# Pond Remediation Case Study – Chatham: Assessment & Selection of Alum Treatment for Lovers Lake & Stillwater Pond

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# Background


- Groundwater-connected kettlehole ponds
- Massachusetts “Great Ponds”
- Located in Pleasant Bay Area of Critical Environmental Concern
- Increasing incidence of phytoplankton blooms
- Chatham’s only active herring run

# What is the significance of being a kettlehole pond ?


- Formed by retreat of glacial ice sheet and remnant block of ice in sandy basin
- Deep central basin, often subject to thermal stratification
- Restricted number of tributaries and often only seasonal outflow
- Groundwater is most important portion of hydrologic budget
- Flushing rate is slow, nutrients are retained and promote growth
- Typically have diverse biotic communities

# Phase 1

- Evaluate available water quality data, reports and other relevant information to assess nutrient stations
  - identify critical data gaps
  - coordinate any needed sampling.
- Develop hydrologic (water) budget for two Ponds
- Develop nutrient budget for two Ponds
  - investigate internal nutrient recycling
  - compare with other potential watershed sources
- Characterize biota of Ponds
  - macrophyte community
  - fish (herring)


Figure 1. Lovers Lake and Stillwater Pond Locus Map.

0 250 500 1,000 Feet

January 2010; NAD83 MA State Plane, feet; 1:5,000 Orthophotography from MASSGIS, data collected in April 2005

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## Phase 2

- Evaluate potential lake management options
  - dredging
  - circulation
  - aeration
  - nutrient inactivation (alum treatment).
- Select management options to alleviate eutrophication, considering:
  - technical feasibility
  - expected water quality or recreational improvements
  - longevity
  - cost-effectiveness
  - permitting issues
- For recommended option, develop specifications, permits and detailed cost estimates
- Identify funding sources for implementation

# Data Evaluation

- Describe physical attributes of the two ponds
  - Basin shape and bathymetry
  - Watershed size and land use
  - Flow characteristics
- Characterize current water quality
  - recent water chemistry results
  - secchi disk observations
  - observations of temperature and dissolved oxygen (DO) profiles
- Characterize biota
  - plankton (algae and zooplankton)
  - macrophyte and shoreline vegetation
  - wildlife (fish and waterfowl)

# General characteristics

## LOVERS LAKE

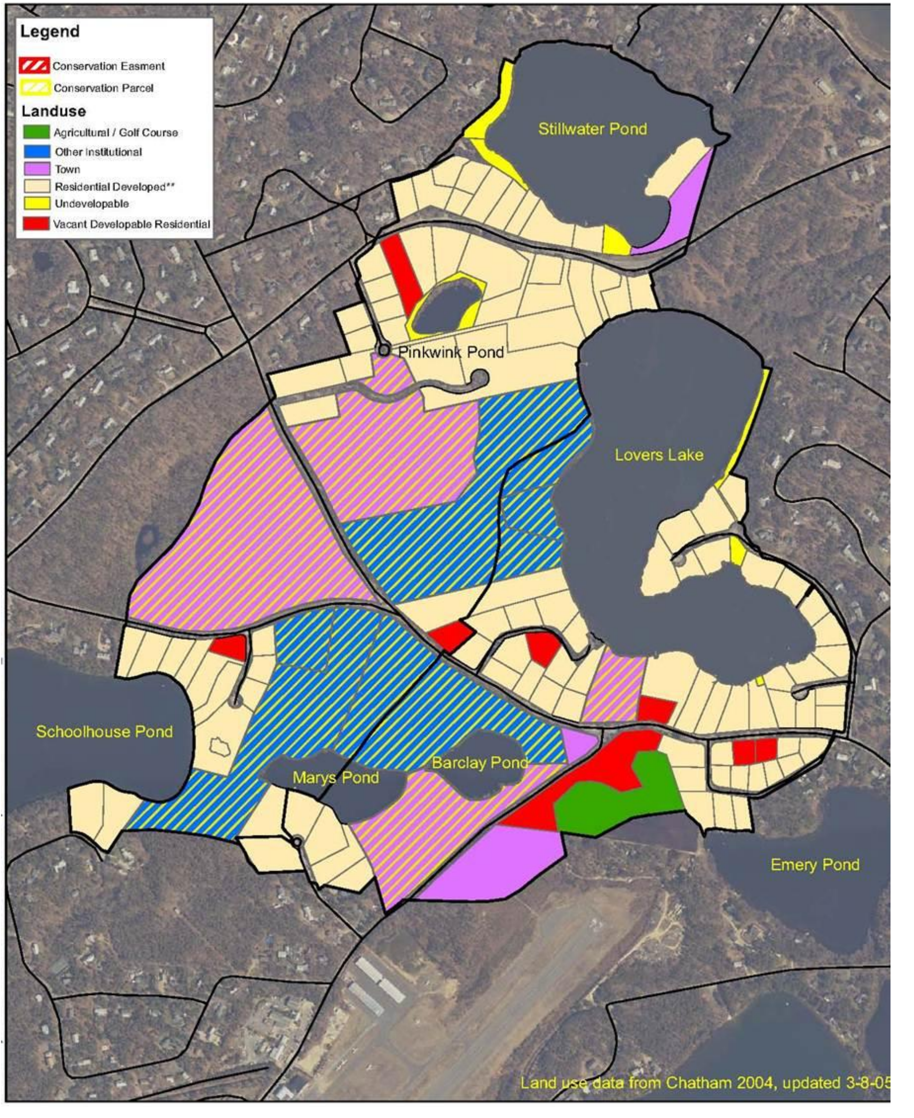
- Kettlehole Pond; MA-designated Great Pond
- Size is 37.7 acres
- Maximum depth about 32 feet
- Connected to Stillwater Pond and Frost Fish Creek
- No public access to pond
- Recreational uses
  - swimming, boating, fishing
  - passive recreational
- Herring run present

