



Hypolimnetic Dissolved-Oxygen Dynamics within Selected White River Reservoirs, Northern Arkansas and Southern Missouri, 1974-2008

White River Basin Comprehensive Study, Sponsor and Interagency Planning Team Meeting

August 24-25, 2010

Yellville, Arkansas

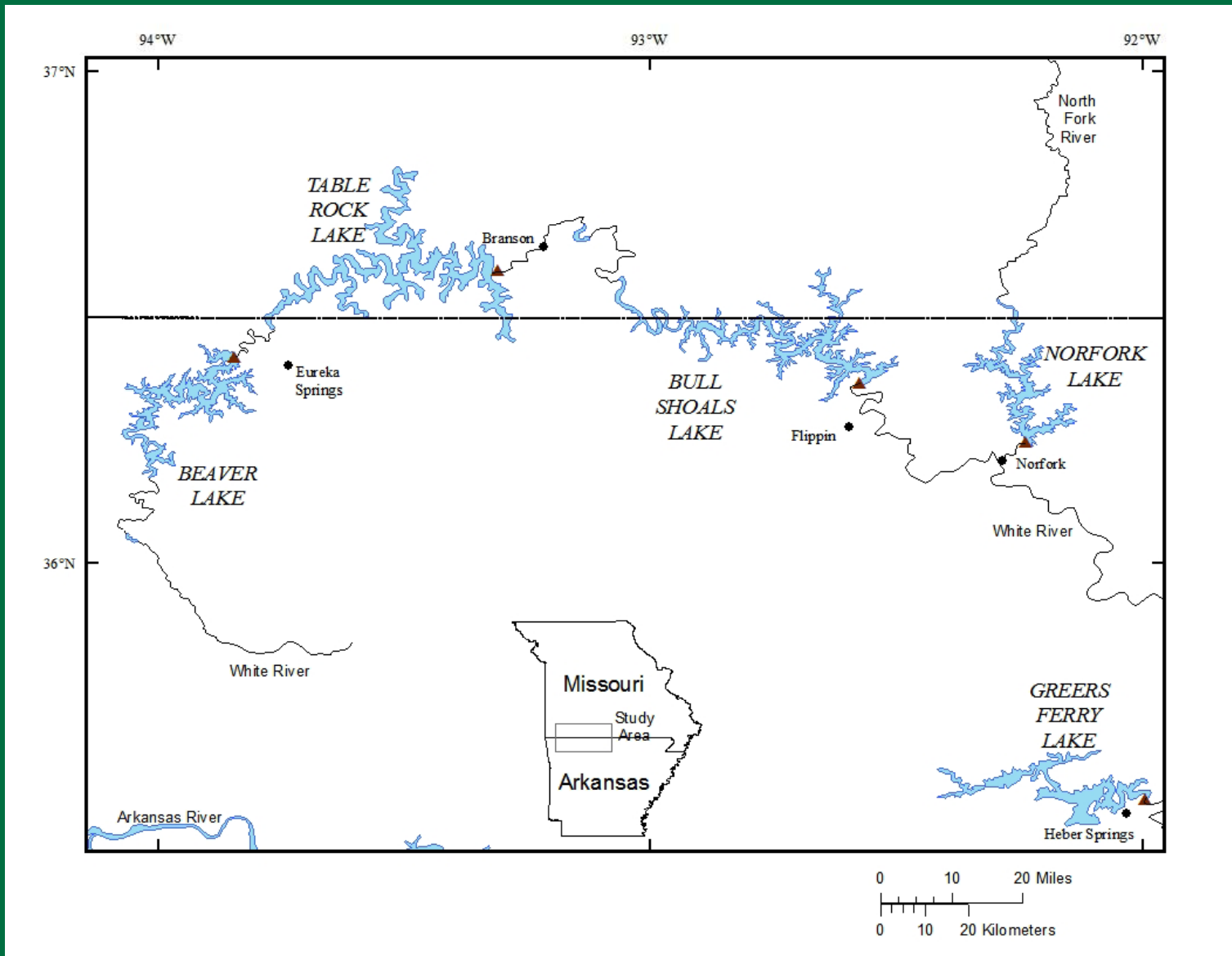
U.S. Department of the Interior
U.S. Geological Survey



US Army Corps of Engineers
Little Rock District

BUILDING STRONG

Study Area



Typical Thermal Stratification of a Lake

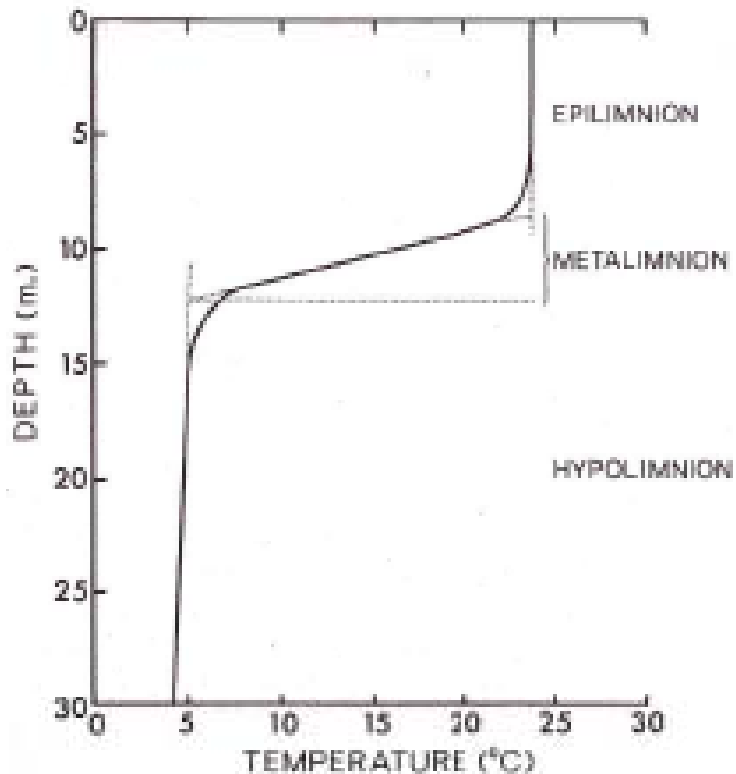
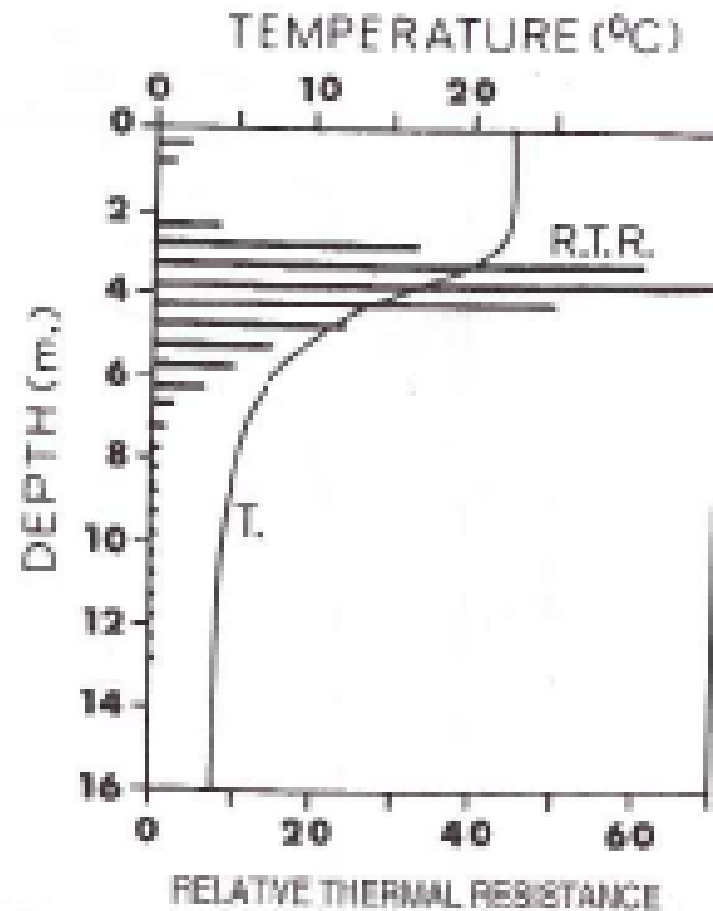
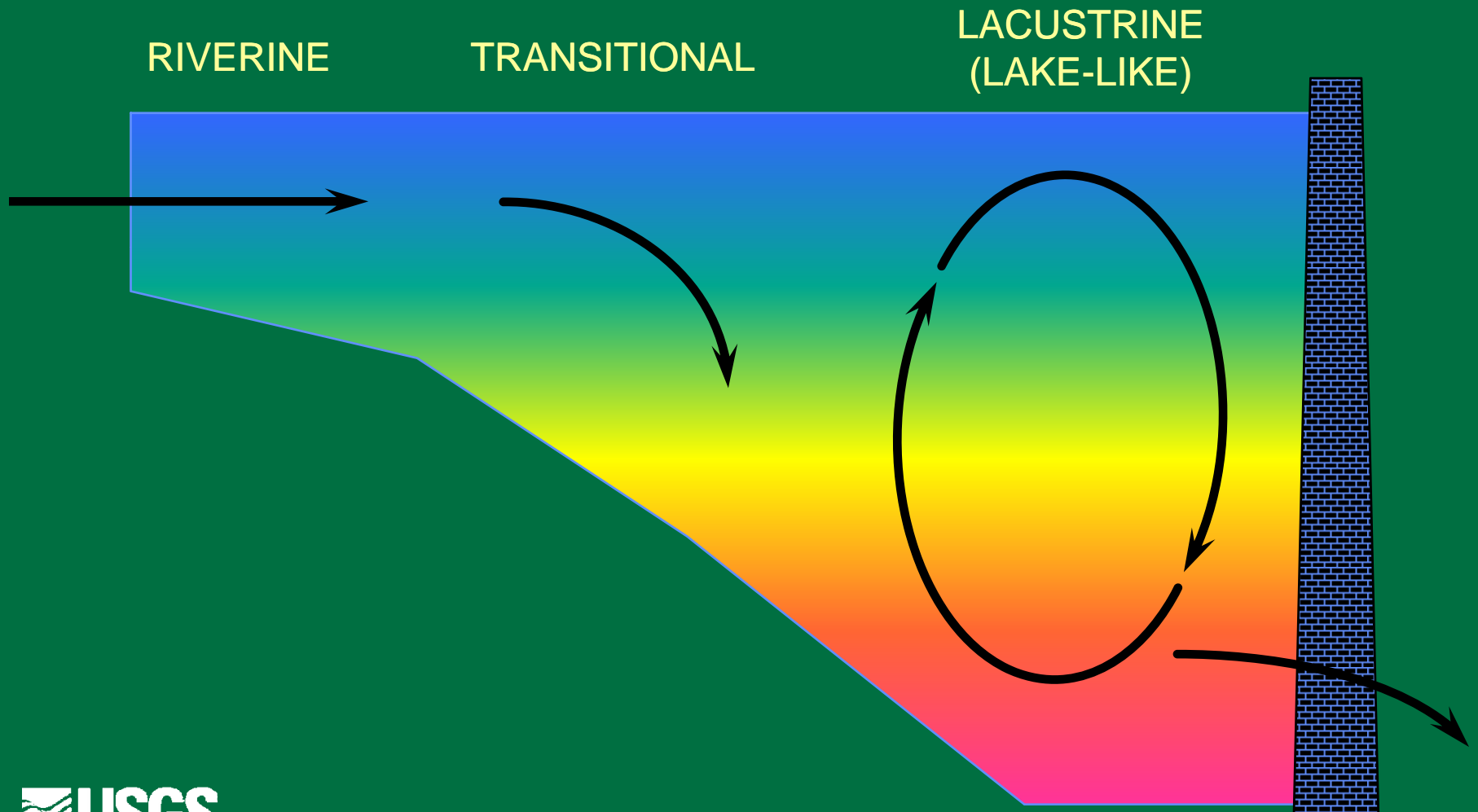


