Action Plan for the Town of Eastham Ponds

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Action Plan for the Town of Eastham Ponds

1 Executive Summary

The Action Plan for the Town of Eastham Ponds is one component of a comprehensive nutrient management initiative underway in this Cape Cod community. Inland kettle ponds are a unique resource throughout Cape Cod, and their water quality and habitat condition are threatened in many areas by the impacts of human activities. Eleven kettle ponds in the Town of Eastham are the focus of this Action Plan; these include Great, Herring, Depot, Little Depot, Widow Harding, Ministers, Schoolhouse, Molls, Bridge, Muddy and Jemima Ponds. The Ministers and Schoolhouse Ponds are considered as one system for the purposes of this evaluation.

Existing conditions are reviewed; we evaluated current water quality and habitat conditions with respect to the ponds' desired uses, from both a human and ecological perspective. Potential sources of phosphorus, the nutrient that controls water quality conditions in most inland kettle ponds, were identified. The data sources for the assessment of current conditions include the Cape Cod Commission's detailed review of pond water quality conditions, as measured between 2001 and 2006 (Eichner 2009). Additional sources of data and information included PALS and National Seashore monitoring data from 2008 – 2010, beach monitoring for bacterial counts, and an August 2011 field assessment and sampling program.

The Action Plan includes an evaluation of alternatives; we review a suite of potential remedial measures, designed to improve the ponds' water quality and habitat conditions. Each alternative is screened for its applicability and potential effectiveness for the 11 Eastham ponds. The results of remedial efforts applied to other Cape Cod kettle ponds are used to help inform this alternatives evaluation.

The alternatives evaluation culminates in a series of recommendations for remedial measures. These measures include an alum treatment program for Herring Pond (top priority) and Great Pond. Enhanced mixing is recommended for several of the smaller ponds, notably the interconnected Ministers and Schoolhouse Ponds.

A matrix to help determine priorities among the ponds for their remedial measures is included. Criteria for setting priorities include the following factors: current water quality and habitat conditions and the extent of use impairment, the outlook for future water quality and habitat conditions in the absence of intervention, pond size, public access and ownership, and prior investment of public funds in restoration. Additional criteria may be added to reflect Town policy and priorities.

Appended to the Pond Action Strategy is a series of Fact Sheets, outlining key features of each of the 11 ponds. As well, we include Fact Sheets summarizing several of the recommended remedial measures.

2 Introduction

2.1 Scope of the Assignment

This report summarizes the current water quality and aquatic habitat conditions of eleven inland freshwater ponds located in the Town of Eastham, Massachusetts, and recommends priority actions to ensure the ponds' protection and restoration. The Town of Eastham is currently working with GHD of Hyannis, Massachusetts to prepare a comprehensive nutrient management strategy to protect both public health and environmental health, including the quality of the coastal embayments, inland freshwater ponds and groundwater. This action strategy for the freshwater ponds is one component of the overall nutrient management initiative. EcoLogic LLC and GHD have teamed to work with the Town of Eastham on this assignment.

The recommendations reflect an evaluation of the effectiveness (both short-term and long-term), costs, environmental benefits and risks, permitting issues and recreational impacts for a range of remedial measures. Two public meetings were held in August, 2011 to gather community input on criteria for screening remedial actions. The screening criteria applied in this report reflect local input and priorities.

Because other towns on Cape Cod have been similarly concerned with kettle pond restoration and protection, local case studies of the effectiveness of remedial measures were used to inform the recommendations for Eastham. The recommended actions include institutional, technical and public education components. Some recommendations are town-wide, while others are directed to specific ponds. An implementation strategy, including priority actions and an overall timeline, is presented for consideration by Town of Eastham officials.

2.2 Wastewater Management Planning in Eastham – Existing Conditions

The Action Plan for the Town of Eastham Ponds is an extension of the Town's Wastewater Management Planning Project; this project has been underway since 2008. In March 2009, GHD (formerly Stearns & Wheler) completed the Needs Assessment Report which went through extensive public review. This report is available on the Town's website and a hard copy is available at the Health Department, located in the Town Hall. GHD engineers documented the community's wastewater needs from two perspectives, human health and environmental health, as described below.

