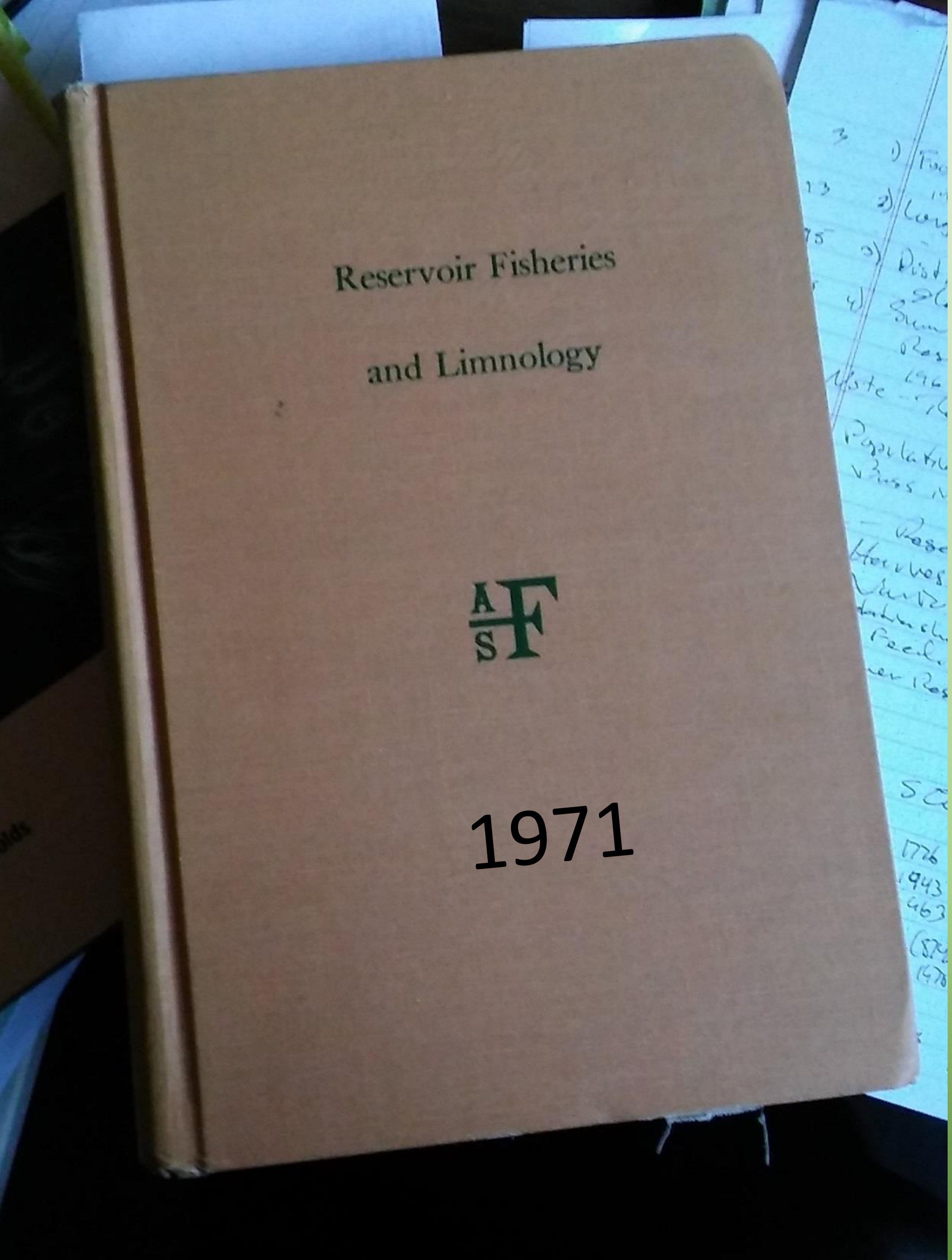
Reservoir Aging – A New Paradigm for Fisheries and Water-Quality Management

- These aren’t your father’s reservoirs.
- How do we manage our aging reservoirs?

Oklahoma Clean Lakes and Watershed Conference

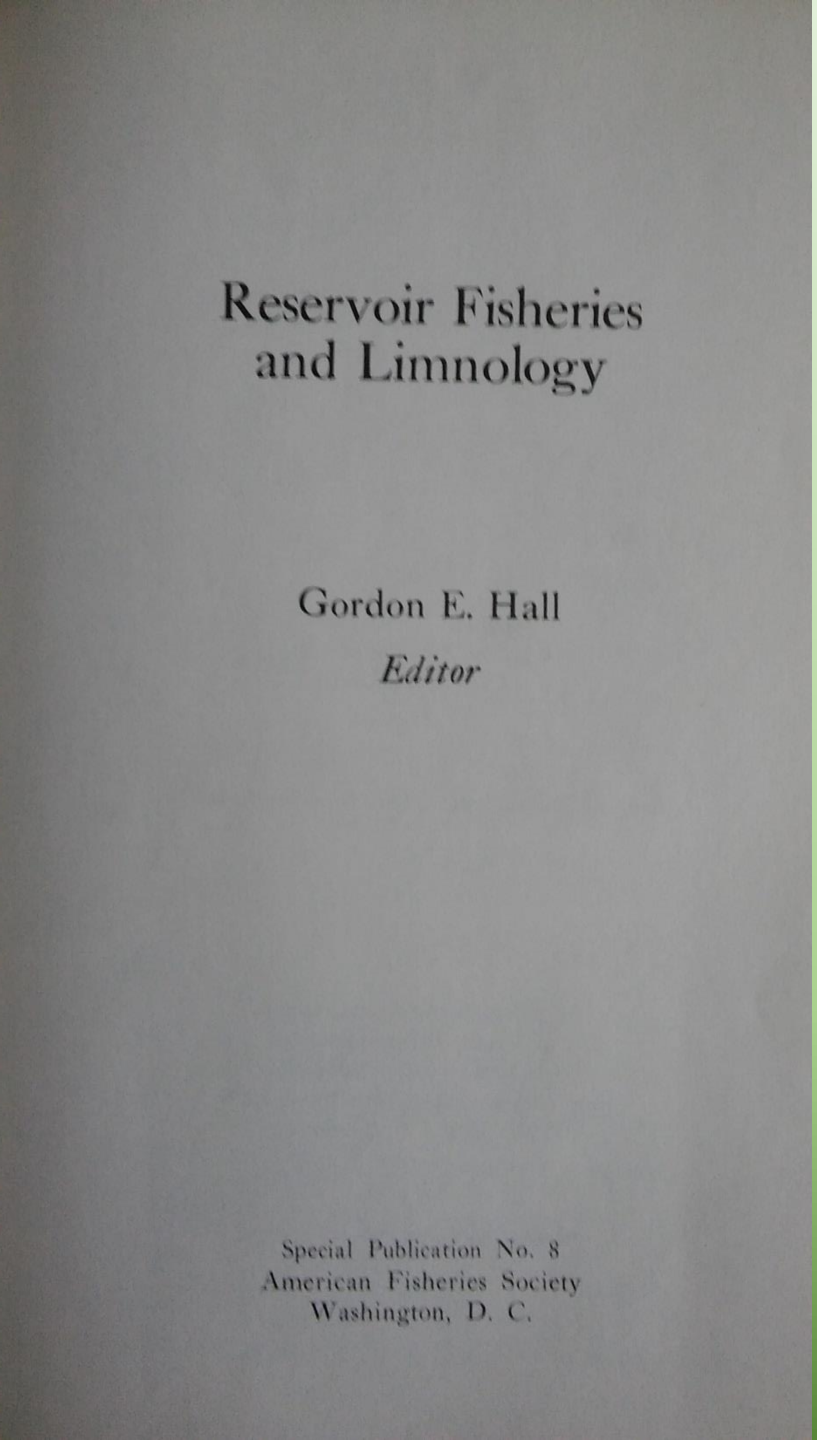
March 29-30, 2016

W. Reed Green, Ph.D., CLP



Preface

"Reservoirs have provided us with a valuable fishery resource, one that we have not yet begun to manage effectively or efficiently. We hope this volume will provide readers with more insight and understanding of where we are and what we are accomplishing with reservoir fisheries now, and stimulate new directions and broader horizons for future reservoir research." -- Gordon E. Hall



Reservoir Fisheries
and Limnology

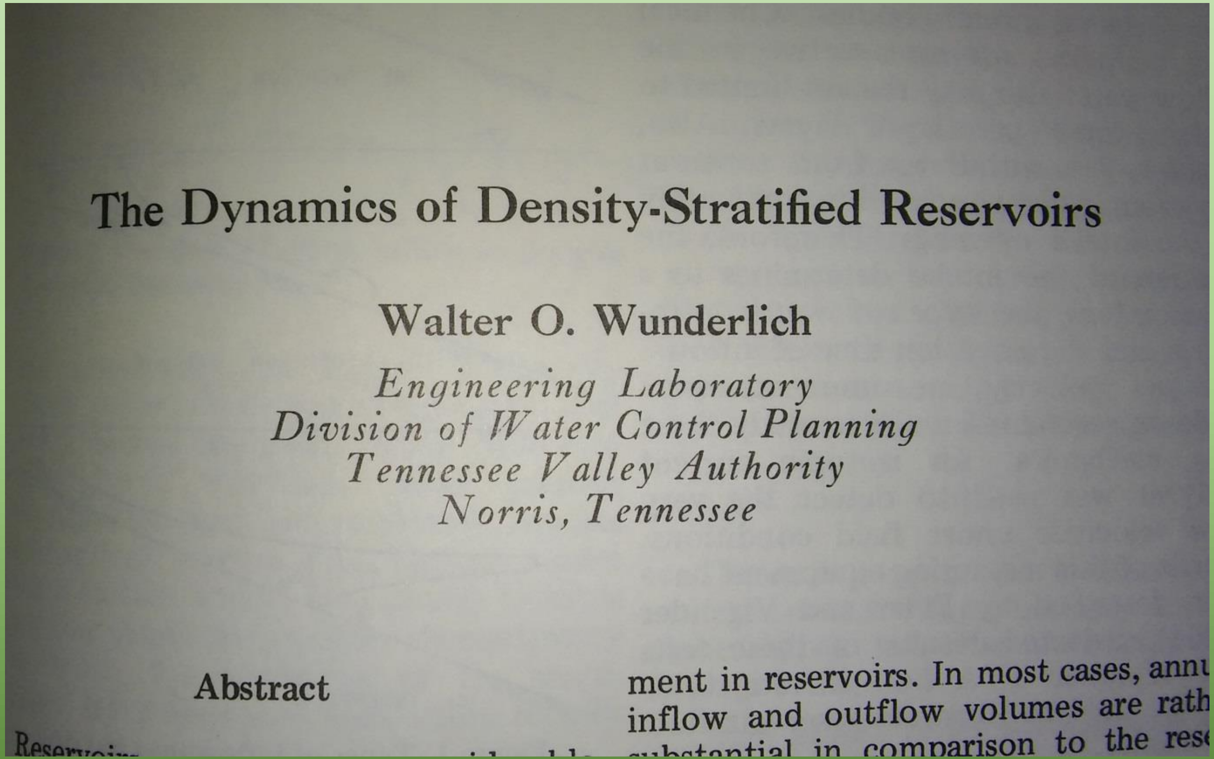
Gordon E. Hall
Editor

Special Publication No. 8
American Fisheries Society
Washington, D. C.

Reservoir Fisheries and Limnology (1971)

- *Reproduction and some aspects of the early life history of walleye in Canton Reservoir, Oklahoma*, by B.G. Grinstead
- *Reproductive biology of the flathead catfish in a turbid Oklahoma reservoir*, by P.R. Turner and R.C. by Summerfelt
- *Factors influencing the horizontal distribution of several fishes in an Oklahoma reservoir*, by R.C. Summerfelt
- *Production of a minimal largemouth bass population in a 3,000-acre turbid Oklahoma reservoir*, by P.L. Zweiacker and B.E. Brown

Reservoir Fisheries and Limnology (1971) brought us



The Dynamics of Density-Stratified Reservoirs

Walter O. Wunderlich

Engineering Laboratory
Division of Water Control Planning
Tennessee Valley Authority
Norris, Tennessee

Abstract

Reservoirs ... ment in reservoirs. In most cases, annu... inflow and outflow volumes are rath... substantial in comparison to the rese...

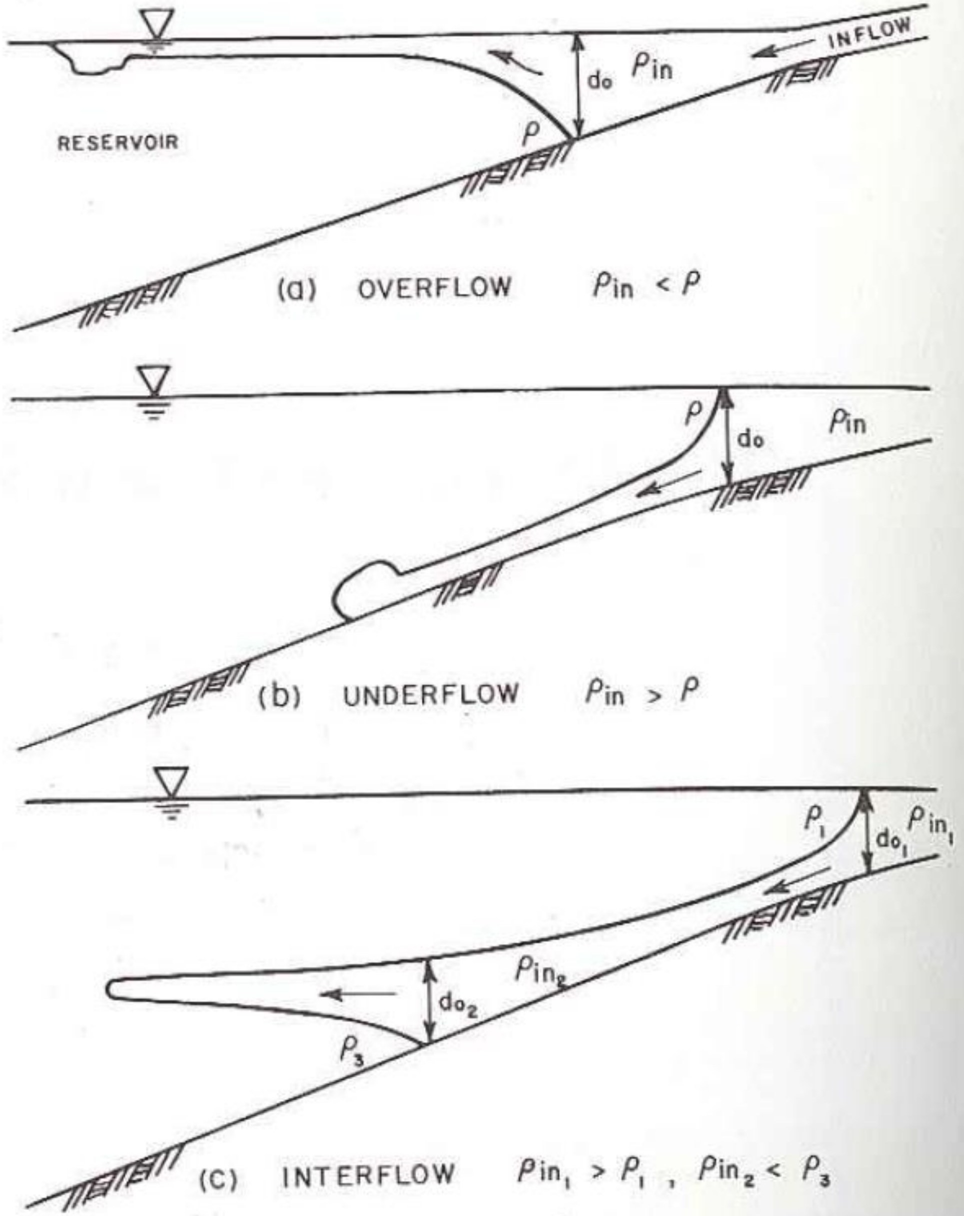


Figure 1. Types of inflow into reservoirs.

