18057-1101

Clean and Clear Program – Ecosystem Restoration Grant:

Control of Internal Phosphorus Loading to Ticklenaked Pond

Summary Project Scope of Work

The Control of Internal Phosphorus Loading to Ticklenaked Pond project is funded by a VT Department of Environmental Conservation (VTDEC), Clean and Clear Program Ecosystem Restoration grant. The grant funds are being used to support contractor support to develop a treatment alternatives analysis, treatment plan, and permit preparation to remediate internal phosphorus loading in a 54 acre pond in Ryegate, VT.

This summary scope of work outlines tasks to be undertaken by AECOM Inc (formerly known as ENSR Inc.) in fulfillment of this grant. This summary scope of work references specific tasks laid out in AECOM's project proposal entitled "Control of Internal Phosphorous Loading to Ticklenaked Pond, Ryegate, Vermont." That proposal details work items associated with six specific tasks, and is provided as Addendum A. The tasks are:

1. Summarize available information from the TMDL and other sources as relates to an analysis of internal load control options and longevity of results from implementation. This task will also include a kickoff meeting with ANR staff and a site visit to the pond. The scope of this task is reduced relative to that shown in Addendum A in consideration of the availability of pre-assembled data that will support the task.
2. Evaluate the readiness of the pond for internal load control, based on watershed loading status and effectiveness of implemented or planned external loading controls, using AECOM's nutrient loading evaluation model.
3. Evaluate options for internal load control including dredging, aeration/mixing, and chemical inactivation of P.
4. Recommend the most advantageous approach to internal P load control and provide detailed design information, a cost estimate, an implementation schedule, a longevity analysis, and permit needs. Identify any data gaps and a plan for filling any such gaps. There will be one meeting with VTDEC associated with discussing the findings of Task 3 and this task.
5. Conduct chemical analysis of sediments from Ticklenaked Pond to determine appropriate alum dosing rates. This is identified in Addendum A as an optional task.
6. Provide permit submissions to facilitate implementation.

The results of Tasks 1 and 2 will be delivered in the winter of 2010-2011 as a data evaluation report which will give an assessment of the "readiness" of the pond for treatment of the internal load. Tasks 3 and 4 will include a report which includes the feasibility study and a status update on the watershed phosphorus control projects. Task 5 will be completed cooperatively by VTDEC and AECOM. Inc. Task 6 will be completed once VTDEC has selected a preferred control alternative. The project is anticipated to be completed by August 30, 2011.

The following project assumptions (revised from Addendum A) have been agreed to by VTDEC and AECOM, Inc.

- Project agreement will be executed in October of 2010
- All data will be delivered to AECOM Inc. in electronic form
- VTDEC may be asked to assist on some data analysis or GIS Tasks.
- Permitting costs are an estimate and will be re-evaluated once an alternative is selected
- Sediment sampling will be conducted by ANR staff. 3 sampling stations will be selected by AECOM during the site visit. Laboratory analysis costs will be included in the AECOM portion of the work.

The following budget (revised from Addendum A) has been agreed to by VTDEC and AECOM, Inc.

Task	Description	Total
1	Data Summary	$3,985
2	Watershed Status Evaluation	$6,990
3	Internal Load Control Evaluation	$6,990
4	Recommended Option Evaluation	$11,880
5	Permit applications	$8,775
6	Optional Sediment Sampling	$2,835
Project Total		$41,455

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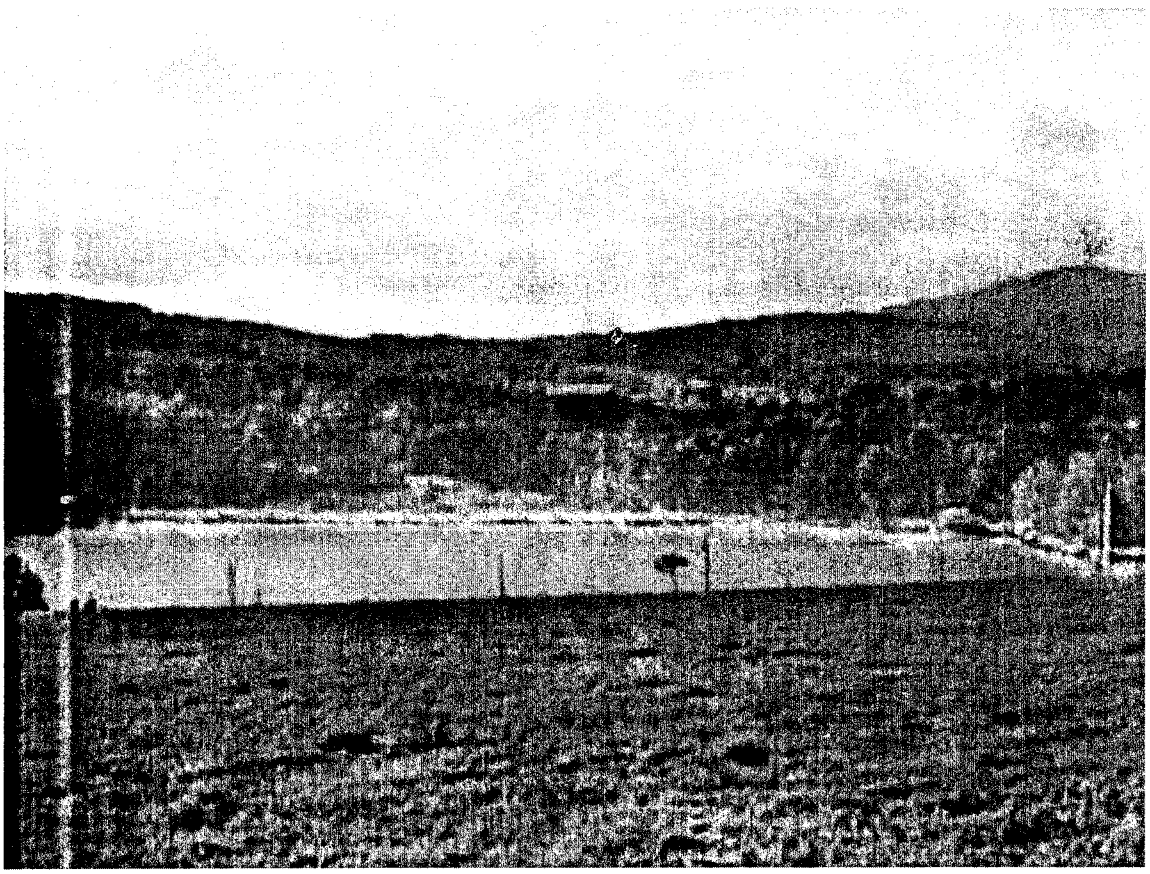
AECOM Environment