Human Health Needs. Nearly all of the properties in Town are served by individual water supply wells and individual septic systems on the same lot. Groundwater in the vicinity of these private wells can be affected by septic effluent and other land use activities (car washing, automotive storage, fertilizer application, pesticide use, etc.) on the small lots. The potential presence of contamination is indicated by elevated nitrate levels detected in the wells. Nitrate is a human health threat; but, more importantly, it indicates the possible presence of wastewater-related contaminants such as viruses, volatile organic carbons, pharmaceuticals, phosphorus, personal care products, etc. in the drinking water. Based on these findings, it was determined that the Town needs to protect the public health by providing a reliable public water supply from a protected source.

Environmental Health Needs. The groundwater system with its elevated nitrogen and phosphorus concentrations recharges into several coastal estuaries and freshwater ponds; the nitrogen acts as a fertilizer in the estuaries, and the phosphorus acts as a fertilizer in the ponds. This "over fertilization" stimulates the growth of algae, which in turn causes several water quality problems in these surface waters including:

- loss of water clarity which makes swimming, fishing, and boating less attractive;
- algae settling to the bottom of the estuaries and ponds where it decays, using up dissolved oxygen (DO) in the process. The impacts of decaying algae and associated low DO can kill fish and shellfish;
- loss of animal habitat and the production of odors from the rotting algae.

State, Federal and regional agencies are now setting nutrient limits (called Total Maximum Daily Loads or TMDLs) on the amounts of nitrogen that can go into an estuary. They have determined that septic system discharges into the estuarine watersheds are the main sources of nitrogen to these water bodies. The limits are still being developed, but evaluations indicate:

- 55 percent of the current wastewater nitrogen discharges need to be removed from the Nauset-Town Cove Estuary Watershed to restore and manage long-term water quality.
- 79 percent of the current wastewater nitrogen discharges need to be removed from the Rock Harbor Estuary Watershed to restore and manage long-term water quality.

In addition to the potential impacts on the coastal ecosystem, Eastham has several watersheds that recharge to inland freshwater ponds. These watersheds have dense residential development that is discharging phosphorus from individual septic systems to the groundwater system, and this phosphorus is entering the ponds. Over time, the increasing phosphorus has led to a decline in water quality. The Cape Cod Commission (CCC) completed an evaluation of several ponds (discussed in detail later in this report) indicating that most of the phosphorus in the inland ponds originates from septic systems. The CCC has further concluded that most of the ponds fail to attain minimum thresholds in the State's surface water regulations, and all of the ponds have average phosphorus concentrations that exceed the CCC criterion for "healthy ponds", set at 10 parts per billion.

The findings of prior investigations framed the scope of this Eastham Ponds Action Strategy. Wastewater needs were evaluated in detail as summarized in the June 2009 Plan Evaluation Report (also available on the Town's website and in the Health Department). Three alternative wastewater management plans were evaluated to address the environmental health needs of the ponds. Two of the plans utilized wastewater collection and treatment technology to prevent additional phosphorus entering the watershed. These alternatives had costs of approximately $50,000 per property served; this estimate was based on the recent wastewater project in the New Silver Beach area of Falmouth. The third alternative utilized in-pond treatment to mitigate the effects of phosphorus. The frequency, potential efficacy and costs of the in-pond treatments need to be evaluated on a pond by pond basis, but costs were expected to be significantly less than installing sewers and providing advanced treatment. Based on an evaluation of treating the ponds with alum (an in-pond treatment technology that is a common practice on Cape Cod for these problems) a cost of $1,500 per property in the watershed was estimated (based on recent alum treatment of two ponds in Chatham). This was significantly less than the typical cost of $50,000 per property for wastewater treatment.

Comparing the cost of sewering with the cost of in-pond treatment (with alum) it was clear that in-pond treatment would be more cost effective even if required on a periodic basis. In-pond treatment has the added benefit that it treats the problems that already exist in the ponds which sewering cannot do. Although the in-pond treatment will not treat the on-going source of the phosphorus (septic systems in the watersheds), it will temporarily restore the environmental health of the ponds faster and in a more cost-effective manner.

In light of this information, the Town of Eastham decided to evaluate the detailed feasibility, costs, risks and benefits of proceeding with in-pond management strategies to address water quality and habitat degradation issues evident in some of the kettle ponds.

