Oxygenation and Circulation Systems

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Two related but separate processes

- Oxygenation – any process that adds oxygen to target waters; circulation can do this if it increases contact with the atmosphere
- Circulation – any process that blends water; can be mechanical or air driven, usually induces oxygenation

For the purpose of this review,

Oxygenation= hypolimnetic aeration or non-destratifying oxygenation

Circulation=mixing, either whole lake or partial

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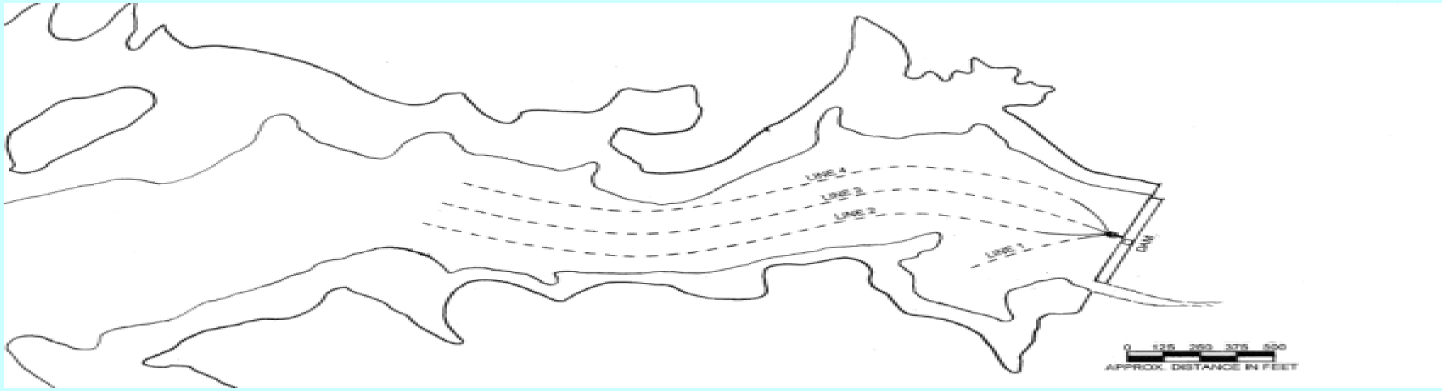
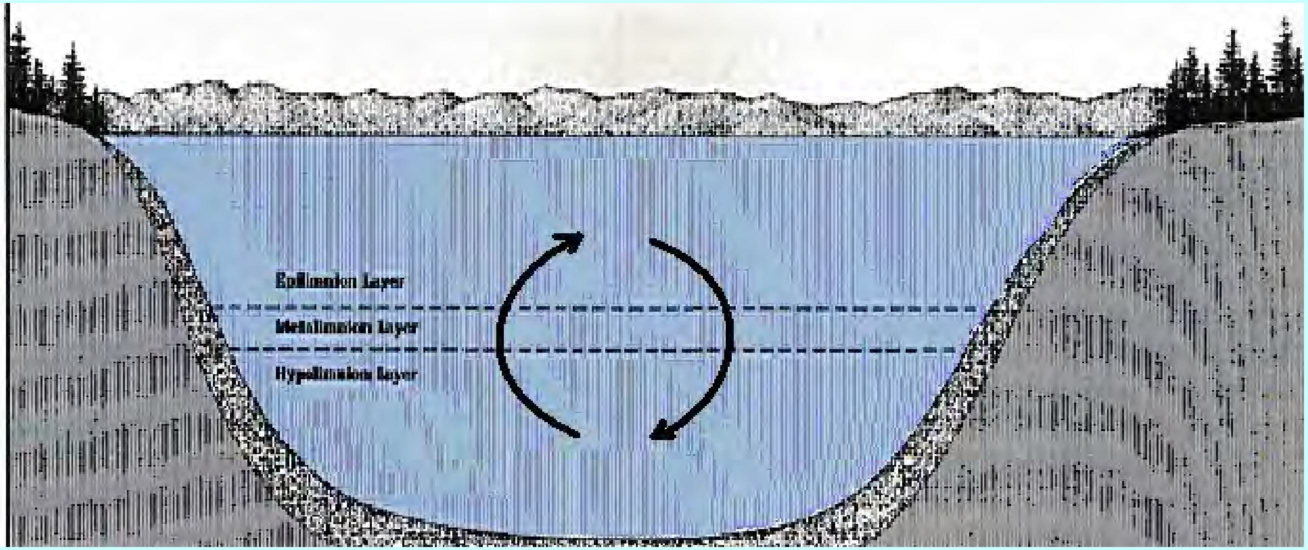
Reasons to oxygenate or circulate