Prepared for:
Vermont Agency of Natural Resources
Waterbury, Vermont

Prepared by:
AECOM
Belmont, NH
September 3, 2010

Control of Internal Phosphorous Loading to Ticklenaked Pond, Ryegate, Vermont



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Control of Internal Phosphorous Loading to Ticklenaked Pond, Ryegate, Vermont

Prepared By Don Kretchmer

Reviewed By Matt Kennedy, PE

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1.0 Introduction and Background

AECOM is pleased to submit this proposal to conduct a feasibility study for the control of internal phosphorus loading to Ticklenaked Pond. It is clear from the discussion in the request for proposals and our review of background information on Ticklenaked Pond that internal loading of phosphorus continues to play a significant role in the phosphorus budget. We have assembled a team of experienced lake professionals that can provide valuable insight to the project and ultimately to the improvement of water quality conditions in Ticklenaked Pond. The AECOM team has extensive experience with each of the potential techniques to be evaluated but has no vested interest in any one technique. This allows AECOM to address each alternative objectively and present all of the alternatives in an unbiased manner. In addition to having experience evaluating, engineering and implementing the candidate techniques, AECOM has specific experience in projecting the likelihood of future cyanobacteria blooms under each future implementation scenario. We look forward to the opportunity to work with the Agency of Natural Resources (ANR) and the local community to address the causes of these problems.

Ticklenaked Pond is located in Ryegate, Vermont. The Agency of Natural Resources (VTANR) identified Ticklenaked Pond as impaired and not meeting VT Water Quality Standards due to excessive phosphorus loading and resultant excessive algal production. Listed water quality problems include late summer cyanobacteria blooms, reduced water clarity, low deepwater dissolved oxygen, and elevated pH. Ticklenaked Pond is listed on the 2008 303(d) List of Impaired Waters as a high priority for TMDL development, with total phosphorus (TP) as the primary target of management actions. The Ticklenaked Pond Watershed Association, the Natural Resources Conservation Service, and watershed landowners have worked within the watershed to reduce sources of phosphorus. VTDEC has studied phosphorus loadings and prepared a TMDL.

Ticklenaked Pond is an enhanced flowage lake (dam expanded on existing natural pond) that covers 54 acres. Maximum depth is 14.5 meters (46 ft) and mean depth is 4.9 meters (16 ft). The lake volume is approximately 1.1 million cubic meters (864 acre-feet). Annual flow is about 3.06 million cubic meters, indicating an average detention time of 0.36 years, or just over 4 months. The watershed covers 1,498 acres, of which 817 acres are forested, 387 in agriculture, 110 in wetland, 91 as residential, and 54 as the lake itself. Agriculture in the watershed includes pasture, barnyard, hayfield, and row crops. Residential land is considered mainly rural, although camps around the lake may contribute disproportionately due to location. Septic system inputs have been assessed separately.

Annual external P loading is estimated at 115-120 kg/yr, with wet year values as high as 202 kg/yr. The distribution of the load among sources includes; 71% from agriculture, 15% from forest or wetland, and 12% from residential areas, including septic systems. The remaining 2% of the load is from direct precipitation and dryfall onto the lake. The internal load may range from 24 to 47 kg/yr, with a best estimate of 41 kg/yr. The average annual total load by summation is about 160 kg/yr, but back-calculation from in-lake features suggests a value of 144 kg/yr.

The resulting in-lake spring TP value is 41 ppb. Summer values are lower, but Secchi transparency averages 1.5 m and chlorophyll averages 15 ppb; with cyanobacteria dominating, this will produce a very large biomass. Dry weight to chlorophyll a ratios for cyanobacteria are on the order of 300:1, so average algal mass could be on the order of 4.5 mg/L, with peaks well over the "high" threshold of 10 mg/L.

The target TP value under the TMDL is 24 ppb. To reach this level, the new watershed load is projected to be 104 kg/yr, with a 10 kg/yr MOS (non-point watershed allocation is therefore 94 kg/yr), a reduction from current loading of 28%. The internal load is to be reduced to 0 kg/yr (which is not truly realistic, but a very low value is achievable). It is not clear that a TP value of 24 ppb will provide acceptable peak algae conditions; one would still expect some blooms at TP=24 ppb, but it would represent an improvement over current conditions. In 2006, a wet year, summer TP was about 28 ppb and SDT was 3 m with chl = 10 ppb, considered acceptable. It is interesting that the best year in recent times was a wet year, when watershed inputs would be increased, albeit perhaps diluted, and the effect of the internal load would be reduced by increased flushing. This suggests that internal loading may indeed be very important to lake condition, particularly during dry years. Additionally, the timing of internal loading coincides with the period of algal blooms.

