

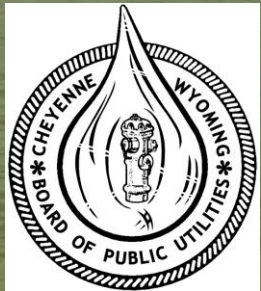
# Colorado Environmental Council for Training, Inc. (CECTI) November 6, 2026



# Hypolimnetic Aeration for Manganese Control: Low Impact Approach



Sarah Clark, P.E., HDR



HDR

With Permission...

# Acknowledgement of Co-Authors:

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- Brian Brown, P.E., HDR
- Phil Brandhuber, Ph.D., HDR
- Gary Fuller, P.E., HDR
- Bud Spillman, Cheyenne Board of Public Utilities
- Mark Mobley, P.E., Mobley Engineering



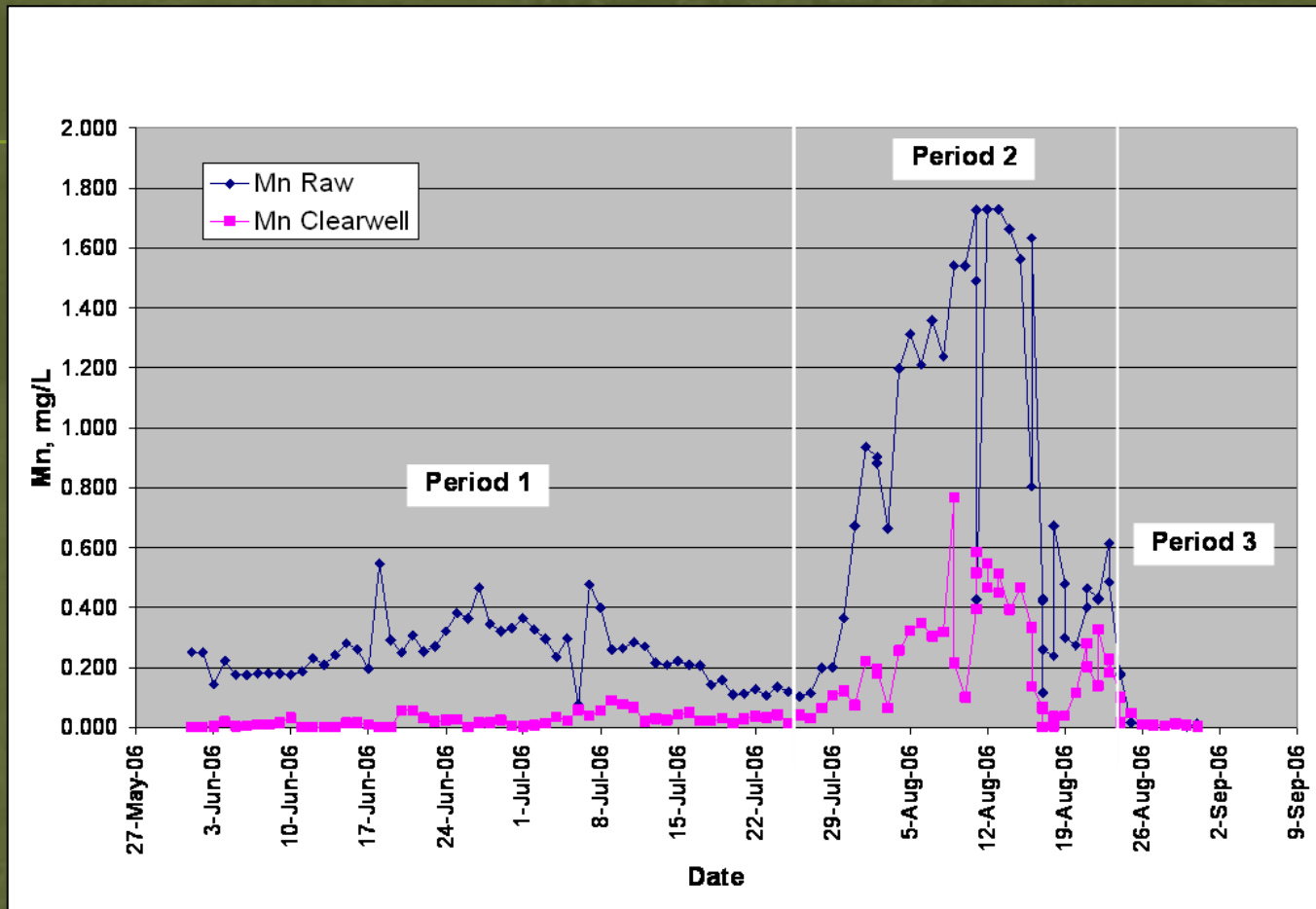
# Overview

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- Origins of Cheyenne's manganese issue
- Manganese solutions implementation
  - Aeration at Crystal Lake
  - Permanganate feed building design
  - Mixing improvements in Sherard plant
- Low impact aeration system
  - Installation
  - Results from first season

