The Lake St. Catherine Conservation Fund, Inc.

<u>Strategy for Lake Restoration</u>

A 30-year commitment to achieving a healthy, balanced lake restored to accustomed use of the past for all users of the lake.

This plan is focused on the Little Lake and its two channels, but can readily be expanded to other areas of Lake St. Catherine.

October 2010

Lake St. Catherine Conservation Fund, Inc.
Wells & Poultney, Vermont

The Lake St. Catherine Conservation Fund is a 501 c 3 Public Charity, Qualified to receive tax deductible donations under the Internal Revenue Service code.

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Foreword: About the Lake St. Catherine Conservation Fund

The Lake St. Catherine Conservation Fund, Inc. is a 501 c3 public charity organized in 2009 to address the problems facing the lake system. With Wells resident Bill Steinmetz as president, and 11 directors, the LSCCF has over 91 member families. LSCCF's vice president, Ron Dreher, serves on the board of directors of the Federation of Vermont Lakes and Ponds.

Focusing first on the Little Lake and its channels, the LSCCF found that the lake is undergoing a degrading process called eutrophication. Unhealthy levels of sediment have accumulated and nuisance levels of aquatic vegetation—native and invasive—are taking over the lake. The profuse nuisance vegetation creates an unsightly surface, renders parts of the lake no longer navigable by motorboats, degrades fishing, and creates an unhealthy environment for aquatic diversity. Applications of herbicides over recent years have failed to effect an improvement in Little Lake. The LSCCF aims to use various techniques to restore the lake to an ecologically balanced condition that offers the accustomed uses of the past: boating, fishing, swimming, and an aesthetically pleasing appearance.

Through surveys, research, observation, and monitoring, the LSCCF has found information about the Little Lake dating back to the 1700's. These data have helped to formulate a long-term strategy that will begin to bring about the desired controls and changes.

Restoration techniques being considered by the LSCCF are hydraulic dredging, a technology called bioremediation, weed harvesting, and the targeted use of herbicides. These methods are detailed in the pages that follow.

In 2010 the LSCCF was awarded its first permit by the Vermont Agency of Natural Resources to conduct a dredging operation in the lower channel. This will temporarily improve shore owners' properties, allow for navigation, and permit better current flow.

In October of 2010, the LSCCF held its first annual Lake Summit, bringing together three representatives of the Vermont ANR, a limnologist from Rensselaer Polytechnic Institute, the Director of Fisheries, the manager of the Poultney-Mettowee Conservation District, and the president of the Lake George Association. Two contractors specializing in bioremediation, and a specialist in hydraulic dredging made presentations. Also in attendance were two mayors who gave testimony about the restoration of their own local lakes, ones which had been examined by LSCCF representatives earlier in the year. The meeting was enthusiastically attended by over 85 people.

This document presents a restoration strategy that is the result of nearly one year of study by the LSCCF of the history of Lake St. Catherine, the current conditions, and contemporary lake management technology. The LSCCF strategy seeks to use the lake management methods described herein wisely and effectively as conditions indicate. The LSCCF awaits permits from the Vermont ANR to implement these techniques. In addition, the LSCCF is seeking grant funding from the Lake Champlain Basin Grant program.

Lake Recovery and Restoration Strategy

Overview

This document presents a strategy for the restoration of Little Lake St. Catherine to accustomed use of the past. History shows that the lake has been in existence as a lake for at least hundreds of years, and our goal is to re-establish the conditions that prevailed during the many years the lake was a beautiful body of water suitable for boating, fishing, swimming, and other water recreational activities, an era that existed consistently until only a few decades ago.

In the Lake St. Catherine Conservation Fund's pursuit of this objective, we have set forth a list of specific aims that we will accomplish over time:

- Reduce sediment / increase depth
- Reduce and control Eurasian milfoil
- Reduce and control native nuisance weeds
- Improve navigation
- Improve fish habitation
- Provide for swimming
- Stabilize and maintain the lake as a balanced system
- Reduce nutrient runoff from surrounding properties

In achieving these goals we have carefully investigated the benefits and disadvantages of the application of various procedures which we have studied and continue to research. These are among the many common lake management practices in use in the United States and around the world.

- Hydro-raking
- Application of herbicides
- Aeration
- Hydraulic Dredging
- Enzyme / Bacterial treatment (Bioremediation)
- Suction Harvesting
- Mechanical Harvesting
- Septic system innovations and upgrades (e.g. peat moss system)
- Weed-eating carp
- Native Weevil used to stabilize milfoil
- Creation of buffer gardens to prevent runoff
- Lake Draw-down
- Benthic Barriers
- UV-blocking dyes

We have created a plan for the lake restoration by selecting from among these options those implementations that appear to hold the most potential for achieving our aims.

During the period of restoration, we will conduct conscientious assessments of our progress and monitor all the aspects of change to insure that safe and healthy conditions prevail as we proceed toward a return to accustomed use.

Introduction

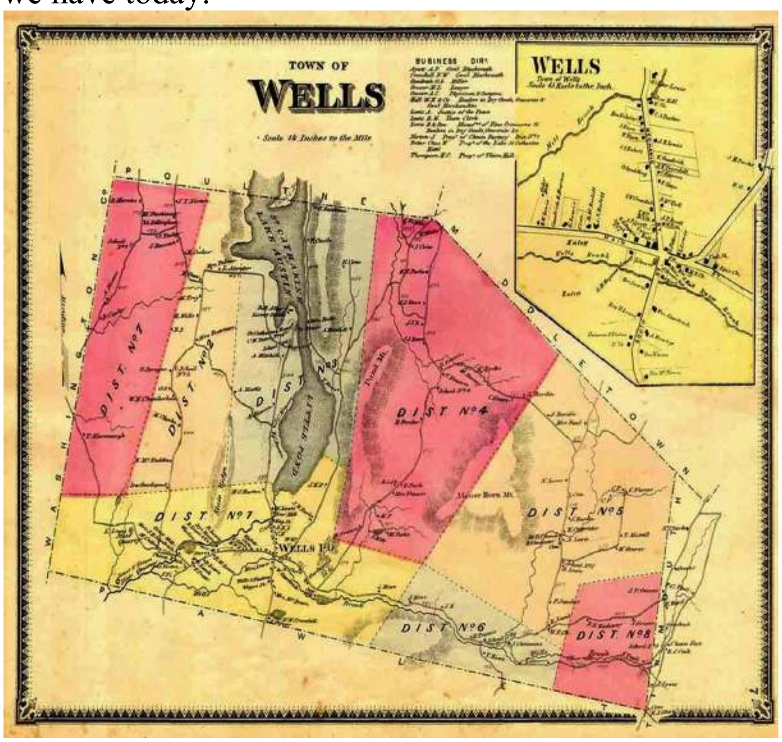
History of Little Lake St. Catherine

In existence for centuries as a lake

A wealth of evidence confirms that the Little Lake has existed as a lake for all of its recorded history, at least the last 260 years. One historical document refers to the need for a bridge between the Little Lake and the main lake. “In April 4, 1774, a committee was appointed to procure timber for building a bridge across the channel, which connects the two ponds that form Lake Austin.” (Highland, Paul, and Parks, Robert, “History of Wells, Vermont for the first century after its settlement,” Tuttle and Co., Rutland, VT, 1869, Cornell University Library). In other words, Lake St. Catherine and Little Lake both existed as lakes in 1774.

Authorization to build dams in the 19th century addresses the existence of Little Lake.

A map from 1880 clearly shows two lakes connected by a channel with a shoreline roughly consistent to the one we have today.



The above-mentioned history refers to an 1804 incident in which the Little Lake was sold to an out-of-state buyer as a “field with no stumps.” It has been clearly established that what was actually sold was a frozen lake to an unsuspecting victim of a swindle by a local opportunist named Merriman. The sale has been confirmed as a hoax by Wells Town Historian Joe Capron and by other historical records.

Historical records document historical existence

The following is a copy of a Surveyors-General report in the Town of Wells recording various land grants. As can be seen from the highlighted text, there was an order to draw down the Little Lake (Wells Pond) on October 30, 1794. It is logical to assume that a draw down could only have been ordered if the lake was in existence at that time.

SURVEYORS-GENERAL OF VERMONT 157

Weathersfield, N. H. Grant to Gideon Lyman and associates, Aug. 20, 1761; confirmed by N. Y. Grant, April 30, 1772.
Charter-Copy attested by N. H. Secy., Sept. 15, 1825, 1 :263A.
Proprietors-Names; 1 :263B.
Plans-Outlines, Charter, 1 :263C; Outlines, J. W., 2 :57 A and Who Plans: 4A, B. Vendues-12 :488 ; 18 :70 ; 26 :123 ; 20 :124 ; 26 :173.

Wells, N. H. Grant to Capt. Eliakim Hall and associates, Sept. 15, 1761 ; part to **Middletown**, 1784; part to **Poultney**, 1798.
Charter-Registered by I. A., S.G, Sept. 26, 1782, 19 :119.
Bounds-Varied by annexing part to Poultney, 1798, 41: 66C.
Area-2:16; 41 :63B.
Survey-West Line by Vt. and N. Y., 1813, 2:1560-Q
Plans-:West Line, Plans: 10; Outlines, J. W., *2:57A.*
Vendues-12 :456; 20: 124; 18 :70.

Act, compelling Proprs. of Mill Dam to draw down Wells Pond, Oct. 30, 1794.

Wenlock, X. H. Grant to Israel Woodward and associates, Oct. 13, **1761**; part from **Caldersburgh**, 1801; annexed to **Brighton** and **Ferdinand**, 1853.
Charter-Registered by I. A., S-G, Aug. 14, 1780, 19 :29 and Sept. 26, 1782, 19 :128.
Proprietors-Names, 41 :48; 18 :170; Names with 2 Draughts ,Wh. Papers: 18A2 ;41 :79 ; 18 :234.
Bounds-Varied by annexing part of Caldersburgh, 1801, 41 :660; 2 :16.
Area-13957 A., J. W., 1 :155, 166B, 169 ;3 :136.
Surveys-Lines by J. W., 1785, North 3:108 and 3:117, South 3 :123, East 3

Recent history and current conditions:

Increasing human activity around the Little Lake has certainly added stress to the natural systems through both nutrient-rich material and sediment from roads and un-buffered shorefront properties, along with one time construction projects.

Many lakefront owners were active through much of the 20th century in clearing sediment by dragging tires down channels, constructing sandbag dams, and allowing the bulldozing of sediment and plant material.

Certainly the state's authorized weed harvesting program begun about 35 years ago had the effect of "mowing the lawn" in Little Lake and elsewhere – but also had other negative effects including spreading milfoil rapidly.

Recent bans on this kind of remedial action along with long, hot summers have encouraged the rapid growth of plant material. Thus, the Little Lake is rapidly narrowing and shallowing.

Little Lake St. Catherine, Summer 2010

Northwest corner: The northwestern portion of the lake has become choked with aquatic vegetation of various types, including Eurasian Milfoil. Water clarity is poorer, algae blooms occur with greater frequency, and the sediment keeps building. The shallowing conditions leave areas with only inches of water. Navigation has become difficult and even impossible in some of this portion of the lake.

Looking into the lake from a dock.

Algae blooms and muck discourage any thought of entering the lake for swimming or skiing.

The problem pervades the whole shoreline.

A muckraking session:

The first rakeful produces lots of milfoil and muck.

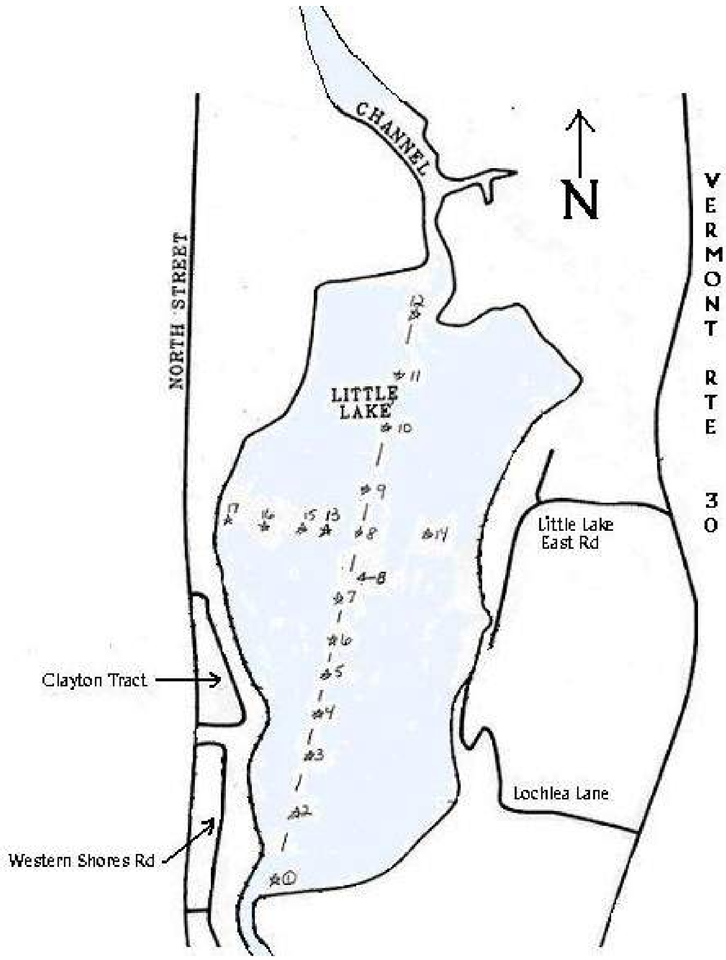
A pile of Eurasian milfoil mounts quickly.

