RICHARD B. RUSSELL DAM AND LAKE - OXYGENATION SYSTEM:

A Summary

21 April 2005
Sacramento, CA

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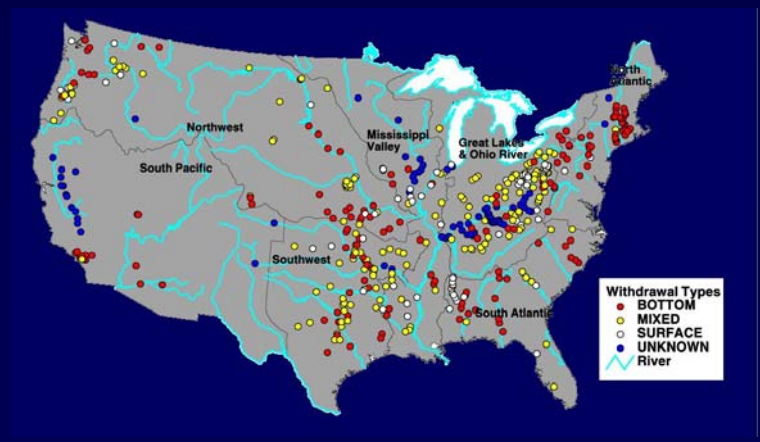


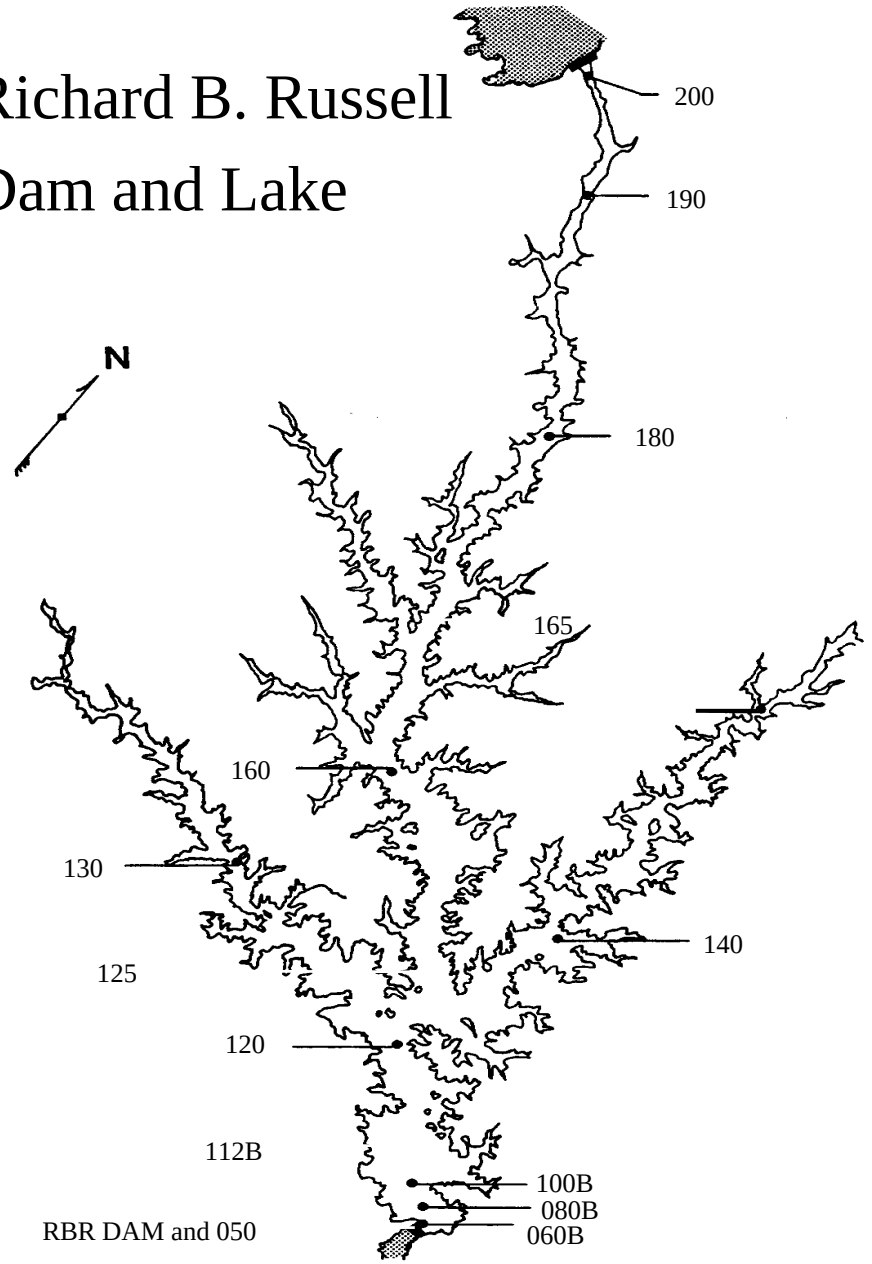
http://www.usace.army.mil/

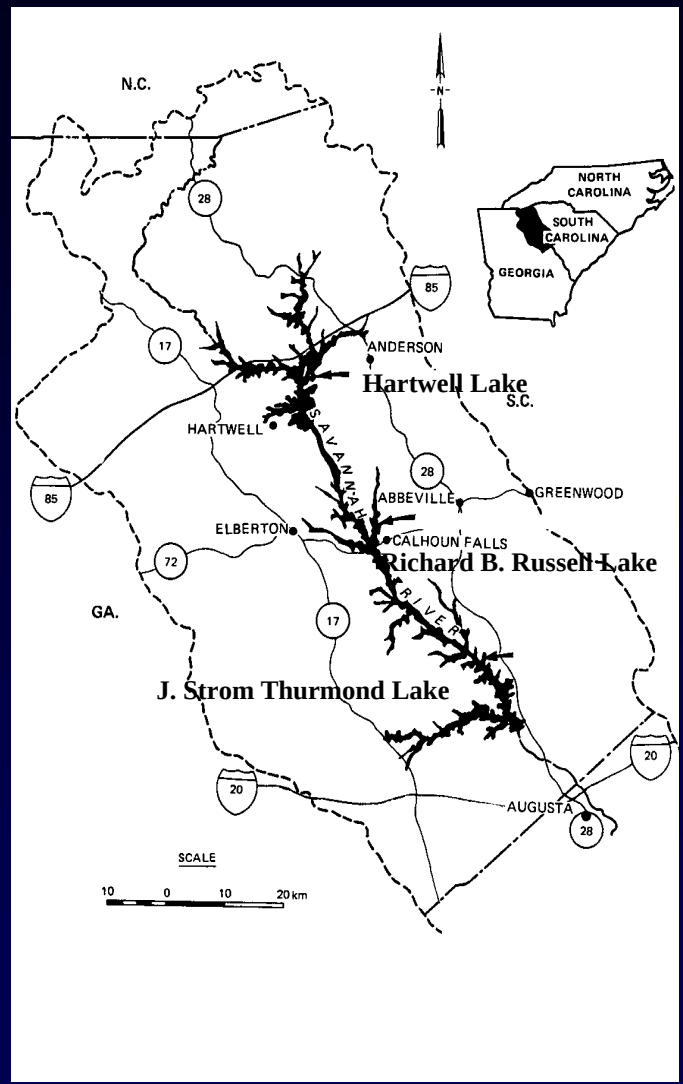
ERDC

US Army Engineer Research and Development Center

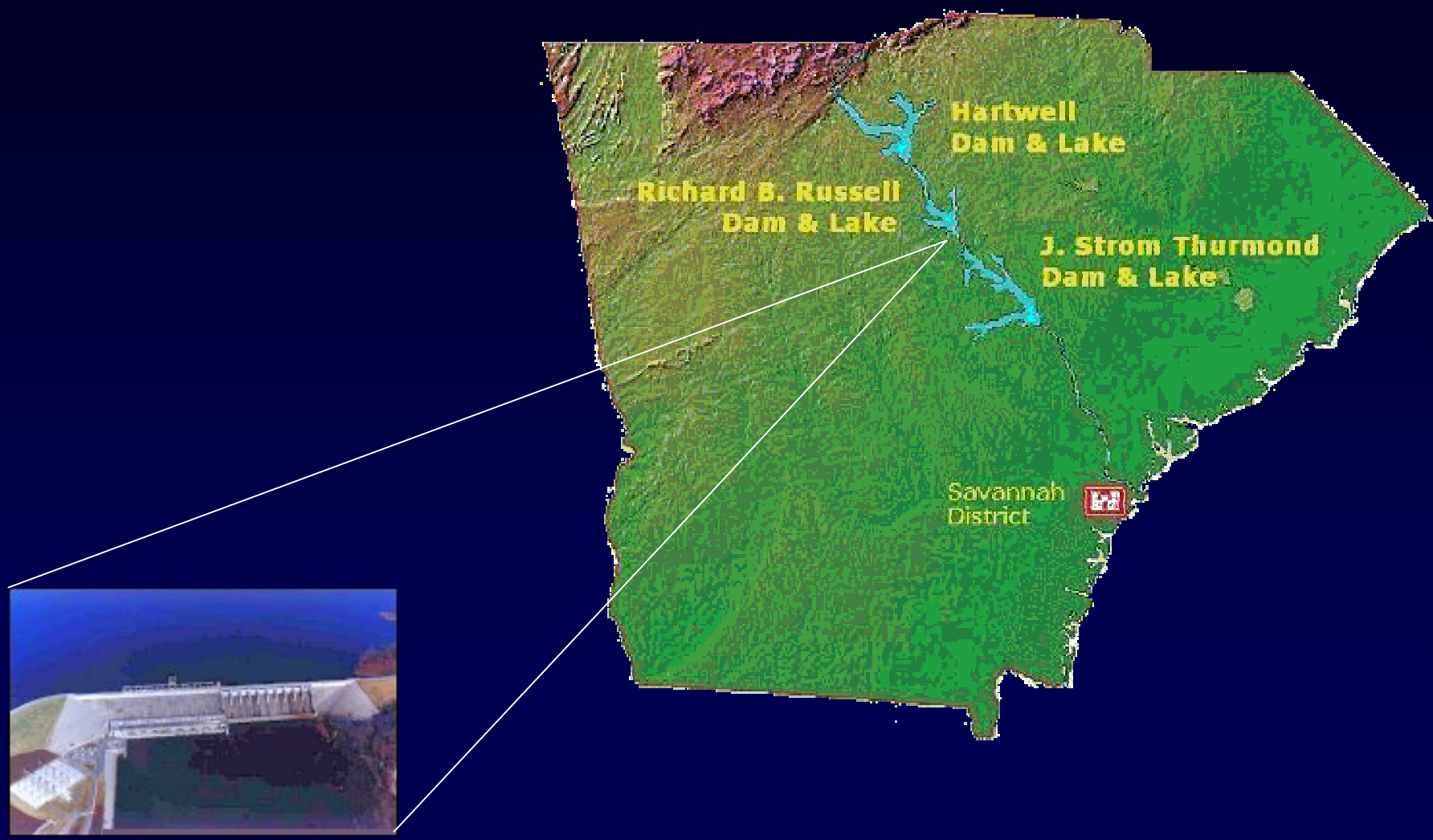
Seven laboratories at four geographical sites, with over 2,000 employees (over 1,000 engineers and scientists), $1.2 billion in facilities, and an annual program exceeding $660 million.

Richard B. Russell Dam and Lake





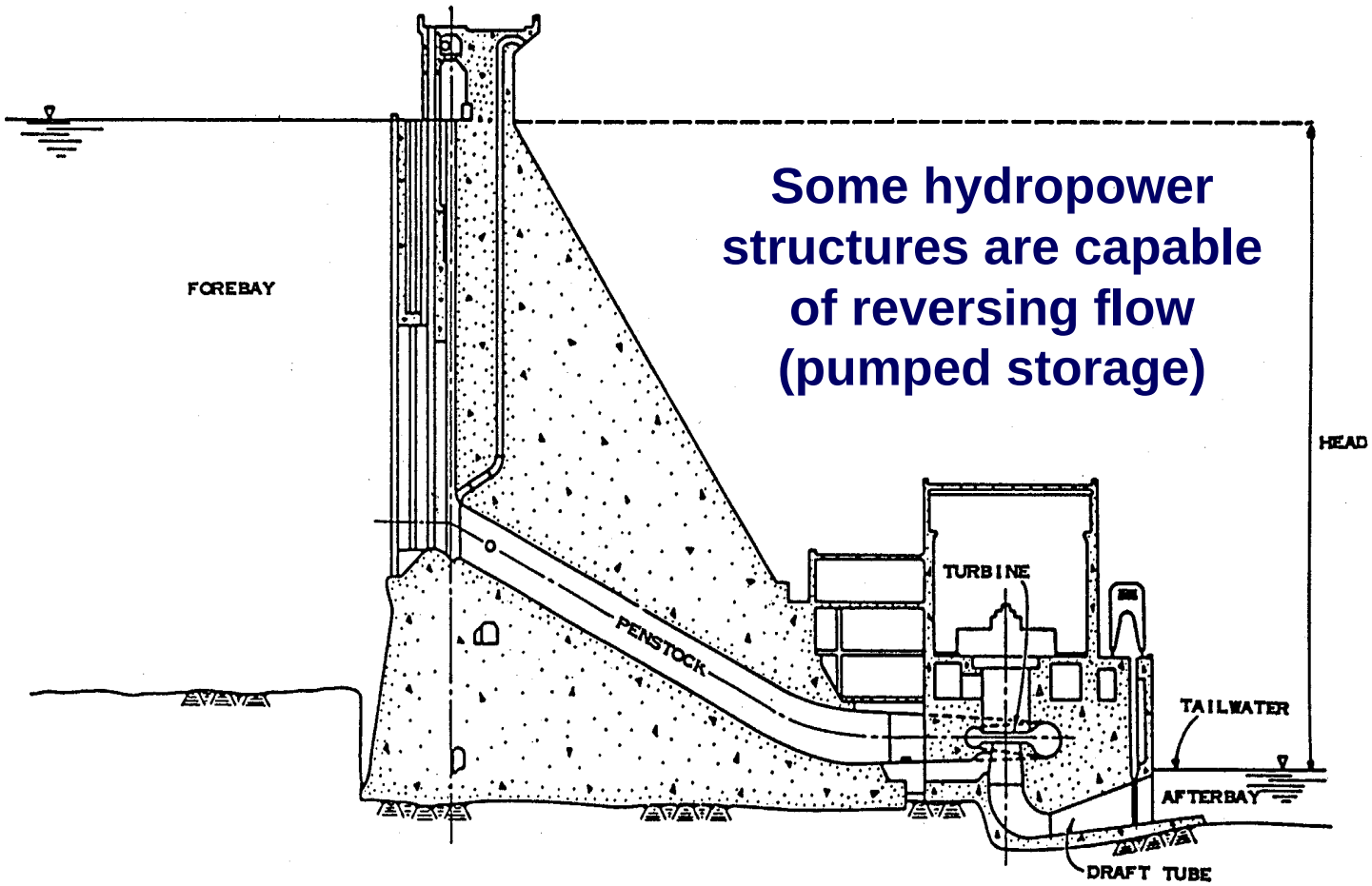
Map Showing Major Physiographical Provinces of the Region