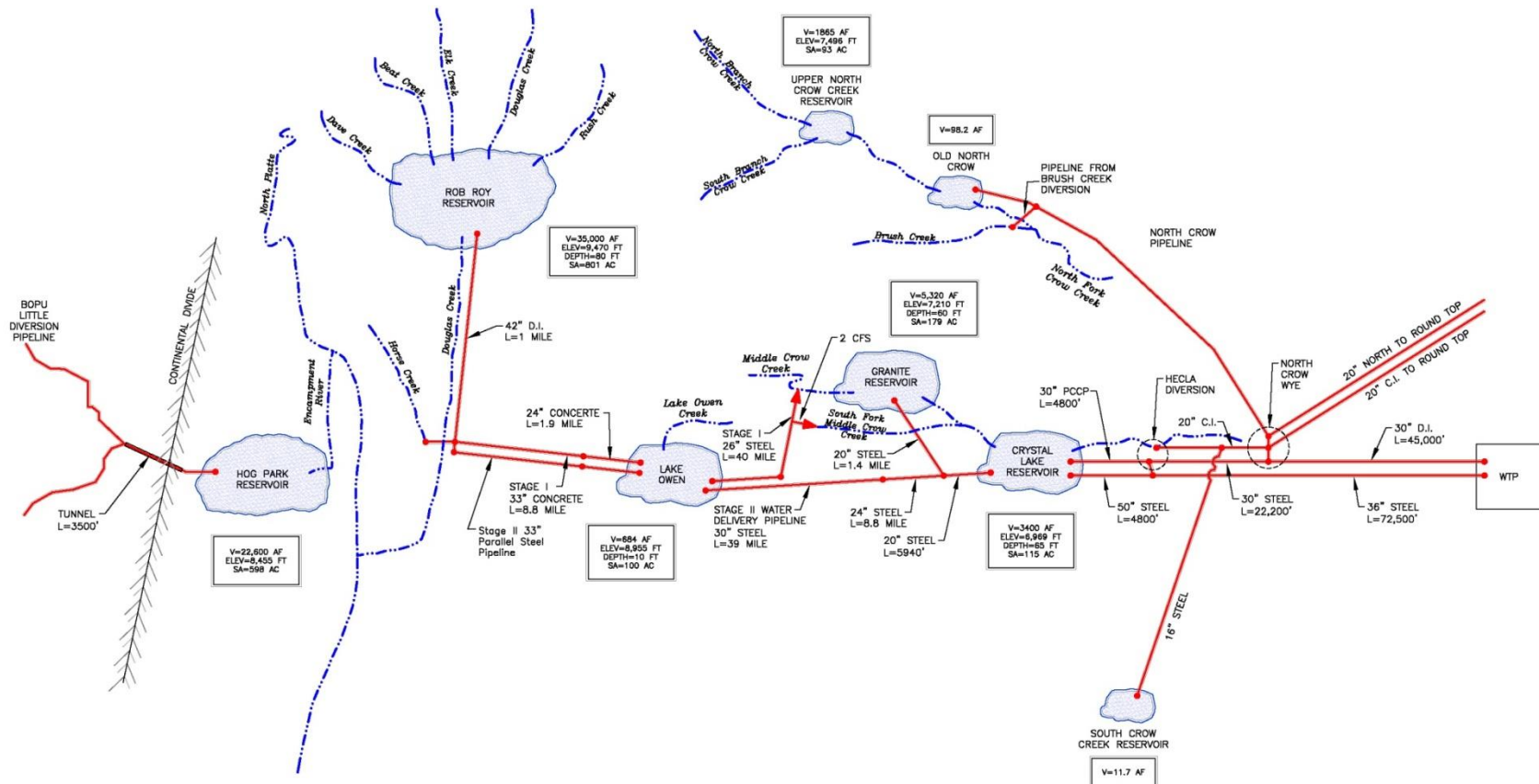


# Problem: Manganese in Distribution System



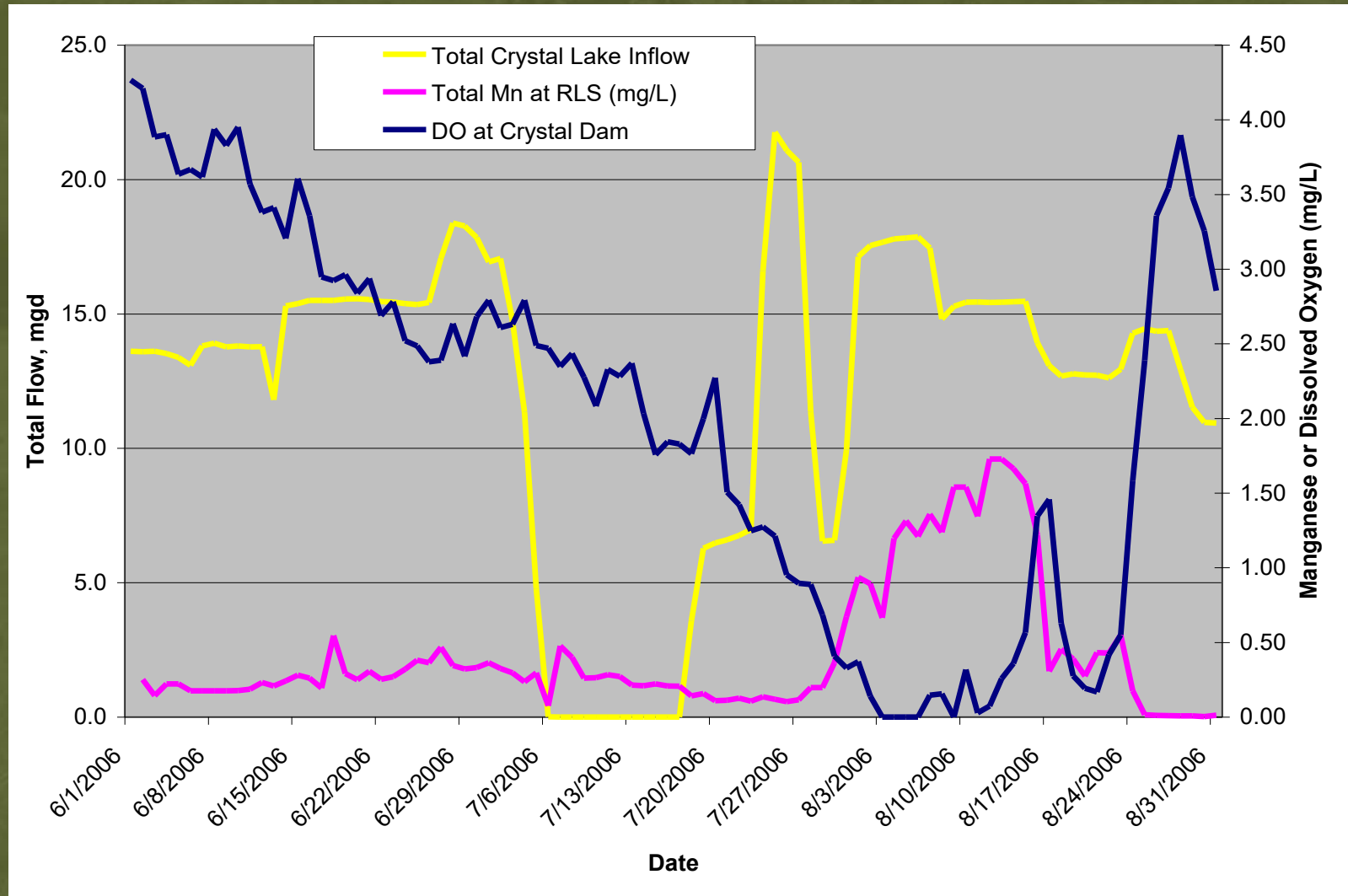
Summer 2006 Colored Water Event

