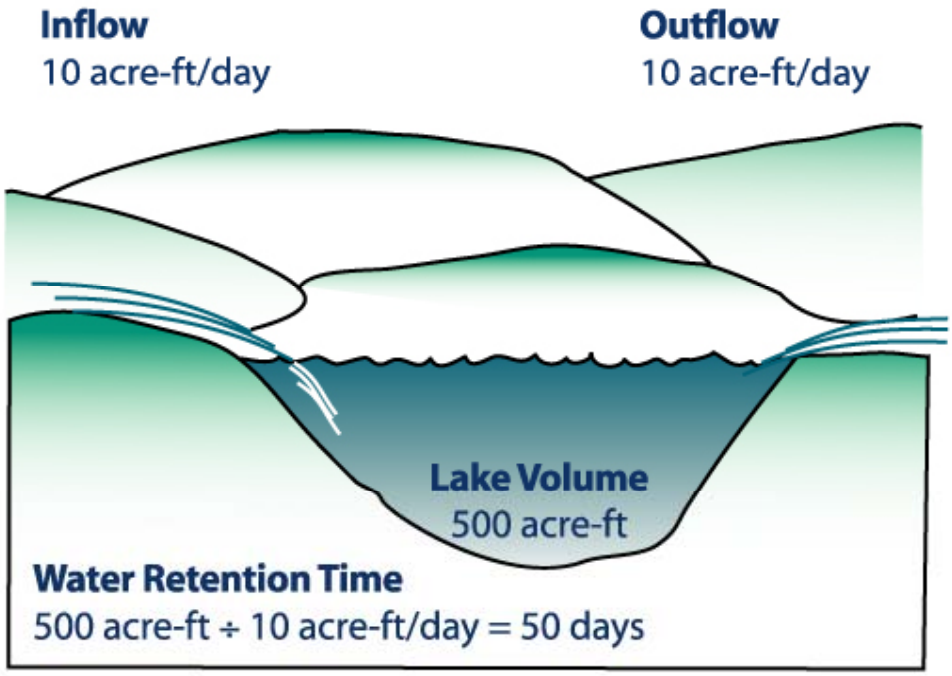
- **Deep Lakes**
  Stratify

- **Shallow Lakes**
  Continuous Nutrient Recycling



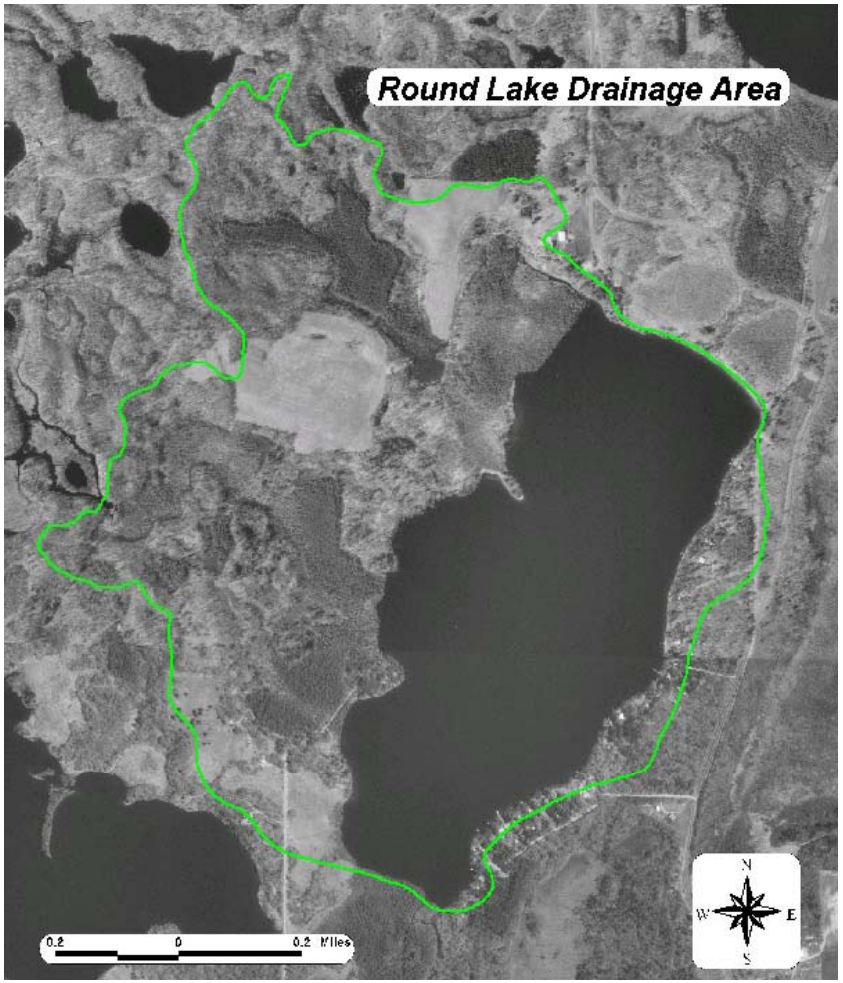
RETENTION TIME/ FLUSHING RATE

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

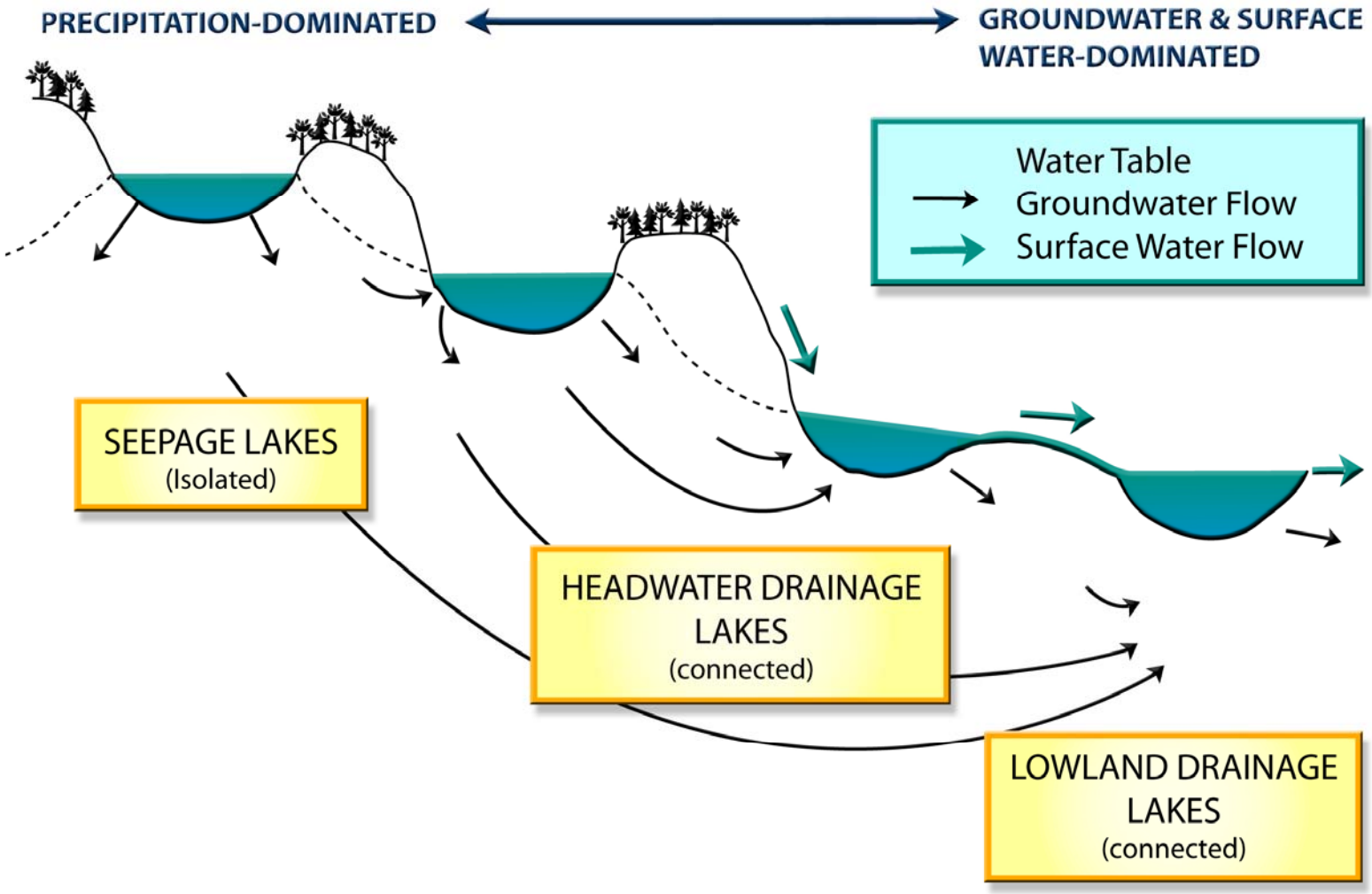


DRAINAGE BASIN/ LAKE AREA RATIO

- 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

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

LIMITING NUTRIENT PRINCIPLE

…That Nutrient in Least Supply
Relative to Plant Needs

N:P Ratio in plant Tissue 10:1 - 15:1

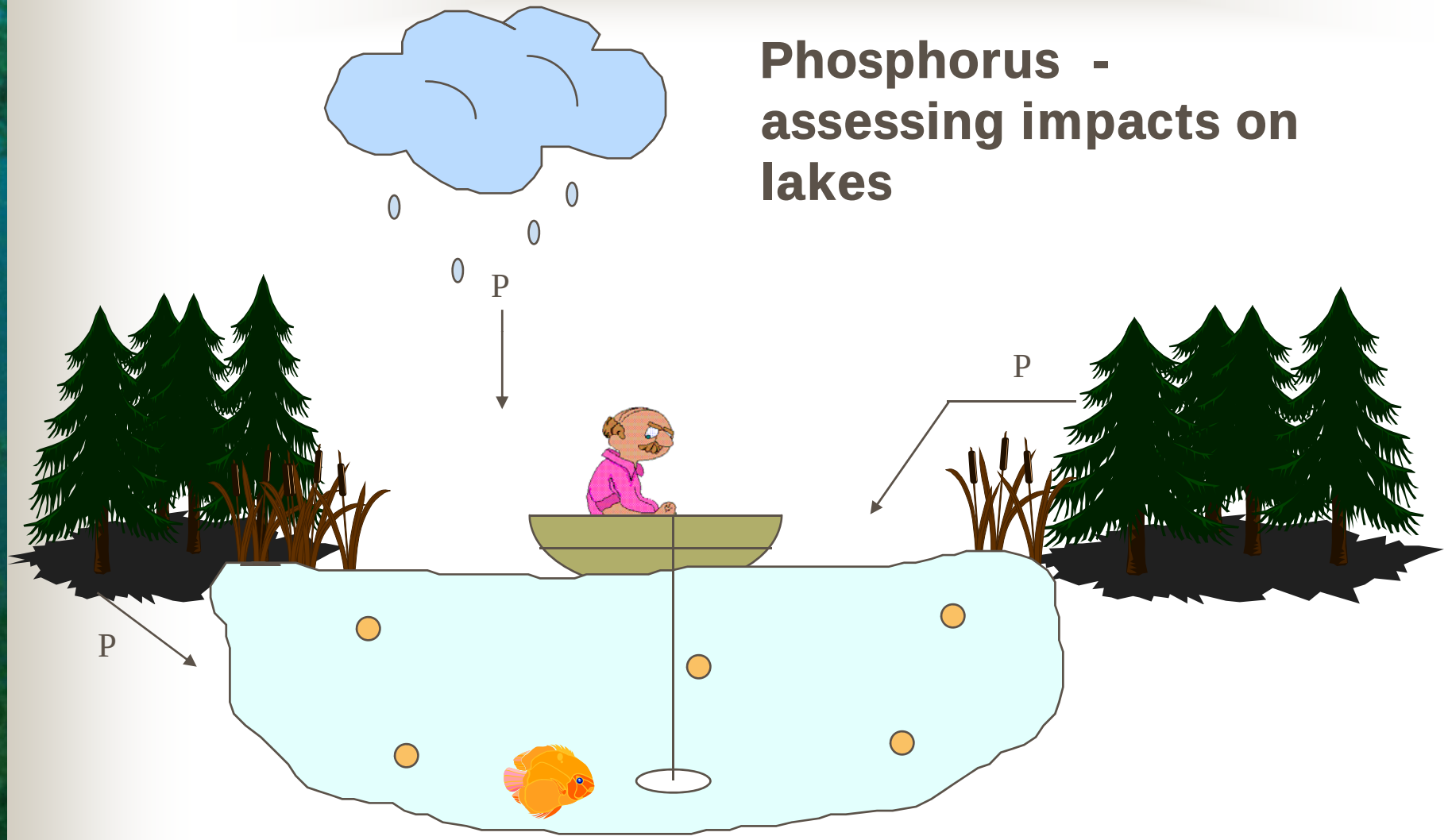
If the Ratio of N:P in Water is

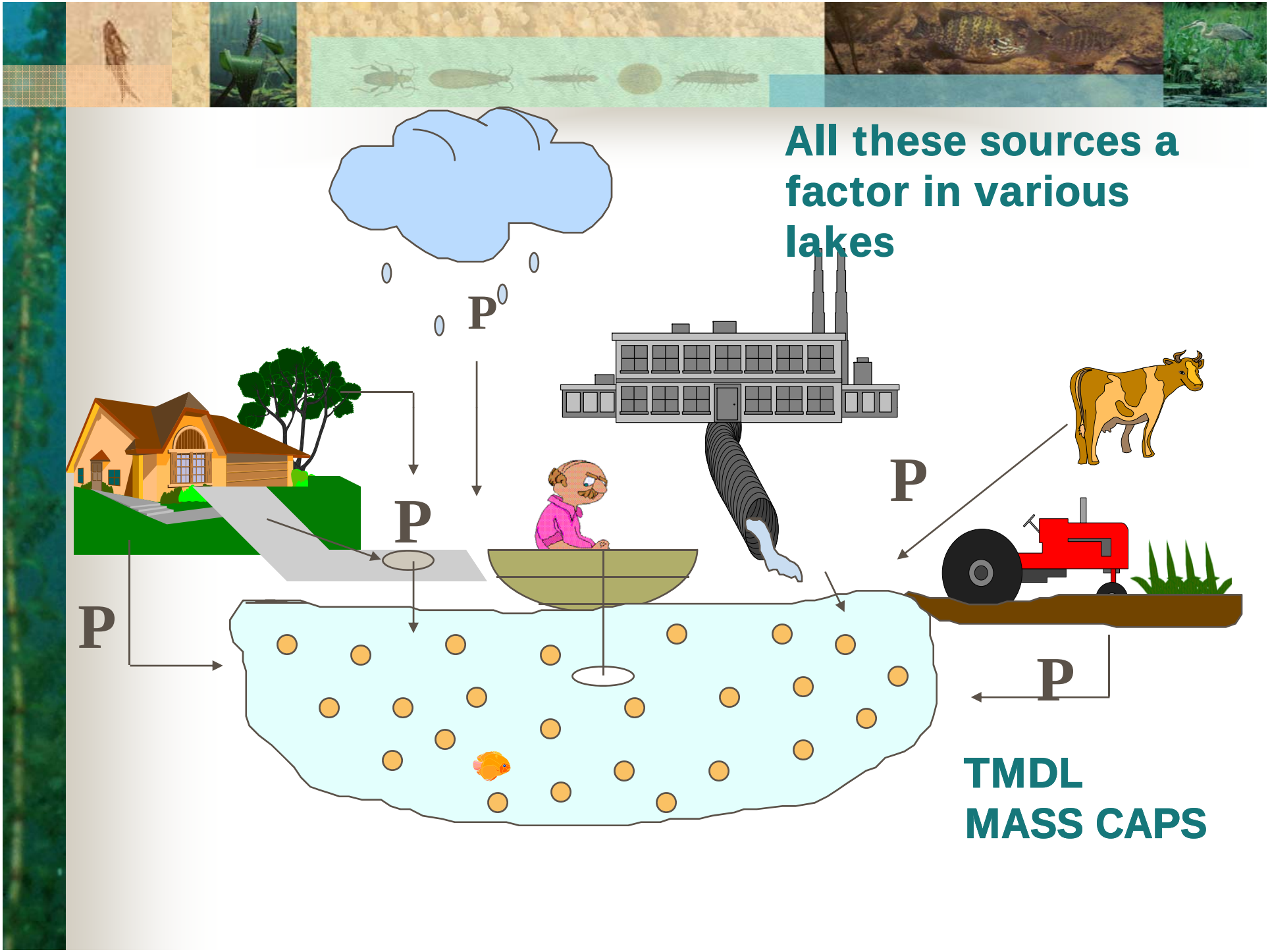
