Reservoir Habitat Restoration Best Management Practices – Nutrient Control

RFHP Annual Meeting, BMP Workshop

October 6, 2018

Reed Green

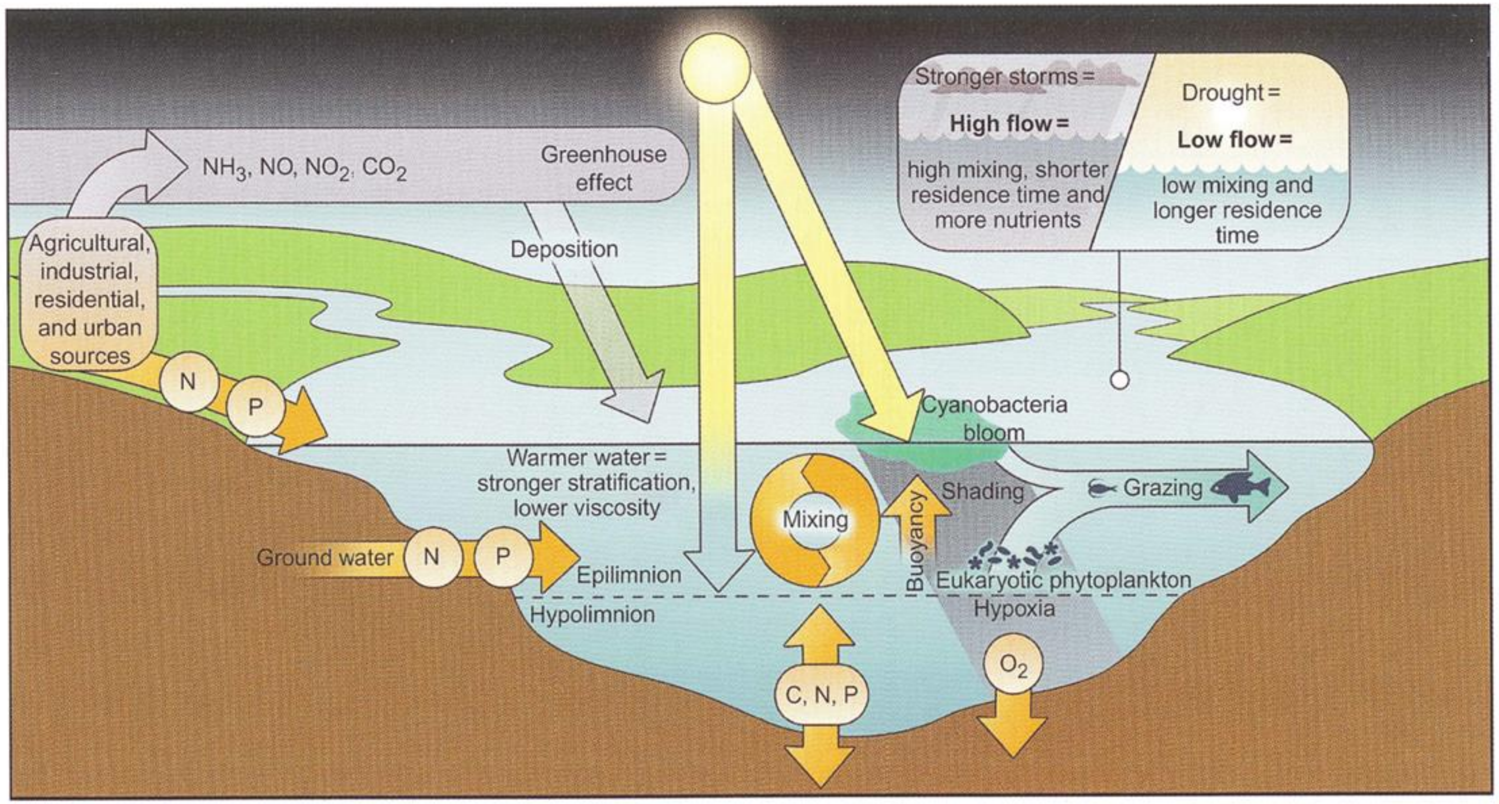

FIGURE 2 Conceptual diagram illustrating external and internal factors controlling growth, accumulation (as blooms), and fate of cHABs in freshwater ecosystems. Factors can act individually or in combined (synergistic, antagonistic) ways.

Wehr, and others, 2015, Freshwater Algae of North America, Chapter 20, figure 2

Commonly known……

Global phosphorus retention by river damming

Taylor Maavara[a,b,1], Christopher T. Parsons[a,b], Christine Ridenour[a,b], Severin Stojanovic[a,b], Hans H. Dürr[a,b], Helen R. Powley[a,b], and Philippe Van Cappellen[a,b]

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ECOLOGY LETTERS

Ecology Letters, (2016)

doi: 10.1111/ele.12658

LETTER

Phosphorus accumulates faster than nitrogen globally in freshwater ecosystems under anthropogenic impacts

Yan, et al.

More recently……

Chesapeake Bay Program
Science. Restoration. Partnership.

IN THE NEWS > RECENT NEWS > WHO IS RESPONSIBLE FOR THE CONOWINGO DAM?

Who is responsible for the Conowingo Dam?

Constructed – 1928

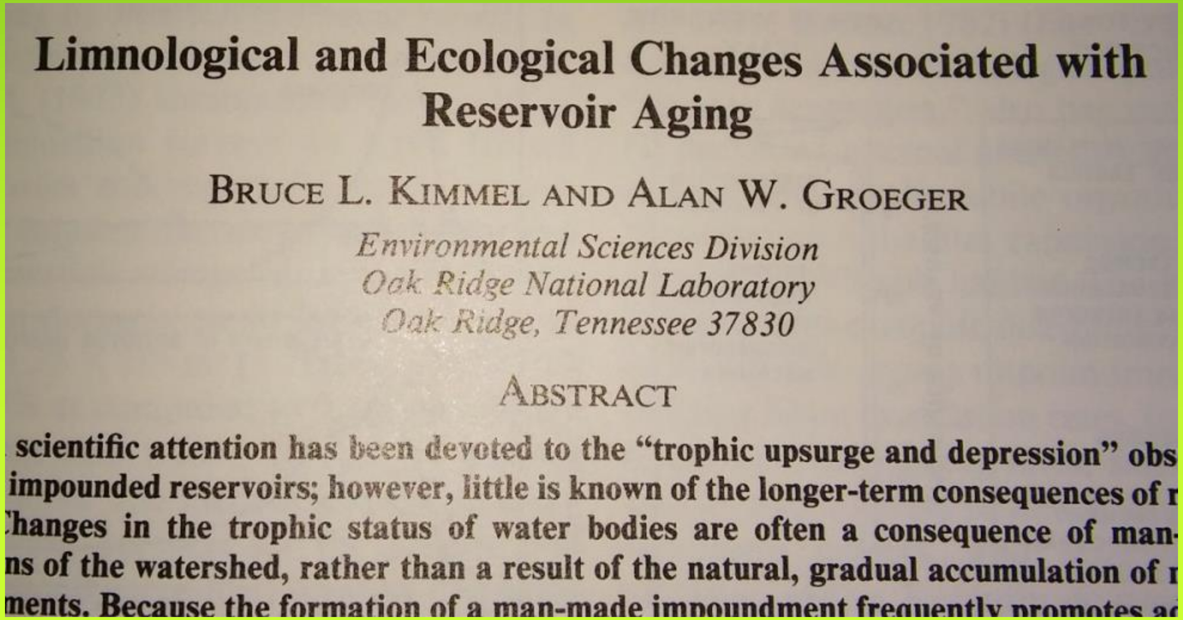
Provides 50% of the freshwater to the Chesapeake Bay.

Traps ~ 3.5 million pounds of P and 4 billion pounds of sediment, per year.

Storage capacity has reached equilibrium.

Source: https://www.chesapeakebay.net/news/blog (4/9/2018)

Reservoir Fisheries Management (1986) brought us, *Limnological and Ecological Changes Associated with Reservoir Aging*



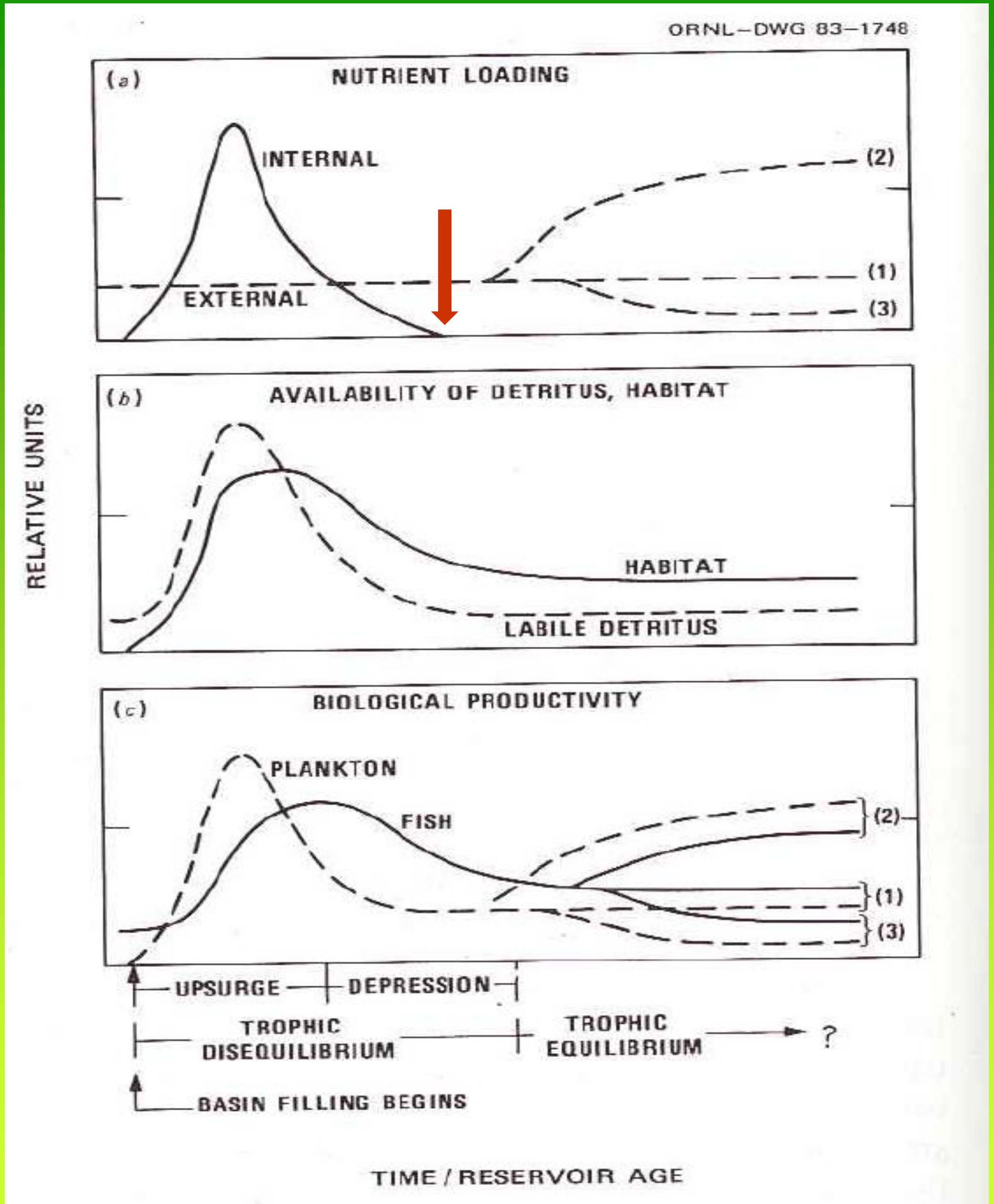
Limnological and Ecological Changes Associated with Reservoir Aging