In just an hour or so, a pile of smelly muck and plant life is amassed.

The same area just a few years ago.

Depth: A 2007 depth survey established the firm lake bottom to be well over 25 feet deep in many parts of the Little Lake, as seen below.

Site	Water Depth	Sedi-ment Depth	Weeds	Total
1	4'	0	none	4'
2	5'	0	none	5'
3	5'	2'	few	7'
4	5'	14'	weeds	19'
5	4'	19'	weeds	23'
6	4.5'	21'	weeds	26'
7	5'	23'	weeds	28'
8	5'	25+	weeds	30+
9	5'	25+	weeds	30+
10	5'	25+	weeds	30+
11	5'	25+	weeds	30+
12	6'	24+	weeds	30+
13	4'	26+	weeds	30+
14	4'	26+	weeds	30+
15	3-4'	11'	weeds	15'
16	2-3'	11'	weeds	14'
17	1-2'	5'	weeds	7'



Accelerated Loss of Water Depth

A recent report suggested that the lake is filling in at the rate of about 1"– 2" per decade. This estimate was offered as a mathematical average, based on a change over a period of several decades. It presumes that the change takes place at a consistent or linear rate. However, anyone who has observed the conditions in the lake can easily testify that the change in the last decade has been dramatically greater than an inch or two.

With the sediment layer increasing annually, the water depth continues to diminish. The process is not linear, but accelerates on a curve with time: As vegetation dies off the sediment layer is increased, and the water depth is decreased. Shallower conditions allow more sunlight to reach the substrate for plant life. The greater amounts of vegetation continue the cycle and the process continues to accelerate at an even greater pace.

Members of the LSCCF have watched and carefully measured the depth of the lake as seen on the previous page. The following chart compares our findings over the last three years, from 2007 to 2010, with both survey figures based on mid-summer readings. It is clearly evident that the loss of water depth is occurring at a rate that seriously threatens the future use of the lake for accustomed use.

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Comparison of Water Depth Measurements in Little Lake St. Catherine Surveys of 2007 and 2010

Location (see depth survey map above)	Year 2007 depth (in inches)	Year 2010 depth (in inches)	Change in depth	% Decrease in depth
1	48	42	-6	0.13
2	60	46	-14	0.23
3	60	48	-12	0.20
4	60	46	-14	0.23
5	48	42	-6	0.13
6	54	44	-10	0.19
7	60	48	-12	0.20
8	60	48	-12	0.20
9	60	48	-12	0.20
10	60	50	-10	0.17
11	60	50	-10	0.17
12	72	58	-14	0.19
13	48	42	-6	0.13
14	48	42	-6	0.13
15	42	38	-4	0.10
16	30	24	-6	0.20
17	18	10	-8	0.44

Average change in water depth = - 9.3 inches
Average % of decrease in water depth = 19%

Coring: A recent core sampling study conducted by Larry Eichler of the Darrin Freshwater Institute of Rensselaer Polytechnic Institute revealed the sediment chemistry of the Little Lake:

Site	% Solids
Outlet Channel	**9%**
Little Lake South	**6%**
Little Lake Center	**3%**

Site	% Solids
Little Lake North	**4%**
Lily Pond South	**5%**
Lily Pond Middle	**4%**
Lily Pond North	**5%**

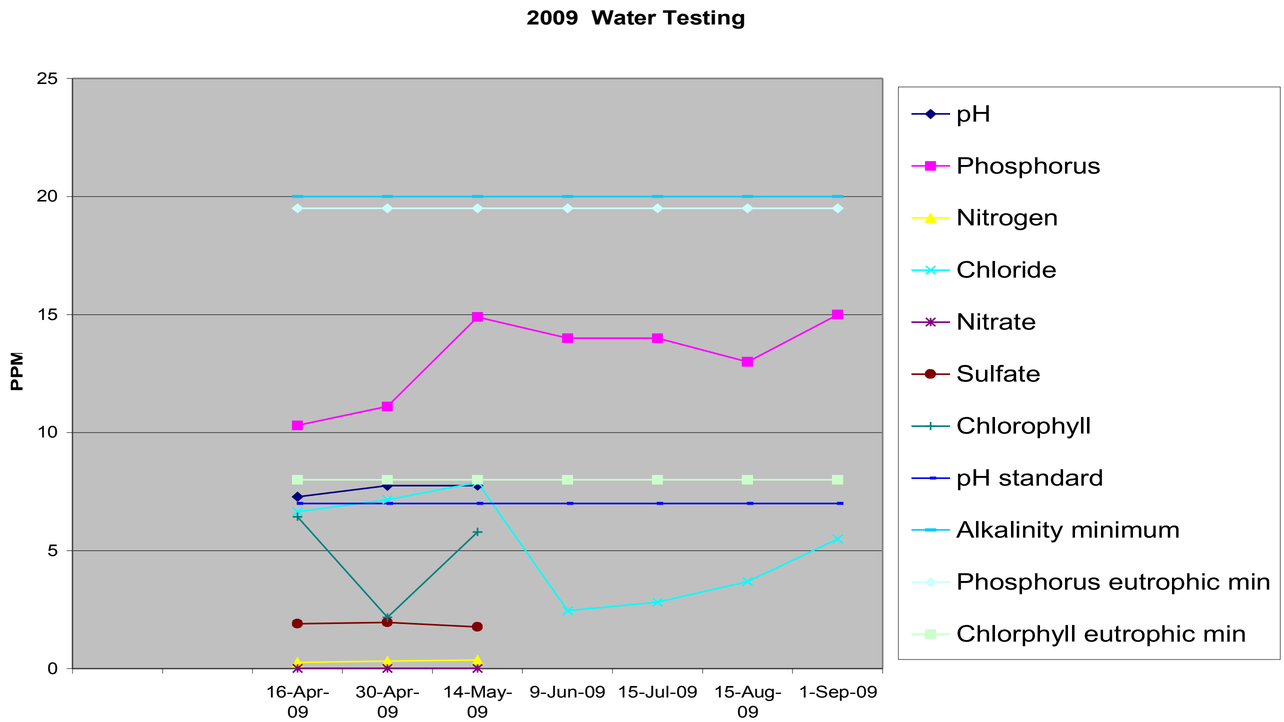
Source: Darrin Freshwater Institute

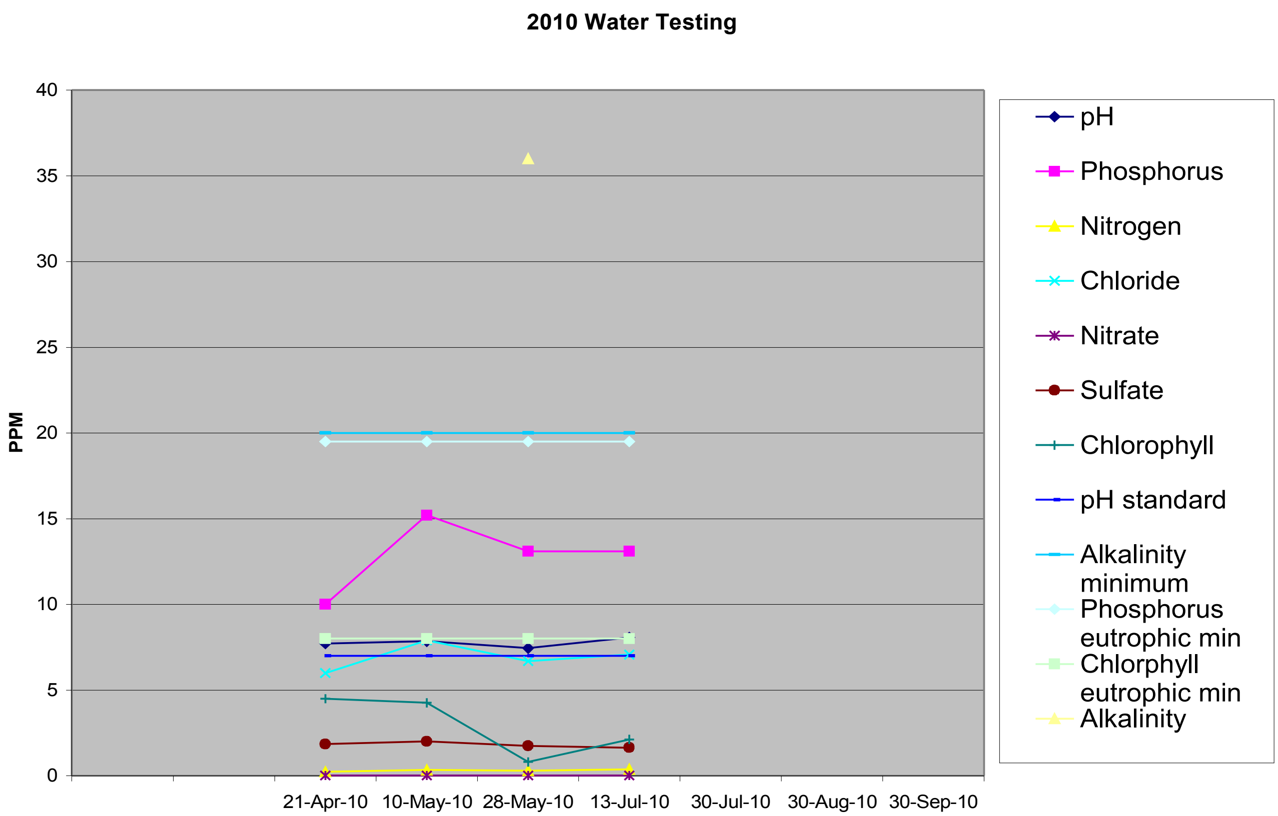
Water quality: Our water quality is also being carefully monitored for phosphorous, chlorophyll, and other materials, as seen in the following table and graphs (next page) for 2009 and 2010.

Values represent parts per million

Date	16-Apr-09	30-Apr-09	14-May-09	9-Jun-09	15-Jul-09	15-Aug-09	1-Sep-09
pH	7.28	7.75	7.76				
Specific Conductance	101	106	104				
Phosphorus	10.3	11.1	14.9	14	14	13	15
Nitrogen	0.269	0.32	0.37				
Chloride	6.65	7.16	7.88	2.45	2.81	3.69	5.5
Nitrate	0.01	0.01	0.01				
Sulfate	1.9	1.96	1.77				
Chlorophyll	6.43	2.17	5.79				
pH standard	7	7	7	7	7	7	7
Alkalinity minimum	20	20	20	20	20	20	20
Phosphorus eutrophic min	19.5	19.5	19.5	19.5	19.5	19.5	19.5
Chlorphyll eutrophic min	8	8	8	8	8	8	8

Date	21-Apr-10	10-May-10	28-May-10	13-Jul-10	30-Jul-10	30-Aug-10	30-Sep-10
pH	7.71	7.84	7.45	8.07			
Specific Conductance	97.3	104.1	110.1	107.1			
Phosphorus	10	15.2	13.1	13.1			
Nitrogen	0.23	0.33	0.3	0.38			
Chloride	5.99	7.9	6.68	7.07			
Nitrate	0.01	0.01	0.01	0.01			
Sulfate	1.85	2	1.74	1.64			
Chlorophyll	4.49	4.26	0.8	2.12			
pH standard	7	7	7	7			
Alkalinity minimum	20	20	20	20			
Phosphorus eutrophic min	19.5	19.5	19.5	19.5			
Chlorophyll eutrophic min	8	8	8	8			
Alkalinity			36				





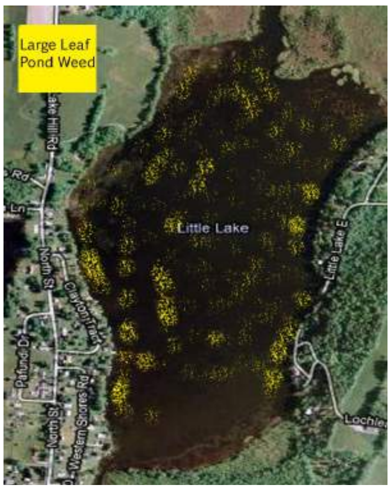
Note: Phosphorus Eutrophic Minimum was changed from actual minimum of 20 for graph visibility
Note: Chlorophyll value suspect

Mapping Aquatic Vegetation

Using ANR's Lay Monitoring Program as our pattern, the LSCCF has developed an Aquatic Vegetation Survey Program for the Little Lake portion of the Lake St. Catherine Lake System.