The TMDL is largely based on an annual timeframe, but consideration of the seasonal aspect is worthwhile. The watershed load is likely to be skewed, with the highest inputs in spring, as crop and natural plant growth is not yet maximal and fertilization would be occurring. The internal load will be a largely summer phenomenon, with a peak in August or September in most years. Because the pond likely flushes very quickly in the spring and during other high flow periods, and more slowly during the summer growing season, particularly during dry years, the internal load becomes relatively even more important to the amount of TP available for summer algal growth. While other loads cannot be ignored, no other load sources are large enough to make as much difference and no other individual source could be practically reduced enough to achieve the desired 28% reduction in TP loading. Much of the external load may be in unavailable forms, necessitating inlake processes before the TP becomes part of an "effective" load; again this points to the internal load as being very important, although ultimately the internal load is dependent on the external load. Reductions in the external load will reduce the internal load over time but likely over a much longer time period than would be experienced with active internal load control coupled with external load reduction.

The TMDL appropriately emphasizes the need to reduce watershed loading to improve the pond in the long run, but also notes the immediate benefit of internal load reduction and its role in longer term pond management. Work under the proposed contract would consist of assessing the status of watershed management efforts in terms of adequacy of current and/or planned loading reductions for protecting the pond and facilitating an internal load reduction that would have lasting results. Work also includes assessment of the most advantageous approach to reducing the internal load.

AECOM's team will be led by Mr. Don Kretchmer, a certified lake manager with 25 years of experience conducting and managing water resource investigations in northern New England and across the country and presenting findings to a variety of audiences. Technical expertise will be provided by Dr. Ken Wagner, also a certified lake manager and a past president of the North American Lake Management Society. In addition to editing a technical guidance manual on lake restoration, Dr. Wagner has evaluated and materially contributed to the improvement of water quality in hundreds of impaired lakes and ponds. He is intimately familiar with all of the techniques that would be appropriate for Ticklenaked Pond. The team will be supported by two additional aquatic ecologists: Aaron Hopkins and Siona Patisteas as well as two engineers: Matt Kennedy and Theresa McGovern. The team qualifications include a mix of biology, water and sediment chemistry, biologic response modeling and engineering. Each of these disciplines is necessary to successfully understand the problem, identify alternatives, comprehensively discriminate between alternatives and fully develop a plan for implementation.

2.0 Technical Approach

From the data provided in reference publications and the TMDL, it appears that a strong case can be made for internal loading as a major factor in algal blooms in Ticklenaked Pond. Curtailing internal loading could prevent blooms, or at least shift the species composition to less objectionable forms, if that internal loading is the controlling influence and an effective control can be implemented. It is also possible to disrupt algal growth by other means, including mixing strategies, without necessarily altering the base level of fertility. We assume that the focus is on reducing internal loading as a control for algal biomass accumulation. We will also consider mixing strategies, since they can control internal loading in addition to providing direct algal control in some cases.

AECOM staff will use the existing loading and sediment data as well as physical data to evaluate the role of internal loading and the extent of internal load reduction necessary to control algal blooms in Ticklenaked Pond. Assuming that internal load control can indeed limit algal blooms, there are three primary strategies for curtailing the internal load:

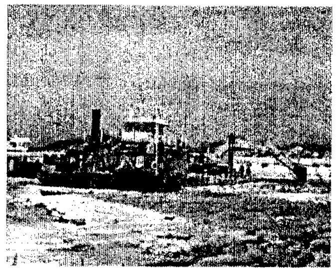
1. Dredging – removal of sediment to expose a layer with lower phosphorus availability
2. Bury phosphorus rich sediments with clean material
3. Phosphorus inactivation –
   - Addition of binders such as aluminum that will lower phosphorus availability
   - Direct Aeration/Oxygenation – elevation of oxygen levels to limit chemical reactions that release phosphorus from the bottom sediments
   - Artificial Circulation – circulation of water to both provide oxygenation (with resultant lowered phosphorus availability) and disrupt planktonic algae growth (often through light inhibition)

The basic approach to evaluating each will include a review of relevant data for Ticklenaked Pond to assess the potential for the above management approaches to yield the necessary level of phosphorus control, an assessment of the range of factors that determine the feasibility for implementation, a review of possible non-target impacts with an estimate of the probability of occurrence of algal blooms or nuisance concentrations, and a cost estimate.

Each of the three primary options has specific data needs for evaluation. There is some overlap, but each has been the subject of review protocol development by the AECOM staff that is summarized in the following sections. Comments are provided at the end of each section with relation to application to Ticklenaked Pond.

