# Oxygen Saturation Technology ®

## *The Future of Aeration*


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Naturalake Biosciences

*Pond Oxygenation Workshop:*

*Learning Through Case Studies*

November 8, 2023

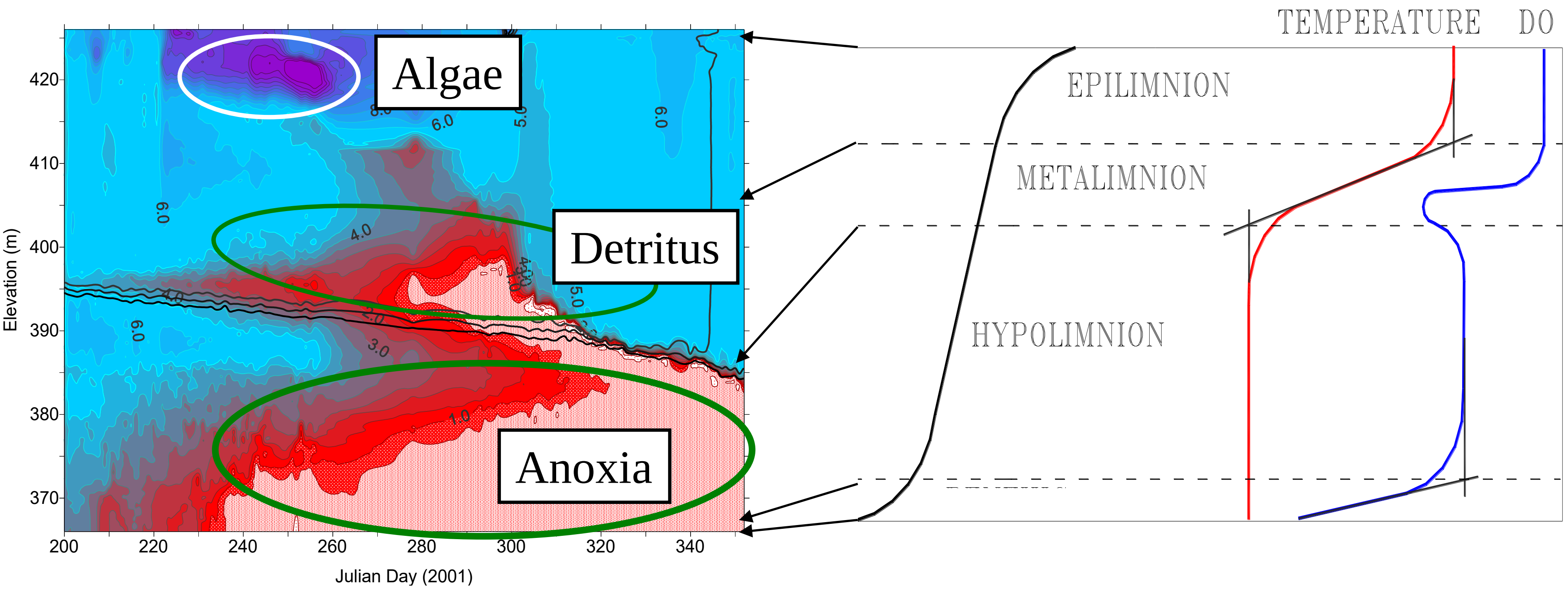
# Outline

- Background
- Back to Science
  - Limnology
  - RedOx Chemistry
  - Biology
  - Algae Control
- Aeration (Destratification/mixing)
- Oxygen Saturation Technology®
- Summary

# Goals

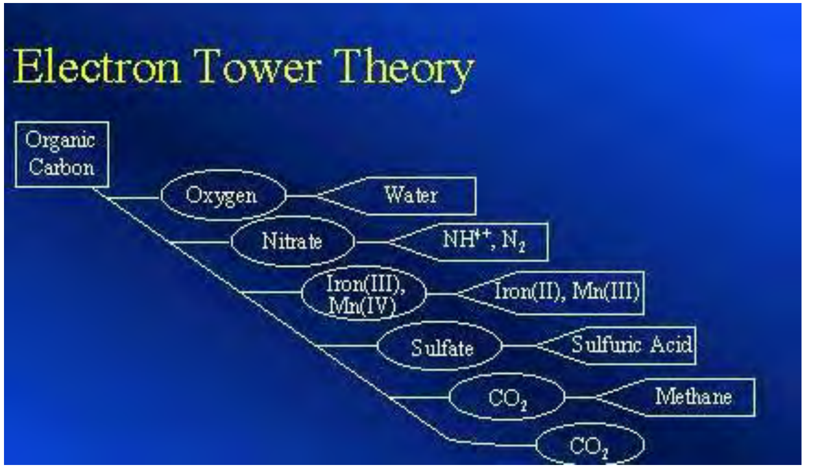
- Understand Why Oxygenate
- Reality of Oxygen Management
- Benefits of Oxygen Saturation Technology®