Proper management of any lake's aquatic vegetation is not merely a process of killing unwanted invasive species, but rather a challenge to maintain the delicate balance of native aquatic plant life as to best serve a diverse ecosystem.

The first step in a well- thought-out management plan is understanding the state of current conditions. The following maps give us a general idea of the aquatic vegetation of the Little Lake as of early July 2010. These maps are based on visual recognition of the plant life and its locations:



Historical Summary

- Little Lake has been a Lake for thousands of years. Like the main lake it most certainly was cut out by the glaciers during the last ice age that ended 12 thousand years ago.
- It has functioned as a *settling basin* for organic material and sediment since then. The shallow lower channel indicates the northern end of the channel probably provided a natural dam for much of this history, undoubtedly aided by beaver activity.
- The settling basin has inevitably filled up, accelerated by high levels of human activity in recent history.
- Many residents attest to swimming easily in parts of the Little Lake as recently as 25 years ago that are now impassable due to banks of weeds and even mud flats.

The conclusion is clear: Little Lake had a bright, healthy multi-use past, the very recent past. Therefore, it is most appropriate to consider restoration techniques and investment in this invaluable resource to return it to "accustomed use."

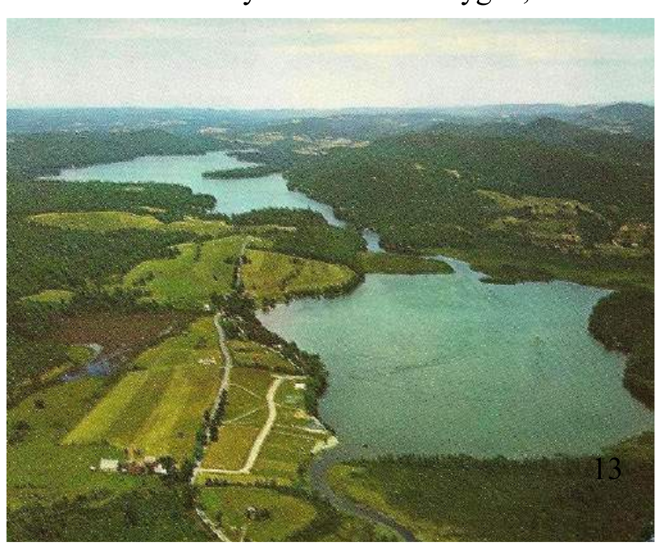
Consistency with Vermont Regulatory Statutes

The Lake St. Catherine Conservation Fund, Inc. aims to restore the Lake St. Catherine lake system for the public good, as defined in Vermont Statute as the "***effect … on water quality, fish and wildlife habitat, aquatic and shoreline vegetation, navigation and other recreational and public uses, including fishing and swimming, consistency with the natural surroundings and consistency with municipal shoreland zoning ordinances or any applicable state plans.***" (Title 29: Public Property and Supplies, Chapter 11: Management of Lakes and Ponds, Paragraph 405)

We proceed with these goals in good faith in the obligation of the state of Vermont to protect the public trust, as stated in VERMONT AGENCY OF NATURAL RESOURCES, DEPARTMENT OF ENVIRONMENTAL CONSERVATION, EXPLANATION OF PUBLIC TRUST: ***Vermont law declares that the lakes and ponds of the state and the lands lying underneath them are held in trust by the state for the benefit of all Vermonters. This basic concept is referred to as the Public Trust Doctrine, a concept which can be traced back through English common law to Roman law.   As trustee of these waters and lands, the state, through the Department of Environmental Conservation, has an obligation to manage Vermont's lakes and ponds in a manner which preserves and protects a healthy environment, guarantees the right of Vermonters to hunt, fish, boat, swim, and enjoy other recreational opportunities, and provides the greatest benefit to the people of the state.***

Our lake is an ecosystem containing many living organisms that interact with one another and with their environment, in a balanced web of life. This lake restoration process will restore and maintain that vital balance. These restoration techniques will remove bottom organic muck, greatly improve fish growth and health, and reduce aquatic weeds, algae, foul odors and disease bacteria. This water restoration process not only helps to improve water quality, it also enhances aesthetic value and life forms in and around the water body. The degeneration we have been experiencing due to the ongoing process of eutrophication, which has been defined as "the increase in mineral and organic nutrients that results from a deficiency in dissolved oxygen, producing an environment that favors plant life over animal life," can be reversed.

An early 20th century photograph shows the lake before the eutrophic process in Little Lake reached the point of serious degradation.



Meeting Our Objectives

With respect to the foregoing, the Lake St. Catherine Conservation Fund, Inc. proposes a strategy that will address the following objectives:

Reduce sediment / increase depth / enhance aquatic ecosystem and fish habitat…

Aeration/enzyme treatment: This process will reduce the level of sediment over time. As the water deepens, the population of aquatic plants will eventually be reduced as well to a more natural balance. The habitat for fish is enhanced, however, because of the increased level of oxygen through aeration, as well as the lowering of water temperature due to increased depth.

Reduce and Control Milfoil…

Application of herbicides is one of the most common ways of controlling Eurasian water milfoil. The LSCCF sponsored a review by Allied Biological, a New Jersey-based lake management concern. This review recommended that a wide-range of herbicides be considered for future treatments, including Sonar to better manage some of the densely populated nuisance native weeds, which now impede navigation and restrict other forms of recreation.

We also recognize the availability of Suction Harvesting as an option for maintaining smaller areas, such as around docks and waterfronts.

Scientific evidence tells us that an overabundance of aquatic plants is also detrimental to the health of the fish population, especially the larger predator-sized fish (V.S. Rao, *Principles of Weed Science,* "Effects of Aquatic Weed Management on Fish," page 479.)

Reduce and Control Native Nuisance Plants …

In spite of the reluctance of the state to address the removal of native species, there is such massive growth in Little Lake that some kind of control is necessary. While we recognize that harvesters are not a solution, we recommend their use of to keep the lake navigable and physically attractive. An additional benefit is the removal of great quantities of biomass that would otherwise become a further addition to the nutrient-rich sediment that is providing a substrate for more plant growth and trapping hydrocarbons that cannot decompose due to lack of oxygen..

Provide Public Access directly on the Little Lake for recreational purposes…

The Delaney Project initiated by the Vermont Land Trust provides an excellent opportunity to achieve this objective.

We urge the Town of Wells to establish a management plan for this property that includes shoreline access for fishing, swimming, canoe and kayak launching

Improve Navigation…

While herbicides and harvesting will improve navigation to an extent, some type of dredging is now needed in places that have become extremely overgrown and are causing the lake to become narrower and shallower. Of the two types of dredging used in Vermont, hydro-raking and hydraulic dredging (into a de-watering system), a preponderance of evidence causes us to recommend hydraulic dredging as the cleaner, more ecologically appropriate system. Use of hydraulic dredging has been suggested in three ways:

1. Clean along shoreline and around residents' docks (also improves critical spawning areas for the fish population of the lake)

2. Cut back areas creeping toward the middle of the lake, causing narrowing.
3. Create a trough down the center of the lake so that sediment will flow into it and away from the shoreline.

We recommend a pilot program in which hydraulic dredging is used in a designated area of the Little Lake to demonstrate the effectiveness of this process (e.g., the northwest corner, center trough, or eastern shore). Hydraulic dredging is a progressive and high-tech solution for removing sediment from the lake bottom. A hydraulic dredge floats on the water and excavates and pumps the material through a temporary pipeline to an off-site location, often several thousand feet away. This dredge acts like a floating surgical vacuum cleaner that can remove sediment very precisely.

With a hydraulic dredge, the dredge discharge line and return line are the only obstructions in the environment. The lines are usually laid on the ground surface. Other than this, the dredge, which is not much larger than a boat, is the only machine to be seen. It is a very unobtrusive method that does not require disturbing the shoreline and only requires one trip in to put the dredge in the water and one trip out when the project is complete.

Hydraulic dredging provides the cleanest and least obtrusive method for sediment removal without damaging the sensitive environment.

A successful pilot program will provide a model for other lakes facing the same type of degeneration.

Provide for Swimming…

At present, swimming is only available in areas where extreme manual cleaning of shoreline has been accomplished by property owners. Although swimming, as an expected activity on Vermont lakes, is a stated goal of the Department of Environmental Conservation**,** we look at swimming activity as a long-term goal, but without an immediate solution. However, the use of hydraulic dredging and weed harvesters will have a somewhat positive effect on providing more desirable water for water skiers, tubers, and swimmers.

Improve shoreline management…

We recommend and encourage voluntary actions by property owners to create barriers to runoff of nutrients into the lake. An effective and inexpensive procedure is to plant a buffer garden (rain garden) along the shoreline. Using locally acclimated species, such a garden will readily take up runoff that would otherwise find its way into the lake. The planting of these gardens can be arranged in cooperation with a program offered by the Poultney-Mettowee Conservation District, in which volunteers will do the planting at no cost to the property owner.

Lake Monitoring…

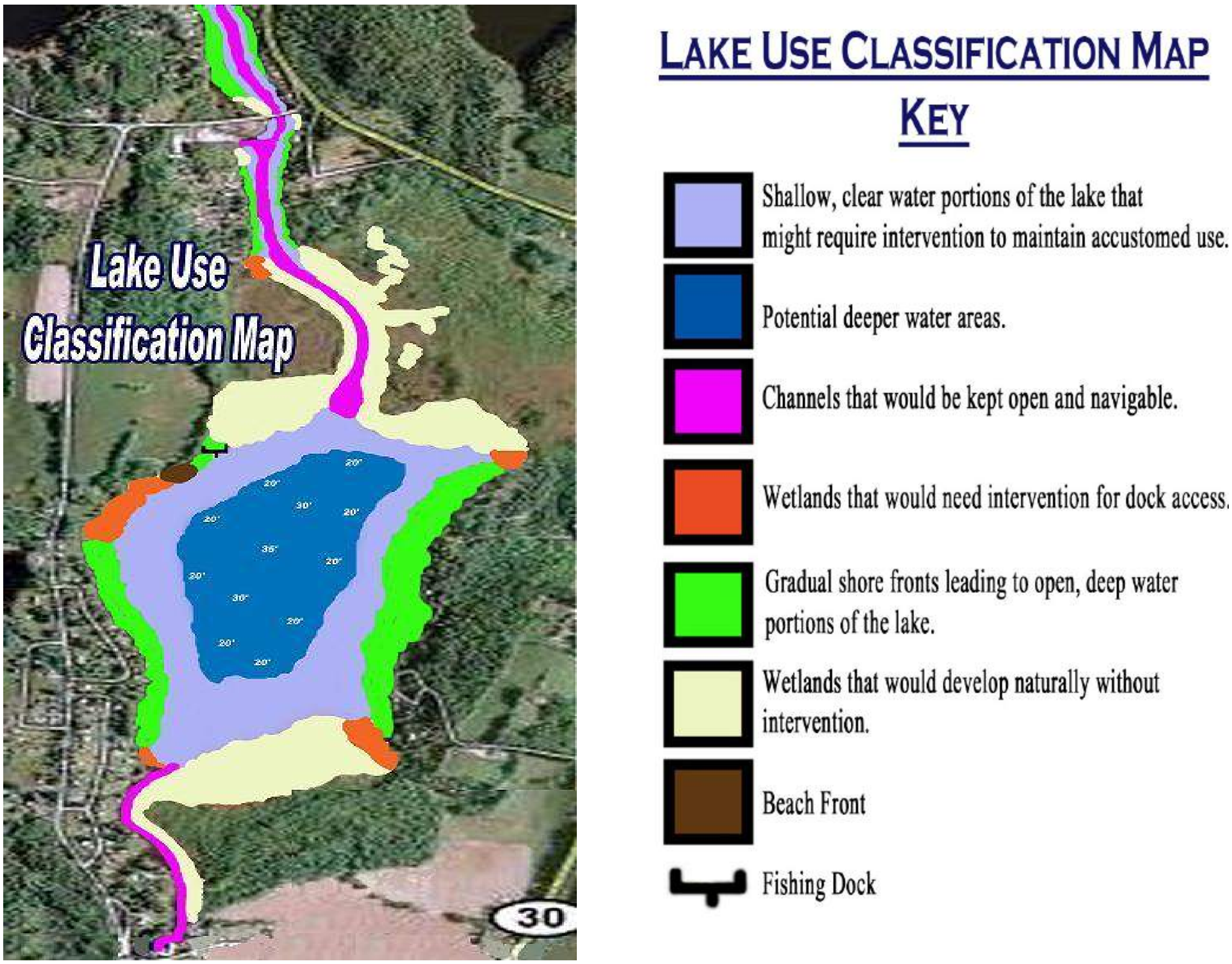
We recommend establishment of an ongoing monitoring of the water quality, the fish populations, and the aquatic vegetation throughout implementation of our lake management plan and during the period following. We will keep accurate records using accepted technology, and record conditions using GPS to be specific about location. We will provide data gathered to state authorities as required or requested.