<10:1 Nitrogen Limited

>15:1 Phosphorus Limited

PHOSPHORUS LIMITATION
LAKE 227

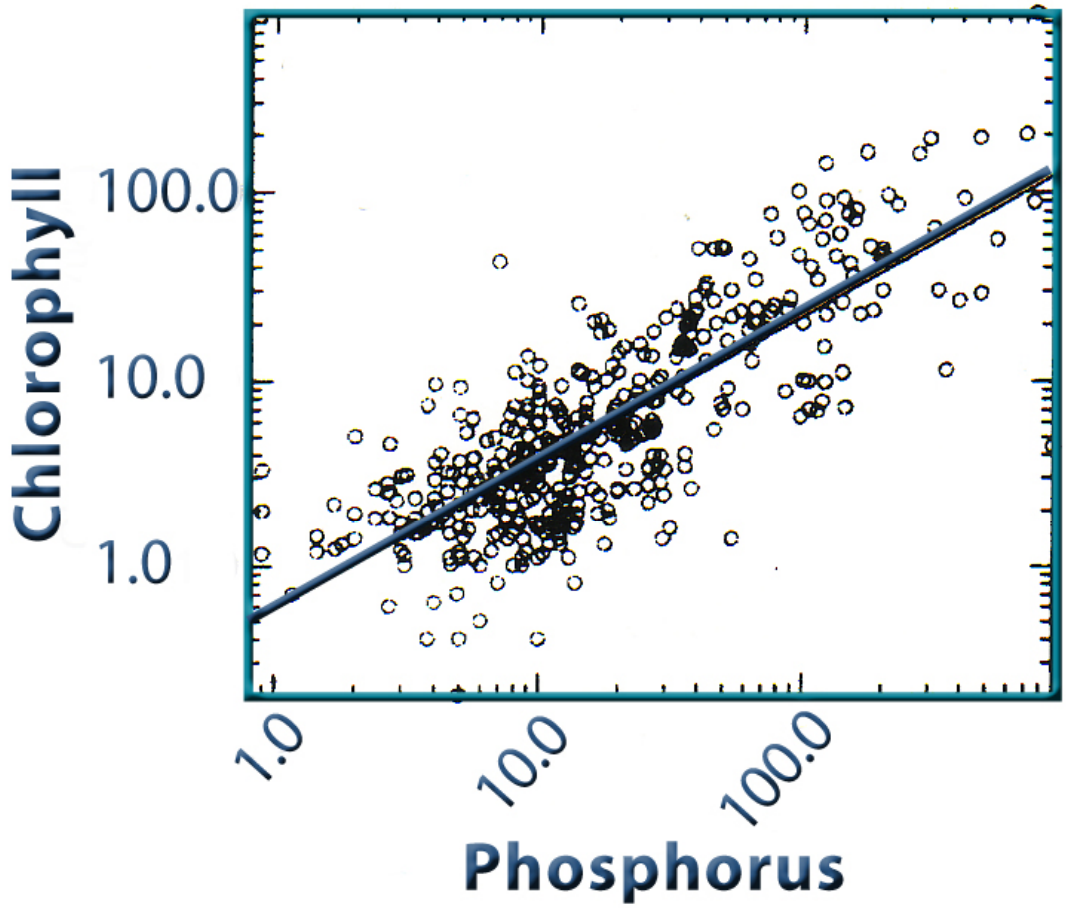
Phosphorus - assessing impacts on lakes

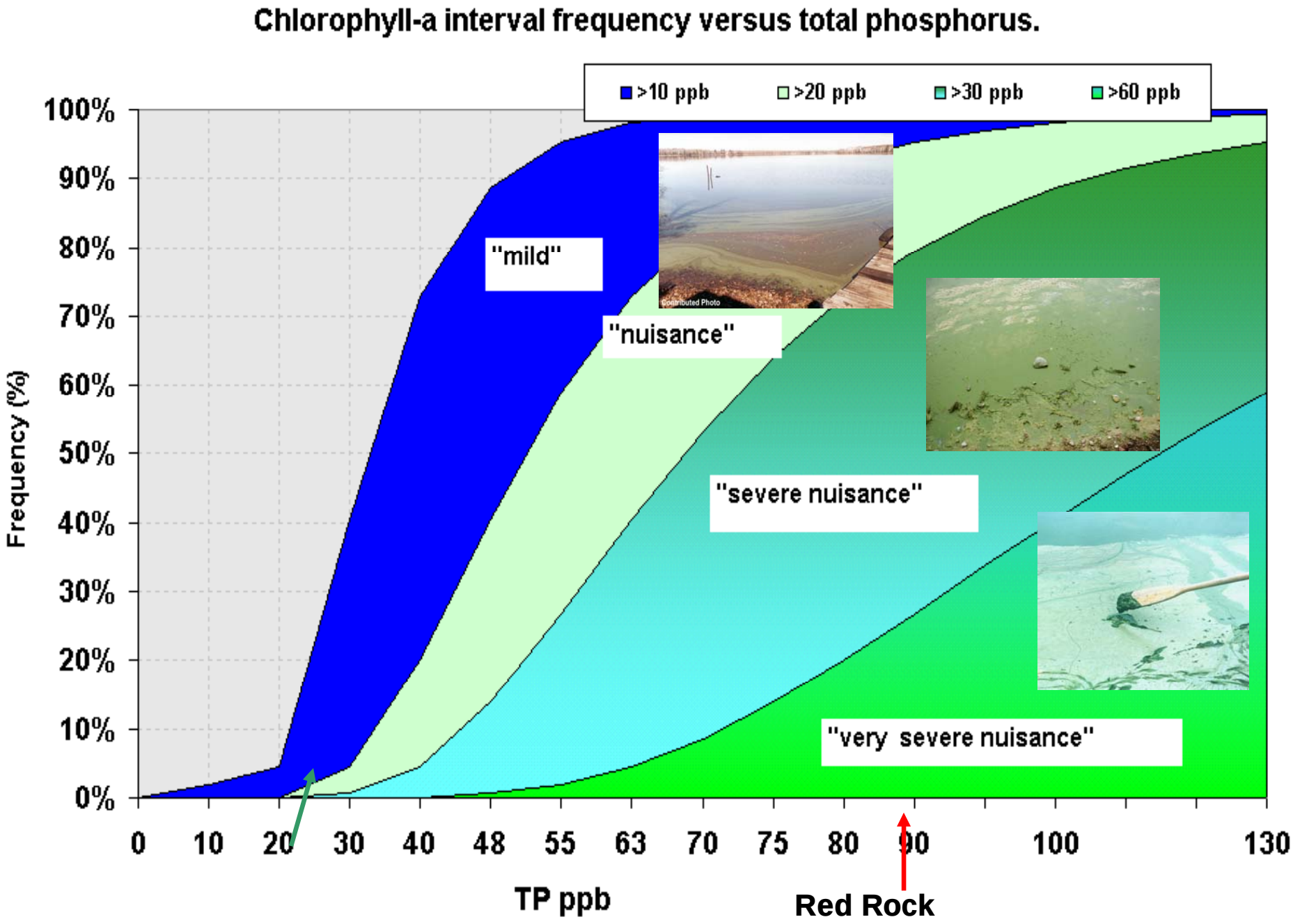



All these sources a factor in various lakes
P
P
P
P
P
P
TMDL
MASS CAPS

TOTAL PHOSPHORUS/ CHLOROPHYLL a RELATIONSHIP

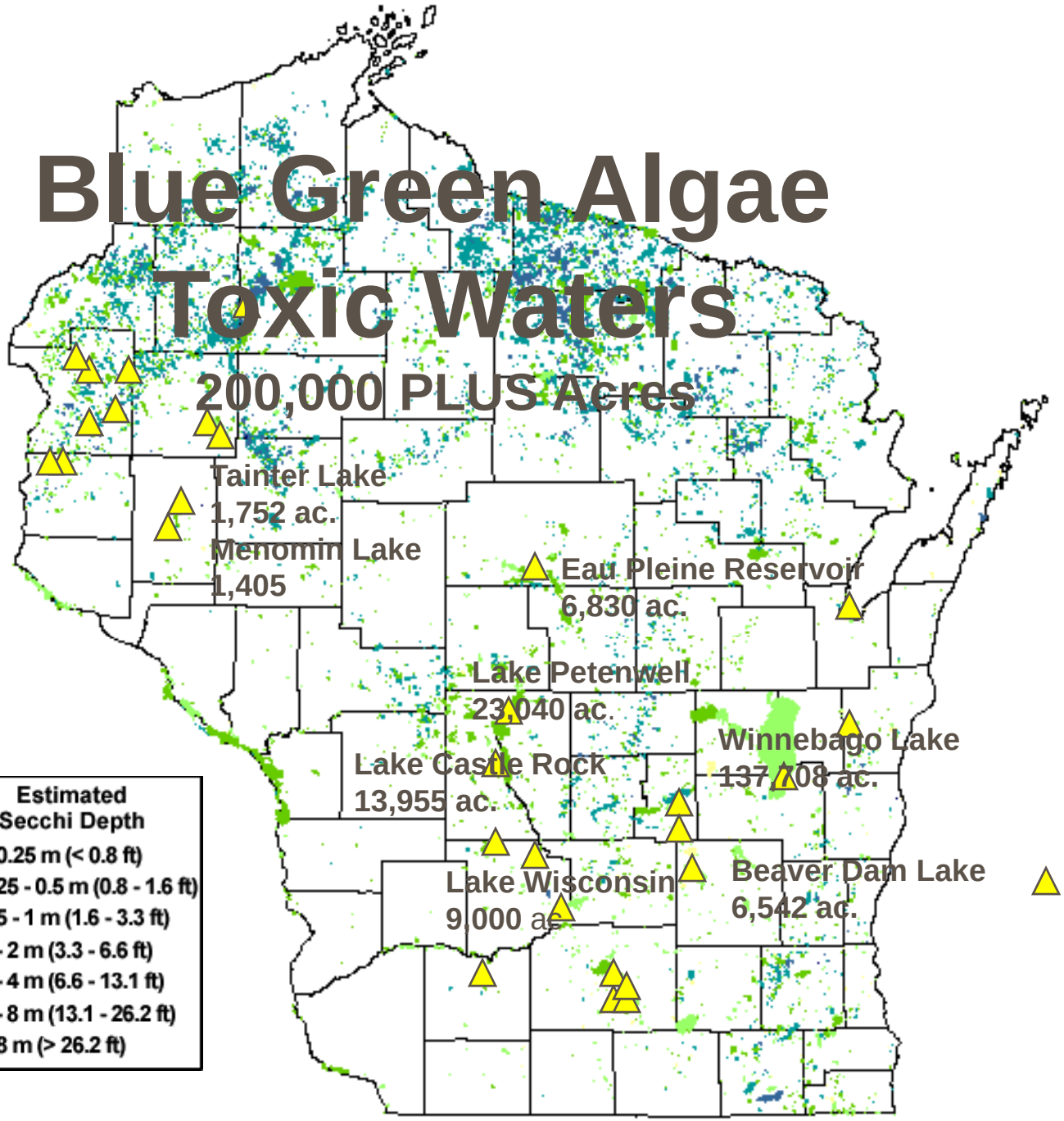
- Phosphorus causes algae to grow




Chlorophyll-a interval frequency versus total phosphorus.
>10 ppb
>20 ppb
>30 ppb
>60 ppb
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Frequency (%)
"mild"
"nuisance"
"severe nuisance"
"very severe nuisance"
0
10
20
30
40
48
55
63
70
75
80
90
100
130
TP ppb
Red Rock