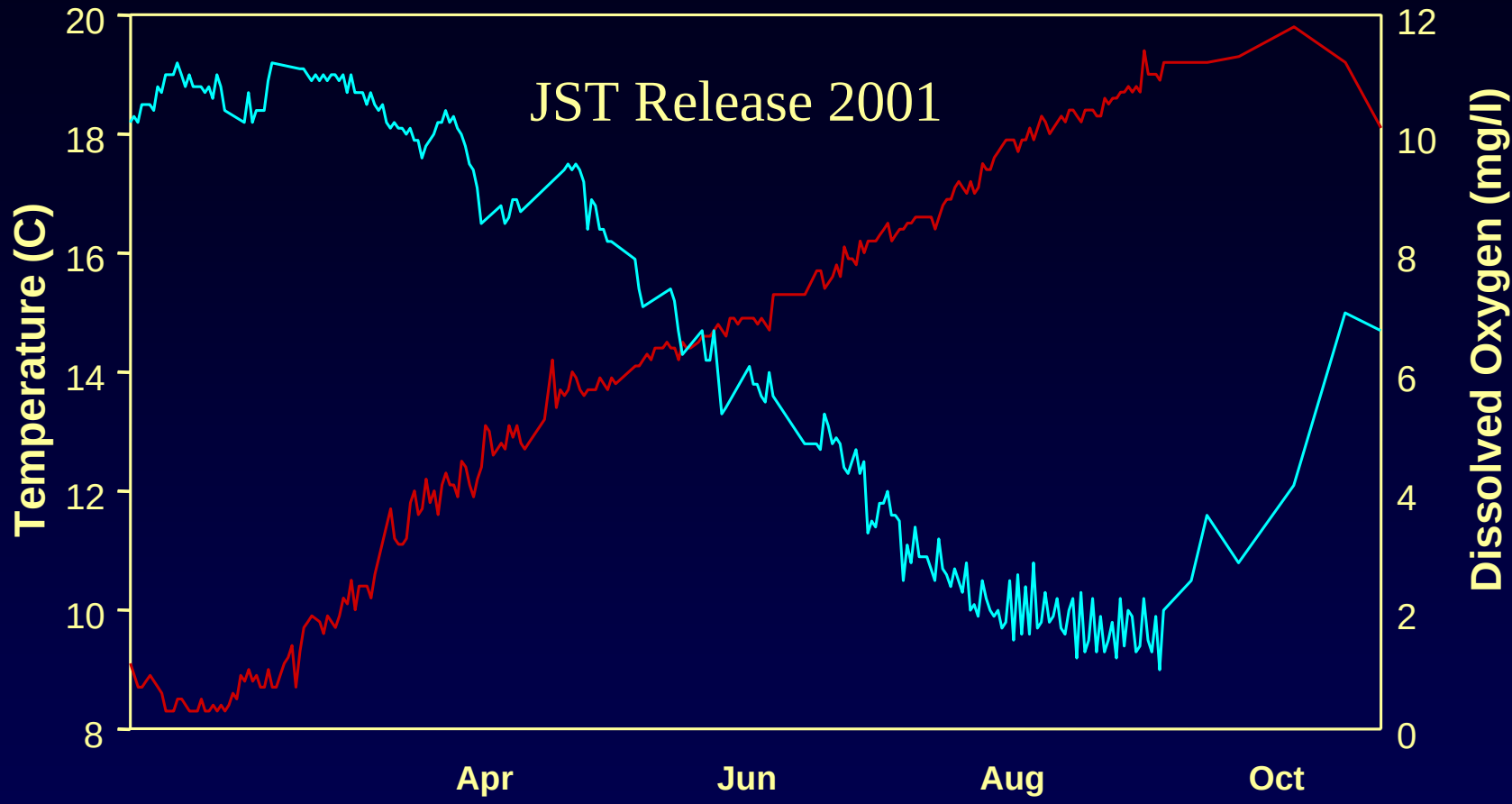


> RBR Dam was completed in 1984 and turbine operation began in 1985.

> Through an agreement with SC and GA, USACE agreed that releases would contain a minimum of 6 mg/l dissolved oxygen.

Hydropower Release Structure

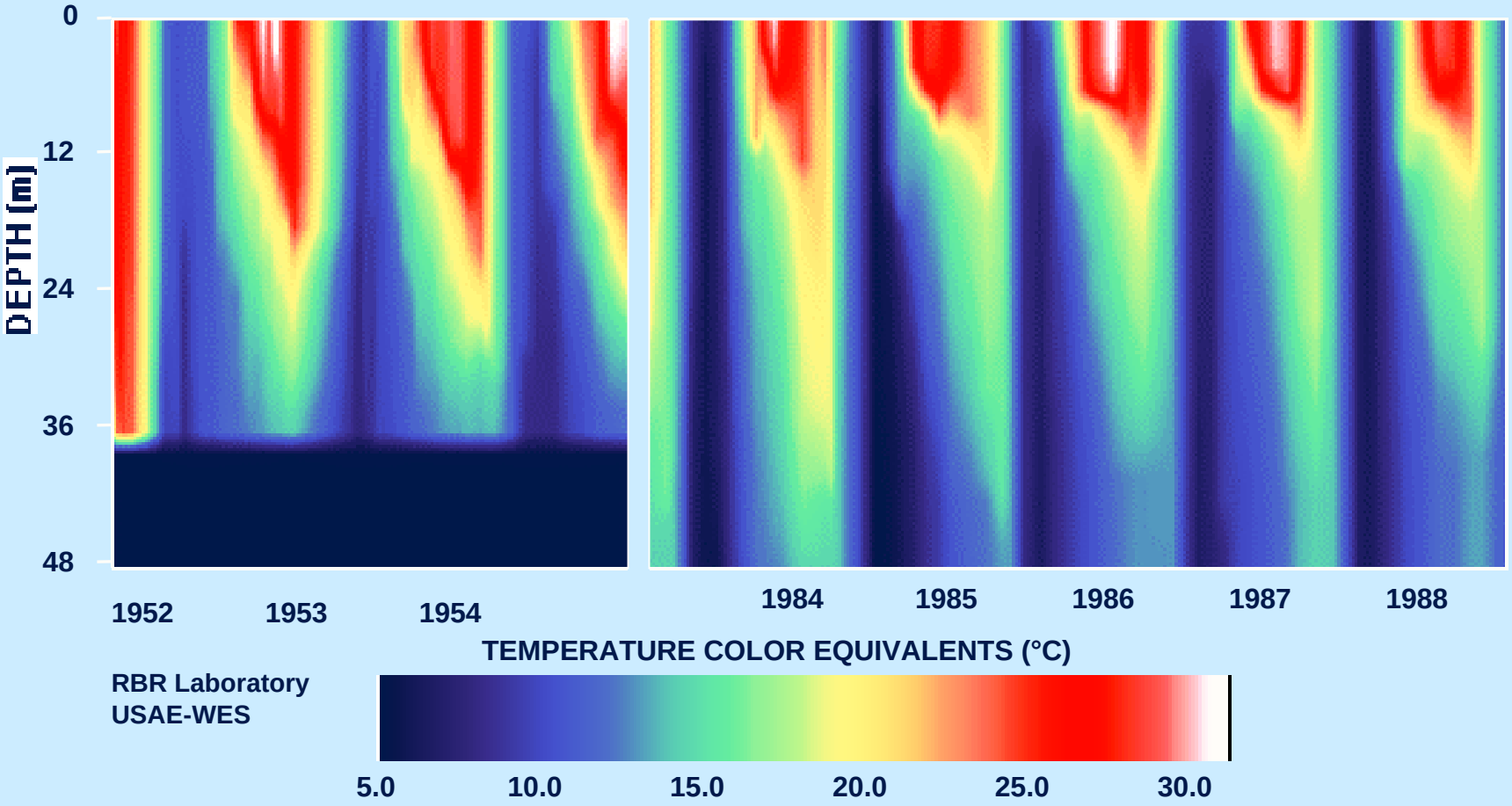




The Fundamental Problem, Common to Hydropower Dams

Thermal Trends in J. Strom Thurmond Lake

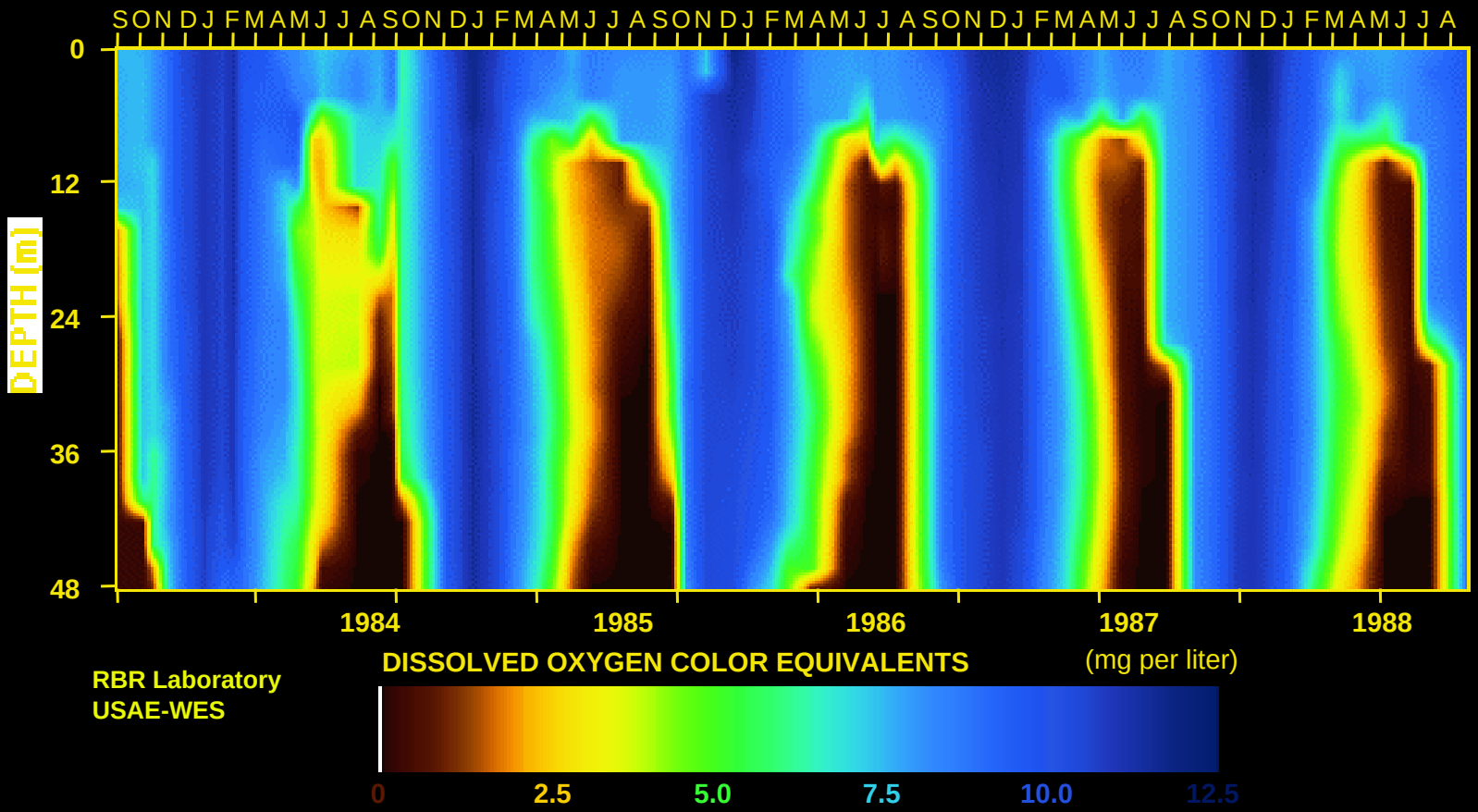
Station 20 (JST Forebay) 1952-1988



The Seasonal Changes in a Monomictic Reservoir

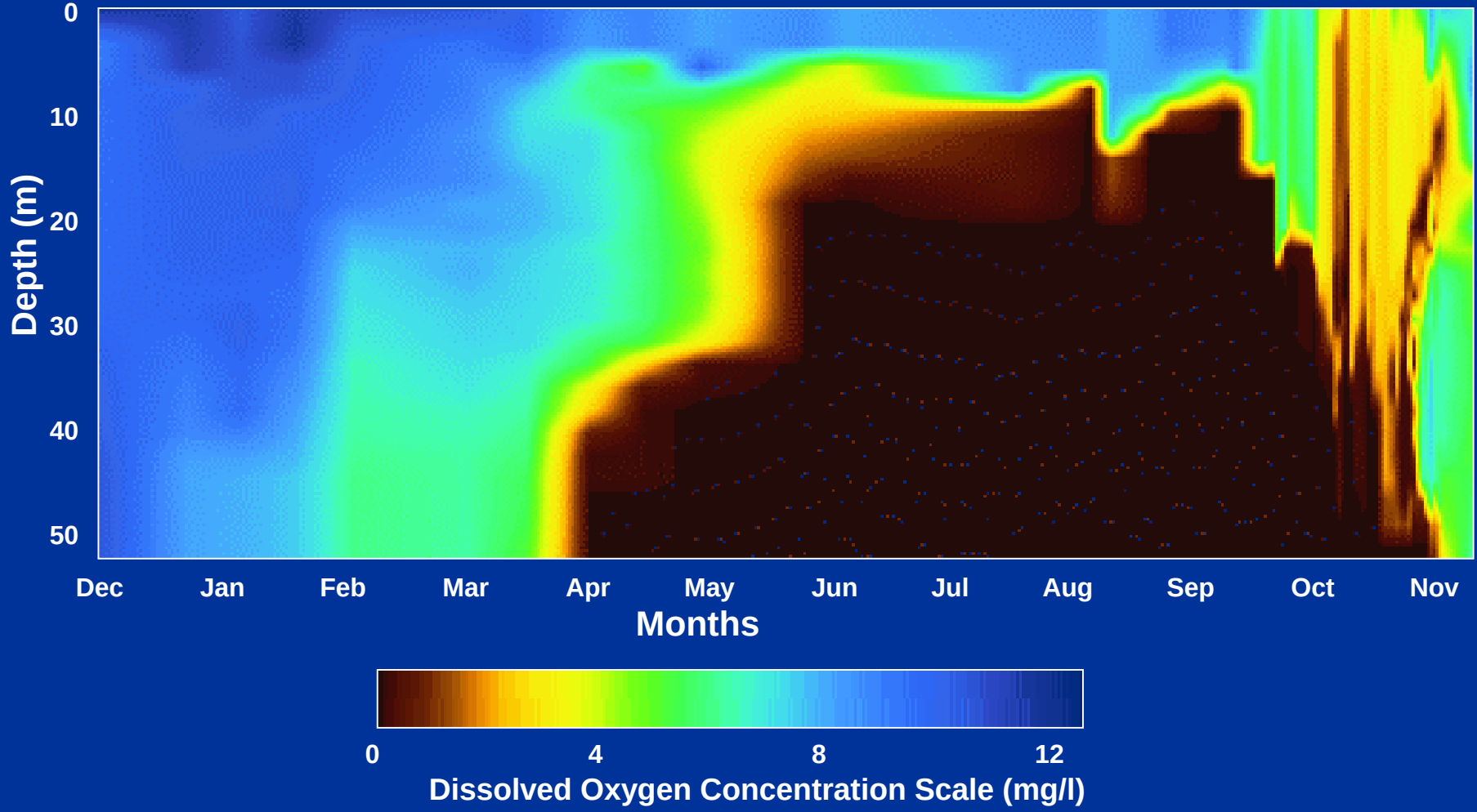
Dissolved Oxygen Trends in J. Strom Thurmond Lake