2.3 Report Organization

The Eastham Ponds Action Plan is organized into four sections and four appendices.

Section 2 (*existing conditions- intuitional framework*) describes the rationale for developing the Action Plan, and summarizes how this effort fits in with the comprehensive wastewater needs assessment and planning initiatives.

Section 3 (*existing environmental conditions*) summarizes the environmental setting of the Eastham ponds, and describes the importance of phosphorus to the kettle pond ecosystems. The concepts of eutrophication and its potential adverse impacts are explained. Water quality data from various sources are compiled and evaluated with respect to attainment of designated uses in the 11 ponds.

Section 4 (*evaluation of alternatives*) outlines the potential remedial measures available to control eutrophication and mitigate its impacts on pond ecosystems. The criteria for selecting among remedial measures are introduced, and a matrix is presented to evaluate the applicability of specific measures to specific ponds. This section ends with a series of specific recommended actions for Town officials to consider.

Section 5 (*recommendations*) outlines an implementation strategy, including recommendations for priority actions.

Appendices provide summary “fact sheets” for each of the ponds (Appendix 1), and for each of the recommended remedial measures (Appendix 2). Details of the EcoLogic field investigations of August, 2011 are included as Appendix 3. Results of laboratory testing of sediment and water quality from the August 2011 event are included as Appendix 4.

3 Environmental Setting

3.1 Ponds Selected for Inclusion

The Town of Eastham has 23 inland freshwater ponds, with a total surface area of 258 acres. Of these 23 ponds, seven are extremely small, surface area less than one acre, and five have a surface area larger than 10 acres. The Commonwealth of Massachusetts classifies ponds larger than 10 acres as "Great Ponds"; these waterbodies are owned by the Commonwealth and held in trust for the public. Great Ponds are subject to Chapter 91 of Massachusetts General Law, known as the Massachusetts Public Waterfront Act. By this Act, the Commonwealth seeks to preserve and protect the rights of the public to access the waters held in trust, and to guarantee that private uses of tidelands and waterways serve a proper public purpose.

The Water Management Task Force identified 11 kettle ponds for inclusion in this Action Plan (Figure 3-1). The ponds are: Great, Herring, Schoolhouse, Depot, Little Depot, Widow Harding, Molls, Jemima, Minister, Bridge and Muddy Ponds. Physical attributes are summarized in Table 3-1. Delineations of the ponds' watersheds are depicted in Figure 3-2.

Table 3-1. Size, depth, watershed area and volume of 11 Eastham ponds.
Ponds listed in bold (blue) font are classified as Great Ponds in Massachusetts (surface area 10 acres and larger).

Pond	Surface Area (Acres)	Maximum Depth (ft.)	Watershed Area (Acres)	Volume (million gallons)
Bridge	6.7	20	7.9	22*
Depot	27.9	33	65	159
Little Depot	2.3	11	2.3	4*
Great	109.7	43	226	431
Herring	44.2	39	80	235
Jemima	6.4	15	18	16*
Ministers **	16.8	14	151	33
Schoolhouse**	5.6	15	5.7	10
Molls	3.4	12	8.1	7*
Muddy	10.5	5	40	12
Widow Harding	8.7	13	26	18*

*Ponds designated with an asterisk have a less precise estimate of volume (bathymetric maps not available)

** Ministers and Schoolhouse are considered one pond complex, with two deep basins

3.2 Kettle Ponds

Most of the inland freshwater ponds of Cape Cod are kettle ponds, formed as depressions left behind by ice blocks as the glacial ice retreated between 14,000 and 17,000 years ago. According to Portnoy et al. (2001), while kettle ponds have a common glacial origin, their subsequent evolution differs based on the depth of the original ice block, landscape position relative to sea level, and the texture (particle size) of the soils in the ponds' watersheds.