## STILLWATER POND

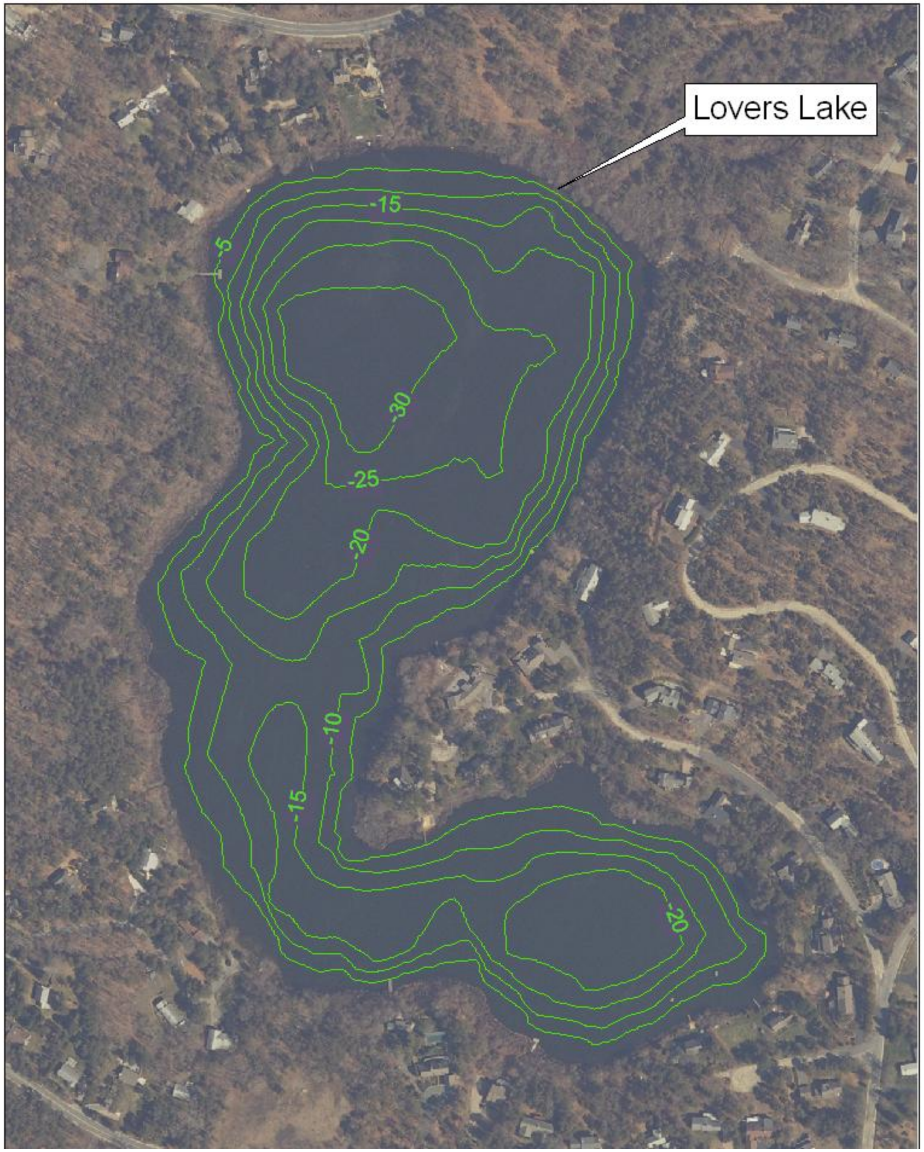
- Kettlehole Pond; MA-designated Great Pond
- Size 18.7 acres
- Maximum depth about 46 feet
- Connected to Lovers Lake and Ryder’s Cove
- Unimproved boat launch
- Recreational uses
  - swimming, boating, fishing
  - passive recreational
- Herring run present