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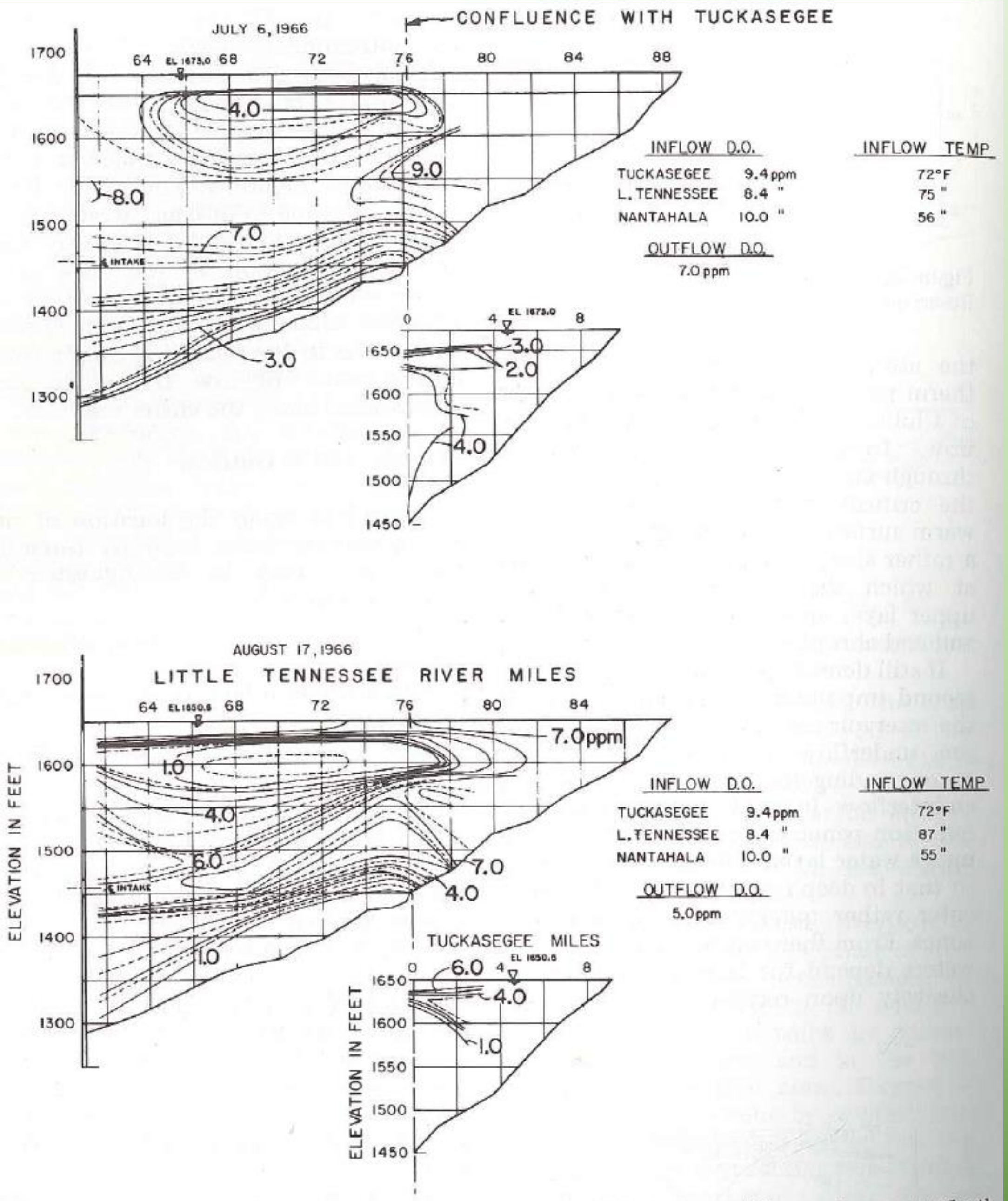
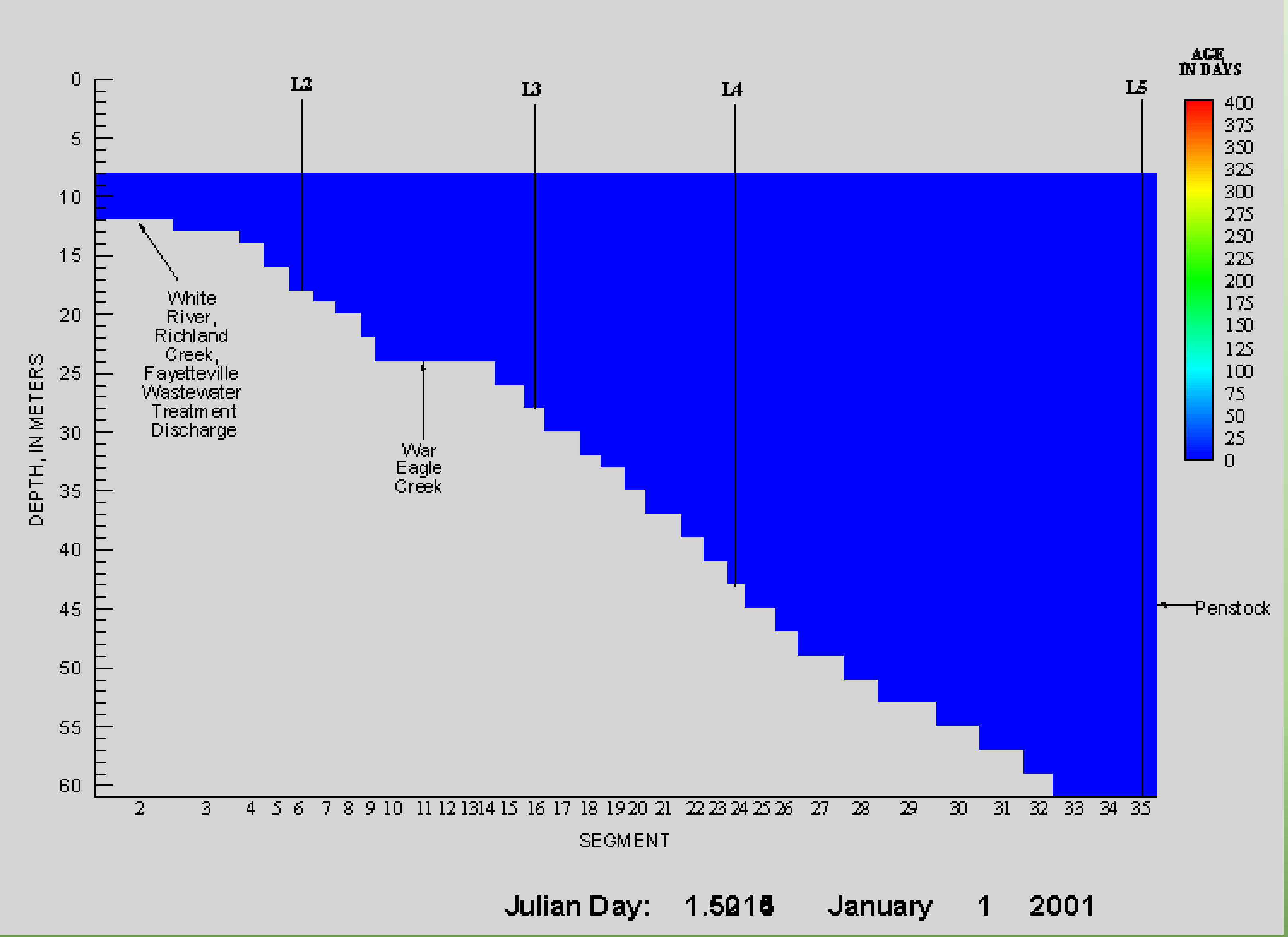
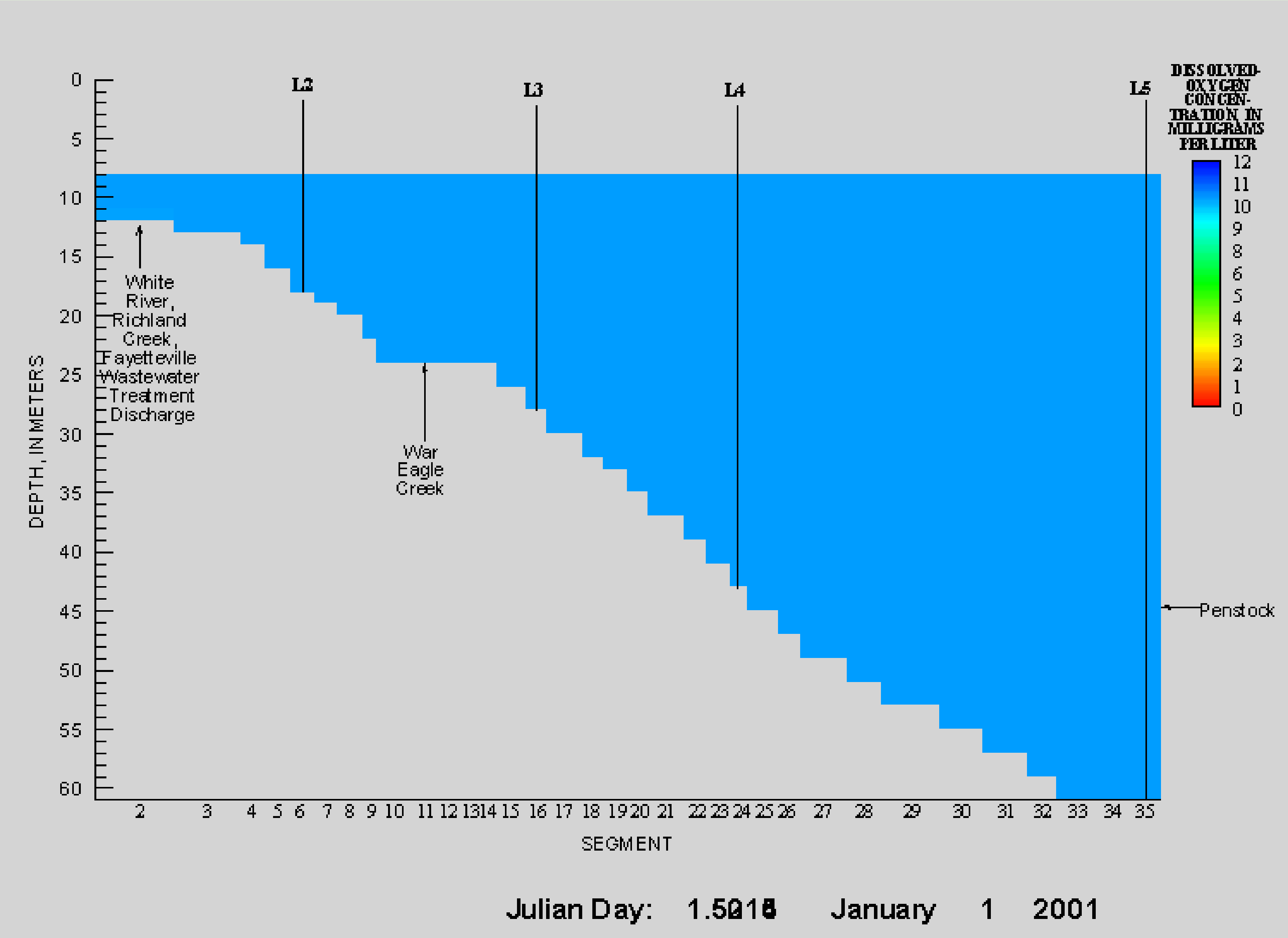


Figure 4. Daily oxygen patterns in Fontana Reservoir and Tuckaseegee River embayment, North Carolina.