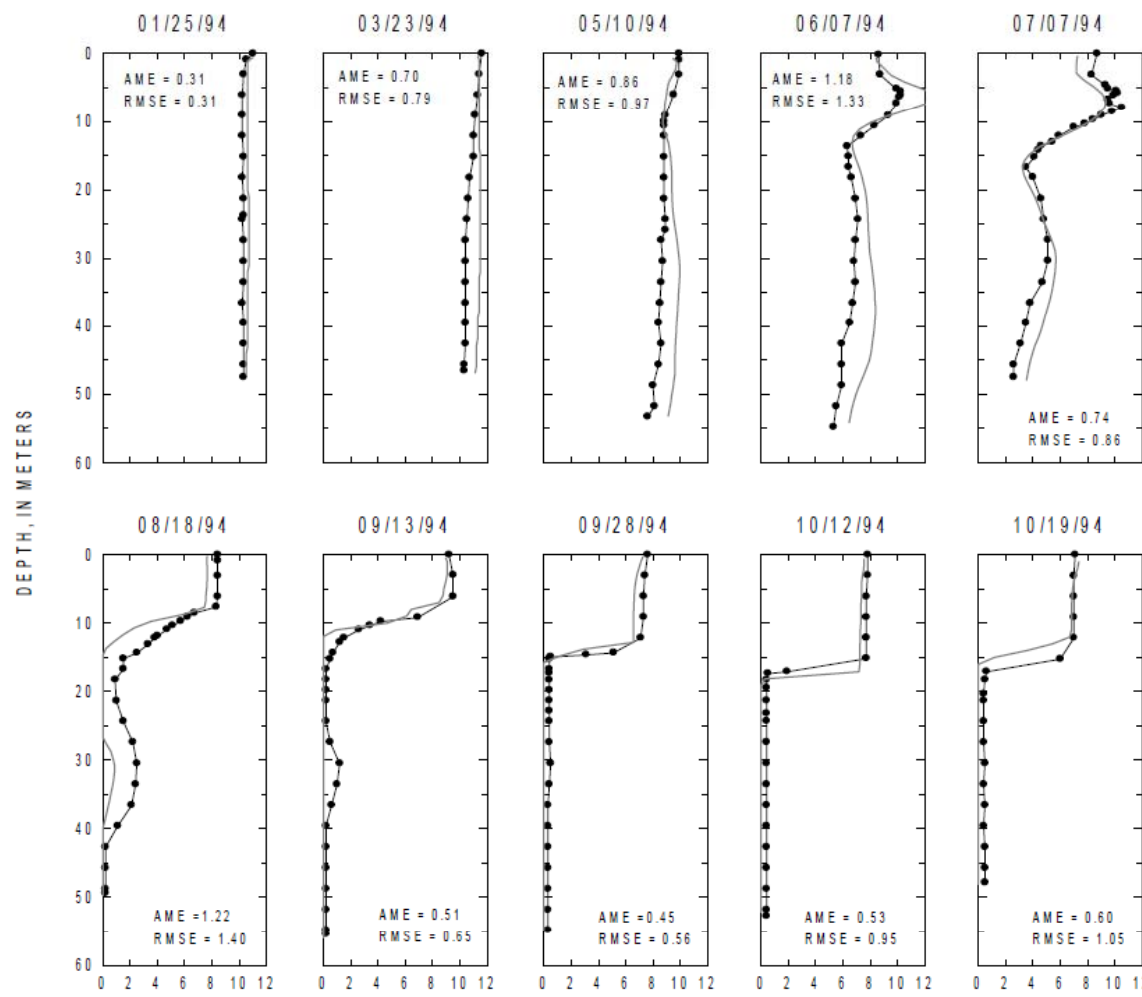
FIGURE 6-3 Typical thermal stratification of a lake into the epilimnetic, metalimnetic, and hypolimnetic water strata. Dashed lines indicate planes for determining the approximate boundaries of the metalimnion (see text).