2.1 Dredging

Dredging involves the removal of sediment, but is remarkably complicated for what seems like a simple process. Conventional dry, conventional wet, and hydraulic/ pneumatic dredging approaches can be applied to increase depth, but dredging can be an effective lake management technique for the control of excessive algae and invasive growth of macrophytes. The management objectives of a



sediment removal project are usually to deepen a shallow lake for boating and fishing, or to remove nutrient rich sediments that can cause algal blooms or support dense growths of rooted macrophytes. Key aspects include:

Information for Proper Application

Table 1 lists the many considerations applicable to a dredging project. Key factors include:

- Sediment quality, which will determine disposal options and cost
- Sediment quantity, which determines disposal volume needs and greatly affects cost
- Ability to control the lake level, which affects choice of dredging method
- Sensitive biological resources, which affects project goals and permitting
- Monitoring to track system recovery and overall project impacts

Table 2-1. Key Considerations for Dredging

Reasons for Dredging:
Increased depth/access
Removal of nutrient reserves
Control of aquatic vegetation
Alteration of bottom composition
Habitat enhancement
Reduction in oxygen demand

Volume of Material to be Removed:
In-situ volume to be removed
Distribution of volume among sediment types
Distribution of volume over lake area (key sectors)
Bulked volume (see below)
Dried volume (see below)

Nature of Underlying Material to be Exposed:
Type of material
Comparison with overlying material

Dewatering Capacity of Sediments:
Dewatering potential
Dewatering timeframe
Methodological considerations

Protected Resource Areas:
Wetlands
Endangered species
Habitats of special concern
Species of special concern
Regulatory resource classifications

Existing and Proposed Bathymetry:
Existing mean depth
Existing maximum depth
Proposed distribution of lake area over depth range
Proposed mean depth
Proposed maximum depth
Proposed distribution of area over depth range

Physical Nature of Material to be Removed:
Grain size distribution
Solids and organic content
Settling rate
Bulking factor
Drying factor
Residual turbidity

Chemical Nature of Material to be Removed:
Metals levels
Petroleum hydrocarbon levels
Nutrient levels
Pesticides levels
PCB levels
Other organic contaminant levels
Other contaminants of concern (site-specific)

Flow Management:
System hydrology
Possible peak flows
Expected mean flows
Provisions for controlling water level
Methodological implications

Table 2-1 (continued). Key Considerations for Dredging

Equipment Access:
Possible input and output points
Land slopes
Pipeline routing
Property issues

Potential Disposal Sites:
Possible containment sites
Soil conditions
Necessary site preparation
Volumetric capacity
Property issues
Long term disposal options

Uses or Sale of Dredged Material:
Possible uses
Possible sale
Target markets

Potentially Applicable Regulatory Processes:
NEPA review (Environmental Notification Form)
Environmental impact reporting (EIR if needed)
Wetlands Permit (Order of Conditions)
Dredging permits (Title 29, Chapter 11)
Act 250 Permit
Local Project Review
Shoreland Encroachment Permit (29 V.S.A. Chapter 11)
Clean Water Act Section 401 (WQ certification)
Clean Water Act Section 404 (USACE wetlands)
Dam safety/alteration permit (DEC)
Waste disposal permit (DEC)
Discharge permits (NPDES, USEPA/DEC)

Relationship to Lake Uses:
Impact on existing uses during project
Impact on existing uses after project
Facilitation of additional uses

Dredging Methodologies:
Hydraulic (or pneumatic) options
Wet excavation
Dry excavation

Removal Costs
Engineering and permitting costs
Construction of containment area
Equipment purchases
Operational costs
Contract dredging costs
Ultimate disposal costs
Monitoring costs
Total cost divided by volume to be removed

Other Mitigating Factors:
Necessary watershed management
Ancillary project impacts
Economic setting
Political setting
Sociological setting

Performance Guidelines

- Address the many considerations for dredging provided in Table 1; pay particular attention to sediment quality and quantity and disposal arrangements
- Design the dredging project with local conditions in mind; address flow control, appropriate equipment, access and staging areas, material dewatering and transport for disposal
- Excavate in accordance with all permits
- Achieve a depth (light) or substrate (hard bottom) limitation if control of plant growth is a project goal; usually this involves removal of all soft sediment or achievement of a water depth in excess of 10 ft
- Remove sediment to expose a low nutrient layer if reduction of internal loading is a project goal; usually this involves removal of all soft sediment

- Restore or rehabilitate all access, temporary containment, and final disposal areas
- Monitor in-lake water quality during wet dredging
- Monitor downstream flows and water quality during wet dredging
- Monitor recovery of lake biota and in-lake conditions relative to project goals (e.g., depth increase, plant control, water quality enhancement)

Application to Ticklenaked Pond

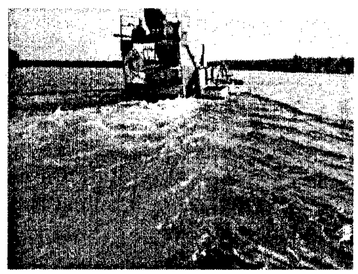
A more complete analysis will be necessary to provide a realistic assessment of the feasibility of using dredging to control internal recycling in Ticklenaked Pond, but the cost is likely to be very high and sediment disposal issues could present a major impediment to success. The capital cost of competing options is so much lower that attempting one or more alternative controls would seem desirable. AECOM will complete this evaluation, but it seems likely that other options would be favored over dredging.

2.2 Sediment Burial

Internal load can be reduced by adding clean fill to limit the interaction between P-rich sediment and the overlying water column. The source of this clean fill can be either from outside the pond or from clean sediment buried under the phosphorus rich sediment (reverse layering). However, this is rarely permitted and can cause other problems, including loss of depth and increased rooted plant growth. This alternative will not be given serious attention unless there is some supported direction to do so.