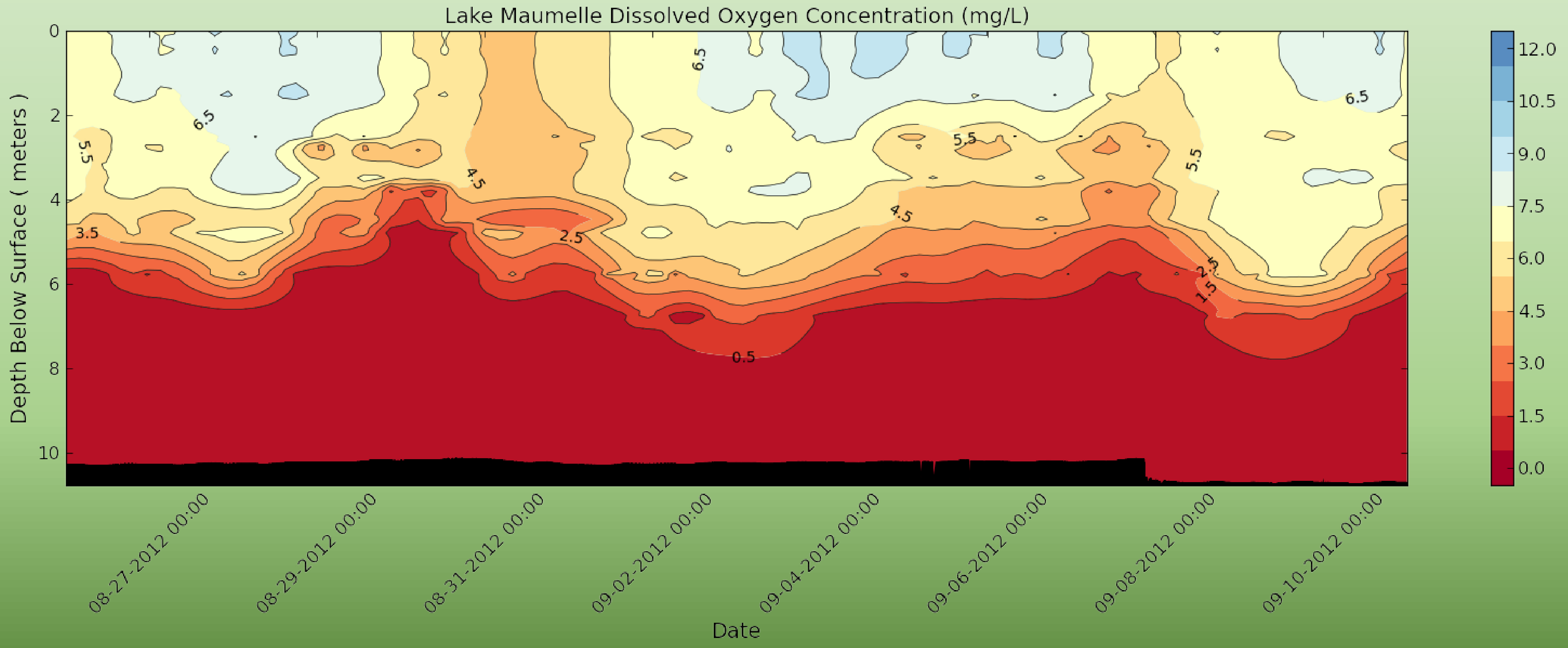
which we can now simulate,



and better understand,

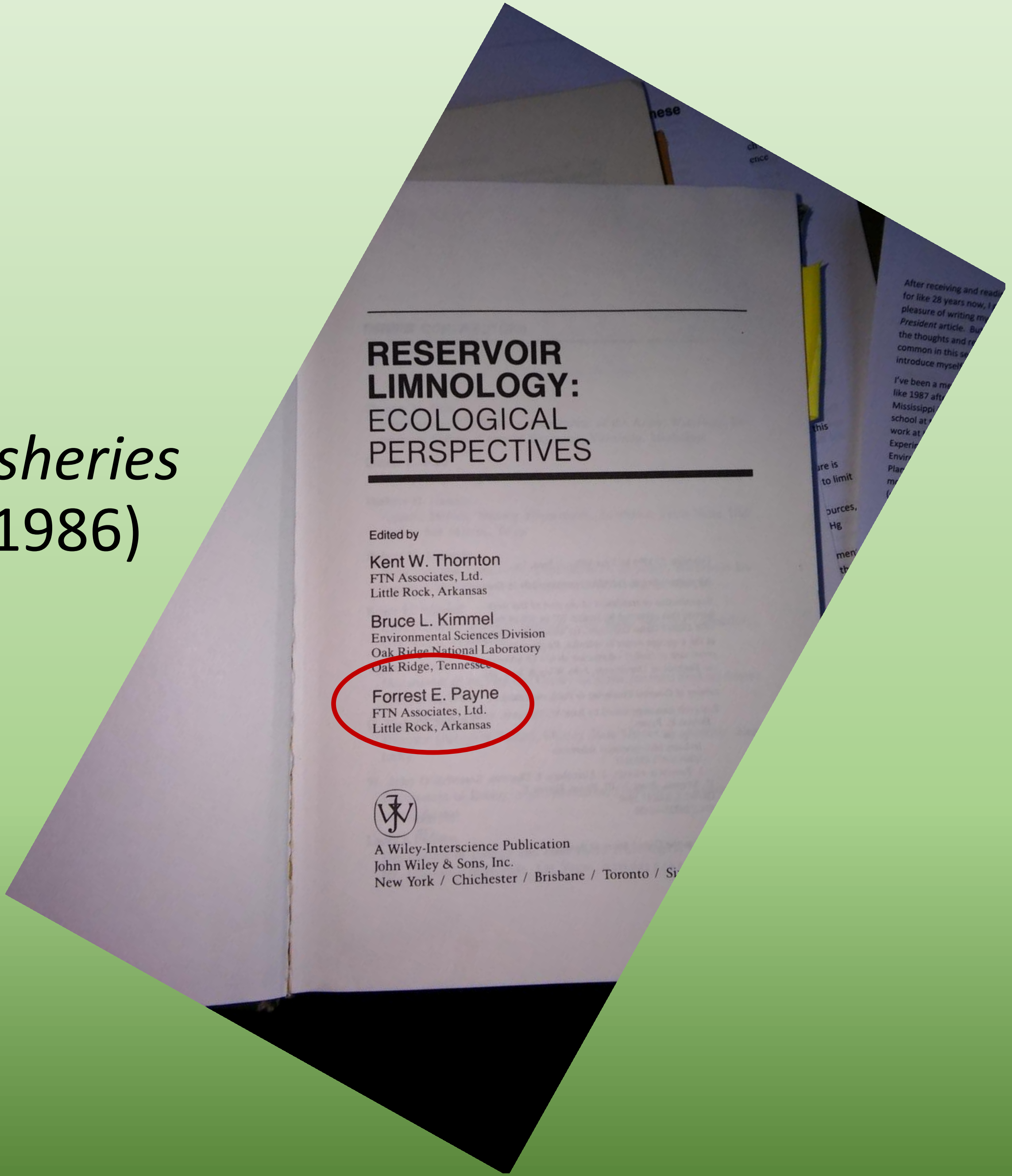


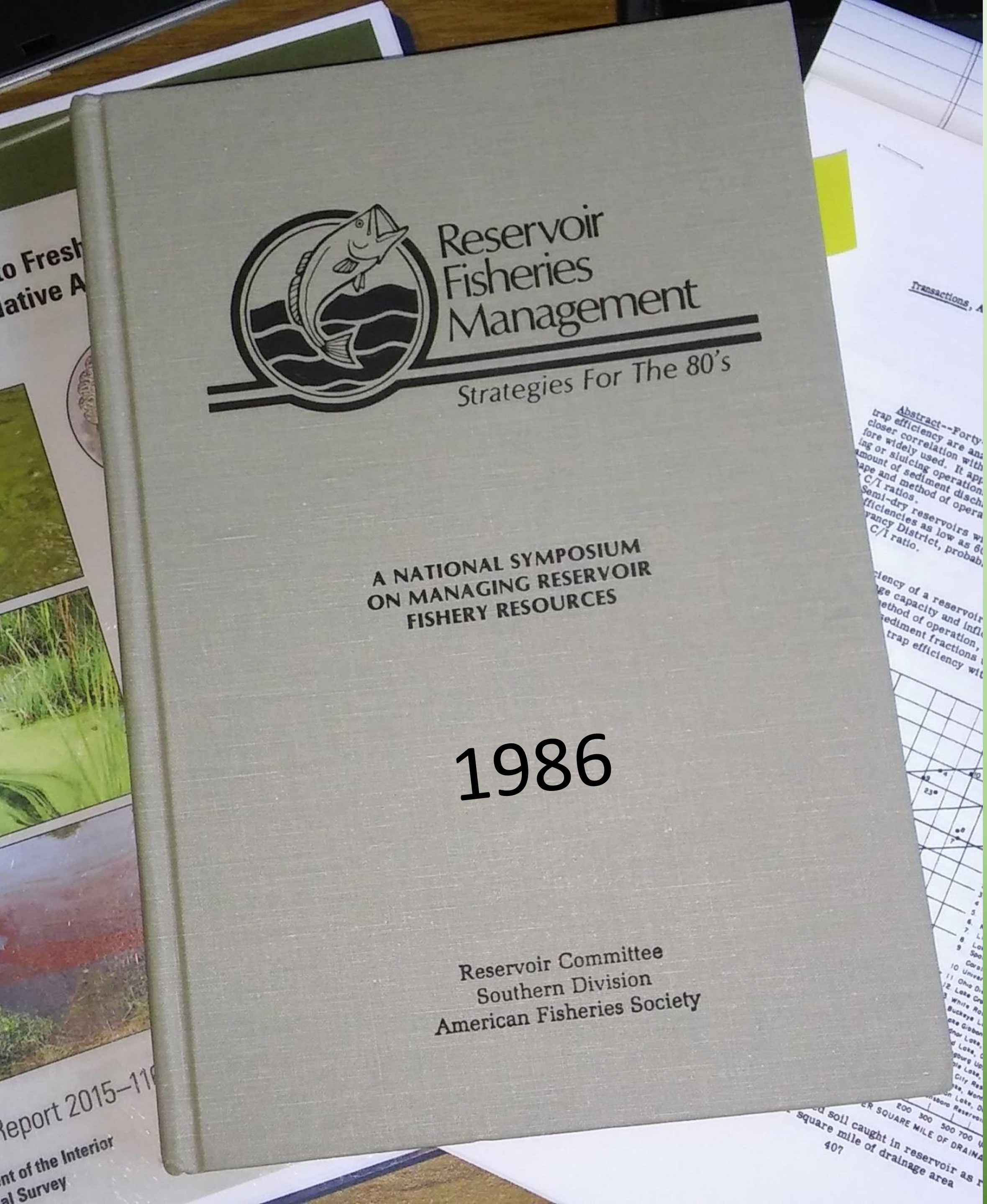
and measure in real time.



Classic text and reference books/manuals:

- 1st edition, Cooke and others' *Lake and Reservoir Restoration* (1983)
- Southern Division of AFS's *Reservoir Fisheries Management: Strategies for the 80's* (1986)
- 1st edition, USEPA's *Lake and Reservoir Guidance Manual* (1988)
- Thornton, Kimmel, and Payne's, *Reservoir Limnology: Ecological Perspectives* (1990)

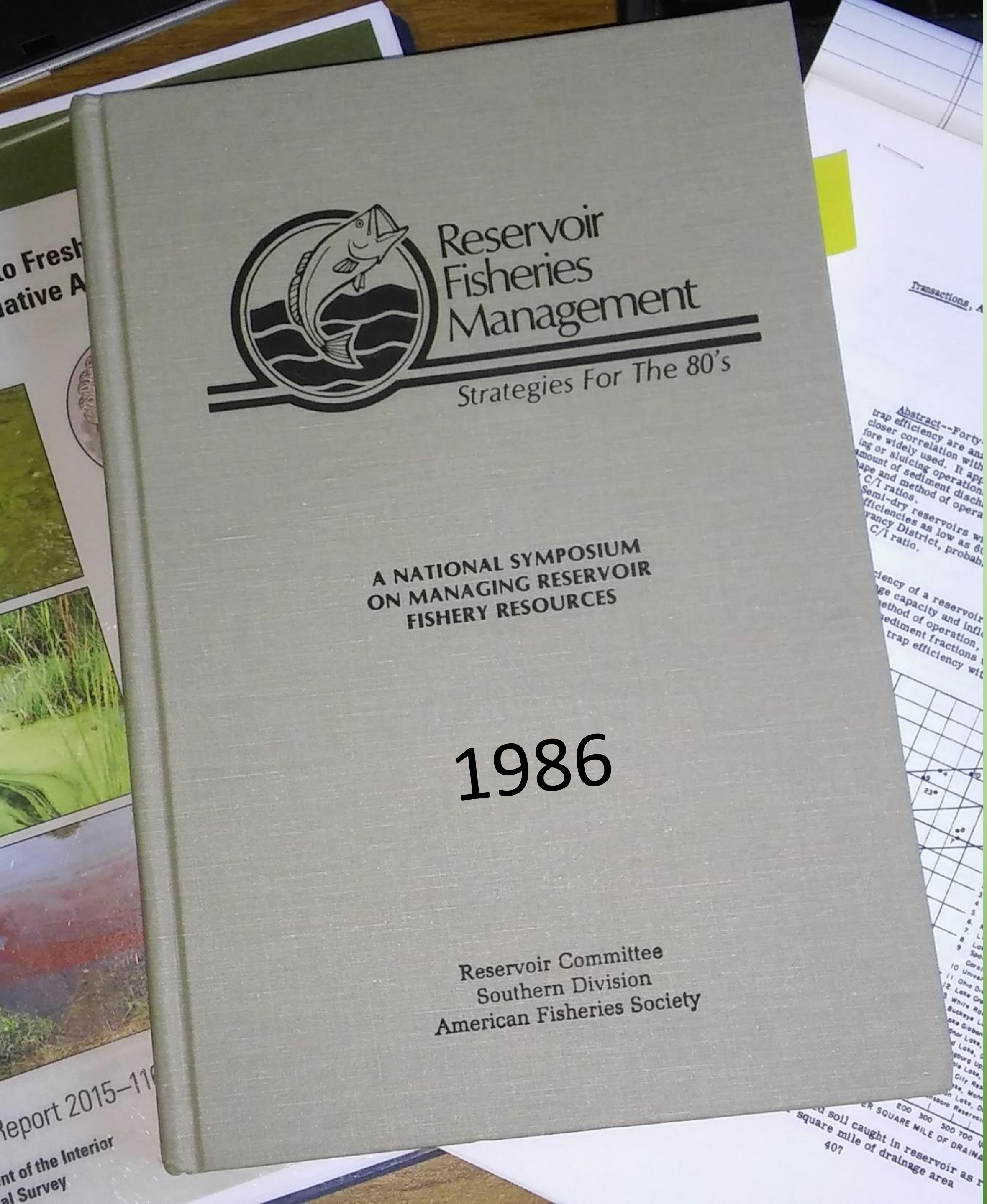




Preface

"Reservoirs now constitute and will undoubtedly continue to be one of our most valuable fishery resources—a resource that is exceedingly complex, poorly understood, and crudely managed, at best. As such, reservoirs continue to provide major fishery management problems and consequently offer tremendous opportunities for improvement……"

– Gordon E. Hall & Fred A. Harris

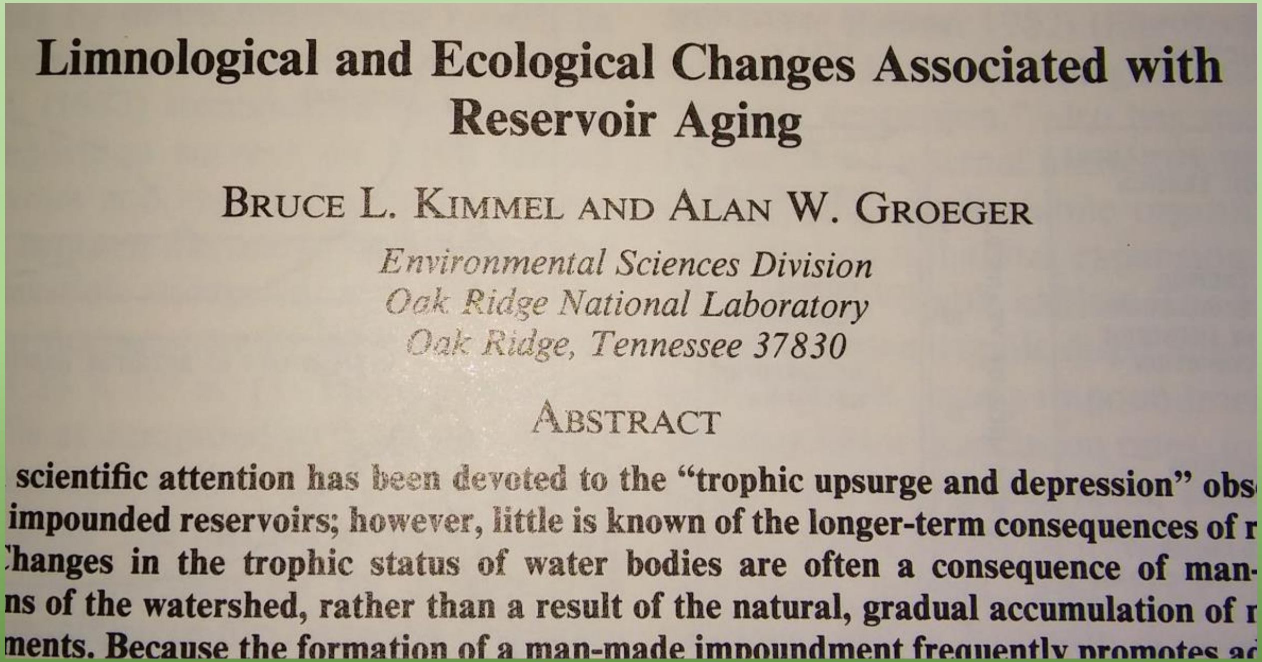


Which brought us,

- *Evaluation of stocking inland silversides as supplemental forage for largemouth bass and white crappie*, by Jeff Boxrucker

- and I'm sure many other reports from Oklahoma.