# Watershed Land Use

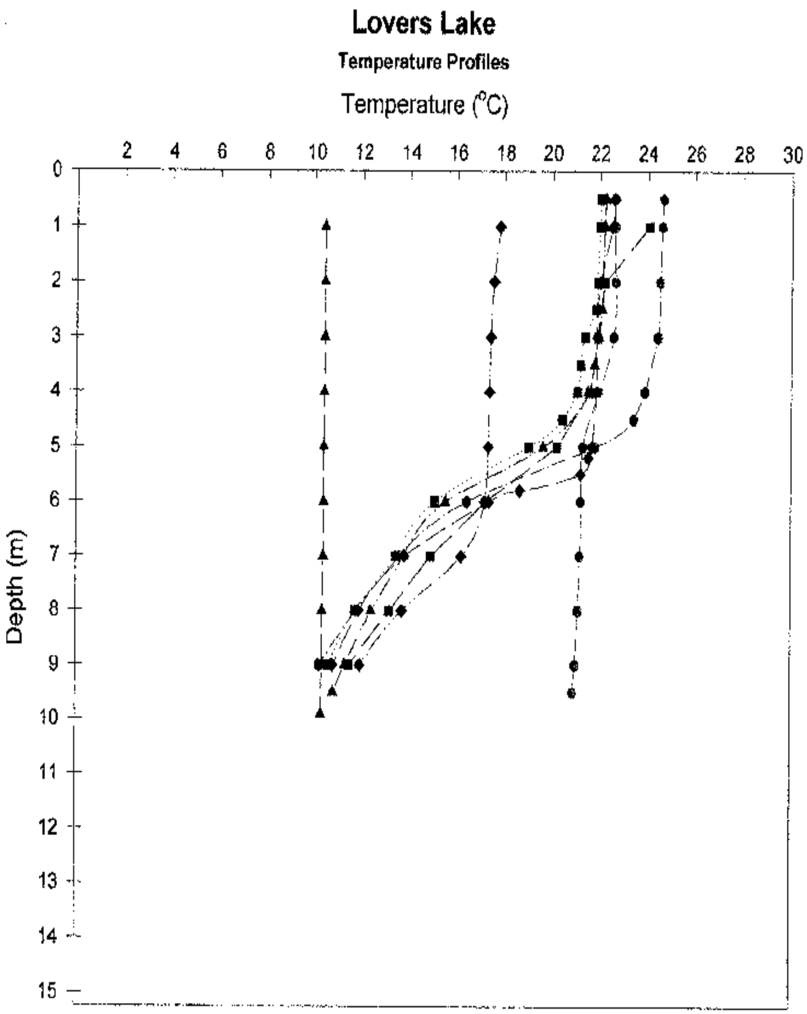
| | Lovers Lake | Stillwater Pond |
|---|---|---|
| Residential | 39% | 34% |
| Roads | 8% | 7% |
| Cranberry Bog | 5% | 0% |
| Open Land | 6% | 0% |
| Forest | 34% | 55% |
| Water/Wetlands | 9% | 4% |