BRUCE L. KIMMEL AND ALAN W. GROEGER

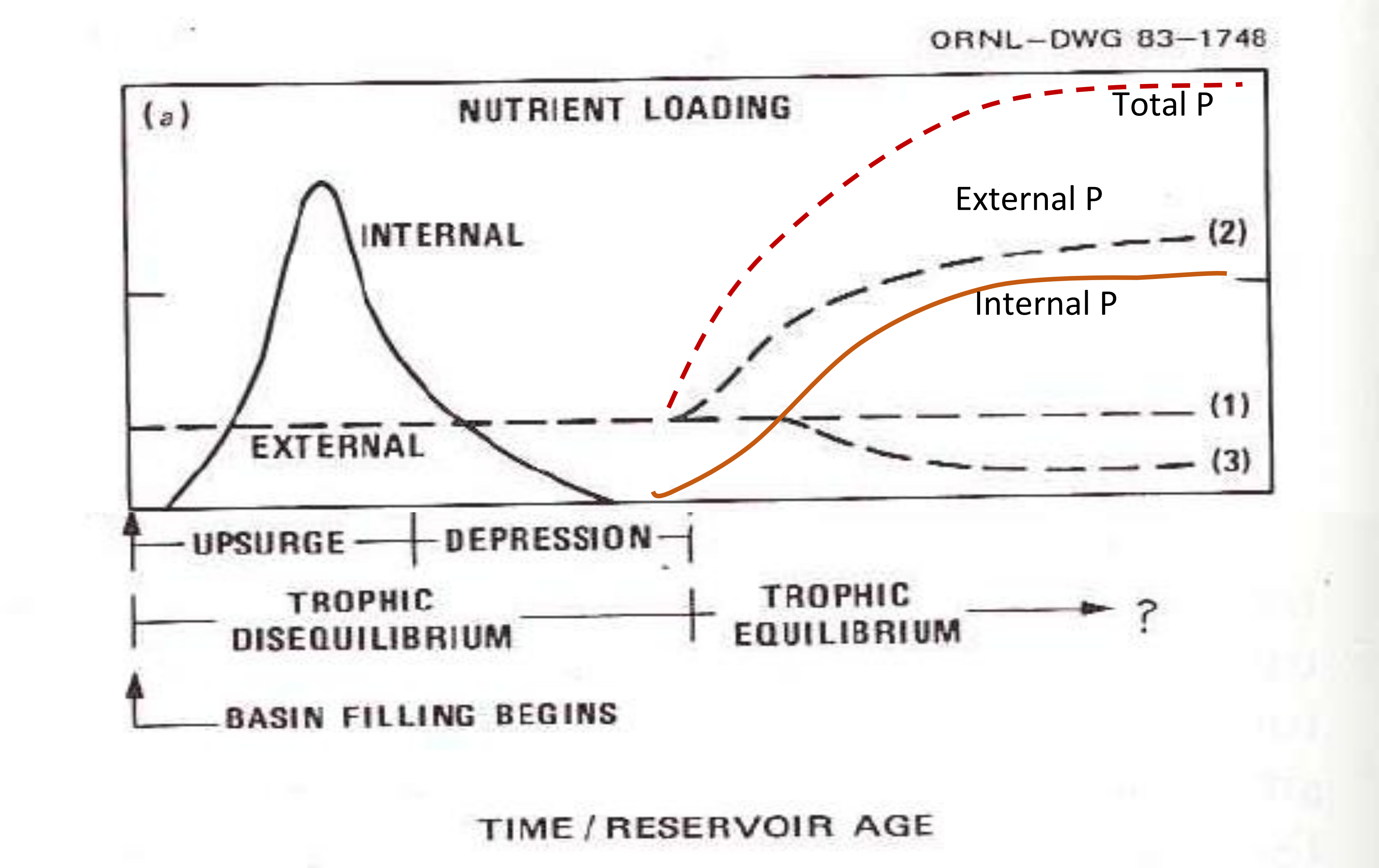
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37830

ABSTRACT

scientific attention has been devoted to the “trophic upsurge and depression” obs
impounded reservoirs; however, little is known of the longer-term consequences of r
hanges in the trophic status of water bodies are often a consequence of man-
ns of the watershed, rather than a result of the natural, gradual accumulation of r
ments. Because the formation of a man-made impoundment frequently promotes ac



Source: https://fisheries.org/bookstore/all-titles/afs-unit-publications/x53012xm/



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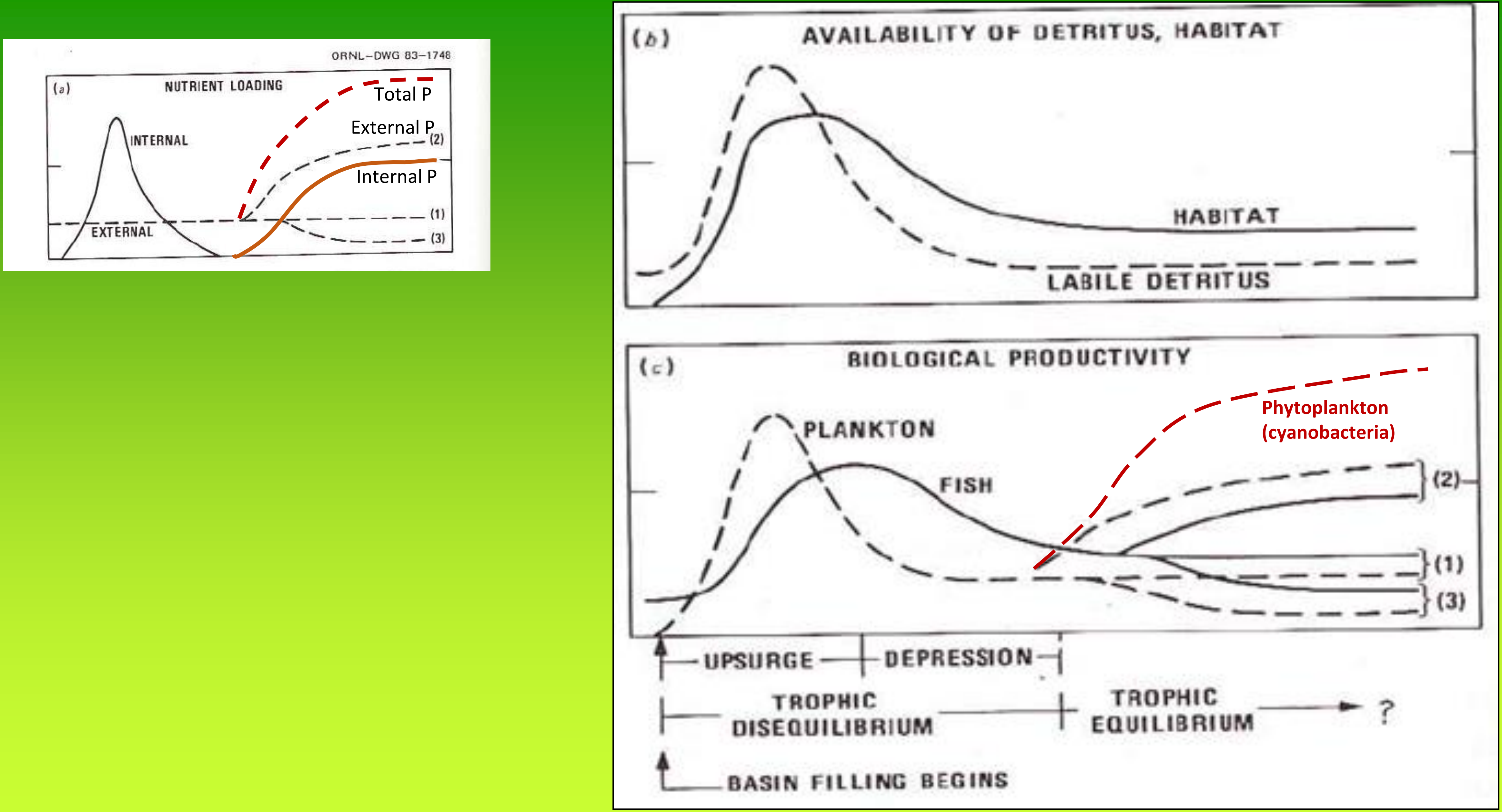

ORNL–DWG 83–1748
(a)
NUTRIENT LOADING
INTERNAL
EXTERNAL
Total P
External P
Internal P
(2)
(1)
(3)
(b)
AVAILABILITY OF DETRITUS, HABITAT
HABITAT
LABILE DETRITUS
(c)
BIOLOGICAL PRODUCTIVITY
PLANKTON
FISH
Phytoplankton
(cyanobacteria)
(2)
(1)
(3)
UPSURGE
DEPRESSION
TROPHIC DISEQUILIBRIUM
TROPHIC EQUILIBRIUM
?
BASIN FILLING BEGINS

Nutrients

- **Nitrogen**, needed for plant growth and production
  - Major component of chlorophyll, and
  - Amino acids, the building blocks of proteins
- **Phosphorus**, plays a critical role in cell development
  - Key component of molecules that store energy (ATP),
  - DNA, and
  - Lipids (fats and oils)

Nitrogen cycle, Ammonium

AMMONIUM **KINETICS**

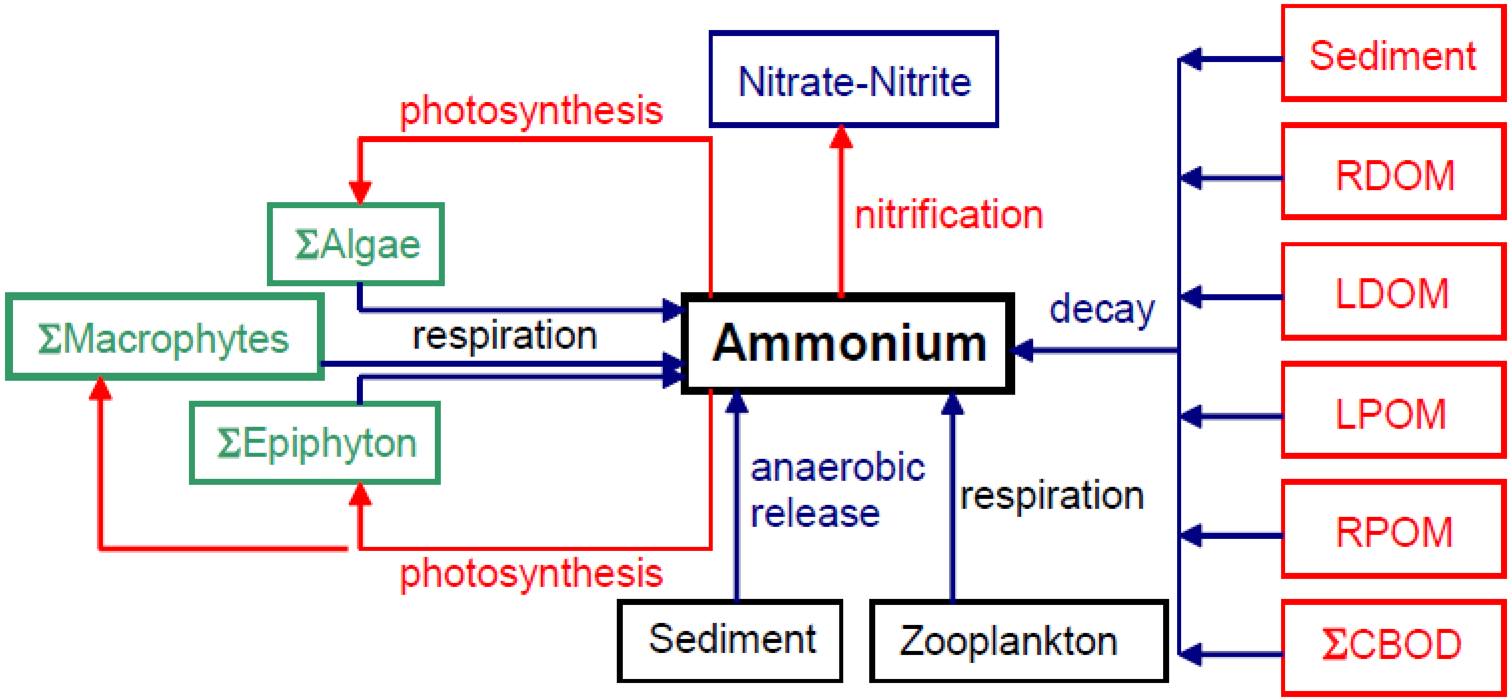


Figure B-18. Internal flux between ammonium and other compartments.

Nitrogen cycle, Ammonium

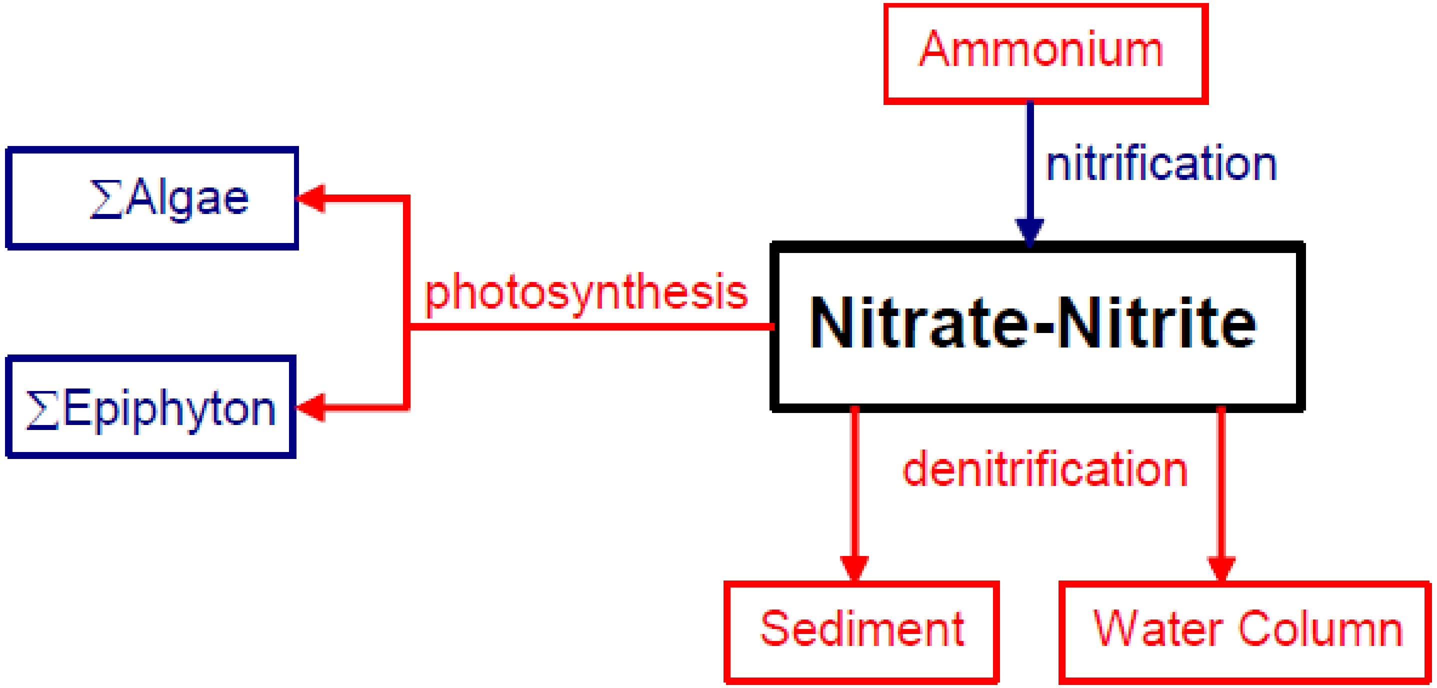


Figure B-19. Internal flux between nitrate + nitrite and other compartments.