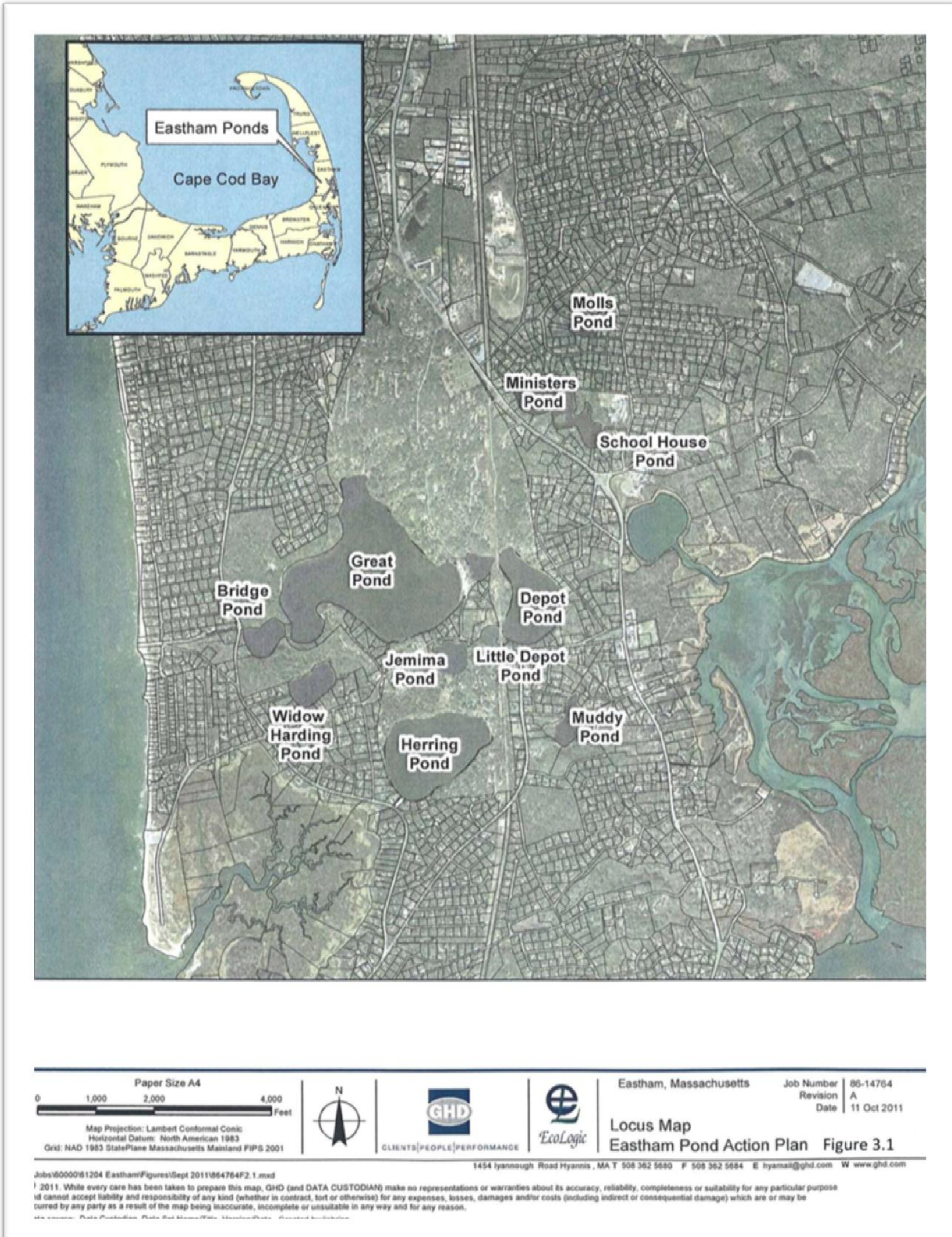

Figure 3-1 Locus Map - Eastham Freshwater Ponds

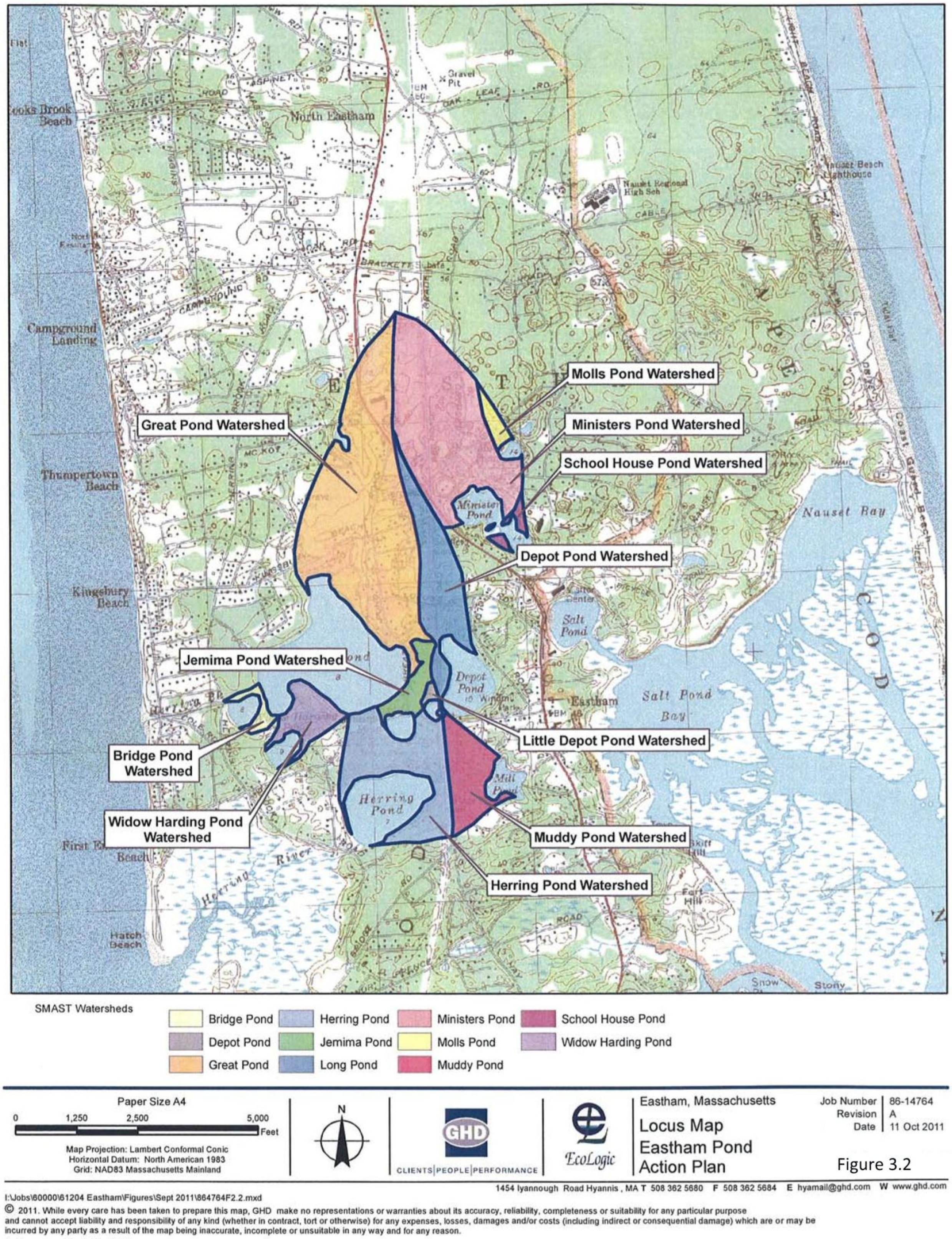

Figure 3-2 Eastham Freshwater Ponds - Watershed Areas

Cultural effects are also to be added to this list; the ponds of Cape Cod are influenced by the amount and type of development in the watershed, presence of exotic species, application of lime to raise the naturally low pH of the waters, and agricultural and fisheries management practices.

Unlike most lakes and ponds, most kettle ponds do not have prominent tributary streams (inlets) and outlets (Figure 3-3). Groundwater inflow and direct precipitation, rather than surface water flows, are the source of water to the kettle ponds. The quality of the water in the ponds, therefore, is directly affected by the quality of the groundwater resource.

