Conceptual Design of an Oxygen Diffuser System to Reduce Anoxic Products in Reservoir Releases

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Impacts of Hydrogen Sulfide at Reservoirs, Dams, and Tailwaters Workshop

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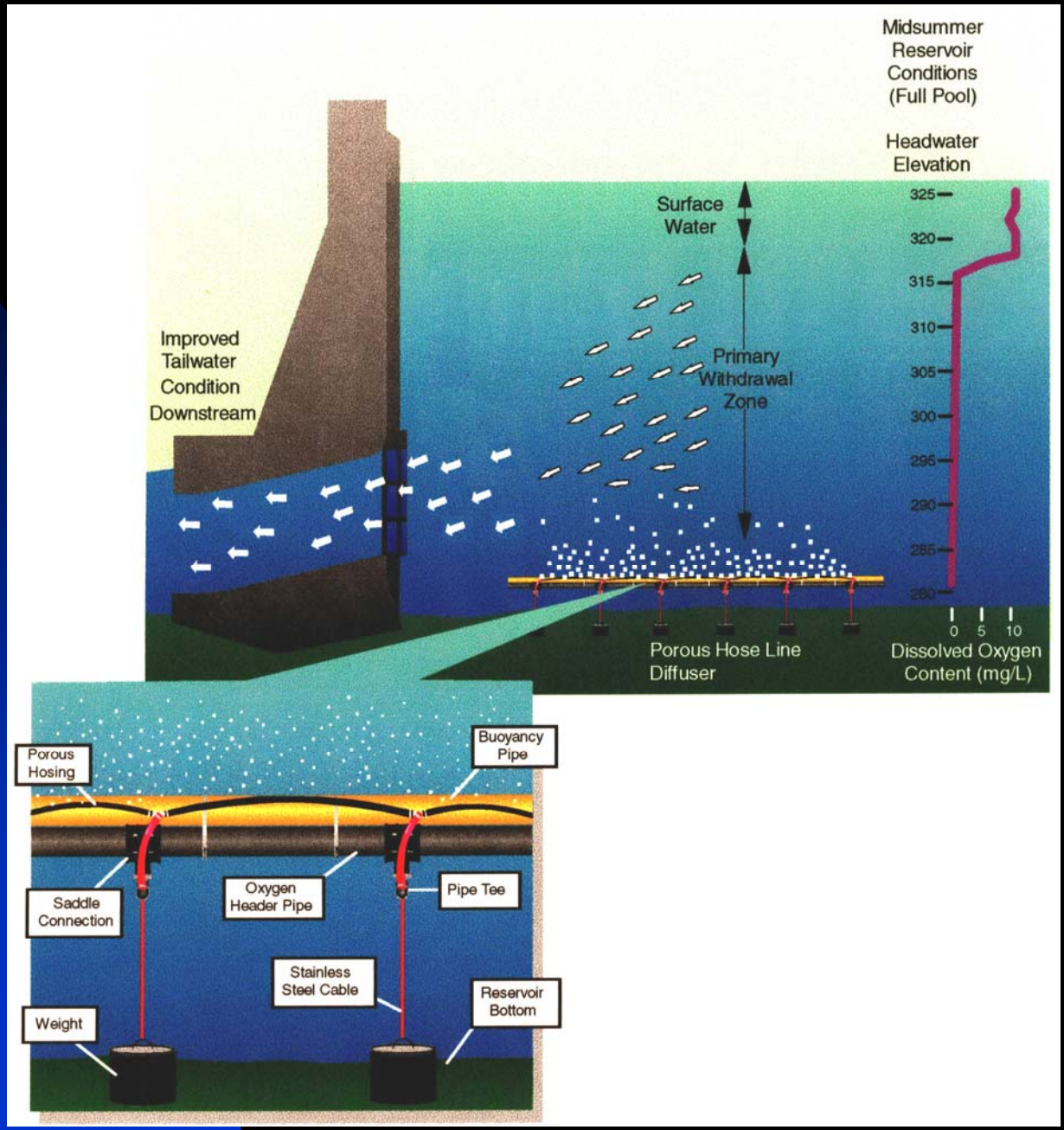
Nashville, TN