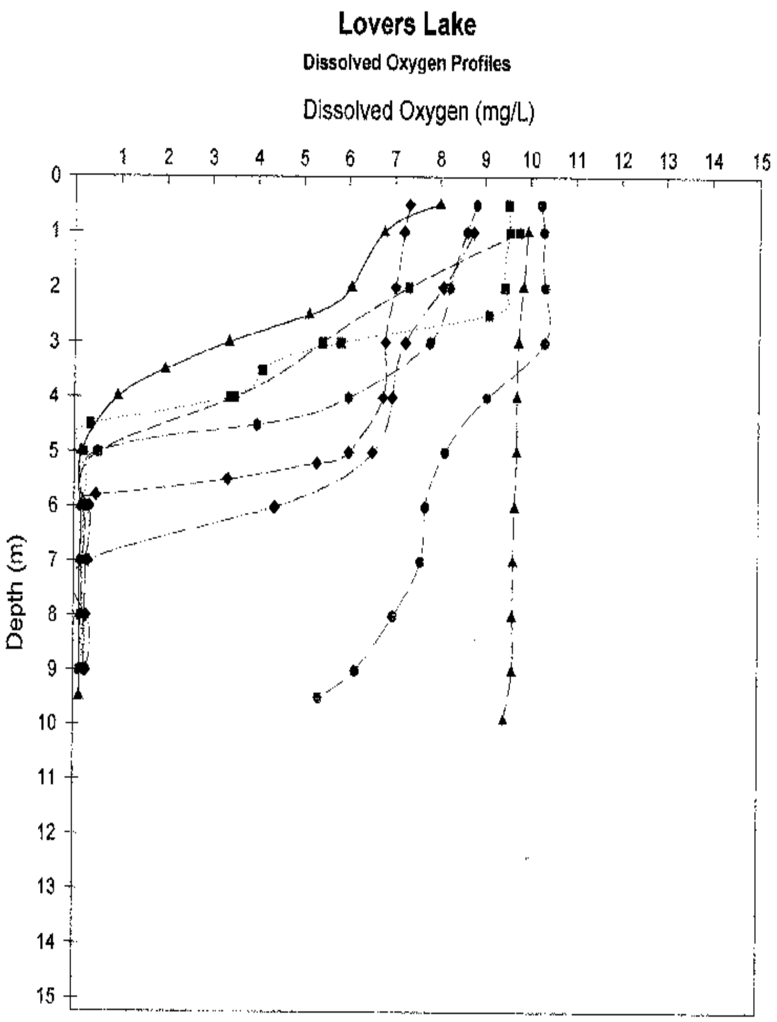


# Lovers Lake Basin Bathymetry

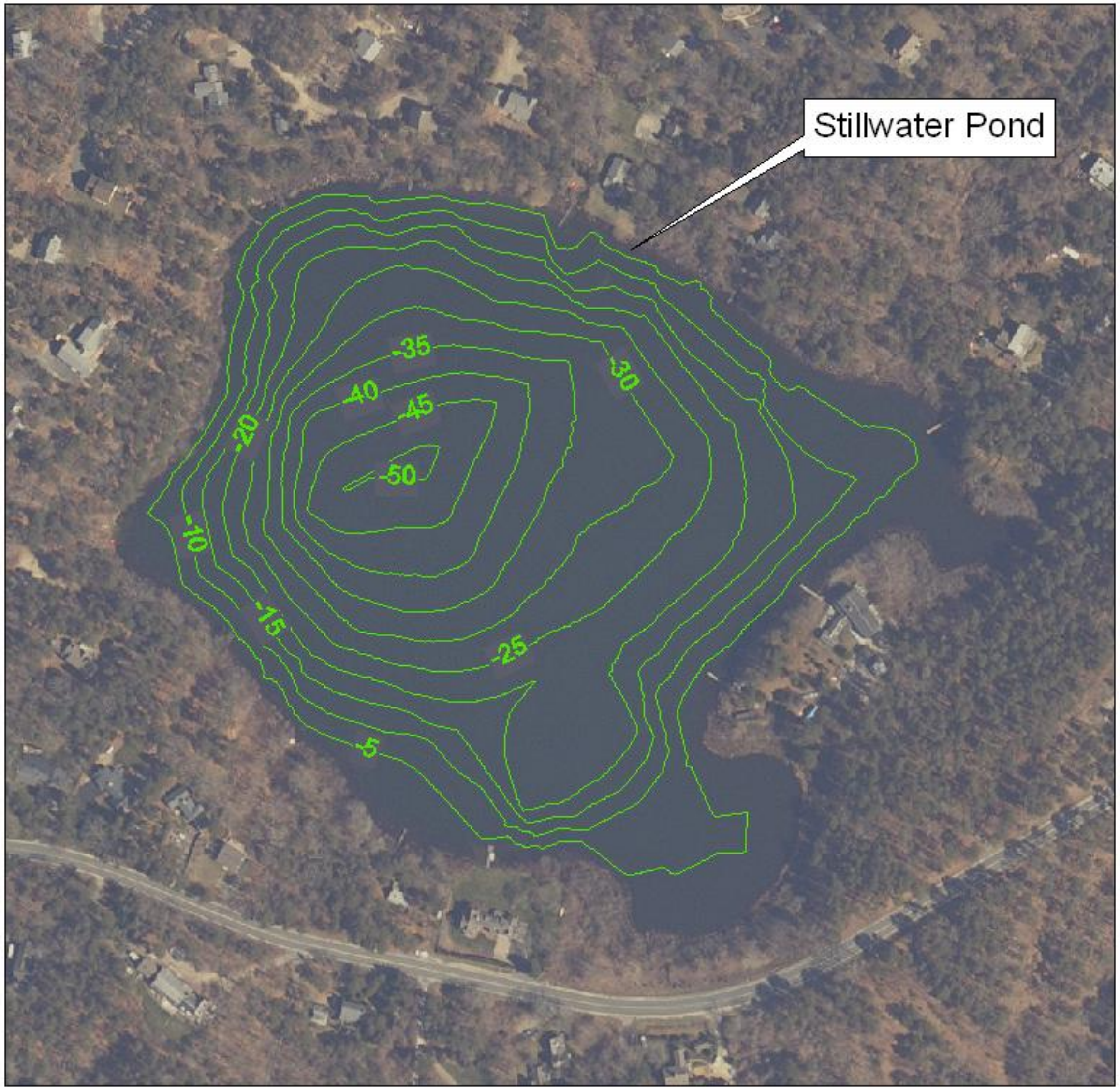


# Lovers Lake Temperature and DO Profiles

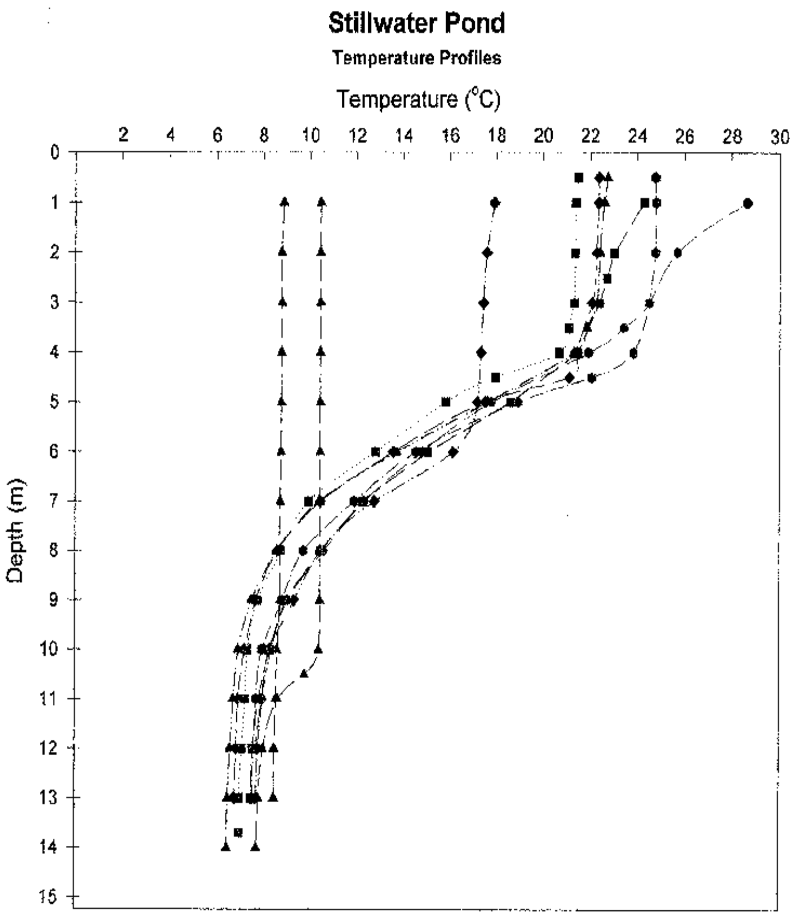


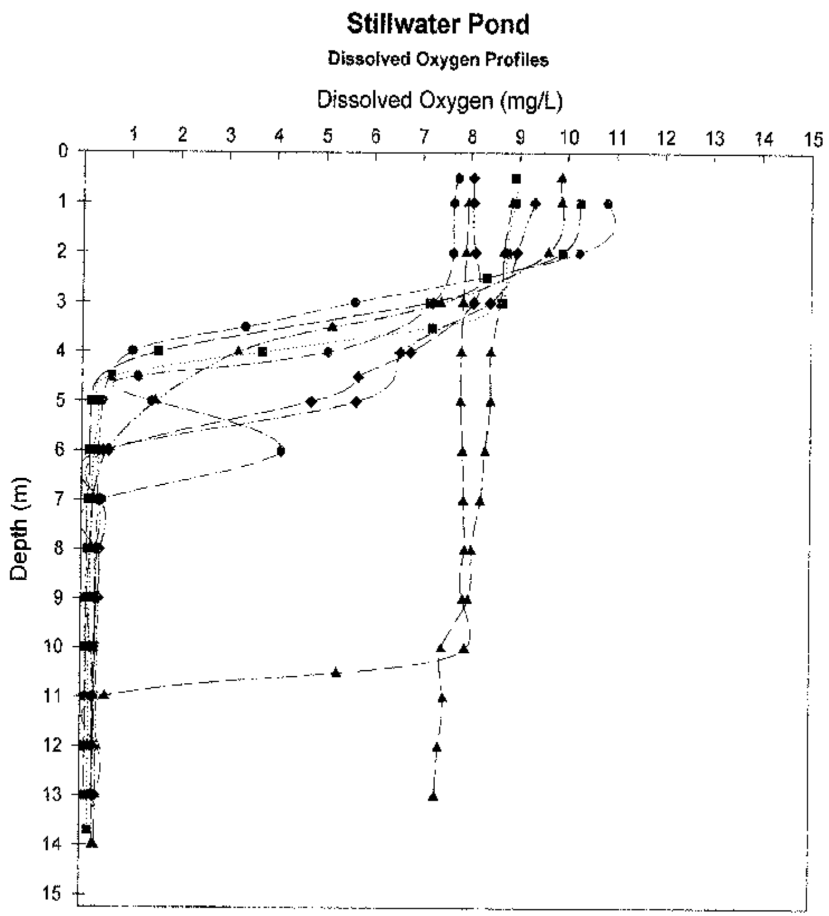



# Stillwater Pond Basin Bathymetry



# Stillwater Pond Temperature and DO Profiles



# Current water quality in Lovers Lake and Stillwater Pond

**LOVERS LAKE**

- Surface total phosphorus (TP) levels about 38.9 ug/L; bottom TP is approximately 125 ug/L
- Secchi disk transparency (SDT) depth ranges from 1.5 to 5.6 ft
- Summer chlorophyll a ranges from 5.4 to 73.3 ug/L with average of 32.2 ug/L
- Anoxic conditions below 12-15 ft in late summer
- Water quality conditions are consistent with eutrophic classification

**STILLWATER POND**

- Surface total phosphorus (TP) levels about 25 ug/L; bottom TP is approximately 312 ug/L
- Secchi disk transparency (SDT) depth ranges from 2.2 to 10 ft
- Summer chlorophyll a ranges from 4.3 to 56.1 ug/L with average of 21.6 ug/L
- Anoxic conditions below 15-18 ft in late summer
- Water quality conditions are consistent with eutrophic classification

# **Hydrologic** Budgets

| Input Source | Water (Million $ft^3/yr$) | % of Total water |
|---|---|---|
| Groundwater in-seepage | 8.46 | 55 |