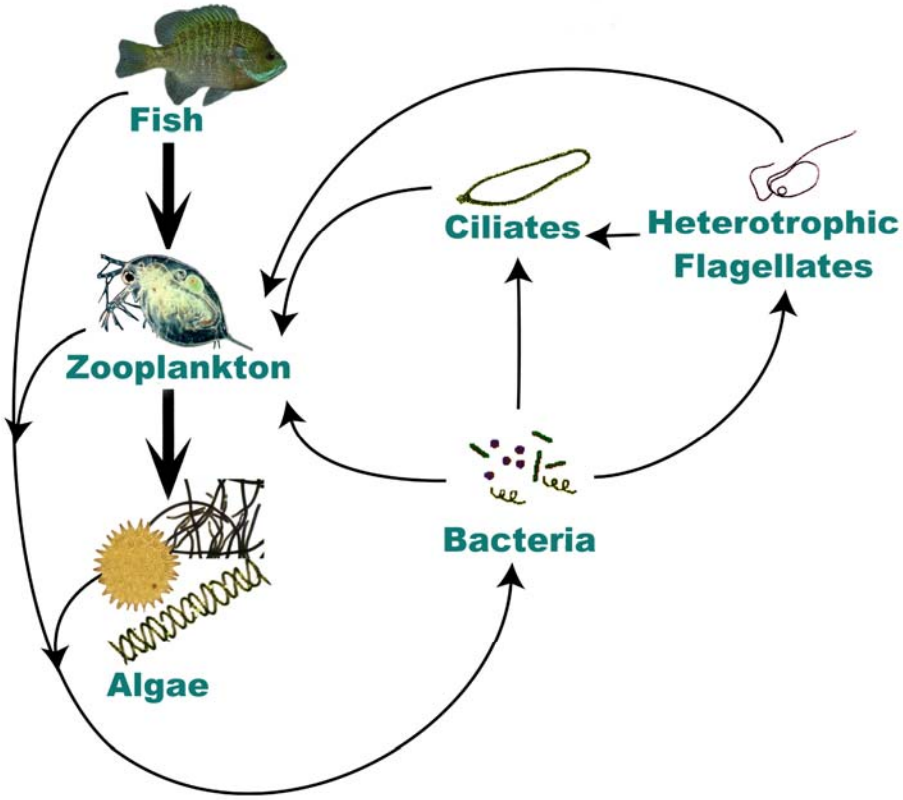
Blue Green Algae Toxic Waters

200,000 PLUS Acres



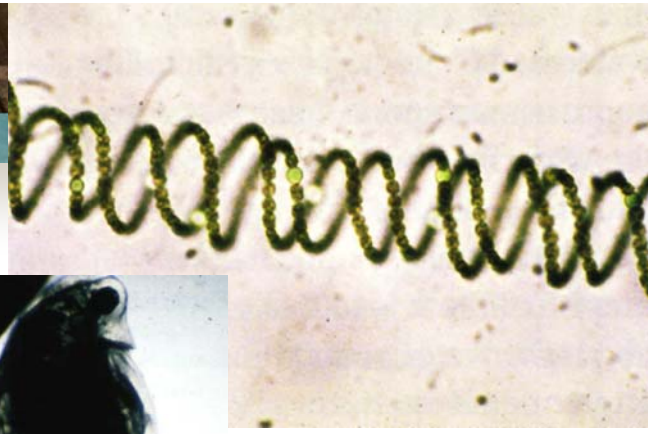
BIOLOGICAL CHARACTERISTICS

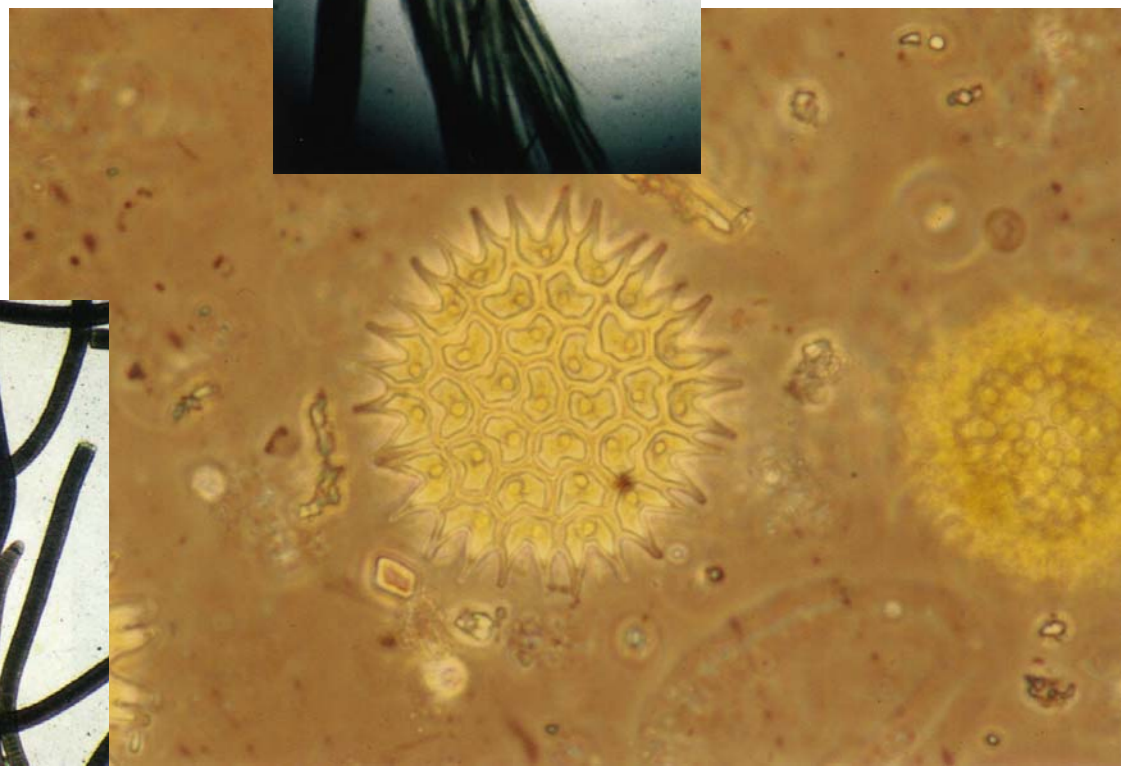
- Viruses/ Bacteria/ Fungi
- Primary - Producers Algae/ Macrophyte
- Zooplankton/ Inverts
- Fish



ALGAE

- Primary Energy Source for Invertebrates
- Can be Nuisance
- Produce O_2





AQUATIC PLANTS

- Habitat
- Energy Dissipation
- O_2 Producers

ZOOPLANKTON & AQUATIC INVERTEBRATES

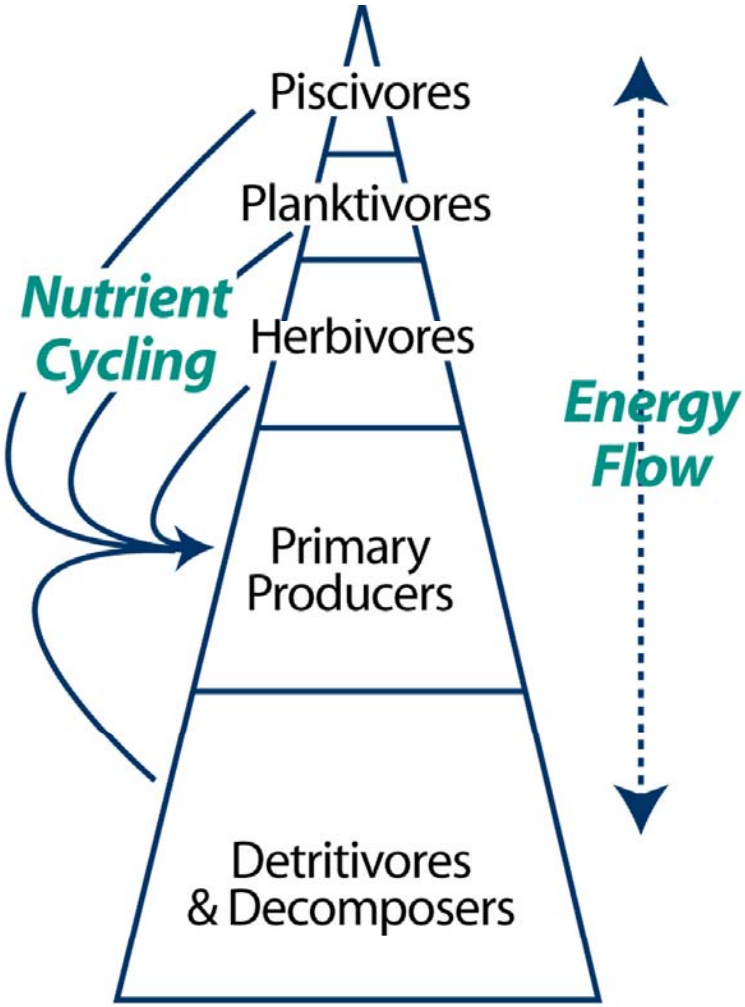
Zooplankton

Dragonfly

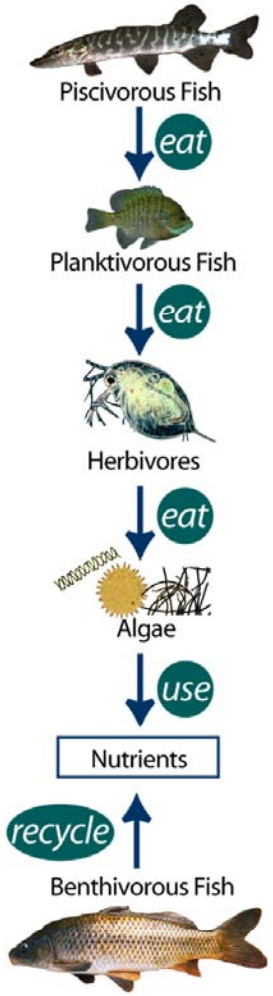
FISH

- Planktivore
- Piscivore
- Benthivore

TROPHIC PYRAMID



ENERGY PYRAMID



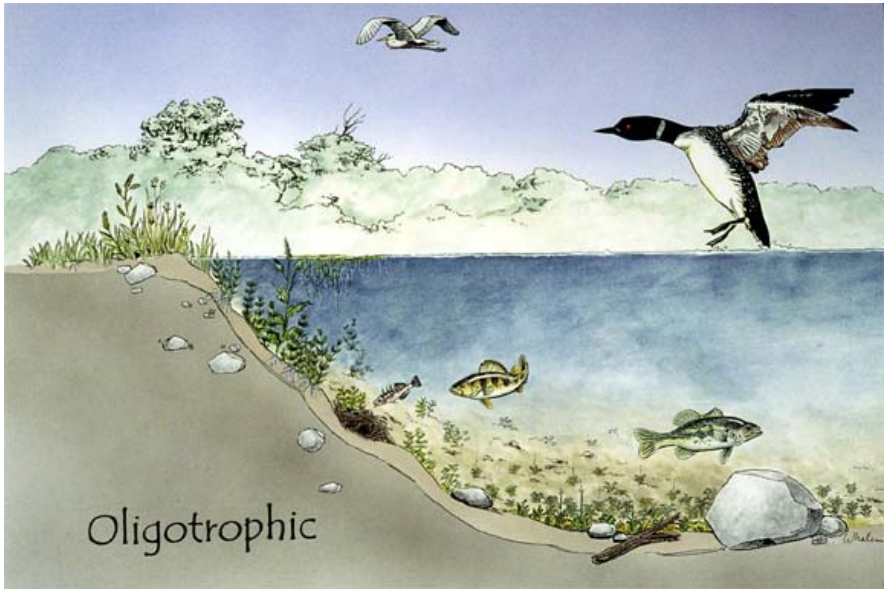
AQUATIC FOOD CHAIN

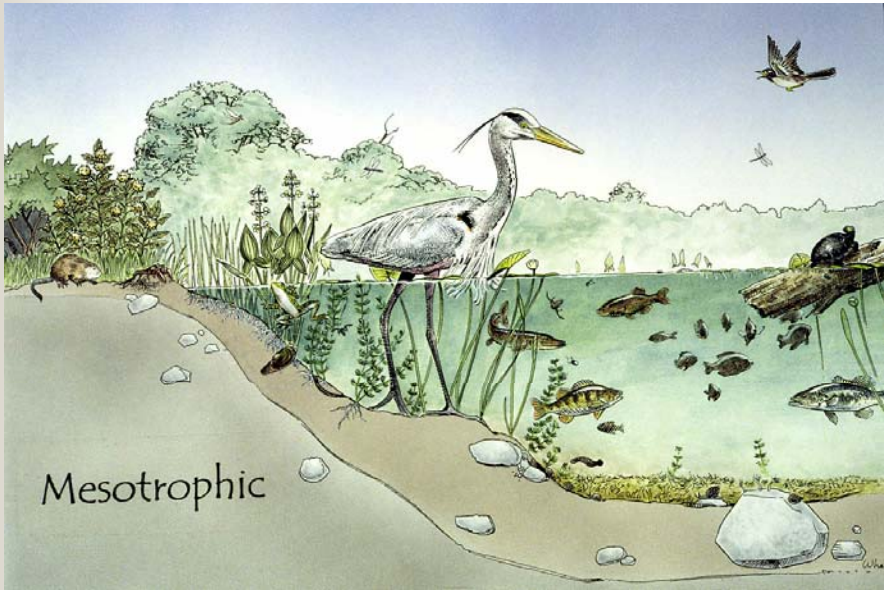
OVERVIEW

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

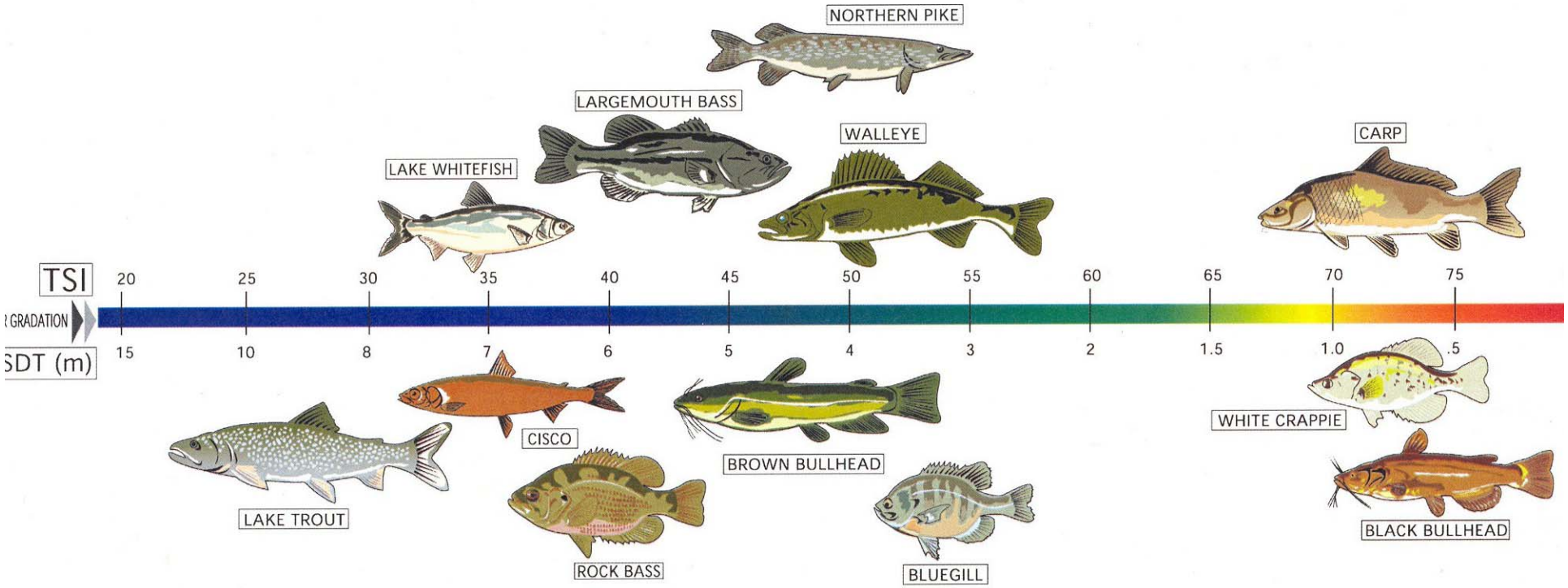
TROPHIC STATE

- Nutrients & Productivity
- Sediment & Accumulation
- Species Shifts
- Species Richness