# The Water Column (*Stratification*)



# Understanding (Additional) Water Lingo

- (RedOx) Chemistry
- Biology

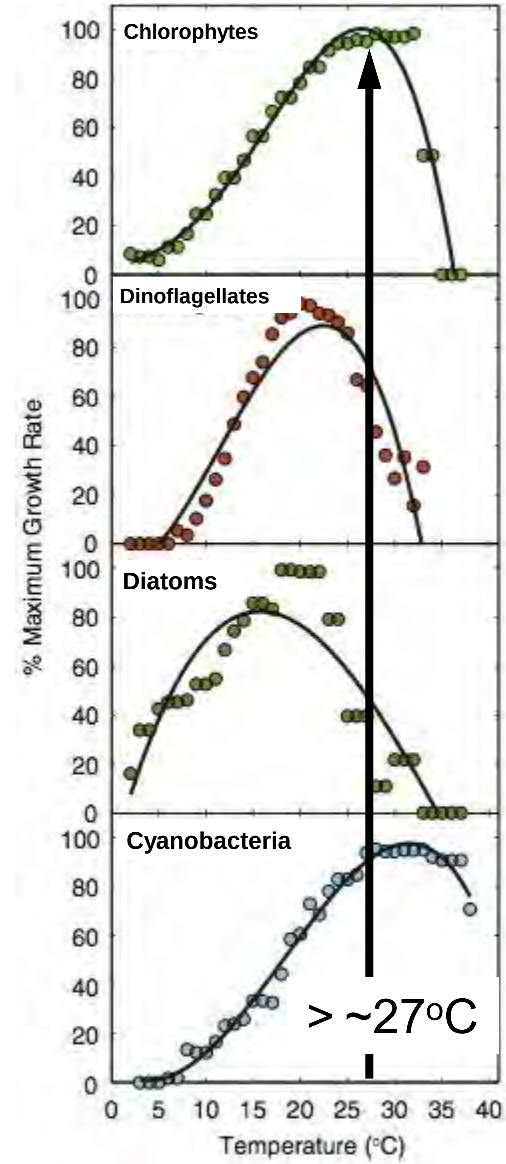



# Biology 101: ~~Blue-Green Algae~~ Cyanobacteria

- Evolved ~3.5 billion years ago, ubiquitous

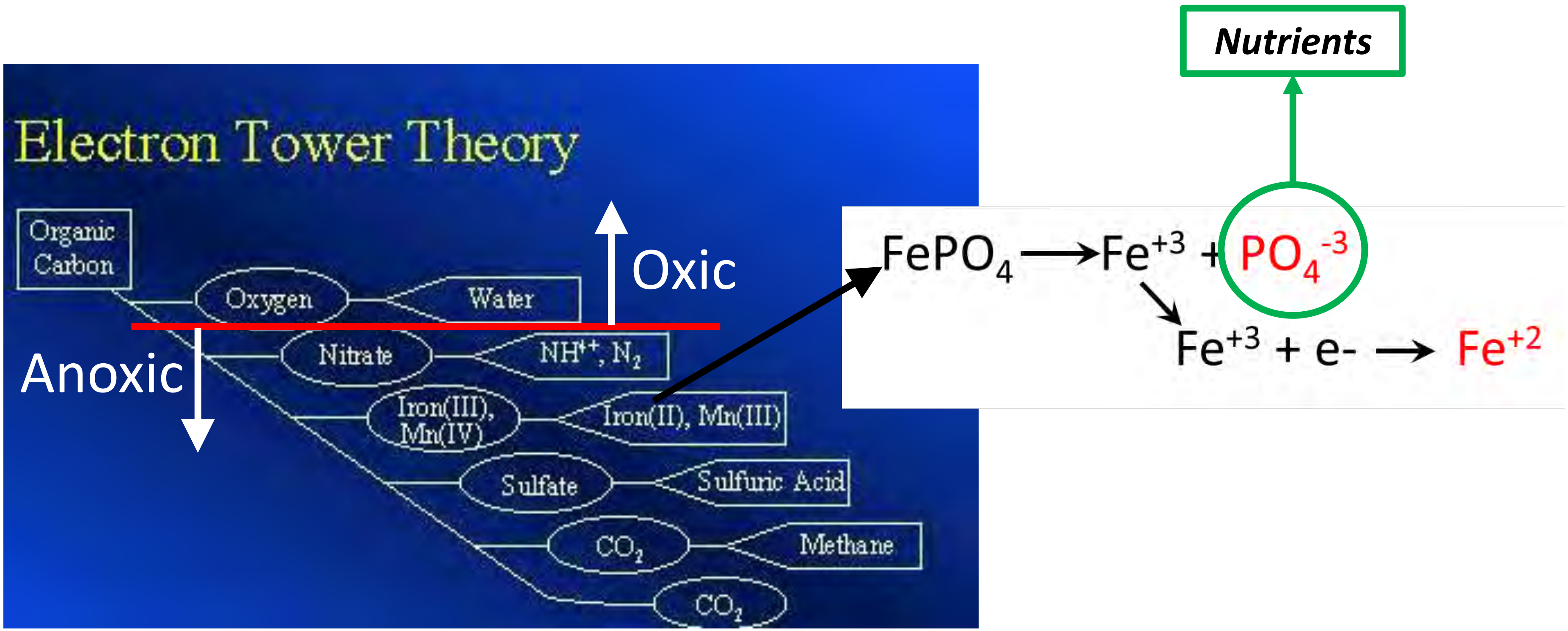
Favored By
- warm,
- well-lit,
- eutrophic conditions, with
- strong thermal stratification

- Important physiological traits:
  - dormant cells (*akinetes*),
  - gas vesicles,
  - Outcompete other phytoplankton in warm waters
  - secondary metabolites (toxins)
- Important for nutrient cycling: *nitrogen fixation* and *phosphorus storage*




Paerl and Otten 2013

# (RedOx) Chemistry 101



# Controlling Cyanobacteria (Theoretical)

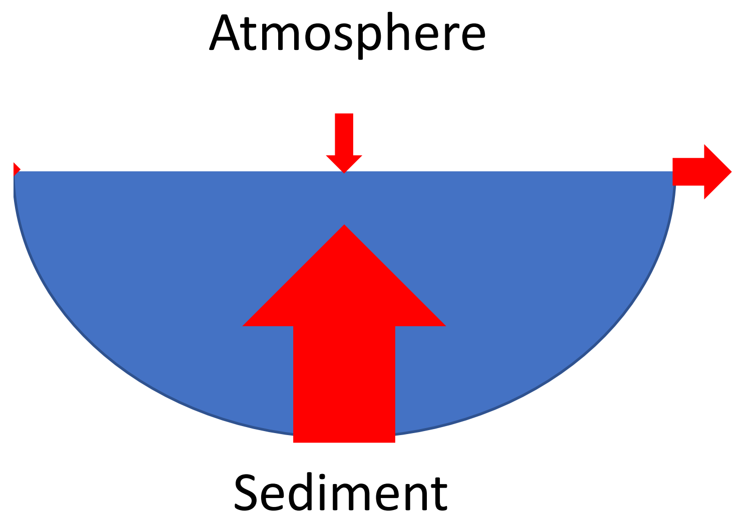
- **Nutrient limitation:**
  - ~~External nutrient control (runoff)~~
  - Internal nutrient control (sediment phosphorous cycling)
    - $FePO_4 \rightarrow Fe^{+3} + PO_4^{-3}$ → ***Nutrients***
    - $Fe^{+3} + e^- \rightarrow Fe^{+2}$
- ~~**Disrupt cell structure / poison** (algecide)~~
- ~~**Disrupt sunlight exposure** (mixing):~~
  - ~~Increase the depth of uniform temperature~~
  - ~~Decrease glycogen stores / increase pressure on gas vesicles~~

**Proactive** ↑

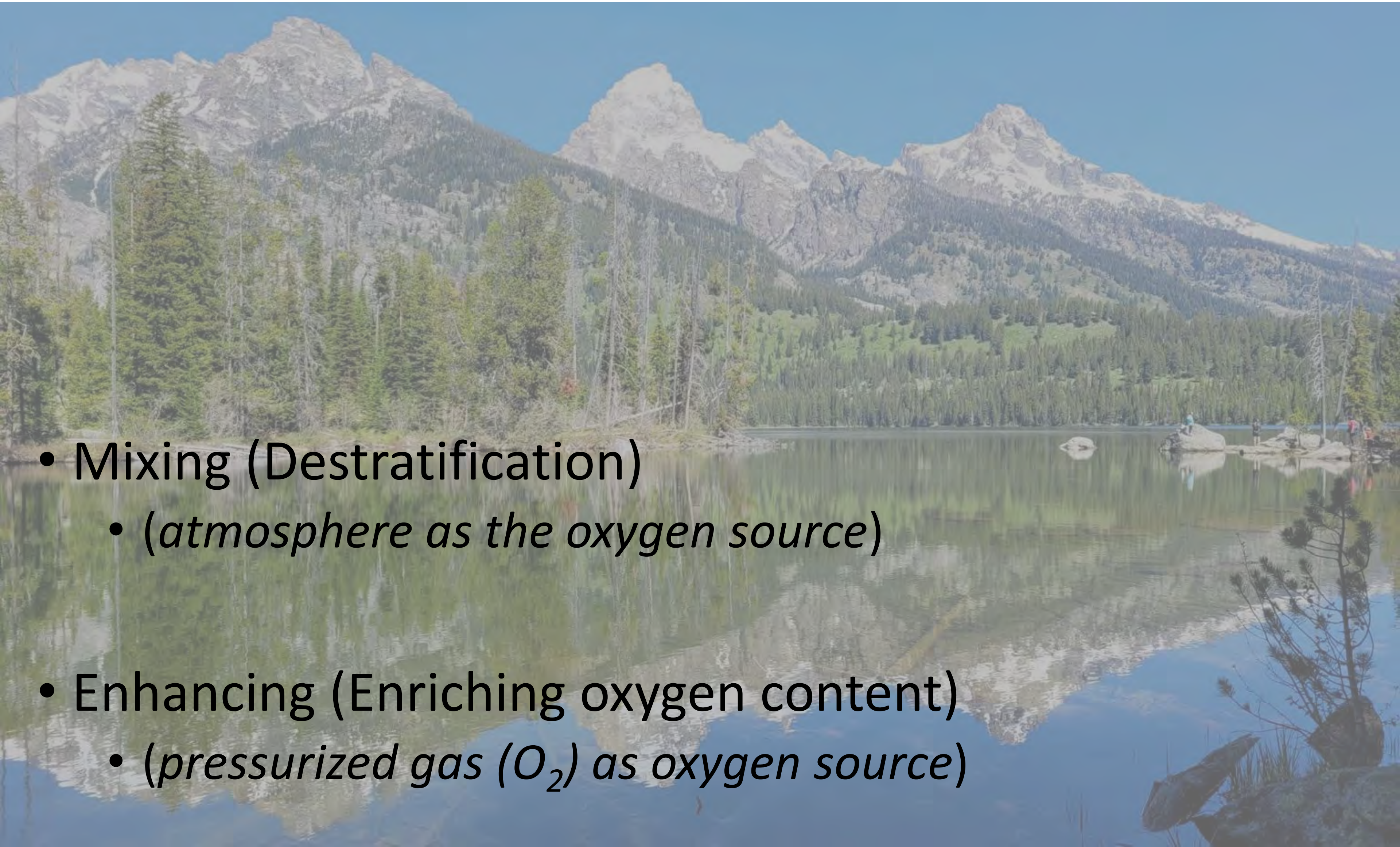
**Reactive** ↓

# Effectiveness of (Internal) Nutrient Control


Verburg et al., (2018). Nutrient Budgets in Lakes, *Lake Restoration Handbook*



# Getting Oxygen Into Water

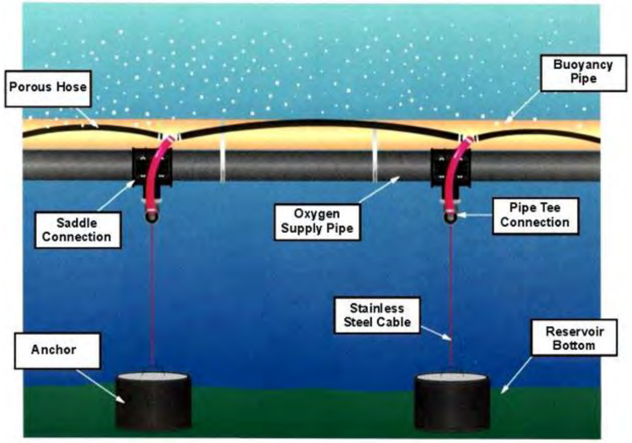


- Mixing (Destratification)
  - (*atmosphere as the oxygen source*)
- Enhancing (Enriching oxygen content)
  - (*pressurized gas ($O_2$) as oxygen source*)