- Avoid low oxygen levels that foster undesirable water quality and increase treatment needs
  - Elevated metals, especially iron and manganese
  - Accumulations of ammonium, hydrogen sulfide
  - Phosphorus release from sediment that supports algae growth
- Reduce algae biomass or change composition
- Provide consistent water quality (limit variation)
- Improve habitat, especially for fish and invertebrates



Circulation is intended to:

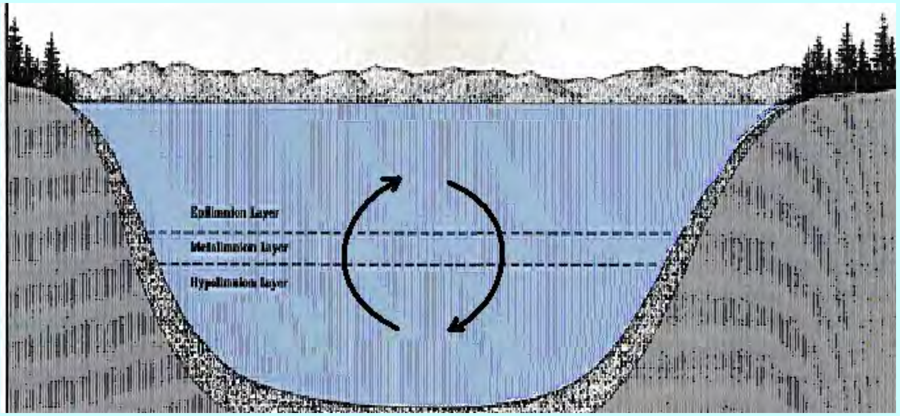
- Homogenize water quality over target zone
- Limit plankton by movement in water column
- Facilitate oxygenation through increased transfer of oxygen from surface water to deeper water

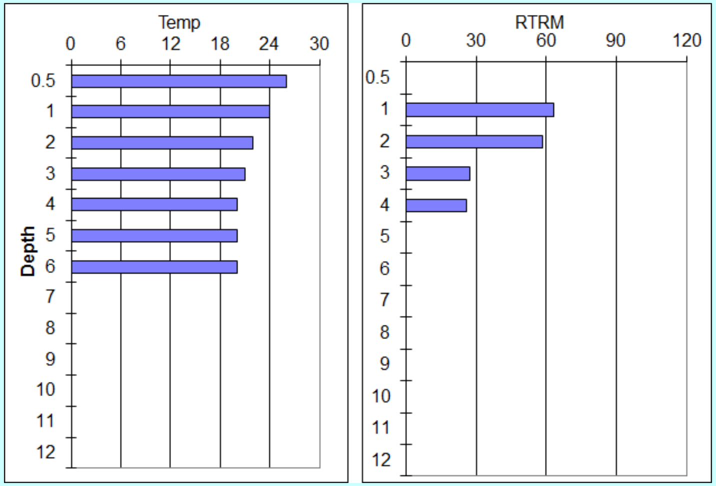


Keys to successful circulation

- Provide enough power to overcome thermal gradient
- Prevent stratification, as the energy necessary to break stratification is much greater than that necessary to maintain mixed conditions

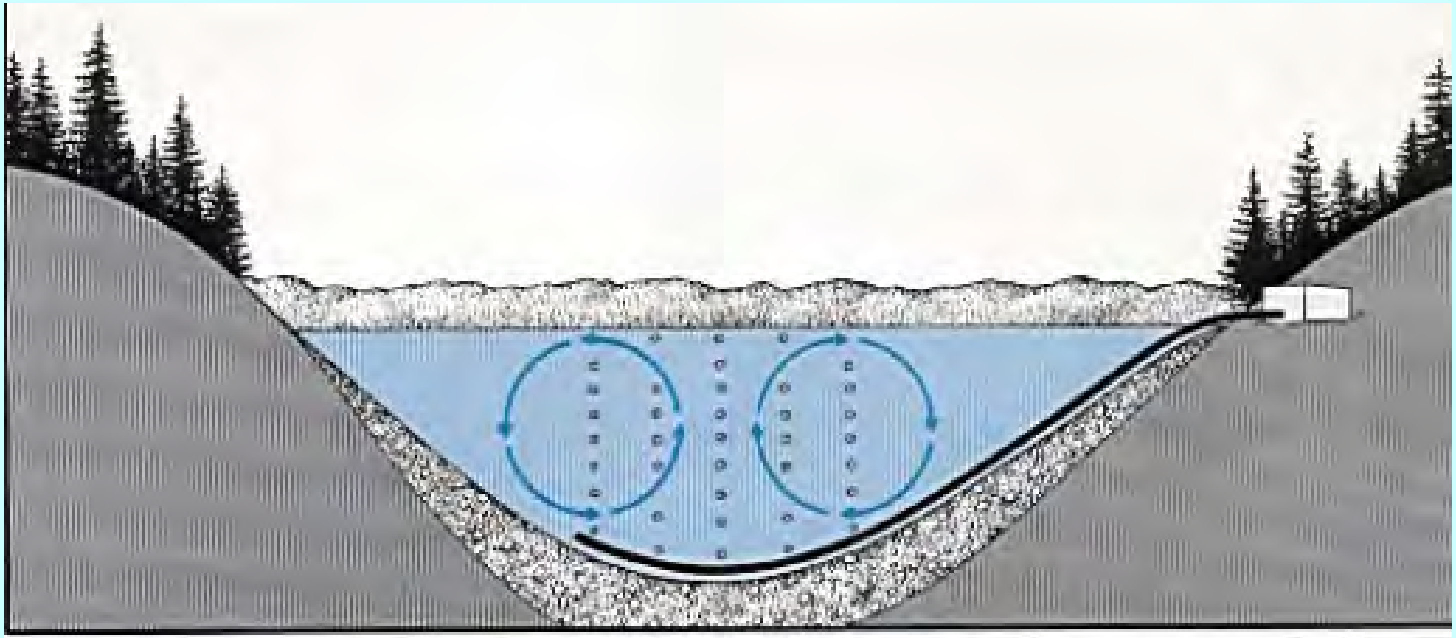
Biggest challenge is the thermal gradient induced by sunlight on the water surface; heat input from a series of hot sunny days is greater than the mixing power supplied by nearly all systems.