Phosphorus cycle

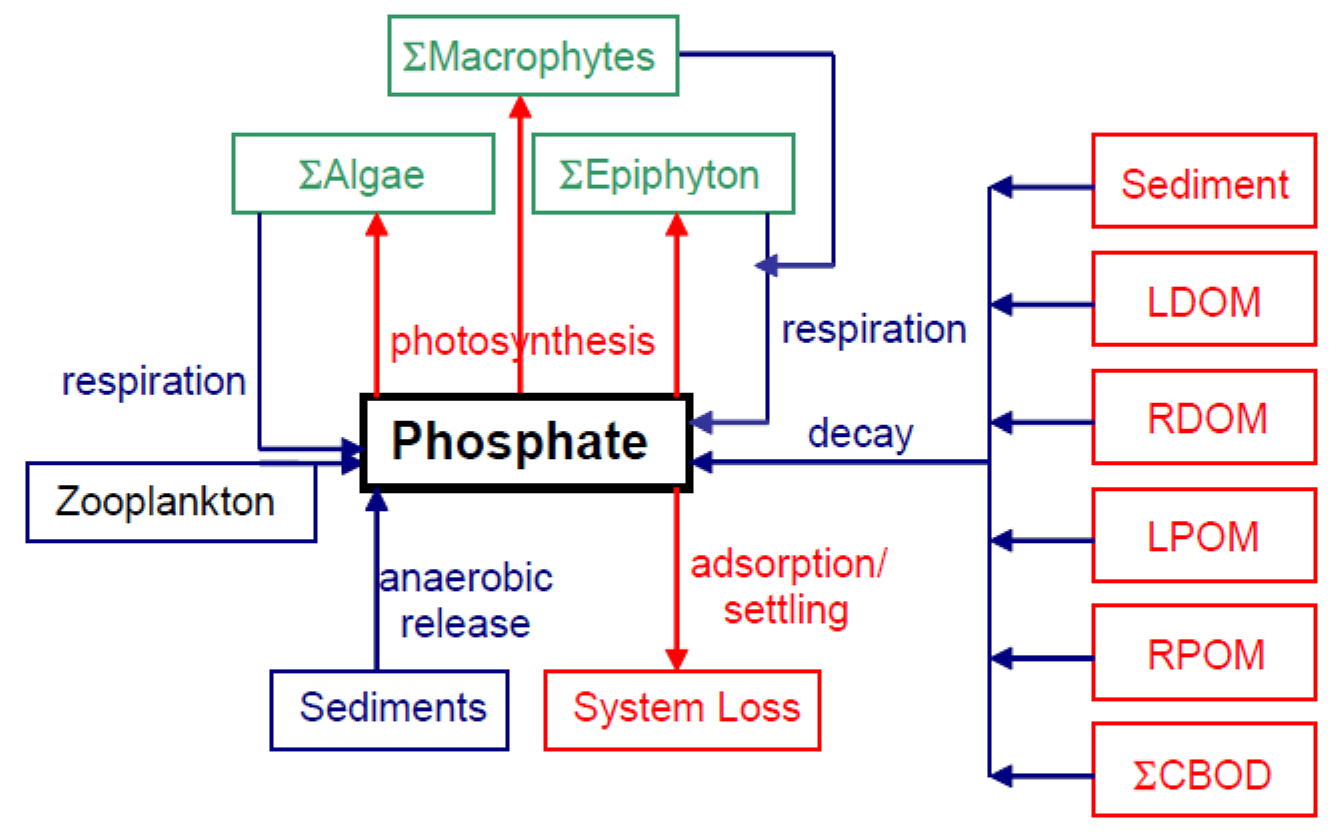
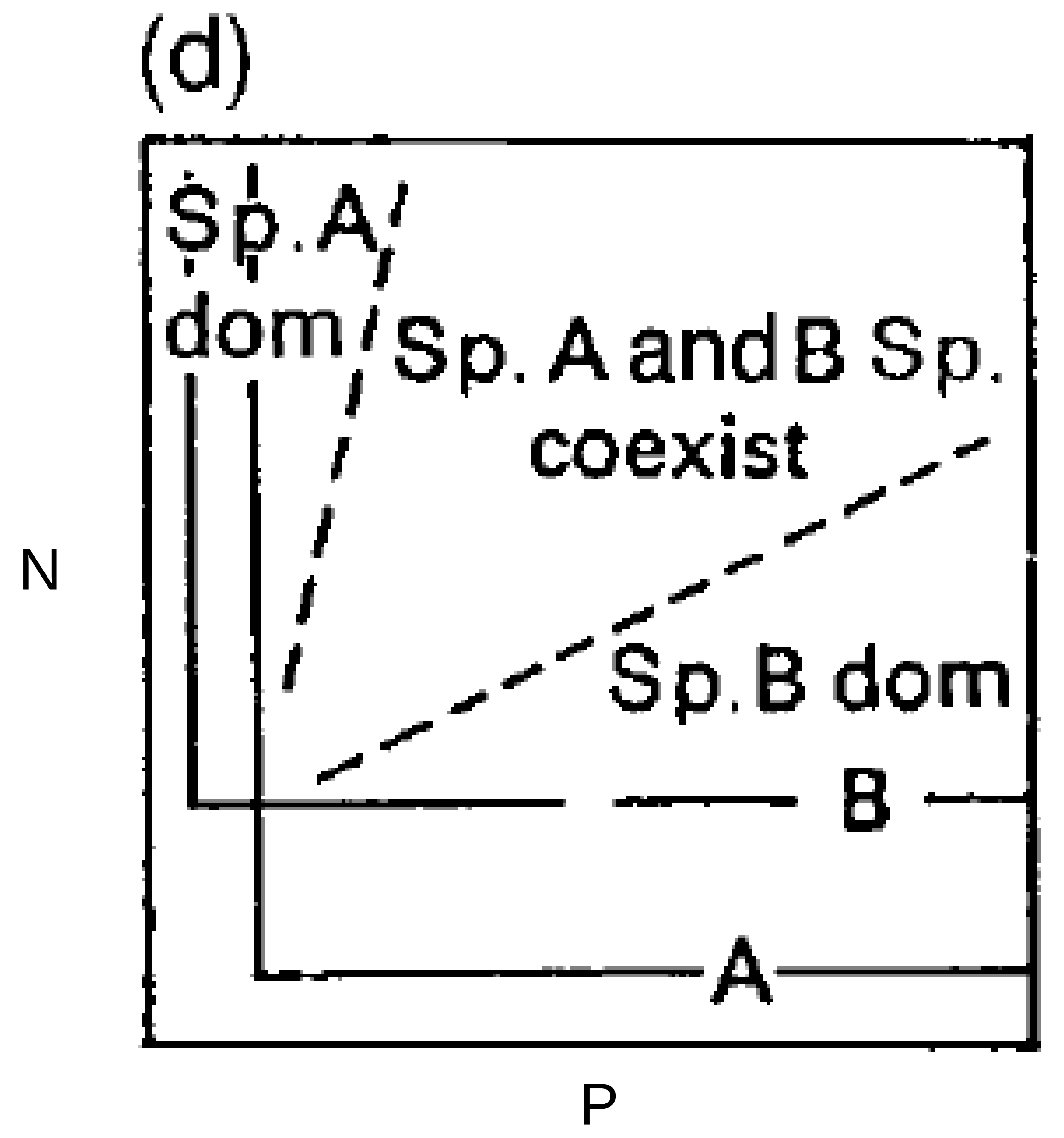


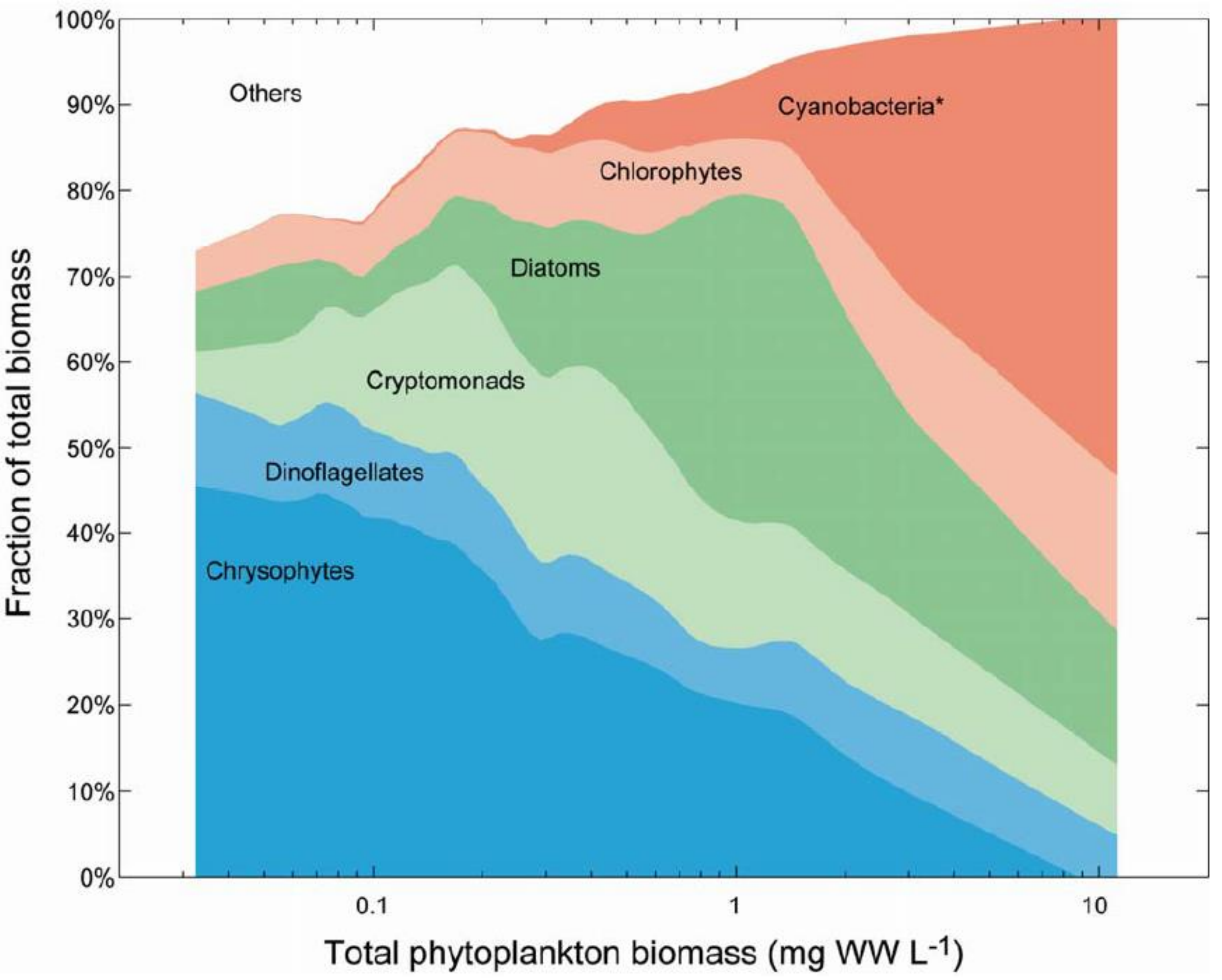
Figure B-17. Internal flux between phosphorus and other compartments.

The limiting nutrient in growth and production



Reynolds. C.S. 2006, *Ecology of Phytoplankton. Cambridge University Press, New York*

Main taxonomic groups as a fraction of total biomass



Brettum P., and Anderson, T. 2005. *The use of phytoplankton as indicators of water quality. Norwegian Inst. for Water Research*. 33 pp.