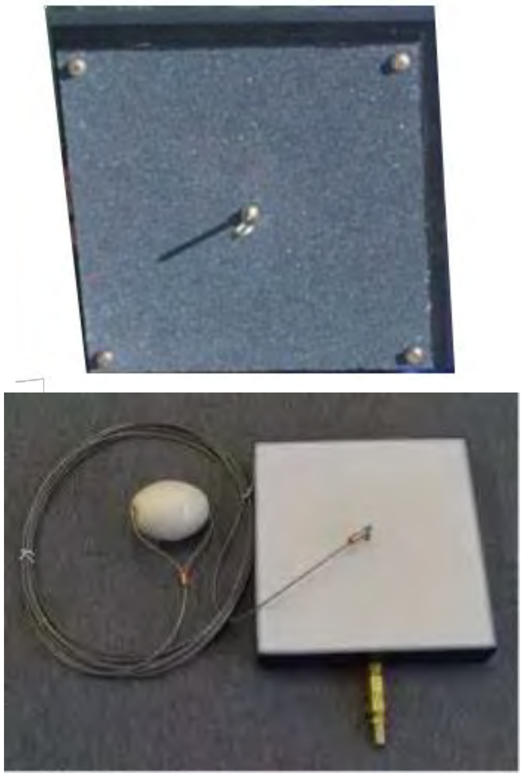
# Mixing

## Aka: **Destrat**ification

# Diffusing Air into Water




Porous Hose Line Diffuser



Ceramic Discs


EPDM Diffusers

# Wind-Driven Surficial Oxygen Transfer

$$J_{O2} = K_L(C_S - C)$$

→ **ΔDO**

$J_{O2}$ = Surficial Oxygen absorption rate (kg/**m²**/s) → **Surface Area**

$K_L$ = Mass Transfer Coefficient (m/s)

$C_s$ = Saturation dissolved oxygen concentration (kg/m³)

C = Bulk dissolved oxygen concentration (kg/m³)

$$K_L = 170.6 \times S_c^{-\frac{1}{2}} \times U_{10}^{1.81} \times \sqrt{\left(\frac{\rho_a}{\rho_w}\right)}$$

$K_L$ = Mass Transfer Coefficient (cm/h)

Sc = Schmidt number (v/D)

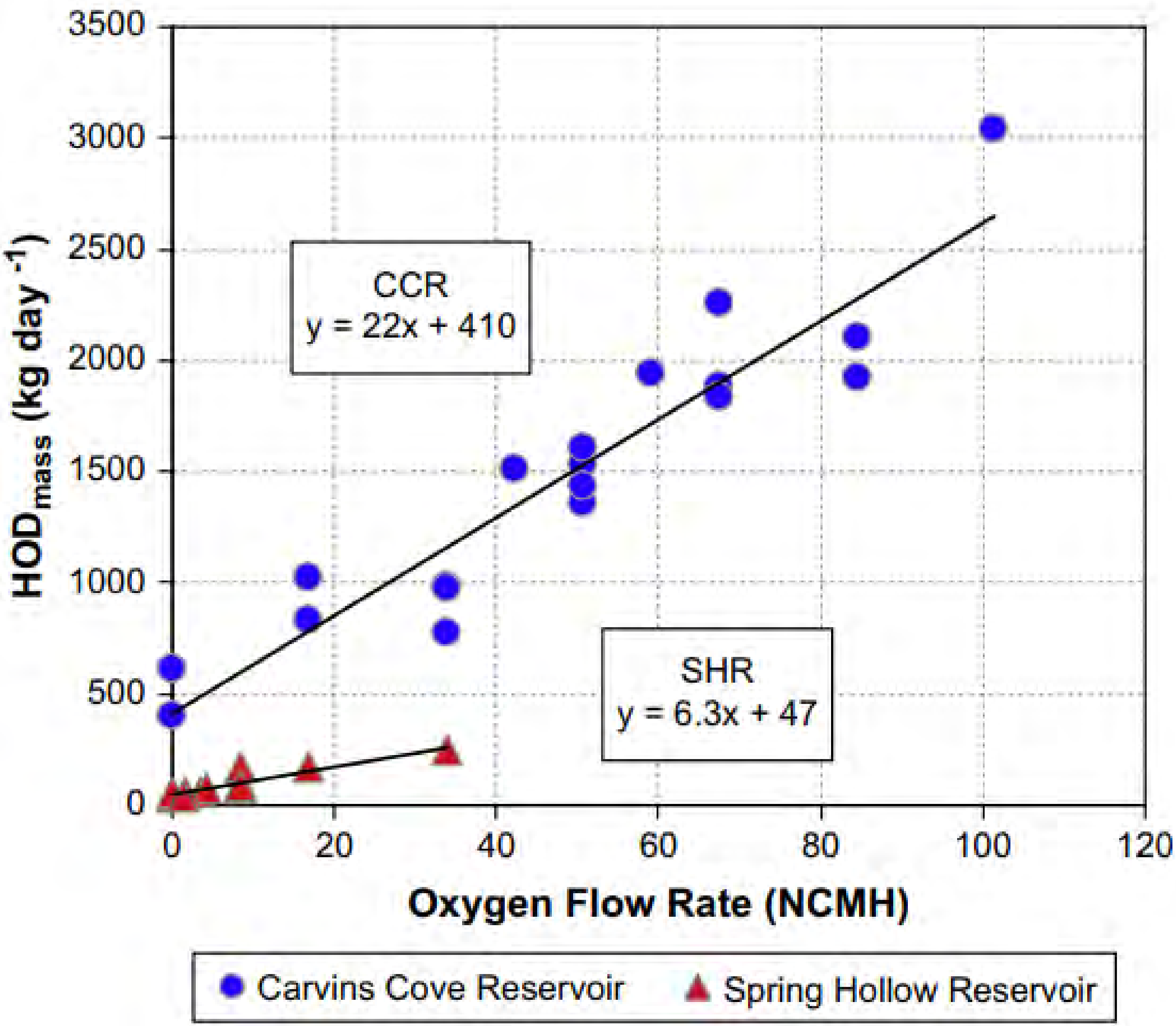
$U_{10}$ = **Wind speed** measured at 10 m (m/s) → **Wind**

$\rho_a$ = Air Density (kg/m³)

$\rho_w$ = Water Density (kg/m³)

Rule of Thumb:
~4 kg/acre/day
To maintain
~70 $DO_{sat}$
(5 – 6 mg/L)

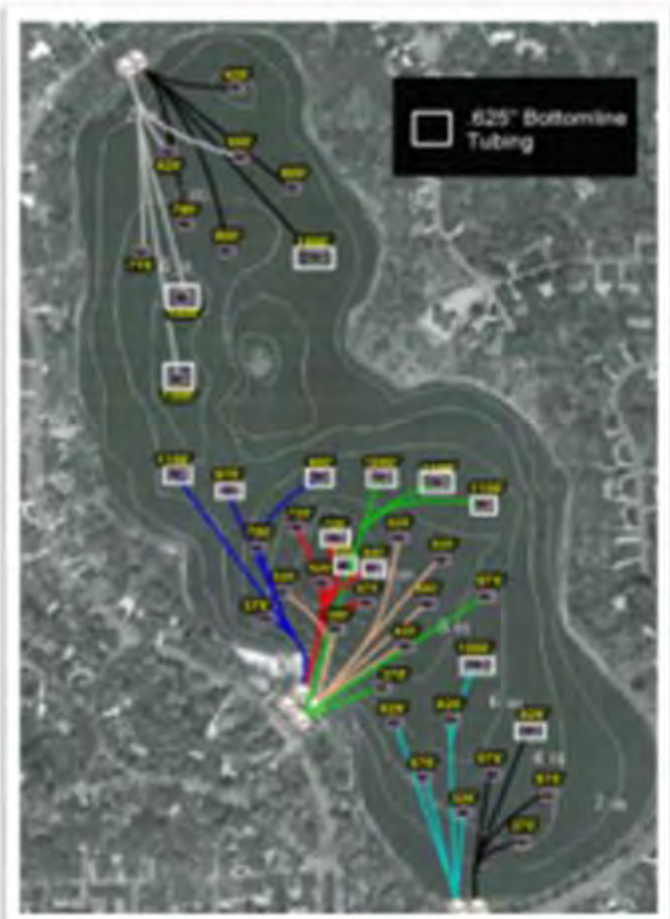
# Increased Gas Flow = Increased Oxygen Demand