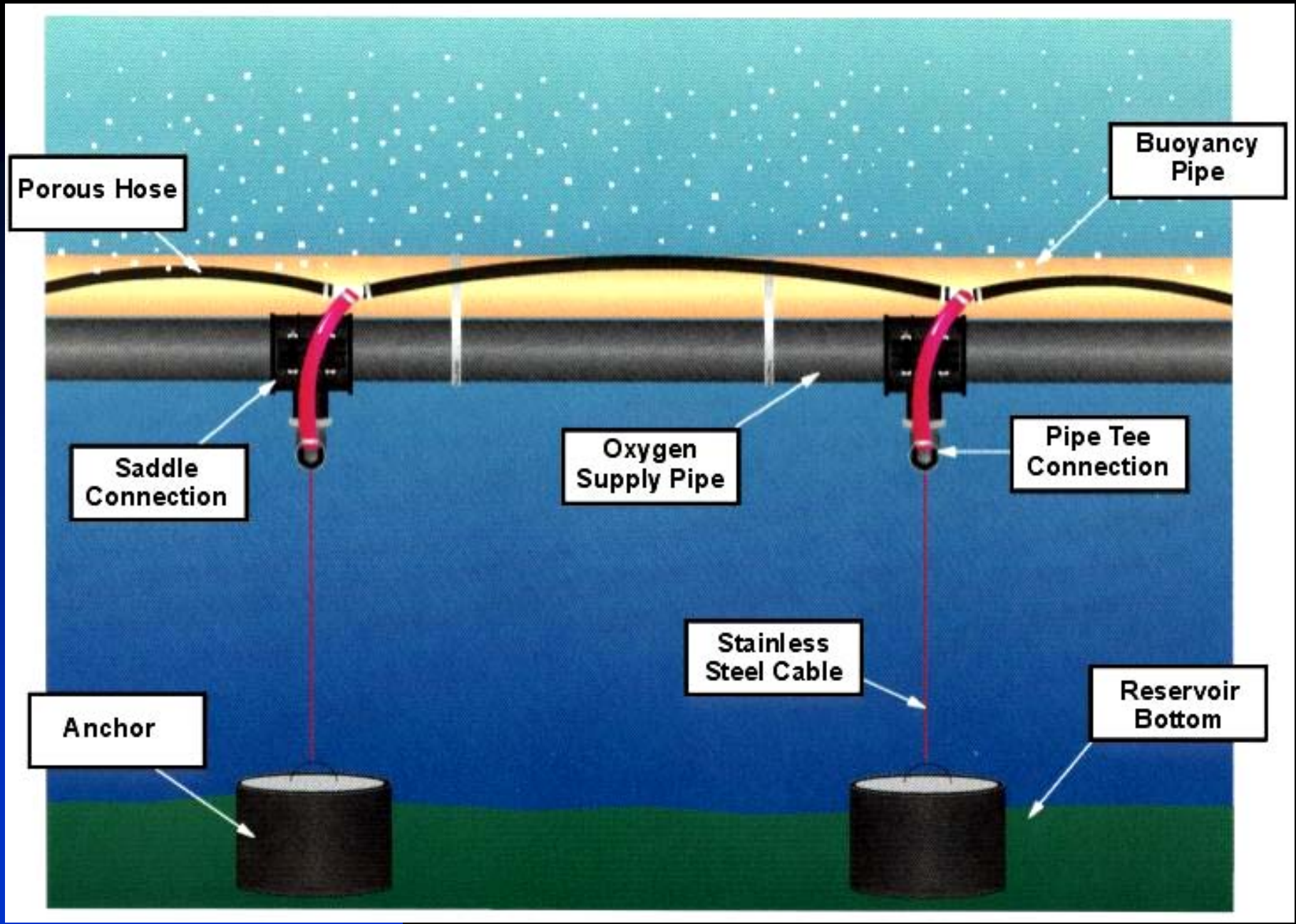
Introduction:

- The US Army Corp of Engineers, Nashville District's J.Percy Priest hydropower project exhibits water quality problems each summer.
- A conceptual oxygen diffuser design to improve water quality conditions was completed in 2000.
- Objectives for the design included:
  - Meet the 5 mg/L State DO standard in the turbine discharge
  - Reduce the release of dissolved iron and manganese
  - Eliminate the hydrogen sulfide odor

Line Diffuser:

- The Line Diffuser places oxygen in the reservoir to achieve optimized DO enhancement of hydropower releases:
  - Diffusers are located on the reservoir bottom usually along the old riverbed.
  - Oxygen bubbles are spread over a large area to obtain high oxygen transfer efficiencies.
  - Operation of the diffusers can be timed with hydro turbine operation or spread over a sufficient volume to meet peaking demands.
  - Anoxic products can be reduced in the reservoir releases.


Midsummer
Reservoir
Conditions
(Full Pool)
Headwater
Elevation
325
320
315
310
305
300
295
290
285
280
Surface
Water
Primary
Withdrawal
Zone
Improved
Tailwater
Condition
Downstream
Porous Hose Line
Diffuser
0
5
10
Dissolved Oxygen
Content (mg/L)
Porous
Hosing
Buoyancy
Pipe
Saddle
Connection
Oxygen
Header Pipe
Pipe Tee
Stainless
Steel Cable
Reservoir
Bottom
Weight