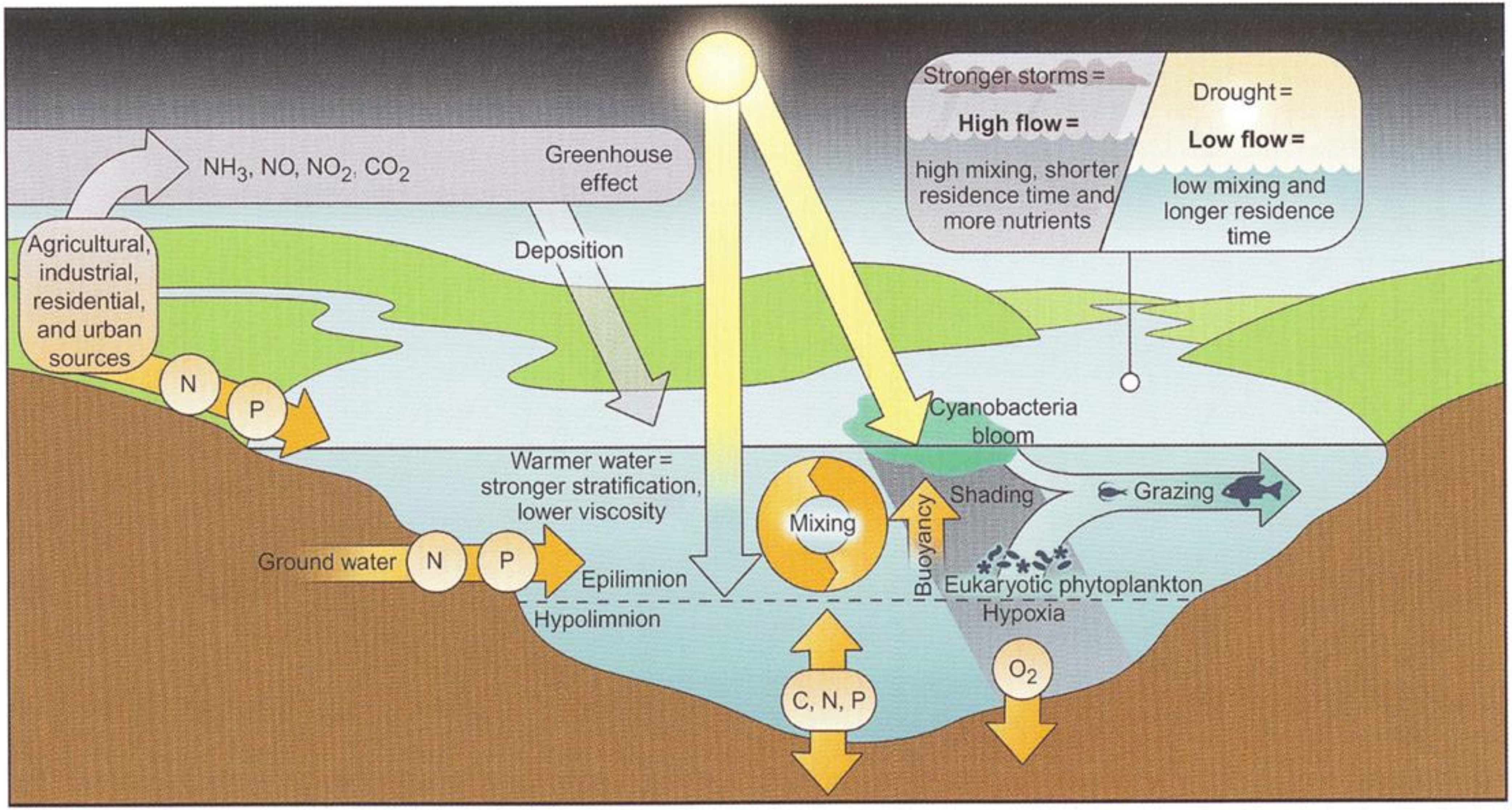
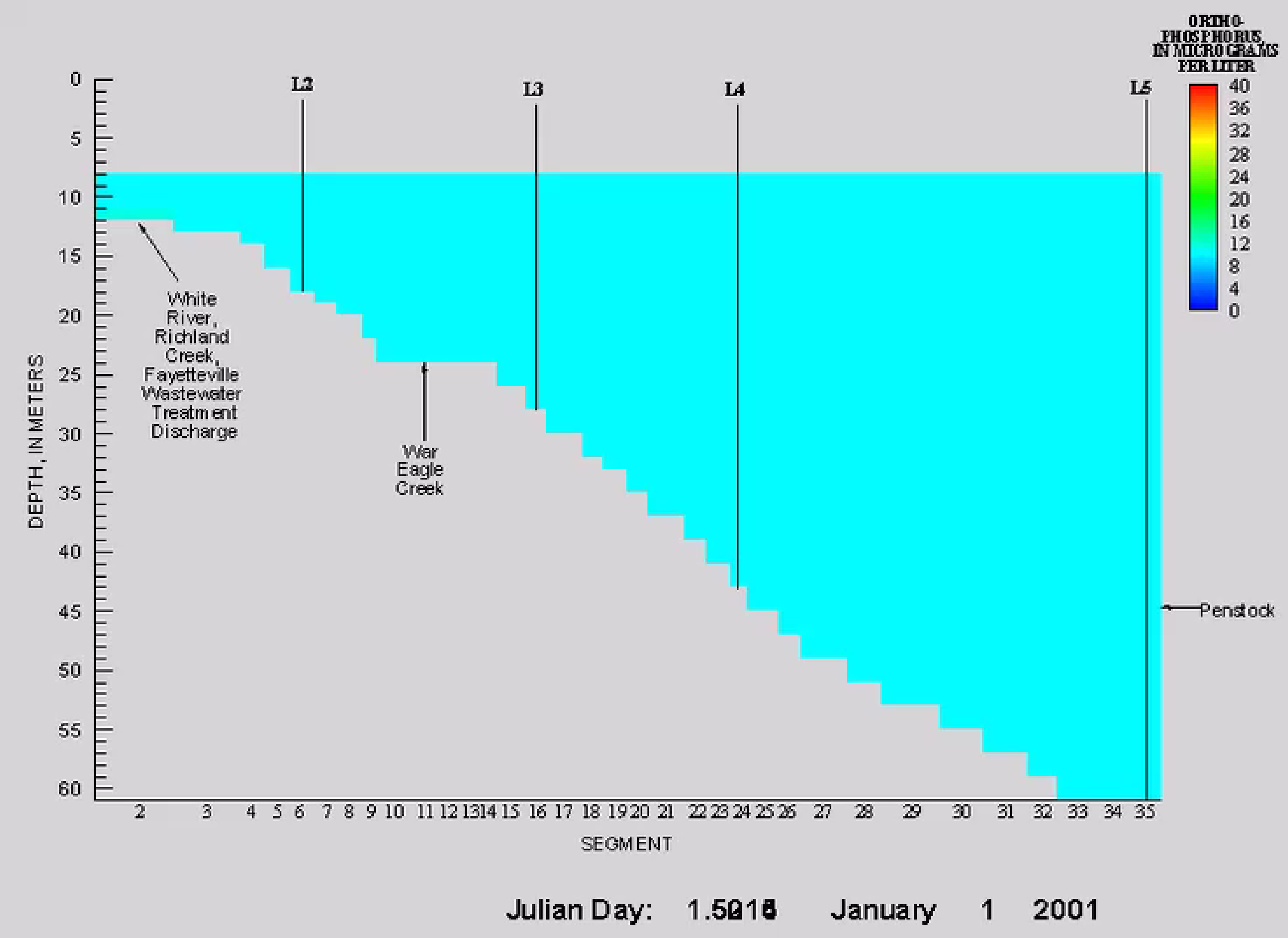
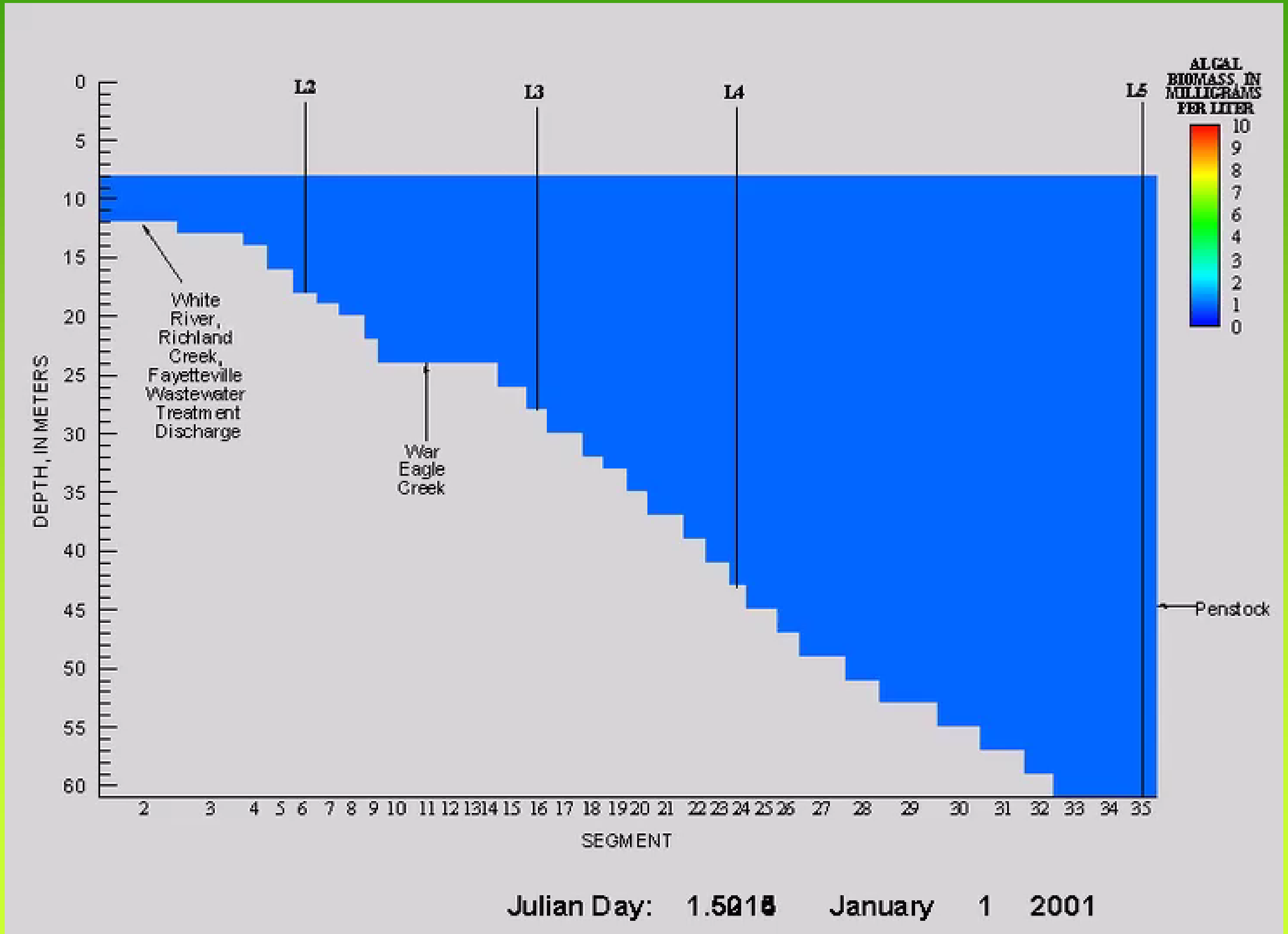


FIGURE 2 Conceptual diagram illustrating external and internal factors controlling growth, accumulation (as blooms), and fate of cHABs in freshwater ecosystems. Factors can act individually or in combined (synergistic, antagonistic) ways.