Reservoir Zones



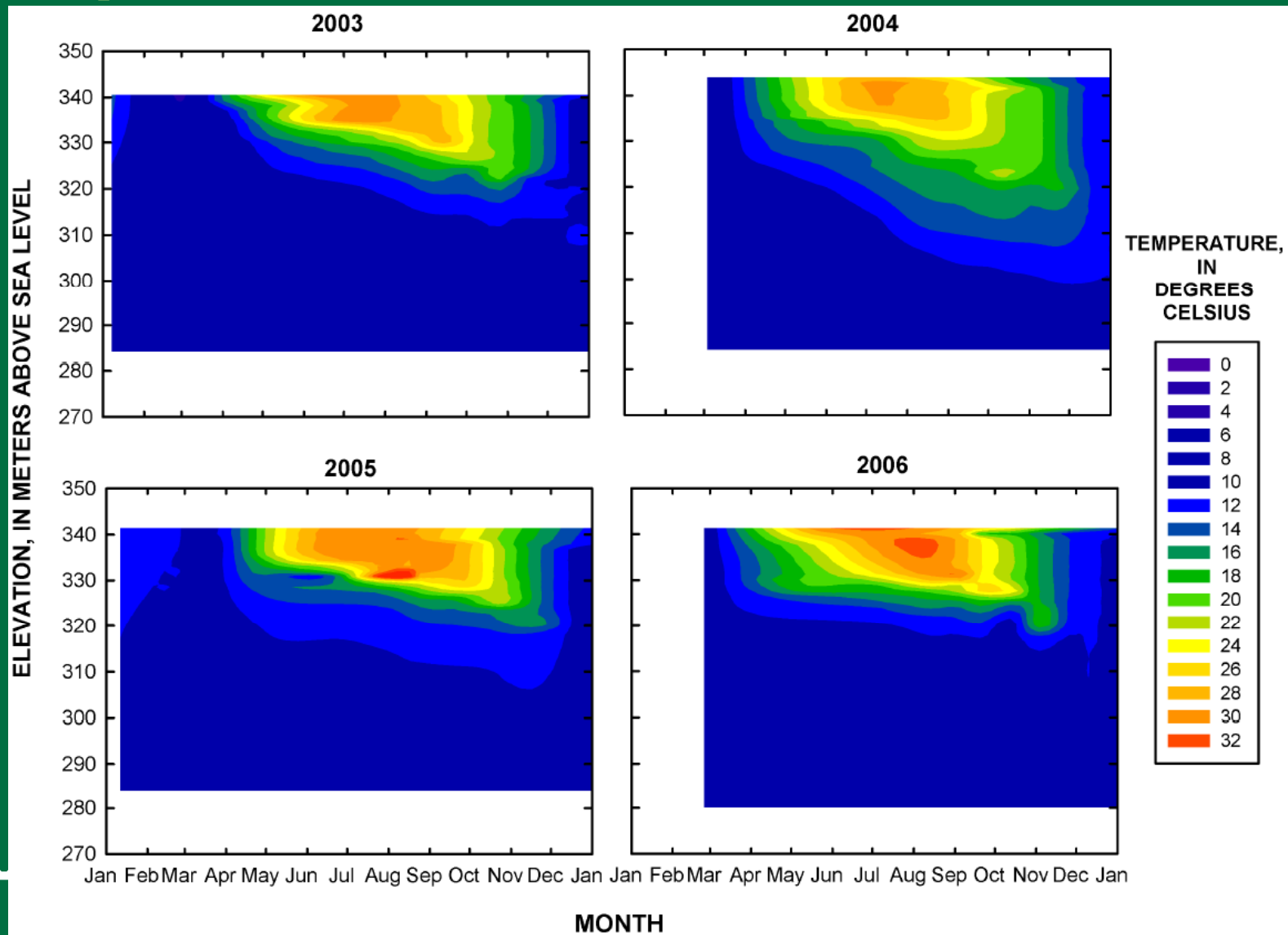
Vertical Dissolved Oxygen Profiles Measured Near the Dam



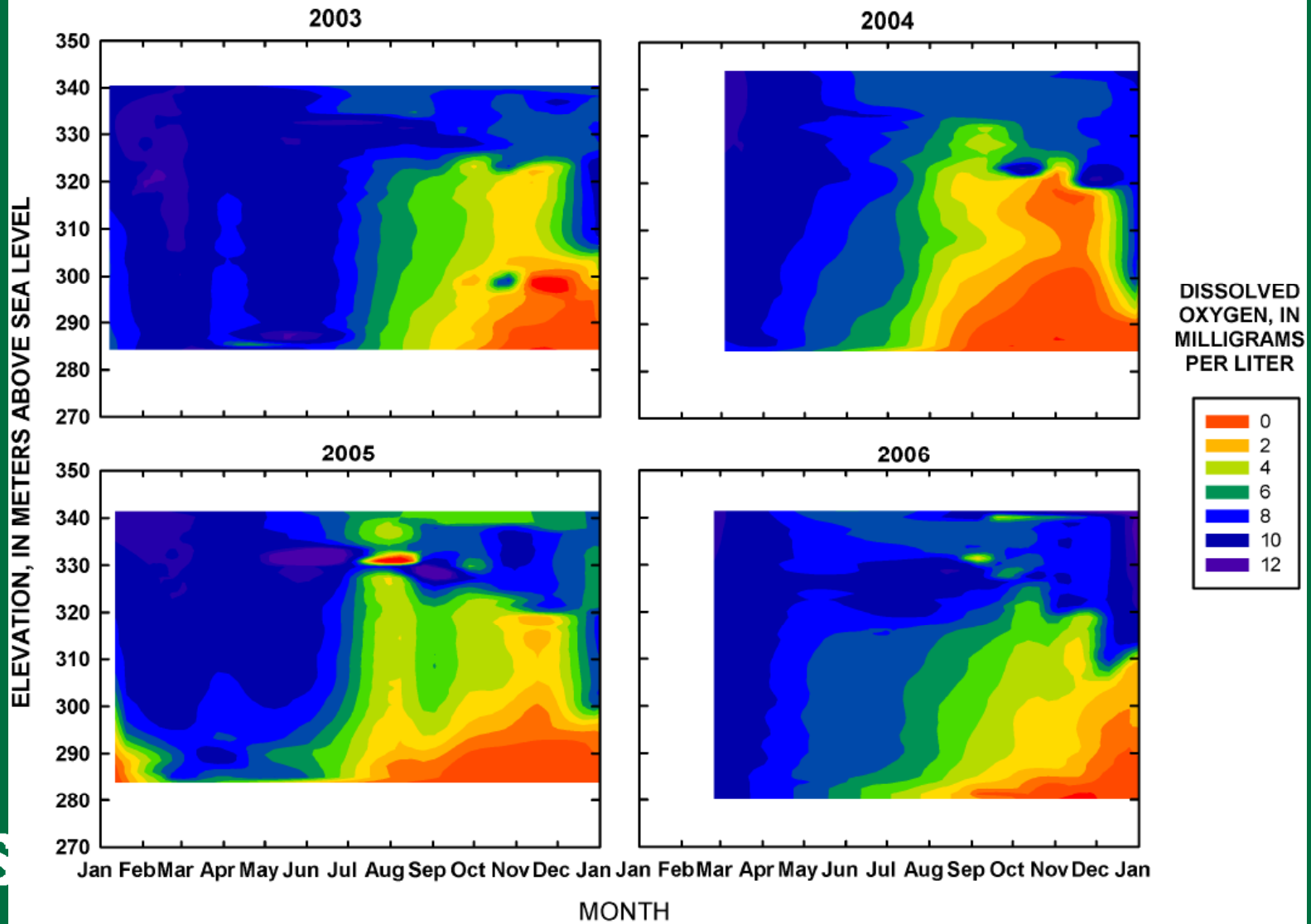
Dissolved Oxygen, in Milligrams per Liter