2.3 Phosphorus Inactivation

2.3.1 Phosphorus Inactivation with binders

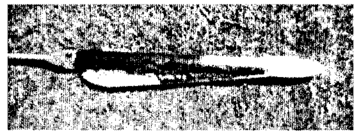


The three most common treatments for lakes employ salts of aluminum, iron, or calcium compounds. Nitrate treatments are very rare and are used to enhance phosphorus binding to natural iron oxides in sediments. For the aluminum, iron and calcium treatments, the typical compounds used include aluminum sulfate ($Al_2(SO_4)_3 \cdot xH_2O$), sodium aluminate ($Na_2Al_2O_4 \cdot xH_2O$), iron as ferric chloride ($FeCl_3$)or ferric sulfate ($Fe_2(SO_4)_3$), and calcium as lime ($Ca(OH)_2$) or calcium carbonate ($CaCO_3$). Additional forms of aluminum are becoming more common.

Inactivators are applied to the surface or subsurface, in either solid or liquid form, normally from a boat or barge. These compounds dissolve and form hydroxides, $Al(OH)_3$, $Fe(OH)_3$, or in the case of calcium, carbonates such as calcite ($CaCO_3$). These minerals form a floc that can remove particulates, including algae, from the water column within minutes to hours and precipitate reactive phosphates. Reactions continue at the surface-water interface, binding phosphorus that could otherwise be released from the sediment. Because aluminum and iron added as sulfates or chlorides dissolve to form acid anions along with the formation of the desired hydroxide precipitates, the pH will tend to decrease in low alkalinity waters unless basic salts such as sodium aluminate or lime are also added. Conversely, calcium is usually added as carbonates or hydroxides that tend to raise pH.

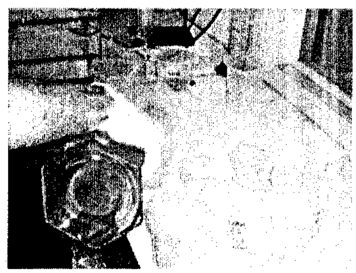
The various floc minerals behave very differently under high or low dissolved oxygen and they also differ in their response to changes in pH. Because of its ability to continue to bind phosphorus under the widest range of pH and oxygen levels, aluminum is usually the preferred phosphorus inactivator. Other binders are applied under specific conditions that favor their use, but not as commonly as aluminum.

Information for Proper Application



- An accurate nutrient budget that includes a detailed analysis of internal sources of phosphorus
- Sediment testing for available sediment phosphorus
- Recent information on pH and alkalinity at all depths to properly predict potential changes in pH and to minimize impacts
- Knowledge of lake oxygen regime and biotic components is helpful in planning treatments
- An accurate depth map of the lake is required to properly evaluate dosing
- In addition to jar tests to establish doses and ratios of chemicals, toxicity tests with a sensitive fish species may be desirable
- Monitoring of pH, alkalinity and any biotic reactions is appropriate during treatment, with follow-up monitoring if any deviations from the expected range are detected
- Estimates of effectiveness should be made for lake recovery in terms of total phosphorus levels and Secchi disk transparency.
- For deep lakes, hypolimnetic dissolved phosphorus concentration should decrease dramatically and should be checked.

Performance Guidelines



- Develop reliable phosphorus budget that demonstrates magnitude of internal loading
- Determine dose necessary to inactivate targeted phosphorus (water column or sediment)
- Determine chemicals to be used; consider oxygen regime and minimize shift in pH unless naturally outside range of 6.0 to 8.0 SU
- Secure appropriate access for equipment and chemicals; adhere to materials handling regulations in the transfer of chemicals to application equipment
- For larger lakes, treat non-contiguous sections of the lake on sequential days
- For higher doses of aluminum, split treatment to yield calculated in-lake aluminum level <10 mg/L on any day
- In pH sensitive lakes with anoxic hypolimnia, consider injecting aluminum at or below the thermocline during stratification

- Monitor phosphorus, the inactivator compound, pH, alkalinity, water clarity, algae, zooplankton, benthic invertebrates and fish before, during and after treatment as appropriate to determine impacts to sensitive resources.

Application to Ticklenaked Pond

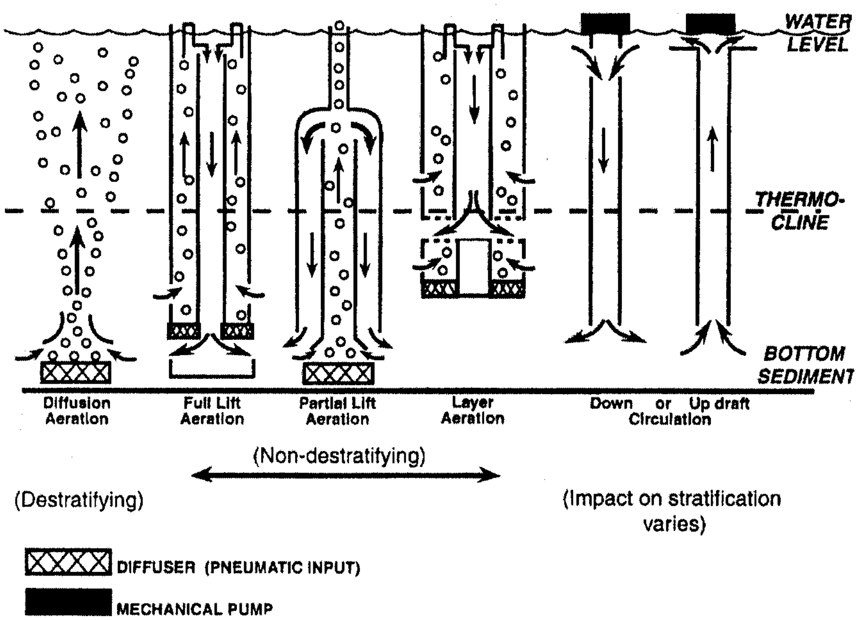
Phosphorus inactivation should be very applicable to Ticklenaked Pond, and would most likely involve aluminum compounds, unless oxygenation is determined to be a desired component of the program, in which case iron should be considered. The available data for sediment phosphorus fractions is quite suitable to the assessment. The rate of phosphorus replacement from external inputs remains an open question for us. It seems likely; however, that aluminum inactivation of sediment phosphorus reserves can be accomplished at a reasonable cost with lasting impact. A careful evaluation of necessary dose, application methods, possible non-target effects, and longevity of results is needed to advance this approach. It would be very useful to have detailed dissolved oxygen profile information in the pond during the summer period when internal loading is at a maximum. We strongly suggest that at minimum dissolved oxygen and temperature profiles are collected at biweekly intervals through August and September of this year to aid in the evaluation of phosphorus inactivation as well as oxygenation and mixing described below. Because algal productivity is so high in the pond, it may also be useful to examine diurnal dissolved oxygen fluctuations by profile in the early morning and again in the mid-afternoon.