During monitoring, we will make concomitant recommendations for modifications in our lake management plan as needs or conditions change.

Lake Use Classification

In seeking the best balance for our lake restoration process and to address the preferences of the property owners around the lake, we have introduced Lake Use Classification.

Property owners have offered their recommendations for the various areas of the lake, and we are developing a map to represent those positions as well as our vision for the future of the lake:



Specific Design for Implementation and Action

In view of the above considerations, we recommend the following plan as a beginning to the restoration of the Little Lake:

- **Winter 2010 onward: Encourage local and state government in siltation management initiatives, including back roads improvements.**

- **Winter 2010 / 2011 onward: Encourage shore property owners in planting runoff barriers and cleaning septic field issues.**

- **Spring 2011 onward: Review of broad spectrum of herbicides and consider treatments earlier in the season, as recommended by Allied Biological.**

- **Spring 2011 onward: Conduct a program of dredging in targeted areas.**

- **Spring 2011 onward: Conduct a pilot program of bioremediation in significant areas of the Little Lake.**

- **Spring 2011 onward: Continue to provide a service for cleaning around property owners' shorelines; either by suction harvesting, hydraulic dredging, or hydro-raking. Develop a program for the channels.**

- **Summer 2011: Begin a program of weed harvesting (either mechanical or diver-assisted) coordinated with other implementation initiatives.**

Immediate Action Plan

Initiate necessary steps to move toward all implementation initiatives in October 2010. Provide adequate data to substantiate the actions through:

1. Depth survey with GPS notations of the Little Lake by radar during winter of 2010-2011.
2. Northwest corner survey and eastern shore survey for depth and aquatic plants.
3. Weed and plant surveys with detailed GPS controlled maps on Little Lake and channels.
4. Advance discussions on herbicide usage based upon Allied Biological Report
5. Investigate Little Lake bottom conditions.
6. Documentation of the efficacy of bioremediation, including October 29 Lake Summit Conference in Wells.
7. Documentation of the efficacy of hydraulic dredging
8. Input from scientists, including Larry Eichler of Rensselaer Polytechnic Institute.
9. Input from the Fish and Wildlife division as well as the Rutland Bass fishing club, with documentation of the optimum plant–to-open water ratio for a healthy ecosystem.
10. Continue search for examples of other lakes that have been successfully restored from similar conditions.
11. Continue to update, extend, modify and improve this Strategic Plan.

Appendix: Presentation of Information and Data

The following pages provide data and information to support this Lake Restoration Strategy, and offer examples of successful use of the implementations we intend to consider.

Lake Restoration Techniques Many methods are used to improve conditions in deteriorating lakes. Here are some typical implementations used in the United States and abroad.

Technique	Advantages	Disadvantages
1. **Hydro-raking**: (mechanically dredging with a boat-mounted scoop [similar to a York rake]…dredged muck is barged away or placed on shore)	Comparatively low cost; Quick and easy method to clean around docks and waterfronts	Stirs up sediment; Incomplete cleaning (leaves some sediment); Displaces organisms residing in area dredged; Unless barged away, disposal of muck can be problem.
2. **Herbicides**: (chemicals that kill vegetation)	Effective at killing plants: Can be broad spectrum or species specific	May have negative effects on fish; Effect is temporary; Decaying vegetation adds to sediment layer; Long-term effects unknown.
3. **Aeration**: (Inserting oxygen to anaerobic sediment layer by use of diffusers which create columns of oxygenated clear water in ever-increasing radii of influence)	Fairly inexpensive; Improves water clarity: Enhances aquatic ecosystem and fish habitat; Encourages sediment decomposition; increases water depth; is known to decrease weed growth.	
4. **Bioremediation**: (usually combined with aeration, the introduction of enzymes or bacteria that accelerate the natural process of biological decomposition of sediment)	Fairly inexpensive; Improves water clarity: Enhances aquatic ecosystem and fish habitat; Encourages sediment decomposition; increases water depth; is known to decrease weed growth.	
5. **Hydraulic dredge**: (dredging by use of a suction device that cuts down to and vacuums the lake bottom)	More thorough cleaning than hydro-raking; May yield useful topsoil; Minimal sediment disturbance	Expensive cost; Unless barged away, disposal of muck can be problem; Displaces organisms residing in the sediment.
6. **Suction Harvesting**: (Use of a vacuum to remove plants after they are hand-pulled by a diver)	Removes plants fairly safely	Slow, expensive process; Useful only in smaller areas such as around docks and waterfronts
7. **Mechanical Harvesting**: (Use of a boat-mounted cutting device to "mow" aquatic plants to a prescribed depth. Cut plants are hauled to shore)	Enhances navigation; Enhances beauty of lake; Removes much unwanted biomass; Moderate cost.	Creates floating fragments which can take root and propagate the species in uninfested areas.
8. **Buffer Gardens**: (plantings along shorelines, usually of native plants, flowers, or shrubs.)	Catches nutrient runoff before it goes into the lake; Beautifies shoreline; Deters Canada geese from coming ashore; Minimal cost to property owner.	
9 **Weed-eating carp and weevils** (still under study for effectiveness)	Reported to be effective at maintaining a reduced level of invasive Eurasian milfoil	
10 **Lake Drawdown**: (reducing the depth of the lake for a period of time)	Promotes killing of aquatic vegetation during winter temperatures; Allows residents to work on docks from dry surface.	Requires movable dam (Lake St. Catherine would need expensive dam reconstruction); Has impact on downstream environment
11. **Benthic Barriers**: (placement of impermeable barriers covering lake bottom to prevent sunlight from reaching aquatic vegetation)	Retards growth of aquatic plants	High cost; Only for smaller areas; is non-specific to species; displaces some sediment-dwelling organisms.
12. **UV-blocking dye**: (Introduction of dyes which prevent ultraviolet rays from reaching growth substrate of lake bottom)	Retards growth of aquatic plants; Dyes are innocuous to other aquatic life and dissipate naturally	Moderate cost; Not species-specific
13. **Hand Pulling of aquatic plants**: (manually uprooting and removing plants)	Minimal disturbance to sediment layer; Useful for small areas along shoreline; No official permission is required	Very slow process; Difficult or impossible in places with deep sediment.

Observing Bioremediation

Report of Visit to Collins Lake

Date of visit: August 24, 2010

Participants: Bill Steinmetz, Tim Makepeace, Lee Evans, Brian Kling of Clean-Flo, Inc., James Marx

On Aug 24, 2010, LSCCF Directors Bill Steinmetz Tim Makepeace, and Lee Evans met with Brian Kling (Clean-Flo) and James Marx (Collins Park Administrator) at Collins Park in Scotia, New York to survey and evaluate the bioremediation project in operation there in Collins Lake.

Collins Lake occupies about 60 acres, and is located in Collins Park in a suburb of Schenectady, New York, essentially an urban setting. In 2003 the lake was suffering from ongoing eutrophication, weed infestations (including Eurasian watermilfoil) and a high level of fecal coliform due to Canada geese. The swimming beach was therefore closed, and the lake developed a reputation as place for fishermen to avoid. In an attempt to rectify the situation, three feet of sediment was dredged out. That project was unsuccessful in bringing about a lasting improvement, and the unacceptable conditions returned within two years..

(We have subsequently learned that border collies or other means were used to either kill or keep the geese at bay. However, neither geese nor dogs were in evidence during our visit. To protect the lake, the practice of dumping plowed snow in Collins Park has also been discontinued in recent years.)

With conditions continuing to deteriorate, at the request of the board of health, a bioremediation system was put in place, using Clean-Flo equipment. It was purchased by the town and was to be managed by the park administrator. The system included three compressors and 26 diffusers. The smaller compressors were housed in enclosures about two feet high and about 5 feet square. One larger compressor was housed in a shed (right). The noise of the compressors was not offensive, and we were told that newer models are even quieter.

An initial application of herbicide was used to “knock back” the vegetation, which was so thick the contractor had to use an airboat to survey the lake and install the aeration system. Also, at the onset of the project a treatment with enzymes was applied.

Within two years, there was a significant improvement in the lake, and swimming was restored. The clean swimming area can be seen in the picture below.

The process has now been in use for six years, and the lake continues to improve. Our observation was of an attractive and well-balanced lake with some lily pads around the edges, a large percentage of clear water, and a clean swimming area.

It was evident that those involved with the lake were enthusiastic about the improvements. All in all, it appeared that the aeration was a positive procedure for restoring the lake. No herbicides, bacteria, or enzymes have been needed or used since the original applications six years ago, and the lake continues to thrive and improve in water clarity and sediment reduction. Lily pads have retreated from the center of the lake, and the invasive Eurasian watermilfoil has been reduced (admittedly, Brian Kling said they had observed this happening in Collins Lake and other lakes they have treated with aeration, but are still unable to explain what process would actually account for the reduction in milfoil).

The decision to purchase rather than lease the equipment has led to a poorer maintenance of the system equipment; the diffusers had not been cleaned for two seasons, as the administrator and his crew were occupied by other matters pertaining to the park. Brian Kling recommended a lease arrangement as preferable to purchasing. When the system is leased, any needed repairs are done immediately and without extra cost. Maintenance activities, such as periodic cleaning of diffusers, are also carried out regularly and reliably.

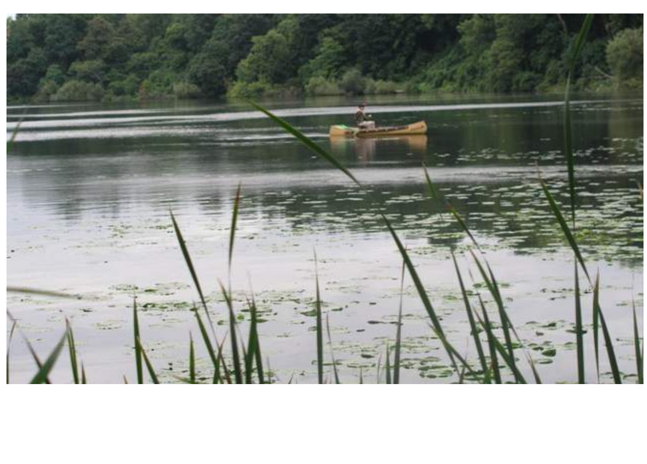
We did observe a very small presence of what looked like algae, particularly along the edges of the lake where other vegetation was growing. Kling and Marx both surmised it was due to a combination of events, including a very recent heavy rainfall (the lake was actually overflowing into the parking area). They pointed out that some of what looked like algae was actually green matter that was associated with the shoreline plants.

According to James Marx, Collins Lake has now become a very popular fishing area. We observed fishermen on the lake, and noticed a number of fish jumping as well. Fishermen have noticed that the area around diffusers is often a location of high fish activity. In the picture (left), the fisherman is concentrating his efforts between two diffuser areas (the bright, bubbling spots are the surface areas above the diffusers).

Northern pike have arrived since the beginning of the project. Apparently they have moved in by way of a connection between the lake and the Mohawk River.

James Marx said that the head of Fish and Game had been skeptical of the value of the process, but now is a proponent after seeing the results.

The picture to the right shows a man fishing in an area of the lake that was previously completely covered by lily pads, according to Brian Kling. The lilies are still there, but the growth is now sparse and mainly contained toward the shoreline.



Bioremediation has been used quite commonly in the South to restore lakes facing the usual problems of eutrophication and shoreline development. Thus, it is important to note that Collins Lake is a northern body of water and that the system is also successful in spite of seasonal differences. We found Lake Collins to be in many ways similar to our Little Lake St. Catherine: it is an ancient body of water with areas whose original depth was in the 30-foot range. Infestations of native and invasive species of plants had created a large buildup of sediment, and weeds were so thick as to prevent navigation. The lake was no longer useful for fishing or swimming. We concluded that bioremediation would likely be of similar value in Little Lake St. Catherine.

Report of Visit to Greenwood Lake

September 13, 2010
Participants: Bill and Judy Steinmetz, Lee Evans, Mayor Barbara Moore, Jim Moore

On September 13, 2010, Bill and Judy Steinmetz and Lee Evans met with Mayor Barbara Moore of Greenwood Lake, New York, to survey the operation of a bioremediation installation installed and operated by Lake Savers (John Tucci) using Clean-Flo (Brian Kling) equipment.