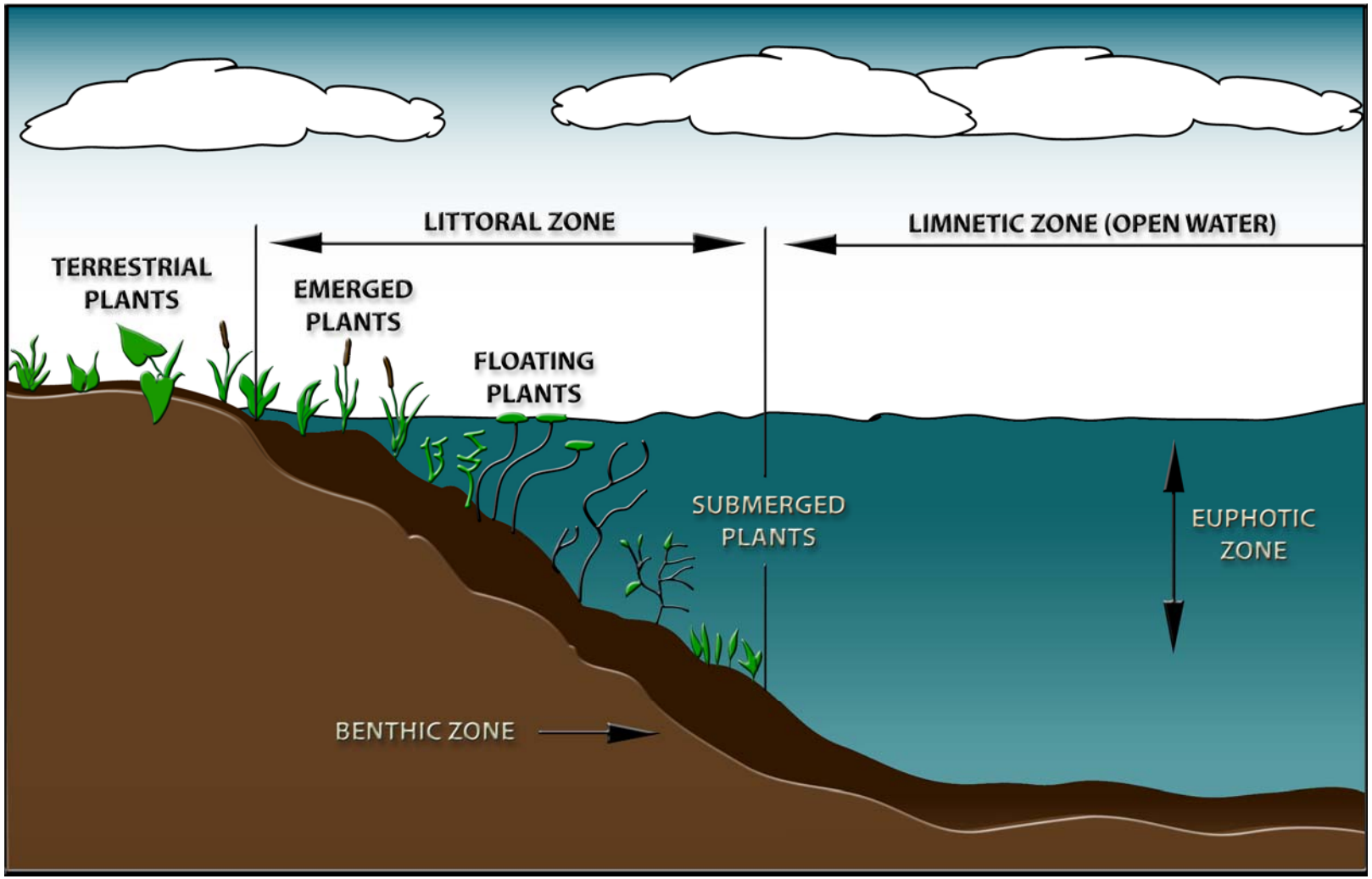


Fish species vary relative to lake trophic status



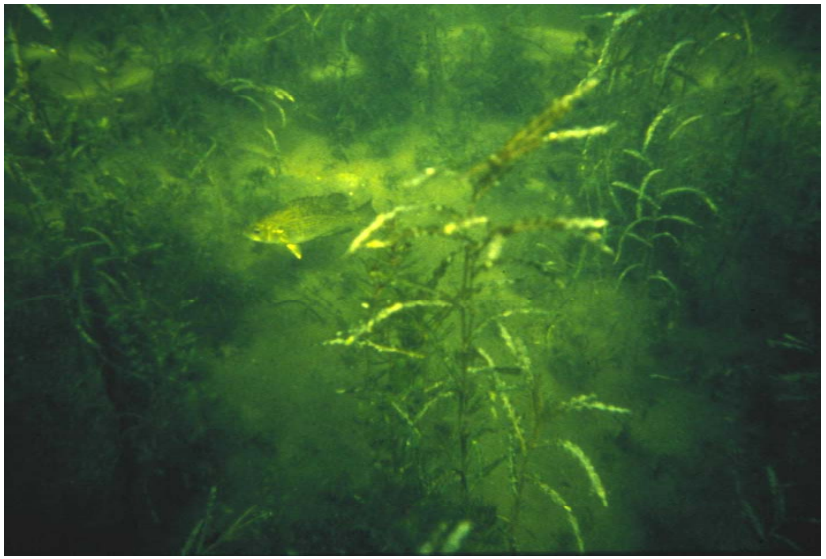
Every change of 10 in the TSI corresponds to a doubling of a lake's algae biomass and a halving of water clarity.