Circulation Methods: DAC

- Air diffuser systems highly varied, very common – effective when properly sized, distributed and operated; compressors are usually the weak link
- Oxygenation through interaction with atmosphere is usually more important than transfer from bubbles (<3% transfer/meter); need >1.3 cfm/ac to mix well



Circulation Methods: UDP

- Updraft mixers tend to be small, low power systems, run by electricity, wind or solar
- Efficiently move water
- Possible compensatory circulation patterns at distance from mixer limited by thermal gradient and not likely significant

Circulation Methods: Fountains

- Fountains – a form of upflow mixing, aerate well, but usually a small volume per unit time; need enough capacity to move the target water volume
- Not common in larger lakes or reservoirs

Circulation Methods: DDP

- Downdraft mixers with wide size range, force oxygenated surface water into deep areas
- Can be solar or wind powered, but run efficiently on electricity
- Data indicate substantial mixing and oxygenation if system large enough, but limited by thermal gradients

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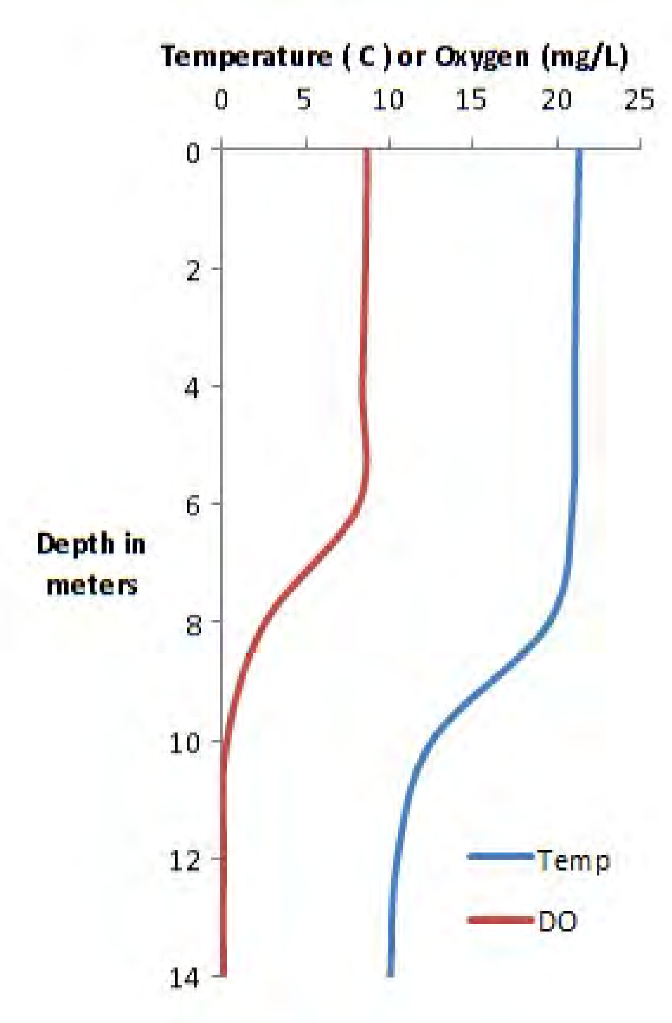