In a brief meeting, the mayor discussed some of the factors that led to the installation of a bioremediation system:

- The two shallow "arms" of the lake at the north end had a serious weed problem with some residents unable to navigate to their docks. Eurasian watermilfoil, lily pads, and other native weeds were continually spreading, and siltation was increasing. Weed harvesting had been going on for some time, but with no improvement in conditions.
- Residents feared for their property values, and demanded action from the town government.
- While buffer gardens were not being promoted, the town had ruled that septic tanks be tested at three-year intervals, and there was a ban on using fertilizers containing phosphorus.
- With harvesting doing little to improve matters, and with the use of herbicides considered unacceptable, the use of bioremediation seemed the best approach.
- Three contractors were considered, with Clean-Flo/Lake Savers being the most thorough and cost-competitive.
- With no permit required, the installation was done in the summer of 2010 in spite of opposition from various agencies. The initial treatment included the introduction of enzymes. The town entered into a 5-year lease contract with Lake Savers, Inc. When this period ends, they expect to evaluate the effects and consider continuing to manage the lake using the bioremediation process.
- The cost of the operation is about $36,000 per year, plus the cost of electricity, bringing the total to about 50K.
- A marina was purchased by the town, and the property was turned into a recreational area with ample parking, swimming beach, picnic areas, and a type of jetty for fishing. Previously, residents without waterfront had no other access to the lake.
- The project is funded in part by the municipality and also the American Recovery and Reinvestment Act.

Following the brief meeting, we walked to a nearby area of the lake and observed a part

under treatment. The area had previously been congested with weeds, but now was sparsely covered only in patches. Lily pads had diminished greatly: The area in this picture (left) had been covered with lily pads now only had them near shore.
A kind of lagoon about 2 or 3 feet deep had previously been inaccessibly by boat, but there were now several boats moored there, and the water was mostly clear. Diffusers could be seen actively bubbling. A total of 8 compressors and 64 diffusers were in operation.

One of the compressors was contained in a type of enclosure that appeared to be coated with pebbles, making it blend in with nature to an extent, as seen on right. The hum of the compressor was not offensively loud, and no complaints had been made by nearby residents.

Mayor Moore pointed out that the area we were looking at had already undergone enormous improvement, both in the reduction of weeds and in water clarity. She said most of the residents were enthusiastically pleased with the progress and the speed at which the improvement came.

Subsequently, we were given a tour of the area by boat and witnessed a large portion undergoing treatment. We were shown areas that were previously very murky and flocculent, but now were quite clear. It was interesting that Mayor Moore and her husband Jim continually commented on how clear the water was, clearer than they had ever seen it in their 15 years of living there. They seemed to express surprise that it had improved even since the last time they looked. We could see areas near the diffusers where there was now what looked like sandy bottom, and it was evident that the area of influence of each diffuser was expanding in an increasing diameter away from the diffusers. However, it should be said that there was still a good deal of milfoil evident beneath the surface of the water, especially in the shallower areas.

Again, we were frequently directed to look at areas where boats were parked that had previously been inaccessible. Those areas looked quite clear.

On our tour, the matter of fishing was discussed. As we heard in our visit to Lake Collins, the fishermen were delighted with the improvement in the fishing, and especially enjoyed fishing near the diffusers to which the fish were attracted. Typically, the diffusers are evidenced by a small circle of bubbles at the surface of the water, as seen in the picture below. The head of the local fishing club has observed the improvements and is cautiously optimistic.

New York will allow the use of the diffusers throughout the winter. Fishing will take place on areas of the lake where the diffusers are not being used. Large "caps" can be placed on the ice over the areas above the diffusers to keep skaters away from the thinner ice.

The mayor ended the session with an offer to be a witness—either in person or by some media device—to the success of their use of bioremediation if we should request her to do so. She looked forward to a reason to visit our lake, which she and her husband would be happy to access by means of their seaplane.

Conclusion: As with Collins Lake in Scotia, New York, the process of bioremediation appears to be making a marked improvement in three areas: water clarity, sediment lowering, and weed abatement. It appears that the improvement began almost immediately, and continues to progress. It should be noted again that the positive results in these two lakes provide evidence that the system is effective in northern lakes, a point that was considered questionable by some authorities.

Managing Nuisance Aquatic Vegetation

From **Carole A. Lembi,** Professor of Botany, Purdue University,
"Aquatic Plant Management"

[Aquatic]…plant growth can get out of hand. Excessive plant growth is usually due to the fact that many of our bodies of water are shallow, which allows sunlight to penetrate to the bottom and support photosynthesis. Also, our bodies of water tend to be rich in nutrients such as nitrogen and phosphorus (substances that are needed by plants for growth). In some cases, exotic species of plants that are extremely aggressive have been introduced and have taken over large areas of aquatic habitat. Some of the problems caused by excessive aquatic plant growth are as follows:

1. Recreational activities such as swimming, fishing, and boating can be impaired and even prevented.
2. Excessive growths can lead to fish stunting and overpopulation. This occurs because the production of too much habitat prevents effective predation of small fish by larger fish.
3. Aquatic plant and algae growths can play a role in causing fish kills. If plant growth is excessive, plants at night can use up most of the oxygen in the water. In fact, fish that are stressed for oxygen often die just before dawn when the oxygen content is lowest. Sometimes they can be observed coming to the surface and gasping for air during the early morning hours. This is a sure sign that the fish are oxygen stressed and may die.

Mechanical Control Methods

Even with preventive measures, many bodies of water still have severe plant infestations. Hand pulling or raking plants is a possible method of control. Since most aquatic plants are perennial, with underground portions that can sprout new shoots, it is essential that below-ground growth also be harvested.

For larger bodies of water, motor-driven underwater **weed harvesters** are available. This equipment usually is a major investment and may have to be operated several times during the season to effectively keep the vegetation cut back. The premise is the same as mowing a lawn. The plants will not be eliminated, but they can be prevented from growing to the surface and becoming a nuisance. Mechanical harvesters have been used successfully to cut channels through vegetation, which allows boat traffic to move out to open water. The cut vegetation should be harvested and dumped where it cannot reenter the water. Plant fragments left to float in the water can produce new plants. The harvested material can be satisfactorily used as a fertilizer or mulch in gardens or as landfill.

Biological controls

Biological controls (organisms that control pest organisms) have received considerable publicity. **Bacteria, fungi, and insects** currently are being tested for their ability to reduce aquatic plant infestations. Certain insects appear to have potential for the control of Eurasian water milfoil. The **grass carp** consumes some types of algae and various plants. The type of grass carp that is most commonly legal is the triploid grass carp, a form that will not reproduce itself. Although the grass carp has provided good control of aquatic vegetation in some situations, it is not the solution for all ponds. Since its effects on vegetation may not be noticed for a year or more, it may be difficult to determine if enough fish are still present in the pond to be effective. In addition, the grass carp prefers certain plant species over others. For example, it will consume native species such as pondweeds before it will feed on truly troublesome weeds such as Eurasian water milfoil or mat-forming algae. The grass carp is not very effective in controlling Eurasian water milfoil.

Habitat Alteration Methods

Certain methods of manipulating or altering the aquatic environment can be effective in aquatic plant management. One of the more successful methods is the **draw-down** technique in which water levels are lowered over the winter. Exposure of the sediments in the shallow areas of a lake or pond to alternate freezing and thawing action will kill the under ground structures of many aquatic plants. This method has been successful for the control of Eurasian water milfoil and water lilies, although the degree of control depends on the severity of the winter. Other types of habitat manipulation include riprapping shorelines or anchoring black plastic sheeting on the bottom sediments to prevent rooted plant growth. **Dyes** such as Aquashade are used to inhibit light penetration throughout the water. This blue dye can be applied right out of the bottle along the shoreline. It mixes throughout the body of water within 24 hours. The dye intercepts light normally used for photosynthesis by underwater plants.

Chemical Control Methods

When properly applied, certain **herbicides** can control aquatic vegetation without harming the fish and other wildlife. In some instances, herbicides can be used selectively, that is, to control certain plant species without killing others. However, it should be noted that, in most cases, aquatic herbicides offer only temporary solutions. The target species usually will reappear, and re treatment or application of another control method usually will be necessary.

Hand Harvesting and Suction Harvesting

Authority: the New York State Department of Conservation

Hand harvesting: Hand harvesting involves grasping the plant material as close to the sediment layer as possible, even digging into the sediment to grab the root crown, and pulling the intact plant out of the bottom sediment. Plants are pulled slowly to minimize fragmentation, and the entire root system should be removed from the sediment if possible.

Hand-harvesting is **cumbersome and tiring**. It is difficult to hand pull large beds of target plants, and inconvenient (from the puller's perspective) to hand pull scattered plants, although this may be the best way to prevent the expansion of single plants into small beds. Efforts to speed up the process, by hand pulling clumps of plants away from the sediment interface at a rapid pace, often results in **fragmentation, incomplete plant removal, high turbidity and bottom disturbance.** Even when performed properly, hand harvesting frequently results in some fragments and floating bits of root and seed and other plant parts, the vegetative stock for new generations of plants when these materials eventually fall back down to the lake bottom.

Suction harvesting: In more extensive diver-operated hand harvesting, a barge on the lake surface with a dredge hose connected to an industrial engine creates suction. The other end of the dredge hose is carried to the lake bottom by a scuba diver. The hose sucks up the plants, roots and top sediments that go into a spoils collection basket on the barge. The basket traps the plants and root fragments, allowing the sediments and water to drain back into the lake.

Collected plants can be disposed of at a site away from the lake, or dewatered or dried and **used for mulch or fertilizers.** Disposal may be confined to small, individual sites, in the case of small dredging operations. Suction harvesting collects a much smaller biomass than does larger-scale mechanical harvesting operations, because only small targeted areas are dredged, and because only the nuisance plants are removed, not all of the native and exotic plants.

Suction harvesting operations can have some significant side effects. **High turbidity, reduced clarity, and algae blooms from nutrient release can result from either the disturbance of bottom sediments, or the release of the sediment slurry from the on-barge collection basket. This may lead to reduced oxygen conditions, and, ultimately, may affect the ecosystem communities.**

Suction harvesting requires a diver, an assistant, and a boat operator.

Suction harvesting also **disrupts the bottom sediments** while removing the plants and roots. This control method can have a **deleterious effect on the animals** living in the sediments and on the plants not dredged but living within the dredged area. Sediments may also contain heavy metals or other potentially hazardous materials. If these materials are present, and proper precautions are not taken, the dredging operation may release these metals into the water, which could have severe repercussions throughout the food web.

Suction harvesting is very costly, as much as two to ten times the cost of mechanical harvesting. While part of the overall cost is incurred at the beginning in capital expenditures, the most significant cost is in operations, due to the slow rate at which diver dredges can be operated. The operations cost also includes skilled labor. Unlike some control techniques, suction harvesting will probably require at least three specialists; one barge operator and at least two scuba divers, all with some experience in these activities. Even if a lake association can pay for the equipment, it is likely that the harvesting cannot be done without additional outside financial assistance. Thus, **suction harvesting is far from a "self-help" control technique**.

Hydro-Raking

Authority: the New York State Department of Conservation

hydro-raking is essentially a technique that uses a mechanical rake, and collects and removes some of the cut material. The plants are usually disposed of on shore. **This technique is generally non-selective,** since the hydro-rakes cannot be easily maneuvered to selectively remove target plant species within diverse beds.

hydro-raking removes the roots as well as the plant, thus **providing a longer control strategy than mechanical harvesting**, although new plant growth can easily occur if root stock is not completely macerated or if seeds are readily dispersed. **This technique has controlled Eurasian water milfoil for as long as two years**, although the spread of the plants from uncut areas may reduce this longevity. This technique provides immediate relief and tends to work faster than large scale harvesting operations.

A hydro rake in operation

Many of the side effects described under hand- or mechanical-harvesting apply to hydro-raking, but are magnified. **hydro-raking significantly disturbs lake bottoms, churning out a brew of sediment, root masses, vegetation, and other debris that may decay on and in the lake. The potential for re-infestation from fragments or seeds of uncollected cut vegetation can be significant for several plant species.**

Plant and animal communities living on the bottom of the lake can be affected significantly by sediment disturbances from hydro-raking. Non-selective removal of plant species can easily change the plant community and ecosystem balance, often by allowing faster-growing exotic species to re-colonize an area following the hydro-raking. Disturbing the bottom sediment can destroy the invertebrate and benthic habitats. Sediment disturbances also may result in localized turbidity and transparency problems, as well as providing an ideal habitat for colonization by opportunistic plants, such as exotic macrophytes (rooted aquatic plants).

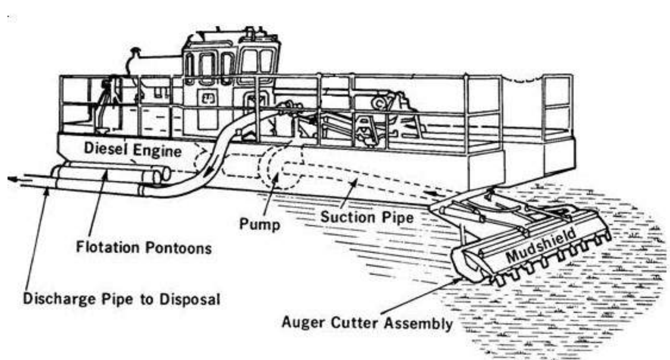
If contracted out, the approximate cost of the technique is on the order of $1500 per acre. This operating cost is slightly lower than for harvesting, though the operation can take twice as long. These costs and time estimates do not consider retrieval and disposal of cut plants.