2.3.2 Oxygenation

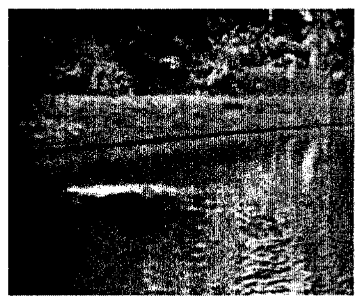
Aeration puts air into the aquatic system, increasing oxygen concentration by transfer from gas to liquid and generating a controlled mixing force. The oxygen transfer function is used to prevent anoxia, usually in a hypolimnion, but potentially in the whole water column where there is no strong stratification. By keeping the hypolimnion from becoming anoxic during stratification, aeration should minimize the release of phosphorus, iron, manganese and sulfides from deep bottom sediments and decrease the build-up of undecomposed organic matter and oxygen-demanding compounds (e.g., ammonium). Hypolimnetic aeration can also increase the volume of water suitable for habitation by zooplankton and fish, especially coldwater forms. Pure oxygen can be used in place of air to maximize oxygen transfer at an increased cost.

A full lift hypolimnetic aeration approach moves hypolimnetic water to the surface, aerates it, and replaces it in the hypolimnion. A partial lift system pumps air into a submerged chamber in which exchange of oxygen is made with the deeper waters. The newly oxygenated waters are released back into the hypolimnion without destratification. An alternative approach involves a process called layer aeration. Water can be oxygenated by full or partial lift technology, but by combining water from different (but carefully chosen) temperature (and therefore density) regimes, stable oxygenated layers can be formed anywhere from the upper metalimnetic boundary down to the bottom of the lake. Each layer acts as a barrier to the passage of phosphorus, reduced metals and related contaminants from the layer below. A variety of other approaches can be used to add oxygen and destratify the system at the same time (Figure 1).

Figure 2-1. Methods of Artificial Circulation and Aeration (from Wagner, 2001)



Information for Proper Application



- Data requirements for this type of nutrient control include an accurate nutrient budget with a detailed analysis of internal sources of phosphorus
- The most critical information for designing an aeration system is the oxygen demand that must be met by the system; calculations and related interpretation for design purposes are best performed by experienced professionals
- Lake morphometry and stratification data are needed to facilitate choice of aerator features and placement of aerators for maximum effectiveness
- Location and details of compressor and power source are needed

Performance Guidelines

- Determine oxygen demand to be counteracted
- Properly size equipment; avoid over - or underpowering
- Properly place equipment; avoid over- or underspacing
- Develop a maintenance plan for equipment

- Operate equipment in accordance with management goals to achieve temporal or spatial results as planned
- Monitor temperature and oxygen as indicators of mixing and aeration, and other water quality or biological variables as necessary to evaluate success

Application to Ticklenaked Pond

An evaluation of current mixing and oxygen regime is needed before any definitive conclusions can be drawn. Aeration, either for direct oxygen input, indirect oxygenation by exposure to the atmosphere, or simple mixing to disrupt algal growth, has substantial benefits and few drawbacks. The primary issues will be level of effectiveness (usually slightly less than for inactivation) and long-term cost (operation and maintenance will require annual expenses). If altering the oxygen regime is viewed as a worthwhile goal, however, this approach offers advantages over the others. As suggested above under alum treatments, the collection of dissolved oxygen and temperature profiles through August and September would greatly improve the evaluation of this alternative.

2.3.3 Artificial Circulation

Algal blooms are sometimes controlled by destratification through one or more of the following processes:

- Introduction of dissolved oxygen to the lake bottom may inhibit phosphorus release from sediments, curtailing this internal nutrient source.
- In light limited algal communities, mixing to the lake's bottom will increase the time a cell spends in darkness, leading to reduced photosynthesis and productivity.
- Rapid circulation and contact of water with the atmosphere, as well as the introduction of carbon dioxide rich bottom water during the initial period of mixing, can increase the carbon dioxide content of water and lower pH, leading to a shift from blue green algae to less noxious green algae.
- Turbulence can neutralize the advantageous buoyancy mechanisms of blue-green algae and cause a shift in algal composition to less objectionable forms such as diatoms.