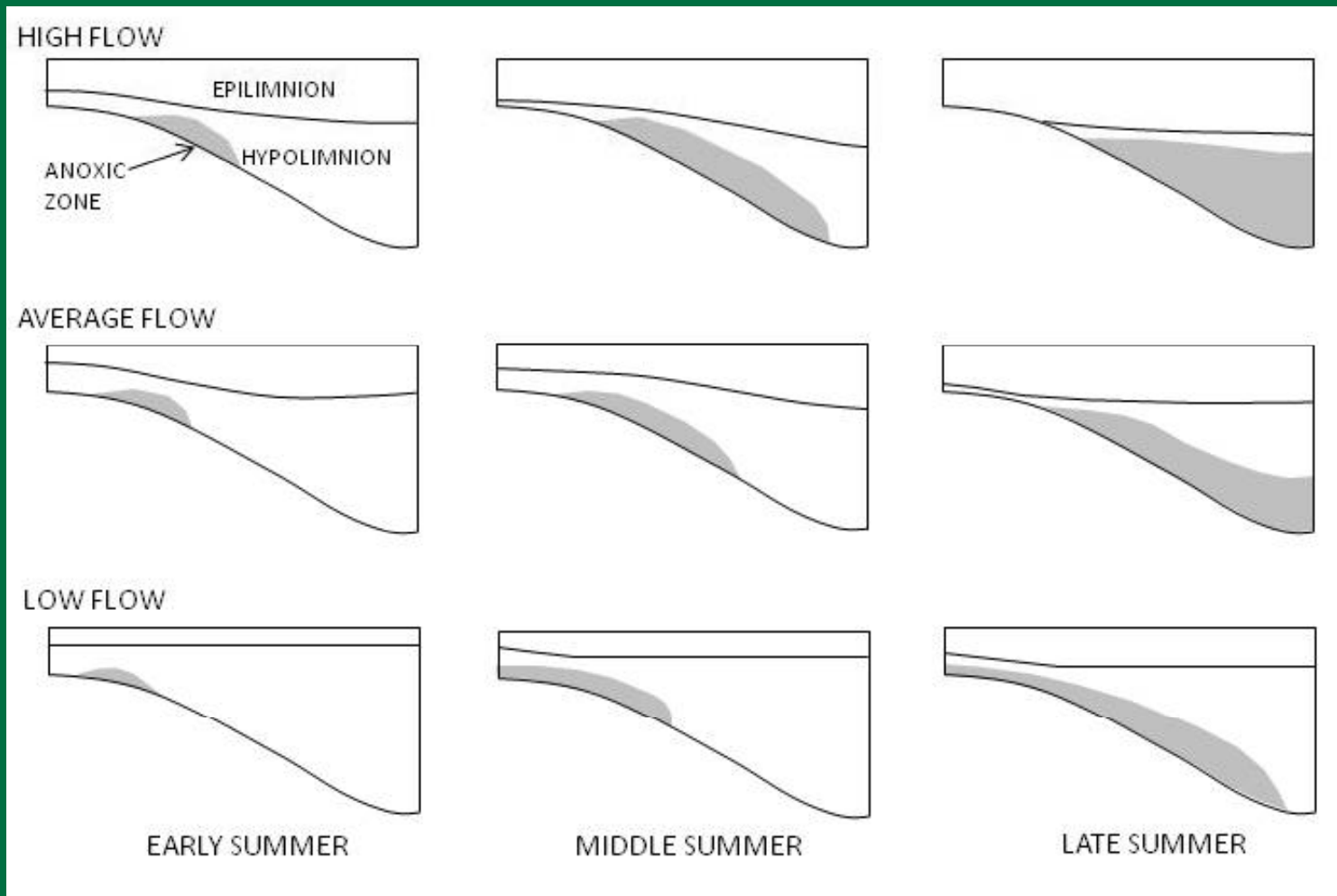
Beaver Lake Measured Water Temperature



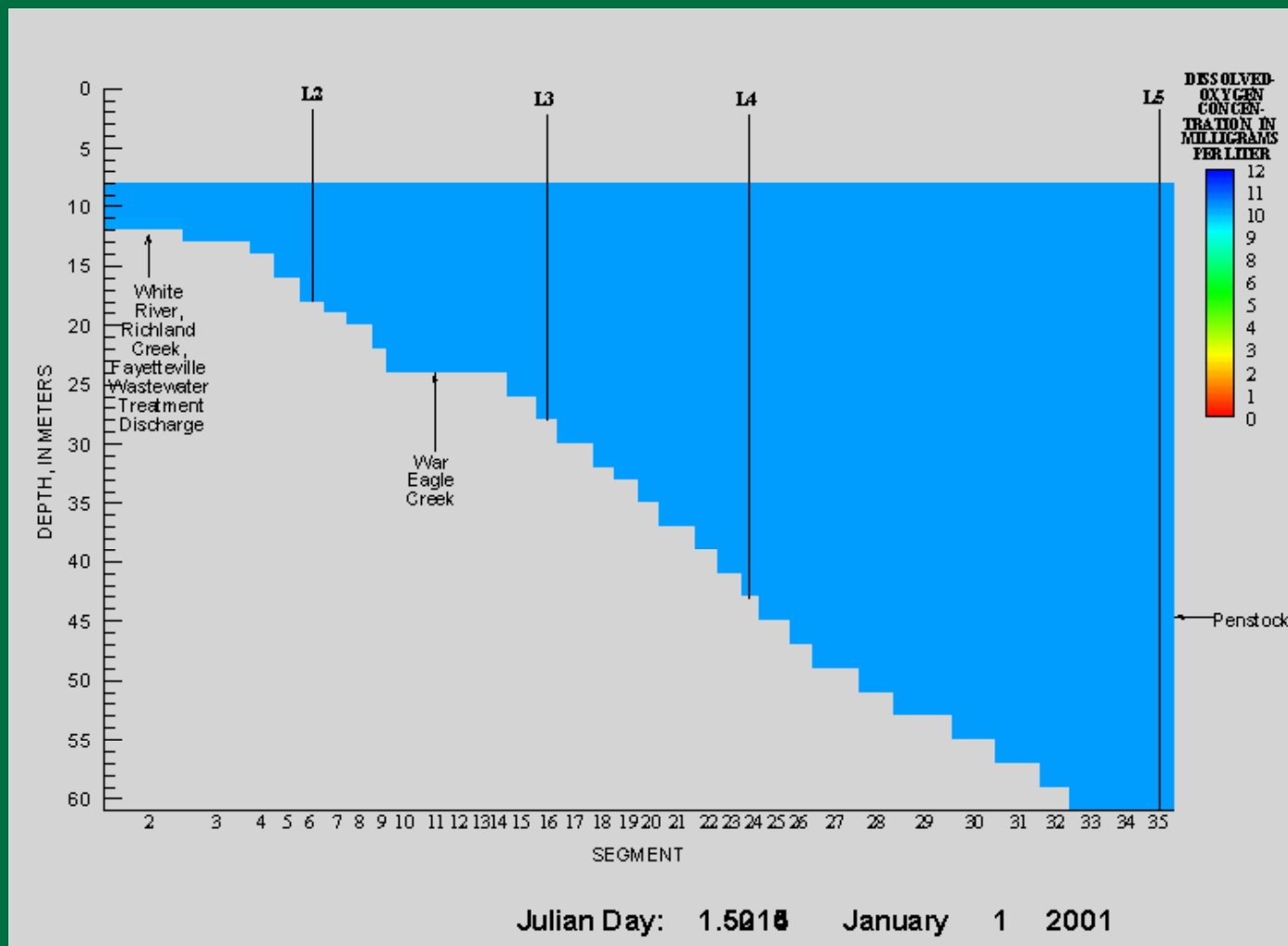
Beaver Lake Measured Dissolved Oxygen



Dissolved Oxygen Patterns



Annual Oxygen Dynamics



Beaver Lake

Annual Oxygen Dynamics

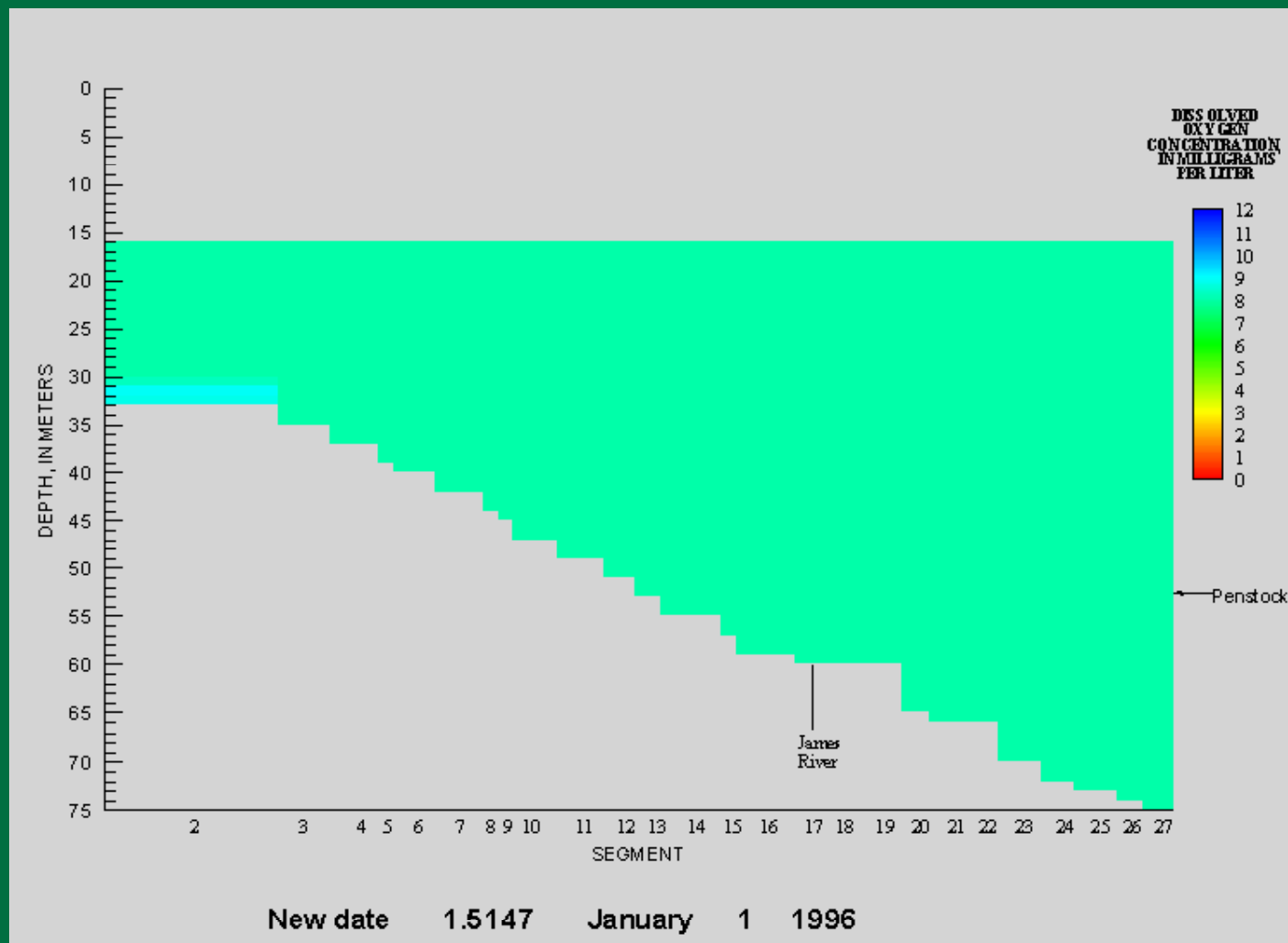
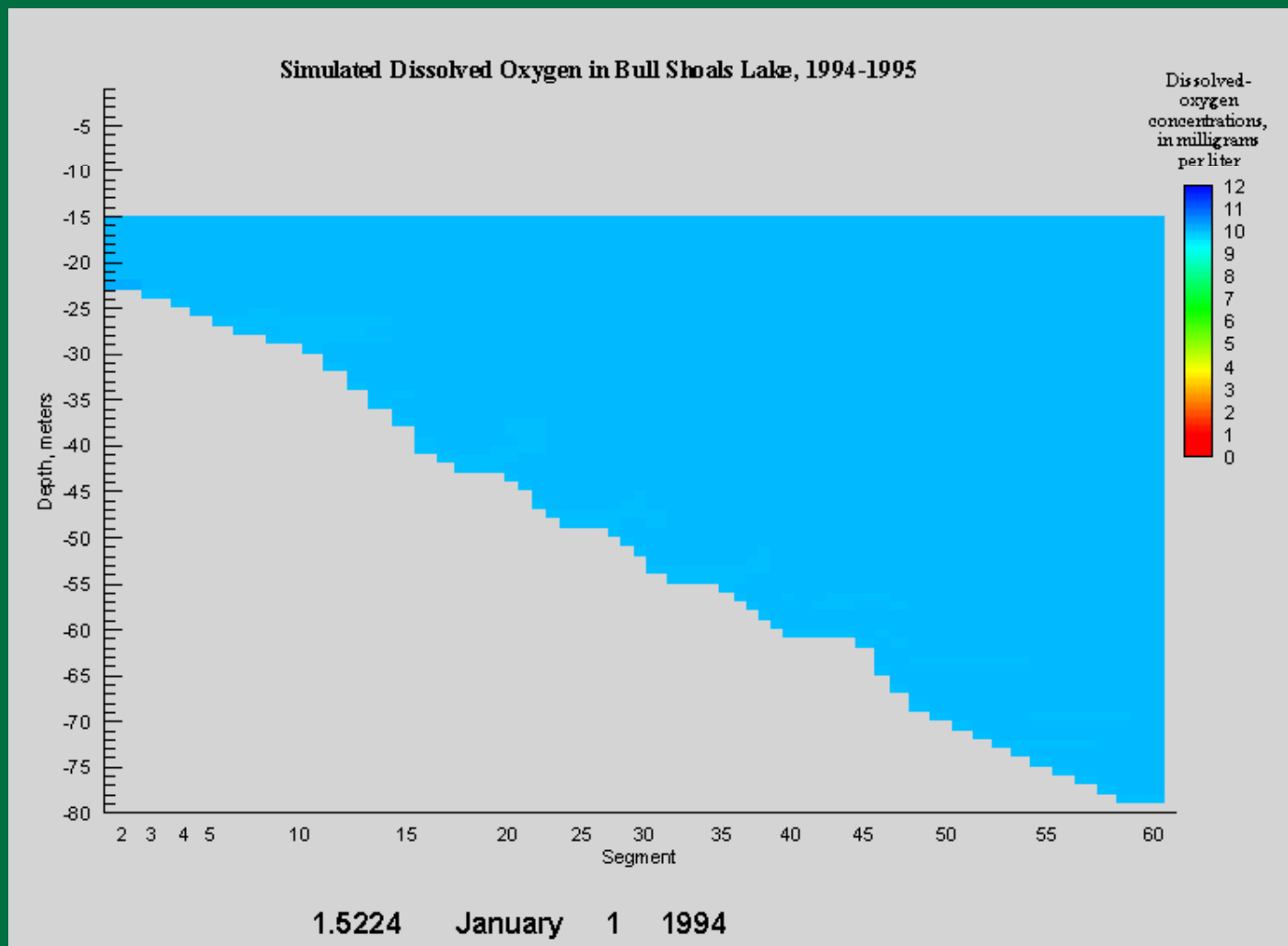


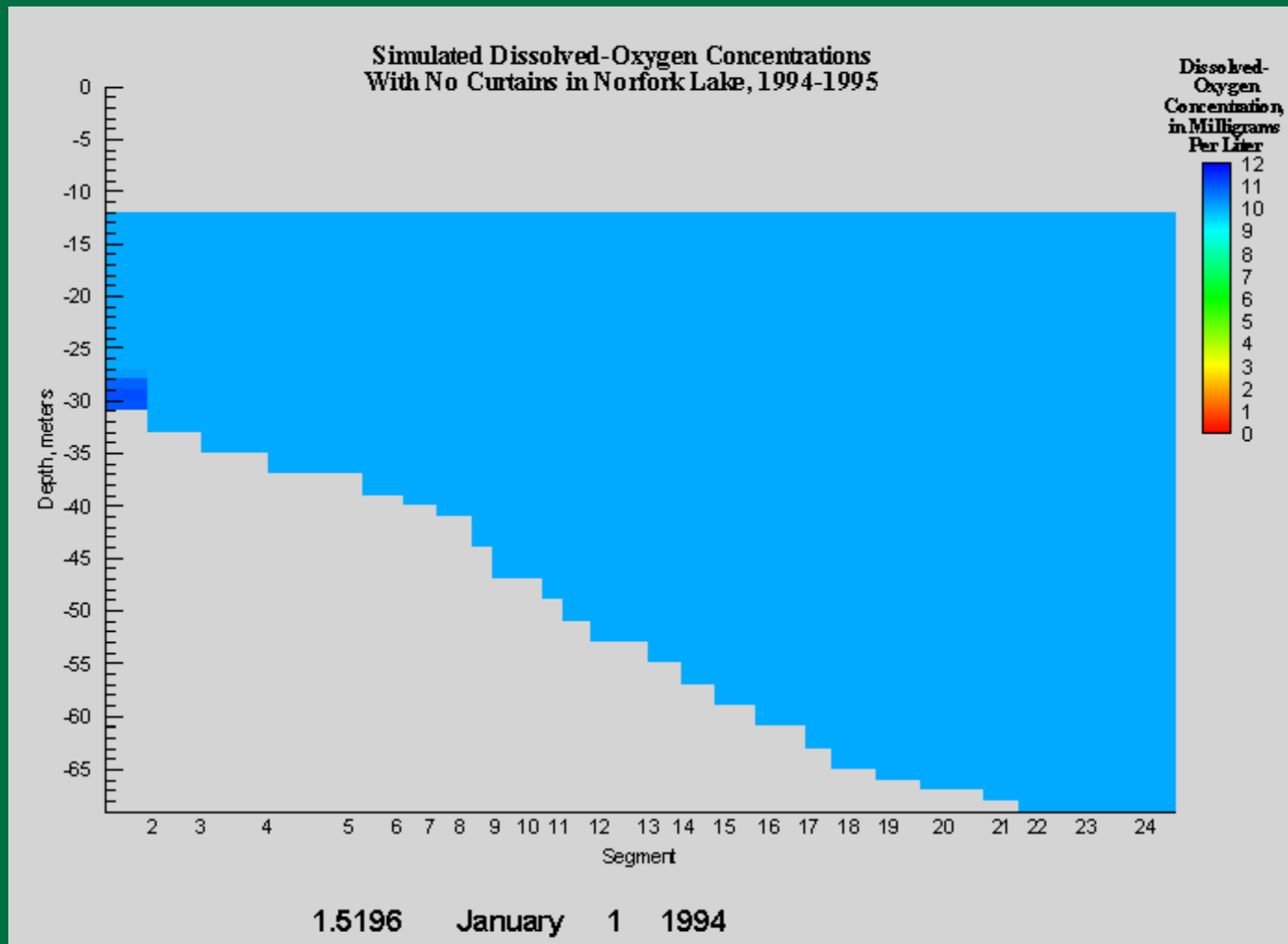
Table Rock Lake

Annual Oxygen Dynamics



Bull Shoals Lake

Annual Oxygen Dynamics



Norfolk Lake

History

- Original study conducted in 1996, in cooperation with Arkansas Game and Fish Commission
- Period of record was 1974-1994, 21 years of record
- Since 1994, 14 more years of data have been collected, 35 years total.

Purpose and Scope

1. Update annual areal hypolimnetic oxygen deficit rates (AHOD) from 1974 through the 2008 stratification season,
2. Examine trends in areal hypolimnetic oxygen deficits to infer trends in eutrophication from 1974-2008, and
3. Develop statistical models for each reservoir based on pool elevation and areal hypolimnetic oxygen content (AHOC) in the spring (April 15) to predict AHOD and therefore future AHOC later in the stratification season (for example, August 1, September 1, etc.).