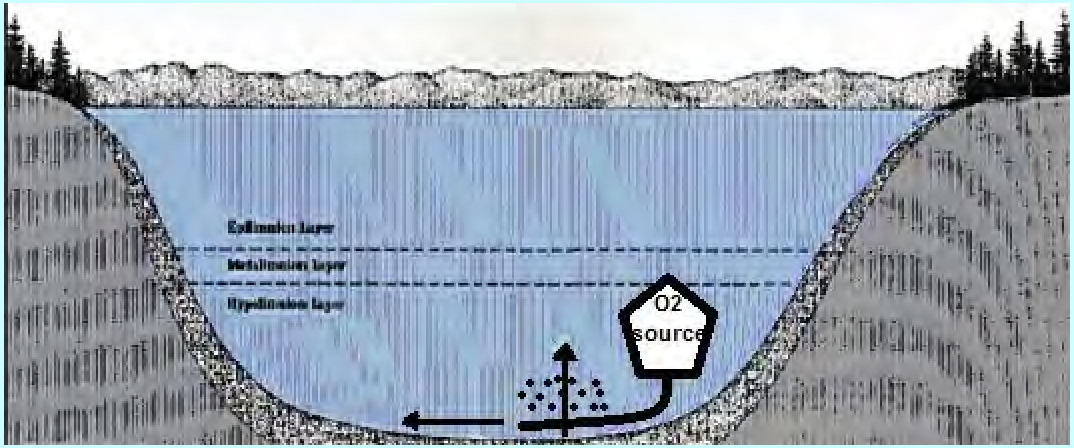
Oxygenation is intended to:

- Increase oxygen levels to avoid anoxia and accumulation of reduced compounds
- Provide deep water habitat with sufficient oxygen
- Maintain natural stratification; not mixing bottom and surface water

Keys to successful oxygenation

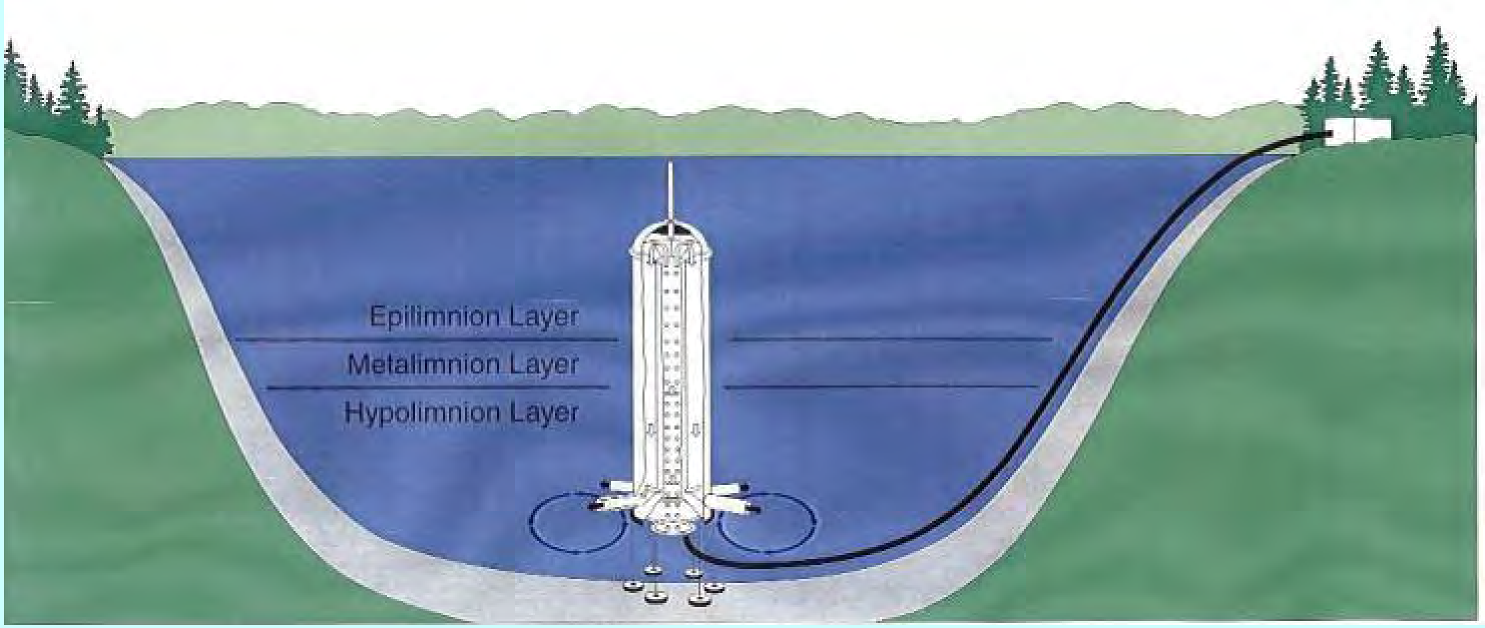
- Quantitatively counter oxygen demand
- Distribute the oxygen to where needed

Biggest challenge is induced oxygen demand, created by movement of water in contact with sediment, which increases the rate of oxygen consumption. Ironically, action taken to satisfy oxygen demand causes increased demand.