- When zooplankton that consume algae are mixed throughout the water column, they are less vulnerable to visually feeding fish. If more zooplankters survive, their consumption of algal cells may also increase.

Information for Proper Application

- An accurate nutrient budget with a detailed analysis of internal P sources
- Data related to each of the five possible control mechanisms (oxygenation/P inactivation, light limitation, pH/carbon source adjustment, buoyancy disruption, and enhanced grazing) should be analyzed and evaluated in terms of potential algal control. Specifically,

a) Is there anaerobic release of phosphorus that can be mitigated by oxygenation of deep waters?

b) Is the mixing zone deep enough to promote light limitation of algae?

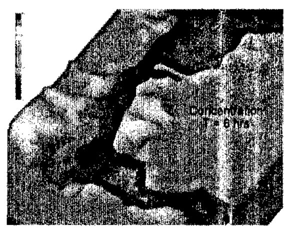
c) Is there a large amount of carbon dioxide in the bottom waters that could be mixed to the surface to favor the growth of non-blue-green algae?

d) Is mixing predicted to counteract the buoyancy advantage of blue-greens over other algae?

e) Will a dark, oxygenated refuge be created for zooplankton?

- Reliable estimate of the oxygen demand that must be met by the system
- Reliable estimate of the amount of air necessary to mix/destratify the lake
- Lake morphometry data that facilitates choice of aerator type and placement of aerators for maximum effectiveness
- Location and details of compressor and power source
- Monitoring to track oxygen and nutrient levels after implementation
- Monitoring to track water clarity and algal types and quantity

Performance Guidelines



- Determine goals for circulation; if oxygenation is desired, oxygen demand must be determined; if destratification is desired, necessary mixing force must be determined
- Properly size equipment; avoid over - or underpowering
- Properly place equipment; avoid over- or underspacing
- Develop a maintenance plan for equipment
- Operate equipment in accordance with management goals to achieve temporal or spatial results as planned
- Monitor temperature and oxygen as indicators of mixing and aeration, and other water quality or biological variables as necessary to evaluate success

Application to Ticklenaked Pond

It may be possible to mix the algal cells deep enough in the water column of Ticklenaked Pond to disrupt growth. Mixing is also applied to keep oxygen levels high enough to let natural binders control phosphorus availability, and may have merit in this system, pending a review of current oxygen regime and related phosphorus availability. Mixing should at least prevent dense scum formation, a factor in taste, odor and toxin issues. We generally regard this approach as less advantageous than controlling the phosphorus directly, but the cost:benefit ratio is sometimes favorable. As suggested above under alum treatments, the collection of dissolved oxygen and temperature profiles through August and September of this year would greatly improve the evaluation of this alternative.

2.4 Combination Approaches

Almost any of the above techniques can be used in combination, and other techniques (algaecides, sonication, dyes) exist as well. Other than combining aeration with use of iron for phosphorus inactivation, however, the above techniques are meant to be stand alone solutions to internal loading problems. We will certainly consider all options and possible combinations, but do not expect to need more than one of the above techniques to control internal loading and related algal blooms.

2.5 Project Elements

As the method for internal load reduction has not yet been selected, it is difficult to identify all project elements in any specific fashion. Certain generalities apply, however, and considerations for each possible approach can be listed.

Design

Design tasks consist of determining the means of application and an array of contingencies that allow safe and effective application. For dredging, the mode of dredging (most likely hydraulic) must be supported by design of staging areas, temporary containment and ultimate disposal areas, return water quality control, and management of obstructions and water depth. Some key considerations were presented in Section 2.1.

For aeration strategies, the primary consideration is the amount of oxygen needed to counter the oxygen demand that leads to conditions under which P is released from the sediments, but there is a key assumption that enough natural P binders are present to inactivate the P if oxygen is adequate. All assumptions must be checked. If the key assumption holds true, the major design factors include maintenance or destruction of stratification, use of oxygen or air, delivery mechanisms for the air/oxygen, and physical distribution of release points. Some key considerations for non-destratifying aeration are contained in Section 2.3.2.

For mixing strategies, which overlap with but are not identical to aeration approaches, the key factor is moving enough water to eliminate gradients that support P release and/or algal blooms. It is possible to mix and disrupt blooms without a major reduction in P, but the most effective approaches are likely to add enough oxygen to enhance natural binding and reduce P concentrations. Design factors include mixing mode (air, various mechanical options), volume of water moved over time, placement of structures, and continuity of mixing during the target period (summer). Some key considerations are contained in Section 2.3.3.

Cost Analysis

AECOM will prepare a preliminary cost analysis to facilitate comparison among options. A more detailed cost estimate will be prepared for the chosen approach.

Implementation Timeline

AECOM will prepare a timeline for implementation, including the design and permitting phases, each step in implementation, monitoring, and adjustment over time to ensure continued success in meeting goals.

Permit Applications

It is difficult to predict which permitting processes will apply until the method of internal load reduction is chosen, but at that time we will list all applicable permit processes and prepare the corresponding submissions. Not knowing which method will be chosen, this is a difficult task for which to budget. As a result, an average level of effort for permitting has been budgeted. Once the final alternative is chosen, AECOM will discuss permitting with the ANR and fully scope permitting costs associated with the chosen alternative. Any changes in the level of effort will be discussed with ANR prior to commencing work on the permitting phase.