# Manganese Investigation Considered Water Supply and Treatment Facilities



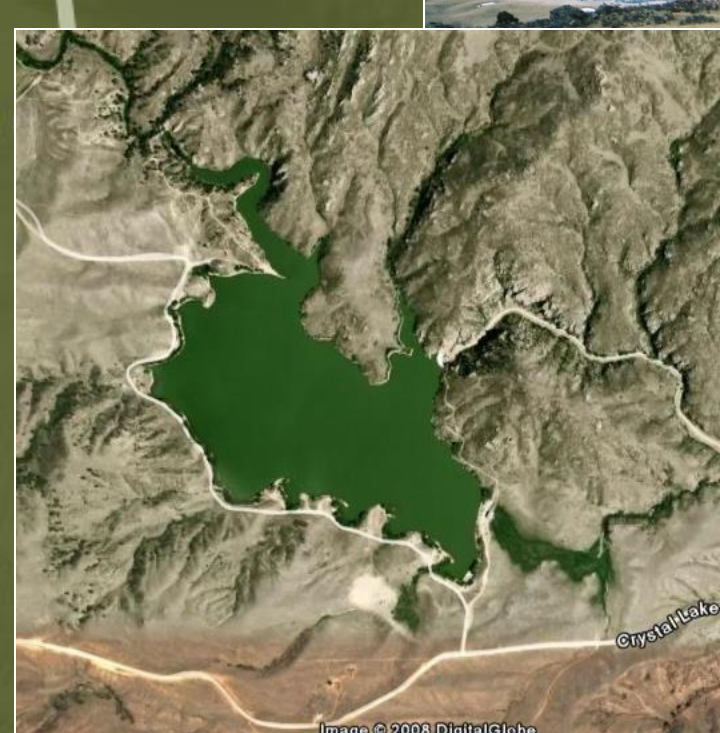
Focused on Crystal Lake for action in raw water supply system