Reservoir Fisheries Management (1986) brought us:



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

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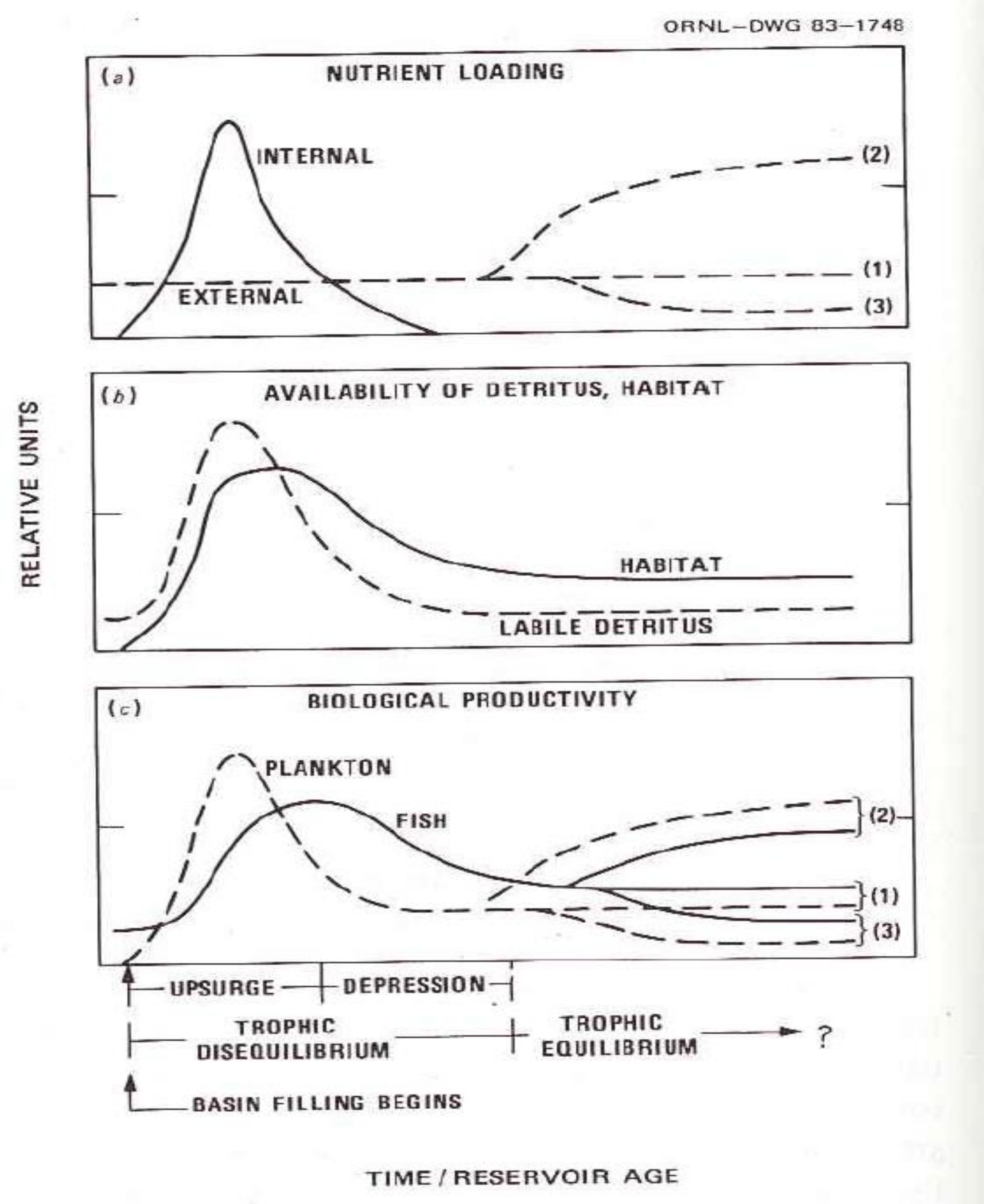


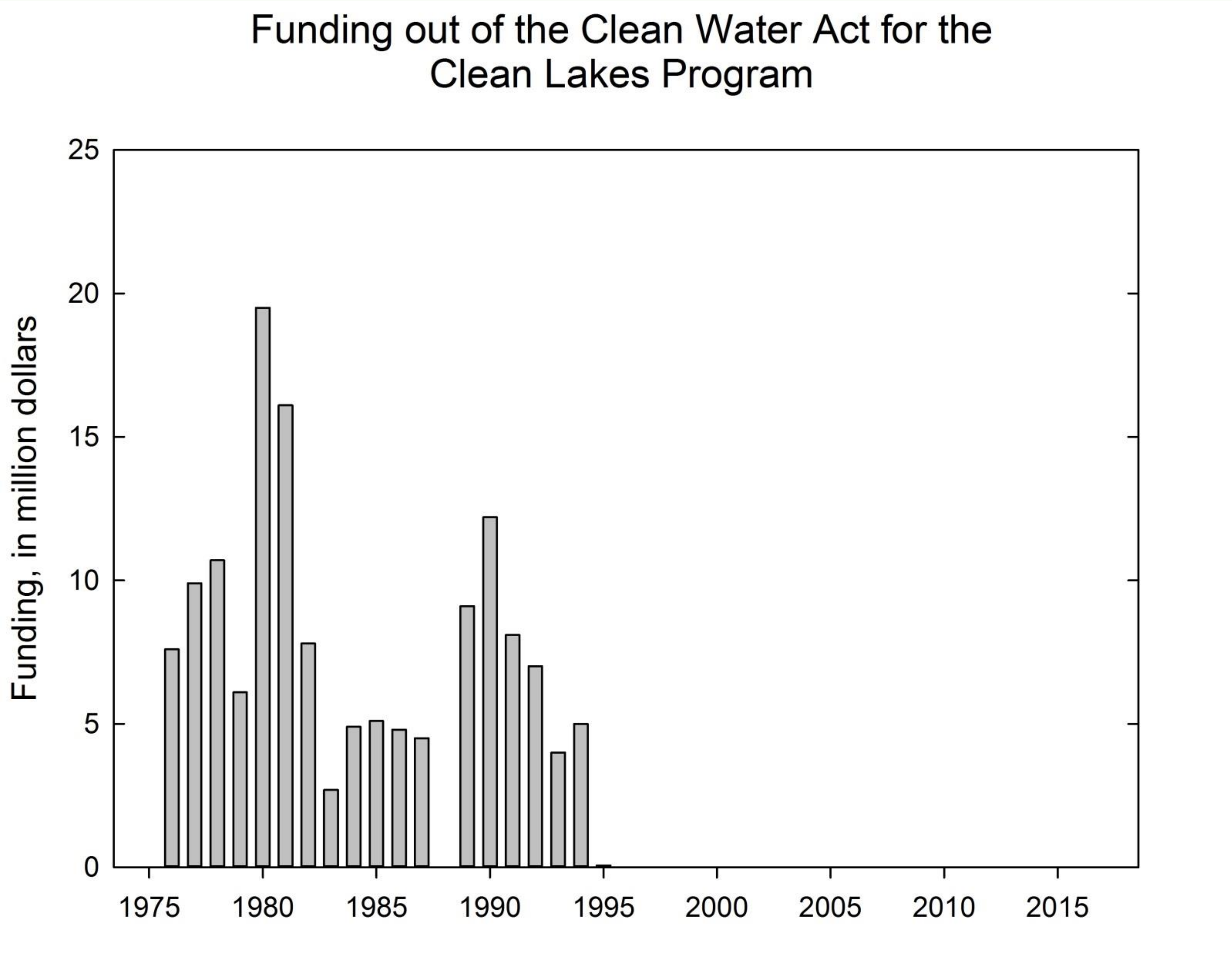
Reservoir Fisheries and Water-Quality Programs that have *expired*

- Tennessee Valley Authority (???)

- USFWS National Reservoir Research Program (early 1980’s)
  - **White River (University of Arkansas)**
  - Upper Missouri River

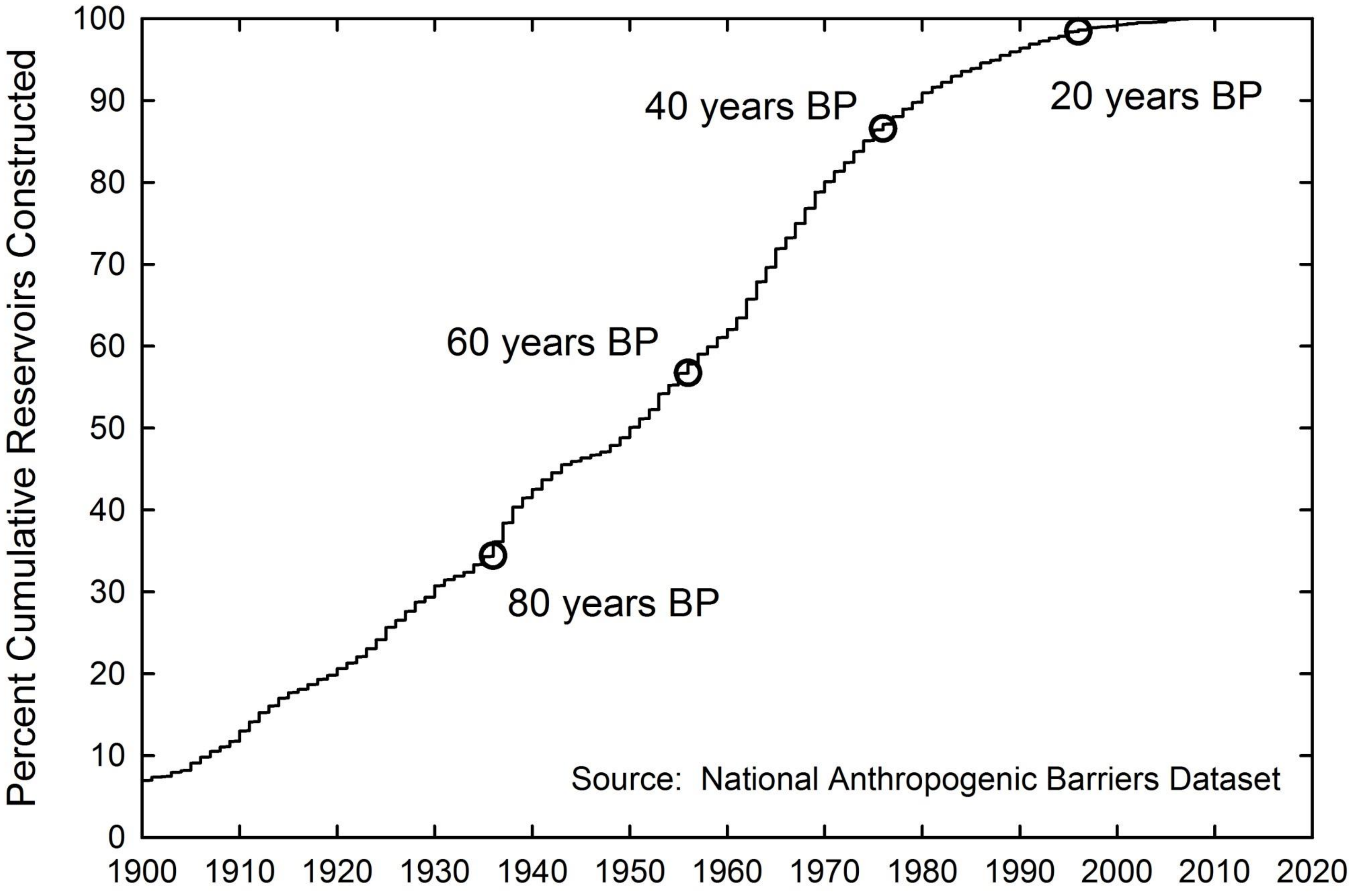
- USACE Reservoir Water Quality Research Program (late 1980’s)