Longevity Projections

AECOM will estimate the longevity of any technique recommended for reduction of internal loading to Ticklenaked Pond. Estimating how long any implementation of internal loading reduction will last is integral to assessing the efficacy of that implementation, and may have bearing on which approach is chosen. We will apply a model developed for this purpose, utilizing the information in the TMDL for current and projected future external loading, to predict the duration of benefits from each proposed alternative for internal load control. This model has been applied successfully in several other projects, most notably the Long Pond P inactivation project on Cape Cod, MA (Figure 1).

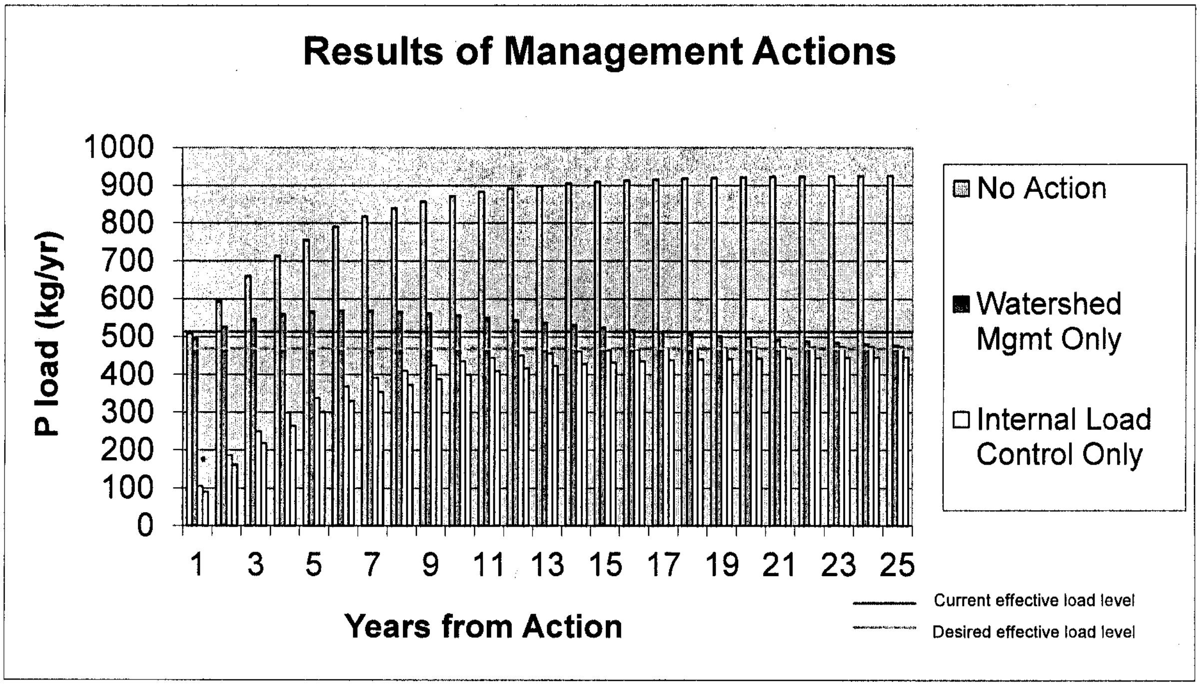


Figure 2-2. Example of longevity projection for phosphorus inactivation from Long Pond, Massachusetts.

3.0 Tasks and Schedule

AECOM has split the project into 5 tasks. The results of Tasks 1 and 2 will be delivered in the winter of 2010-2011 as a data evaluation report which will give an assessment of the "readiness' of the pond for treatment of the internal load. Tasks 3 and 4 will include a report which includes the feasibility study and a status update on the watershed phosphorus control projects. The tasks are presented below and a budget by task is presented in Section 4. An optional task includes the costs associated with collecting and analyzing sediment samples for detailed evaluation of phosphorus inactivation. Should alum be the preferred alternative, analytical results from this task will be critical to completion of the detailed feasibility study of alum.

1. Summarize available information from the TMDL and other sources as relates to an analysis of internal load control options and longevity of results from implementation. This task will also include a kickoff meeting with ANR staff and a site visit to the pond.
2. Evaluate the readiness of the pond for internal load control, based on watershed loading status and effectiveness of implemented or planned external loading controls.
3. Evaluate options for internal load control including dredging, aeration/mixing, and chemical inactivation of P.
4. Recommend the most advantageous approach to internal P load control and provide detailed design information, a cost estimate, an implementation schedule, a longevity analysis, and permit needs. Identify any data gaps and a plan for filling any such gaps. We are assuming that there will be one meeting with ANR associated with discussing the findings of Task 3 and this task.
5. Provide permit submissions to facilitate implementation.

Optional Task. Sample sediments for available phosphorus and binders and perform alum jar tests.

Task and Schedule Assumptions

1. Project will be awarded and begin in early fall 2010.
2. Project will be completed by June 2011.
3. All monitoring data and reports will be available in electronic form.
4. Optional sampling and laboratory testing of sediment will assist in the preliminary screening of alternatives and is recommended for a more complete assessment. This sampling could be completed in conjunction with the site visit/kickoff meeting included as a part of Task 1.

4.0 Budget

The budget detailed below was developed using year 3 rates provided as a part of the master contract with Vermont ANR.

Table 4-1. Project Budget

Task	Task Total
1. Data Summary	$6,215.00
2. Watershed Status Evaluation	$6,990.00
3. Internal Load Control Evaluation	$6,990.00
4. Recommended Option Evaluation	$11,881.00
5. Permit applications	$10,364.00
Total without option	**$42,440.00**
6. Optional Sediment Sampling	$5,435.00
Total with option	**$47,875.00**