**Gantzer et al., (2009).**

# Bottom Aeration Case Study – Silver Lake– HAB control

**2014**




| Depth Profile - Depth 3 | | | |
|---|---|---|---|
| Depth (m) | Temp | DO % | DO mg/L |
| Surface | 24.61 | 85.1 | 7.05 |
| 1 | 24.54 | 83.4 | 6.97 |
| 2 | 24.58 | 84.6 | 7.08 |
| 3 | 24.56 | 85.6 | 7.12 |
| 4 | 24.54 | 85.6 | 7.12 |
| 5 | 24.55 | 84.9 | 7.06 |
| 6 | 24.55 | 85.4 | 7.05 |
| 7 | 24.50 | 82.2 | 6.84 |
| 8 | 24.46 | 80.1 | 6.66 |
| 9 | 24.38 | 71.3 | 5.95 |
| 10 | 24.36 | 64.1 | 5.37 |
| 11 | 23.94 | 9.1 | 0.71 |

**System Design:**

- 148 cfm (*119 CFM 1982 design*)
- 41 diffusers fine pore EPDM membranes.

*Information/data courtesy of Patrick Goodwin*

# Desired Dissolved Oxygen Levels

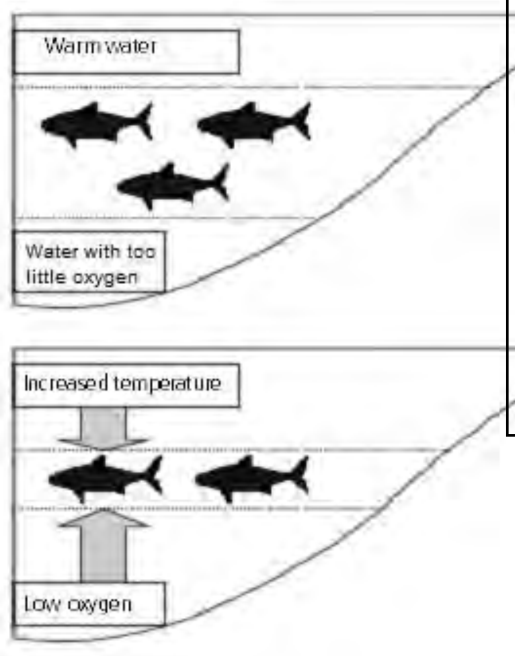
- **Aquatic life – Habitat**
  **Stiff** et al., (1992)

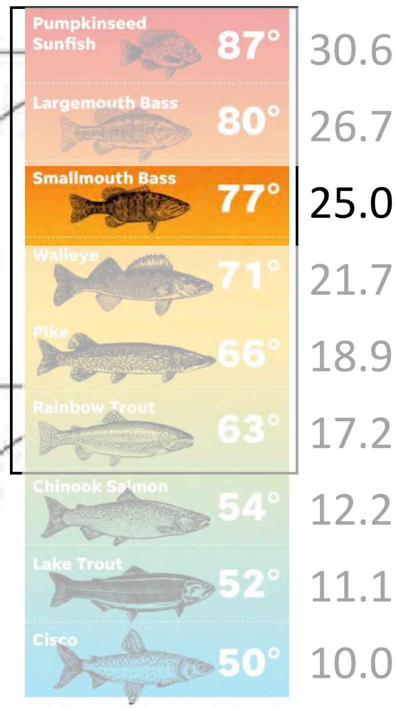
**>8 mg/L** *(< 25)* **in the bulk water**

- **Phosphorus – Iron-P**
  - Harmful Algae Blooms (HABS)
- **Nitrogen – $NH_4^+ \rightarrow NO_3^-$** **Beutel** (2001)
- **Metals – Iron/Manganese** **Gantzer et al.,** (2009)
- **Organic content in water/sediment**
- **Fecal Coliform**

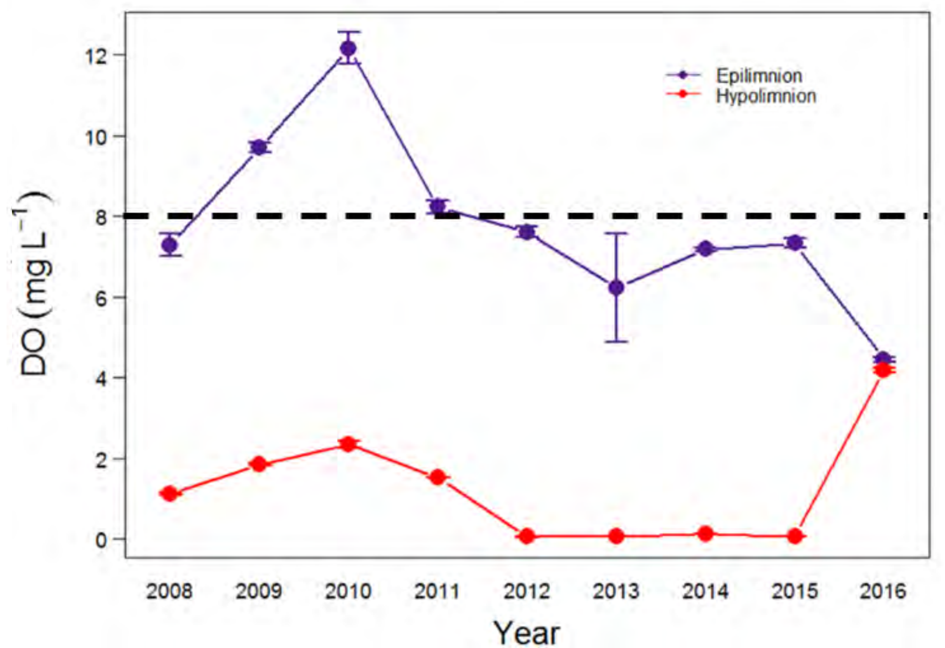
**> 10 mg/L** *(< 25)* **over the sediments**

# Destratification (Aeration) and Fisheries Management




*Circulation increases water temperature close to that of the atmosphere*




*Circulation decreases bulk water DO < optimal for fish*

# Destratification (Aeration) Performance Record

**Table 4.3 Summary of goal achievement in case histories**

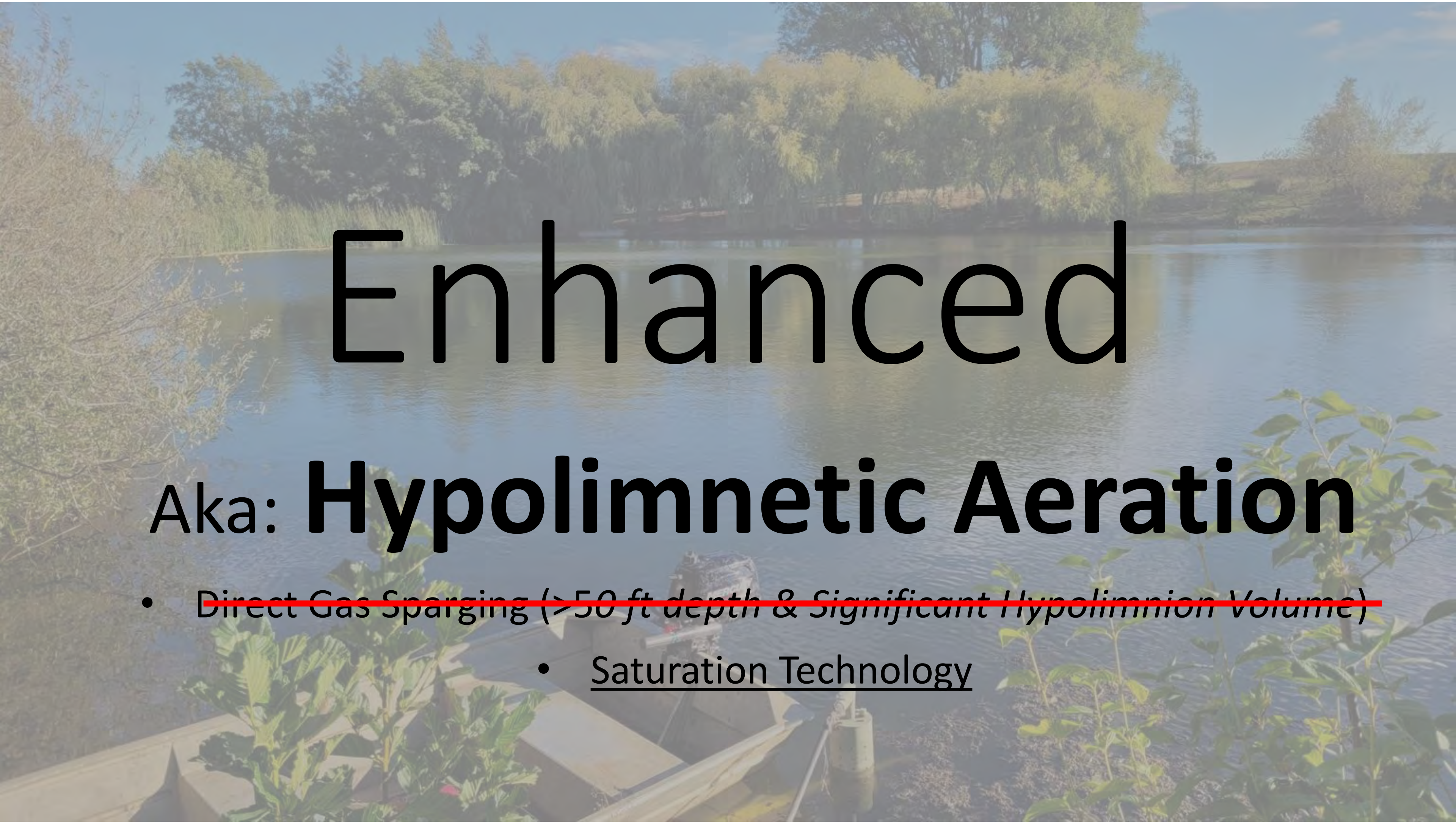
| | Goals Achieved | | |
|---|---|---|---|
| **Technique** | **Yes** | **Partial** | **No** |
| HAC | 22.2 | 67.7 | 11.1 |
| DOX | 90.9 | 9.1 | 0.0 |
| DBC | 75.0 | 25.0 | 0.0 |
| SSS | 80.0 | 20.0 | 0.0 |
| DAC | 57.2 | 28.5 | 14.2 |
| UDP | 15.3 | 38.5 | 46.2 |
| DDP | 55.5 | 44.5 | 0.0 |