Station 20 (JST Forebay) 1983-1988

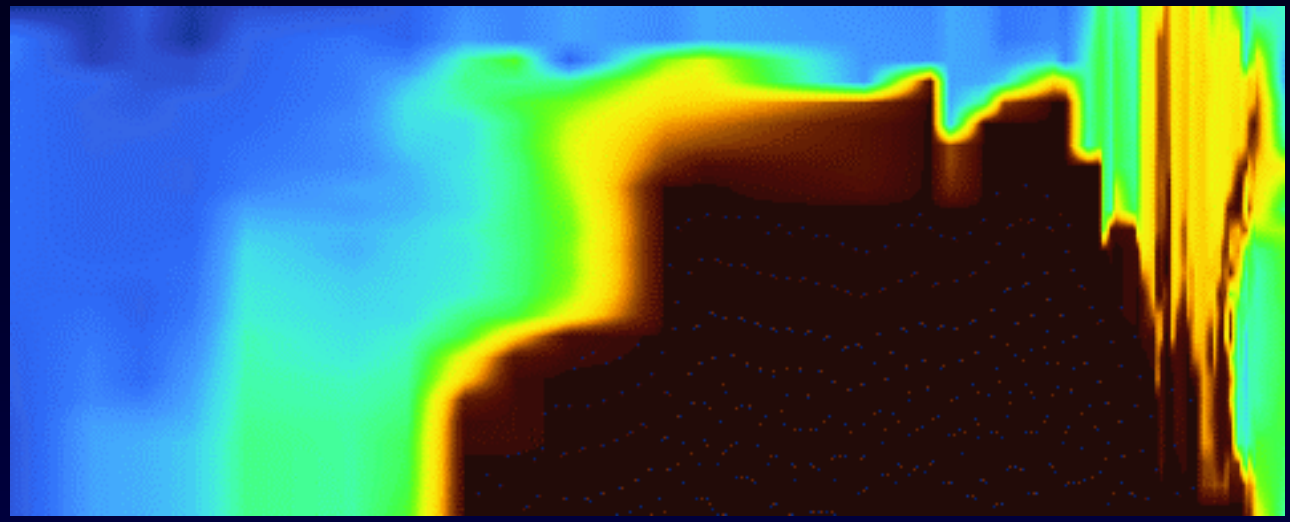


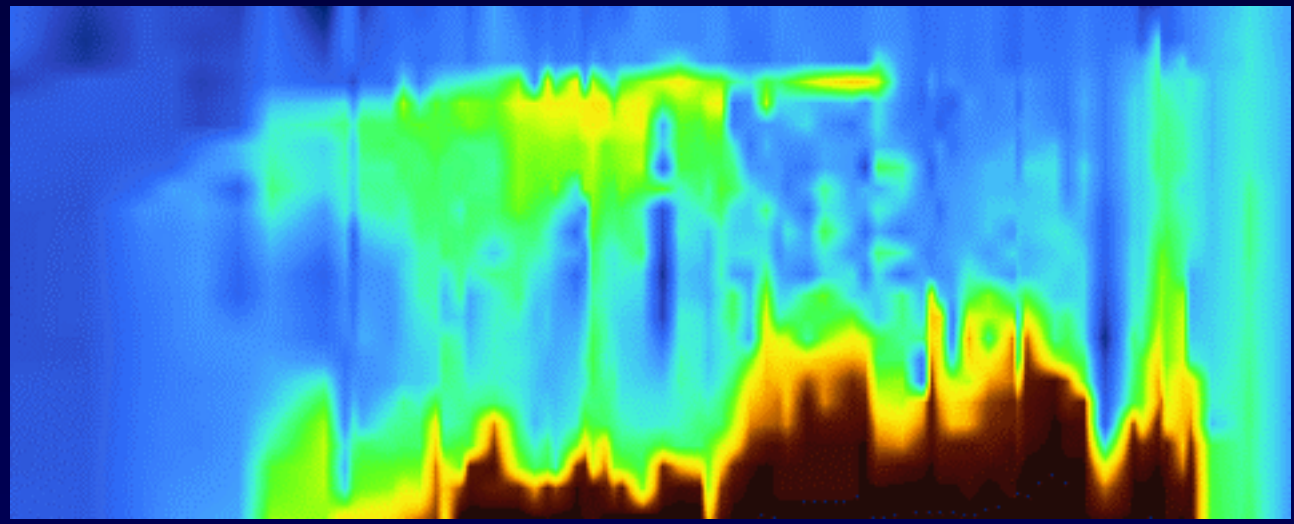
The Seasonal Changes in a Monomictic Reservoir

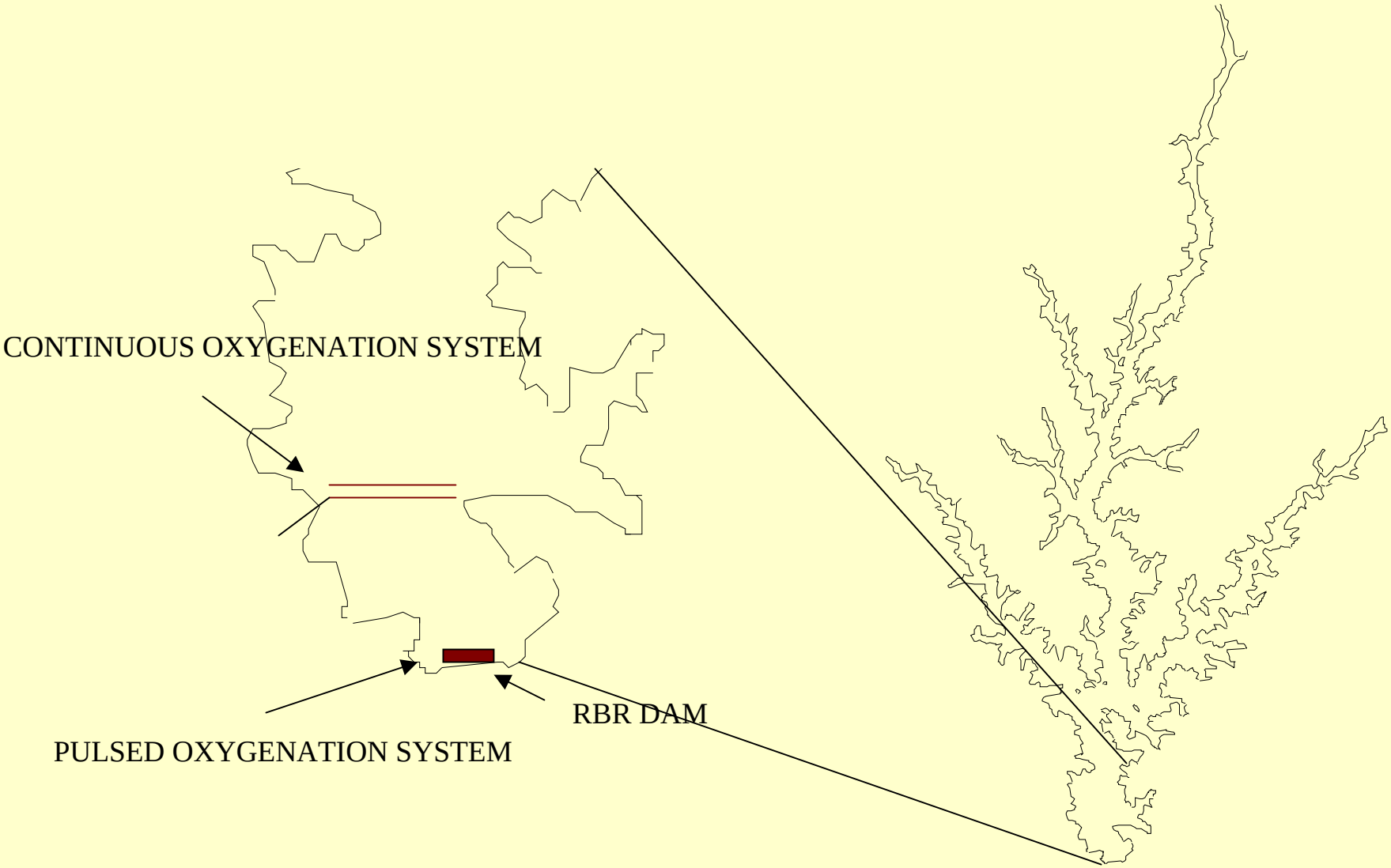
Richard B. Russell Lake, SC/GA
First Full Year, 1984



Demonstration of the gradual fall mixing process in a deep Southeastern monomictic reservoir.





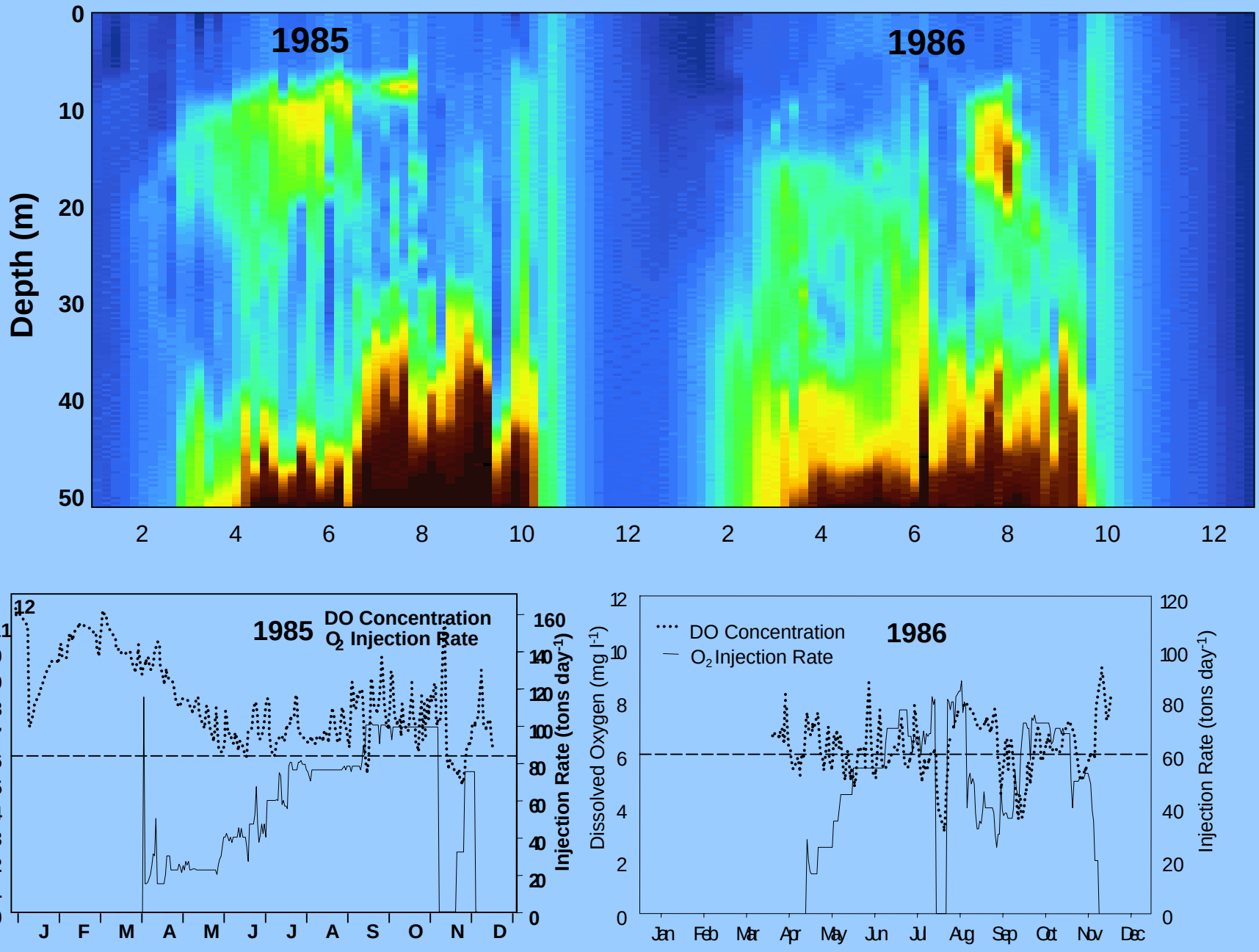

CONTINUOUS OXYGENATION SYSTEM
RBR DAM
PULSED OXYGENATION SYSTEM

Oxygen Supply

- The lines can be supplied with pure gaseous oxygen
- Liquid oxygen is trucked to a storage tank onsite
- Vaporization of oxygen provides the pressure to move the gas through the diffusers


A B C D E


How Has the System Performed?


1985
1986
Depth (m)
0
10
20
30
40
50
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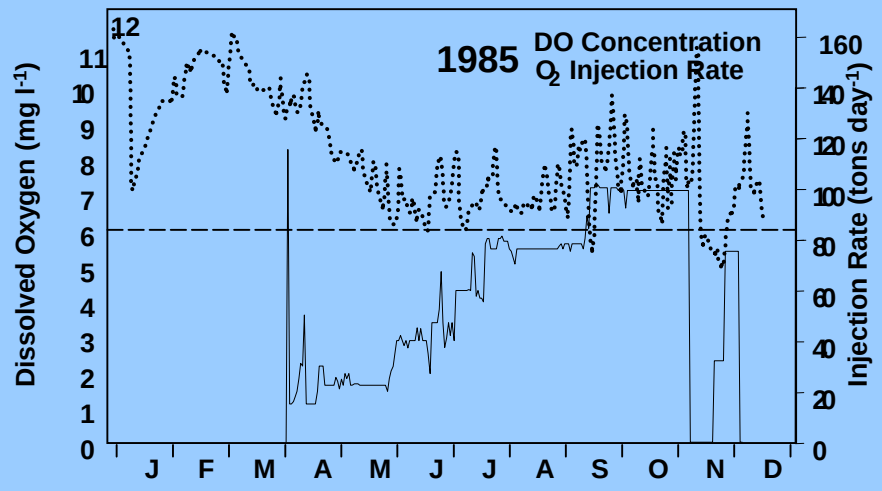
4
6
8
10
12
2
4
6
8
10
12


1985
DO Concentration
O2 Injection Rate
Dissolved Oxygen (mg l-1)
Injection Rate (tons day-1)
J
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M
A
M
J
J
A
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O
N
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1986
DO Concentration
O2 Injection Rate
Dissolved Oxygen (mg l-1)
Injection Rate (tons day-1)
Jan
Feb
Mar
Apr
May
Jun
Jul
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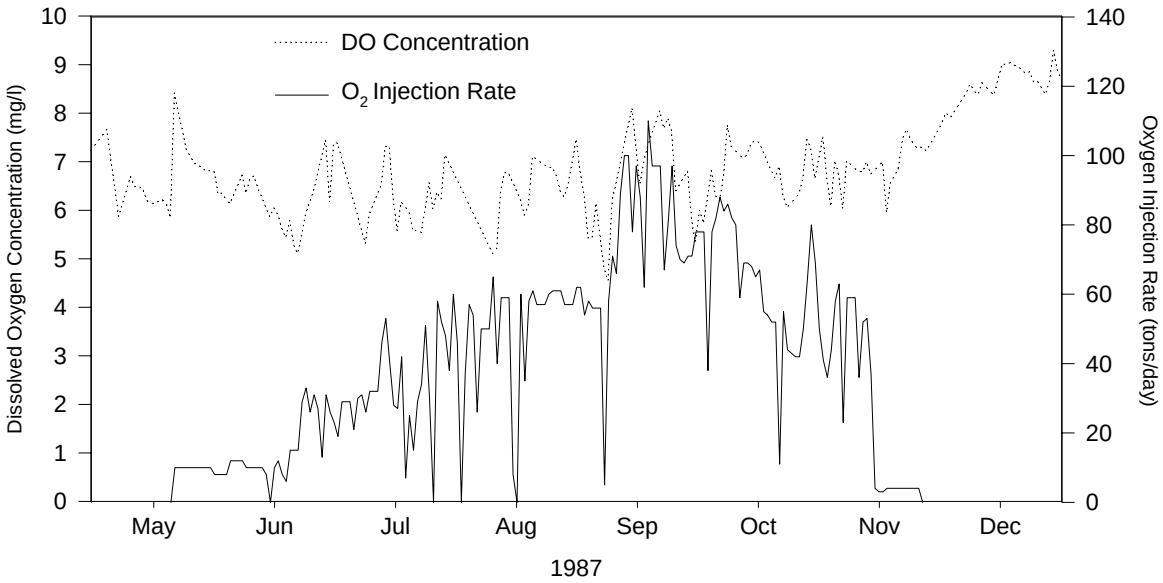
Sep
Oct
Nov
Dec

Initial Performance

- Questions about efficiency
  - Initial calculations indicated good efficiency – 95%
  - Widespread leakage and erratic bubble plumes
  - Offgas analysis indicated low efficiency – 20%
  - New calculations found errors in originals
  - Revised efficiency: 40-70% depending on conditions
- Ceramic heads became damaged by cracks and fouling – Show Them
- In late-1980s replaced many of the ceramic heads with flexible membrane design – Show Them

Even obvious things sometimes must be explained in detail.