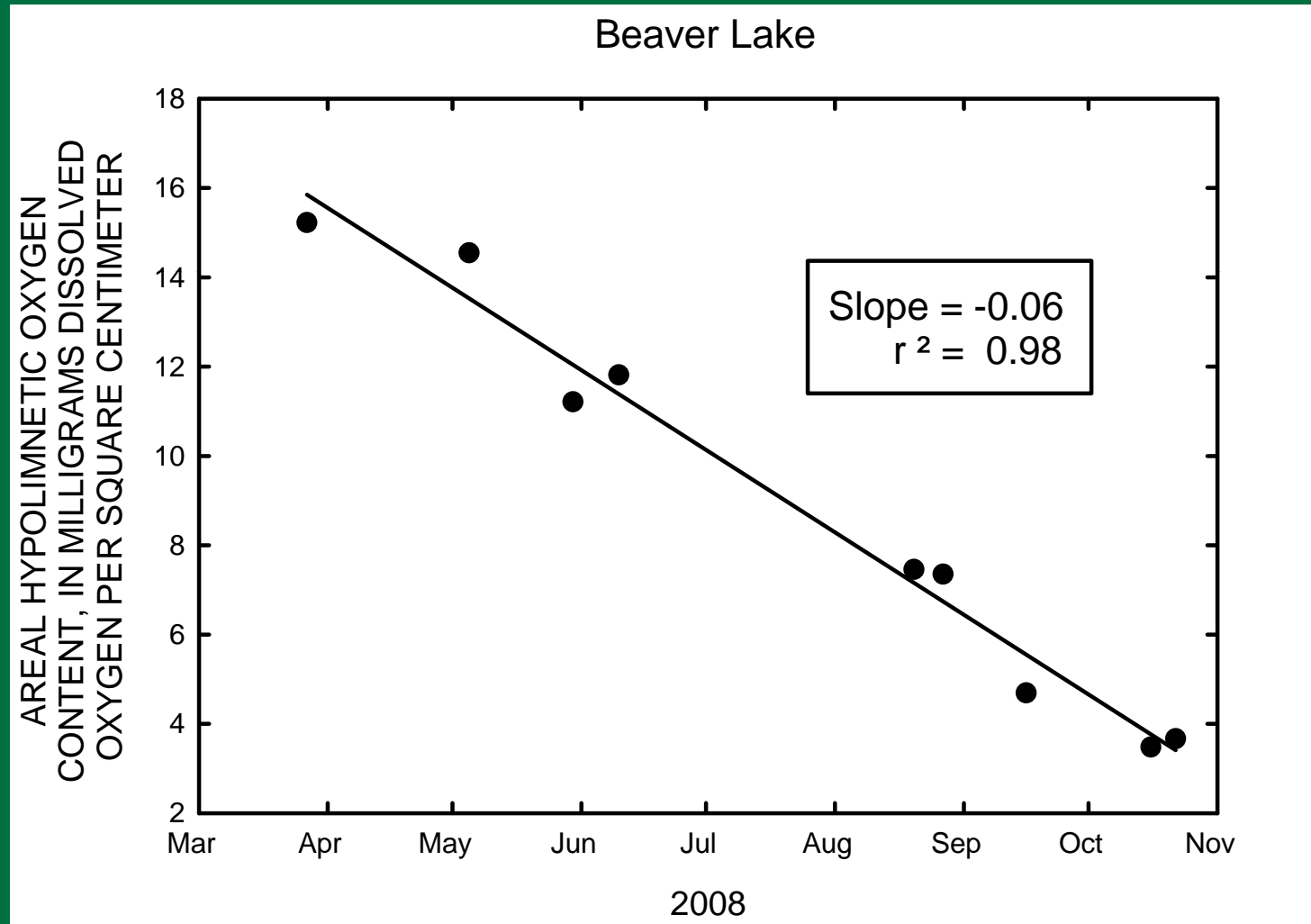
Approach

- Downloaded water temperature and dissolved oxygen profiles measured at the dam of each reservoir
- Received daily pool elevations from USACE
- Determined the vertical position or elevation of the thermocline for each profile
- Determined the oxygen content (AHOC) below the thermocline (hypolimnion) for each profile using USACE depth-capacity curves
- Determined the rate of change (slope) in hypolimnetic oxygen content over the stratification season becomes the deficit rate (AHOD)

Approach, continued

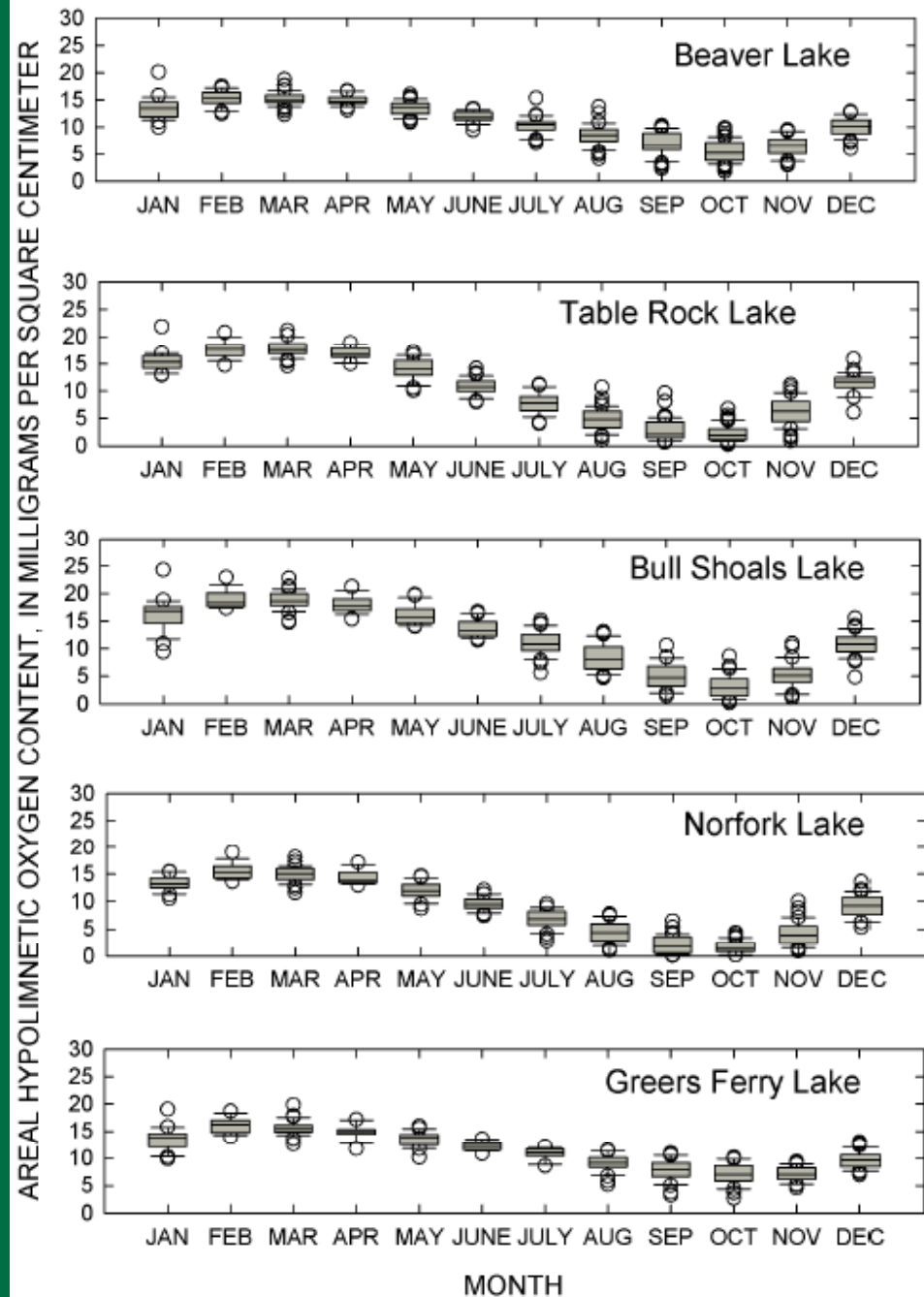
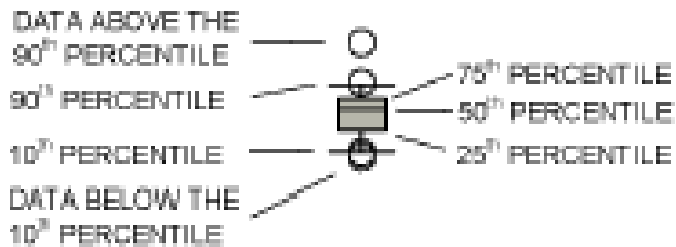
- **Assumption -- Changes in annual oxygen deficit rates over the period of record (35 years) provide an indication of changes in eutrophication**
- **Average flushing rate was determined for each reservoir, for each stratification season**
- **Flushing-rate adjusted oxygen deficit rates were determined to re-examine eutrophication trends**
- **Predictive equations were developed to estimate hypolimnetic oxygen content throughout the stratification season, using pool elevation and hypolimnetic oxygen content on April 15**