SSS = Side Stream Supersaturation
DOX = Diffused Oxygen
HAC = Hypolimnetic Aeration Chamber
DBC = Downflow Bubble contact Chamber (Speece Cone)
DAC = Diffused Air Circulation *(20)*
UDP = Up Draft Pump
DDP = Down Draft Pump

**Wagner, (2015)**.
Oxygenation and Circulation to Aid Water Supply Reservoir Management

# Destratification (Aeration) Take Aways

- Atmosphere is oxygen source, not bubbles.
- DO limitations
  - o Throughout the water column
  - o Over sediment
- Increases overall water temperatures
- Increased turbulence
  - o Causing increased DO demand
  - o Potential for sediment resuspension

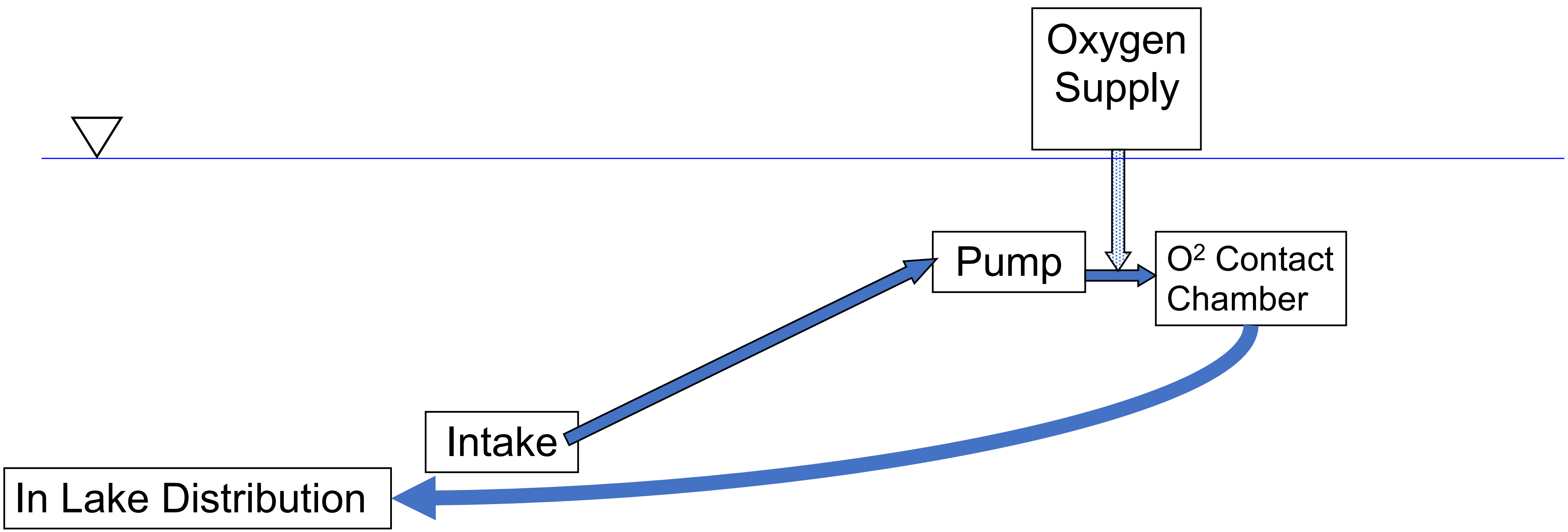


# Enhanced

## Aka: **Hypolimnetic Aeration**

- ~~Direct Gas Sparging (*>50 ft depth & Significant Hypolimnion Volume*)~~
  - <u>Saturation Technology</u>