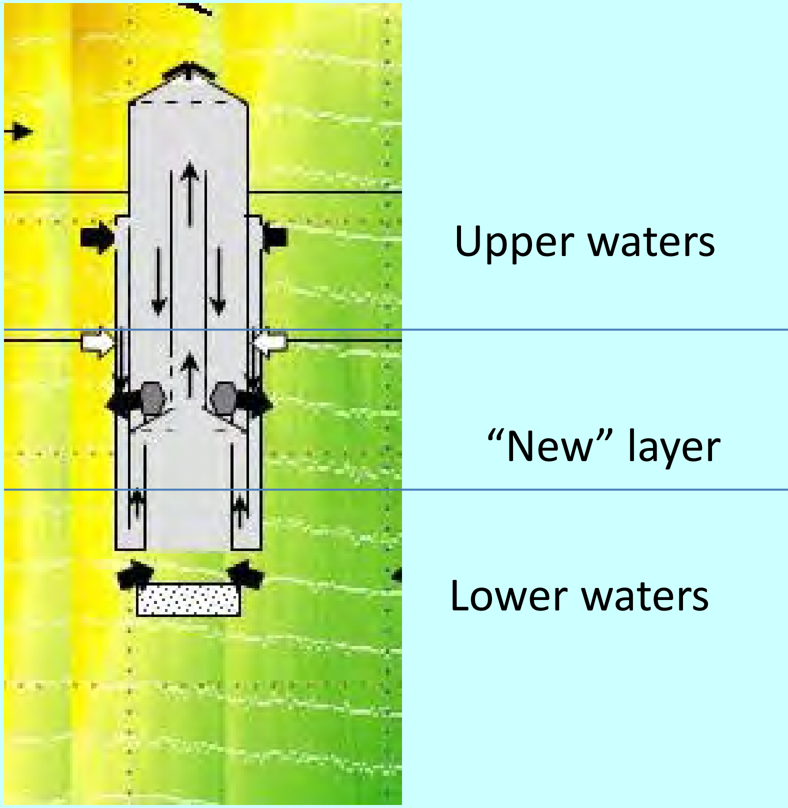
Oxygenation Approaches: HAC

- Hypolimnetic aeration chambers popular in 1980s-1990s, potentially effective but not overly efficient
- Non-destratifying, increased bottom DO, some undersizing but more distribution/maintenance issues
- If internally supplied P is dominant source, may control algae; need to understand seasonal P loading



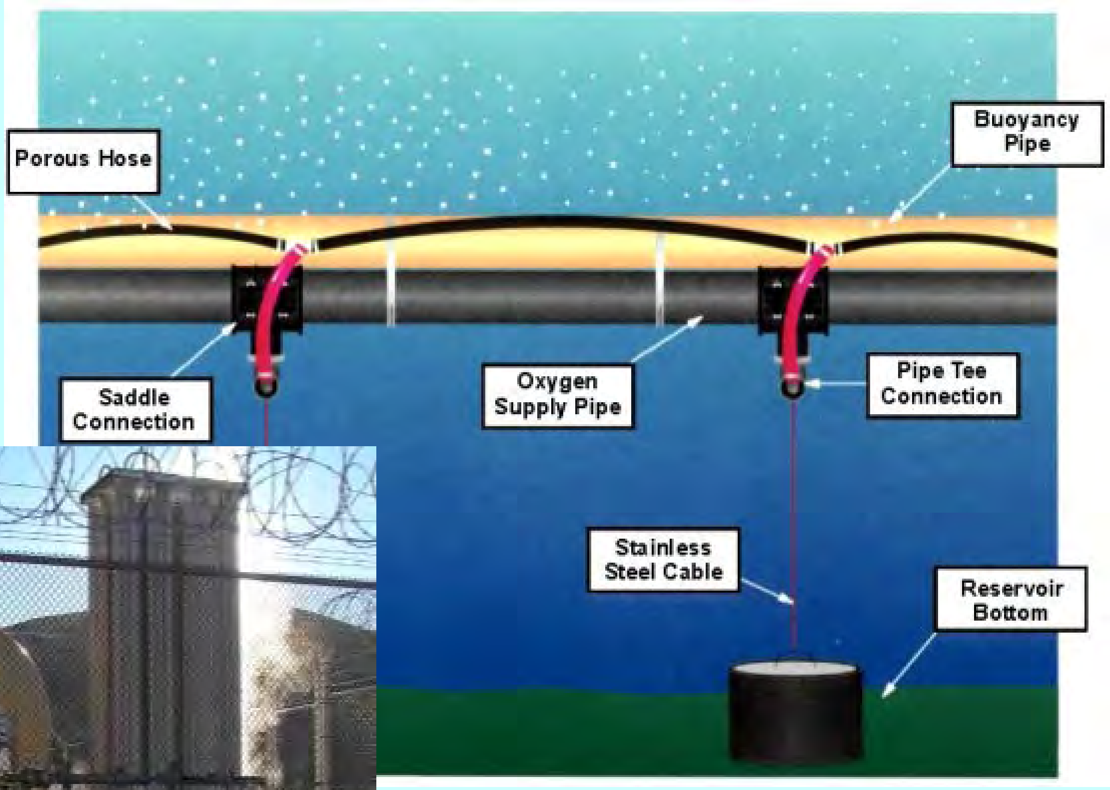
Oxygenation Approaches: HAC with a twist