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


10/31/01 8:20am


40


6092-DC
11/14/01 11:27am


11/9/01 3:15pm


TN-6092-DC
Mobley Engineering


Buzzard Roost
Bubble Pattern
5 29 '97


30
60
90
120
150
LMS-I
MAP
Nearest
ZOUT
PAGES
MENU
ENT
ICONS

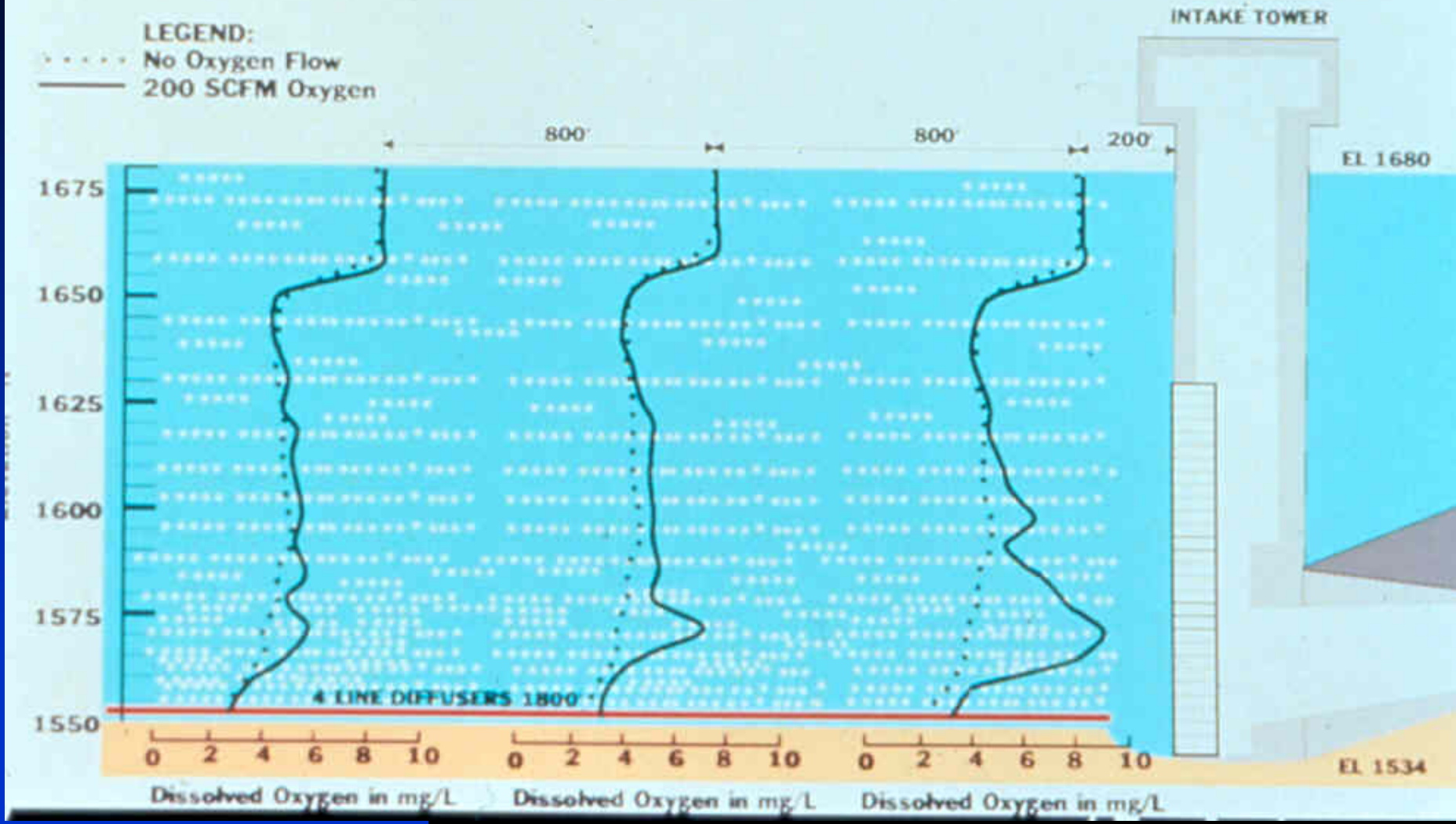
Oxygen Supply

- Line diffusers are typically supplied with oxygen for hydro power applications
- Liquid oxygen is trucked to onsite storage tank
- Vaporization from liquid to gas provides pressure to move gas through the diffusers

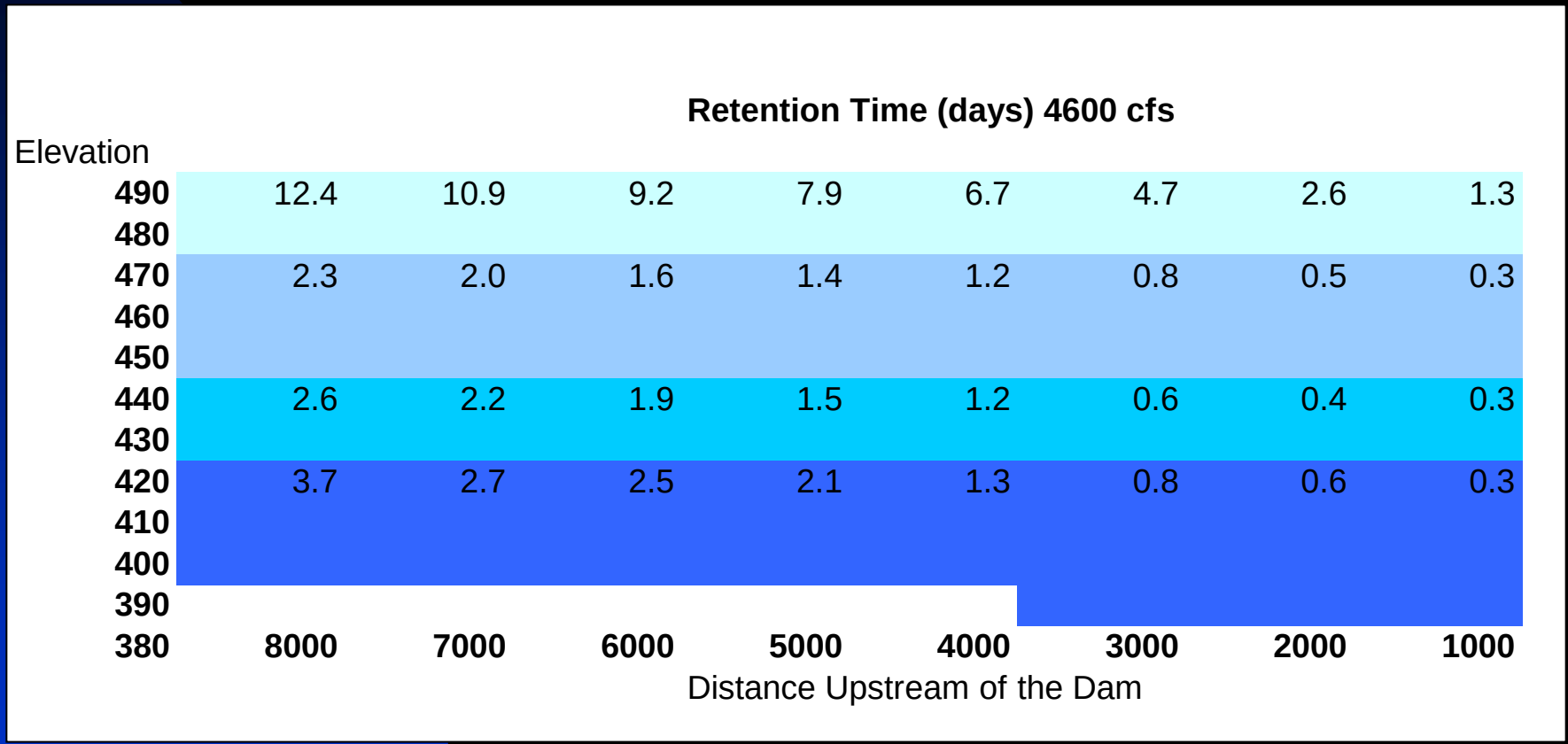
Application to J. Percy Priest

- Oxygen input of the diffusers was sized to provide:
  - ★3 mg/L increase in turbine flow
  - ★Satisfaction of the oxygen demands exerted during turbine operations
  - ★Maintenance of the oxygenated forebay volume during non-turbine operation periods