# Saturation Technology
# aka: Side-Stream Saturation (**SSS**)

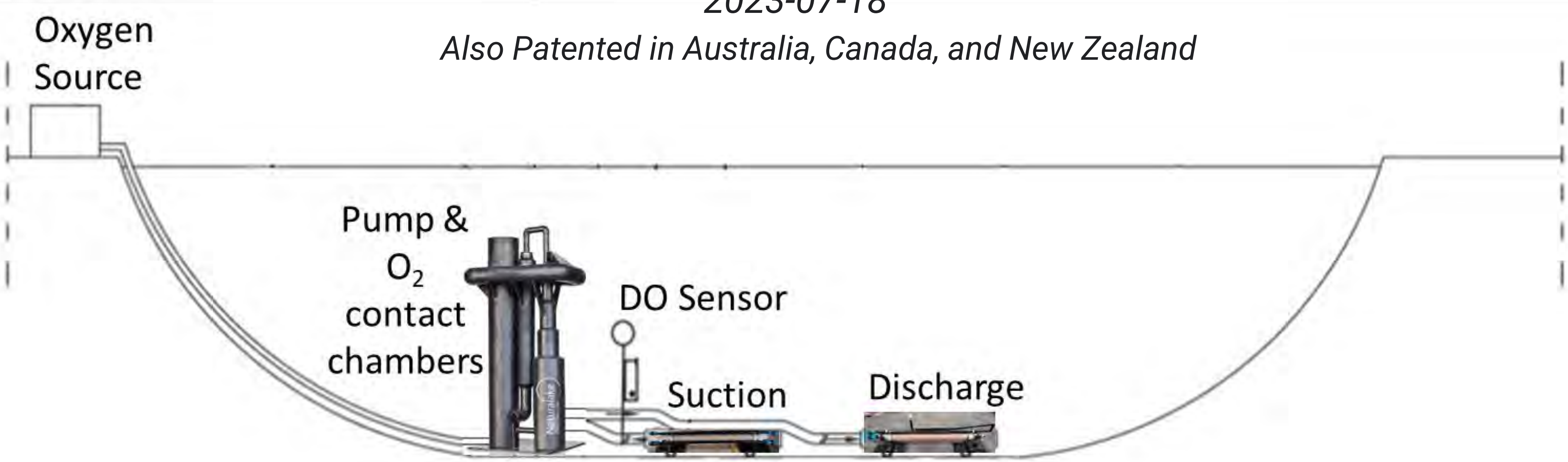


# Oxygen Saturation Technology ®

*US Patent US3643403A*

*2023-07-18*

*Also Patented in Australia, Canada, and New Zealand*




## <u>Key Design Characteristics</u>

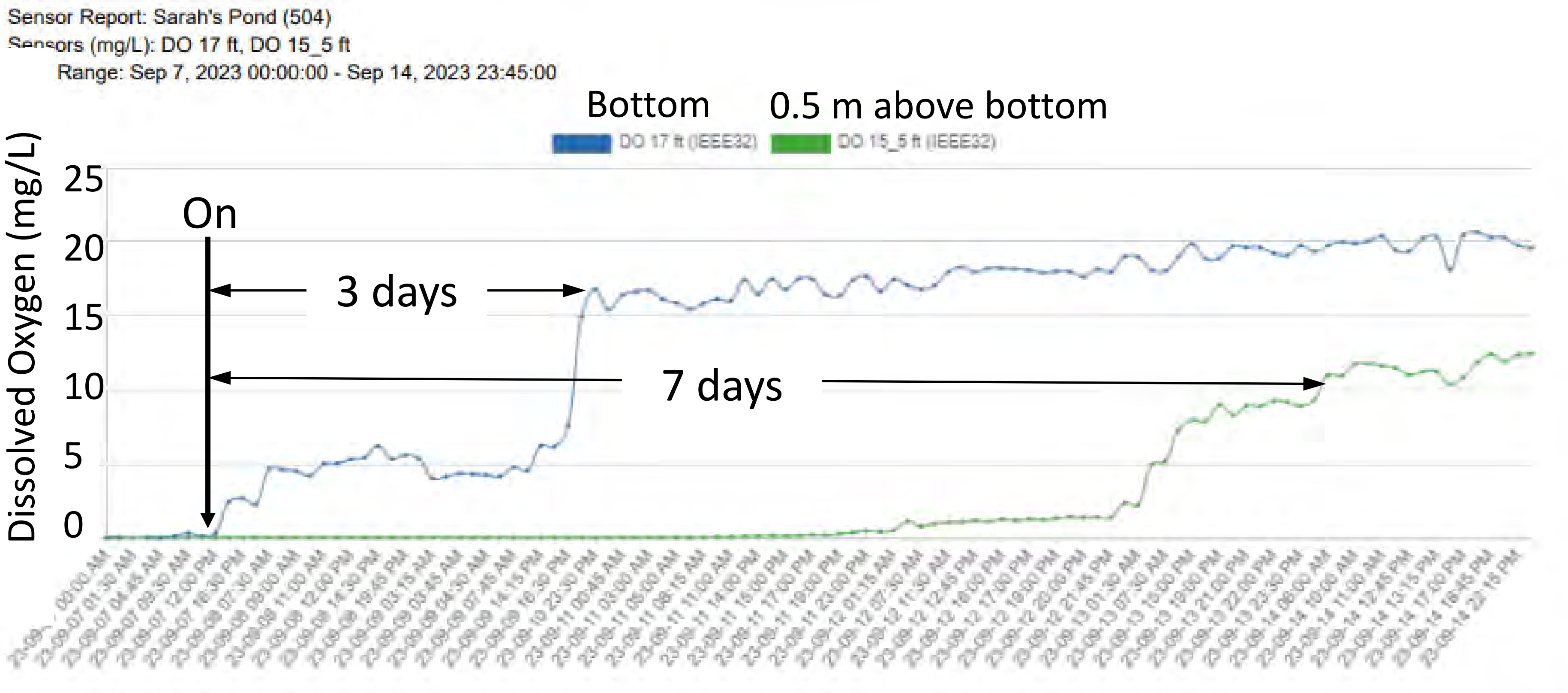
- Uses oxygen gas (90% nominal purity)
- No bubbles
- No mixing (induced turbulence)
- Preserves thermal structure (ice cover and/or summer stratification
- Automated (DO feedback)
- Modular and Scalable