DO Concentration
O2 Injection Rate
Dissolved Oxygen Concentration (mg/l)
Oxygen Injection Rate (tons/day)
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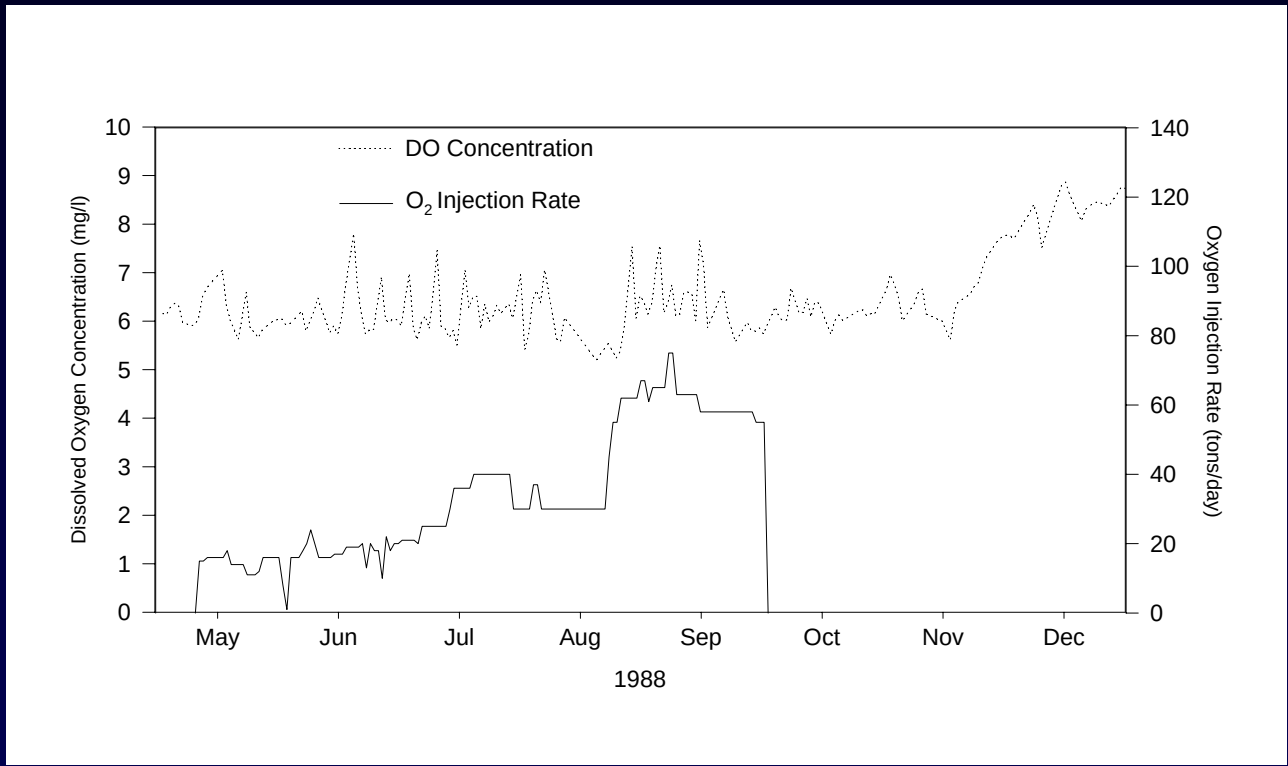
1987