# High Manganese at Plant Coincided with Low Dissolved Oxygen at Crystal Lake

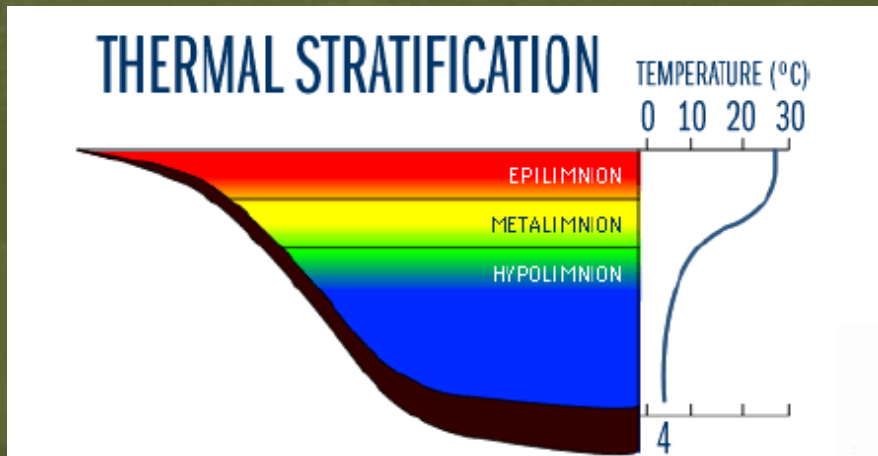


# Crystal Lake – First step in multi-barrier approach to mitigating manganese problem

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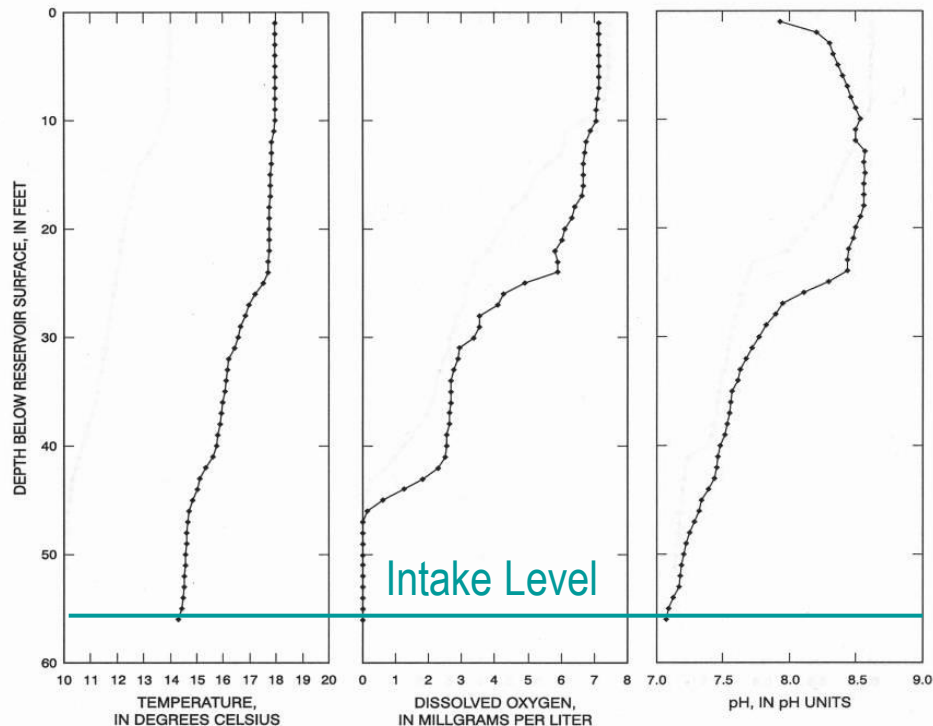


# Crystal Lake Stratification Impacts Water Quality



Crystal Lake typically stratifies in summer

Decreased DO & pH drive lake biological processes to release Mn from sediments into lake



Crystal Lake; Aug 4, 1998; USGS

Temperature

Dissolved  
Oxygen

pH

# Aeration Goal: Improve Raw Water Quality

- Raise DO without complete mixing of Crystal Lake
- Maintain DO > 4 mg/L in lake bottom
- Oxygen-diffuser system located on lake bed
  - Increases DO
  - Decreases iron
  - Decreases manganese
  - Decreases ammonium
  - Moderately decreases phosphorus



# Aerating Lake Hypolimnion With Oxygen

$O_2$

Epilimnion

Hypolimnion

Intake  
Elevation

Controls soluble Mn by eliminating dissolution of Mn from sediment and biological substrate, not by oxidizing Mn