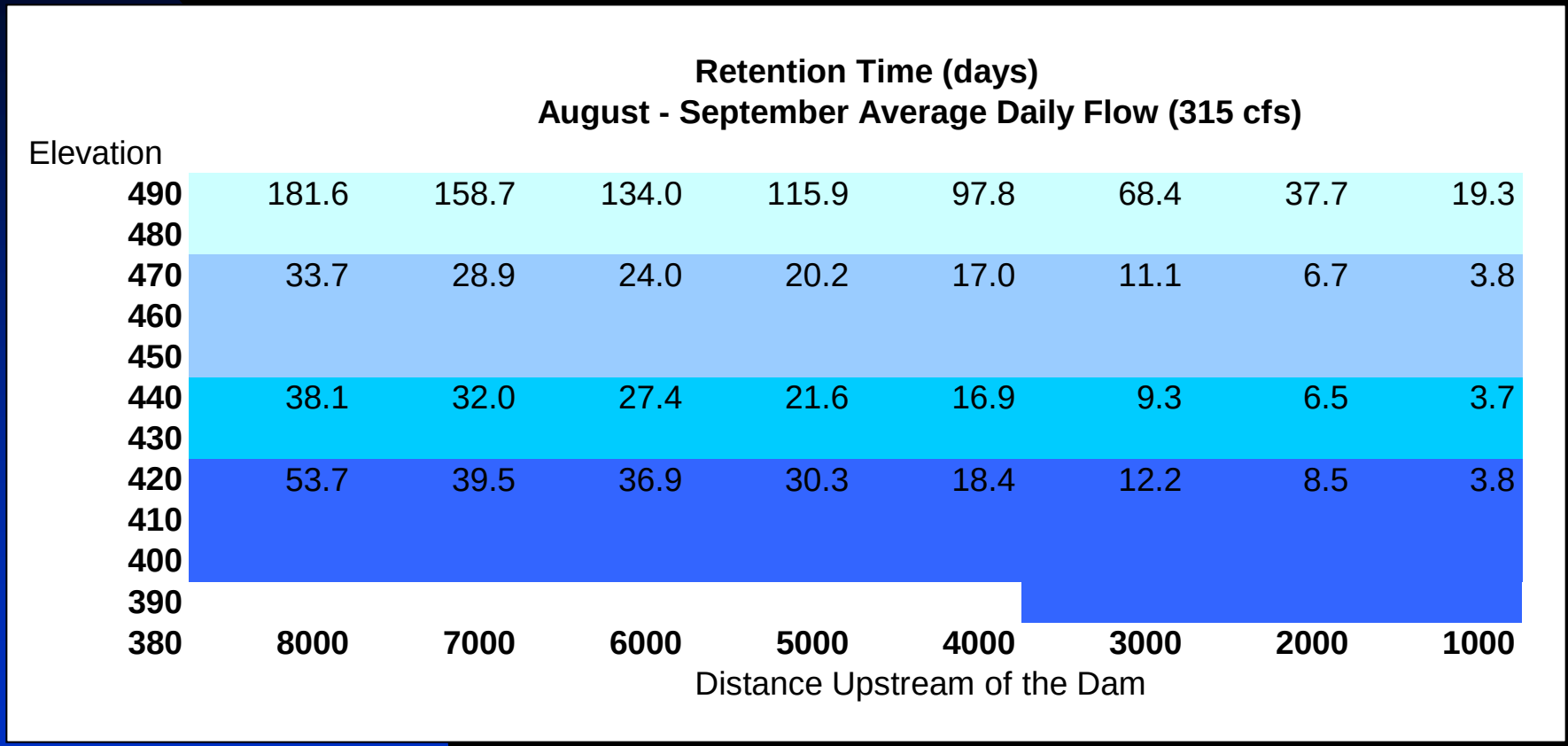
Blue Ridge Forebay
Oxygen Diffuser System
September 14, 1994
Centerline Dissolved Oxygen Profiles