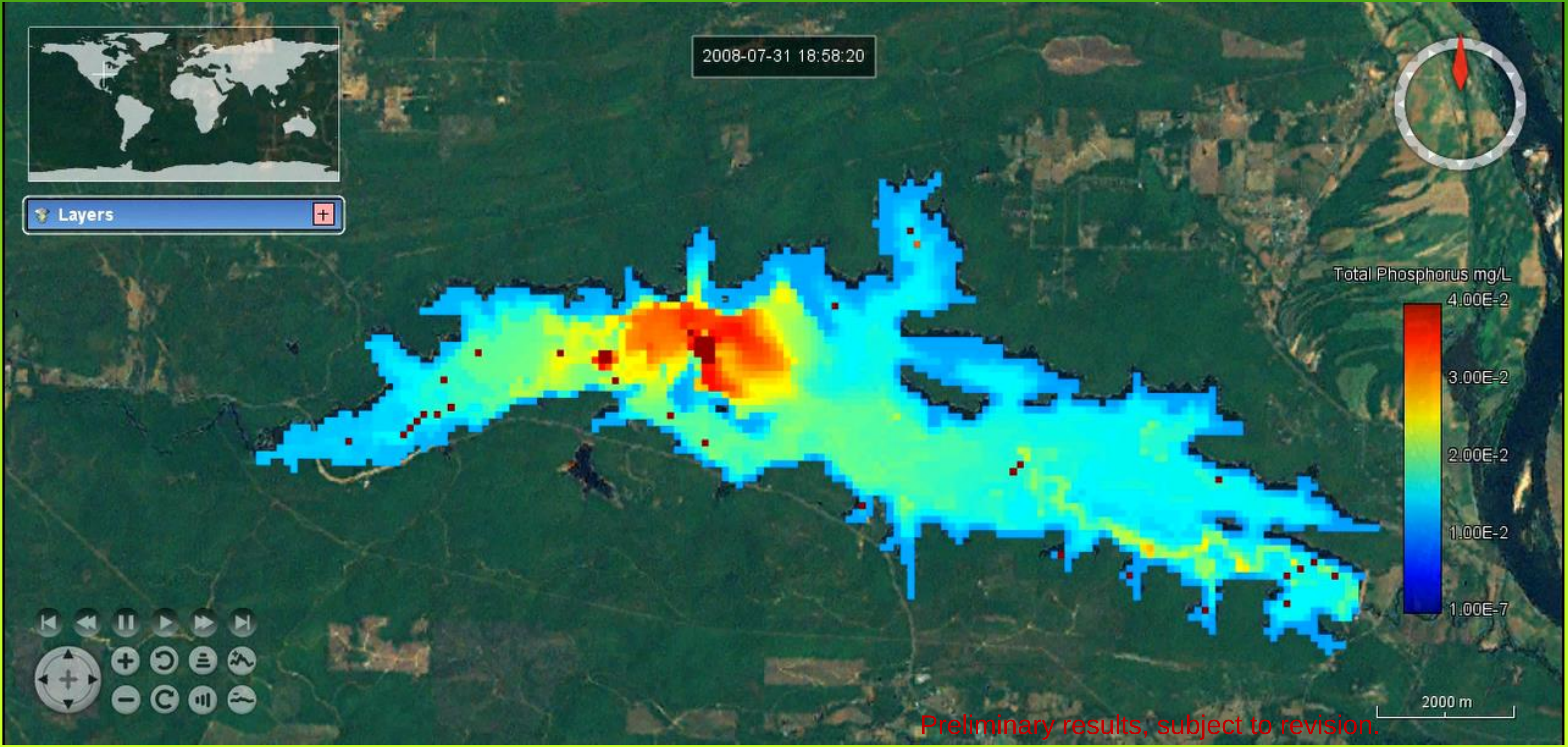
Phosphate (biologically available P)



Chlorophyll (algal biomass)

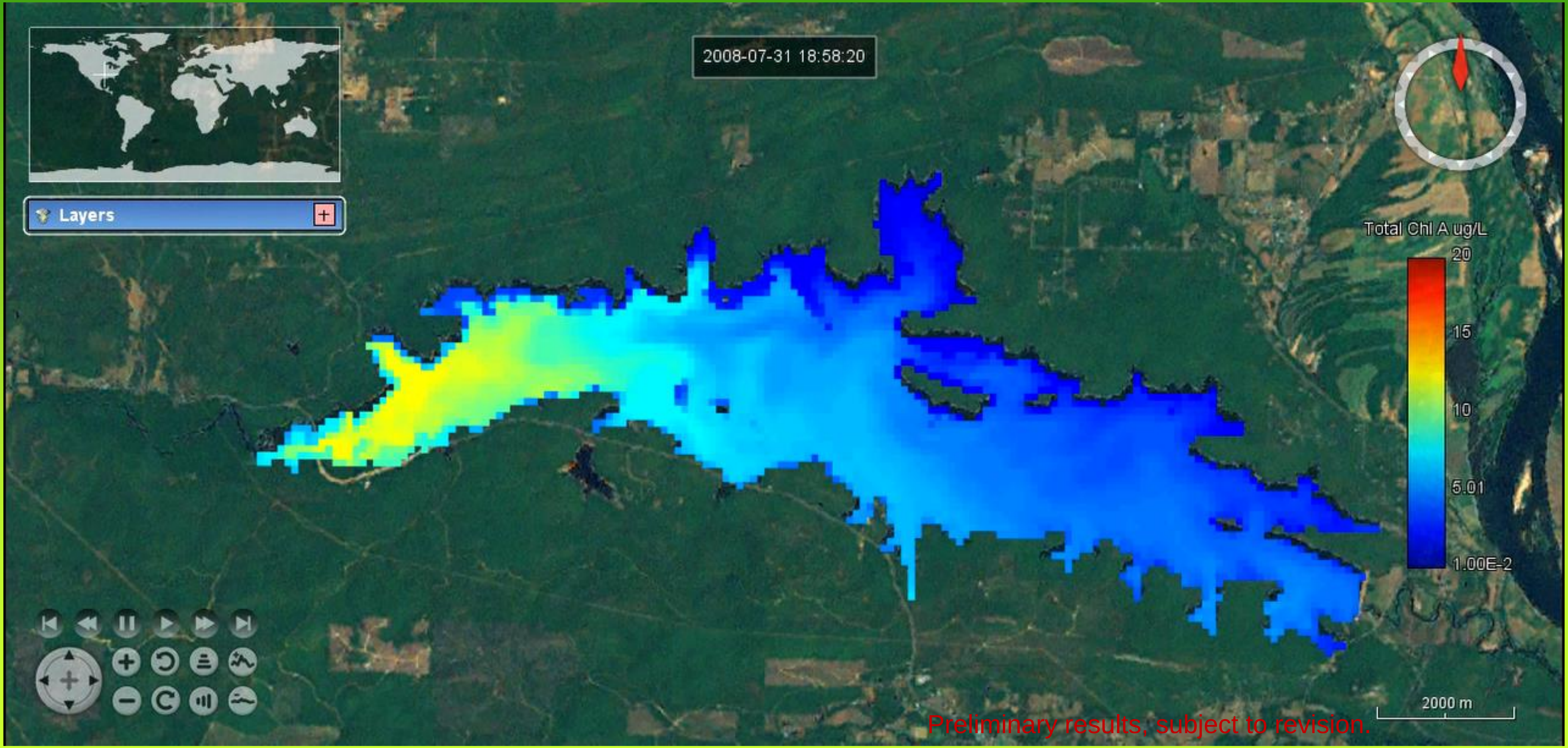


Total Phosphorus

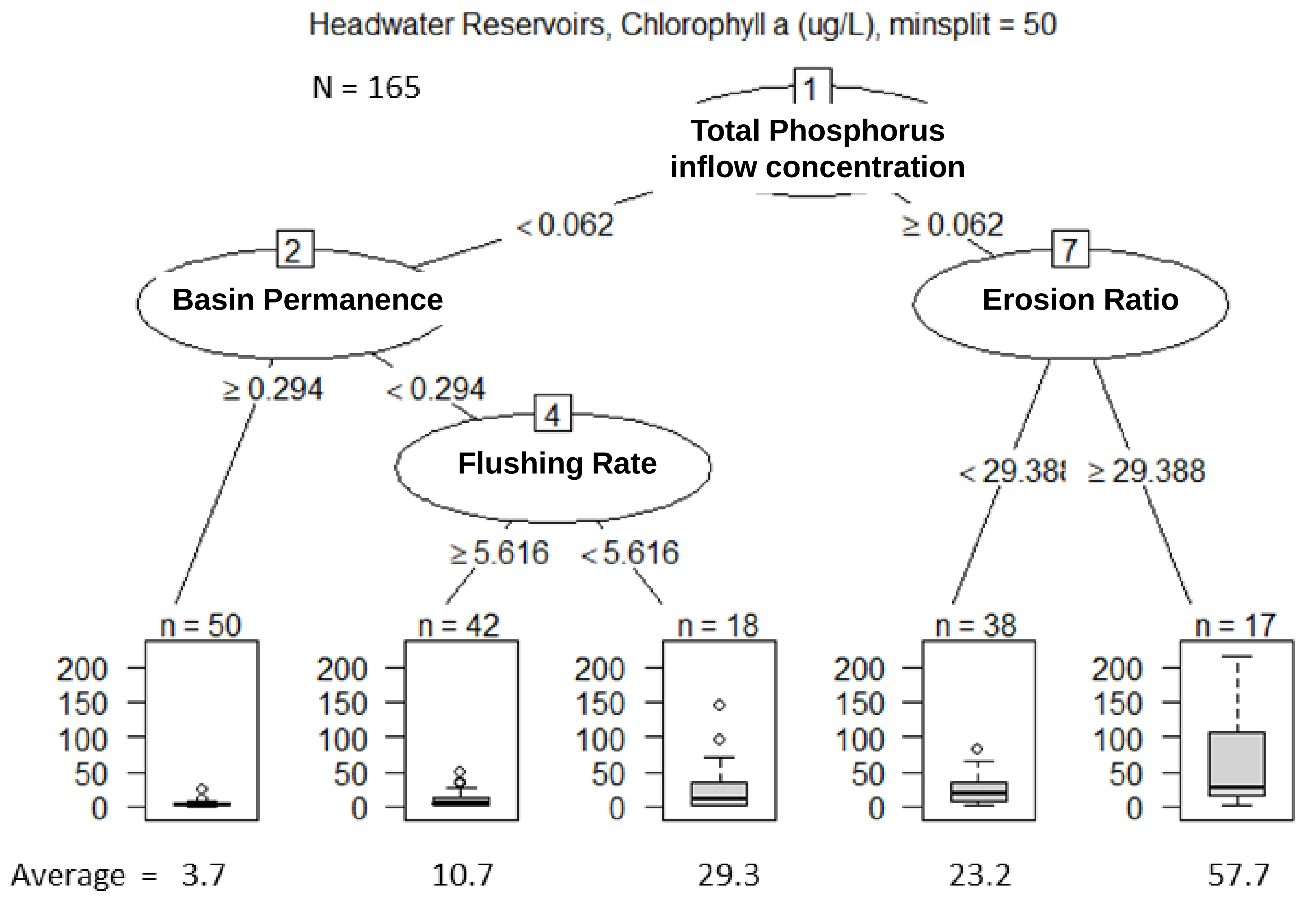


Preliminary results, subject to revision.

Chlorophyll

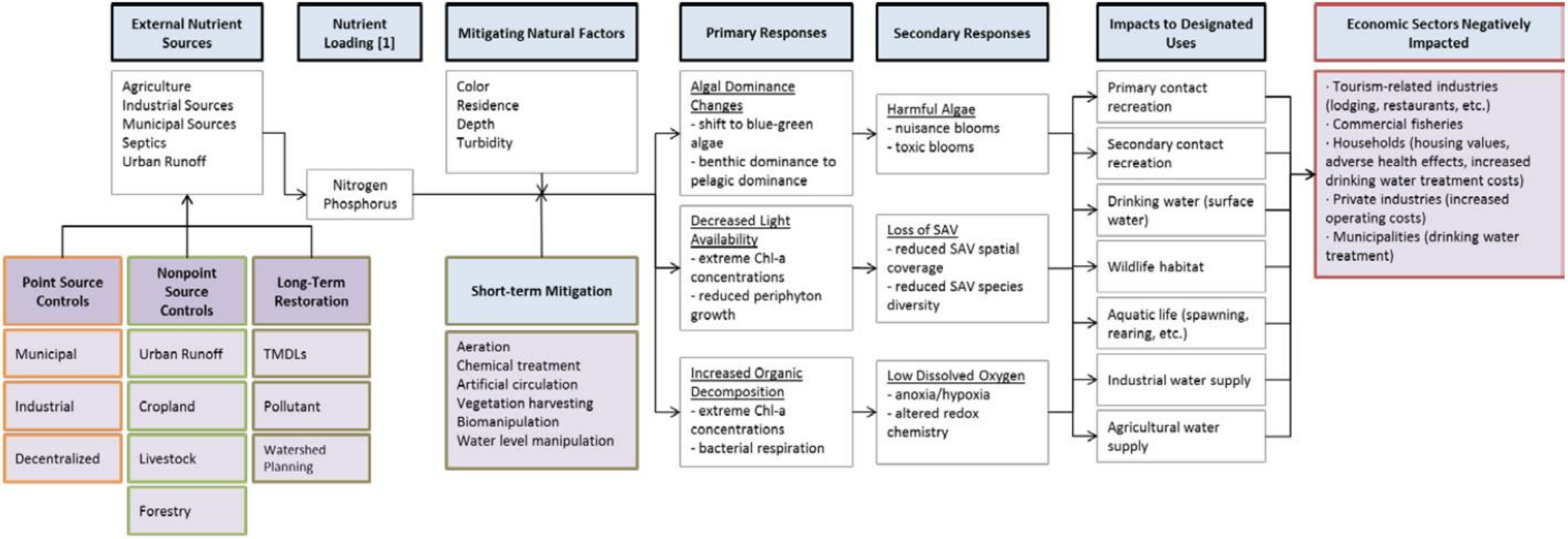


Preliminary results, subject to revision.



Preliminary results, subject to revision.

Relationship of nutrient discharges to economic impacts associated with water quality in lakes and flowing waters.