Hydraulic Dredging

Authority: the New York State Department of Conservation

Where it is difficult or impossible to drain a lake, **hydraulic dredges have proved effective in removing nutrient-rich sediments that can promote excessive weed growth.** Cutterhead hydraulic pipeline dredges are most commonly used to remove lake sediments as an in-lake dredging operation. The system is operated from a floating steel hull, moved by raising and lowering vertical pipes ("spuds") to "walk" the dredge forward. The cutterhead typically consists of three to six smooth or toothed conical blades, mounted on a movable steel boom or ladder at the bow of the platform. When the cutterhead is lowered to the lake bottom and moved from side to side, the rotating blades loosen the sediments, which are transported to the pickup head by suction from the dredge pump. The sediment slurry (10-20% sediment and 80-90% water) is then pumped through a pipeline for discharge at the disposal site. Such slurries require relatively large disposal sites, designed to allow adequate residence time for the water to evaporate. (Some operations use a large bag that allows the dredged material to dewater. As the water leaves the bag it is filtered and can return to the lake as clean and clear.)

Most cutterheads have been designed to loosen sand, silt, clay or even rock. Few, if any, conventional cutterheads have been designed to remove soft, loosely clumped sediments. Although they are effective, most of these machines are not the most efficient means of dredging lakes. However, specialized dredges have been designed specifically for use in lakes, and can be trailered from lake to lake. Some of these use a horizontal auger to move the sediments to the suction pipe, reducing resuspension and turbidity associated with other cutterhead dredges.



The hydraulic dredge cuts into the sediment and immediately sucks up the "spoils" and pumps the material to a destination on shore.

Dredging may help control weed growth in several ways. Plants and the nutrients entrapped within the plants are physically removed by the dredging process. **The bottom sediment, which contains the root system of the plant and serves as a nutrient reservoir for plant and algae growth, is also removed.** In addition, **dredging serves to reduce rooted vegetation growth by increasing the lake depth and reducing the amount of sunlight that reaches the sediment.** Since plants require sunlight for growth, reducing the light levels will reduce the plant levels. This will be “permanent” as long as light transmission is limited by water depth, although a shift in aquatic plant communities (from shallow water to deepwater–dominating plants) may change plant growth patterns.

In lakes where nutrient loading from sediments is a major factor affecting nuisance weed and algae growth, **sediment removal may improve the overall water quality**. Dredging removes the top layer of sediment, which contains the most biologically available nutrients and participates most readily in sediment-water interactions and exchanges. If heavy metals and other toxic materials are present in bottom sediments, dredging these sediments can reduce the concentration of these hazardous substances in the sediments, and ultimately in the overlying water and organisms living in the sediment and water.

Dredging has proven to be an effective control technique for many lakes for increasing mean depth, reducing excessive vegetation levels, controlling nutrient release from sediments, and reducing the concentrations of toxic substances in sediment. It has been used for the entire lake basin in small lakes, or only a small portion of the basin for large lakes.

It is one of the few multipurpose aquatic plant control strategies. Sediment removal is used to deepen a lake for recreational and navigational purposes. **Deepening a lake may be the only recourse when the lake has become too shallow for boat navigation, swimming and fishing.** Other control methods such as adding chemicals or installing bottom barriers are of little use when water depth is no longer sufficient for the lake's intended uses.

If dredging is not done properly, it can actually make lake conditions worse by causing excessive turbidity, fish kills and algal blooms. As a result, **dredging projects should be accompanied by an extensive water quality monitoring program.** The main problems occur when bottom sediments mix with lake water while the sediments are being removed or when return water from a settling basin is discharged back into the lake. Nutrients, toxins and other contaminants may be carried back into the lake.

Dredging can harm fish, not only by causing turbidity but also by eliminating the benthic organisms upon which the fish feed. After the dredging of a lake, it could take two or three years for benthic fauna to become re- established. For this reason, it is advisable to leave a portion of the lake undredged.

Disposal areas for dredged sediments ("spoils") should be selected carefully. A carefully engineered and diked upland area or a de-watering bag may be the best options. Dredging is usually very expensive.

Costs vary depending upon site conditions, desired depth of excavation, available access, nature of the sludge, disposal, transport and monitoring arrangements.

From the “**Lake Notes**” series
Illinois Environmental Protection Agency
Chicago, Illinois 1997

Lake Notes

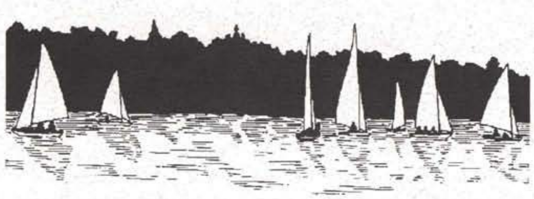
Lake Aeration and Circulation

The purpose of aeration in lake management is to increase the dissolved oxygen content of the water. Various systems are available to help do this—by either injecting air, mechanically mixing or agitating the water, or even injecting pure oxygen.

Aeration can increase fish and other aquatic animal habitat, prevent fishkills, and improve the quality of domestic and industrial water supplies and decrease treatment costs. In some cases, nuisance algal blooms can be reduced or a shift to less objectionable algae species can occur. However, aeration can be misused. It is not a "cure-all" for a lake's ills. It's important to understand what aeration can and can't do for your lake so you don't end up with unexpected or unwanted results—and possibly a waste of money.

This issue in the *Lake Notes* series focuses on ***artificial circulation*** as a lake aeration technique. We'll explore its applicability, potential consequences, and other factors to be considered before deciding to invest in an artificial circulation system—or in reevaluating the system you already have in place.

> **Note to the Reader:**
> This *Lake Notes* fact sheet uses some rather complex terms that may be unfamiliar to you. In order to better understand their meaning, you are encouraged to first read another fact sheet in the *Lake Notes* series, "Lake Stratification and Mixing."



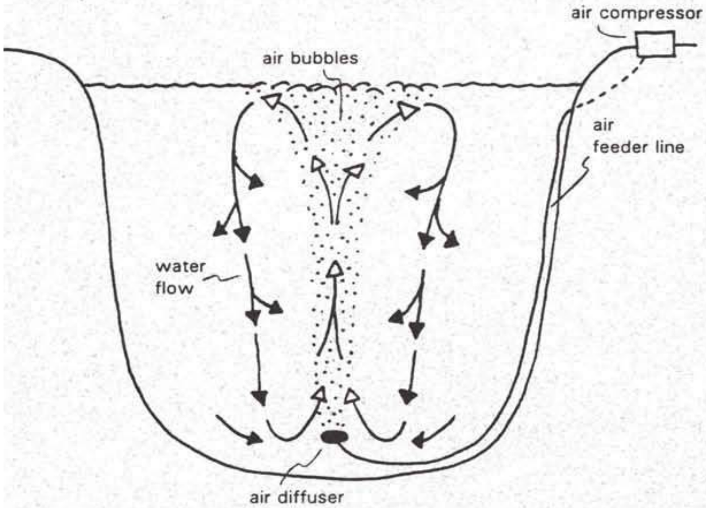
Artificial Circulation Systems

Lakes get much of their oxygen from the atmosphere through a process called diffusion. Artificial circulation increases a lake's oxygen by forcefully circulating the water to expose more of it to the atmosphere. Proper choice and design of an artificial circulation system depends on your lake management goals and the lake's physical characteristics.

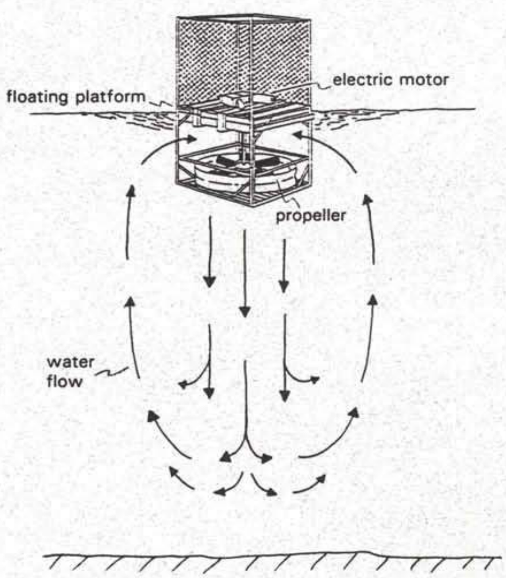
Destratifiers

Destratification is a type of artificial circulation that completely mixes a stratified lake's waters from top to bottom and thereby eliminates or prevents summer stratification (the division of a lake into water layers of different temperatures). Two techniques are most common: air injection and mechanical mixing.

■ **Air Injection (Diffuser) Systems** are the most common destratification method. A compressor on shore delivers air through lines connected to a perforated pipe(s) or other simple diffuser(s) placed near the bottom, typically in the deep area of the lake. The rising air bubbles cause water in the hypolimnion (the cold, bottom water layer) to also rise, pulling this water into the epilimnion (warm, surface water layer). When the colder, hypolimnetic water reaches the lake surface, it flows across the surface and eventually sinks, mixing with the warmer epilimnetic water. If the system is adequately powered and enough air is injected, this process continues and the metalimnion (transition zone between the epilimnion and hypolimnion) is broken down. Eventually, the entire lake becomes of nearly equal temperature with oxygen distributed throughout. Many people are surprised to learn that the majority of oxygenation occurs through the water's contact with the atmosphere; relatively little oxygen increase occurs through direct diffusion from the bubbles. This aeration technique is sometimes referred to as the ***air-lift*** method of circulation, since bottom waters are "lifted" to the lake surface through the action of the injected air.



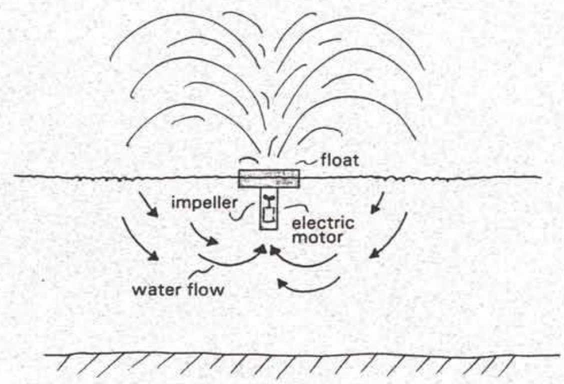
■ **Mechanical Axial Flow Pumps** use a "top-down" approach to set up a circulation pattern. A floatation platform and frame support an electric motor, gearbox, drive shaft, and large propeller (6–15 foot diameter). The propeller is suspended just a few feet below the water surface. Its rotation "pushes" water from the lake surface downward, setting up a circulation pattern that prevents thermal stratification. Oxygen-poor water from the lake bottom is circulated to the lake surface, where oxygenation from the atmosphere can then occur. These systems are being utilized in several Illinois water supply reservoirs.



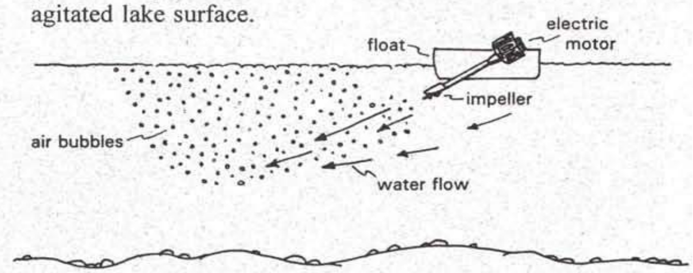
Other Systems

Other mechanical circulation systems include surface spray units, impeller-aspirators, and pump-and-cascade systems. While they do set up a circulation pattern in the water, they typically are not designed to destratify a lake. Hence, they probably have more applicability in non-stratified (shallow) lakes and ponds to enhance the water's oxygen content.

■ **Surface Spray** units consist of a float supporting an electric motor-driven impeller. The rapidly-turning impeller pulls water up a vertical tube and throws it out in an umbrella- or fountain-shaped spray a few to many feet above the lake surface. Atmospheric reaeration occurs in the sprayed water and at the agitated lake surface.



■ **Impeller-Aspirator** systems consist of an electric motor-driven impeller at the bottom of a hollow shaft extending at an angle down into the water. The assembly floats on the lake surface. The rapidly-turning impeller draws air down the shaft and propels water and air bubbles into the lake. Aeration takes place through air bubble/water contact and at the agitated lake surface.

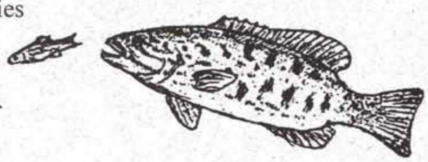


■ **Pump-and-Cascade** systems consist of a large pump that moves lake water to the top of a ramp-like chute containing numerous baffles. The water cascades down the ramp and falls back into the lake at a point located as far as possible from the water inlet (to prevent recycling of just-pumped water). Aeration occurs in the cascade chute and in the plunge pool as the water flows away from the ramp.