Forebay Retention Times During Turbine Operation



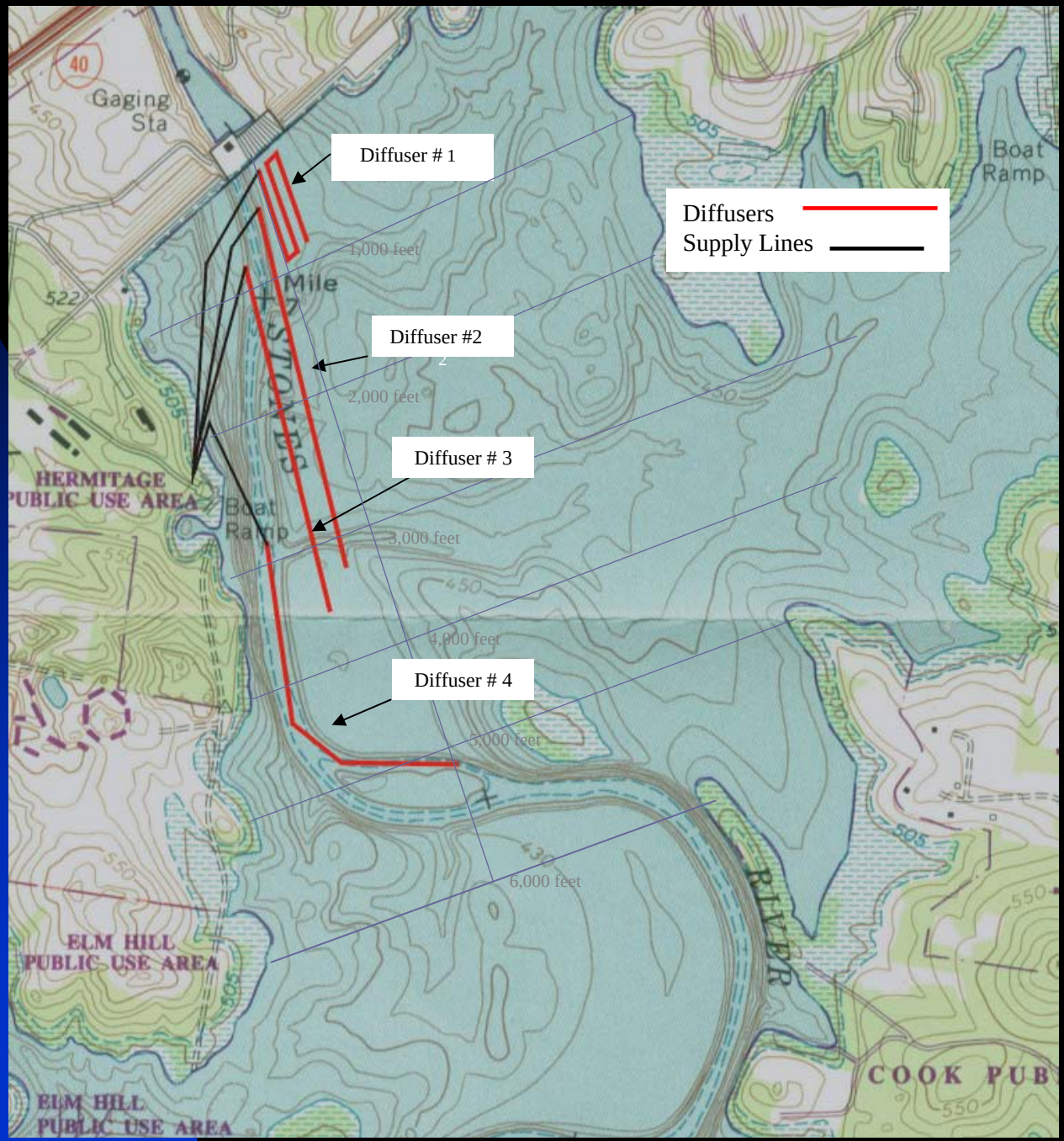
Forebay Retention Times During Non-Turbine Operation