External Nutrient Sources

Agriculture
Industrial Sources
Municipal Sources
Septics
Urban Runoff

Point Source Controls

- Municipal
- Industrial
- Decentralized

Nonpoint Source Controls

- Urban Runoff
- Cropland
- Livestock
- Forestry

Long-Term Restoration

- TMDLs
- Pollutant
- Watershed Planning

Nutrient Loading [1]

Nitrogen
Phosphorus

Mitigating Natural Factors

Color
Residence
Depth
Turbidity

Short-term Mitigation

Aeration
Chemical treatment
Artificial circulation
Vegetation harvesting
Biomanipulation
Water level manipulation

Primary Responses

Algal Dominance Changes
- shift to blue-green algae
- benthic dominance to pelagic dominance

Decreased Light Availability
- extreme Chl-a concentrations
- reduced periphyton growth

Increased Organic Decomposition
- extreme Chl-a concentrations
- bacterial respiration

Secondary Responses

Harmful Algae
- nuisance blooms
- toxic blooms

Loss of SAV
- reduced SAV spatial coverage
- reduced SAV species diversity

Low Dissolved Oxygen
- anoxia/hypoxia
- altered redox chemistry

Impacts to Designated Uses

- Primary contact recreation
- Secondary contact recreation
- Drinking water (surface water)
- Wildlife habitat
- Aquatic life (spawning, rearing, etc.)
- Industrial water supply
- Agricultural water supply

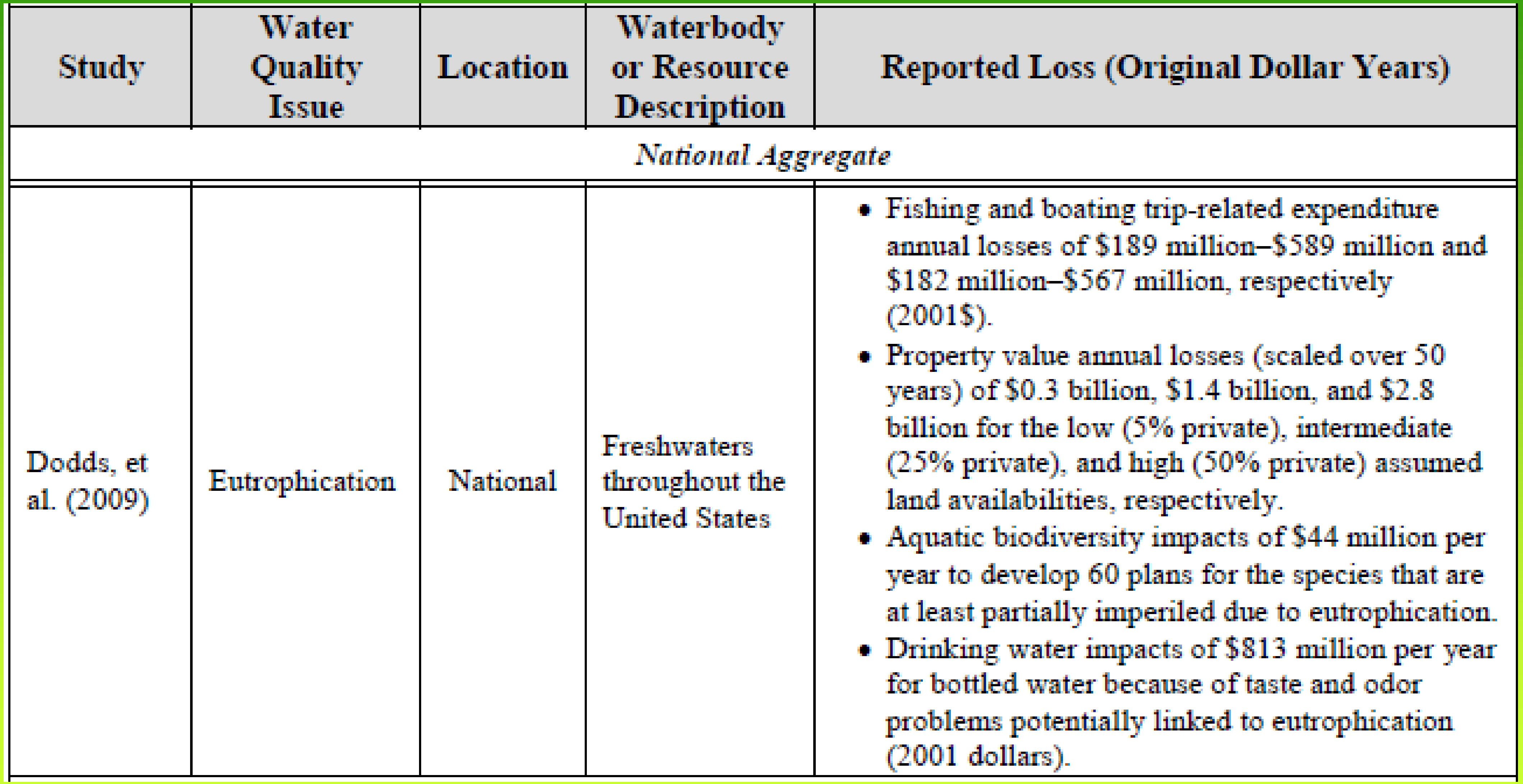
Economic Sectors Negatively Impacted

- Tourism-related industries (lodging, restaurants, etc.)
- Commercial fisheries
- Households (housing values, adverse health effects, increased drinking water treatment costs)
- Private industries (increased operating costs)
- Municipalities (drinking water treatment)

Source: Based on Weaver (2010) and Dodds et al. (2009)

https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

Example of the costs of nutrient pollution and eutrophication



Study	Water Quality Issue	Location	Waterbody or Resource Description	Reported Loss (Original Dollar Years)
National Aggregate				
Dodds, et al. (2009)	Eutrophication	National	Freshwaters throughout the United States	• Fishing and boating trip-related expenditure annual losses of \$189 million–\$589 million and \$182 million–\$567 million, respectively (2001\$). • Property value annual losses (scaled over 50 years) of \$0.3 billion, \$1.4 billion, and \$2.8 billion for the low (5% private), intermediate (25% private), and high (50% private) assumed land availabilities, respectively. • Aquatic biodiversity impacts of \$44 million per year to develop 60 plans for the species that are at least partially imperiled due to eutrophication. • Drinking water impacts of \$813 million per year for bottled water because of taste and odor problems potentially linked to eutrophication (2001 dollars).

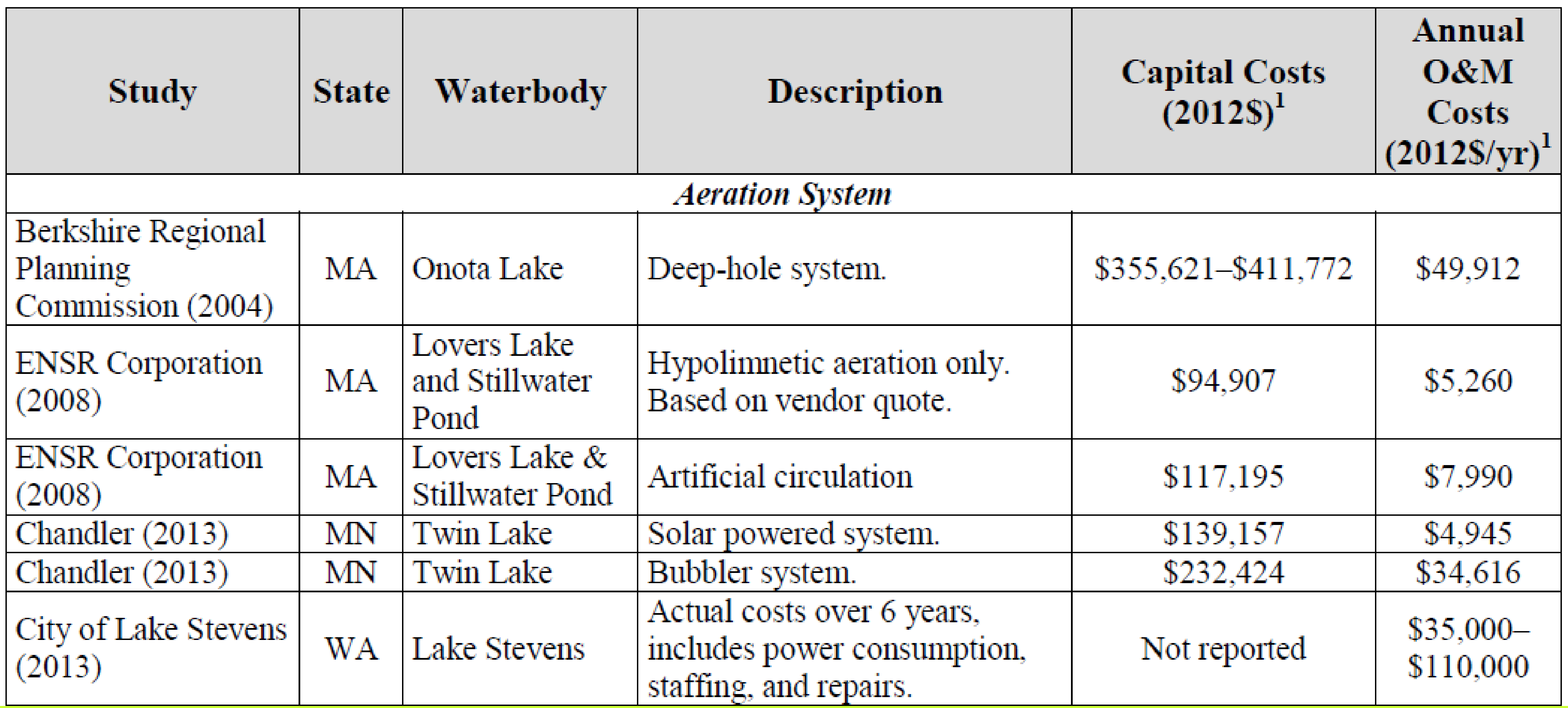
https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

So, how do we control nutrients in our reservoirs?

- Watershed remediation (pg. 66*)
- Constructed wetlands (pg. 67)
- Pre-dams (pg. 70)
- In lake remediation (pg. 71)
  - Guide curve revision (pg. 72)
  - Inflow routing (pg. 72)
  - Dilution (pg. 72)
  - Flushing (pg. 72)
  - Selective withdrawal (pg. 72)
  - Hypolimnetic aeration and oxygen (pg. 74)
  - Sediment removal (pg. 74)
  - Sediment drying (pg. 75)
  - Phosphorus precipitation and inactivation (pg. 75)
- Biomanipulation (pg. 79)
  - Fish populations (pg. 79)
  - Fish harvesting (pg. 80)
  - Macrophytes (pg. 81)
  - Floating wetland islands (pg. 81)

* Page numbers are for Miranda’s BMP manual.

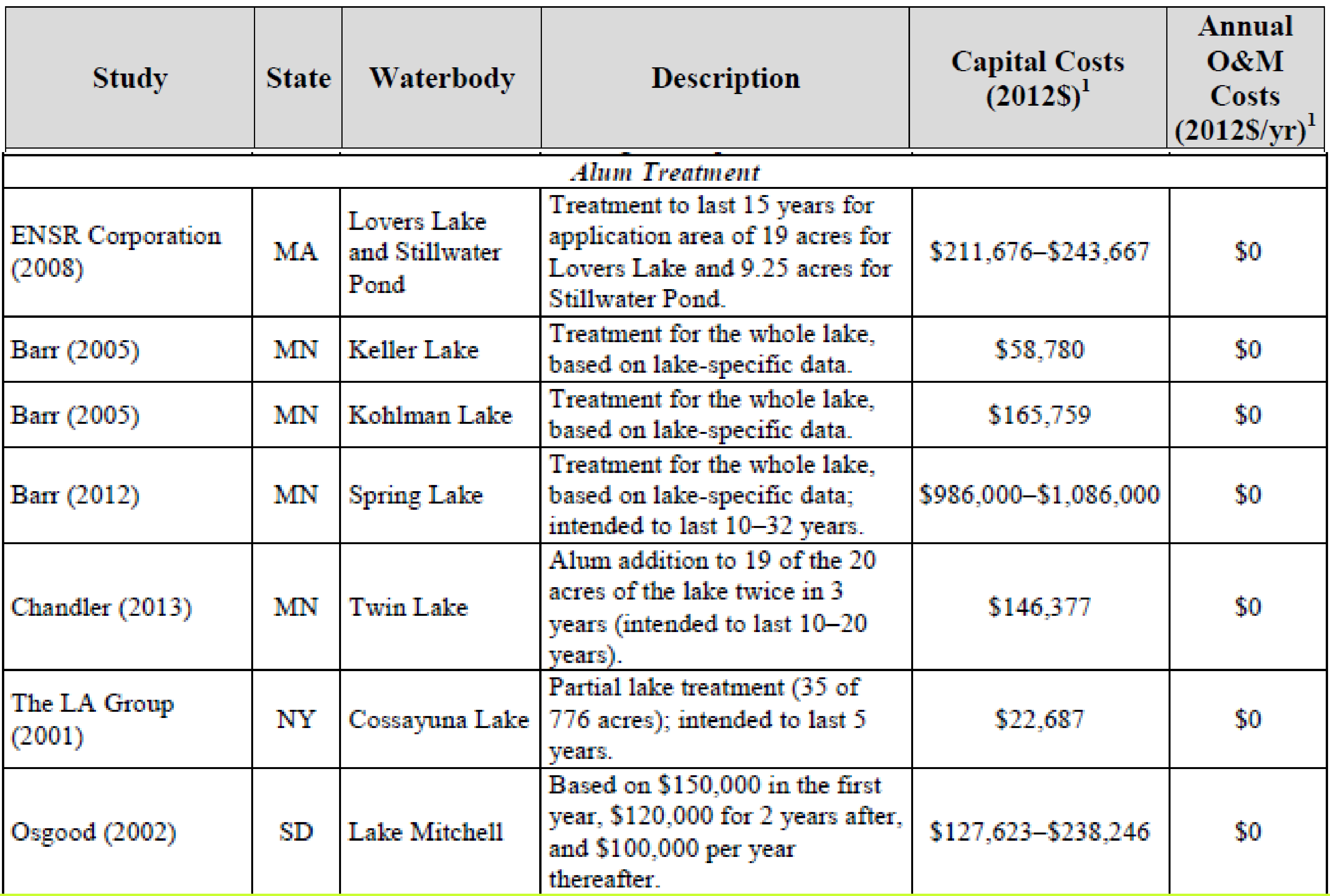
Mitigation Costs Associated with Excess Phosphorus in Lakes