| Direct Precipitation | 6.06 | 39 |
| Riparian Zone Runoff | 0.76 | 5 |
| Septic Discharge | 0.13 | 1 |
| Total | 15.41 | 100 |
| *Output Source* | | |
| Surface Water Outflow | 13.9 | 78 |
| Evaporation | 3.83 | 22 |
| Groundwater Out-seepage | 0 | 0 |
| Total | 17.7 | 100 |

Lovers Lake

| Input Source | Water (Million $ft^3/yr$) | % of Total water |
|---|---|---|
| Surface Water Tributary | 13.9 | 60 |
| Groundwater in-seepage | 5.82 | 25 |
| Direct Precipitation | 3.01 | 13 |
| Riparian Zone Runoff | 0.41 | 2 |
| Septic Discharge | 0.07 | $\leq 1$ |
| Total | 23.2 | 100 |
| *Output Source* | | |
| Surface Water Outflow | 11 | 48 |
| Evaporation | 1.9 | 8 |
| Groundwater Out-seepage | 10.3 | 44 |
| Total | 23.2 | 100 |

Stillwater Pond

## Evidence of Internal Phosphorus Recycling

- Strongly anoxic hypolimnion, lack of oxygen in bottom releases phosphorus from iron-complex into overlying water
- Observations of elevated amounts of TP in bottom water - difference most profound in late season observations
- Lack of significant surface tributaries or obvious overland routes
- Persistent phosphorus levels despite watershed management BMPs
- Nutrient control is the key to long-term control of algae problems; watershed management has top priority, but in-lake controls may be expedient and/or necessary.