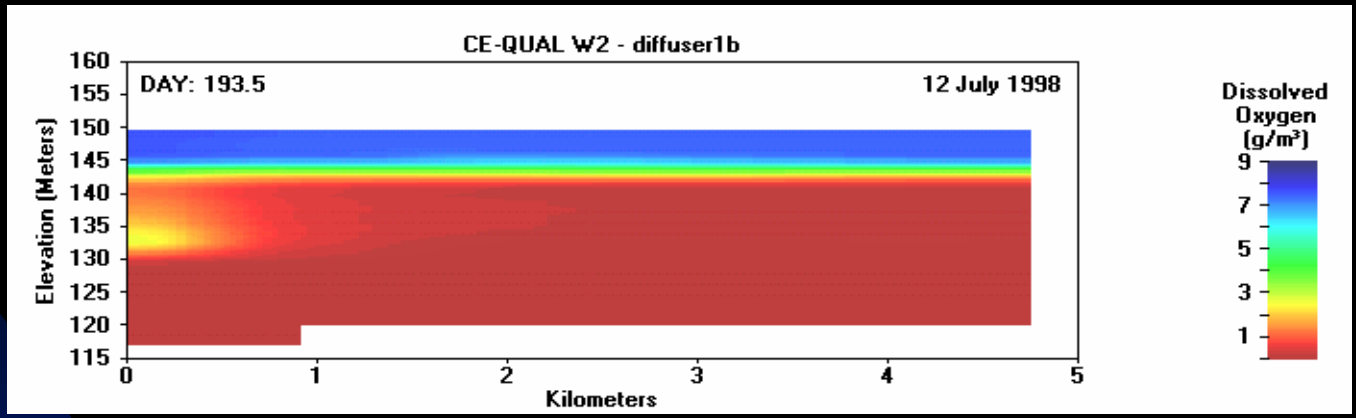
Diffuser Design Flows

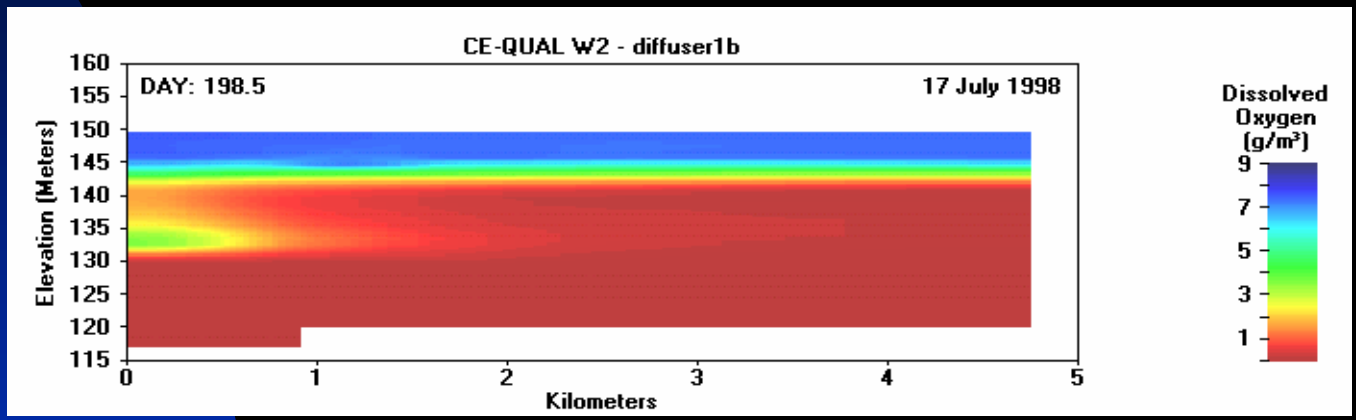
J. Percy Priest Flow Rates

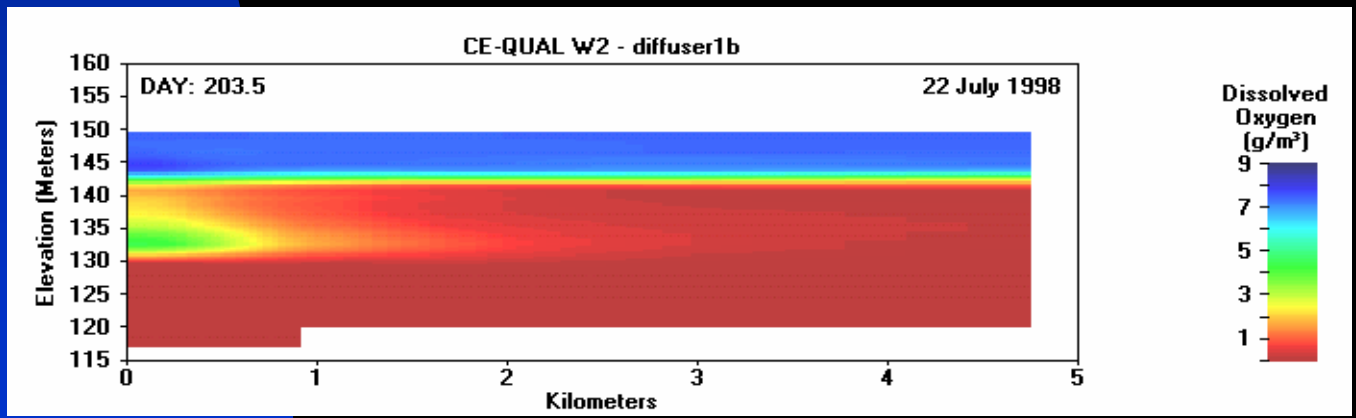
		TURBINE ON				TURBINE OFF					
	Length	**Turbine**		**Turbine Make-up**		**Turbine Maintenance**		**Forebay Maintenance**		**Forebay Make-up**	
	(feet)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)	O2 Flow (scfm)	Flux (scfm/ft)
#1	**2,500**	260	0.12			17	negl				
#2	**2,500**	260	0.12								
#3	**2,850**			300	0.12			27	negl	4.7	negl
#4	**3,150**	260	0.12	63	0.12			16.5		1.4	
Total	**11,000**	780		363		17		27		4.7	

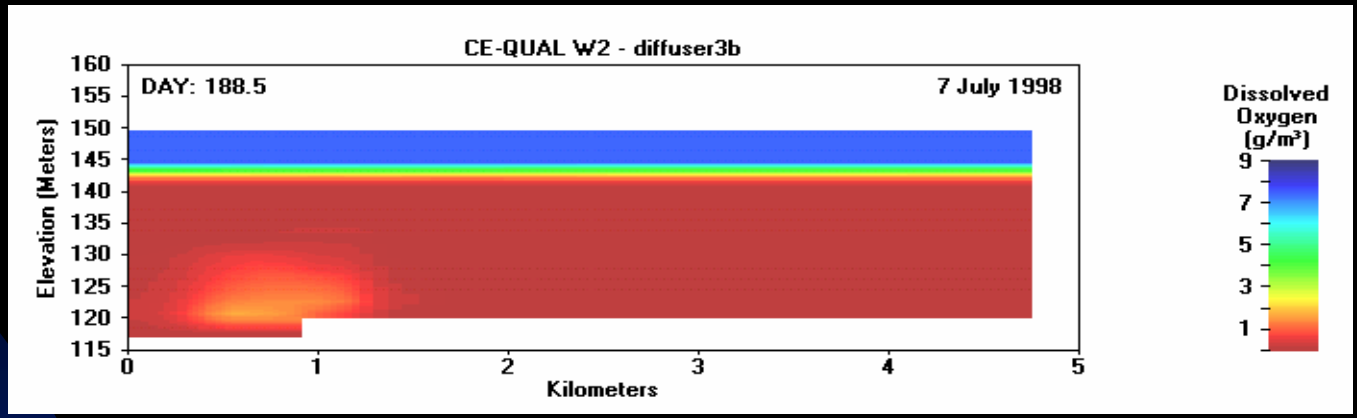

Diffuser # 1
Diffuser #2
Diffuser # 3
Diffuser # 4
Diffusers
Supply Lines
1,000 feet
2,000 feet
3,000 feet
4,000 feet
5,000 feet
6,000 feet
Gaging Sta
Boat Ramp
Mile
HERMITAGE PUBLIC USE AREA
ELM HILL PUBLIC USE AREA
ELM HILL PUBLIC USE AREA
RIVER
COOK PUB