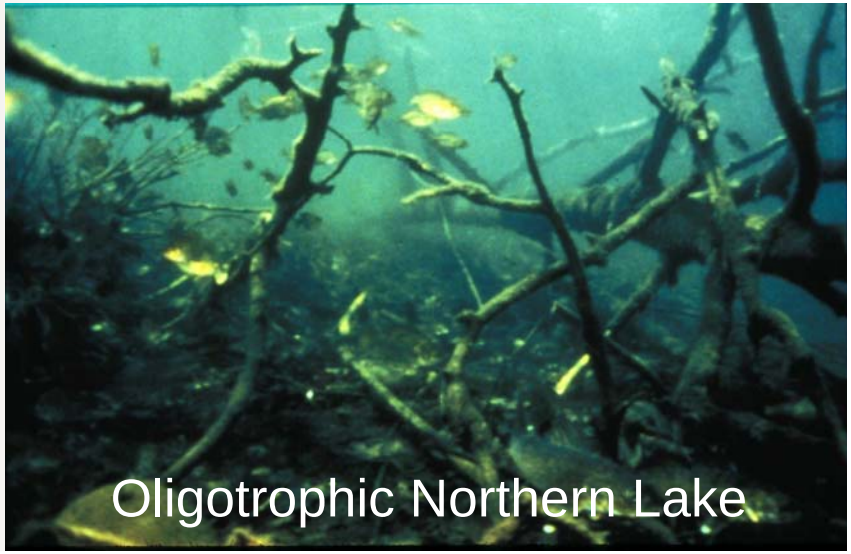
LAKE HABITAT ZONES



LAKE LITTORAL ZONE

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



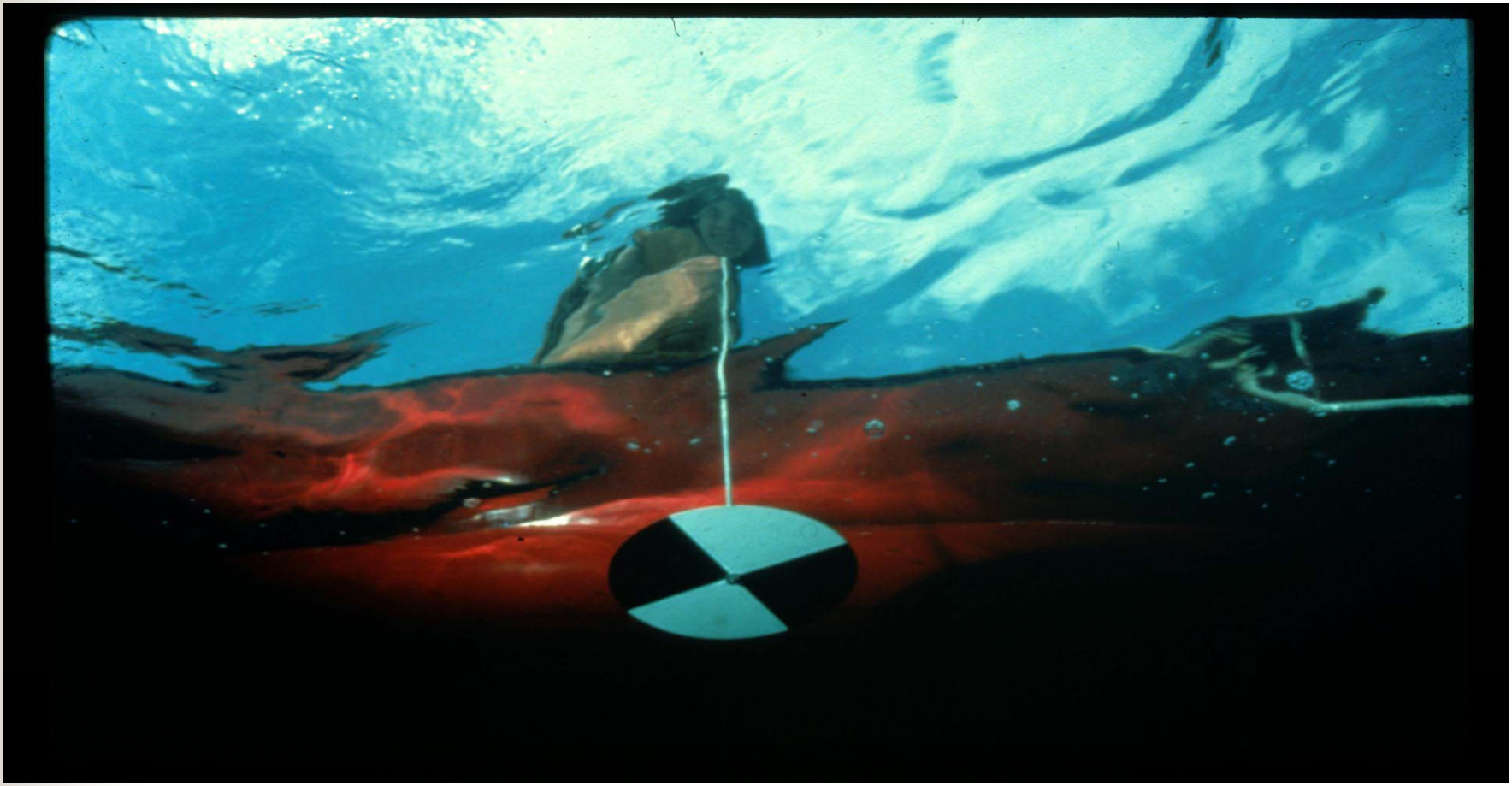


Oligotrophic Northern Lake

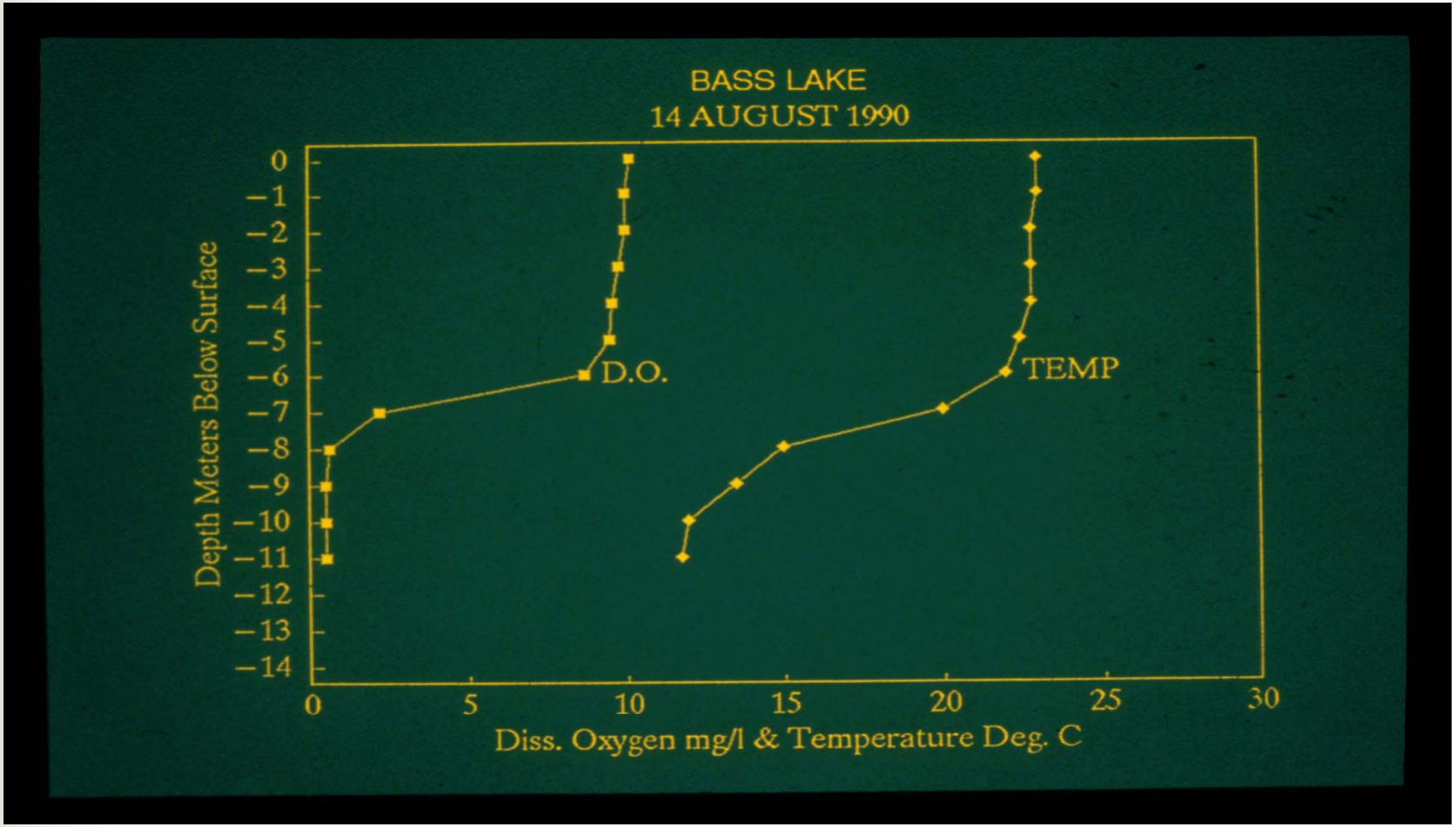
Eutrophic Southern Lake

ENVIRONMENTAL SIGNS OF DEGRADATION

LOSS OF WATER CLARITY

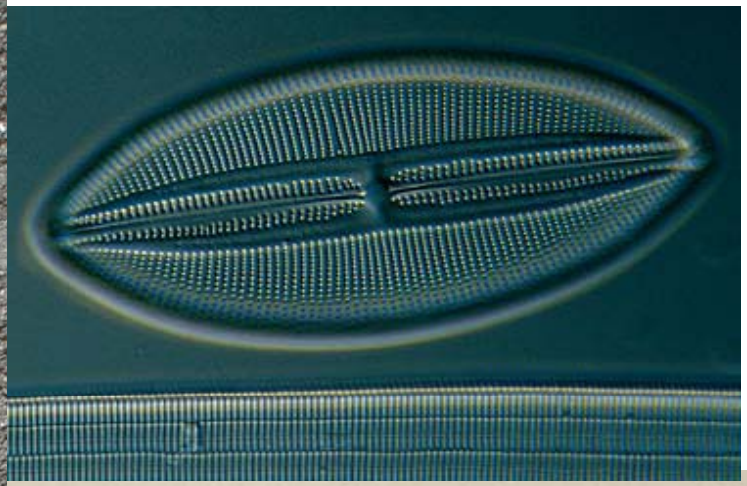


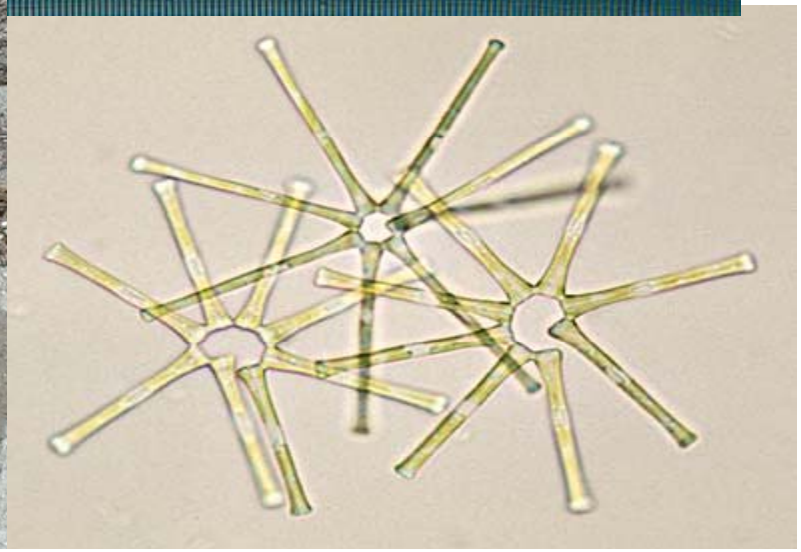
HYPOLIMNETIC DO DEPLETION



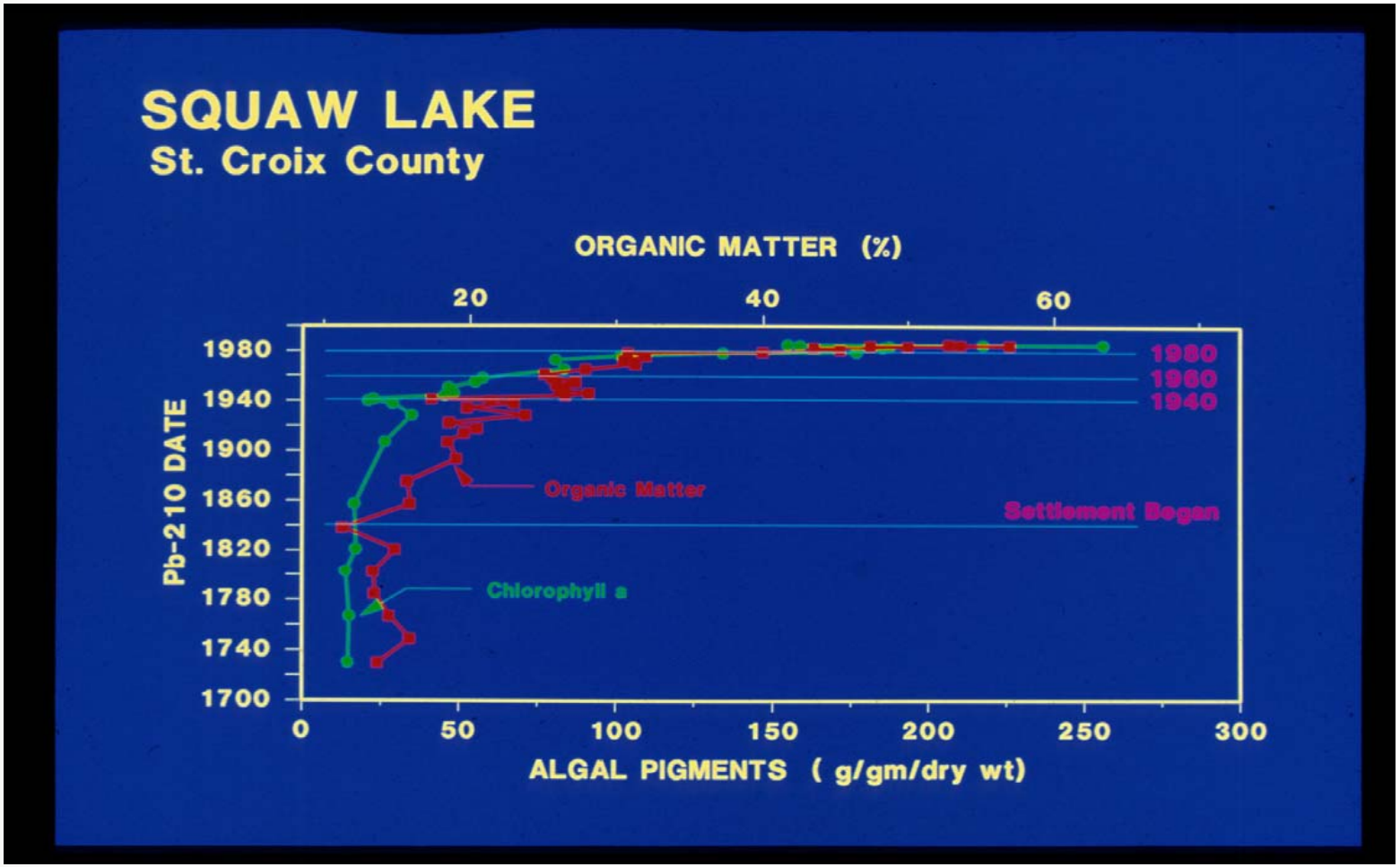
Aquatic Invasive Species

PALEOLIMNOLGY

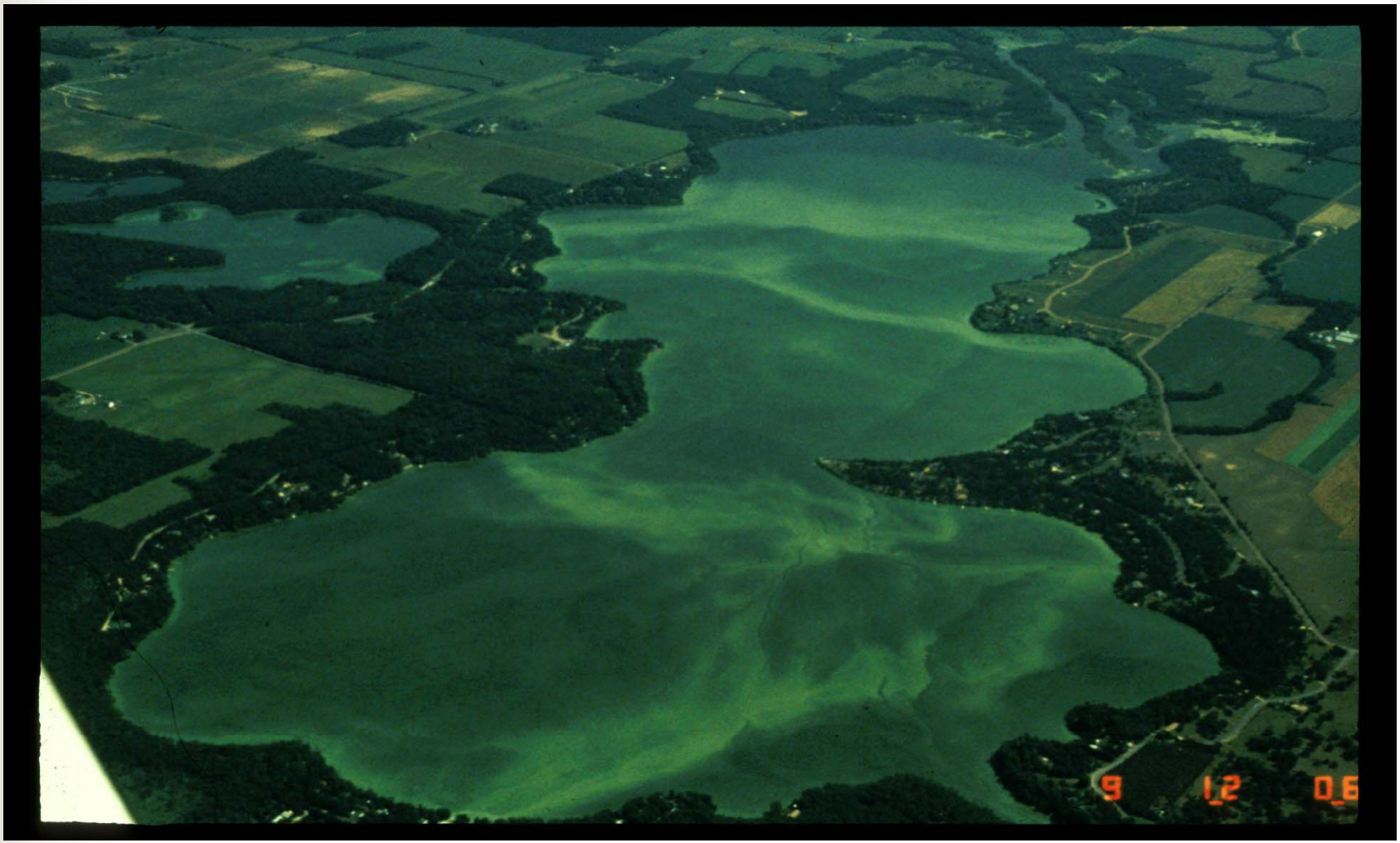




PALEOLIMNOLGY



NUISANCE ALGAE BLOOMS

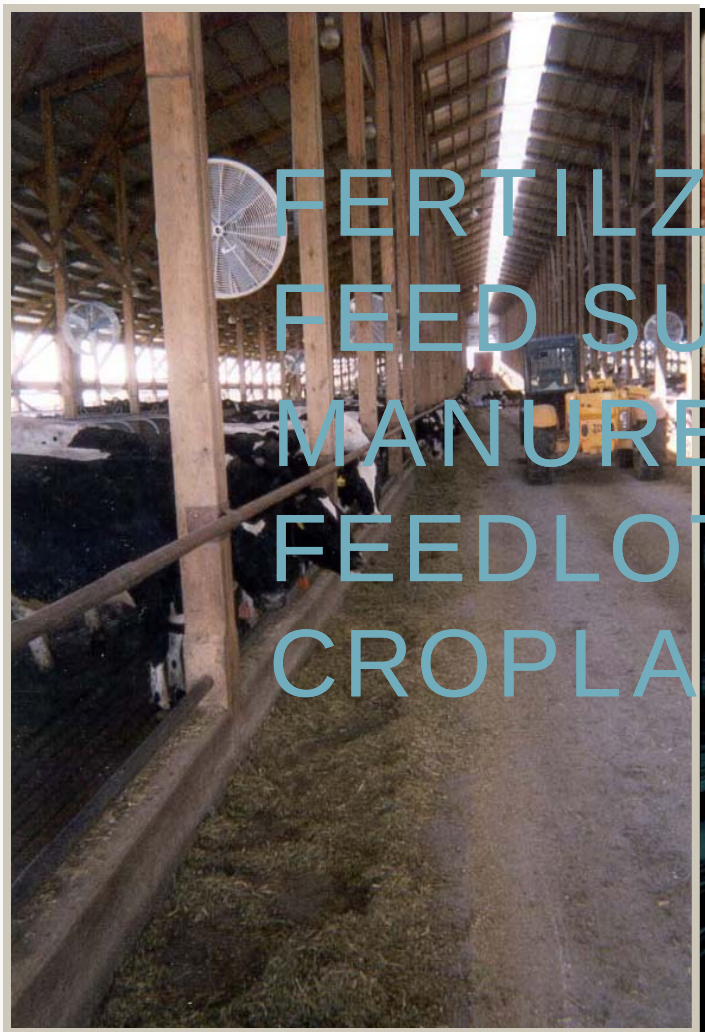


FISHERIES DEGRADATION

LAND USE AND WATERSHED IMPACTS

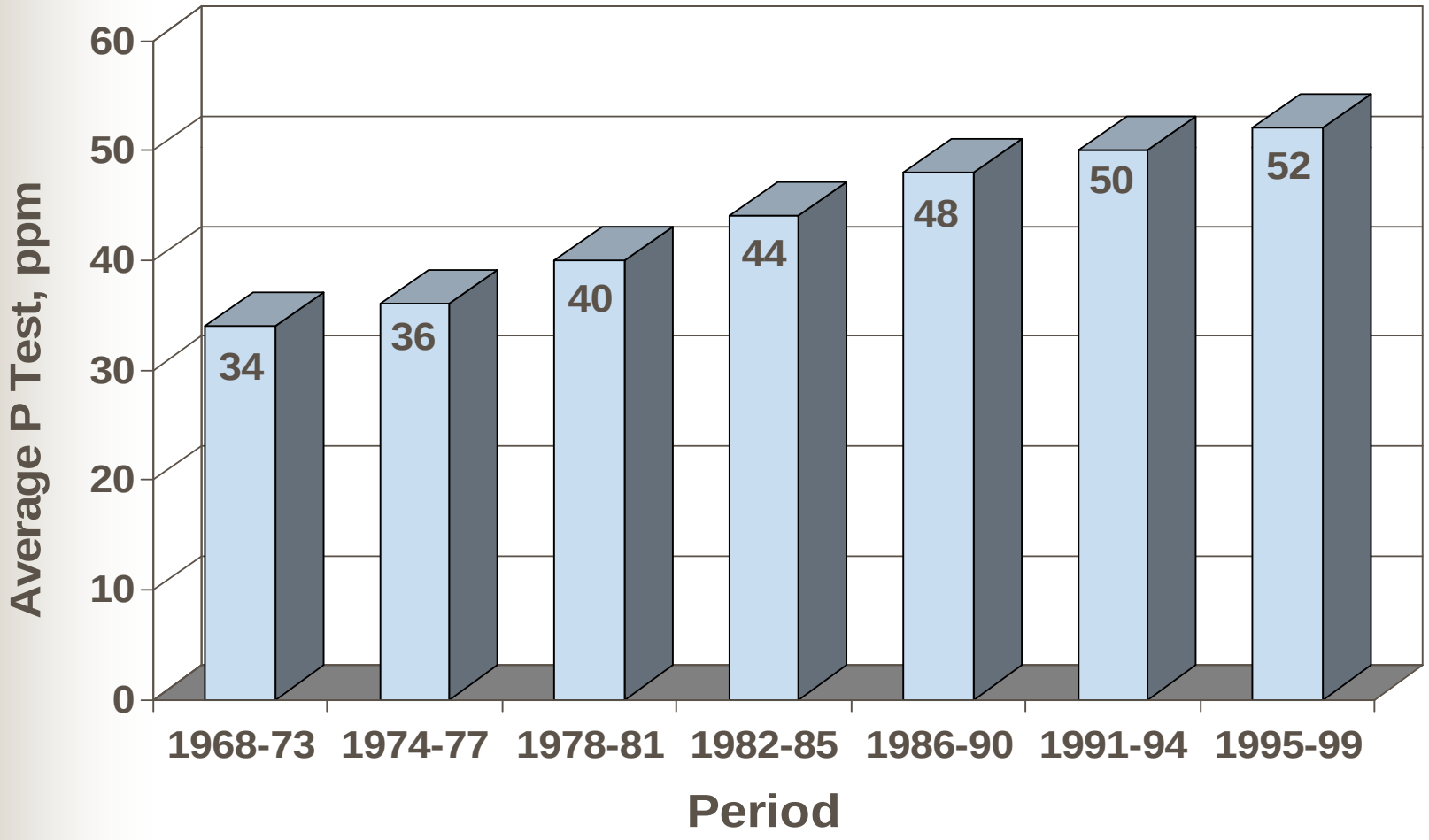
General-development lake type

AG PHOSPHORUS SOURCES



FERTILZER
FEED SUPPLEMENTS
MANURE RUNOFF
FEEDLOT RUNOFF
CROPLAND RUNOFF

Average Soil Test P in Wisconsin