# **Phosphorus** Budgets

| *Input Source* | TP Load (kg/yr) | % of TP |
| --- | --- | --- |
| Atmospheric | 3.8 | 9 |
| Internal Recycling | 18.3 | 43 |
| Waterfowl | 4 | 9 |
| Septic Systems | 4.6 | 11 |
| Watershed GW Load | 0.3 | 1 |
| Watershed Runoff Load | 11.5 | 27 |
| Total | 42.5 | 100 |
| *Output Source* | | |
| Surface Water Outflow | 15 | 35 |
| Out-seepage (assumed) | 0 | 0 |
| Storage | 27.5 | 65 |
| Total | 42.5 | 100 |

Lovers Lake

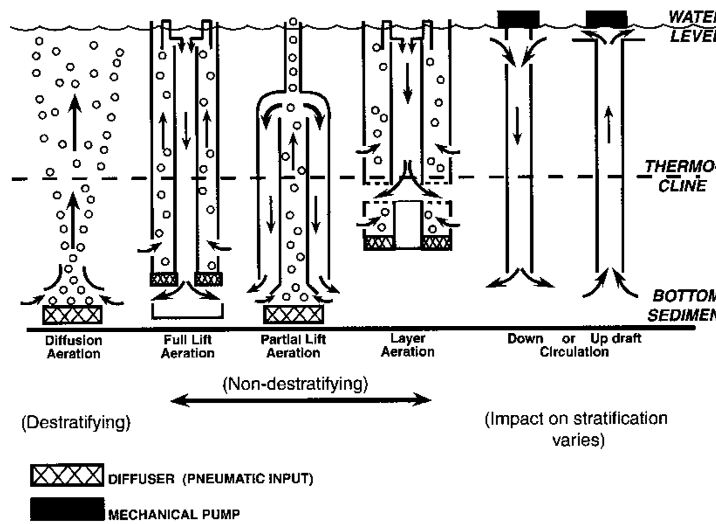
| *Input Source* | TP Load (kg/yr) | % of TP |
| --- | --- | --- |
| Inlet (LL Outlet) | 15 | 31 |
| Atmospheric | 1.9 | 4 |
| Internal Recycling | 27 | 55 |
| Waterfowl | 2 | 4 |
| Septic Systems | 2.6 | 5 |
| Watershed GW Load | 0.002 | <.01 |
| Watershed Runoff Load | 0.4 | 1 |
| Total | 48.5 | 100 |
| *Output Source* | | |
| Surface Water Outflow | 12.5 | 26 |
| Out-seepage (assumed) | 0 | 0 |
| Storage | 36 | 74 |
| Total | 48.5 | 100 |

Stillwater Pond

# Internal P Recycling – Potential Restoration Approaches

Different methods to reduce internal loading:

- Dredging removes nutrient reserves
- Aluminum treatments bind P most permanently; iron or calcium may be appropriate in some cases
- Aeration will limit release by iron; mixing (circulation) may help too




## Dredging:

- Dry (conventional)
- Wet (bucket/dragline)
- Hydraulic (piped)

- Removes “seed” bank
- Potential mat control
- Essential to remove all nutrient-rich sediment for maximum effect

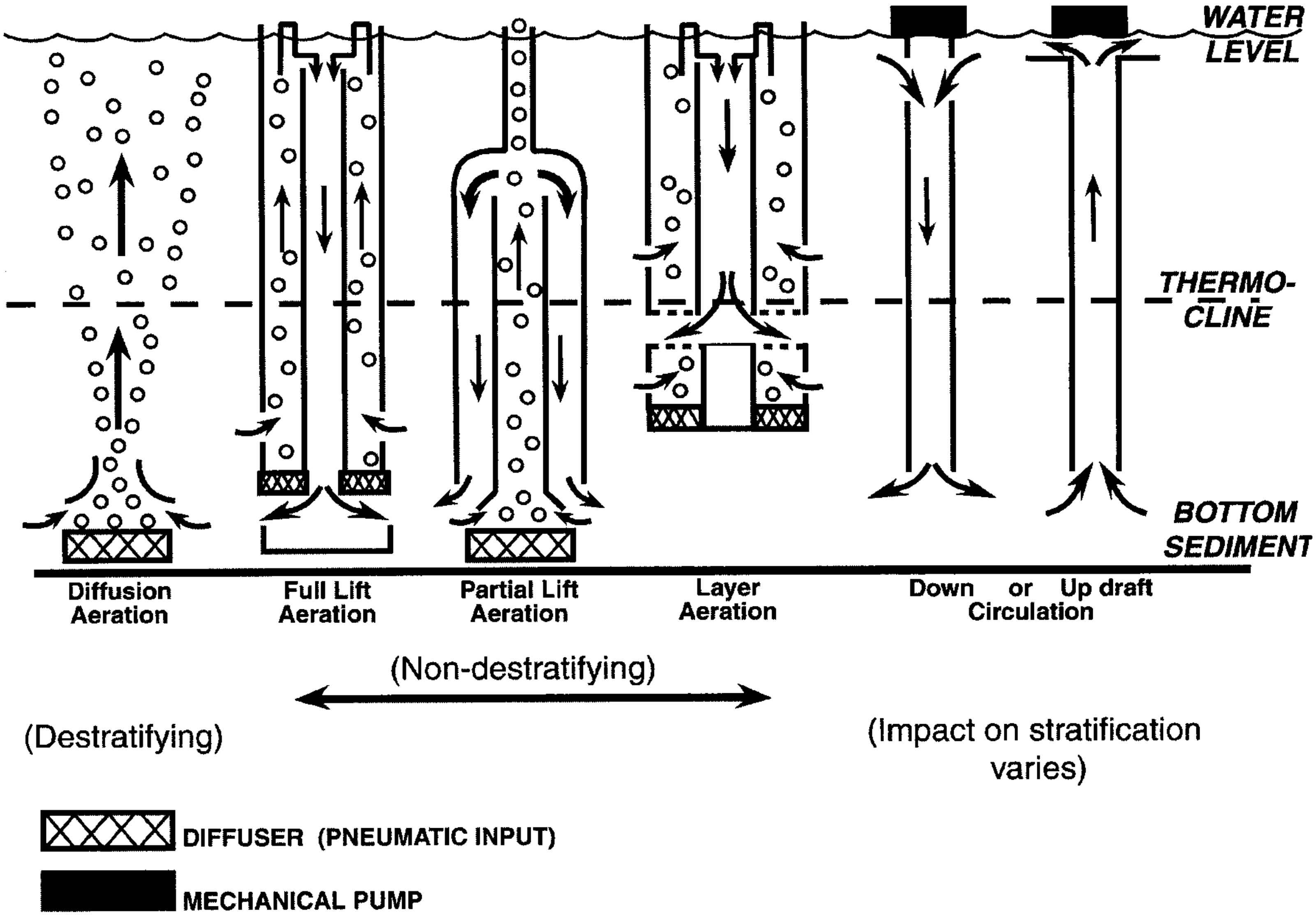
## Information Needs in Planning to Dredge:

- ♦ Sediment quality – controls disposal
- ♦ Sediment quantity – affects cost and method
- ♦ Flow control – affects method
- ♦ Disposal site features – affects method and rate
- ♦ Affected resources – controls mitigation needs
- ♦ Equipment access – affects method
- ♦ Relation to lake uses – affects timing and interference

## Aeration/mixing can work by:

- Adding oxygen and facilitating P binding while minimizing release from sediments
- Physical mixing that disrupts growth cycles of some algae
- Alteration of pH and related water chemistry that favors less obnoxious algal forms
- Turbulence that neutralizes advantages conveyed by buoyancy mechanisms
- Creation of suitable zooplankton refuges and enhancement of grazing potential

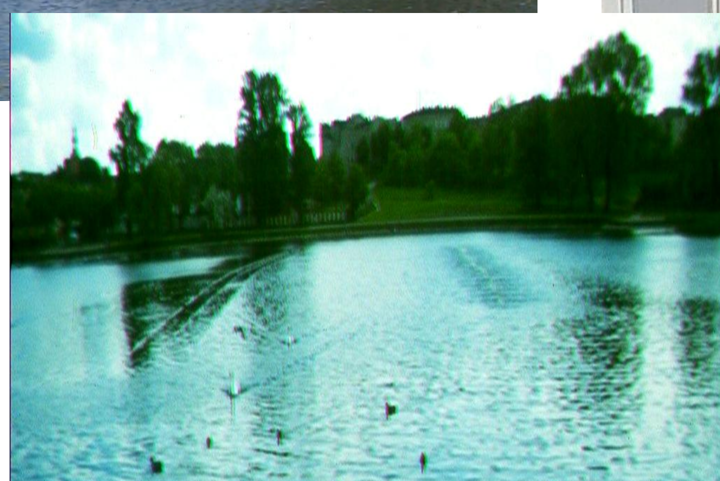
# Aeration systems:



## Key factors in aeration:

- Adding enough oxygen to counter the demand in the lake (usually about 75% from sediment) and distributing it where needed in the lake
- Maintaining oxygen levels suitable for target aquatic fauna (fish and invertebrates)
- Having enough of a P binder present to inactivate P in presence of oxygen
- Not breaking stratification if part of goal is to maintain natural summer layering of the lake

# Mixing systems:

## Key factors in mixing:

- Moving enough water to prevent stagnation; may mix whole lake or just the top layer (if any)
- Fostering greater homogeneity in mixed zone and greater interaction with the atmosphere (oxygen and pH effects may be large)
- Getting enough motion or change in water quality to disrupt target algal species; moving algae to dark zone helps, but may be possible to disrupt with only surface layer mixing

## Info needs for aeration/mixing:

- Oxygen demand and its component parts (sources)
- Bathymetry and light penetration
- P binder forms and abundance
- Energy necessary to destratify
- Forms of algae and zooplankton
- Potentially sensitive biological receptors
- Power availability
- Nearby land availability

## Lake Sediment Treatment:

- Reduce P release from sediment; can control P in lake if sediment is the major source
- Normally planned to react with upper 2-4 inches of sediment, more if very loose
- Dose usually 25-100 $g/m^2$ – based on amount and form in which P is bound in sediment

## Phosphorus Inactivators:

Aluminum - Most permanent binder, works well at all DO levels and best at an initial pH range of 6.0-8.0

Iron - Most common natural binder, works well at high DO and moderate to high pH (>6.0)