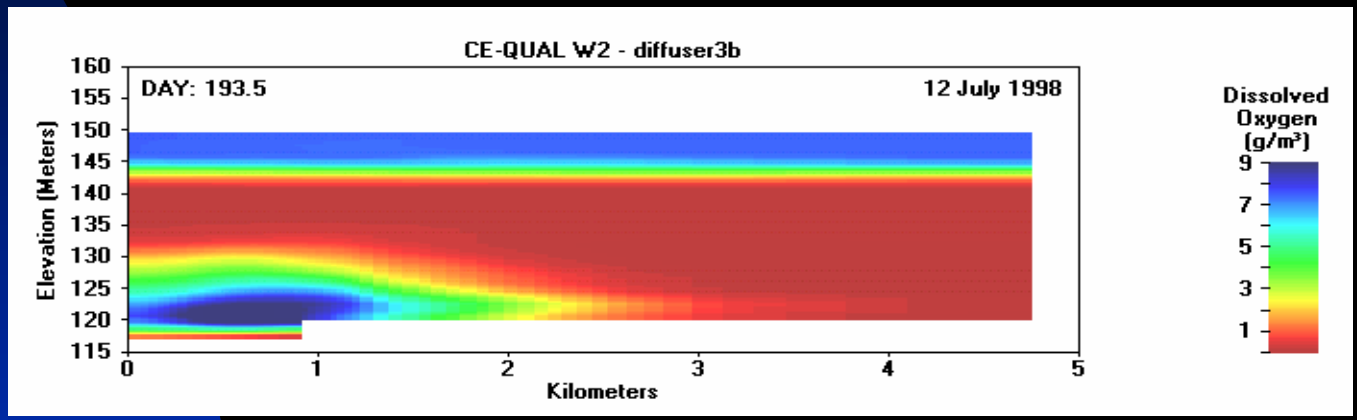
												WSE (meters)
												150
												149
												148
							O2 Input (Tons/day)		0.80	0.80		147
												146
								% Input	0.1	0.1		145
									0.1	0.1		144
									0.3	0.3		143
									0.5	0.5		142
									1	1		141
									2	2		140
									2	2		139
									4	4		138
									6	6		137
									8	8		136
									10	10		135
									12	12		134
									15	15		133
O2 Input (Tons/day)		0.30	0.30	0.30	0.30	0.24	0.18		18	18	Dam	132
									21	21		131
	% Input	0.1	0.1	0.1	0.1	0.1	0.1		Diffuser # 1			130
		0.2	0.2	0.2	0.2	0.2	0.2					129
		0.4	0.4	0.4	0.4	0.4	0.4					128
		1	1	1	1	1	1					127
		3	3	3	3	3	3					126
		5	5	5	5	5	5					125
		8	8	8	8	8	8					124
		10	10	10	10	10	10					123
		13	13	13	13	13	13					122
		16	16	16	16	16	16					121
		19	19	19	19	19	19					120
		23	23	23	23	23	23					119
		Diffuser # 3										118
												117
304.8	304.8	152.4	152.4	152.4	152.4	121.92	91.44	91.44	152.4	152.4	Cell Length (meters)	
1000	**1000**	**500**	**500**	**500**	**500**	**400**	**300**	**300**	**500**	**500**	Cell Length (feet)	

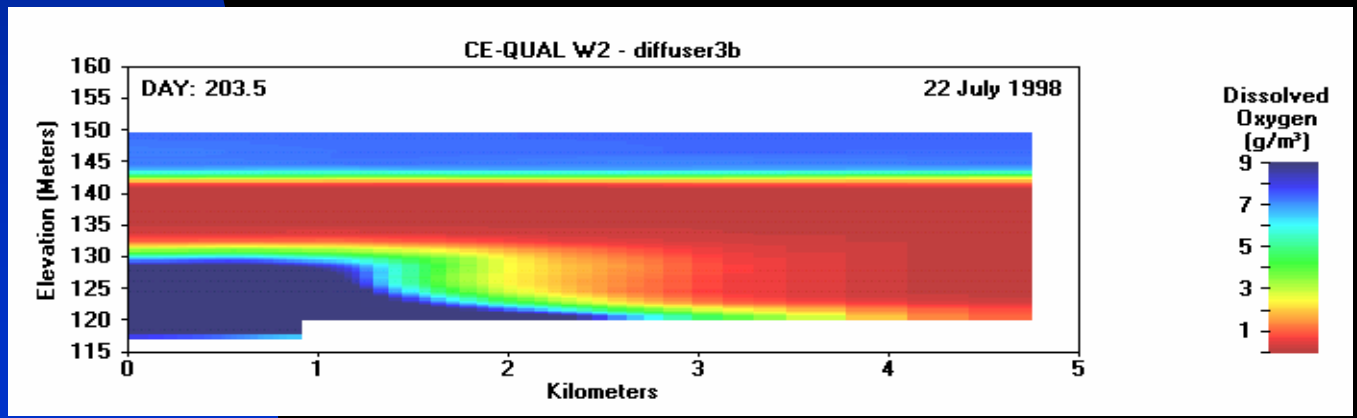

CE-QUAL W2 - diffuser1b
DAY: 193.5
12 July 1998
Elevation (Meters)
160
155
150
145
140
135
130
125
120
115
0
1
2
3
4
5
Kilometers
Dissolved Oxygen (g/m³)
9
7
5
3
1