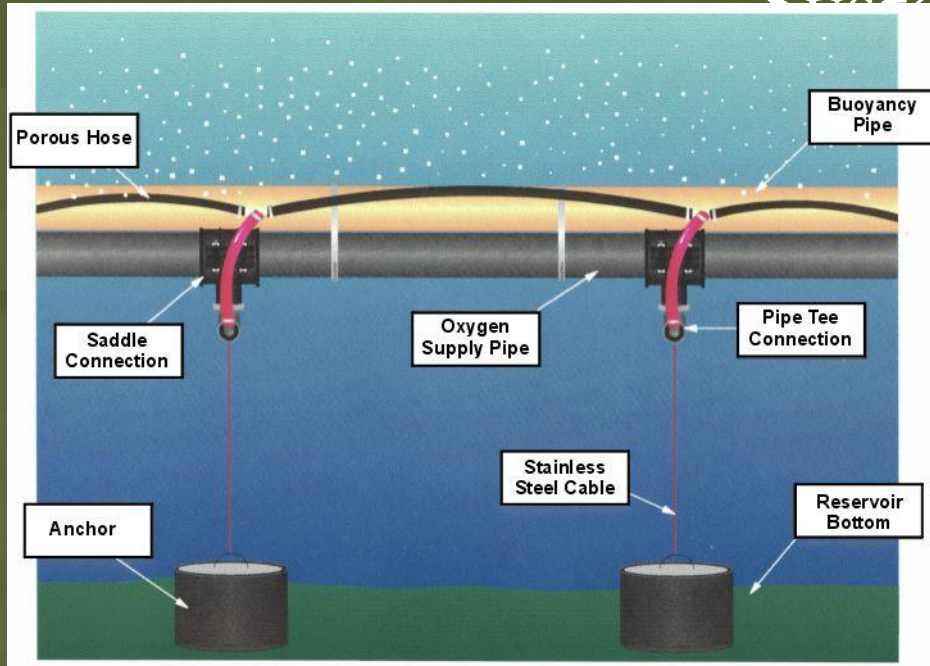
# LOX/Oxygen Gas System Components

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- Land System
  - LOX tank and enclosure
  - Buried supply lines
- Lake System
  - Submerged supply lines with anchors
  - Diffuser hoses with anchors



# Production End of Oxygenation System



Submerged oxygen supply system details



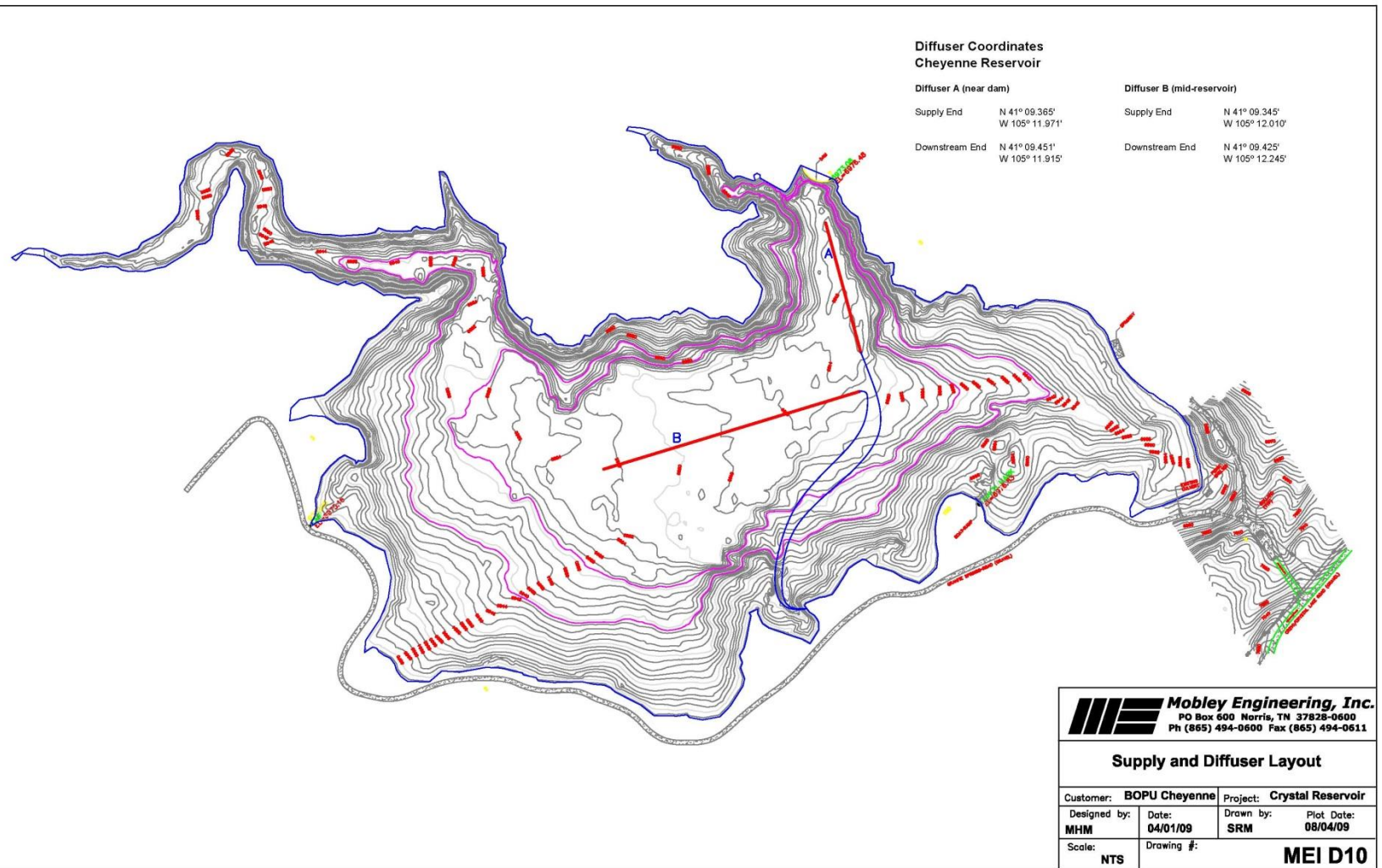
Oxygen bubbles out of the system as supply lines sink