- Layer Air (ECS creation) allows creation of a thermally distinct, oxygenated layer
- Pulls in oxygen-rich upper waters and adds oxygen to oxygen-poor lower waters, creating intermediate layer
- Does not need to address entire oxygen deficit to achieve desired conditions at targeted depth



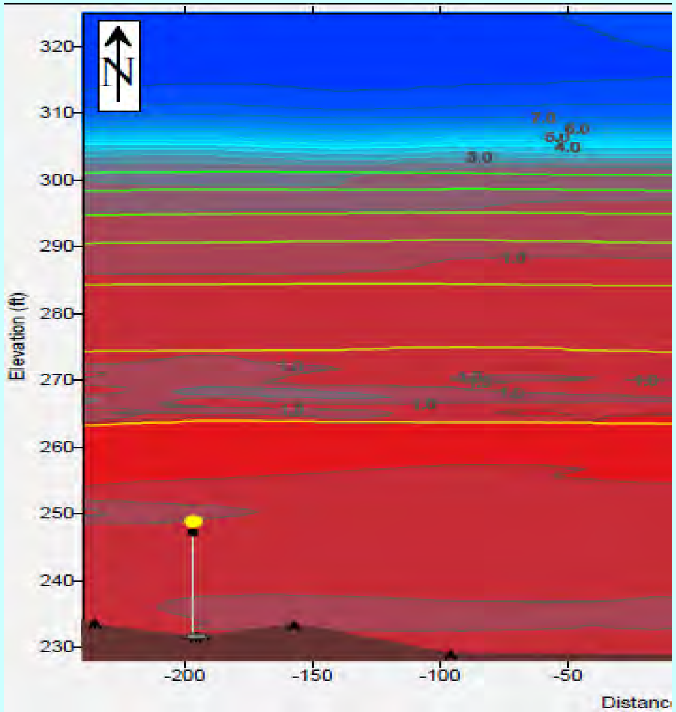
Oxygenation Approaches: DOX

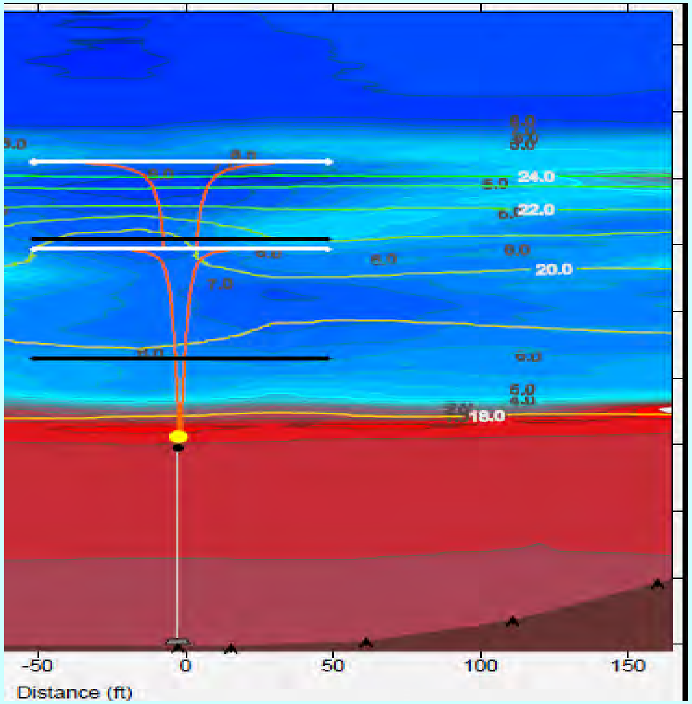
- Pure oxygen diffusers - simplicity of diffuser system with efficiency of oxygen transfer