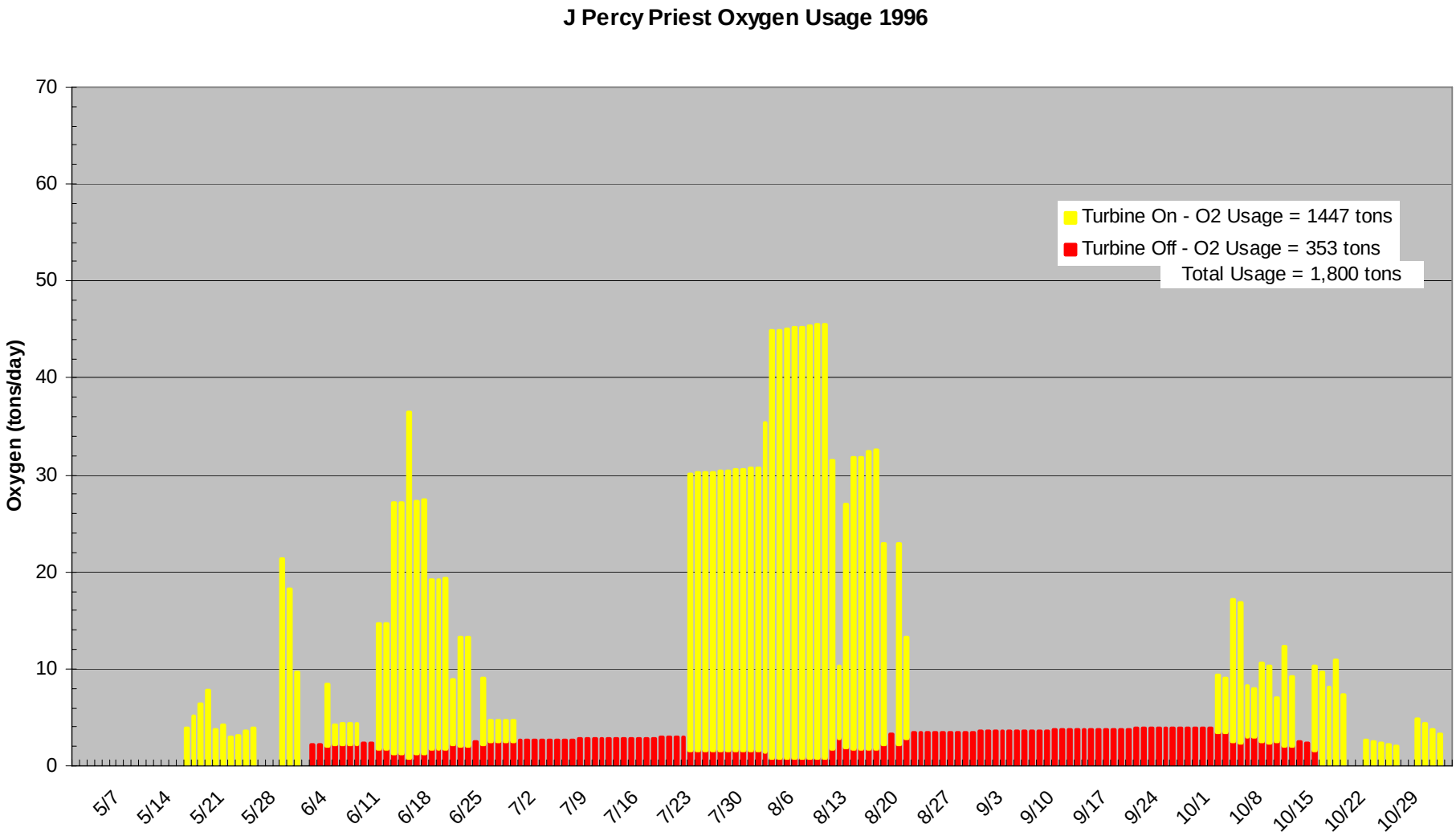

CE-QUAL W2 - diffuser1b
DAY: 198.5
17 July 1998
Elevation (Meters)
160
155
150
145
140
135
130
125
120
115
0
1
2
3
4
5
Kilometers
Dissolved Oxygen (g/m³)
9
7
5
3
1


CE-QUAL W2 - diffuser1b
DAY: 203.5
22 July 1998
Elevation (Meters)
160
155
150
145
140
135
130
125
120
115
0
1
2
3
4
5
Kilometers
Dissolved Oxygen (g/m³)
9
7
5
3
1


CE-QUAL W2 - diffuser3b
DAY: 188.5
7 July 1998
Elevation (Meters)
160
155
150
145
140
135
130
125
120
115
0
1
2
3
4
5
Kilometers
Dissolved Oxygen (g/m³)
9
7
5
3
1


CE-QUAL W2 - diffuser3b
DAY: 193.5
12 July 1998
Elevation (Meters)
160
155
150
145
140
135
130
125
120
115
0
1
2
3
4
5
Kilometers
Dissolved Oxygen (g/m³)
9
7
5
3
1


CE-QUAL W2 - diffuser3b
DAY: 203.5
22 July 1998
Elevation (Meters)
160
155
150
145
140
135
130
125
120
115
0
1
2
3
4
5
Kilometers
Dissolved Oxygen (g/m³)
9
7
5
3
1


J Percy Priest Oxygen Usage 1996
Oxygen (tons/day)
70
60
50
40
30
20
10
0
Turbine On - O2 Usage = 1447 tons
Turbine Off - O2 Usage = 353 tons
Total Usage = 1,800 tons
5/7
5/14
5/21
5/28
6/4
6/11
6/18
6/25
7/2
7/9
7/16
7/23
7/30
8/6
8/13
8/20
8/27
9/3
9/10
9/17
9/24
10/1
10/8
10/15
10/22
10/29

Costs $$$

- Estimated Costs for Oxygenation System at J Percy Priest:
  - Oxygen Supply Facility and Diffusers
    - 70 tons per day
    - 11,000 feet of diffuser
    - $1.0M to $1.2M capital costs
  - Operating Costs
    - 1,675 to 2,500 tons per year
    - $172,000 to $250,000