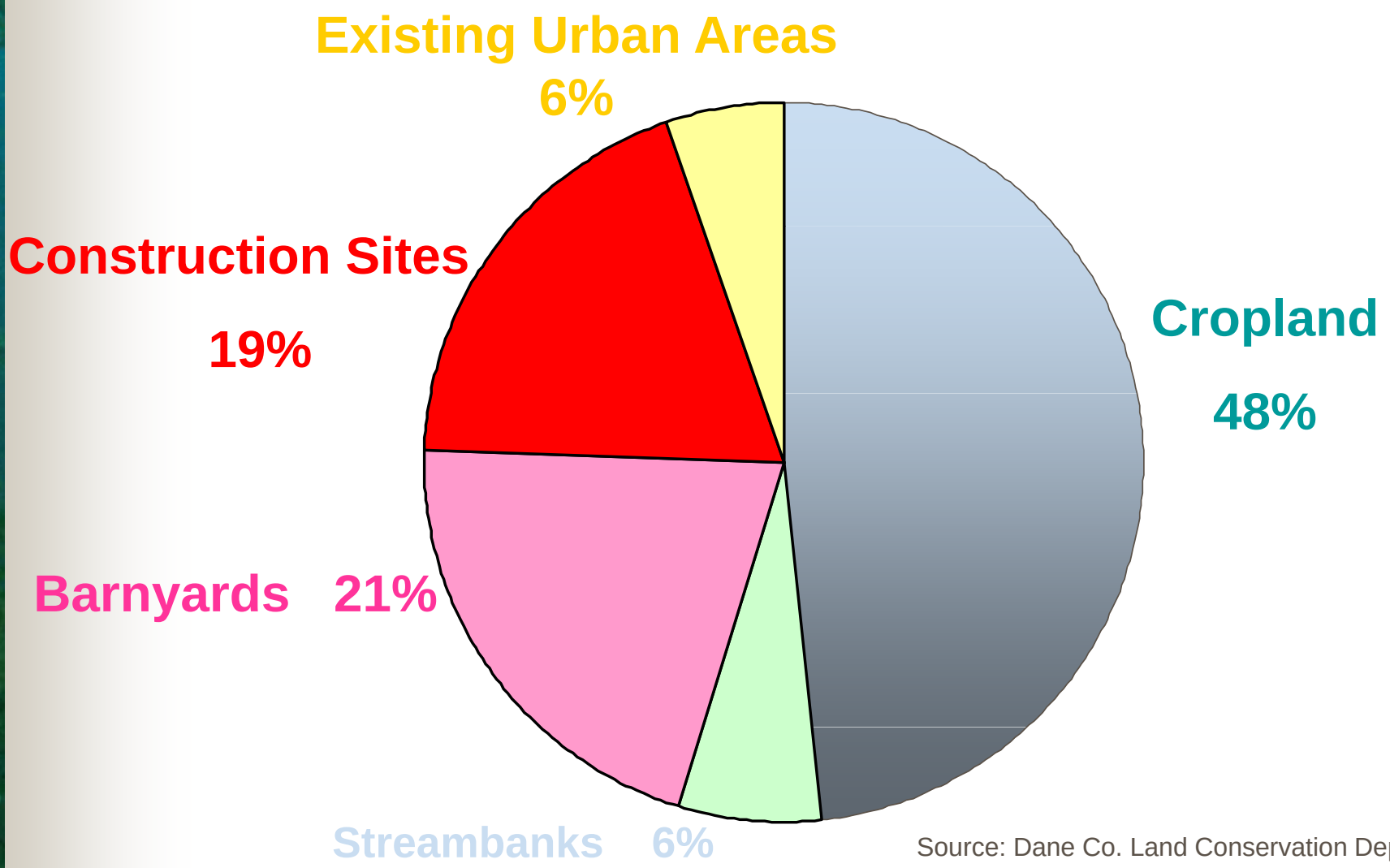
Empirical Watershed Models

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

P Loading Sources to Lake Mendota



Source: Dane Co. Land Conservation Dept.

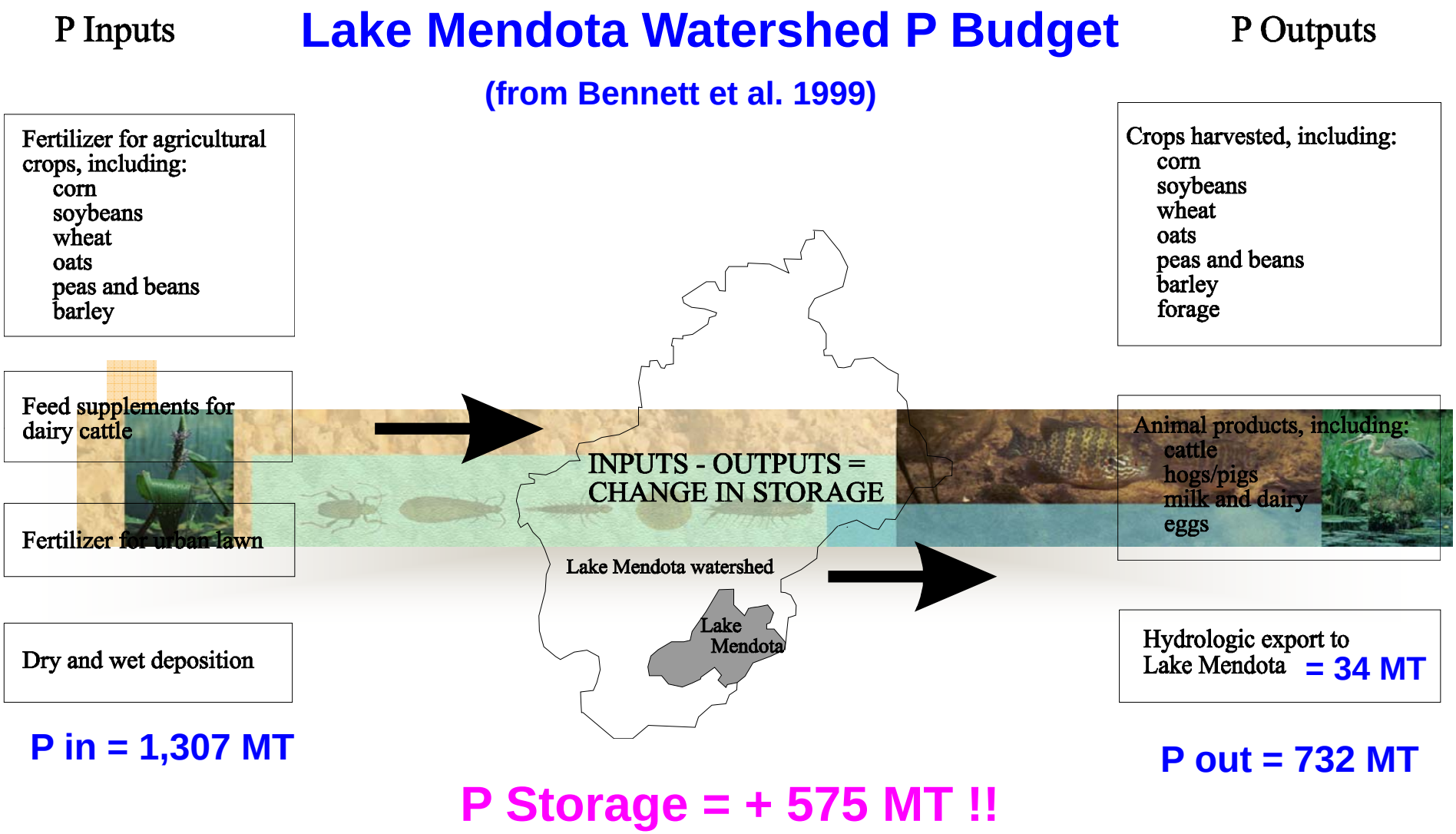
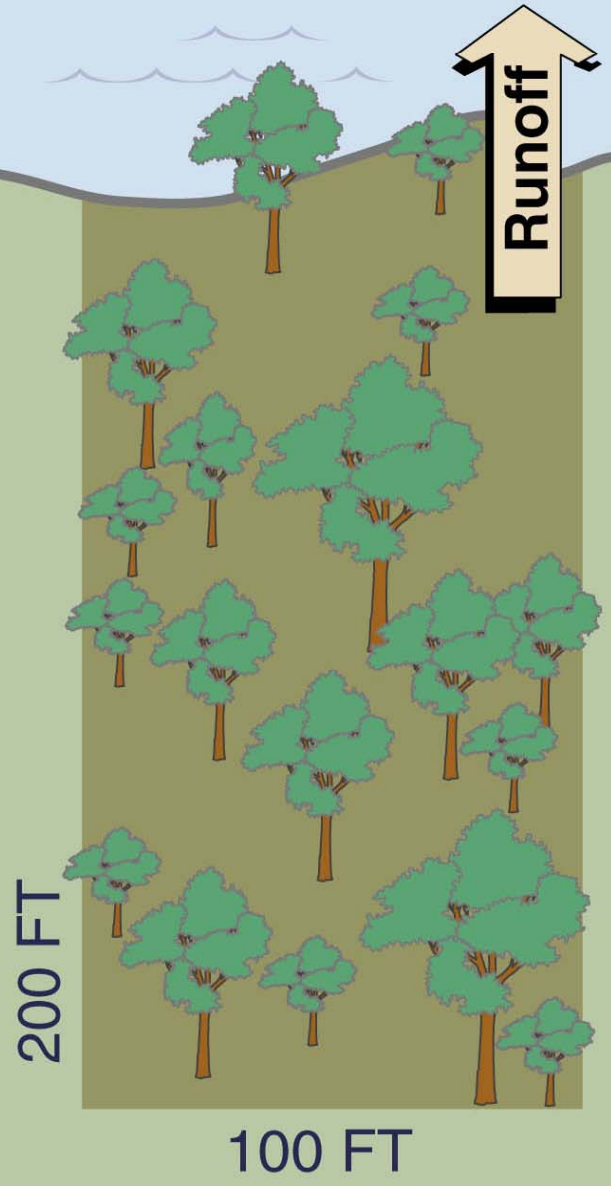


Figure 1. Schematic diagram of inputs and outputs used to calculate a P budget for the Lake Mendota watershed for 1995.

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

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

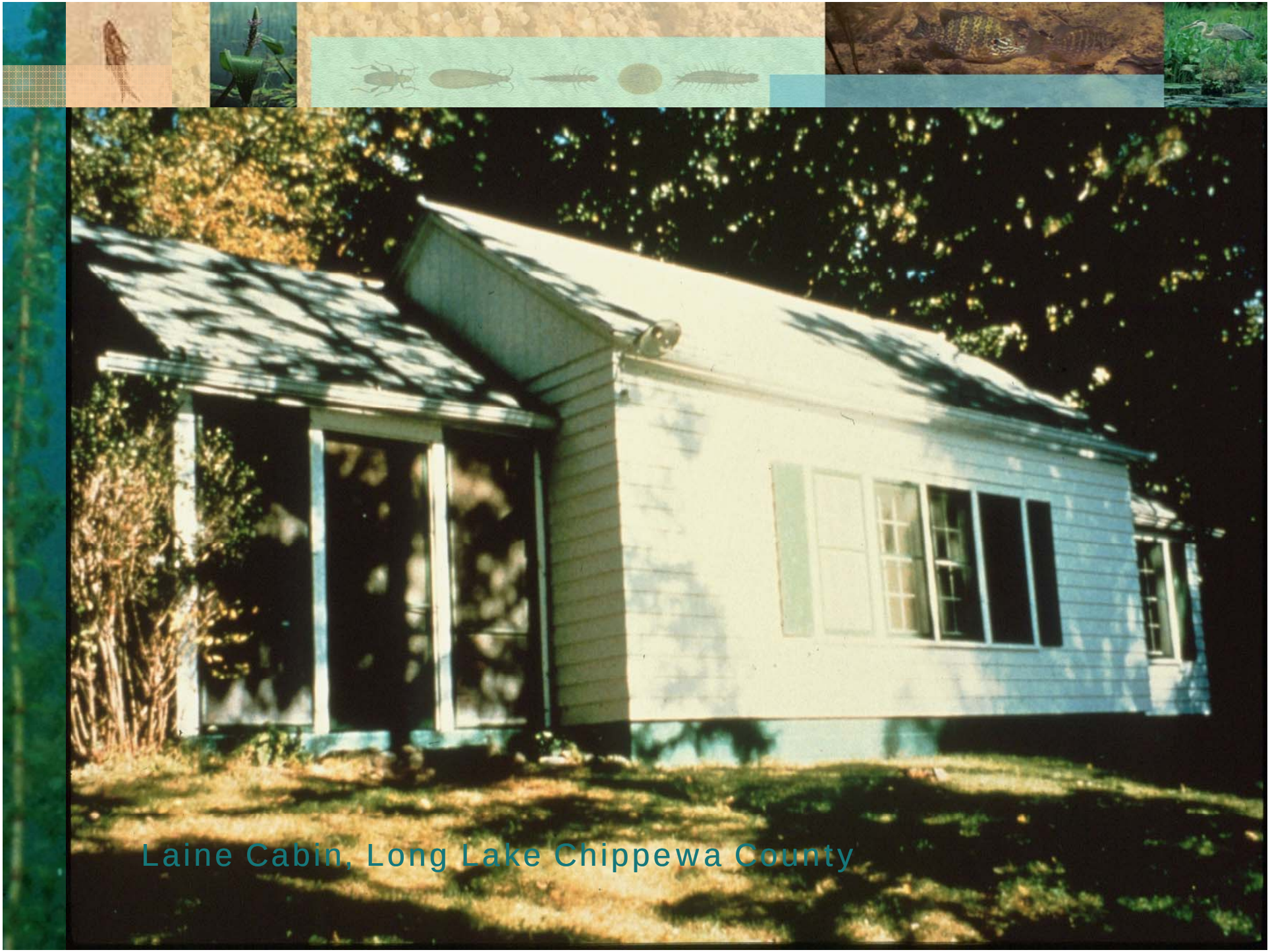


IMPACT ON LAKE
(April - Oct.)

- 1,000 ft^3 runoff to lake
- 0.03 lbs. phos. to lake
- 5 lbs. sediment to lake

Source: Wisconsin Dept. of Natural Resources

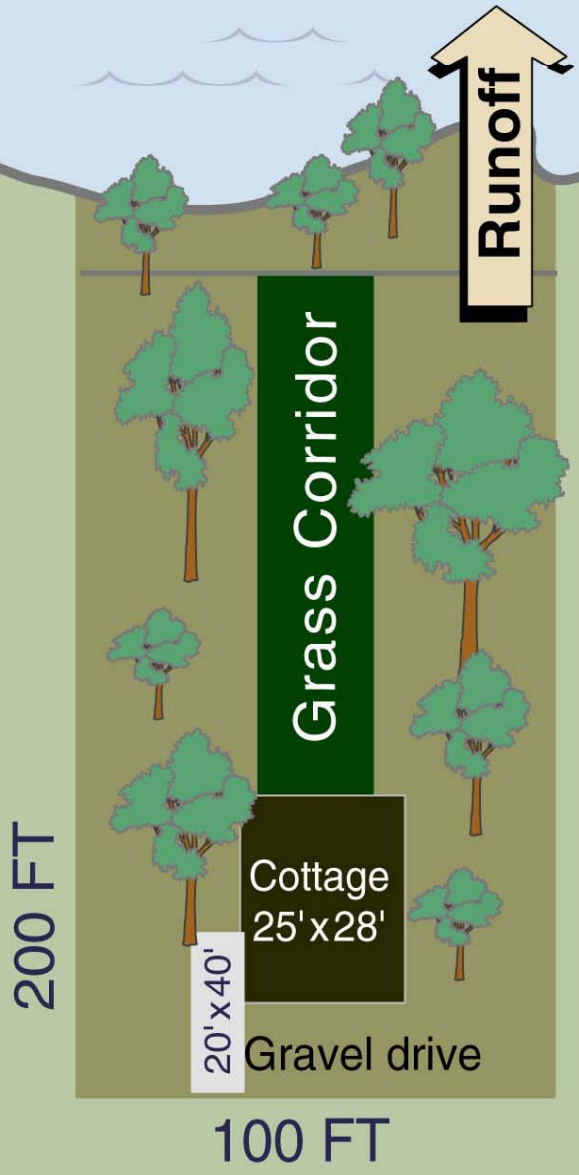
The Wisconsin Lakes Partnership



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^2 perimeter
- gravel drive 800 ft^2
- 35'-wide buffer strip



IMPACT ON LAKE
(April - Oct.)