Oxygenation Approaches: DOX

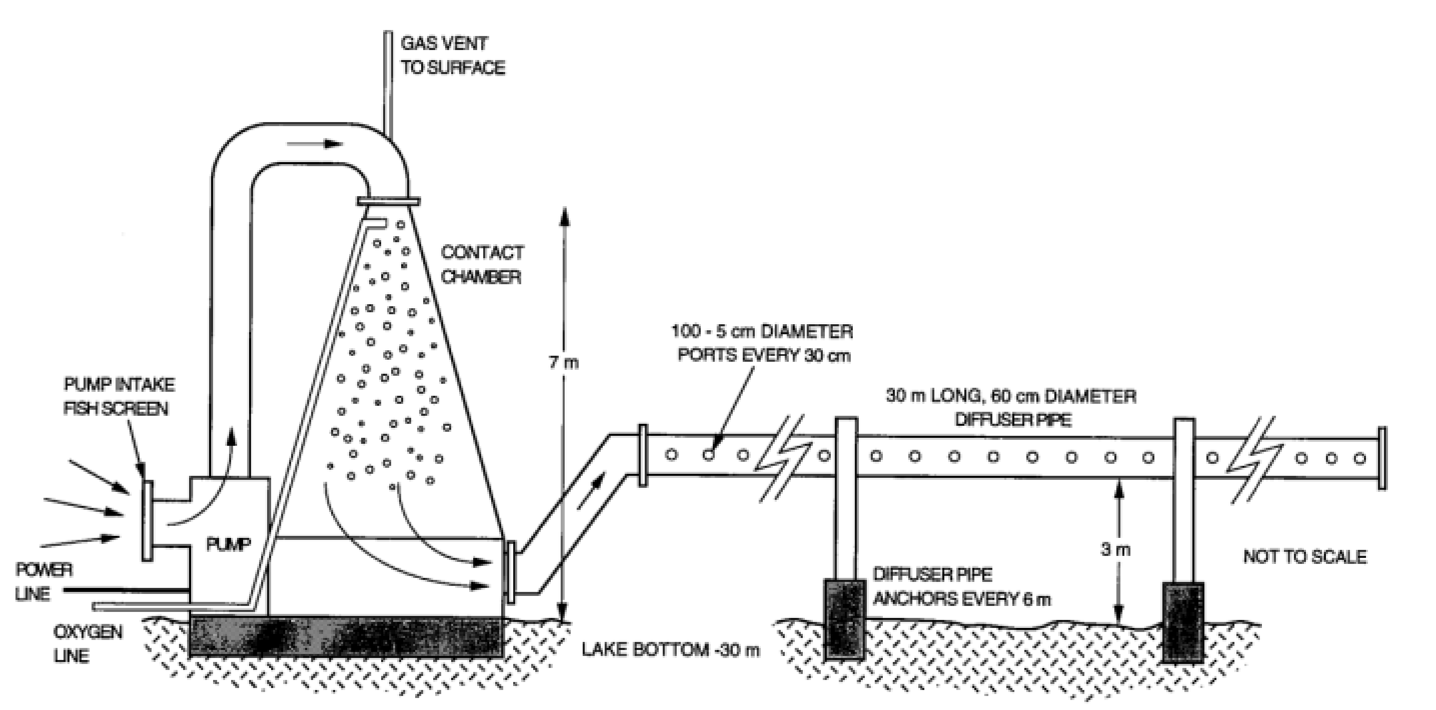
- Pure oxygen released as small bubbles, dissolve before causing destratification
- Can be done without pumps, min power use; gaseous oxygen moves by own pressure





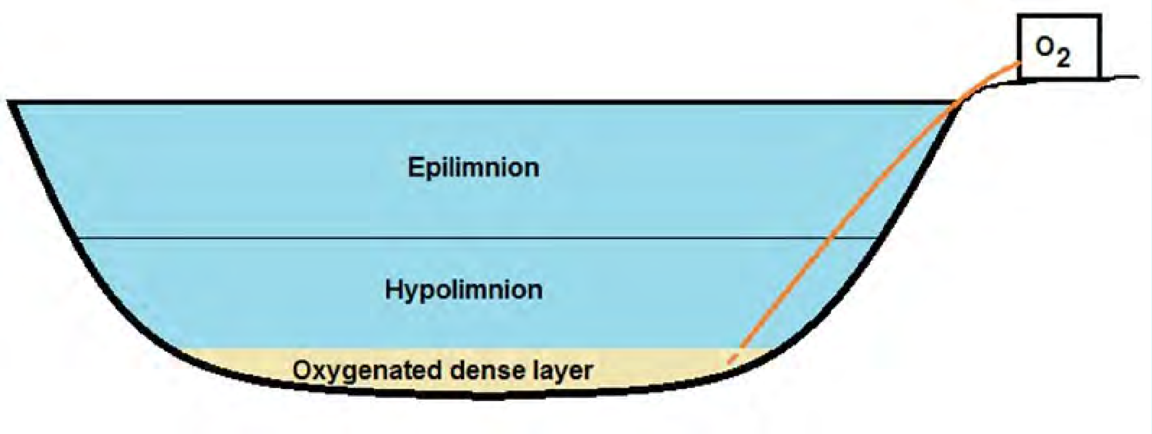
Oxygenation Approaches: DBC or Speece cone