Rate of Change in Areal Hypolimnetic Oxygen Content



Annual Cycle of Areal Hypolimnetic Oxygen Content

EXPLANATION



Areal Hypolimnetic Oxygen Deficit Rates

MEASURED AREAL HYPOLIMNETIC OXYGEN DEFICIT, IN MILLGRAMS DISSOLVED OXYGEN PER SQUARE CENTIMETER PER DAY

BEAVER LAKE

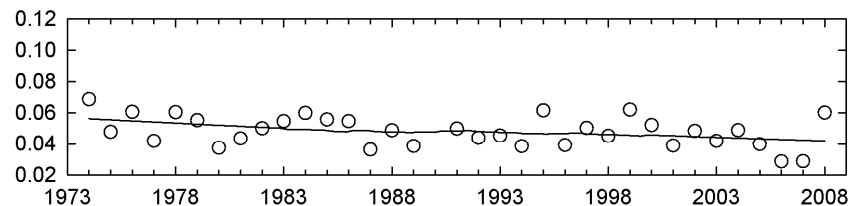
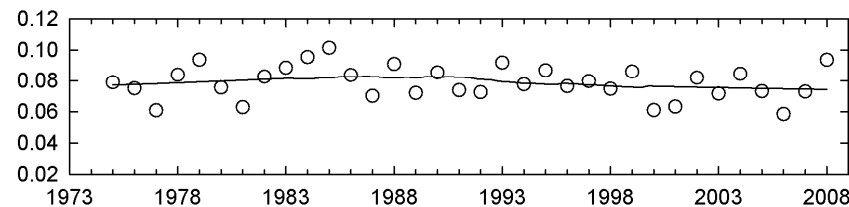
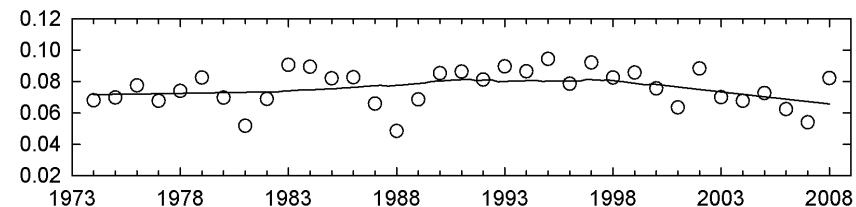