# OST Installations

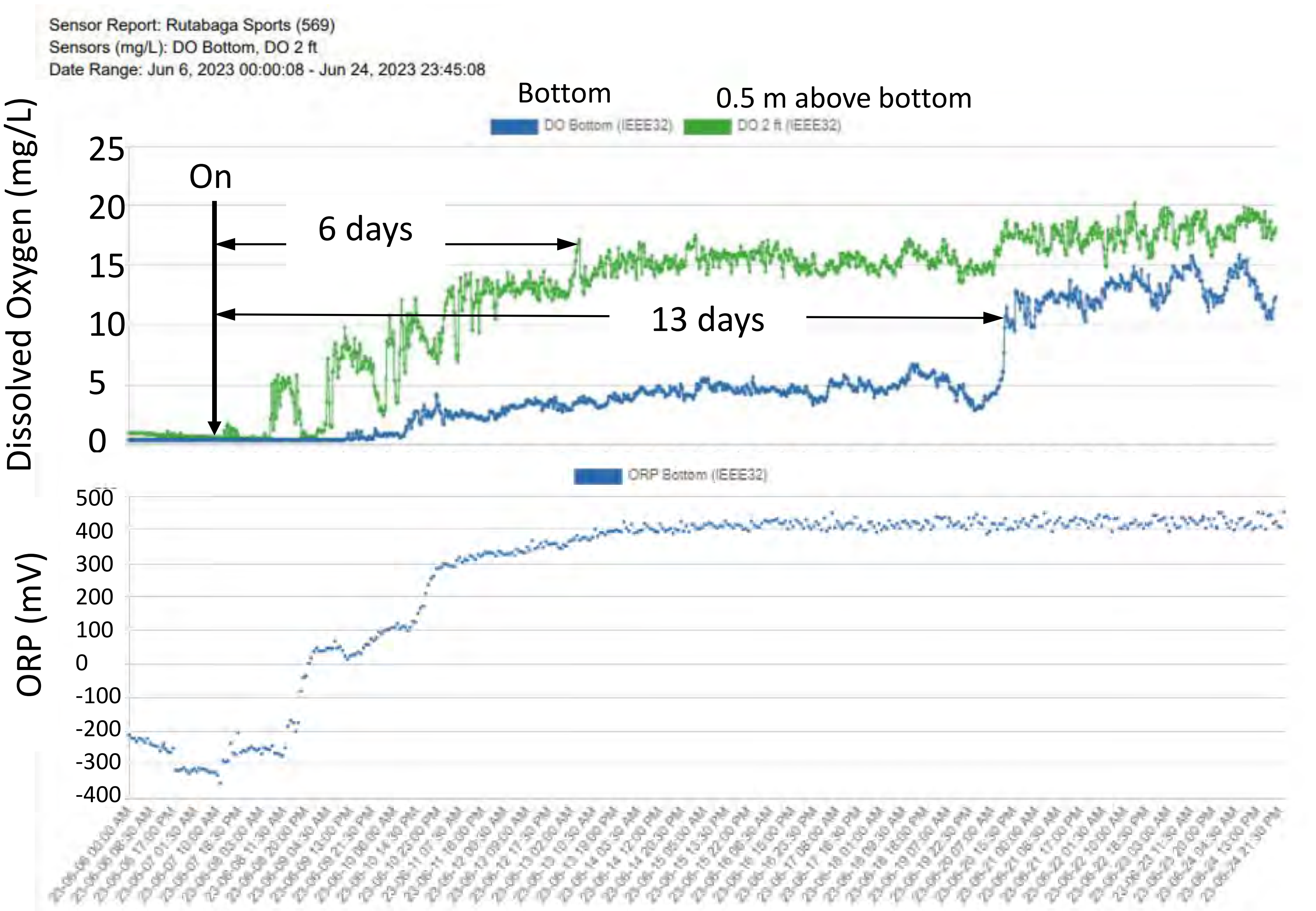

*Not on Telemetry*

* *1st Generation*

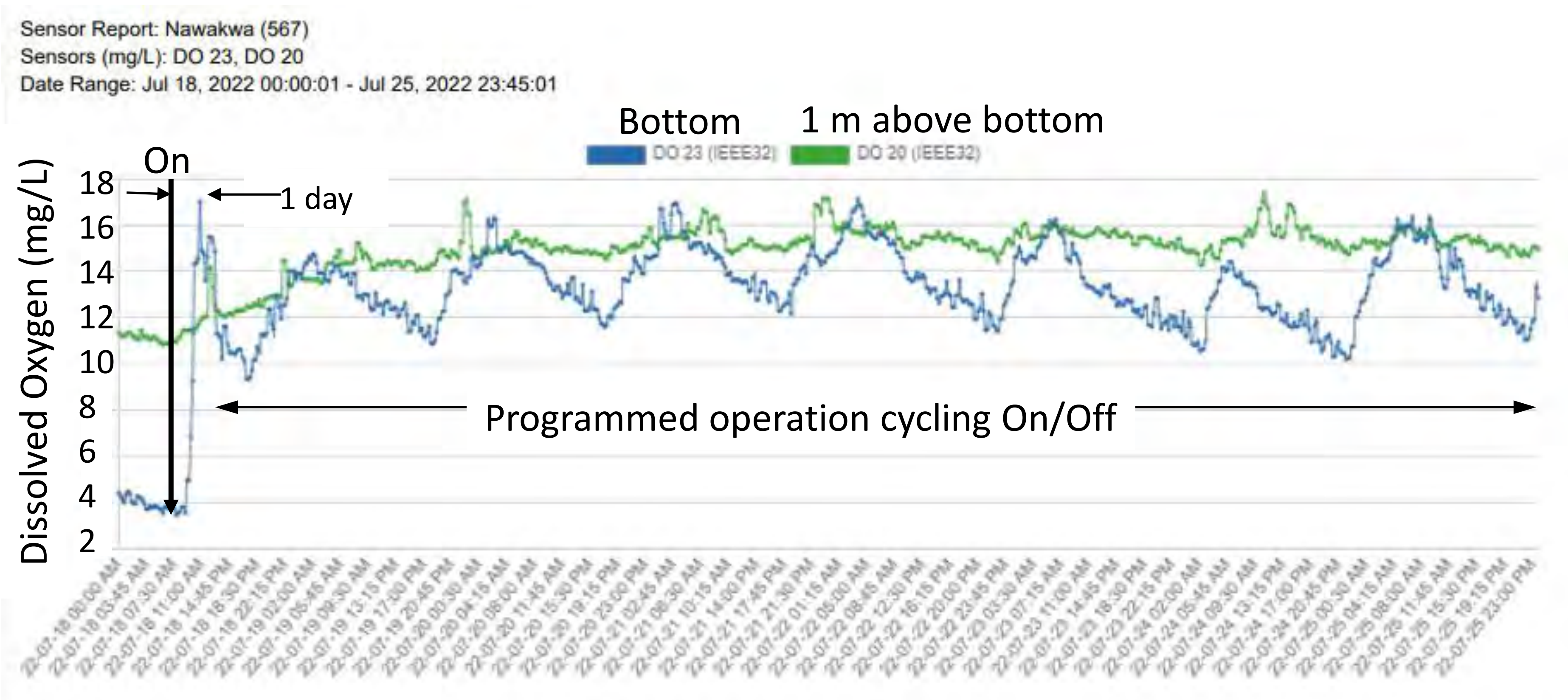
# Results (Cape Cod, MA)



# Results (Madison, WI)

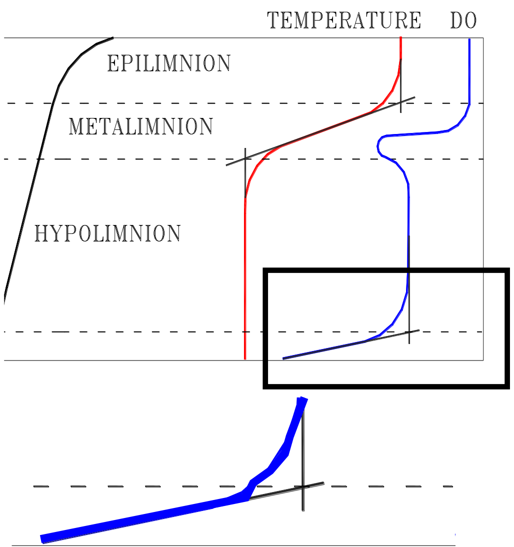


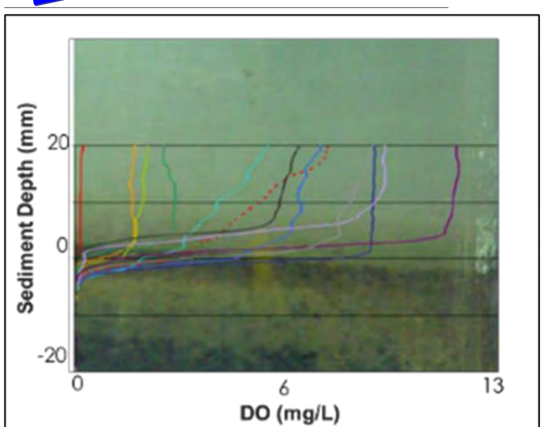
# Results (Geneva, WI)