DO Concentration
O2 Injection Rate
Dissolved Oxygen Concentration (mg/l)
Oxygen Injection Rate (tons/day)
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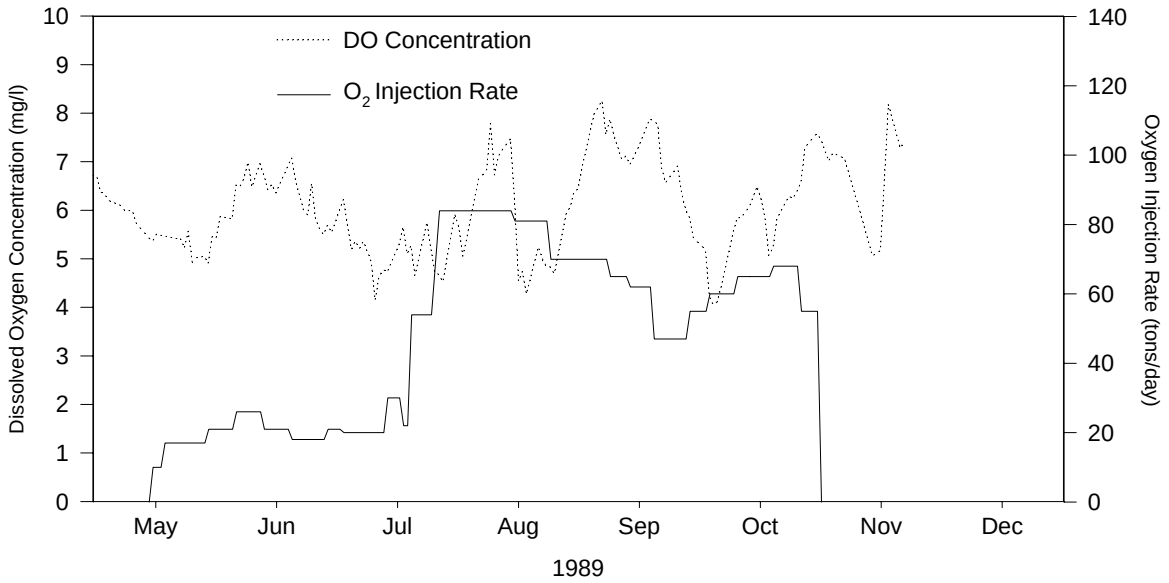
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Dissolved Oxygen Concentration (mg/l)
Oxygen Injection Rate (tons/day)
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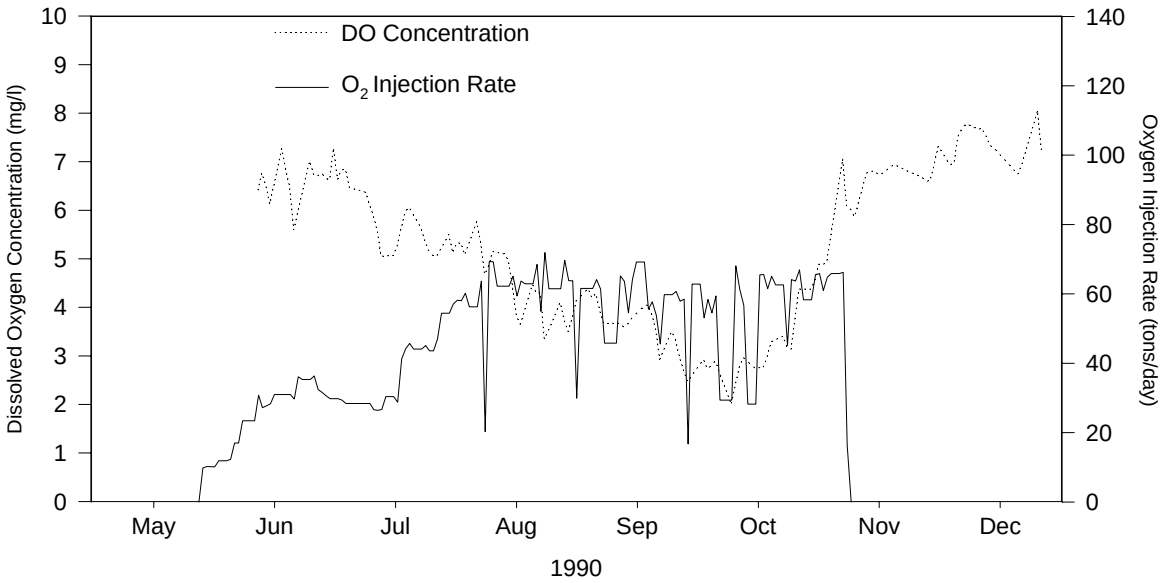
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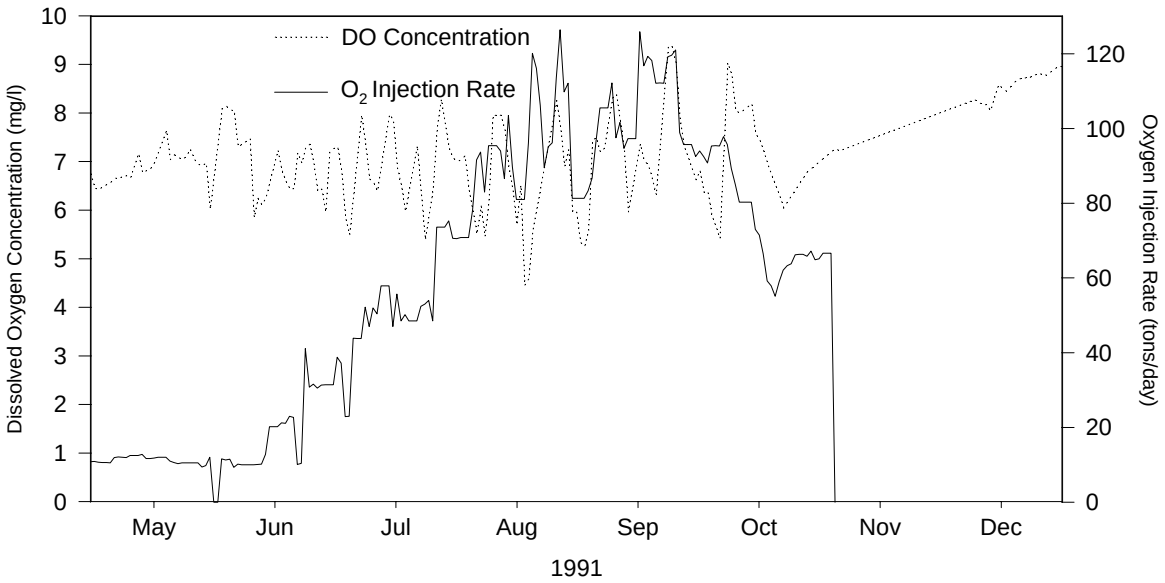
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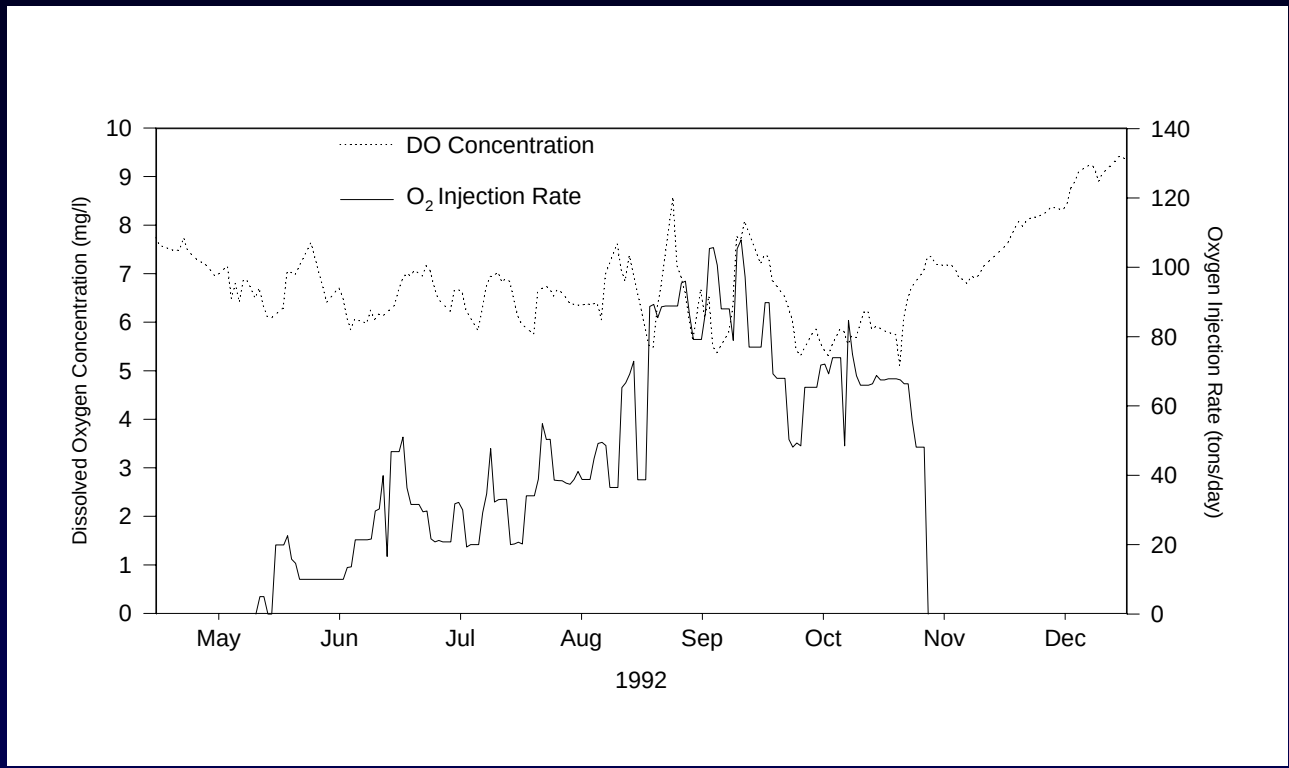
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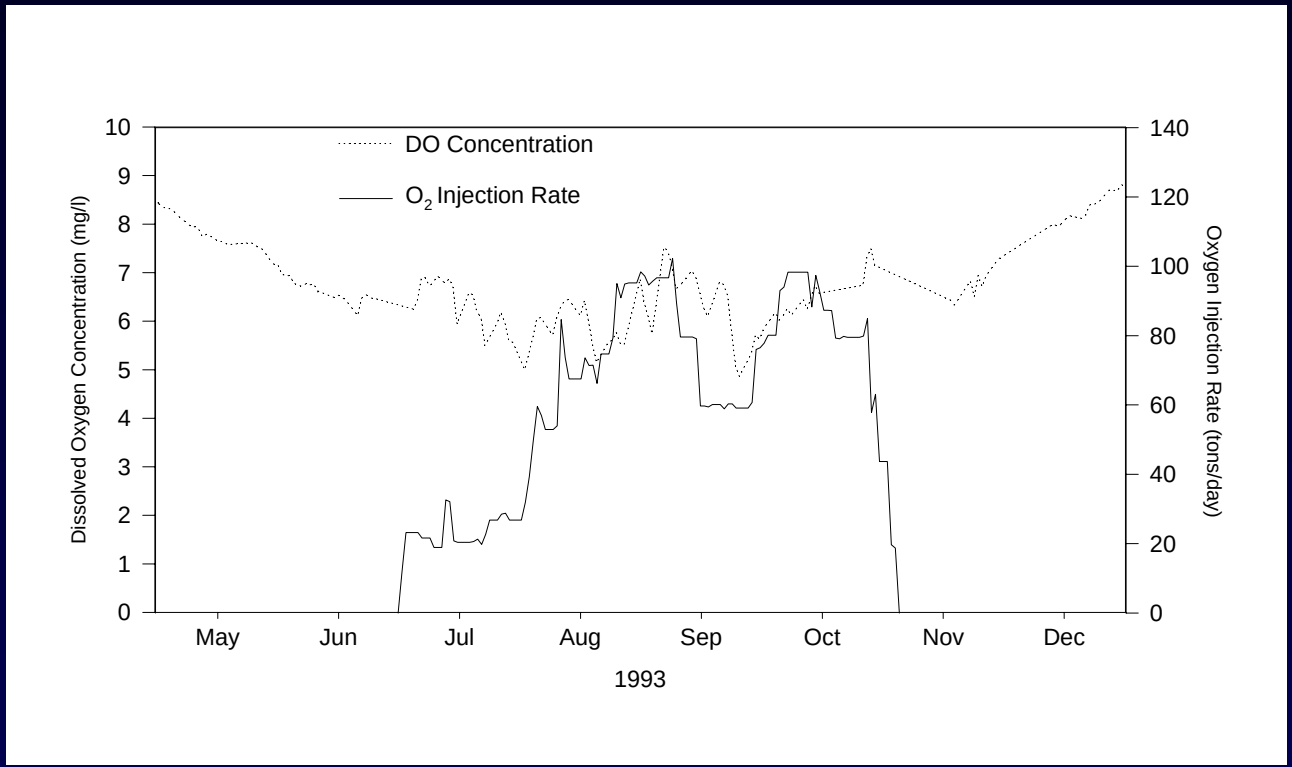
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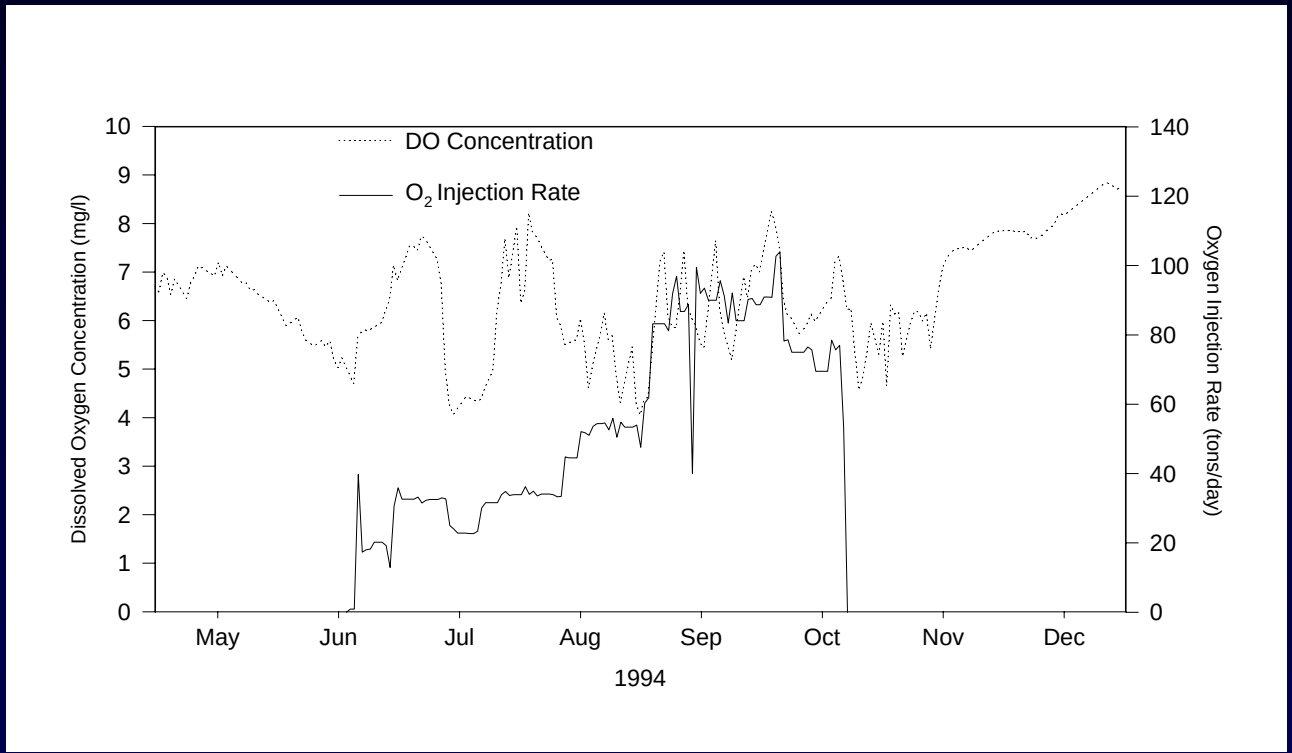
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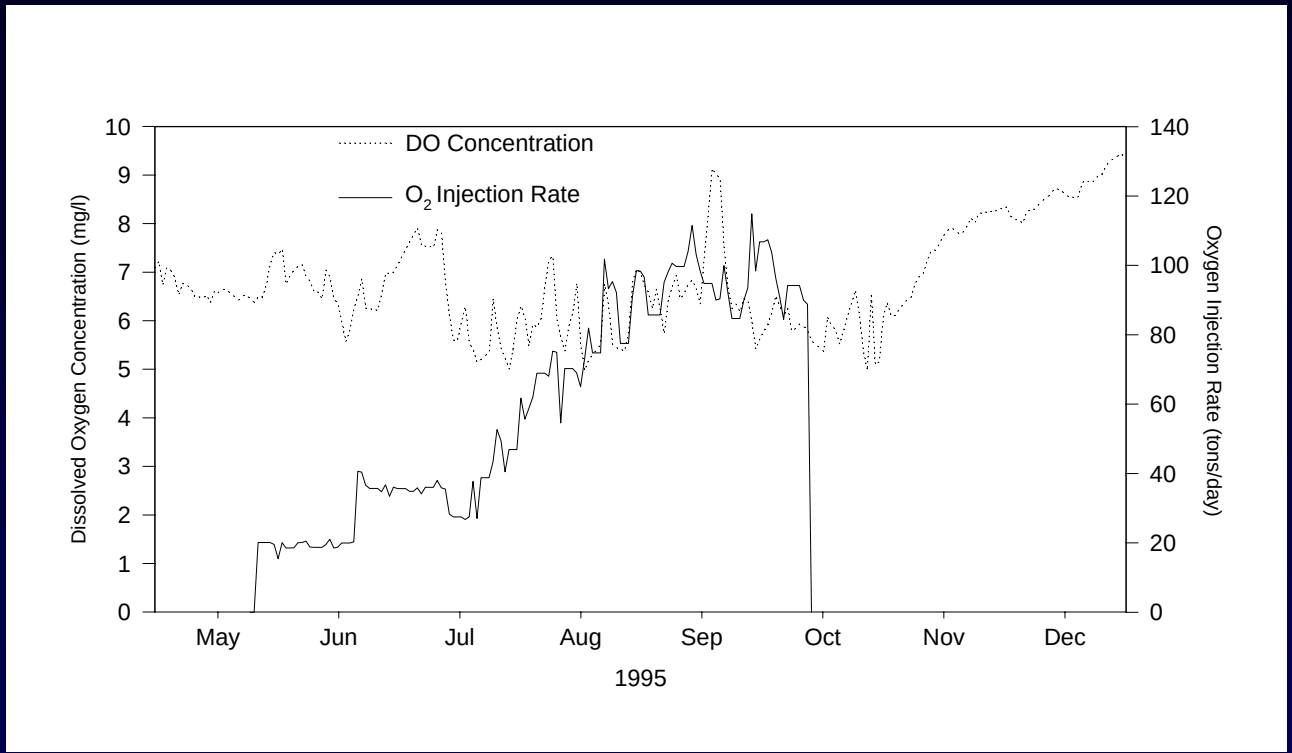
1994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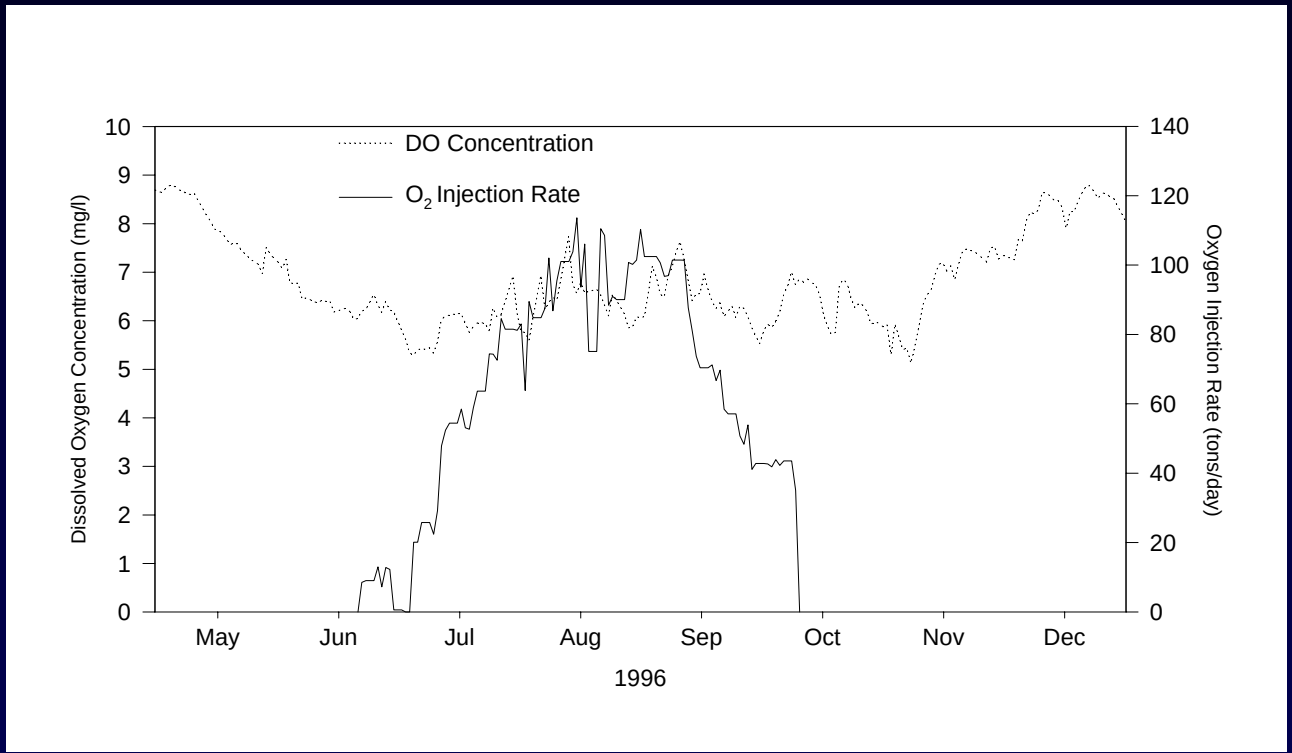
Pumped-Storage: The Issues

- Fish entrainment
- Temperature alterations
- Habitat loss
- Changes in dissolved oxygen distributions

PHASE III Studies Performed in 1996 to simulate full pumped-storage operation

Results of studies (draft report) used for court decision


DO Concentration
O2 Injection Rate
Dissolved Oxygen Concentration (mg/l)
Oxygen Injection Rate (tons/day)
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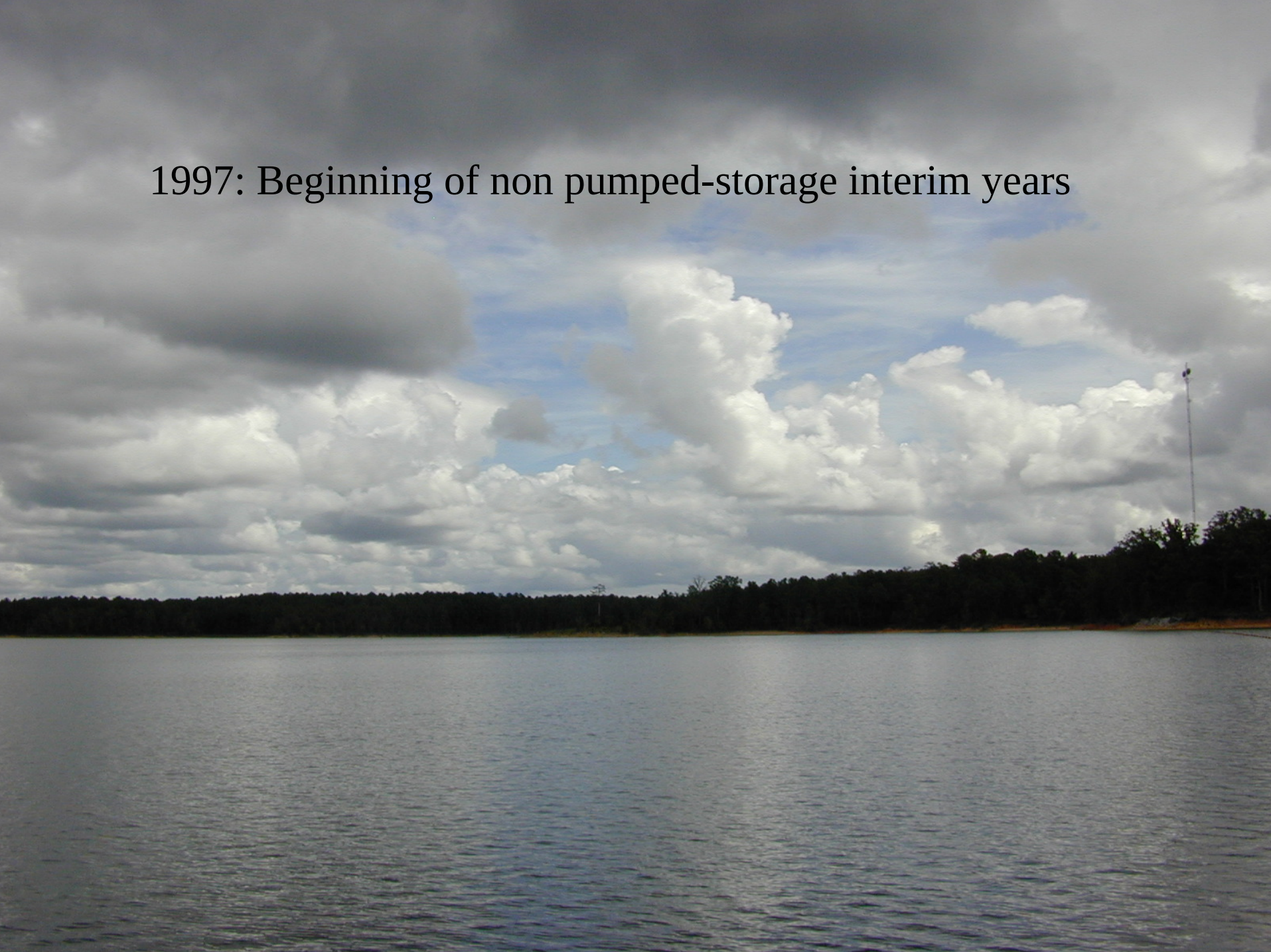
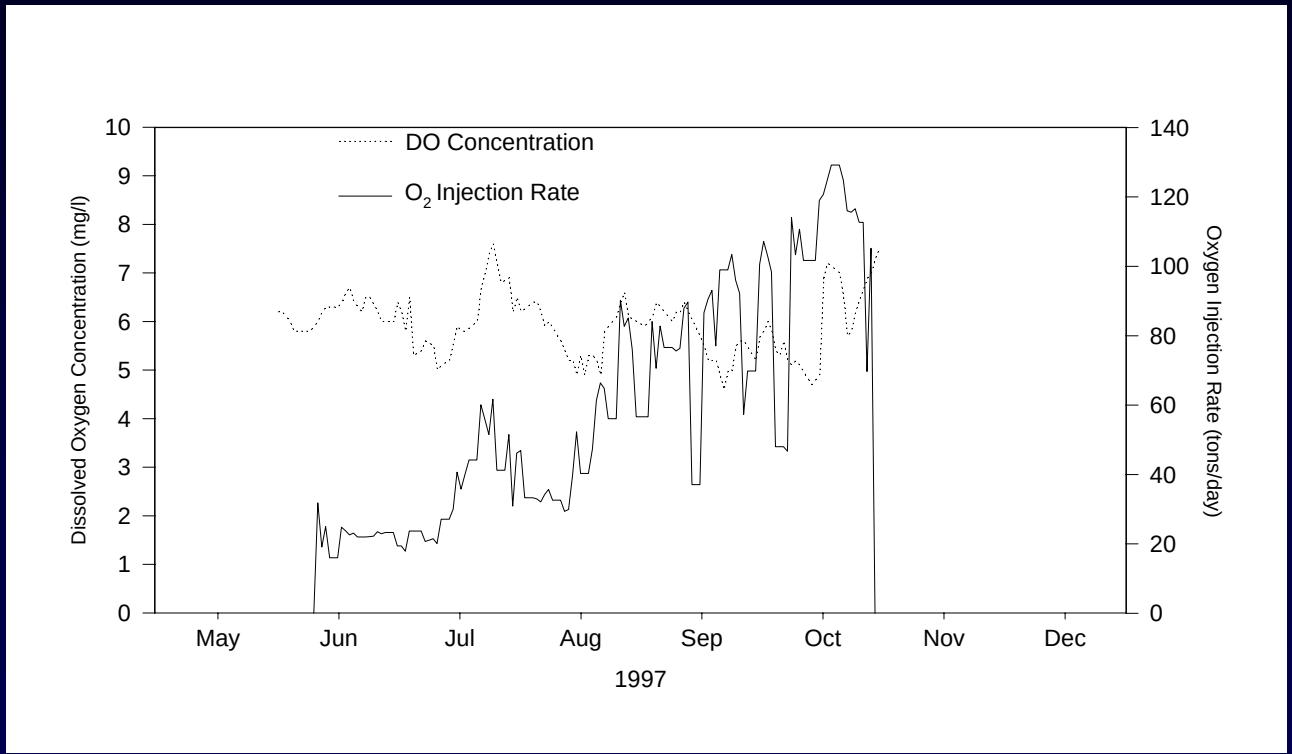
1996