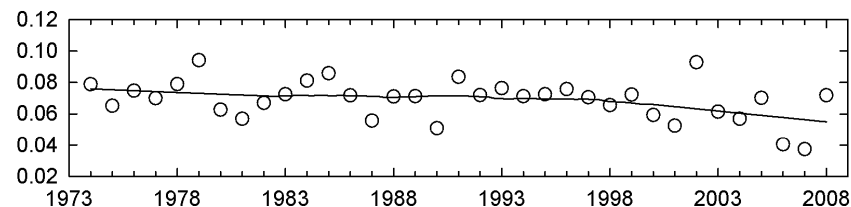
TABLE ROCK LAKE



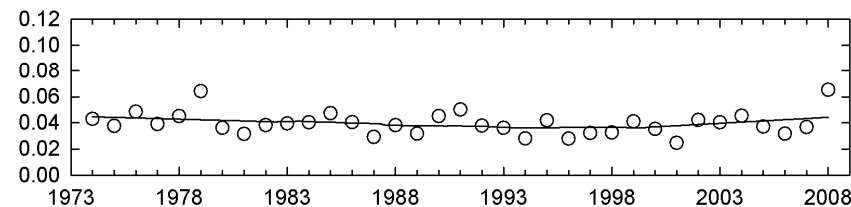
BULL SHOALS LAKE



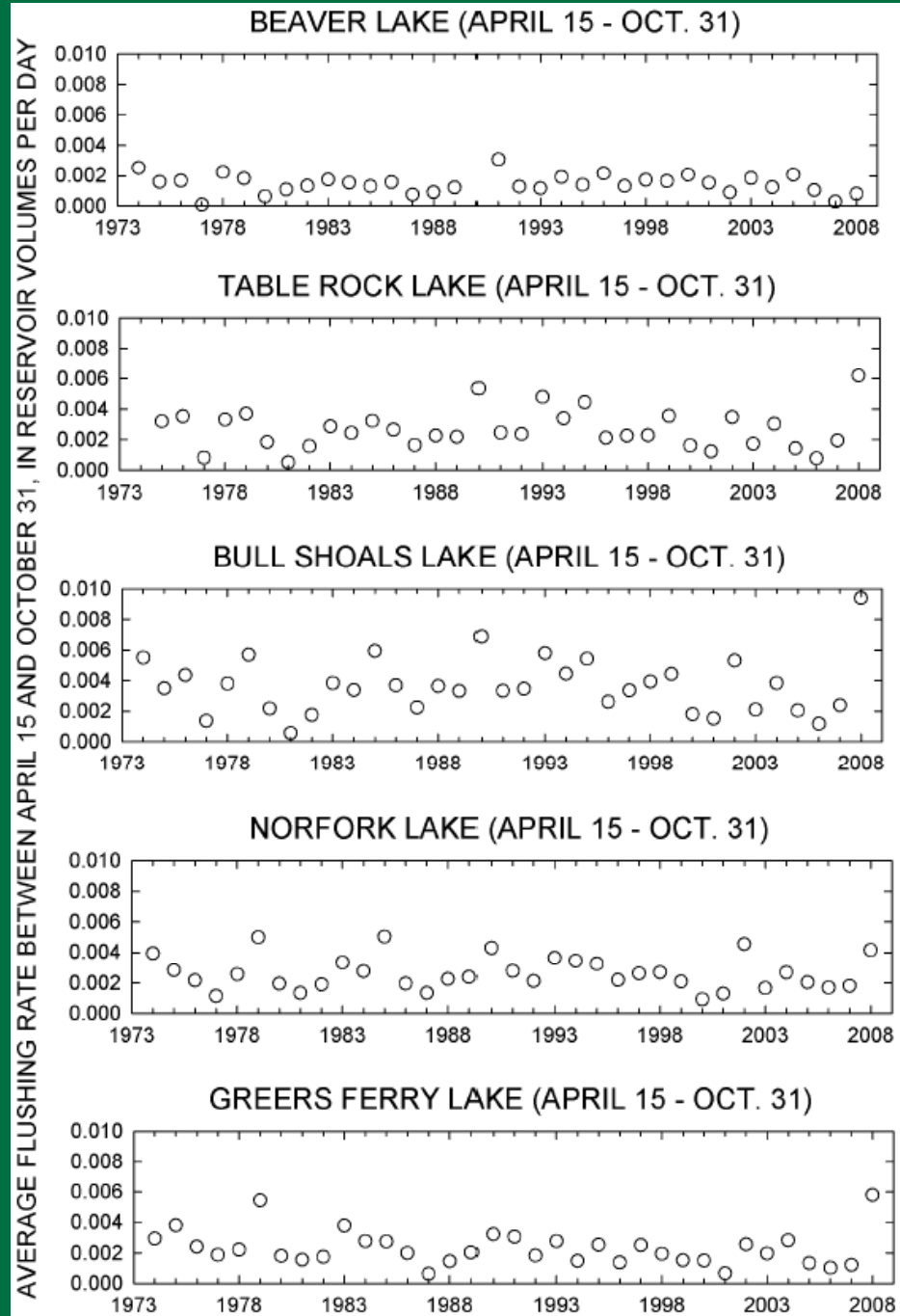
NORFORK LAKE



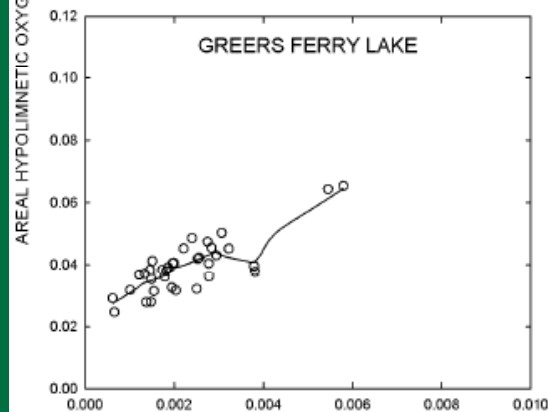
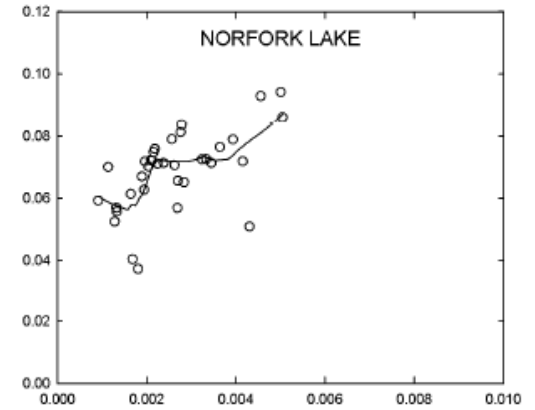
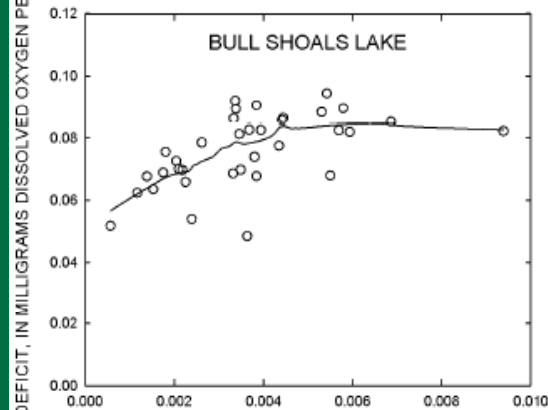
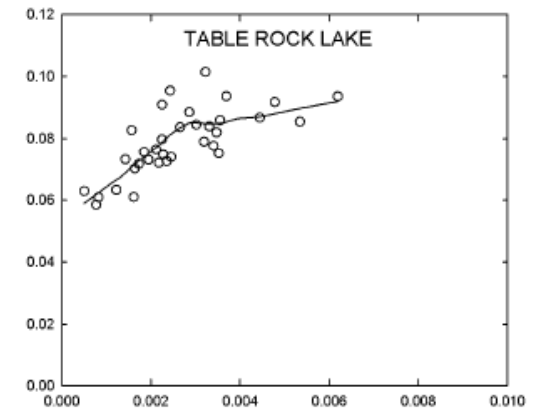
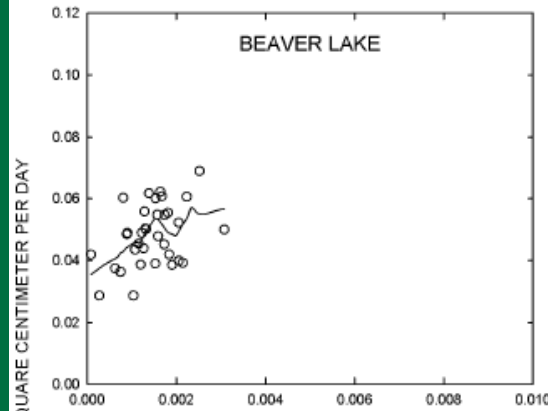
GREERS FERRY LAKE



Flushing Rate



Flushing Rate Relations with AHOD



MEAN APRIL 15 THROUGH OCTOBER 31 FLUSHING RATE, IN RESERVOIR VOLUMES PER DAY

MEAN APRIL 15 THROUGH OCTOBER 31 FLUSHING RATE, IN RESERVOIR VOLUMES PER DAY

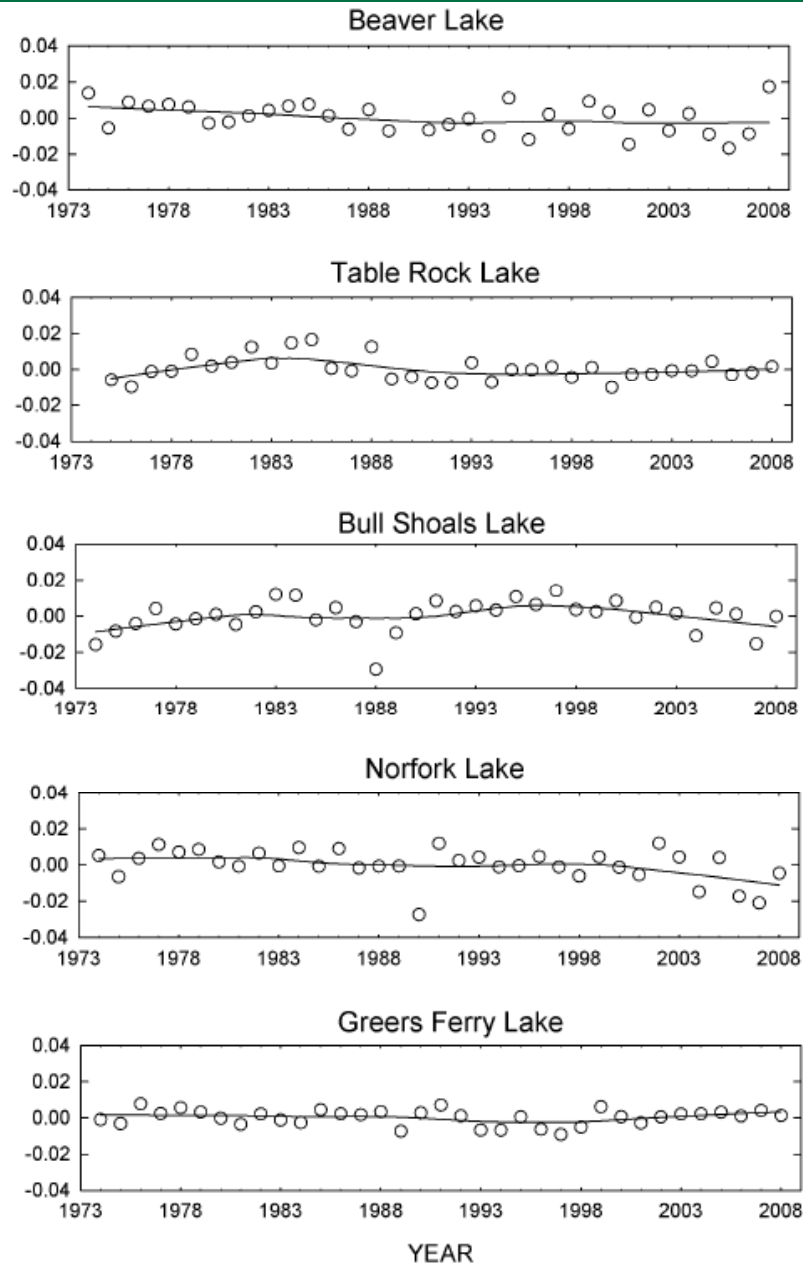
EXPLANATION

- DATA POINT
- LOESS SMOOTH FIT LINE

Flushing Rate Adjusted Areal Hypolimnetic Oxygen Deficit



RESIDUALS FROM THE FLUSHING RATE ADJUSTED AREAL HYPOLIMNETIC OXYGEN DEFICIT MODEL,
MEASURED VALUES - ESTIMATED VALUES



EXPLANATION
 ○ DATA POINT
 — LOESS SMOOTH TREND LINE

Predictive Equations

1) $AHOD = \beta_1 + \beta_2$ (hypolimnetic oxygen content on April 15) + β_3 (pool elevation on April 15)

2) $AHOD = \beta_1 + \beta_2$ (year) + β_3 (hypolimnetic oxygen content on April 15) + β_3 (pool elevation on April 15)

Predictive Equations

Areal Hypolimnetic Oxygen Content plus Pool Elevation on April 15

	R ²	P
Beaver Lake		
AHOD = -0.474 + (0.000754 * AHOC) + (0.000457 * Pool)	0.083	0.262
Table Rock Lake		
AHOD = -0.934 + (0.00221 * AHOC) + (0.00107 * Pool)	0.564	<0.001
Bull Shoals Lake		
AHOD = -0.150 + (0.000269 * AHOC) + (0.000337 * Pool)	0.084	0.247
Norfolk Lake		
AHOD = -0.445 + (0.00400 * AHOC) + (0.000831 * Pool)	0.508	<0.001
Greers Ferry Lake		
AHOD = -0.363 + (0.000299 * AHOC) + (0.000859 * Pool)	0.350	0.001

Predictive Equations

Year (1974-2008) plus Areal Hypolimnetic Oxygen Content plus Pool Elevation on April 15

	R ²	P
Beaver Lake		
AHOD = 0.374 + (-0.000482 * Year) + (-0.00156 * AHOC) + (0.000586 * Pool)	0.277	0.020
Table Rock Lake		
AHOD = -0.630 + (-0.000202 * Year) + (0.00112 * AHOC) + (0.00120 * Pool)	0.583	<0.001
Bull Shoals Lake		
AHOD = -0.262 + (0.0000568 * Year) + (0.000469 * AHOC) + (0.000330 * Pool)	0.086	0.420
Norfolk Lake		
AHOD = 0.112 + (-0.000289 * Year) + (0.00324 * AHOC) + (0.000884 * Pool)	0.551	<0.001
Greers Ferry Lake		
AHOD = -0.0666 + (-0.000149 * Year) + (-0.000259 * AOC) + (0.000877 * Pool)	0.376	0.002

Where we are today:

- The report has been drafted and in review.
- Predictive equations have been developed to test hypolimnetic oxygen deficit rates for the summer season given initial conditions of hypolimnetic oxygen content and pool elevation.
- Future efforts will be to examine different averaging periods for flushing rate to see if better relations can be developed