Effects of Destratification/ Circulation

■ **Dissolved Oxygen:** The most common result of destratification is an improvement in dissolved oxygen levels—and consequent benefits on warmwater fish and water supply quality.

■ **Fish:** Destratification is generally considered beneficial for warmwater fish. Fish require adequate dissolved oxygen levels and cannot survive in an oxygen-deficient hypolimnion. Warmwater fish (e.g., bass, bluegill) require a minimum dissolved oxygen concentration of 5 mg/L, and coldwater fish (e.g., trout) need 6-7 mg/L. Destratification allows warmwater fish to inhabit the entire lake, and enhances conditions for fish food organisms as well. However, because destratification warms the deep waters, some coldwater fish species may be eliminated or prevented from inhabiting that lake.



■ **Water Supply Quality:** A common result of destratification is an improvement in industrial and drinking water supply quality (in fact, the first artificial circulation system was used in 1919 in a small water supply reservoir). Under anoxic (without oxygen, anaerobic) conditions, lake bottom sediments release metals (iron, manganese) and gases (hydrogen sulfide)—which can cause taste and odor problems in drinking water. When the anoxic hypolimnion is eliminated, these problems are eliminated or greatly reduced as well. Water treatment costs also decrease.

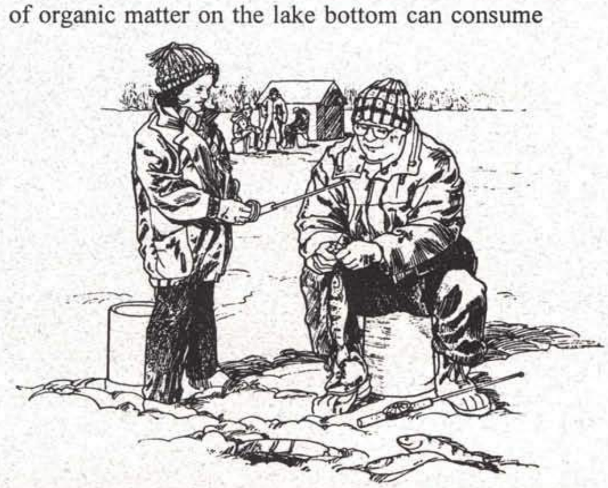
■ **Phytoplankton:** The effects on phytoplankton (algae) are less predictable. Destratification *may* reduce algae through one or more processes: 1) algal cells will be mixed to deeper, darker lake areas, decreasing the cells' time in sunlight and thereby reducing their growth rate, 2) some algae species that tend to sink quickly and need mixing currents to remain suspended (e.g., diatoms) may be favored over more buoyant species such as the more noxious blue-greens, 3) changes in the lake's water chemistry (pH, carbon dioxide, alkalinity) brought about by higher dissolved oxygen levels can lead to a shift from blue-green to less noxious green algae or diatoms, and 4) mixing of algae-eating zooplankton into deeper, darker waters reduces their chances of being eaten by sight-feeding fish; hence, if more zooplankton survive, their consumption of algal cells also may increase.

While algal blooms have been reduced in some lake destratification/circulation projects, in other lakes phytoplankton populations have not changed or have actually increased. For shallow lakes, it's even less likely that complete circulation would result in any of the above-mentioned benefits. This is because algae are less likely to become light-limited in shallow lakes, nor would water chemistry changes be as pronounced.

■ **Phosphorus:** Destratification has the potential to reduce phosphorus (P) concentrations in some lakes. During summer stratification when the hypolimnion is oxygen-poor, P becomes more soluble (dissolvable) and is released from the bottom sediments into the hypolimnion. Because stratified lakes can sometimes partially mix, this allows greater amounts of P to "escape" into the epilimnion. These increased P levels in the lake's surface waters can potentially stimulate an algal bloom. For similar reasons, algal blooms often are seen at fall turnover. Because destratification increases the bottom water's oxygen content, it follows that P release from the sediments should be reduced, which in turn can lead to decreased algae abundance. However, the most suitable candidates for P reduction are deep, stratified lakes where a majority of the lake's P comes from anoxic, hypolimnetic sediments (i.e., internal sources). In lakes where the majority of P comes from external sources (such as watershed runoff, the atmosphere, waterfowl, septic systems), a reduction in sediment P release may not be enough to notice a change in algae abundance.

Winter Operation

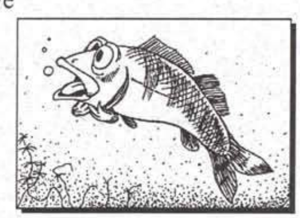
Artificial circulation systems also can help prevent winter fishkills in ice-covered lakes. Low dissolved oxygen levels during winter occur because ice covering the lake prevents diffusion of atmospheric oxygen into the water. Even though photosynthesis by some algae and rooted aquatic plants occurs in the winter months under the ice, bacterial decomposition of organic matter on the lake bottom can consume



more oxygen than photosynthesis can replace. Furthermore, if enough snow covers the ice or if the ice is opaque, sunlight will be unable to penetrate and photosynthesis will stop. If under-ice oxygen levels become too low before ice-out, a partial or total fishkill will occur. Shallow lakes are most susceptible to dissolved oxygen depletion since they have a smaller amount of water as compared to deeper lakes.

Studies in Wisconsin and Minnesota have found that air diffuser systems seem most effective in providing efficient, reliable winter aeration. To save energy costs, the system can be run only on an as-needed basis. Careful monitoring of dissolved oxygen levels throughout the winter can be used to determine when, or even if, aeration in a particular year is necessary. Oftentimes, dangerously low oxygen levels do not appear in Illinois lakes until late winter. In most cases, if a lake's average dissolved oxygen level was found to be between 4 and 5 mg/L, start-up would be warranted. After you become more familiar with your lake's situation, start-up can be fine-tuned.

Turbulence from the rising air bubbles and uplifting of the slightly warmer bottom waters will begin opening the ice within a few hours after system start-up. Be aware that if the system is turned on when oxygen concentrations already have fallen too low, mixing of anaerobic bottom water with low-oxygen water just under the ice may cause the entire lake to have oxygen levels too low for fish survival.



Surface spray units, impeller-aspirators, and pump-and-cascade systems also can be used in the winter to keep an area ice-free. Of the three, pump-and-cascade systems appear to be the most reliable in averting winter fishkills. They also can be moved from lake to lake. On small lakes, their wintertime performance has compared favorably with air diffuser systems.

Design Considerations

There are several technical issues to consider when designing and installing an artificial circulation system. For example, if the air diffuser is positioned too far above the lake bottom, an anaerobic zone will remain below it. However, if the diffuser is placed on or too near the lake bottom—or if the system is oversized (mixing is too vigorous)—sediments may be stirred up and resuspended in the lake. If the system is undersized, mixing will be incomplete. In very large lakes, mixing will be limited unless more than one device is used.

To Aerate—or Not to Aerate?

It's a good idea to seek experienced professional help when considering the installation of and in designing a properly-sized aeration system. The first question to consider is whether your lake can really benefit from a destratification/circulation (or other) aeration system. Would summer and/or winter operation be most effective? Answering these questions requires background knowledge of your lake's physical and water quality characteristics. You also should have established lake use goals (e.g., what you'd like to use the lake for, how you'd like the lake to look). Seek out the advice of unbiased water quality professionals—don't limit your advice to just the individual or company proposing to sell you a system! By examining your lake's characteristics together with your goals, you can then better determine whether aeration, and what type of system, might meet your objectives.

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This *Lake Notes* publication was prepared by Holly Hudson and Bob Kirschner of the Northeastern Illinois Planning Commission, Chicago, Illinois. Illustrations by Holly Hudson, University of Wisconsin-Extension, Wisconsin Department of Natural Resources, and Illinois State Water Survey.

For more information about other publications in this series and to request copies, please contact: Illinois Environmental Protection Agency, DWPC-Lake and Watershed Unit, P.O. Box 19276, Springfield, Illinois, 62794-9276; 217/782-3362.

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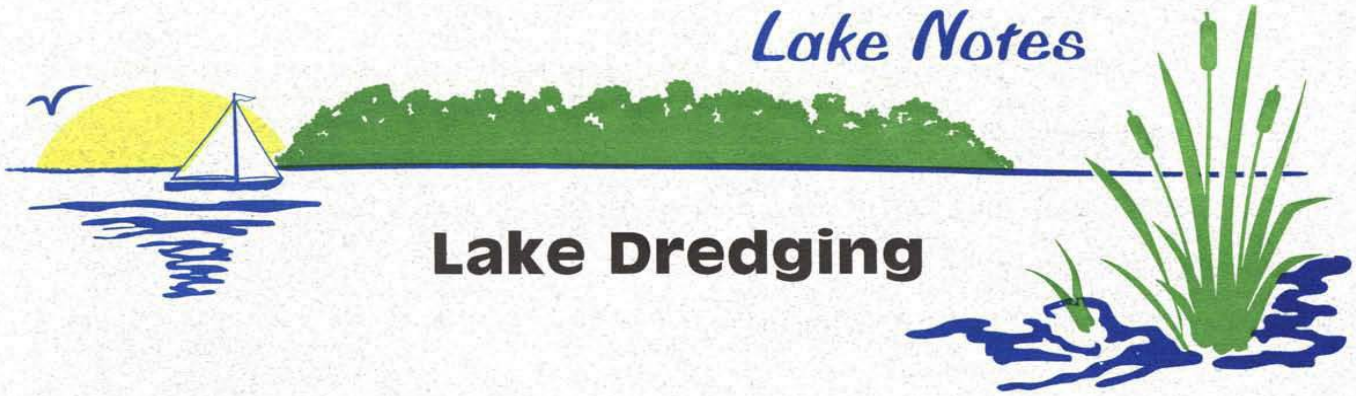


Lake Dredging

The Dredging Feasibility Study

Dredging is the removal of accumulated lake bottom sediments ("muck"). The decision to dredge should be based on sufficient study that shows accumulated sediment is having an adverse impact on water quality, recreation, or navigation. This decision process includes defining what you want to use the lake for (such as recreation or water supply) and how you'd like the lake to appear (water quality), and then determining if lake sediment is affecting these factors. If so, the study should compare alternatives to dredging to see if sediment removal is indeed the most cost-effective solution.

The study should identify the sources of the sediment coming into the lake and calculate how much sediment has accumulated. Sediment sources from the watershed (such as from construction sites, eroding streambanks and shorelines, urban and agricultural runoff) should be controlled. Dredging is too expensive to do repeatedly!

Sometimes it is necessary to employ the services of an experienced professional to conduct a dredging feasibility study and help determine if dredging is the most practical alternative. Engineering data and design are almost always needed. The sediment's chemical composition must be tested to determine if contaminants are present. Disposal sites for the dredged sediment must be identified, costs must be calculated, bids must be let . . . as you can see, there are many aspects to the dredging decision. This *Lake Notes* publication is designed to give you the background to help make that decision.

Why Remove Sediments?

Sediments are commonly removed to improve navigation; restore recreational access for leisure boating, swimming, and fishing; or regain lost storage capacity in water supply reservoirs. Dredging also is done to remove nutrient-rich sediments, remove toxic substances, reduce rooted aquatic plant growth, lessen sediment resuspension by winds and waves, and improve fish habitat.

Dredging sometimes can improve water quality by reducing the amount of nutrients available from the sediments, thereby reducing nuisance algae blooms. This can occur through direct removal of nutrient-rich sediments, or by deepening the lake enough to allow thermal stratification to develop and thereby limit nutrient movement from deep-water areas to the upper waters (see the *Lake Notes* fact sheet "Lake Stratification and Mixing"). Dredging in areas of rooted aquatic plants controls their growth through direct removal, and also can limit future regrowth if the new water depths are deeper than sunlight can reach. For lakes that freeze over in the winter, fish survival can be enhanced by removing oxygen-demanding sediments and creating deeper water areas.

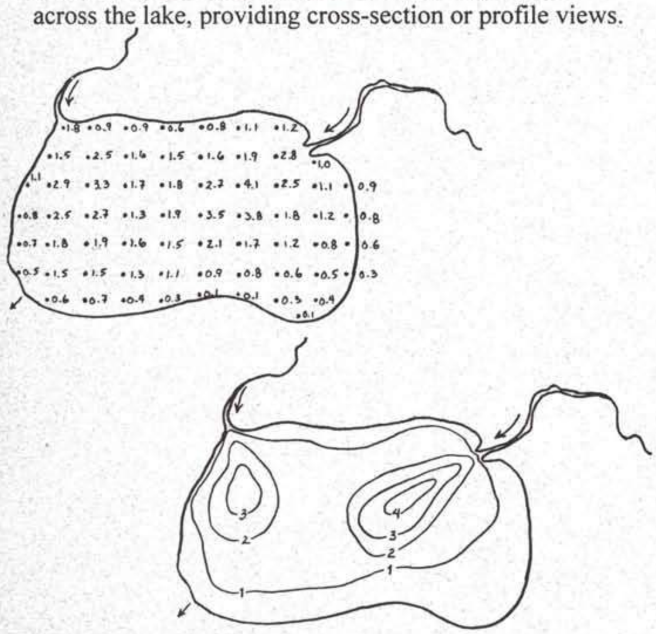
Sometimes, however, sediment removal can dig up the unexpected. Dredging too shallow may uncover fertile sediments and provide a perfect place for aquatic plants to grow if the bottom gets enough sunlight. Dredging too deep may expose old arsenic treatments (a herbicide used years ago to treat algae) or nutrient-rich wastes from a forgotten sewage treatment plant. Before dredging begins, you'll need to have sediment cores analyzed by a qualified professional.