- Oxygen injected into chamber with low DO water flowing downward, ideally bubbles held in position until dissolved (must balance oxygen and water flow)
- Distribution of oxygen is key issue; movement across density gradient is limited



Oxygenation Approaches: SSS

- Can also super-oxygenate outside water body and inject the water where desired
- Oxygenated water tends to move within density layer more than across gradient to areas of lower oxygen
- Distribution remains the key issue, but density differences might be used to advantage
- Nanobubble approach an offshoot of SSS, has not worked well on deep waters so far



Oxygenation Approaches: SSS/OST

- Considerable recent advances with SSS; Gantzer OST with chamber in lake or on shore, multiple innovations
- Targets high oxygen at sediment-water interface to drive anoxic zone deeper in sediment and provide extra oxygen in case of shutdown
- OST tends to be used on smaller lakes with on-site generation of oxygen, but not limited by lake size
- Important to use quality materials and invest in monitoring systems and automation

Experience with Oxygenation and Circulation

- Oxygen, algae, iron and manganese are the main reasons for oxy/circ systems in water supplies
- Oxygen for habitat often important to power producers
- Recreational lake managers looking for reduced HABs
- Possible to get acceptable results with proper use.
- Success linked to both system features and operational considerations

	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

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Oxygenation Experience Conclusions

- Added oxygen benefits water quality; suboptimal systems still partially meet goals
- IOD requires more oxygen addition than suggested by oxygen demand measures
- Must avoid anoxia to P release; hard to recover if oxygen is lost for even a week
- DOX offers successful simplicity, mainly limited by thickness of target layer
- SSS and DBC can target thinner bottom layers successfully, but more complicated systems

Circulation Experience Conclusions

- Target area must be completely mixed during entire target period; difficult to achieve with hot sunny weather, hard to mix right to bottom; must understand thermal gradient
- DAC provides highly flexible operation, limited by compressor function & diffuser distribution
- DDP provide benefits even when suboptimal; forcing water down preferable to upflow
- UDP mainly limited by small affected volume; compensatory flow not achieved
- Changes types of algae but not often quantity

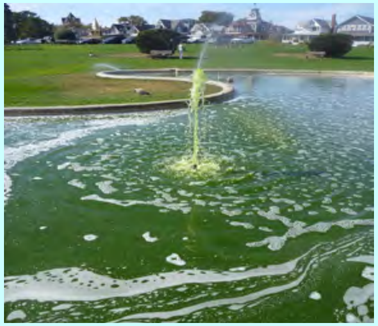
Technical and Cost Factors in System Choice

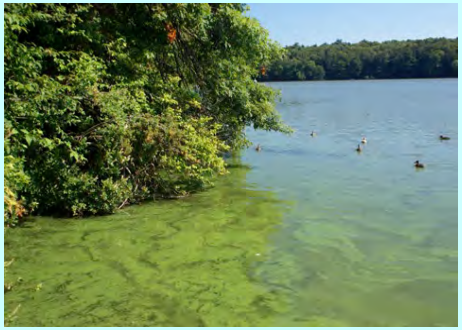
- Oxygen demand, system fertility
- Size and shape of target area
- Target depth (affected by intake levels)
- Weather pattern (especially sun and wind)
- Rate of flow through target area
- Source and cost of oxygen
- Availability and cost of power
- Quality/cost of materials (lines, tanks, compressors)
- Ease of installation/maintenance/replacement
- Sensitive receptors in area (mostly people issues)

An apparent top technical choice can be trumped by economics or sociopolitical factors

Algal Control Options

- Algaecides – reliable reduces algae, but adds to oxygen demand, not usually proactive
- P inactivation – prevents blooms at reasonable cost but will not eliminate oxygen demand
- Dredging – removes offending sediment, many benefits, but also very expensive and hard to permit
- Circulation – may shift algal types but rarely results in clear water
- Oxygenation – can provide multiple benefits but requires good design and attentive operation





Summary

- Countering oxygen loss in aquatic habitats can provide water quality and habitat benefits beyond most other techniques
- Successfully countering oxygen loss can be accomplished by multiple techniques, but is not easy or inexpensive and requires ongoing activity
- There are many considerations associated with circulation and oxygenation that must be addressed to have a successful project
- There is no “magic” solution or “free lunch” – managing algae in lakes requires data, analysis, expertise, perseverance, and funding

I think I'm gonna need another one after that!

QUESTIONS?