- 1,000 ft^3 runoff to lake
- 0.03 lbs. phos. to lake
- 20 lbs. sediment to lake

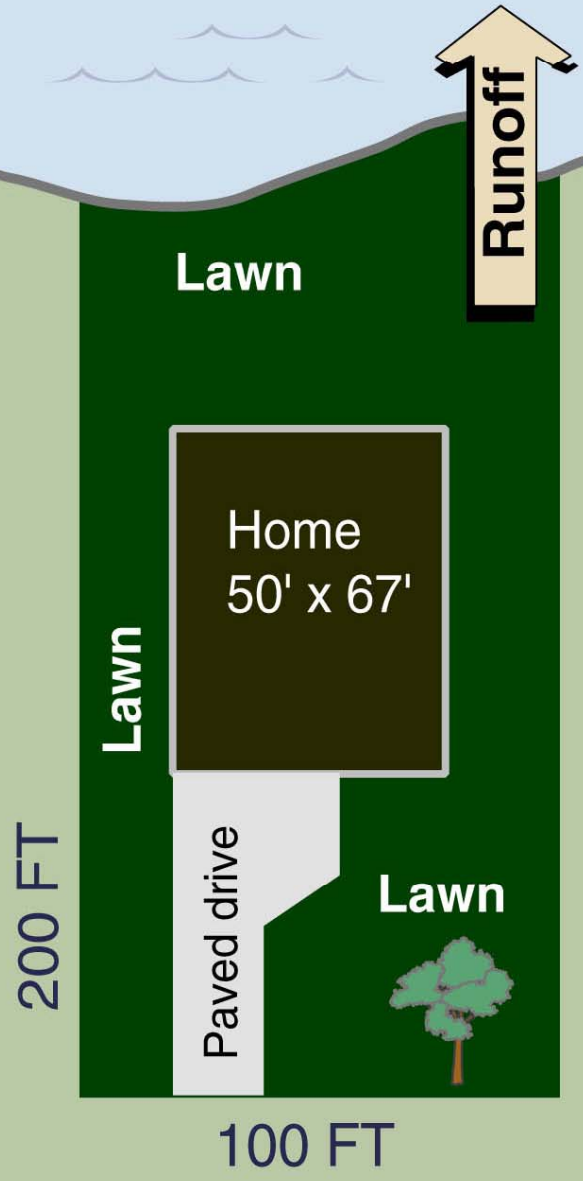
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership


Redevelopment Long Lake Chippewa County
4 26 '24

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

- maintained lawn, soil graded
- 6% slope to lake
- home 3,350 ft²
  perimeter
- paved drive 770 ft²



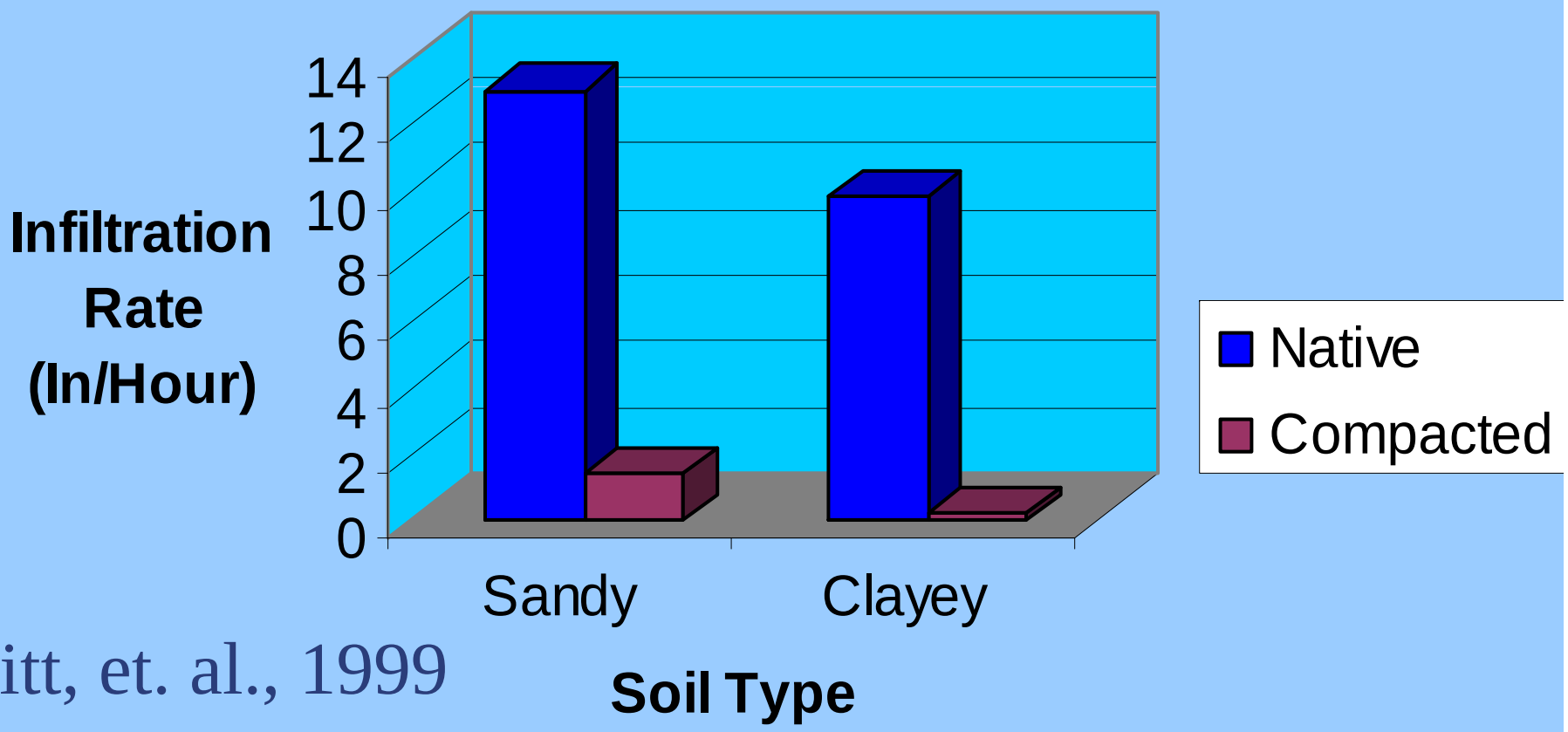
IMPACT ON LAKE
(April - Oct.)

- 5,000 ft³ runoff to lake
- 0.20 lbs. phos. to lake
- 90 lbs. sediment to lake

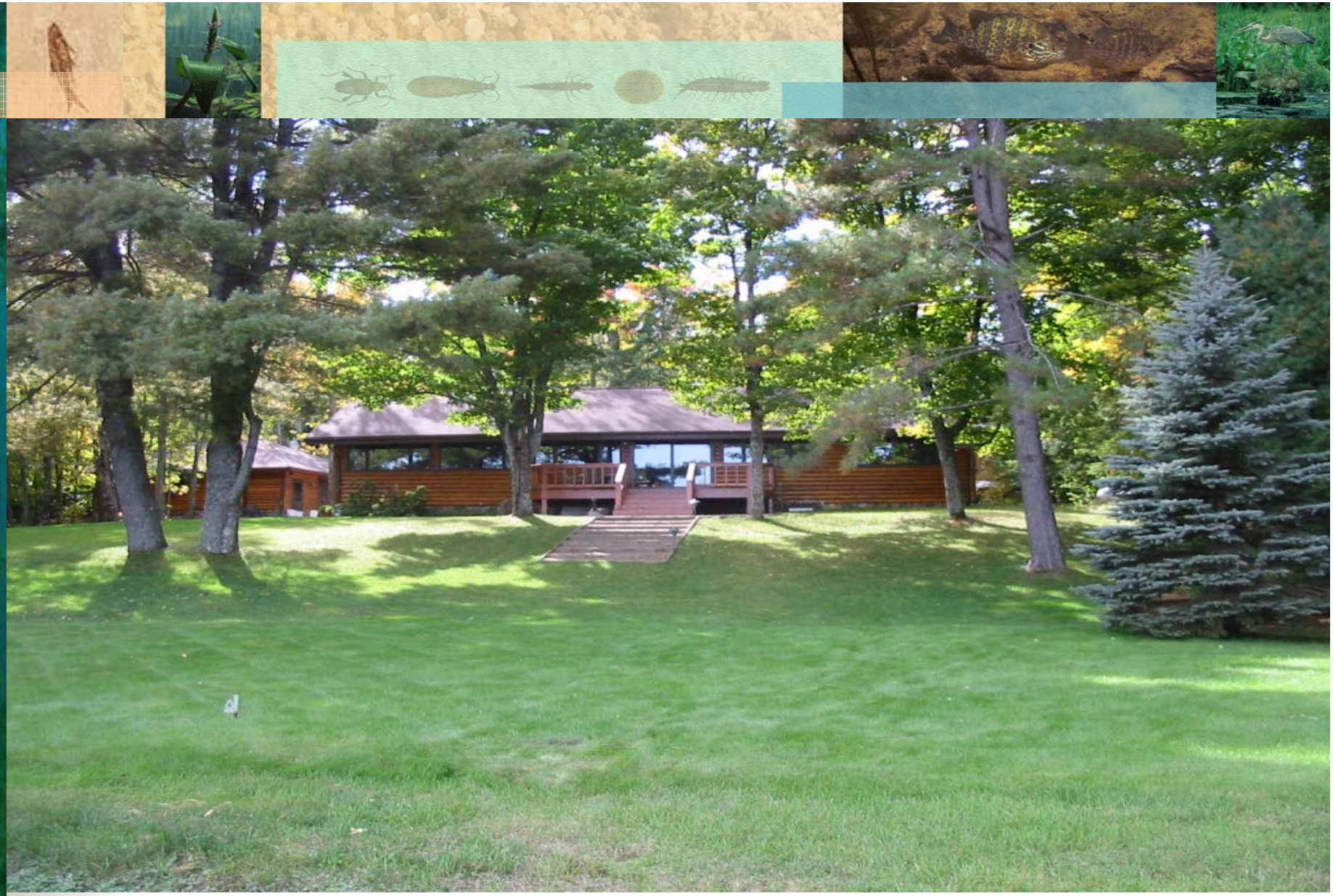
Source: Wisconsin Dept. of Natural Resources

The Wisconsin Lakes Partnership

Effect of Compaction on Infiltration Rate



Pitt, et. al., 1999



Pfefferkorn Residence, Butternut Lake

Comparison of Median Nutrient Yields with Past Studies (kg/ha/yr)

Citation	Landuse	TKN	T-P
King et.al.(2001)	Stream draining turf		0.33
Dennis (1996)	Residential		1.75
Rechow et.al.(1980)		5.5	1.1
Panuska,Lillie (1995)	Urban		0.52
Thomann (1987)	Urban	5.0	1.0
Panuska, WiLMS	Rural Res.		0.1
Rechhow et.al.(1980)	Residential	2.46	0.2
Barten (2001)	Lawn		
Our Study	**Lawn**	**0.16**	**0.025**

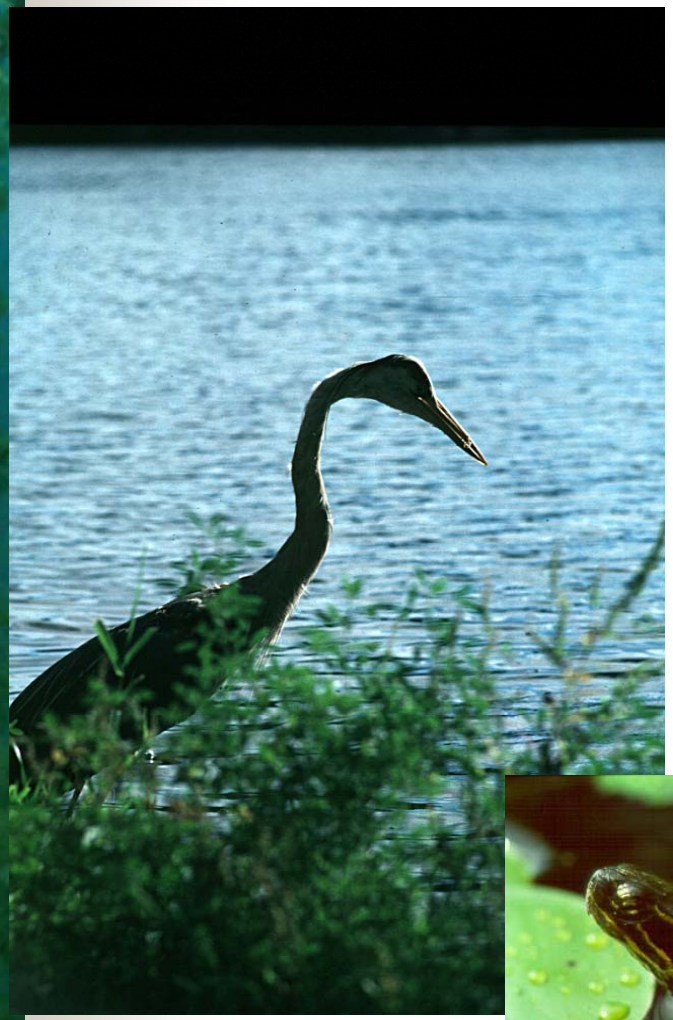
Panuska,Lillie (1995)	Forest		0.09
Thomann (1987)	Forest	3.0	0.4
Dennis (1996)	Forest		0.19
Panuska (WiLMS)	Forest		0.08
Our Study	**Forest**	**0.015**	**0.003**

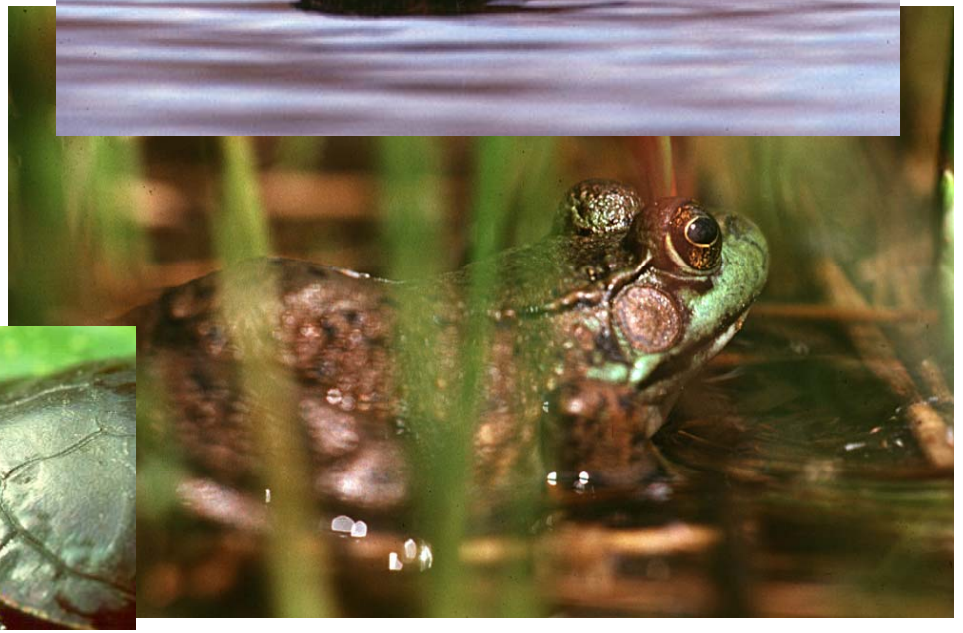
Wisconsin Department of Natural Resources