# Reason for Selecting Oxygen-Supplied Bubble Plume Aeration System

- No divers necessary for installation
- Only 120V power required for equipment
- Simple mechanical systems/requirements
- Quiet operation / minimal attendance
- Cost effective – capital cost \$548,187
- Contractor expertise



# Crystal Lake Aeration Layout



# Land Facilities Minimize Park Impact

## Tank Enclosure

- Minimizes visual impacts to park
- Enclosure protects tank from line-of-sight from road
- Fence and camera provided for security



## Oxygen Tank

- Vaporization provides pressure to operate diffusers
- Tanker trucks deliver liquid oxygen

# Installing Diffusers in Lake

Pipe assembly from boat



Surface deployment of  
supply pipelines prior to  
sinking



# Submerged Diffuser Surface Bubble Plume – Full Throttle

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# System Operation Protocol

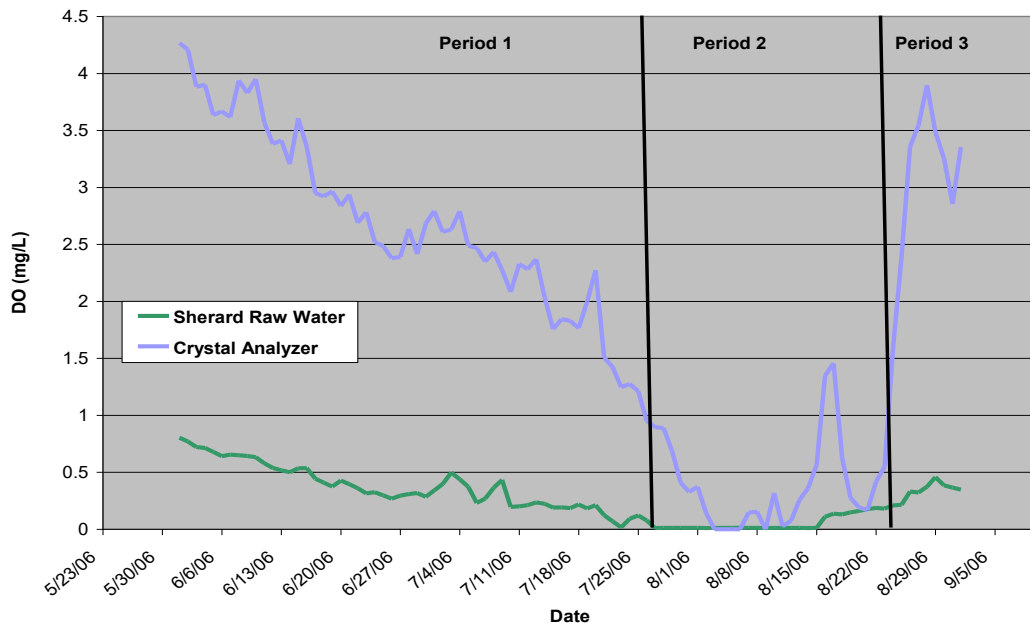
- Operating season is May - September
- Utility monitoring DO at fixed sample locations
- Oxygen feed rate is adjusted locally
  - 2010 – Purchased & installed remote flow-control valve/meter device
- Security features – camera and video feed to WTP
- No negative impacts to recreation – potential improvement of deep fishery
  - Absolute improvement in local Fishery: “...Bigger, Pink & Feisty...”