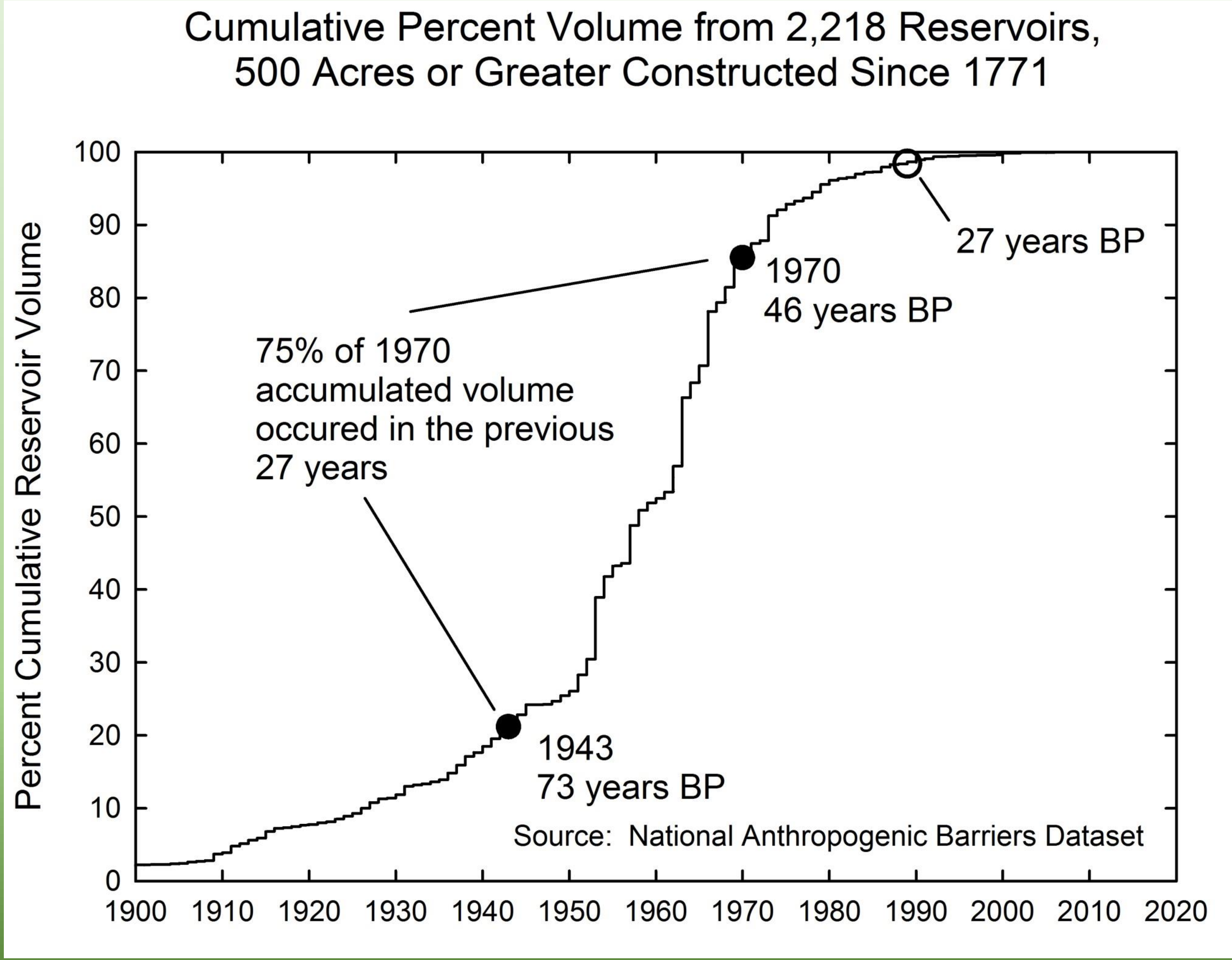
Federal Clean Lakes Program Funding:



Source: http://water.epa.gov/type/lakes/lakesb.cfm

Cumulative Percent of 2,218 Reservoirs, 500 Acres or Greater Constructed Since 1771




Cumulative Percent Volume from 2,218 Reservoirs,
500 Acres or Greater Constructed Since 1771
Percent Cumulative Reservoir Volume
0
10
20
30
40
50
60
70
80
90
100
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
75% of 1970
accumulated volume
occured in the previous
27 years
1970
46 years BP
27 years BP
1943
73 years BP
Source: National Anthropogenic Barriers Dataset

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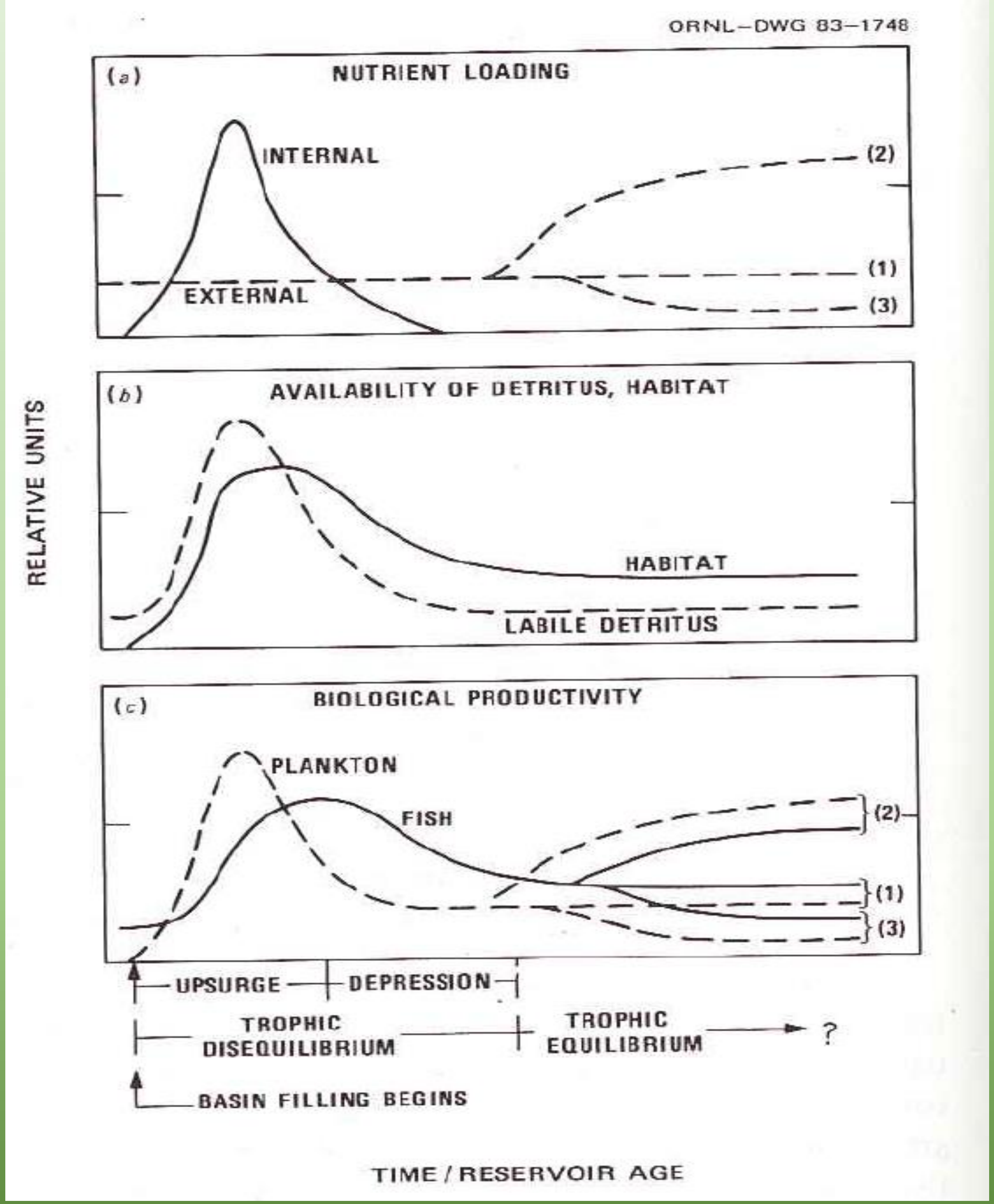
Much scientific attention has been devoted to the "trophic upsurge and depression" observed in recently impounded reservoirs; however, little is known of the longer-term consequences of reservoir aging. Changes in the trophic status of water bodies are often a consequence of man-induced alterations of the watershed, rather than a result of the natural, gradual accumulation of nutrients and sediments. Because the formation of a man-made impoundment frequently promotes additiona



Sediment (phosphorus) Trapping Efficiency

Brune, G.M., 1953, Trap efficiency of reservoirs. Transactions of the American Geophysical Union, 53: 407-418

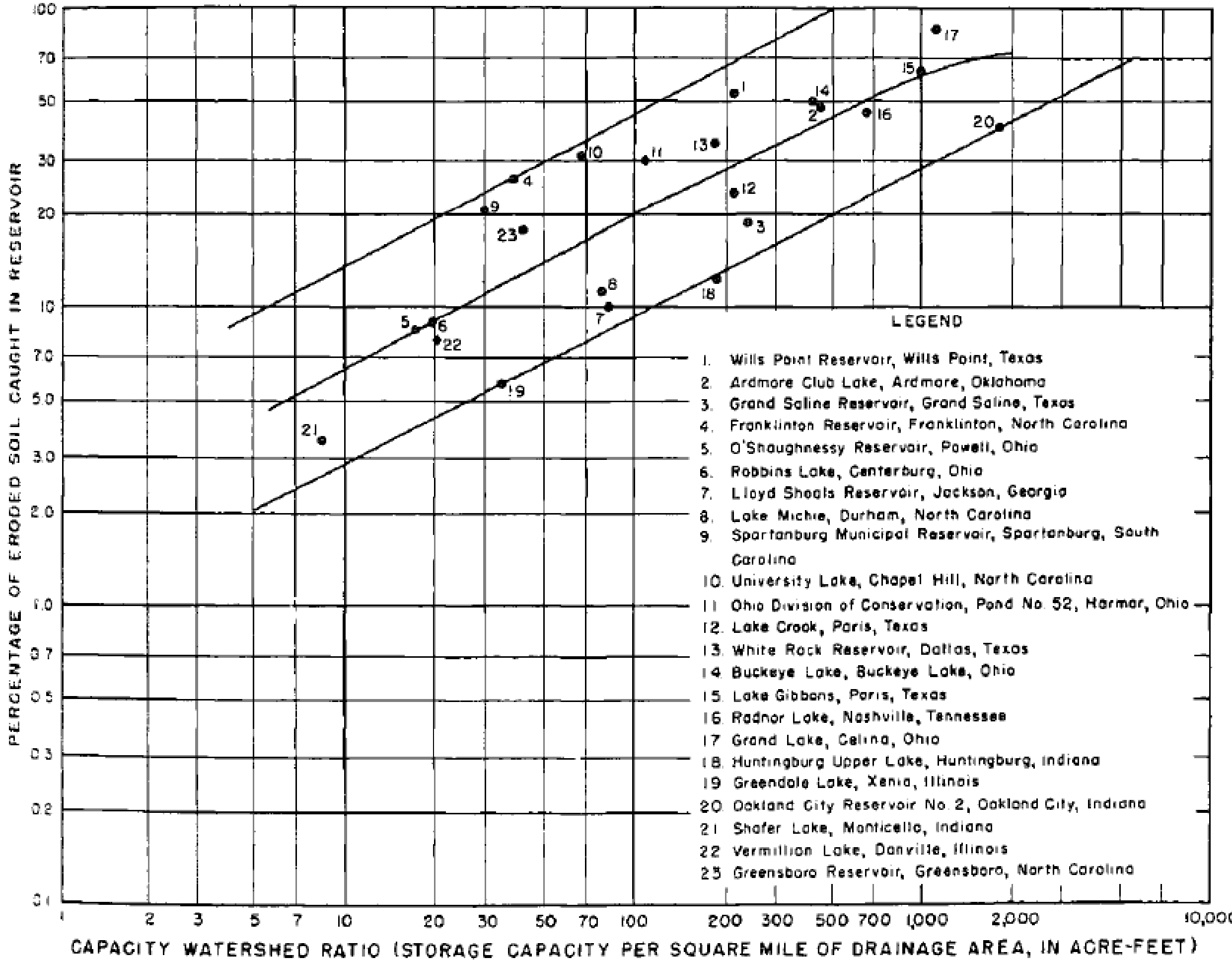


Fig. 1--Percentage of eroded soil caught in reservoir as related to capacity per square mile of drainage area

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]

[a]Ecohydrology Research Group, Water Institute, University of Waterloo, Waterloo, ON, Canada N2L 3G1; and [b]Department of Earth and Environmental Sciences, University of Waterloo, Waterloo, ON, Canada N2L 3G1

December 2015

- Mass of TP trapped in reservoirs nearly doubled between 1970 and 2000
- By 2030, about 17% of the global river TP load will be sequestered in reservoir sediments
- The resulting growth in riverine phosphorus export will likely contribute to the expanding eutrophication of surface waters worldwide.

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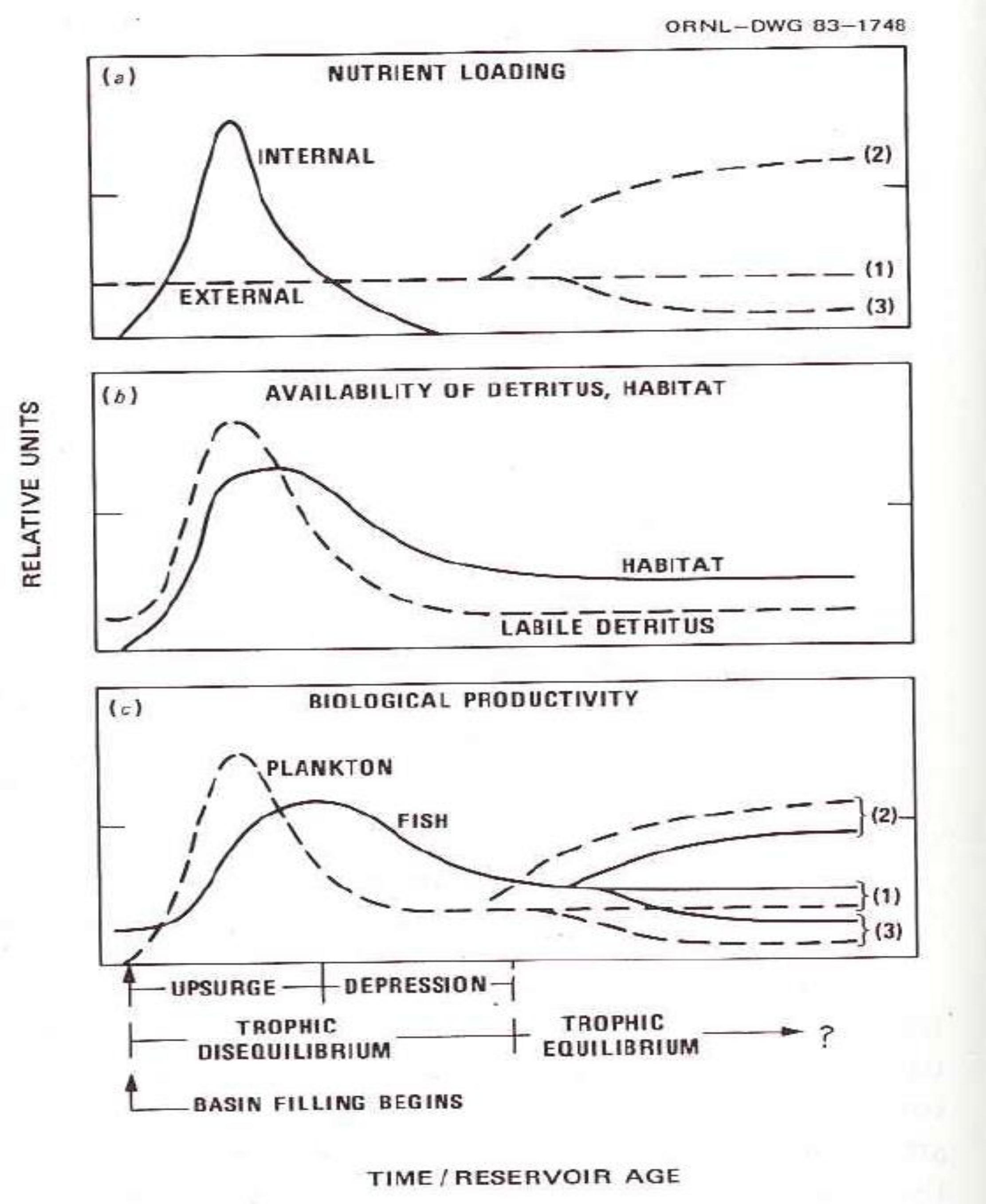