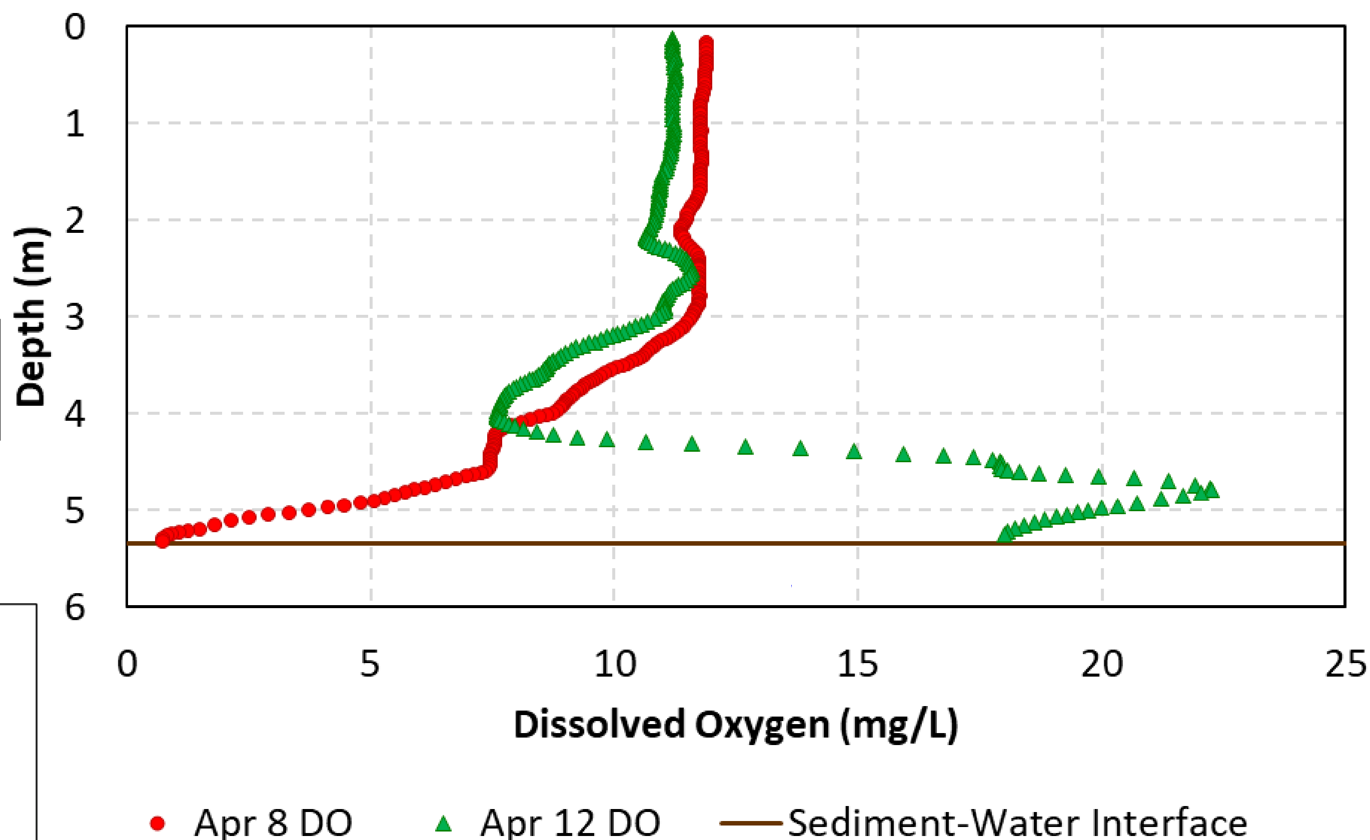
# Oxic / Anoxic Boundary

*(Why DO so high?)*

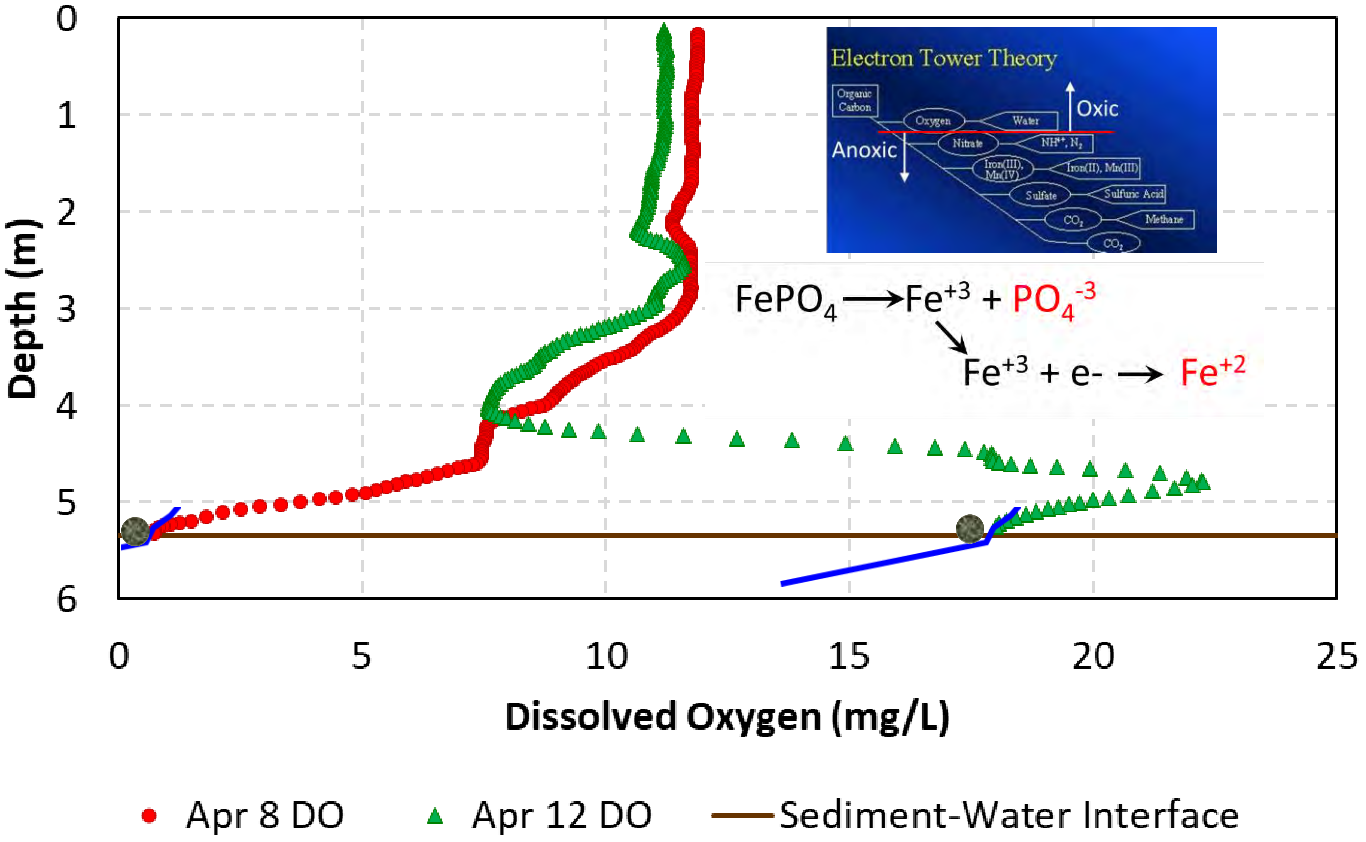



**Bryan et al., (2010)**.

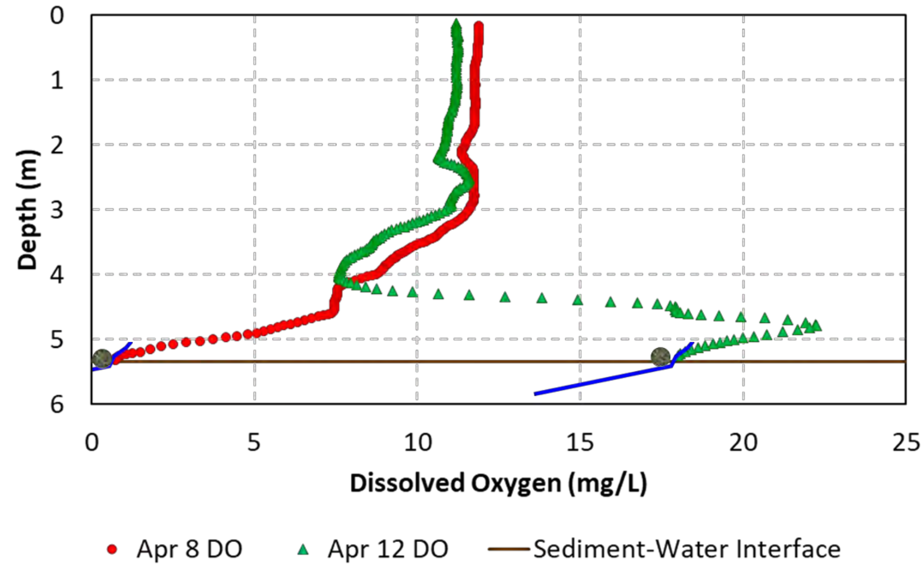


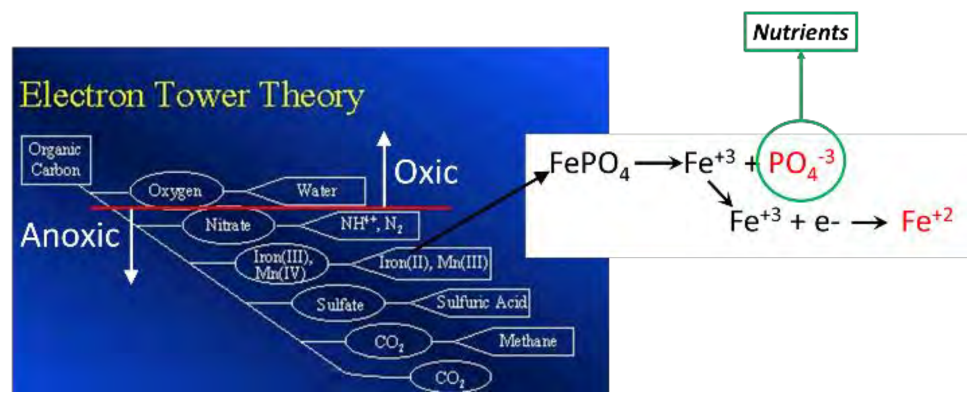
# Akinetes and the Sediment-Water Interface



# Summary
# (*Cyanobacteria Control*)

- Air/atmosphere as $O_2$ source has limits to DO levels
- Pure $O_2$ higher achievable DO levels
- Higher DO in bulk water
- Oxic/anoxic boundary deeper
  - Akinetes Not in Contact w/$PO_4^{-3}$
- NO bubbles
- NO Induced turbulence or sediment resuspension



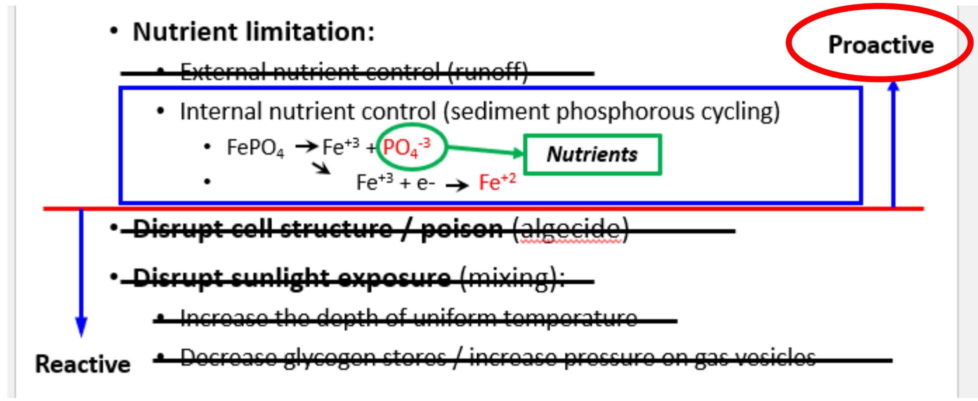



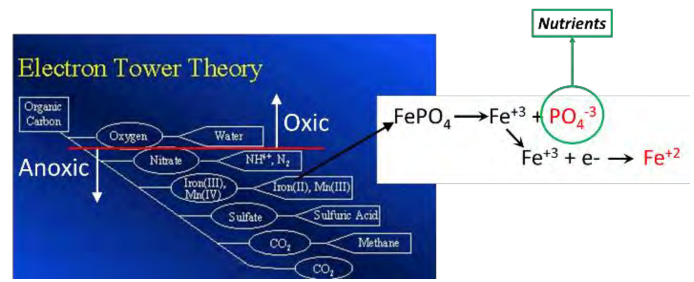
# Oxygen Saturation Technology ®
# Key Takeaway(s)

1. Proactive strategy to prevent Cyanobacteria from growing,

2. Maintaining Oxygen as the terminal electron acceptor to maintain Fe-$PO_4$ bond, and

3. Maintain adequate O2 levels
   - Oxic/anoxic boundary
   - Habitat
   - Oxygen dependent processes




- **Aquatic life – Habitat** Stiff et al., (1992) — **>8 mg/L** *(< 25)* **in the bulk water**

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