Study	State	Waterbody	Description	Capital Costs (2012$)[1]	Annual O&M Costs (2012$/yr)[1]
			Aeration System		
Berkshire Regional Planning Commission (2004)	MA	Onota Lake	Deep-hole system.	$355,621–$411,772	$49,912
ENSR Corporation (2008)	MA	Lovers Lake and Stillwater Pond	Hypolimnetic aeration only. Based on vendor quote.	$94,907	$5,260
ENSR Corporation (2008)	MA	Lovers Lake & Stillwater Pond	Artificial circulation	$117,195	$7,990
Chandler (2013)	MN	Twin Lake	Solar powered system.	$139,157	$4,945
Chandler (2013)	MN	Twin Lake	Bubbler system.	$232,424	$34,616
City of Lake Stevens (2013)	WA	Lake Stevens	Actual costs over 6 years, includes power consumption, staffing, and repairs.	Not reported	$35,000–$110,000

https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

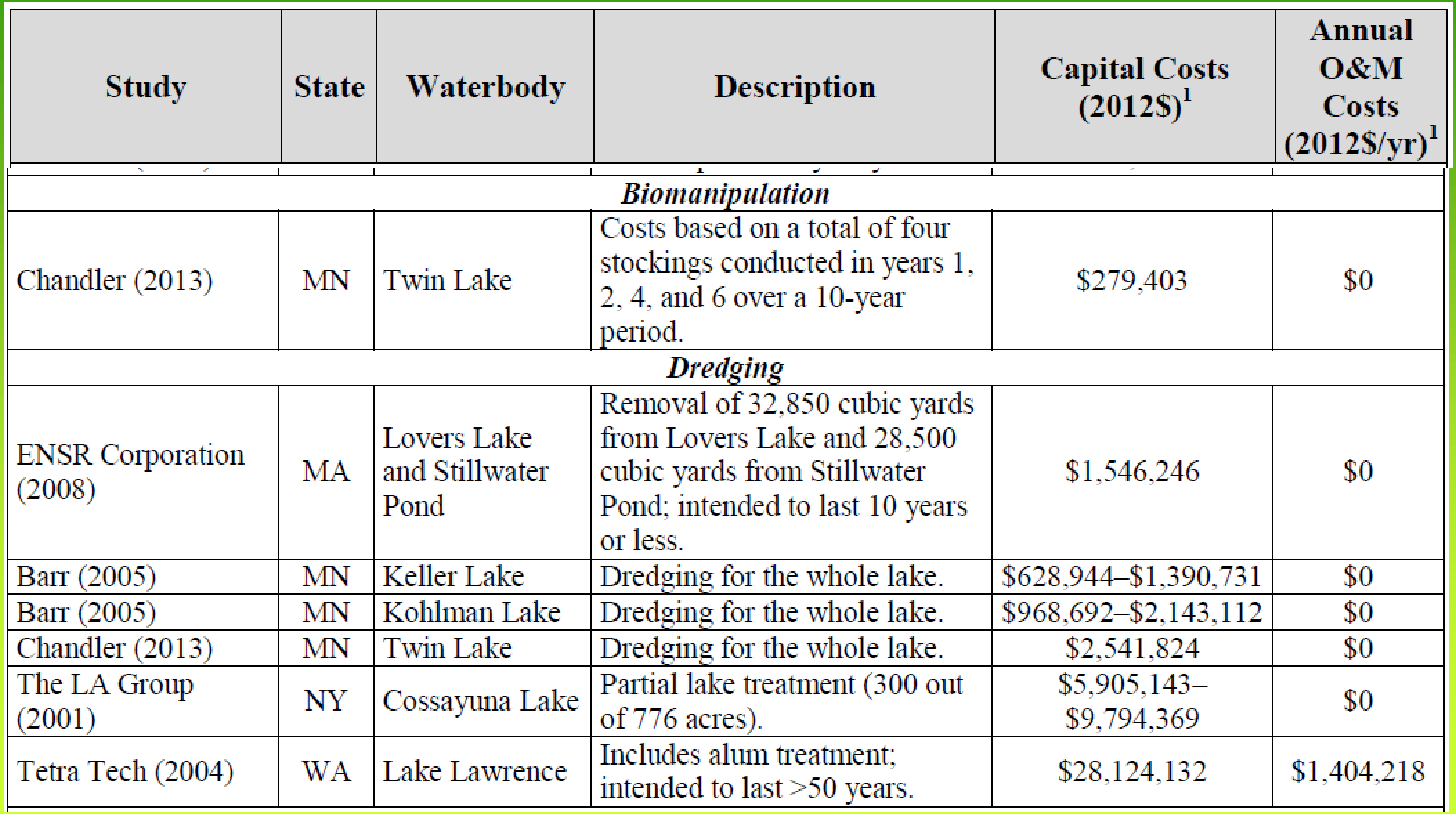
Mitigation Costs Associated with Excess Phosphorus in Lakes



Study	State	Waterbody	Description	Capital Costs (2012$)[1]	Annual O&M Costs (2012$/yr)[1]
Alum Treatment					
ENSR Corporation (2008)	MA	Lovers Lake and Stillwater Pond	Treatment to last 15 years for application area of 19 acres for Lovers Lake and 9.25 acres for Stillwater Pond.	$211,676–$243,667	$0
Barr (2005)	MN	Keller Lake	Treatment for the whole lake, based on lake-specific data.	$58,780	$0
Barr (2005)	MN	Kohlman Lake	Treatment for the whole lake, based on lake-specific data.	$165,759	$0
Barr (2012)	MN	Spring Lake	Treatment for the whole lake, based on lake-specific data; intended to last 10–32 years.	$986,000–$1,086,000	$0
Chandler (2013)	MN	Twin Lake	Alum addition to 19 of the 20 acres of the lake twice in 3 years (intended to last 10–20 years).	$146,377	$0
The LA Group (2001)	NY	Cossayuna Lake	Partial lake treatment (35 of 776 acres); intended to last 5 years.	$22,687	$0
Osgood (2002)	SD	Lake Mitchell	Based on $150,000 in the first year, $120,000 for 2 years after, and $100,000 per year thereafter.	$127,623–$238,246	$0

https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

Mitigation Costs Associated with Excess Phosphorus in Lakes



Study	State	Waterbody	Description	Capital Costs (2012$)[1]	Annual O&M Costs (2012$/yr)[1]
Biomanipulation					
Chandler (2013)	MN	Twin Lake	Costs based on a total of four stockings conducted in years 1, 2, 4, and 6 over a 10-year period.	$279,403	$0
Dredging					
ENSR Corporation (2008)	MA	Lovers Lake and Stillwater Pond	Removal of 32,850 cubic yards from Lovers Lake and 28,500 cubic yards from Stillwater Pond; intended to last 10 years or less.	$1,546,246	$0
Barr (2005)	MN	Keller Lake	Dredging for the whole lake.	$628,944–$1,390,731	$0
Barr (2005)	MN	Kohlman Lake	Dredging for the whole lake.	$968,692–$2,143,112	$0
Chandler (2013)	MN	Twin Lake	Dredging for the whole lake.	$2,541,824	$0
The LA Group (2001)	NY	Cossayuna Lake	Partial lake treatment (300 out of 776 acres).	$5,905,143–$9,794,369	$0
Tetra Tech (2004)	WA	Lake Lawrence	Includes alum treatment; intended to last >50 years.	$28,124,132	$1,404,218

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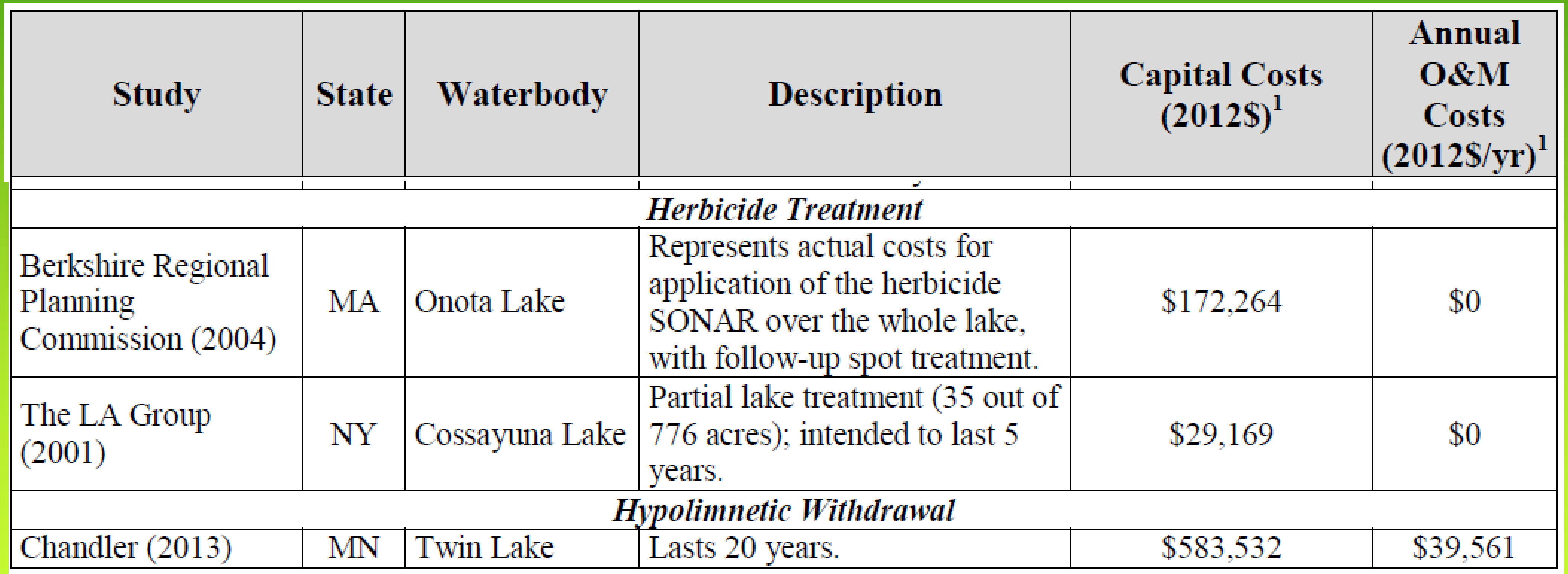
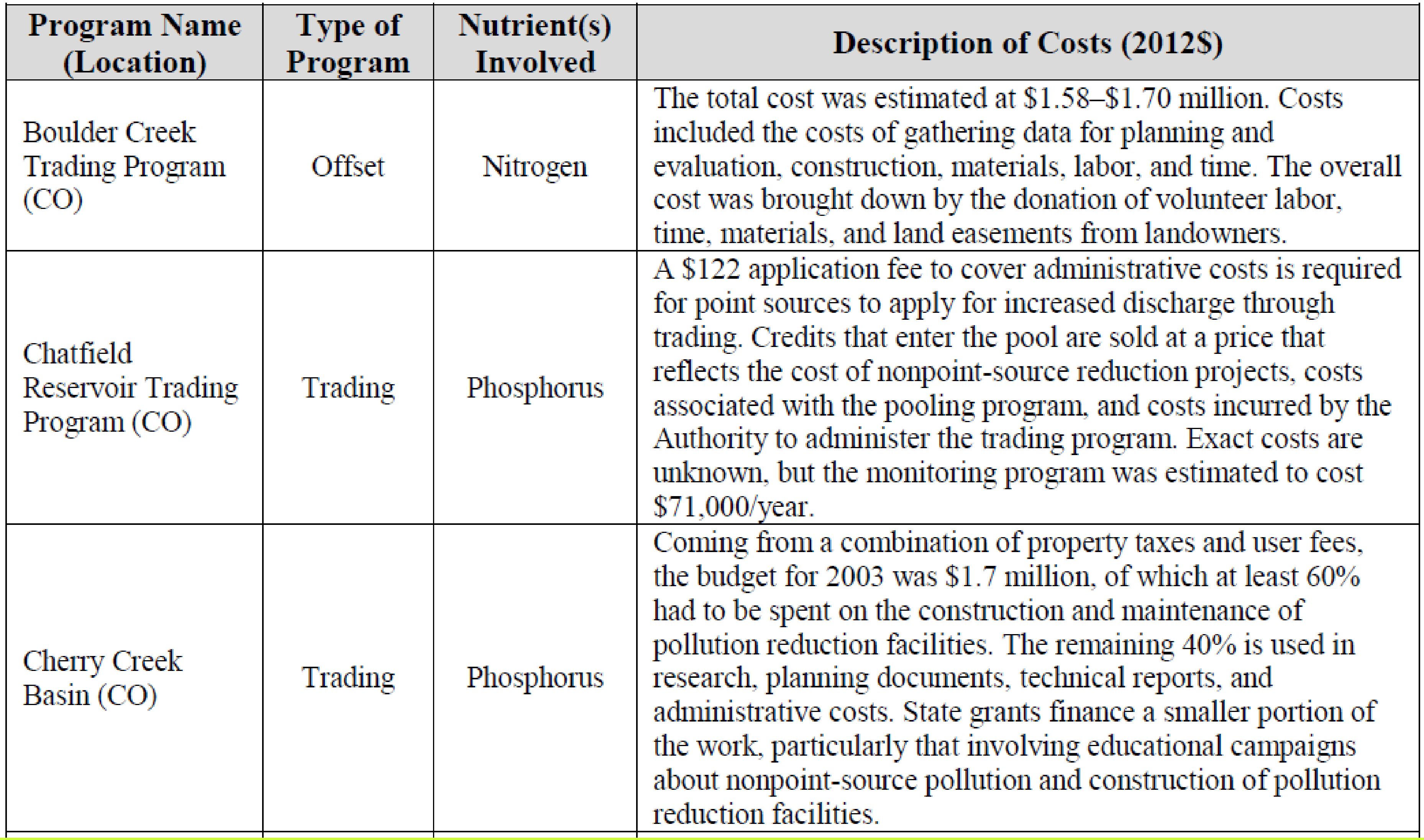
Mitigation Costs Associated with Excess Phosphorus in Lakes