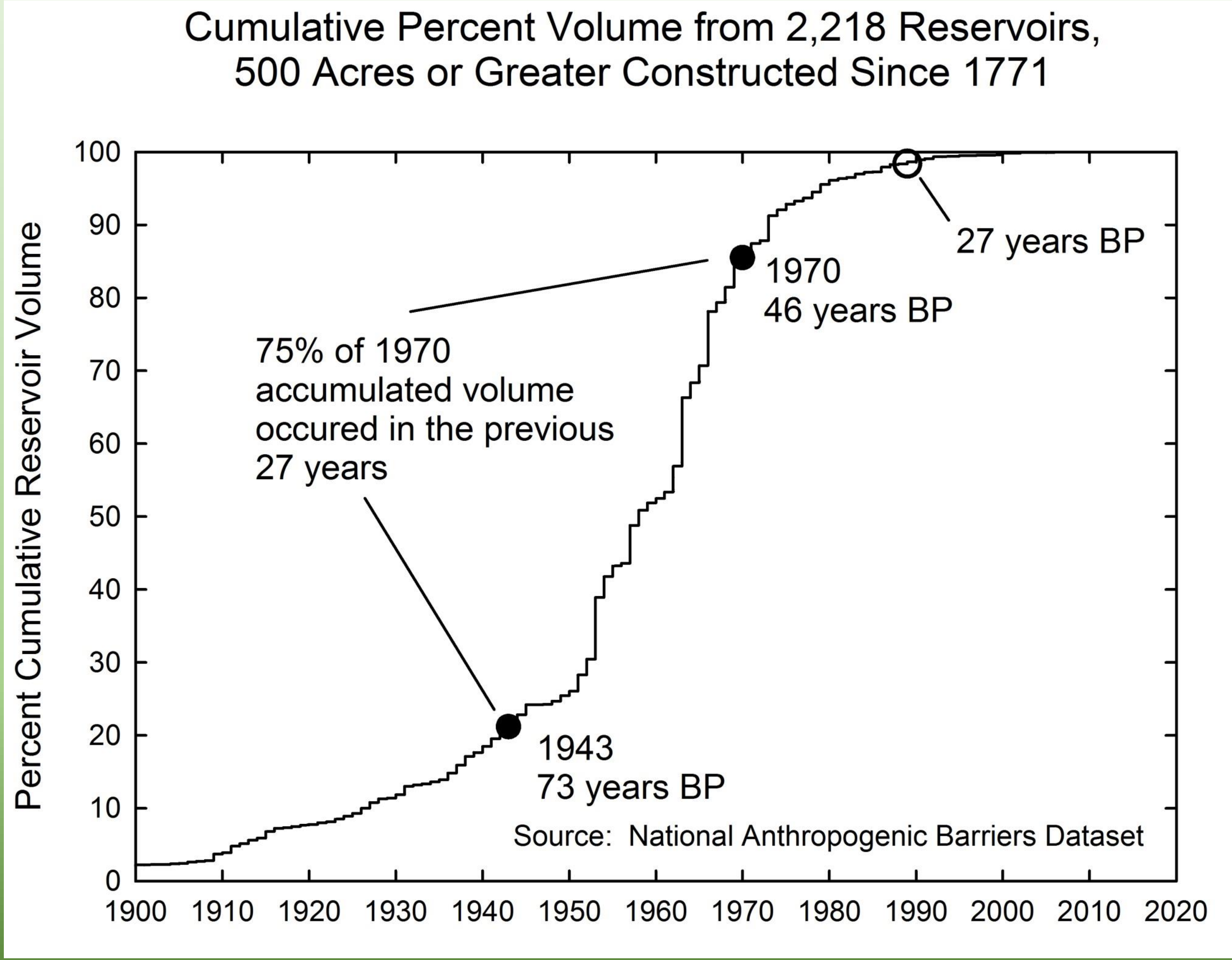
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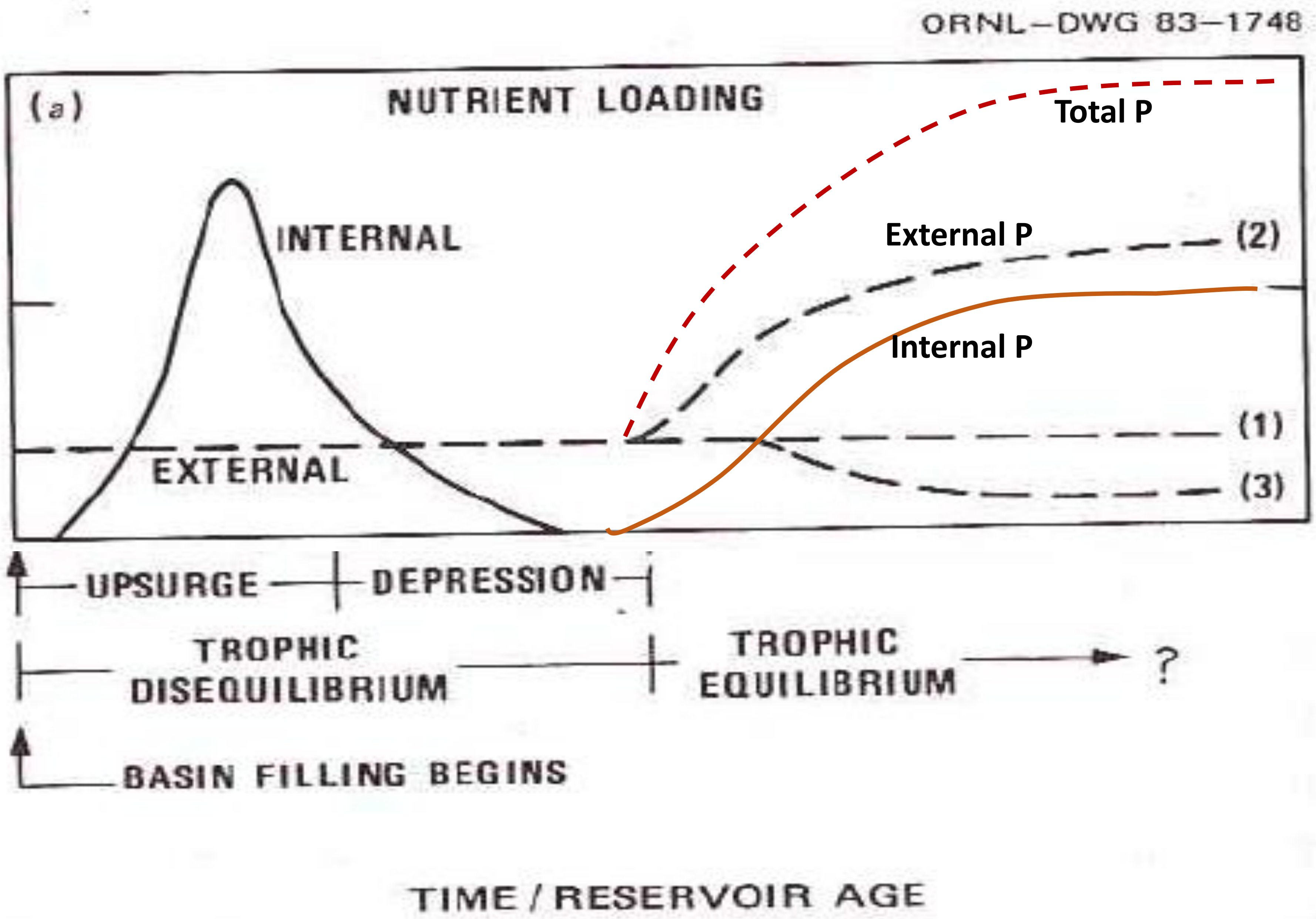
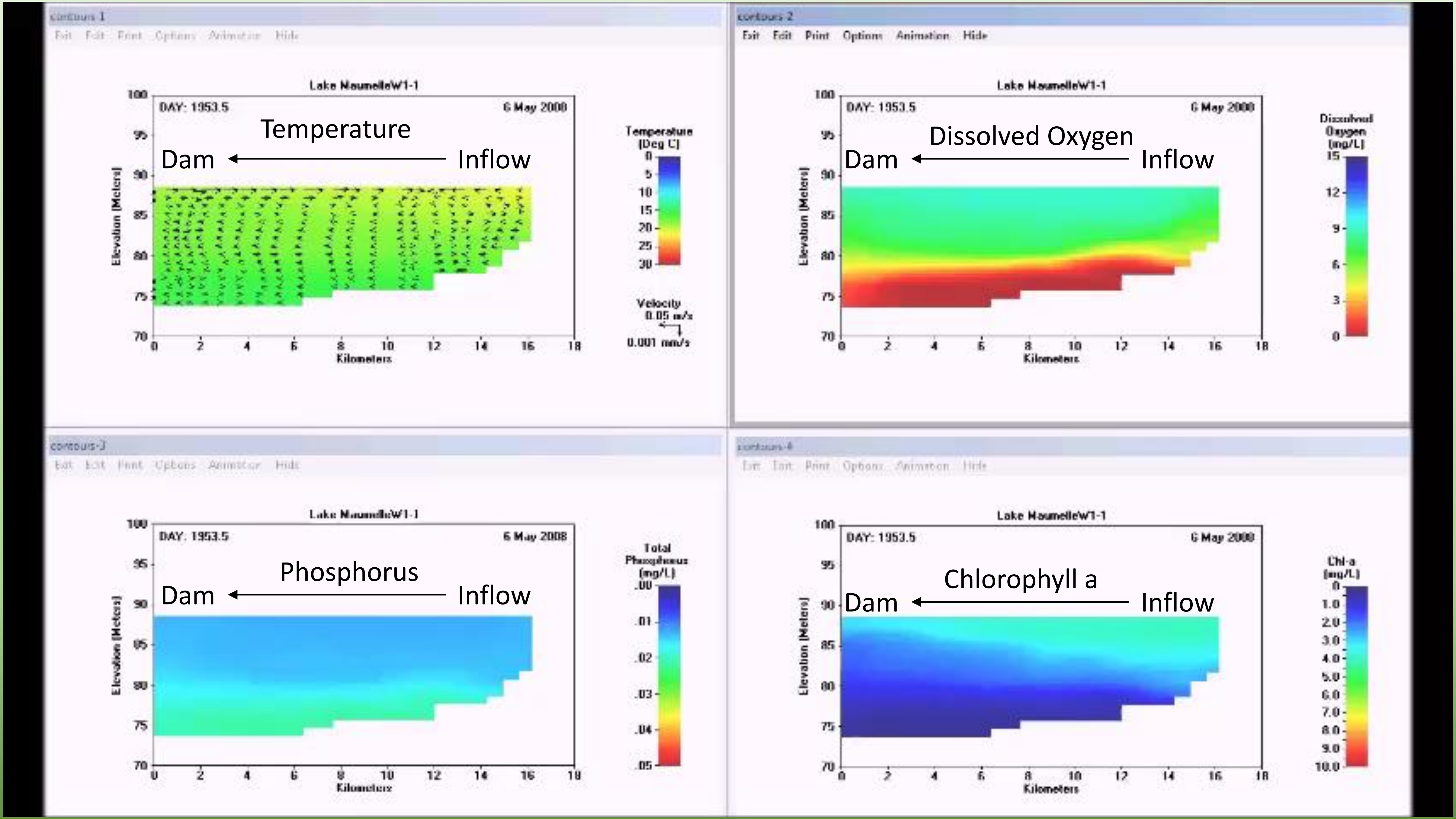
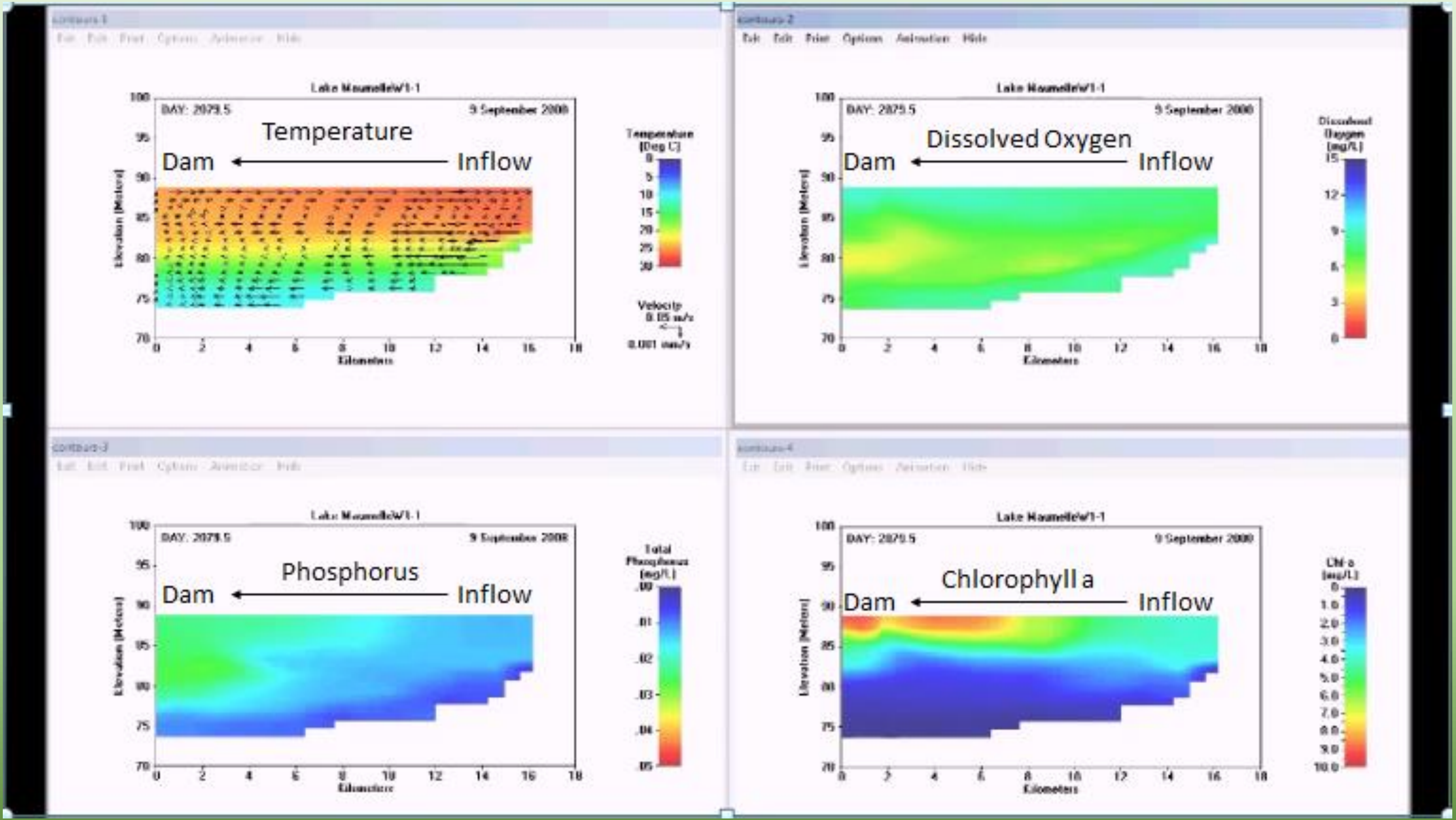
90
100
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
27 years BP
1970
46 years BP
75% of 1970
accumulated volume
occured in the previous
27 years
1943
73 years BP
Source: National Anthropogenic Barriers Dataset