# Water Quality and Treatment Results

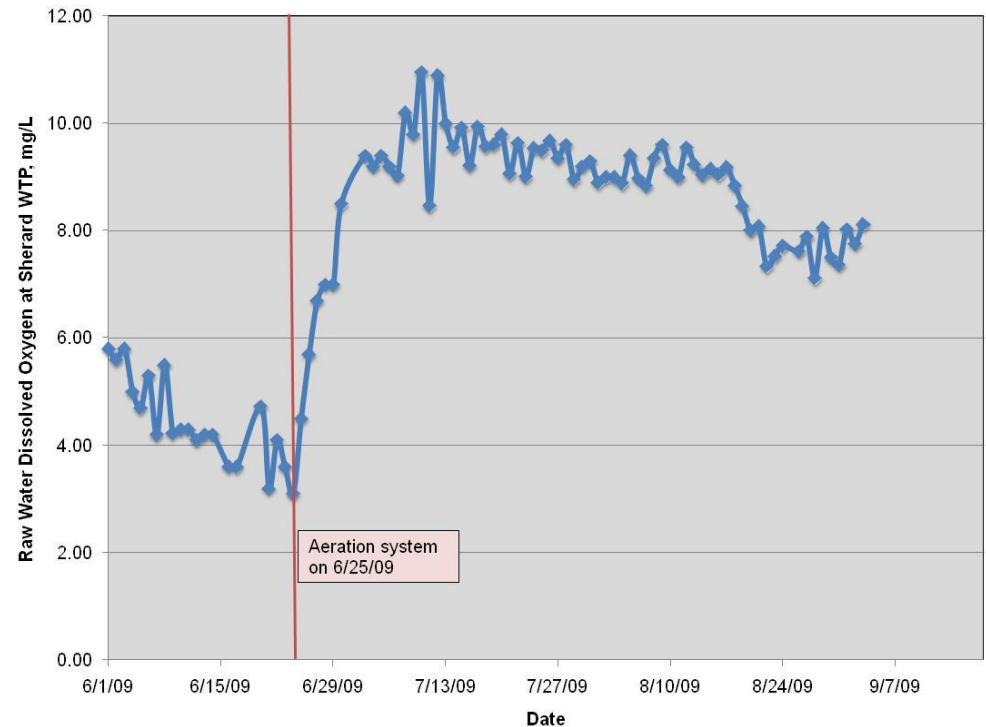
- Lake DO shifts within 48 hours of oxygen feed rate adjustment
- Manganese levels very low in raw water at plant with DO maintained
- No  $\text{ClO}_2$  feed needed summer 2009
- No chlorite lab work necessary
- Minimal Mn lab work required