1997: Beginning of non pumped-storage interim years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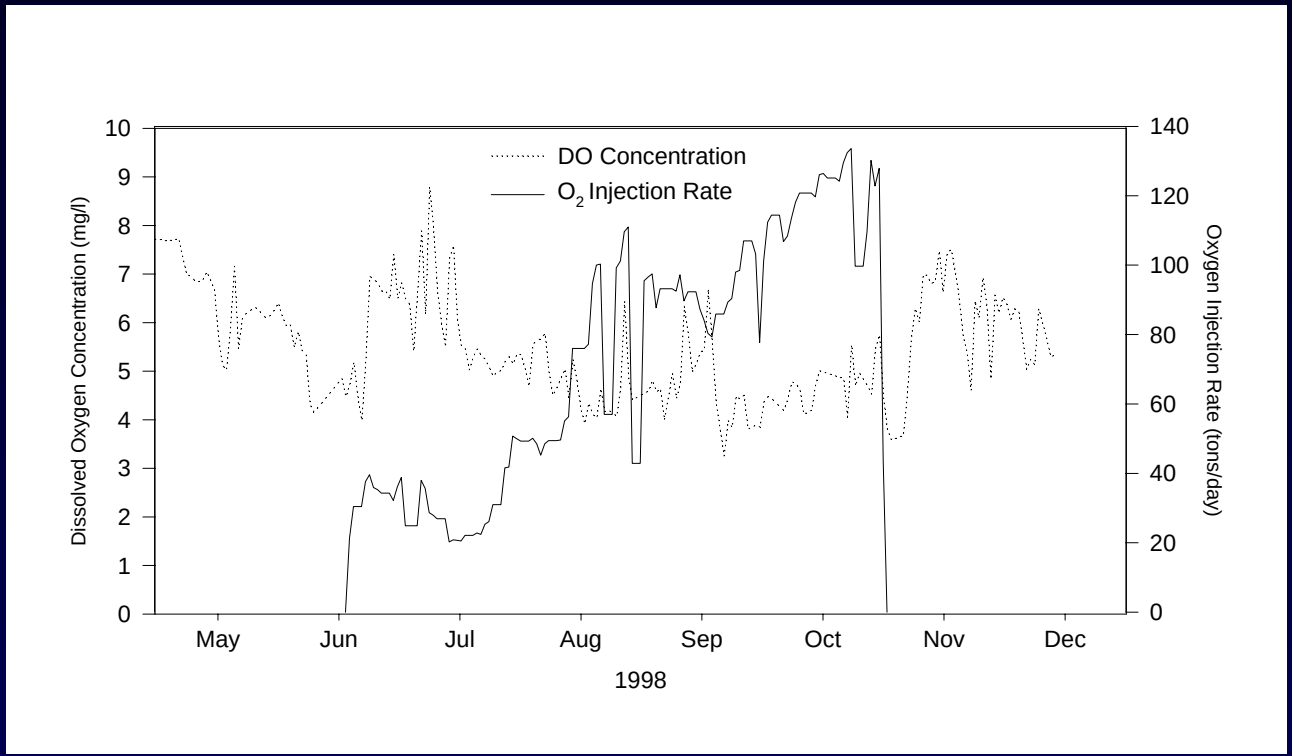
1997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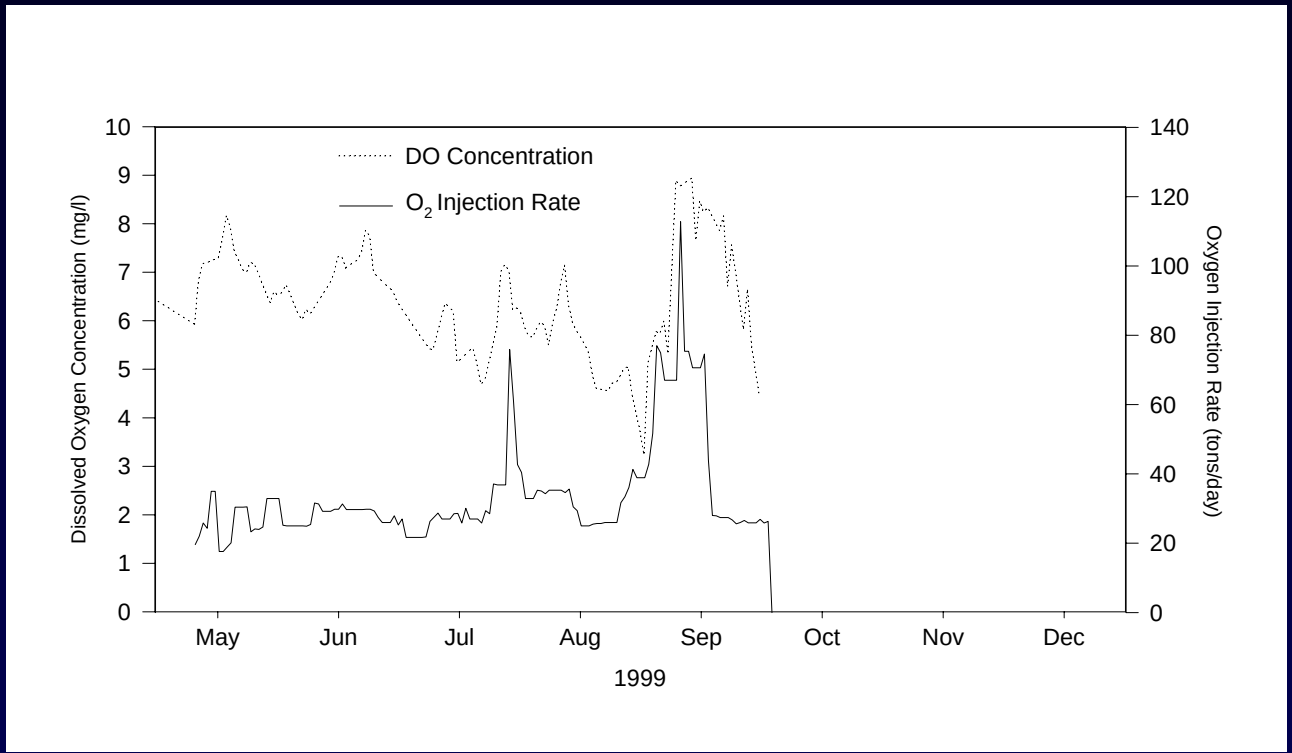
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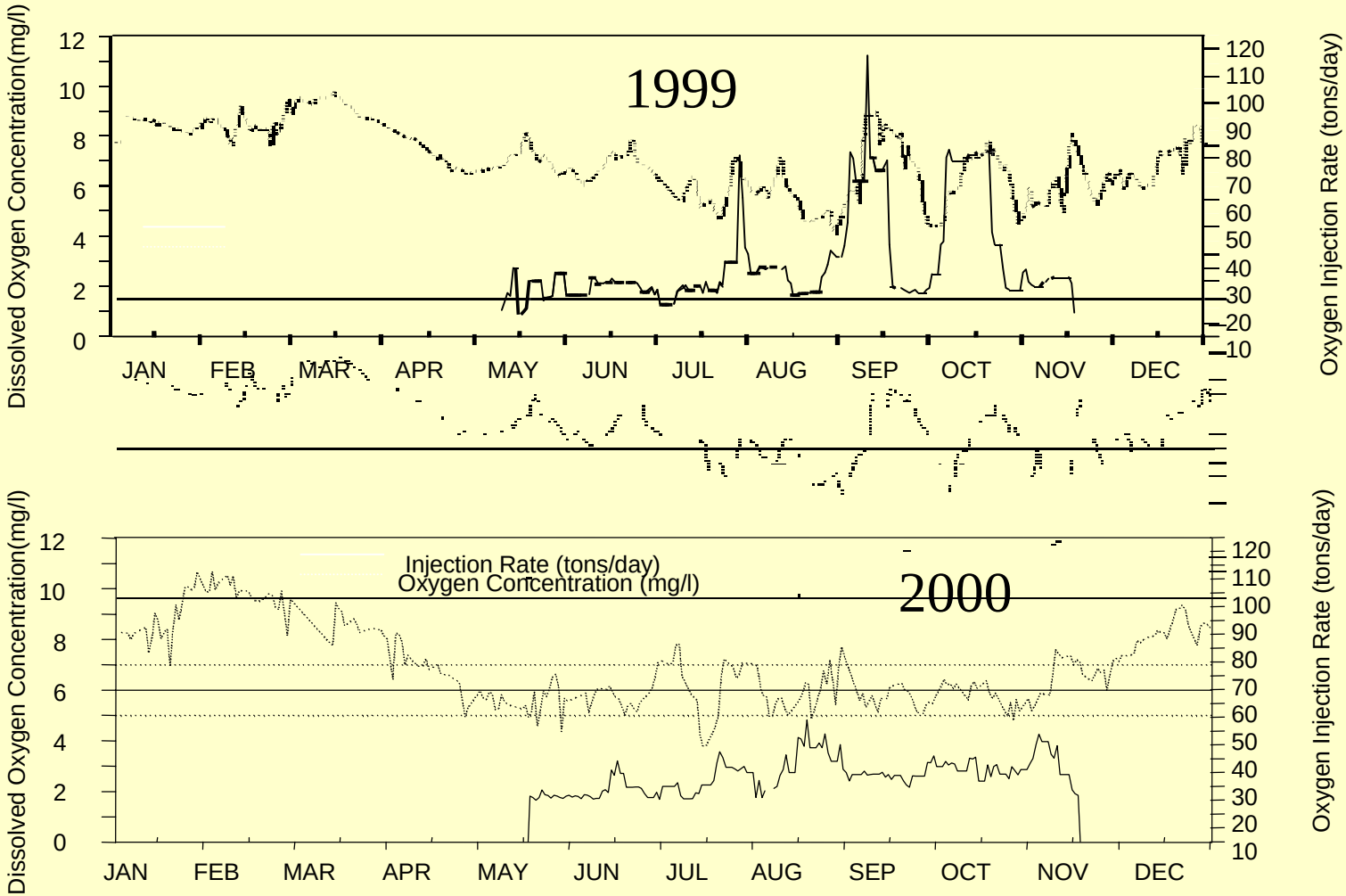
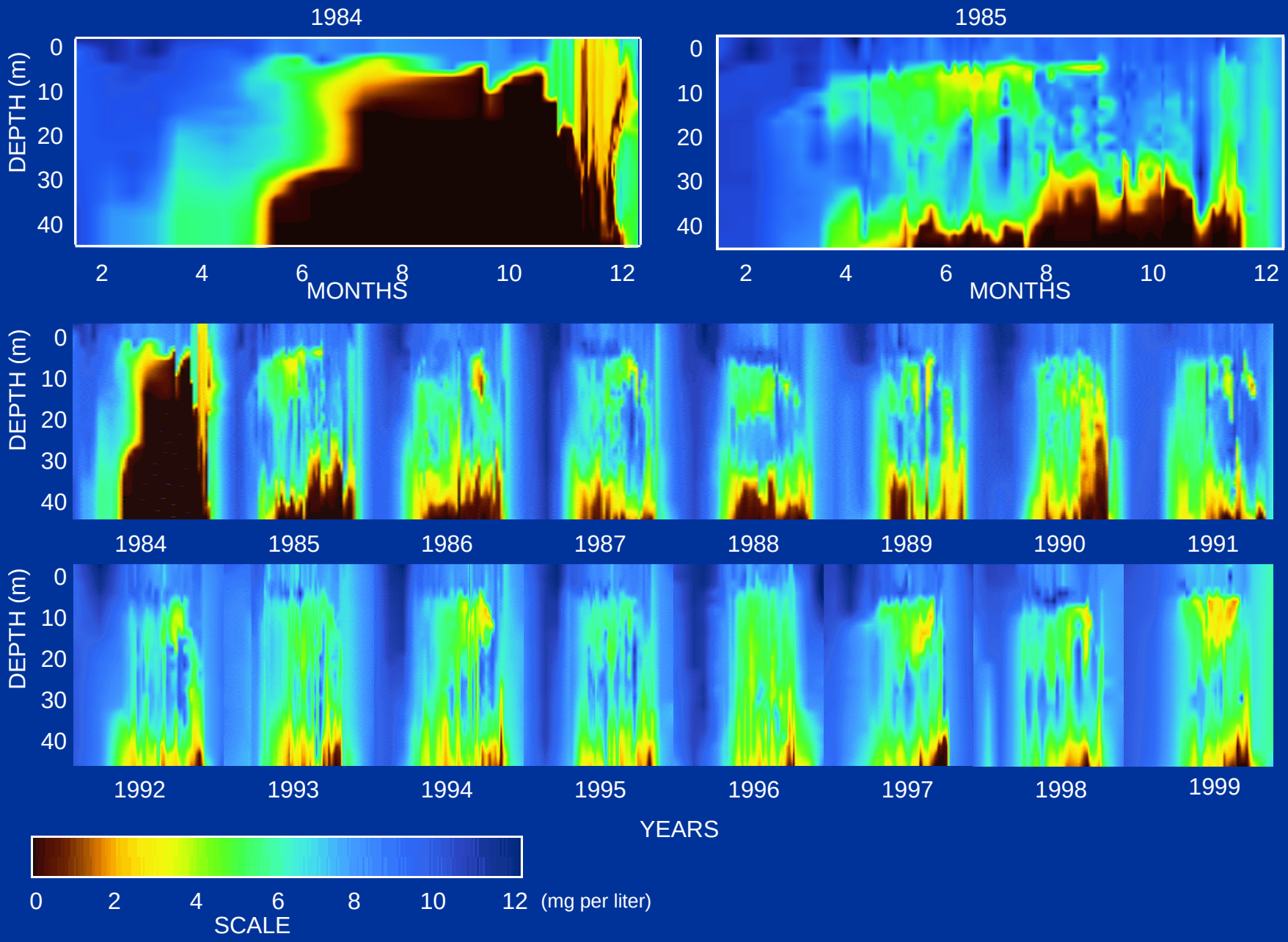
1999