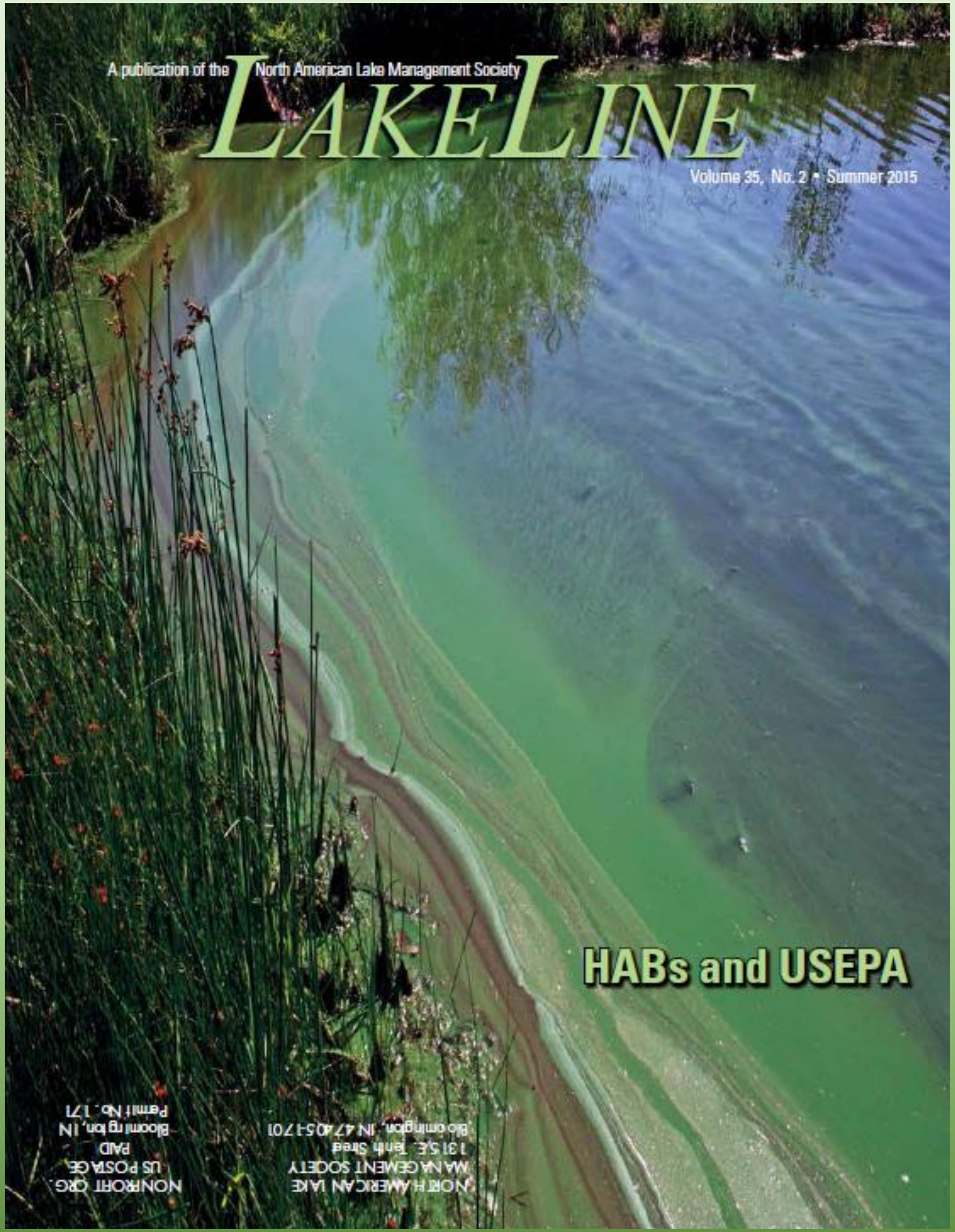

ORNL–DWG 83–1748
(a)
NUTRIENT LOADING
Total P
INTERNAL
External P
(2)
Internal P
(1)
EXTERNAL
(3)
UPSURGE
DEPRESSION
TROPHIC
DISEQUILIBRIUM
TROPHIC
EQUILIBRIUM
?
BASIN FILLING BEGINS
TIME / RESERVOIR AGE



contours-1
Exit Edit Print Options Animation Hide
Lake MaumelleW1-1
DAY: 1953.5
6 May 2008
Temperature
Dam
Inflow
Elevation (Meters)
Kilometers
Temperature (Deg C)
Velocity
0.05 m/s
0.001 mm/s
contours-2
Exit Edit Print Options Animation Hide
Lake MaumelleW1-1
DAY: 1953.5
6 May 2008
Dissolved Oxygen
Dam
Inflow
Elevation (Meters)
Kilometers
Dissolved Oxygen (mg/L)
contours-3
Lake MaumelleW1-1
DAY: 1953.5
6 May 2008
Phosphorus
Dam
Inflow
Elevation (Meters)
Kilometers
Total Phosphorus (mg/L)
contours-4
Lake MaumelleW1-1
DAY: 1953.5
6 May 2008
Chlorophyll a
Dam
Inflow
Elevation (Meters)
Kilometers
Chl-a (mg/L)


Temperature
Dam
Inflow
Dissolved Oxygen
Dam
Inflow
Phosphorus
Dam
Inflow
Chlorophyll a
Dam
Inflow
DAY: 2079.5
9 September 2008
Kilometers
Elevation (Meters)

Cyanobacteria – harmful algal blooms



Conditions affecting blooms

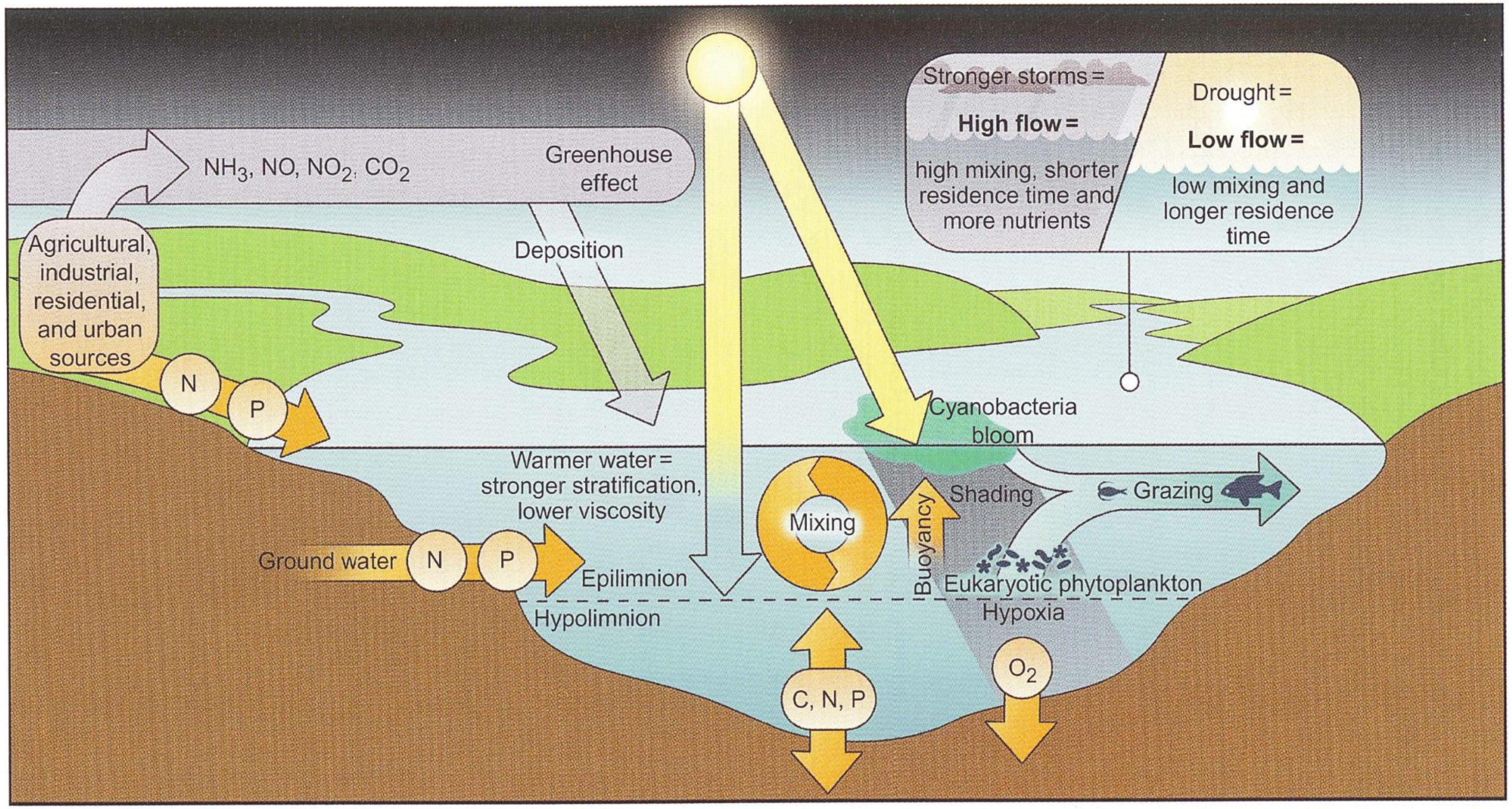


FIGURE 2 Conceptual diagram illustrating external and internal factors controlling growth, accumulation (as blooms), and fate of cHABs in freshwater ecosystems. Factors can act individually or in combined (synergistic, antagonistic) ways.

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

Reservoir Metrics

- **Osgood Index** – a reflection of the degree of mixing of a lake or reservoir due to the forces of wind. A low Osgood Index number indicates a large, shallow waterbody which is readily mixed by wind. The lake or reservoir may become stratified during periods of less wind or calm. Osgood Index is determined by dividing the mean depth Z (m) by the square root of the surface area A (km^2)

  = Z / SQRT A.

- **Areal Erosion** – is a percentage of the lake bed that is subject to erosion and transportation processes

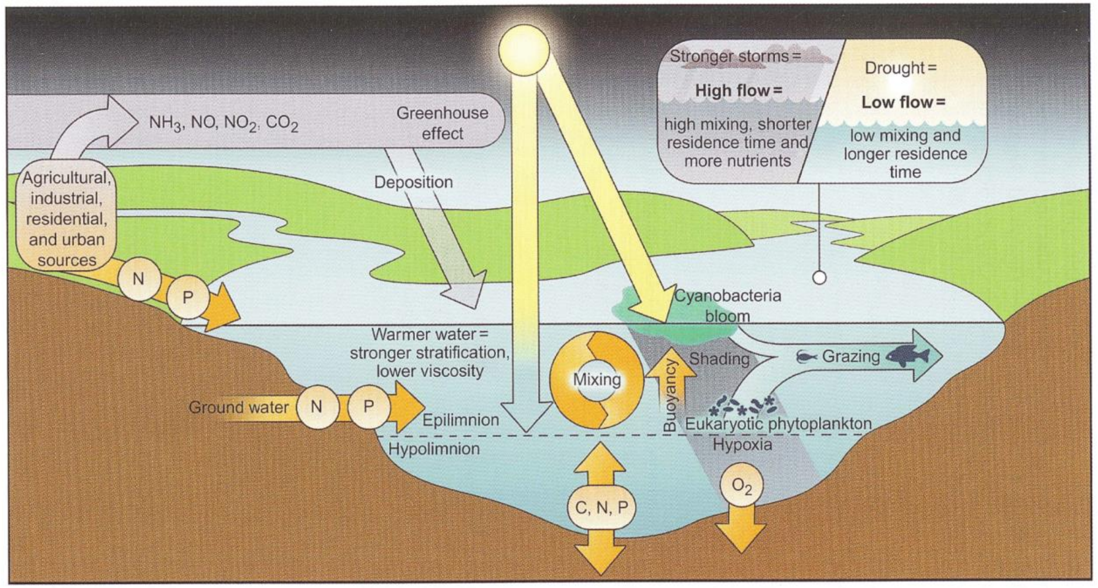
  = $25*((\text{SQRT } A) / (Z*(41^{(0.061*Z/\text{SQRT}(A))})))$.

Oklahoma reservoirs (dams) with the lowest Osgood Index

1. Hulah Lake
2. Great Salt Plains Lake
3. Eufaula Lake
4. McGee Creek
5. Robert S. Kerr L&D
6. Wister Lake
7. Oologah Lake
8. Hugo Lake
9. Copan Lake
10. Ft. Gibson Lake-Dike 9
11. Webbers Falls L&D
12. Keystone Lake
13. Canton Lake
14. Sardis Lake
15. Fort Supply Lake
16. Waurika Lake
17. Kaw Lake
18. Cushing Lake

Relations between TN, TP and microcystin

Scott, J.T. et al. 2013. Comment: An alternative interpretation of the relationship between TN:TP and microcystins in Canadian lakes. Can. J. Fish. Aquati. Sci. Vol. 70: 1265-1268.