Study	State	Waterbody	Description	Capital Costs (2012$)[1]	Annual O&M Costs (2012$/yr)[1]
Herbicide Treatment					
Berkshire Regional Planning Commission (2004)	MA	Onota Lake	Represents actual costs for application of the herbicide SONAR over the whole lake, with follow-up spot treatment.	$172,264	$0
The LA Group (2001)	NY	Cossayuna Lake	Partial lake treatment (35 out of 776 acres); intended to last 5 years.	$29,169	$0
Hypolimnetic Withdrawal					
Chandler (2013)	MN	Twin Lake	Lasts 20 years.	$583,532	$39,561

https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

Summary of Costs to Administer Nutrient Trading and Offset Programs



Program Name (Location)	Type of Program	Nutrient(s) Involved	Description of Costs (2012$)
Boulder Creek Trading Program (CO)	Offset	Nitrogen	The total cost was estimated at $1.58–$1.70 million. Costs included the costs of gathering data for planning and evaluation, construction, materials, labor, and time. The overall cost was brought down by the donation of volunteer labor, time, materials, and land easements from landowners.
Chatfield Reservoir Trading Program (CO)	Trading	Phosphorus	A $122 application fee to cover administrative costs is required for point sources to apply for increased discharge through trading. Credits that enter the pool are sold at a price that reflects the cost of nonpoint-source reduction projects, costs associated with the pooling program, and costs incurred by the Authority to administer the trading program. Exact costs are unknown, but the monitoring program was estimated to cost $71,000/year.
Cherry Creek Basin (CO)	Trading	Phosphorus	Coming from a combination of property taxes and user fees, the budget for 2003 was $1.7 million, of which at least 60% had to be spent on the construction and maintenance of pollution reduction facilities. The remaining 40% is used in research, planning documents, technical reports, and administrative costs. State grants finance a smaller portion of the work, particularly that involving educational campaigns about nonpoint-source pollution and construction of pollution reduction facilities.

https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

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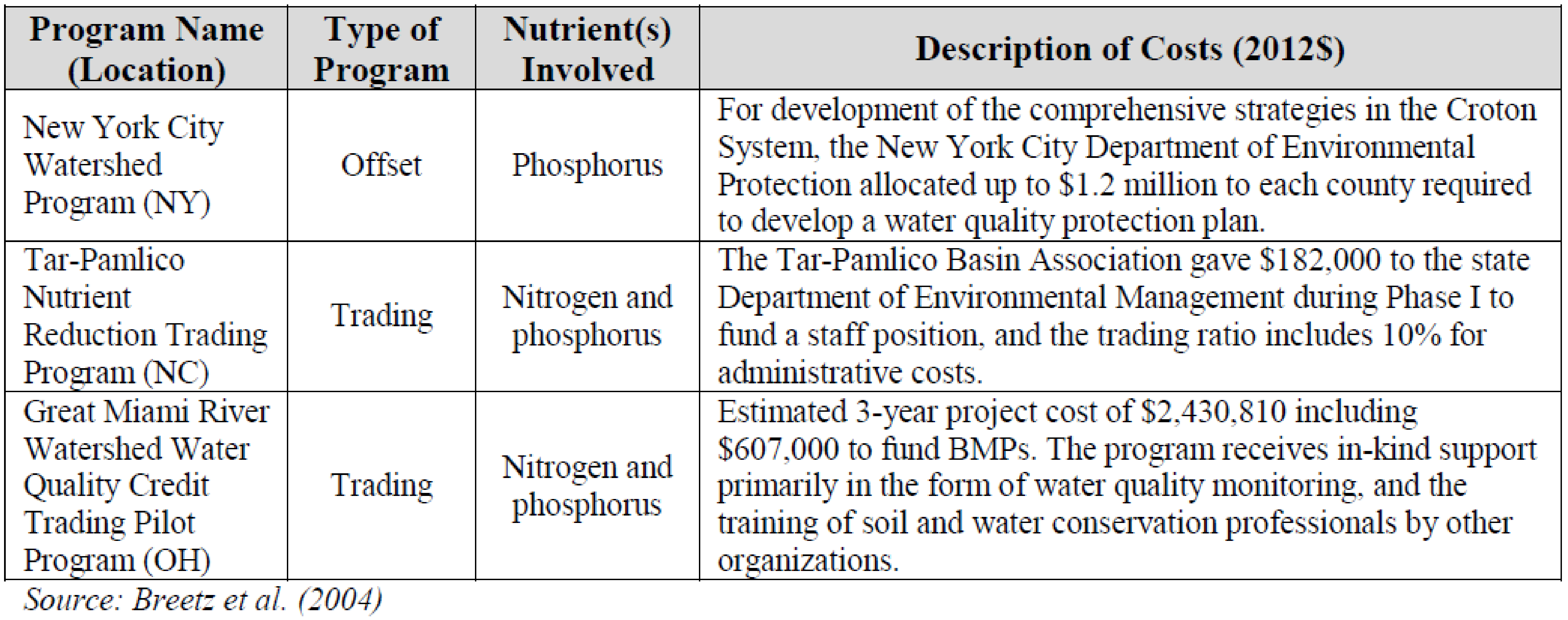

Program Name (Location)	Type of Program	Nutrient(s) Involved	Description of Costs (2012$)
New York City Watershed Program (NY)	Offset	Phosphorus	For development of the comprehensive strategies in the Croton System, the New York City Department of Environmental Protection allocated up to $1.2 million to each county required to develop a water quality protection plan.
Tar-Pamlico Nutrient Reduction Trading Program (NC)	Trading	Nitrogen and phosphorus	The Tar-Pamlico Basin Association gave $182,000 to the state Department of Environmental Management during Phase I to fund a staff position, and the trading ratio includes 10% for administrative costs.
Great Miami River Watershed Water Quality Credit Trading Pilot Program (OH)	Trading	Nitrogen and phosphorus	Estimated 3-year project cost of $2,430,810 including $607,000 to fund BMPs. The program receives in-kind support primarily in the form of water quality monitoring, and the training of soil and water conservation professionals by other organizations.

Source: Breetz et al. (2004)

https://www.epa.gov/nutrient-policy-data/compilation-cost-data-associated-impacts-and-control-nutrient-pollution

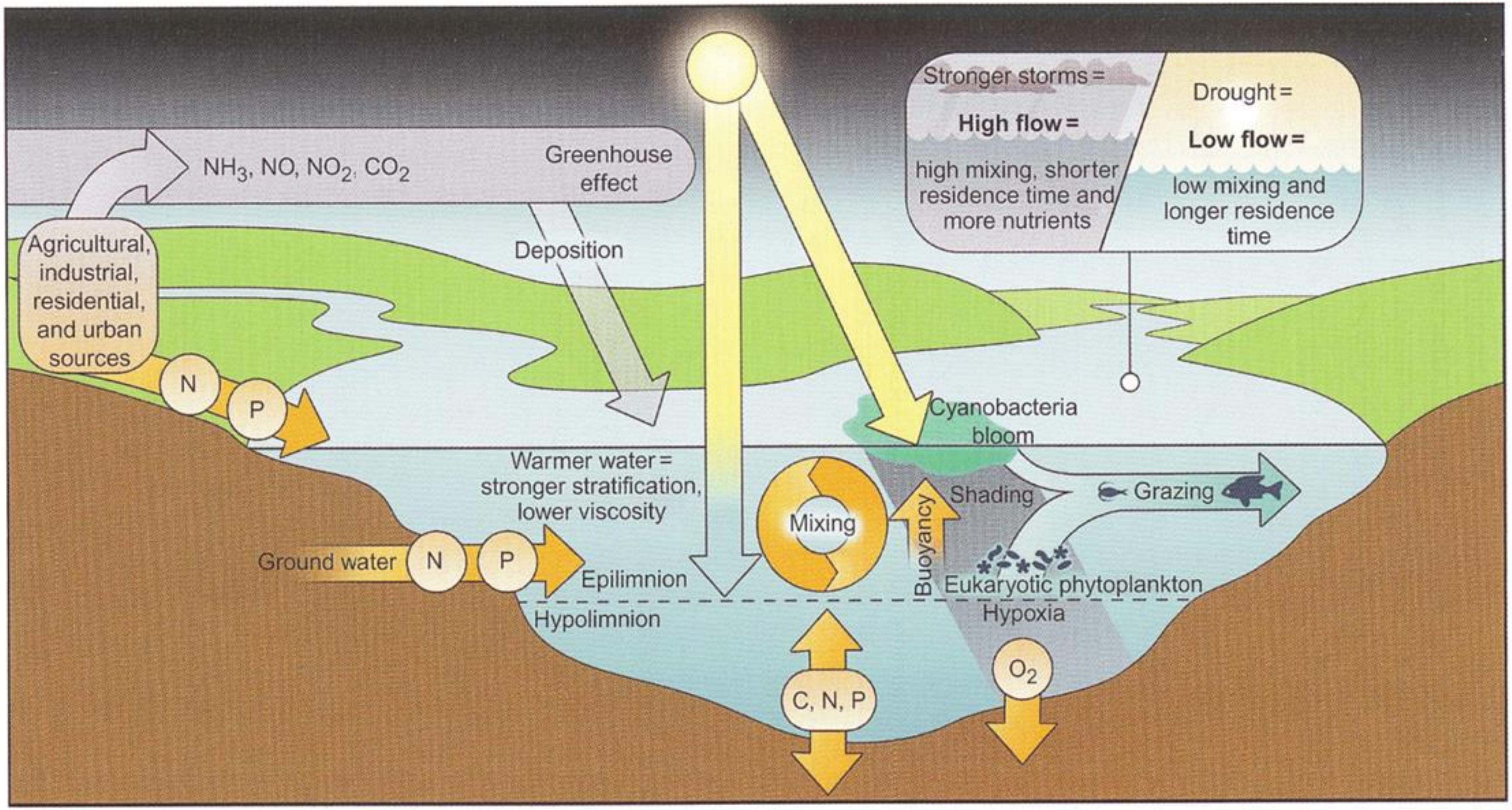

FIGURE 2 Conceptual diagram illustrating external and internal factors controlling growth, accumulation (as blooms), and fate of cHABs in freshwater ecosystems. Factors can act individually or in combined (synergistic, antagonistic) ways.

NALMS Position Statements

https://www.nalms.org/nalms-position-papers/

- Source Water Protection
- Use of Alum
- Climate Change
- Herbicides
- Watercraft Safety
- Invasive Species
- Harmful Algal Toxins
- Clean Water Act