Calcium - Precipitates at elevated concentrations at high pH (>8.0), not greatly affected by DO

Organic complexes - Most common at low pH (<6.0), may inactivate or chelate P

Synthetic polymers - May capture and inactivate P as part of flocculation process

## When to Use Aluminum:

- Internal P load is high relative to external load, or external load is pulsed such that one treatment covers much of the annual load
- Detention time is high
- pH is 6-8 and alkalinity (buffer capacity) is high (>20 ppm, preferably >40ppm)
- Potentially sensitive receptors are few, or avoidable, or impacts are acceptable
- Rooted plant density in the targeted area at the time of treatment is low

## Extra data may be needed to evaluate choices

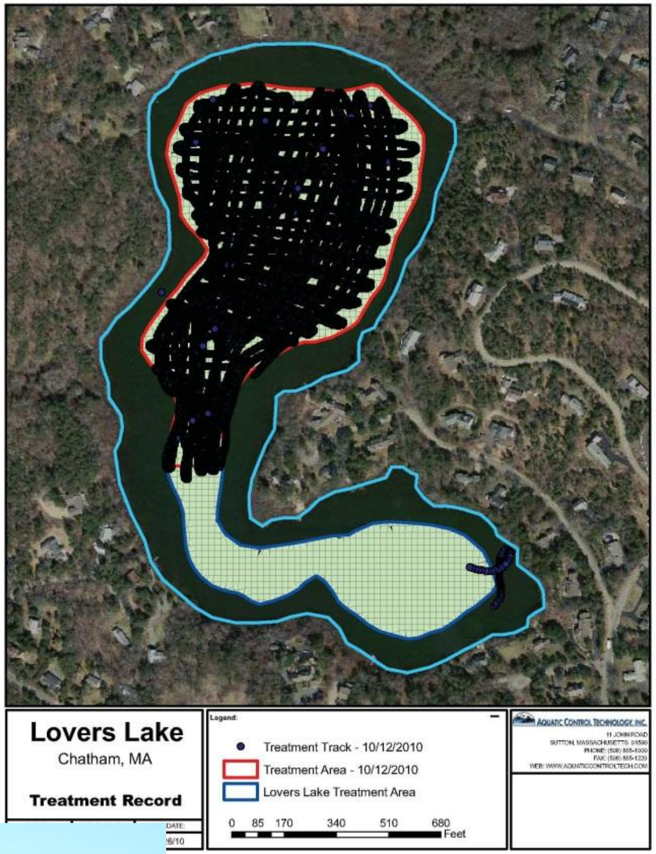
- Lake volume and flushing rate estimates
- Water quality over season – spring TP concentrations
- DO concentrations in hypolimnion from spring turnover until mid-stratified period to document DO loss rate for estimate of aeration
- Sediment quality – to evaluate amount of desorbable phosphorus and calculate amount of alum inactivation
- Sediment characteristics to evaluate volume, handling, and disposal options for dredging
- Information on herring fishery, T/E species, any other special considerations

## Selection of the appropriate pond restoration method requires clearly-defined objectives

- What are current uses of pond and the desired endpoints.
  - Boating, swimming, fishing
  - Other types of uses ?
- What level of water quality improvement is needed to:
  - improve aesthetic appearance ?
  - meet all water quality standards
  - promote ecological health or biological diversity ?
  - enhance recreation ?
- How we will measure success ?
  - Increase SDT to allow swimming all summer ?
  - Decrease number and frequency of algal blooms ?
  - Property values increase ?

# **Alum** Treatment in October 2010

- Determination of sediment phosphorus
- Calculation of aluminum dosage
  - 100 g AL/m2 (two applications of 50 g AL/m2 for each pond)
- Bioassay testing
- Application took place over a two week period with waiting periods between applications to check water chemistry and observe pond biota (fish)
- No adverse impacts
- Post-application monitoring
- until August 2012




# **Trophic State** Summary

| 2001-2006 TSI Values | SDT (m) | TP (ug/L) | TSI-SDT | TSI-TP | Mean TSI Value | Trophic State |
|---|---|---|---|---|---|---|
| Lovers Lake | 1.1 | 32.2 | 58 | 54 | 56 | Eutrophic |
| Stillwater Pond | 1.6 | 27.5 | 53 | 52 | 53 | Eutrophic |

| 2007 TSI Values | SDT (m) | TP (ug/L) | TSI-SDT | TSI-TP | Mean TSI Value | Trophic State |
|---|---|---|---|---|---|---|
| Lovers Lake North Basin | 0.9 | 42.5 | 61 | 58 | 60 | Eutrophic |
| Lovers Lake South Basin | 1.0 | 36.5 | 60 | 56 | 58 | Eutrophic |
| Stillwater Pond | 1.0 | 35.5 | 61 | 56 | 58 | Eutrophic |

| 2011-2012 TSI Values | SDT (m) | TP (ug/L) | TSI-SDT | TSI-TP | Mean TSI Value | Trophic State |
|---|---|---|---|---|---|---|
| Lovers Lake North Basin | 3.7 | 10.5 | 41 | 38 | 40 | Mesotrophic |
| Lovers Lake South Basin | 4.0 | 12.5 | 40 | 41 | 40 | Mesotrophic |
| Stillwater Pond | 3.8 | 6 | 41 | 30 | 35 | Oligo-Mesotrophic |


Questions?