Where to Dredge?

Sediments can be removed from either the entire lake basin or just selected spots. Dredging the whole lake increases its average depth, but that can be prohibitively expensive—and can (at least temporarily) impact the lake's ecosystem. Dredging just in certain areas ("spot" dredging) is less expensive and less ecologically damaging since only a portion of the lake bed is disturbed. Furthermore, a smaller sediment disposal area is needed. Spot dredging can be beneficial in improving boat and shoreline access, clearing clogged channels or bays, creating hollows for coolwater fishes in the summer and deeper areas for fish in the winter, and forming boat and fish "cruising lanes" through aquatic plant beds.

How Do You Calculate How Much Sediment to Remove?

One method used to determine the accumulated sediment volume involves setting up a grid pattern over the proposed dredging area. At each grid point the water depth and depth to original lake bottom are measured using graduated probing poles. A "contour map" of sediment thickness is created from these measurements. Other methods include the Average End Area Method and Dobson's Prismoidal Formula. Both utilize sediment measurements made along transects across the lake, providing cross-section or profile views.



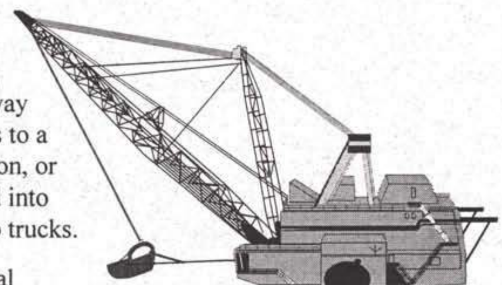
Lake sediment thickness measurements and resulting contour map (arrows indicate inflowing and outflowing

For small areas you may be able to do the field measurements and calculate the accumulated sediment volume yourself. For big jobs, more sophisticated equipment and/or a consultant may be necessary. Resource agencies and consultants can provide guidance on choosing an approach.

How are Sediments Dredged?

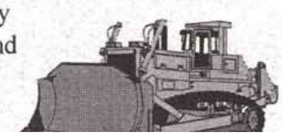
For small jobs of a few to no more than 50 to 100 cubic yards, you may be able to do it yourself using buckets, shovels, small pumps, or small excavating equipment. For big jobs, large earthmoving equipment or hydraulic dredges are needed.

MECHANICAL DREDGING can be done either "in the dry" or "in the wet." Dry mechanical dredging involves either partially or completely draining the lake to expose the sediments to drying or freezing conditions. Conventional earthmoving equipment such as bulldozers, scrapers, backhoes, and draglines are used to remove the sediment. The equipment either works from shore or moves down onto the dewatered lakebed. The sediment may be stockpiled on shore and then hauled away in dump trucks to a disposal location, or directly loaded into awaiting dump trucks.



Wet mechanical dredging does not involve drawing the lake down. Backhoes, draglines, or grab buckets are used to scoop up the sediment. The equipment can either work from shore or a floating barge. Wet mechanical dredging usually causes severe sediment resuspension and turbidity (muddiness).

Mechanical dredging is better at removing hard or rocky material than hydraulic dredges. It is useful for small projects such as dredging bays and shorelines, and for small projects can be less expensive than hydraulic dredging. It may be the only option if land for a sediment disposal basin is not nearby, or if the lake's water volume is too small to allow hydraulic dredging. Mechanical dredging is ineffective at removing watery deposits, is labor intensive, and can disrupt lake usage (if the lake is drawn down).

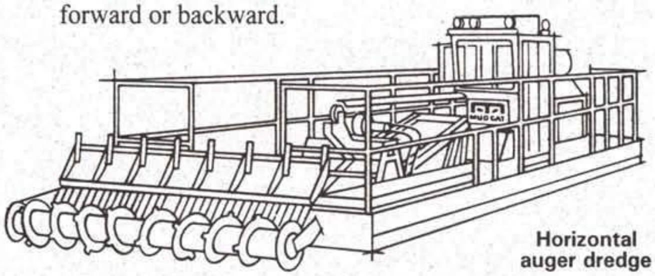


HYDRAULIC DREDGING does not involve drawing down the lake water. The dredging machinery is incorporated onto a floating hull. A cutter with steel blades dislodges the sediments, and a centrifugal pump "sucks up" the muck. This sediment/water mix (called a slurry) is piped to a disposal basin on land where the water is drained off and the sediments are left to dry. Because lake water is removed along with the sediment (hydraulic dredging slurries are commonly 80-90 percent water), this type of dredging requires that enough water volume is maintained in the lake to keep the dredge floating.

Hydraulic dredging is faster than mechanical dredging, creates less turbidity than wet mechanical dredging, and can effectively remove loose, watery sediments (greater than 70 percent water). It is typically the most cost-effective method for large dredging projects (though some small projects also may be more economical using hydraulic dredging).

Two types of hydraulic dredges are best suited for most Illinois lake sediments: horizontal auger and cutterhead dredges.

A **horizontal auger dredge** utilizes vertical "knives" on a rotating auger to cut and loosen the sediments. The auger is mounted on a boom at the front of the dredge hull. The dredge moves across the lake by a winch attached to a taut cable, and it can cut while moving forward or backward.

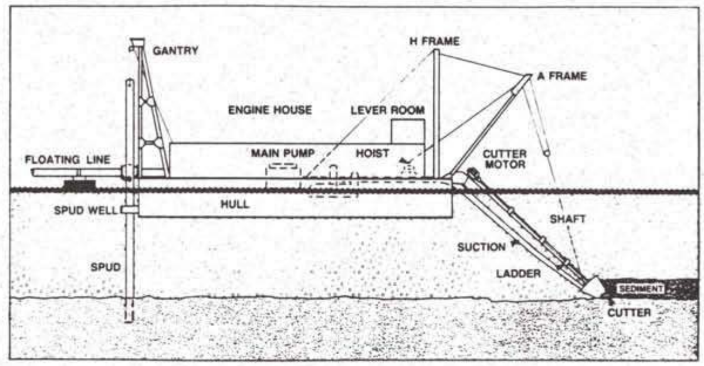


Horizontal auger dredge

These types of dredges work well for soft silts and cause little turbidity. The auger dredge is smaller than a cutterhead dredge and removes sediment in a more concentrated form (less water is removed from the lake). The dredge operator can closely control the auger position and cutting depth. Horizontal auger dredges can remove sediments in up to 20 feet of water (30 feet with extensions), and can remove up to 120 cubic yards of silt per hour.

The **cutterhead dredge** utilizes a rotating "basket" comprised of smooth or toothed blades (depending on the sediment consistency) to dislodge the sediment. The cutter is mounted on a boom ("ladder") at the front of the dredge hull. The ladder also supports the suction pipe. The cutterhead is "swung" through the sediment to cut it as the is dredge stabilized by one of two spuds (vertically mounted pipes located at the rear of the dredge on each side) pushed into the lake bottom. After a swing is completed, the dredge "walks" forward using the spuds. Cutterhead dredges are larger, can dredge deeper (up to 26 feet, or 55 feet with ladder extensions), and have higher production rates (150–350 cubic yards per hour) than horizontal auger dredges. They can cut compacted sediments and some original lake bottom soils, and can work where there is debris and weeds. As with auger dredges, the cutterhead dredge operator can closely control the cutting depth.

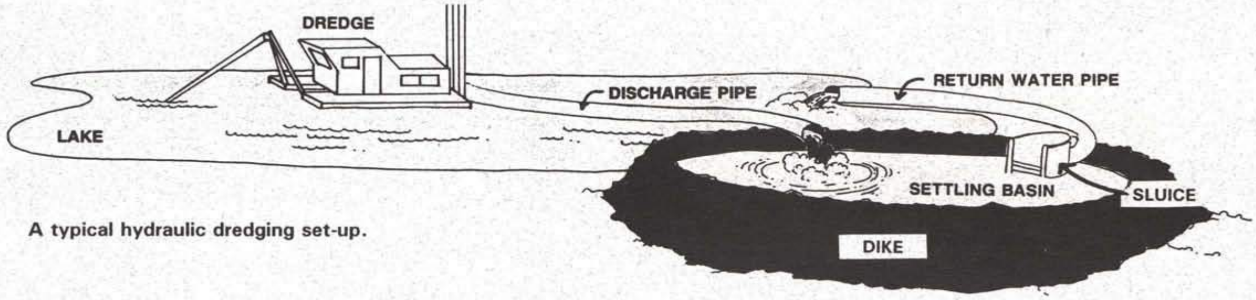
Configuration of a typical cutterhead dredge.



Where are the Sediments Put?

Croplands and pasturelands are commonly utilized for land-application of trucked sediments or for siting disposal basins. Landfills are another option for trucked sediments, although landfill fees greatly increase project costs. The closer the disposal site is to the lake, the better. In urban areas where open land is scarce, finding a proper site nearby may be very difficult. Generally, dredging is more cost-effective when the disposal site is located within one mile of the dredging area. However, it is not uncommon to hydraulically pump sediments up to two miles or more, or truck sediments even farther. Dried sediments later may be incorporated into the landscape at the disposal site. Alternatively, the dried sediments may be removed and used as fill or disposed of elsewhere.

For hydraulic dredging projects, a disposal basin must be designed and constructed to hold not only all the dredged sediments once they've dried, but also be large enough to allow the pumped sediment/water slurry enough time to settle out the solids and return relatively clear water to the lake. Also, because lake sediments tend to increase in volume temporarily during hydraulic dredging, a "bulking factor" is added when designing the disposal basin. A 120% bulking factor is typical. For example, if 10,000 cubic yards of sediment were to be dredged, the disposal basin would have to be sized to



A typical hydraulic dredging set-up.

Geology of the disposal site must be considered as well. Some sites may be too porous and could allow nearby lakes or streams, or the groundwater table, to be impacted. Costs increase when the sediments must be trucked far away or the disposal site modified to contain the sediments. If the lake sediments themselves are found to have elevated concentrations of contaminants (e.g., heavy metals, certain pesticides), special handling and disposal will be required. Nutrient-enriched sediments are not considered contaminated and therefore do not require special handling.

Costs

Any costs associated with conducting the dredging feasibility study are separate from actually removing the sediments from the lake. As you've probably heard, dredging can be expensive. However, when coupled with measures to control soil erosion in the watershed, the effectiveness and benefits of dredging can be longer-lived.

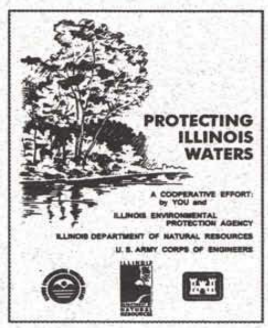
Dredging contractors are usually paid on the basis of cubic yards of sediment removed. Dredging costs can vary greatly—from $5 to $15 per cubic yard for hydraulic dredging (including engineering design and construction of the disposal basin), and from $8 to over $30 per cubic yard for mechanical dredging projects (including disposal). It's a good idea to get quotes from several experienced dredging contractors.

As an example, let's calculate how much it might cost to remove 1 acre of sediment 5 feet thick that has clogged a channel. This equals 5 acre-feet or 8,067 cubic yards of sediment. Using a hydraulic dredging cost of $15 per cubic yard for such a relatively small project, this equates to about $121,000.

Costs can be reduced by scaling back your project, pumping or hauling shorter distances, or, if possible, conducting the work during winter when construction equipment tends to be idle.

Permits

Dredging projects, both mechanical and hydraulic, are subject to permitting by the U.S. Army Corps of Engineers, Illinois Department of Natural Resources–Office of Water Resources, and Illinois Environmental Protection Agency. It is best to begin the permitting process as early as possible during your project's planning phase. You can contact Illinois EPA's Division of Water Pollution Control, Permits Section, at 217/782-0610 for more information and to request a permit application.



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Hydraulic auger dredge illustration courtesy of Mudcat Division of Ellicott International. Hydraulic dredging operation illustration courtesy of Tennant's Industrial Dredging. Cover illustration from University of Wisconsin-Extension's *Lake Leaders Handbook.*

This *Lake Notes* publication was prepared by Holly Hudson of the Northeastern Illinois Planning Commission, Chicago, Illinois. Thanks are extended to Peter Berrini, Bruce Yurdin, and Bob Kirschner for their review and comments.

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