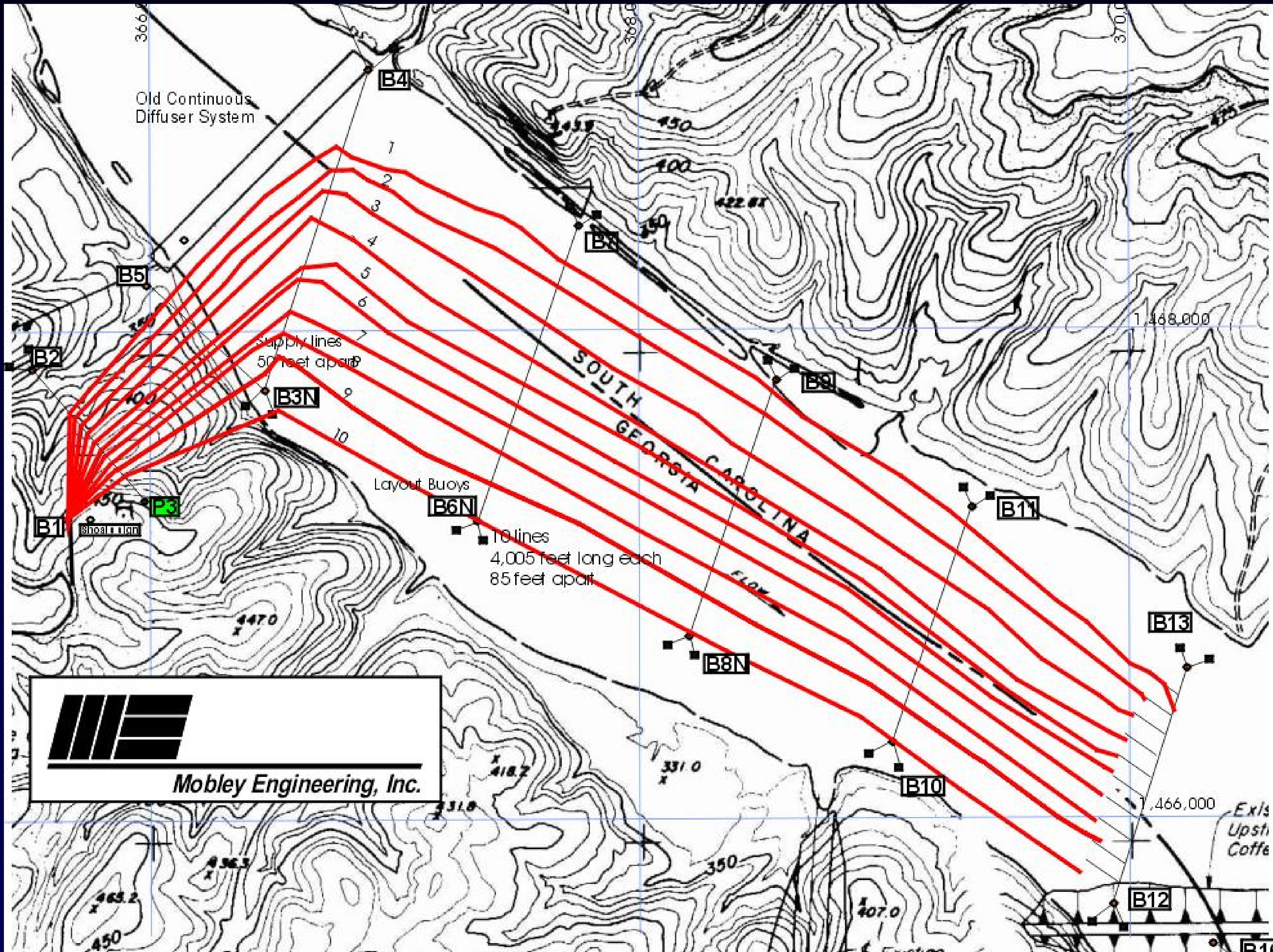

Dissolved Oxygen Concentration(mg/l)
Oxygen Injection Rate (tons/day)
1999
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Injection Rate (tons/day)
Oxygen Concentration (mg/l)
2000

Dissolved Oxygen in the RBR Forebay, 1984-1999



System Replacement with New Design

- Original design based on Speece pilot study in JST Lake
- Original RBR installation consisted of rigid pipe with circular ceramic, later flexible-membrane bubblers
- TVA (Mobley Engineering) developed new delivery design based on ‘soaker hose’ material
- New design adopted by USACE as replacement for original RBR oxygenation system
- 3 May 2002, Court decided in favor of USACE regarding pumped-storage at RBR Dam

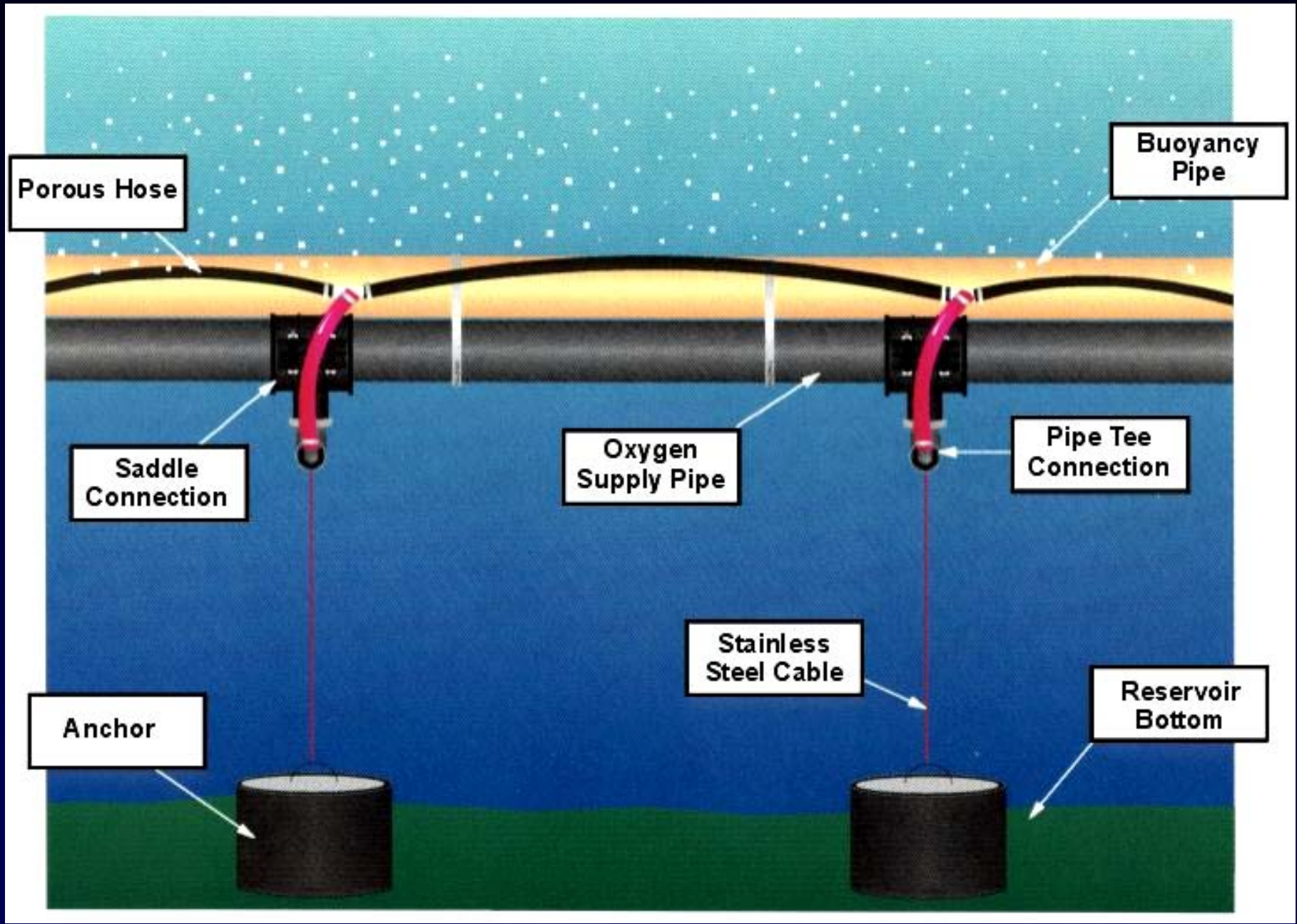


Old Continuous
Diffuser System
B4
B5
B2
B3N
B1
P3
B7
B9
B11
B13
B6N
B8N
B10
B12
B16
Supply lines
50 feet apart
Layout Buoys
10 lines
4,005 feet long each
85 feet apart
SOUTH
GEORGIA
CAROLINA
FLOW
1,468,000
1,466,000
Mobley Engineering, Inc.

What is This Design?

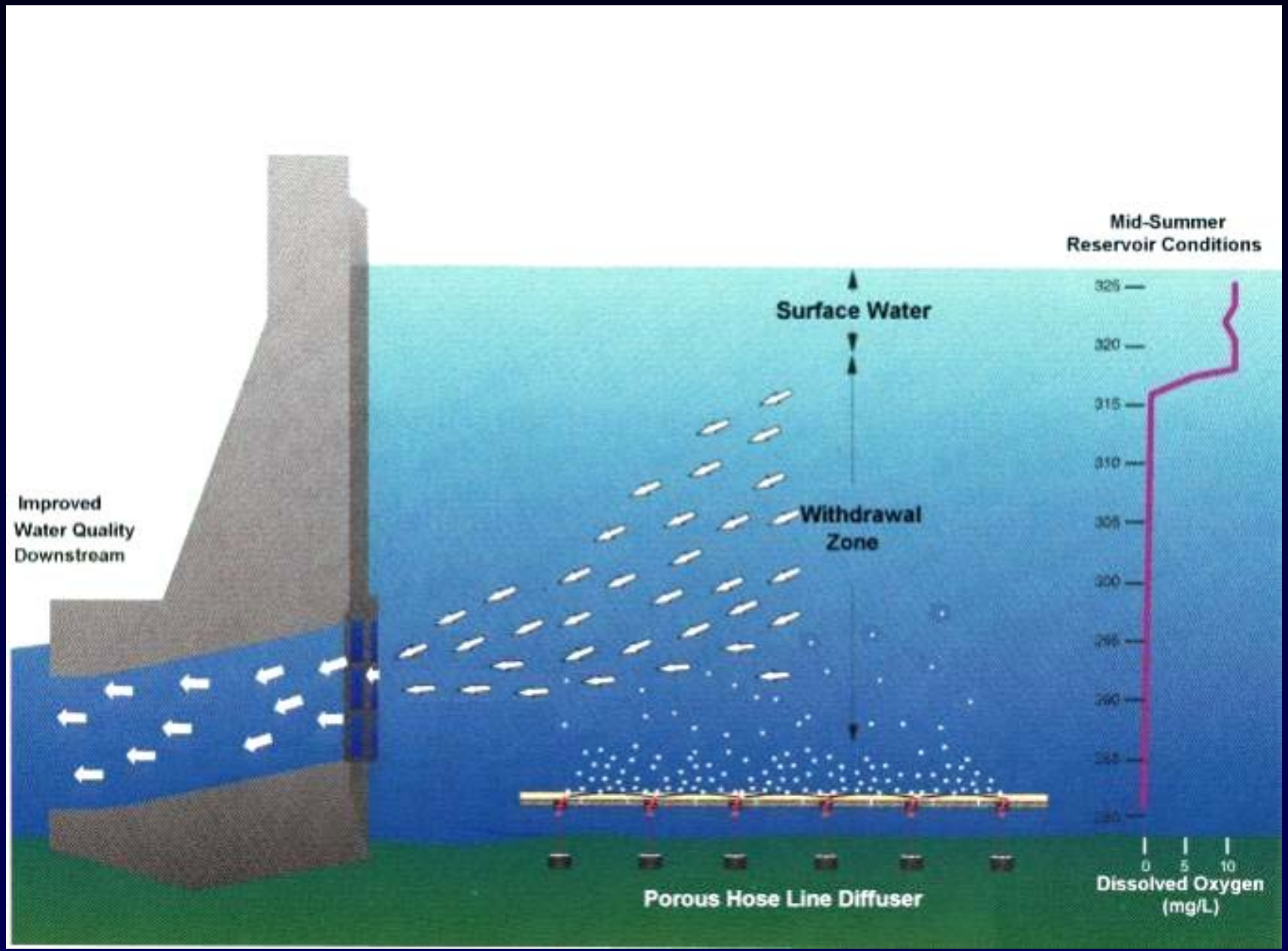
The new design is a system of HDPE pipes, porous hose, misc. parts that are connected to a liquid oxygen system and specially engineered to:

- place oxygen in specific layers
- cover large areas of the reservoir
- in order to achieve optimized DO enhancement both in-lake and in outflows


Porous Hose
Buoyancy Pipe
Saddle Connection
Oxygen Supply Pipe
Pipe Tee Connection
Stainless Steel Cable
Anchor
Reservoir Bottom

WHY use this design?

- Oxygen bubbles are spread over large areas to obtain high oxygen transfer efficiencies.
- Separate Lines are utilized to spread oxygen input far upstream of the dam.
- Lines are located at specific elevations above the reservoir bottom.
- Oxygen outflow is distribution along the length of the lines and controlled with engineered orifice sizes.