Stewardship of Shoreline Habitat

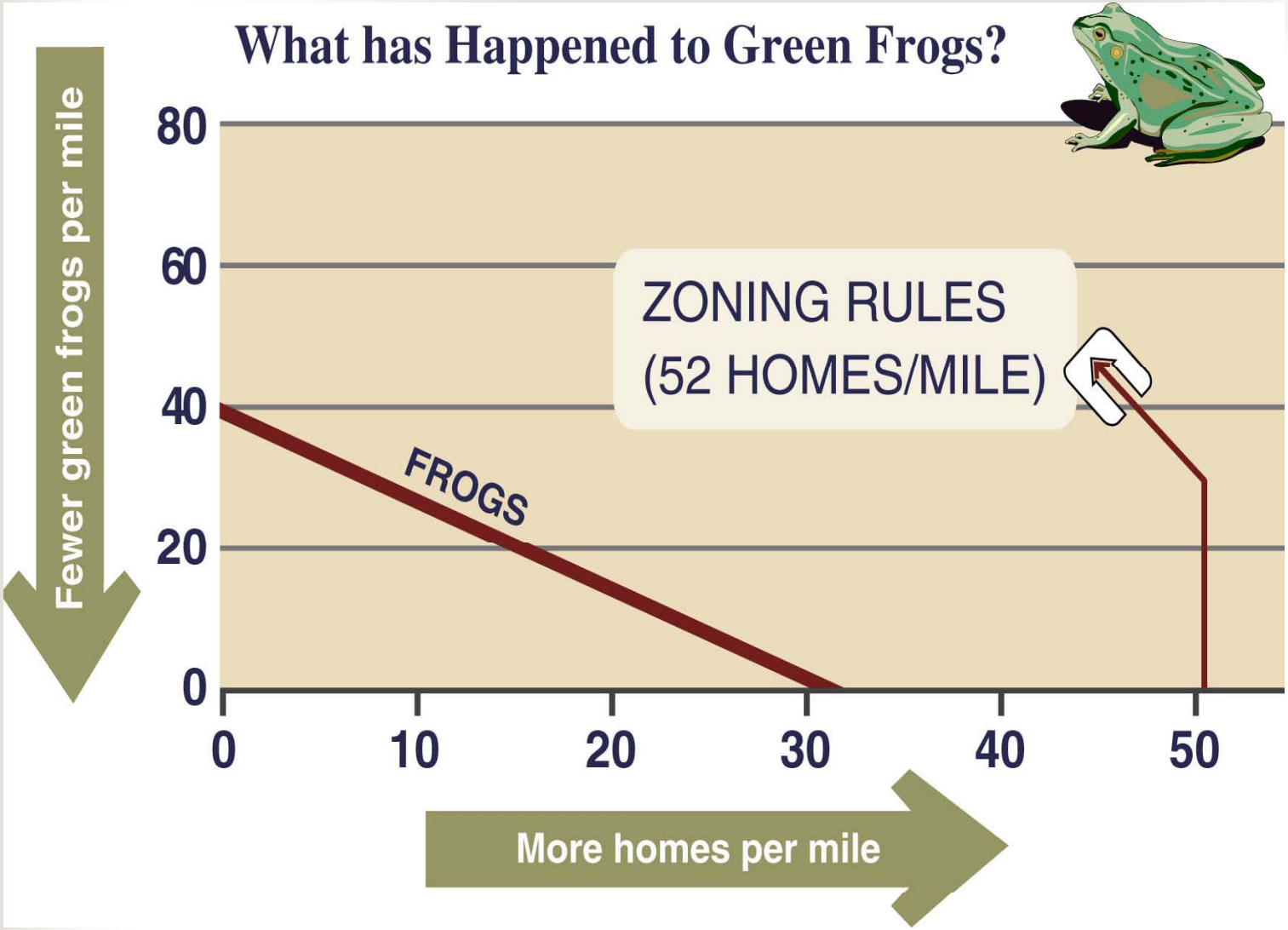
Photo: Michele Woodford

Without habitat, they are gone





Shoreland green frog trends

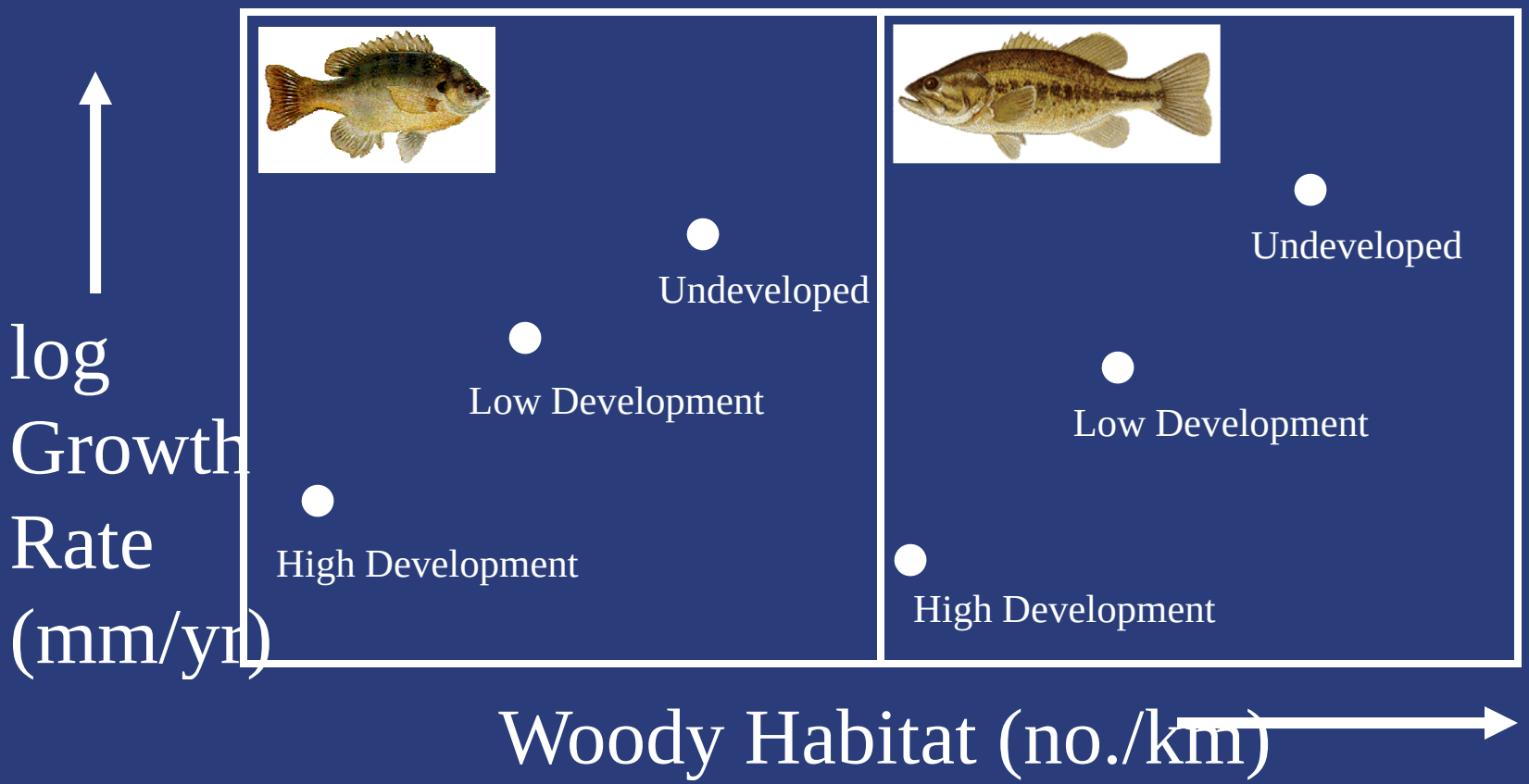


Source: Wisconsin Dept. of Natural Resources

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

Elements of a Lake Management Plan

- Resource Assessment and Trends
  - Water Quality
  - Habitat (Aquatic plants and nearshore habitats)
  - Fisheries
- Watershed Assessment
- A summary of the historical lake information
- Establish community values for the lake
- Develop lake goals
- Management strategy and actions to achieve
- Monitoring plan to evaluate success.
- Implementation Strategies
- Annual Evaluations

Long Lake Management Plan 2006

Planning Team
LLLPRD, TW OF SAMPSON
CHIPPEWA COUNTY AND WDNR

- Long Lake, Chippewa County

LLLPRD SURVEY RESULTS 2005

PEACE AND TRANQUILITY
GOOD WATER QUALITY
FAMILY TRADITION
PROXIMITY TO HOME

79 of 170 Returned

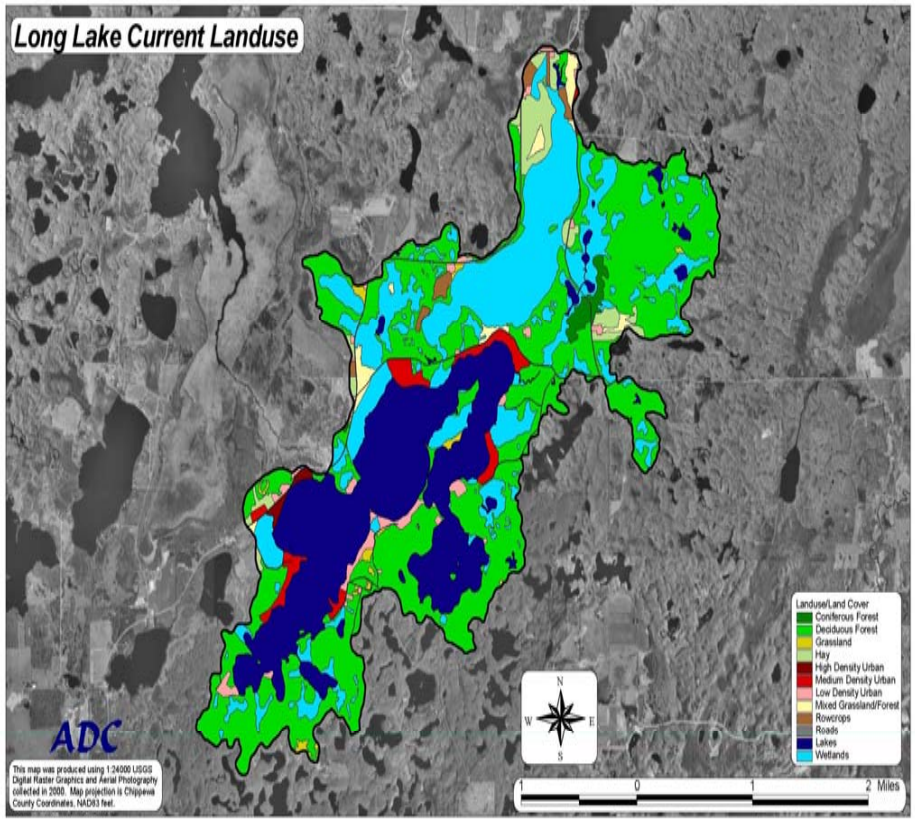
- Long Lake, Chippewa County

RESOURCE ASSESSMENT USING COLLABORATIVE DATA BASE ASSESSMENT

DATA ANALYSIS, RESOURCE AND WATERSHED MONITORING AND MODELING

DRAINAGE BASIN/ LAKE AREA RATIO

- **Long Lake Watershed**
- **Ratio is 3.5:1**



Landuse Nutrient Loads 2006

Landuse	Acres	Kg/Year	Lbs/Year
High Density Urban	17.3	11	24.3
Medium Density Urban	125.7	25	55.1
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
Total		323.25	712.7

RESOURCE GOAL SETTING

FRAME LAKE GOALS IN THE CONTEXT OF SOCIEATAL RESOURCE VALUES AND ECOLOGICAL VALUES

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.**

OBJECTIVE STATEMENTS

- Conduct 2 year pilot project for up to 30 riparian properties which will control stormwater runoff and restore natural shoreland buffers. These restorations will serve as demonstrations at multiple sites around the lake. 2007 and 2008. Lake District, Chippewa County, WDNR.
- Apply for lake management planning grant in January 2007 to fund staffing to conduct inventory, planning and design for stormwater runoff and shoreland restorations. 2007. Lake District, Chippewa County.
- Apply for lake protection grant in April 2007 to implement up to 30 stormwater plans and shoreland restorations. 2007. Lake District and Chippewa County.
- Apply for lake management planning grant July 2008 to conduct community based social marketing assessment. This assessment will be used to determine the most effective strategies to obtain 60 – 80 percent participation of riparian property owners for installing stormwater management practices and shoreland buffer restorations. 2008 Lake District.

IMPLEMENTATION PLAN

- **WHO WILL PROVIDE OVERSIGHT**
- **FREQUENCY OF REVIEW**
- **DEFINE RESPONSIBILTY FOR IMPLMENTATION**

Cooperative Agreement for the Restoration and Improvement of Lake Tomah

This cooperative agreement between the City of Tomah, Monroe County Land Conservation Department and the State of Wisconsin Department of Natural Resources will govern the implementation of management actions identified in the Lake Tomah Management Plan July 2008. The community of Tomah through the City Council and the Lake Committee (community members appointed by the mayor and approved by City Council) working in partnership with community residents, the Monroe County Land Conservation Department staff and staff from the Wisconsin Department of Natural Resources have completed an Lake Tomah Revitalization Plan. This plan outlines a framework of lake stewardship activities which will provide improved motorized and non-motorized recreational activities, fishery, fish and aquatic life habitats and water clarity. This lake plan includes clearly defined goals and activities which will be the road map to improve the attributes of Lake Tomah which are valued by the residents of the community.

The cooperators agree to commit to implement the restoration activities identified in the Lake Tomah Restoration Plan. The City of Tomah, Monroe County Land Conservation Department and Wisconsin Department of Natural Resources commit to work together to implement the objectives identified in the plan by providing volunteer time, staff time and financial resources as described in the plan to achieve the goals identified in the plan. The achievement of the goals will improve the quality of the recreational experiences for all who enjoy the recreational opportunities provided by Lake Tomah.

Cooperators:

City Of Tomah

Date:_____

Mayor: _____

Wisconsin Department of Natural Resources

For the Secretary:

Water Leader: _____ Date:_____

Monroe County Department of Land Conservation

Land Conservationist:_____ Date:_____

IMPLEMENTATION PLAN

- **WHO WILL PROVIDE OVERSIGHT**
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IMPLEMENTATION PLAN

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LEAVING A LEGACY

Help Protect Wisconsin's…

WATER RESOURCES.