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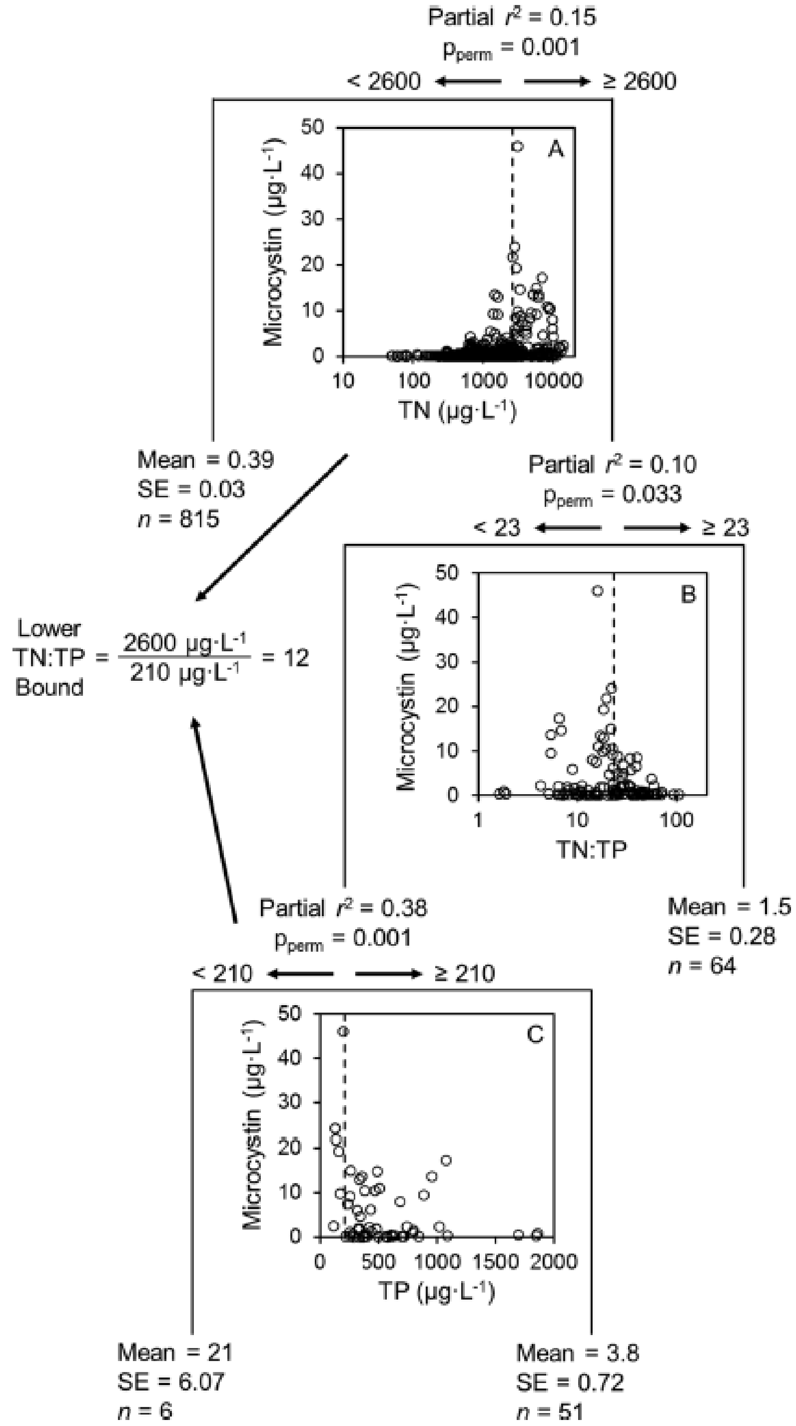

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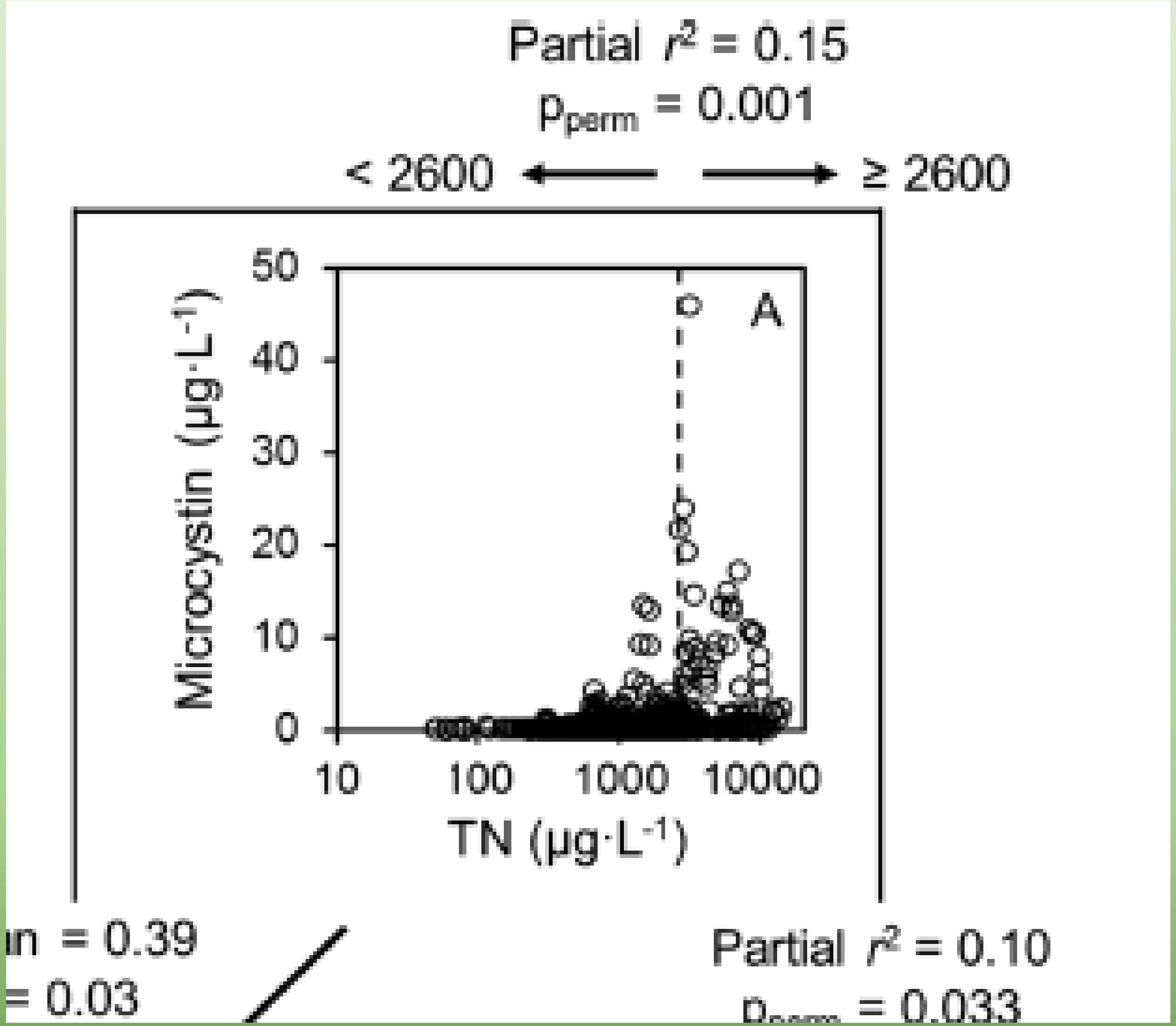

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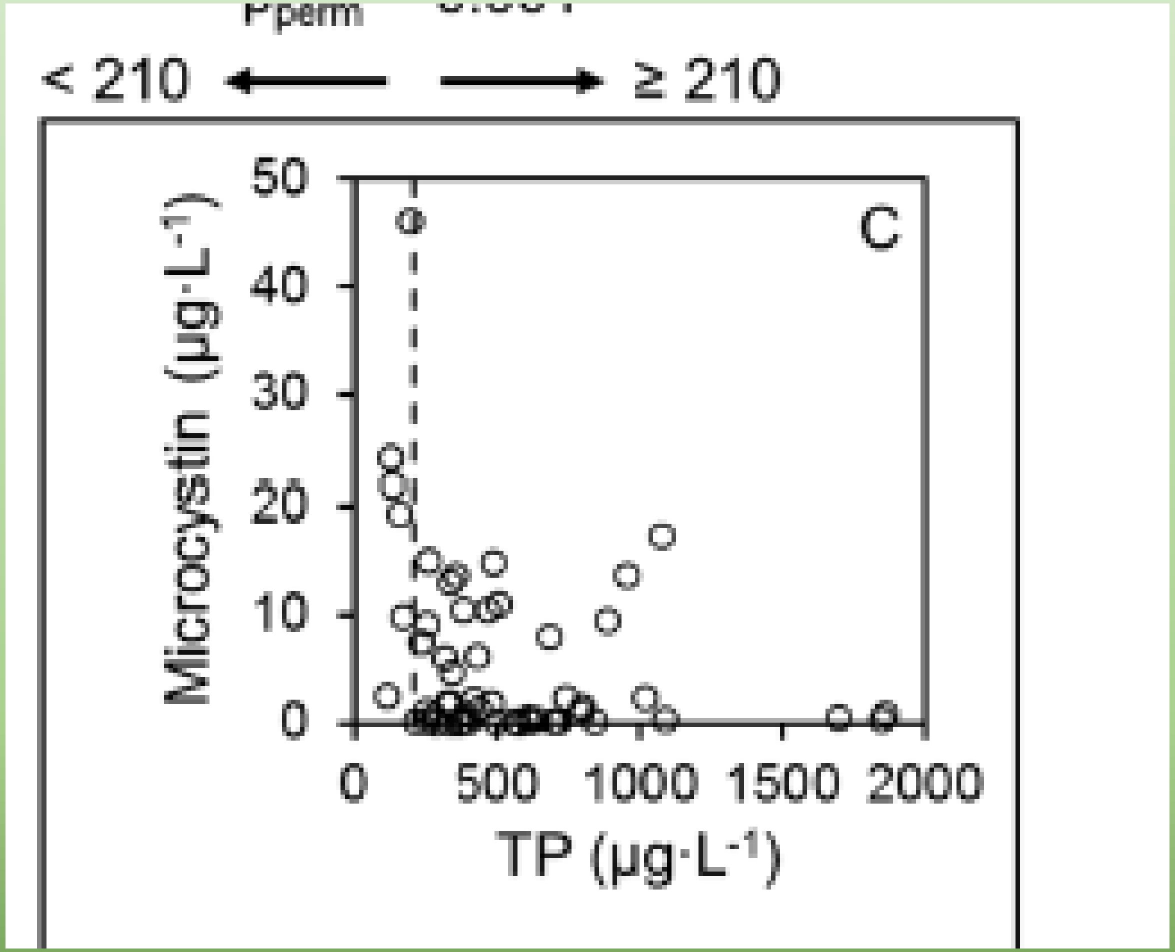

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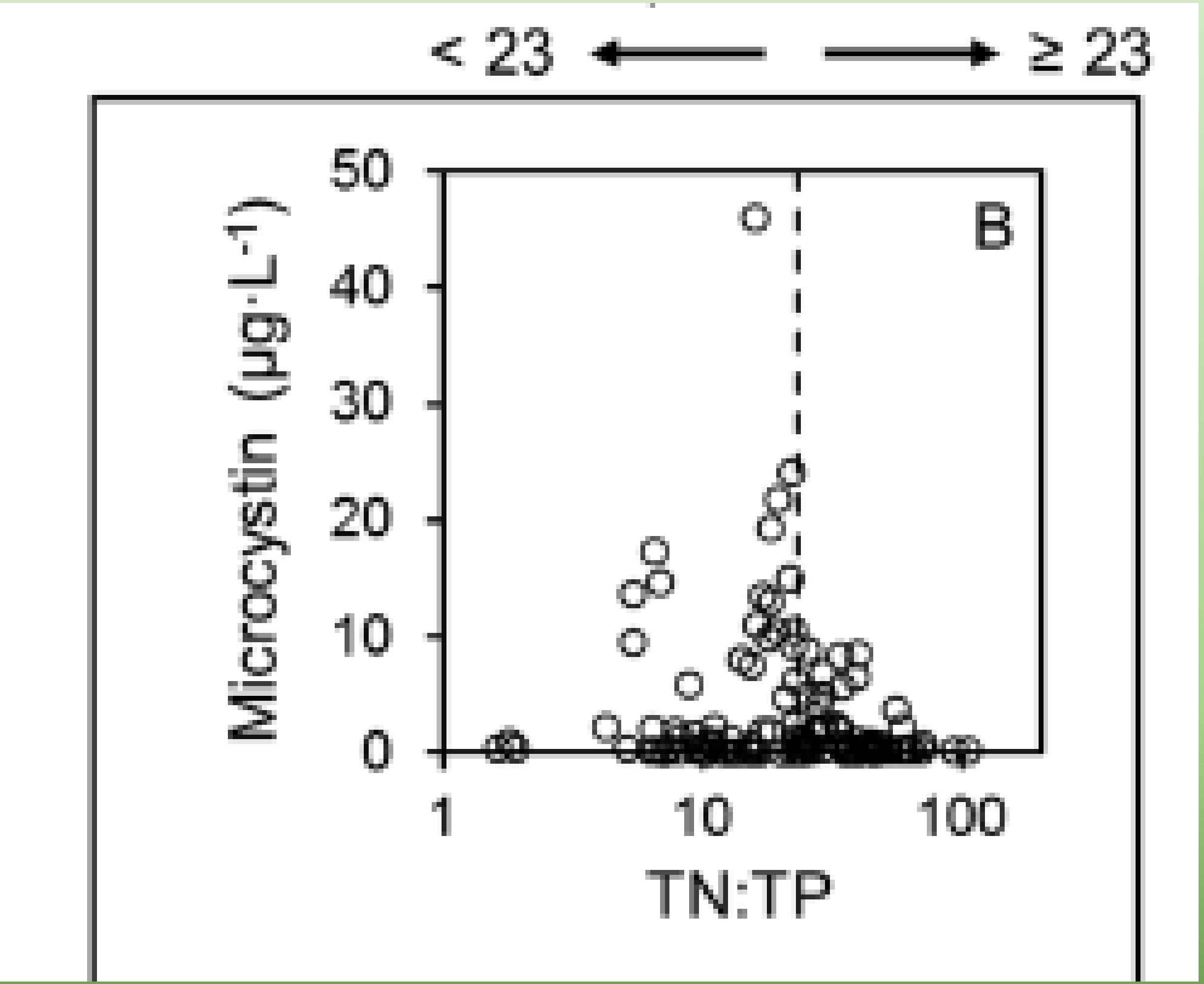

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-- Gordon E. Hall & Fred A. Harris

2016 (preface):

Reservoirs continue to be …………… (fill in the blank)?

How do we manage our aging reservoirs?

Internal phosphorus loading has to be recognized and accounted for in addition to external loading.

In many cases, episodic internal phosphorus loading during the summer thermal stratification season can be catastrophic in driving cyanoHABs and the consequences can be devastating.