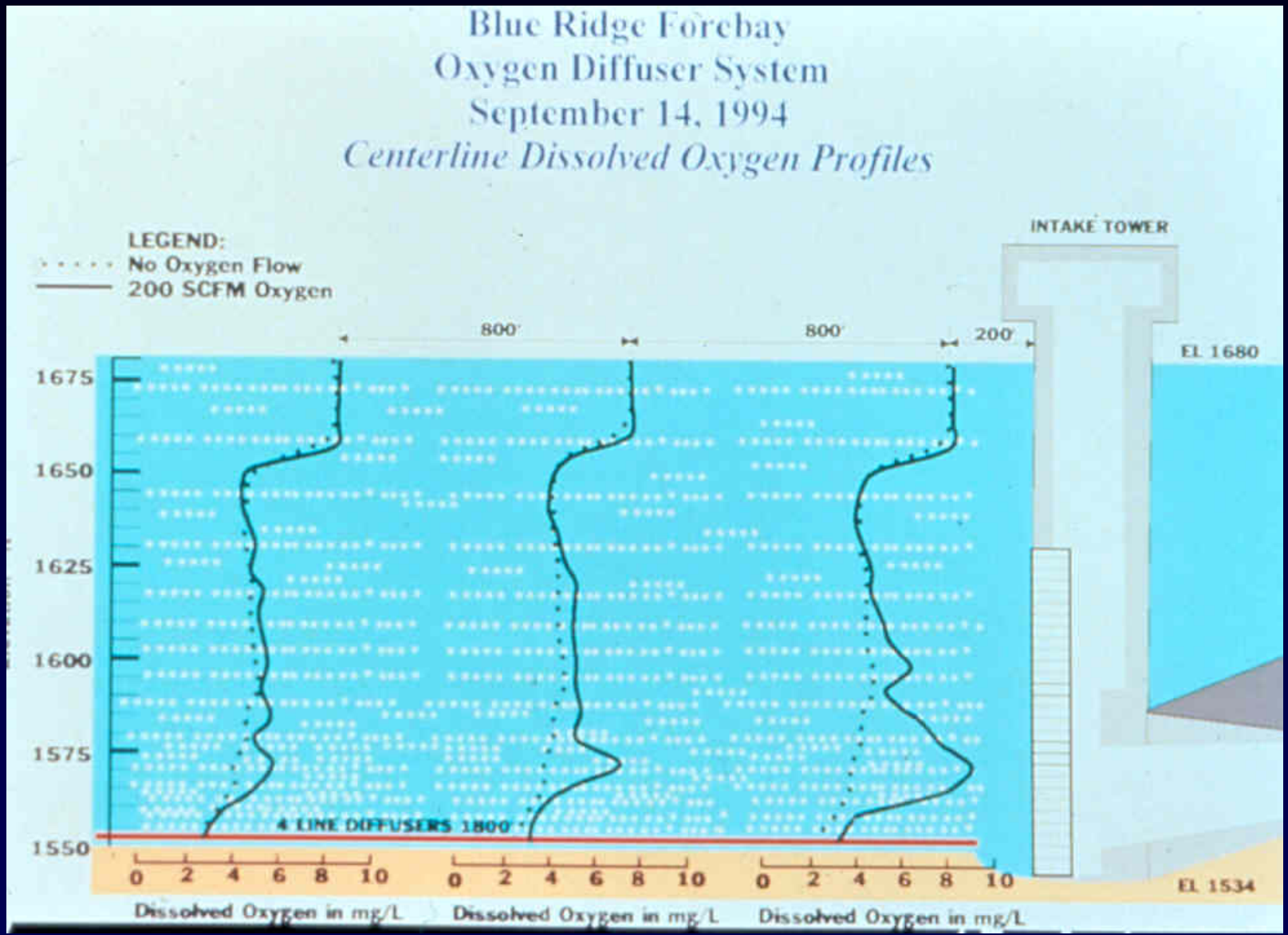

Mid-Summer
Reservoir Conditions
325
320
315
310
305
300
295
290
285
280
Surface Water
Withdrawal
Zone
Improved
Water Quality
Downstream
Porous Hose Line Diffuser
0
5
10
Dissolved Oxygen
(mg/L)

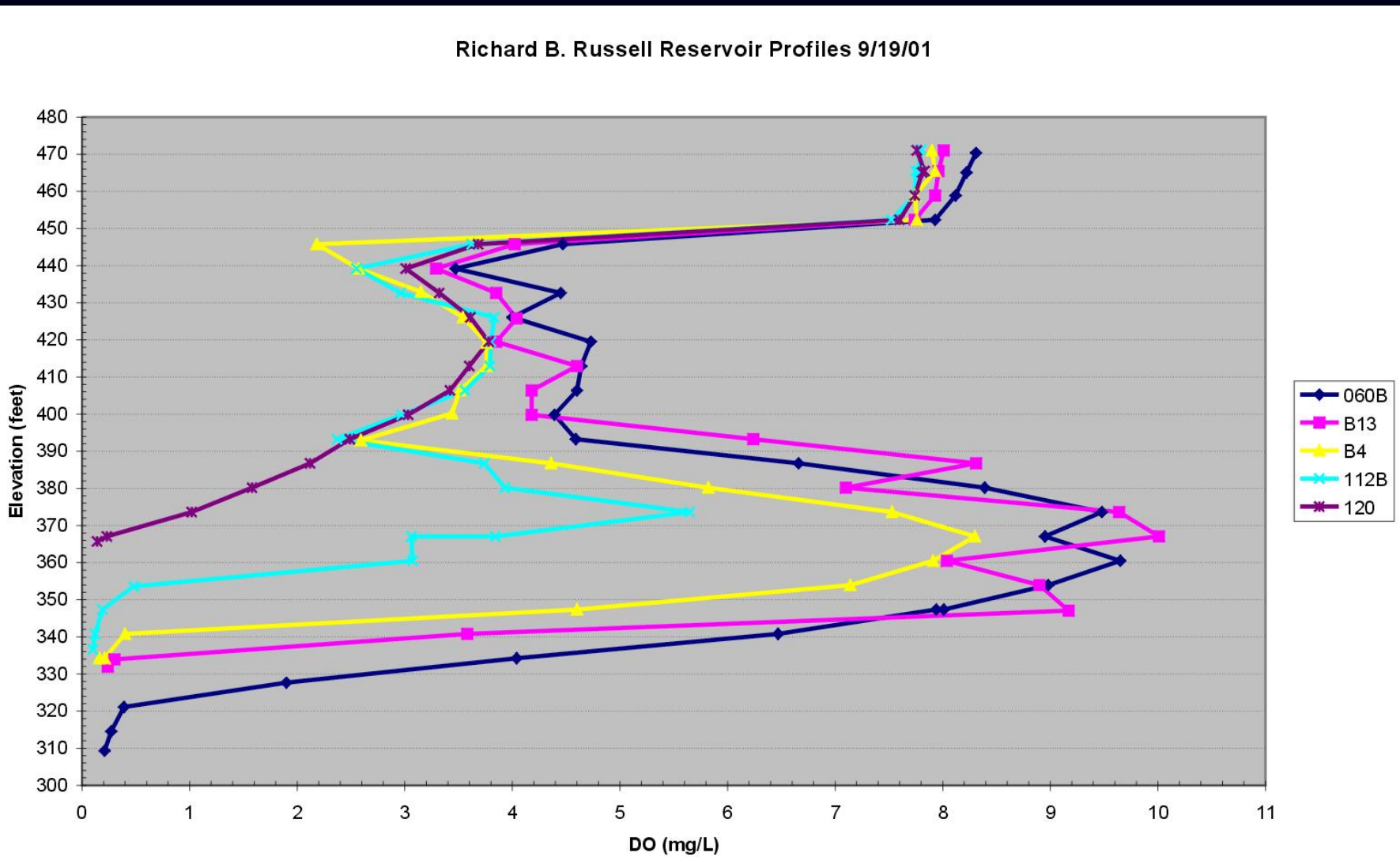

COACH


RESTRICTED AR
#26922


03
STA 8400
11/14/01 11:26am

Blue Ridge Forebay
Oxygen Diffuser System
September 14, 1994
Centerline Dissolved Oxygen Profiles



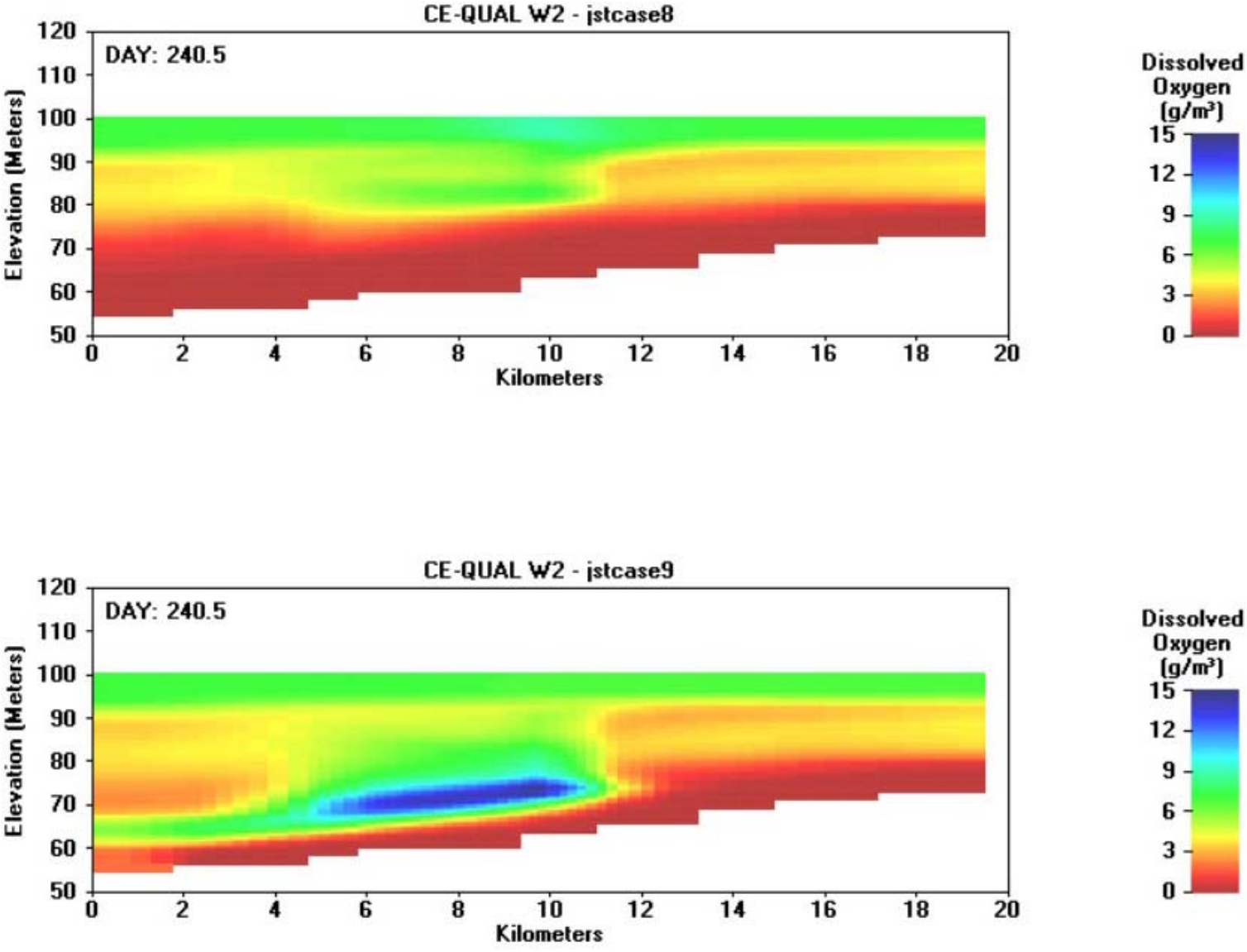

Richard B. Russell Reservoir Profiles 9/19/01
Elevation (feet)
480
470
460
450
440
430
420
410
400
390
380
370
360
350
340
330
320
310
300
0
1
2
3
4
5
6
7
8
9
10
11
DO (mg/L)
060B
B13
B4
112B
120

Potential Results in a Reservoir

- ⇧ Increased DO concentrations
- ⇩ Decreased Mn and Fe concentrations
- ⇗ Slightly greater pH
- ⇖ Slightly increased temperature possible
- ⇩ Ammonia N (NH_4-N) decreased
- ⇧ Nitrogen as Nitrate increased
- ⇧ Total Nitrogen load increased
- ⇩ Phosphate decreased
- ⇩ Geosmin levels decreased

Fish Habitat

- Reservoir oxygenation can be used to create and maintain fish habitat
  - Place oxygen in elevation layer of desired temperature
  - Spread oxygen over a large volume


CE-QUAL W2 - jstcase8
DAY: 240.5
Elevation (Meters)
120
110
100
90
80
70
60
50
0
2
4
6
8
10
12
14
16
18
20
Kilometers
Dissolved Oxygen (g/m³)
15
12
9
6
3
0
CE-QUAL W2 - jstcase9
DAY: 240.5
Elevation (Meters)
120
110
100
90
80
70
60
50
0
2
4
6
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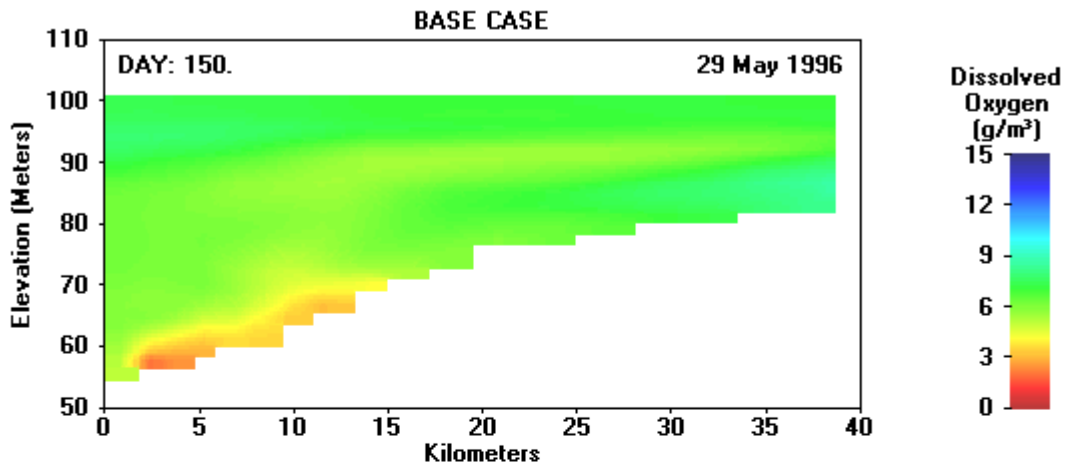
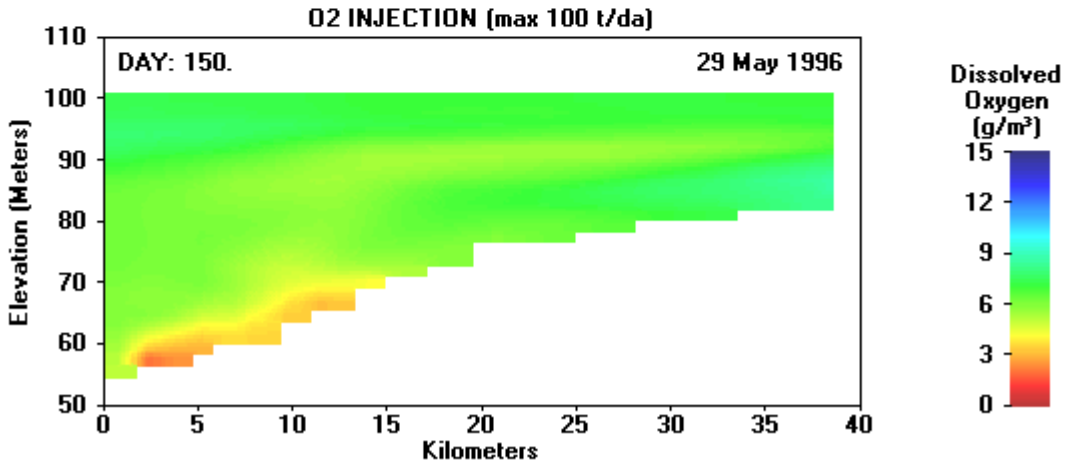
12
14
16
18
20
Kilometers
Dissolved Oxygen (g/m³)
15
12
9
6
3
0

Exit Print Options Animation Hide



Exit Print Options Animation Hide




Questions?