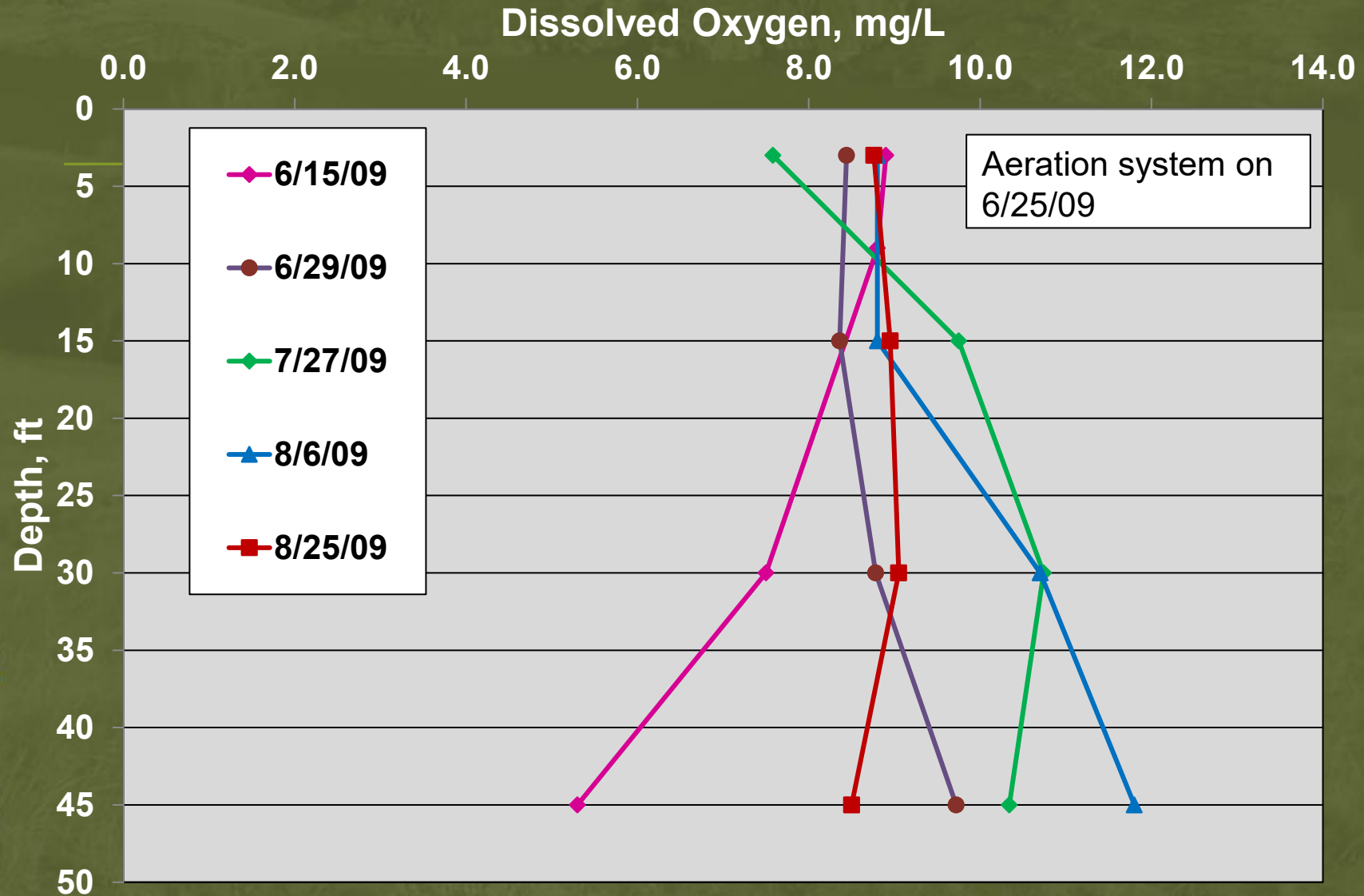


Raw water dissolved oxygen in 2006

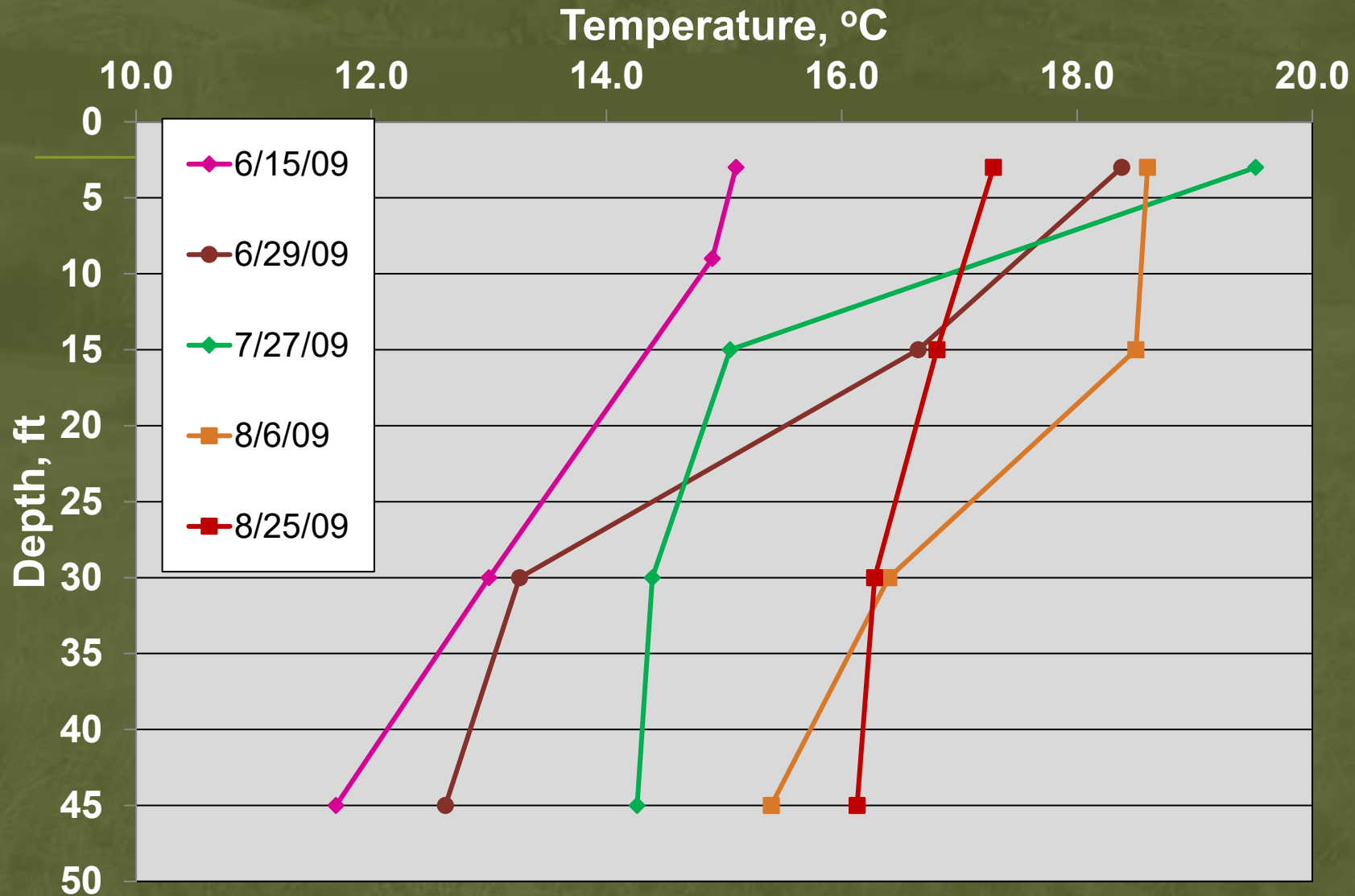
Raw water dissolved oxygen in 2009



# Dissolved Oxygen Profiles at Dam



# Temperature Profiles at Crystal Dam



# O&M Cost Comparison

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- Costs during 2009 season
  - Liquid oxygen cost = \$14,420
  - Liquid oxygen tank rental = \$11,700
  - Manganese tests = 28
- Costs during 2008 season
  - Chlorine dioxide chemical cost = \$15,681
  - Chlorine dioxide tests = 150
  - Manganese tests = 350



# Results of Aerating Crystal Lake

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- No manganese event in 2009!
- No impact to lake recreation
- Cost efficient compared to old treatment approach
- Allowed plant to optimize treatment without concern for manganese removal in treatment
- Plant currently evaluating secondary benefits of aeration



# Questions?



# Thank You

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