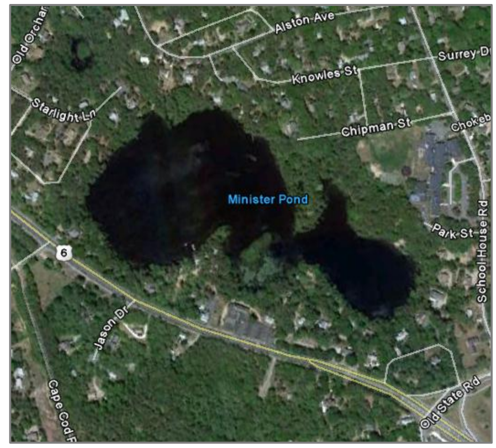

Figure 3-3 Kettle pond in Eastham

The lack of defined inlets and outlets for most kettle ponds has some important implications for the cycling of nutrients and organic material. Nitrogen and phosphorus enter the ponds primarily as dissolved nutrients where they are incorporated into biomass. Water leaves the ponds through groundwater outflow and evaporation. Particulate biomass consequently remains in the ponds, and the nutrients continue to cycle through the food web. Through this natural phenomenon, kettle ponds become increasingly enriched over time, as there is little opportunity for particulate material to leave the system.

Ponds deeper than about 5 m (16 ft.) typically exhibit some degree of thermal stratification during the summer. Bottom waters isolated from the atmosphere become depleted of oxygen as the microbial community decomposes organic material that settles to the lake bottom. As ponds become more fertile, oxygen depletion is evident higher in the water column during periods of thermal stratification.

The Cape Cod Commission reviewed dissolved oxygen (DO) profiles collected in 1948 and 2001 from 41 deeper kettle ponds. DO concentrations in the lower waters of 76% of these ponds had declined, providing strong evidence of increasing level of fertility in the ponds over the intervening five decades (Cape Cod Commission, May 2003 p. 46).

The shallowest of the inland kettle ponds do not develop stable thermal stratification, because the winds are able to keep the water column mixed from top to bottom. As a consequence, oxygen added to the pond from the atmosphere and from photosynthesis mixes throughout the water column and the waters remain oxygenated.

Ponds deep enough to stratify and productive enough to experience seasonal anoxia have elevated concentrations of phosphorus in the lower waters, due to the chemical changes at the sediment surface that occur during anoxia. Due to these chemical changes, phosphorus in dissolved form is released from sediments to the overlying waters. In some lakes, wind-induced mixing and internal waves may draw the phosphorus-rich water into the upper sunlit layer where the nutrient can support algal growth (the photic zone) during the summer. Some shallower ponds may also be susceptible to the effects of internal phosphorus loading during summer. As waters cool in the fall, the density gradients that prevented wind mixing break down and the phosphorus-rich layer is mixed into the water column of all ponds, regardless of depth.

Another important consideration for the kettle ponds of Eastham is that the shallow ponds have extensive wetland/littoral zones and macrophyte communities. Cooke et al. (1993) point out that the complexity of nutrient flux and food web interactions at the sediment-water interface in highly productive shallow regions of lakes and ponds cannot be ignored. Nutrient cycling and biological interactions in shallow, weedy sections of the ponds may contribute to maintaining elevated nutrient levels and undesirable plant growth long after external loading controls have been implemented.

3.3 Phosphorus and Eutrophication

Eutrophication, the term for both the process and the effects of increased nutrients in surface water (including lakes, ponds, estuaries, and reservoirs), is a significant water quality concern. As the nutrient supply increases, aquatic systems support more plant and algal growth. As organic material and silt increase, the ponds' volume decreases. Aesthetic quality and habitat conditions are degraded, and affected waters may no longer be suitable for drinking water or recreation. The habitat for the aquatic biota is altered and certain species, such as cold water fish, may no longer survive as eutrophication proceeds.

Eutrophication is a natural process that can be greatly accelerated by human activities. There are numerous lakes and ponds included in the Commonwealth of Massachusetts compendium of impaired waters; most are listed due to excessive nutrient inputs from sources such as agricultural or urban runoff, or groundwater inflow from on-site wastewater disposal systems. Less frequently, the impairment of surface waters is attributed to excessive discharge of nutrients from inadequately treated wastewater, either industrial or municipal.

Water resources managers focus on identifying and controlling the sources of nutrients, organic material, and silt to aquatic ecosystems in an effort to slow the eutrophication process. Phosphorus is most often the limiting nutrient for primary productivity and algal growth in inland lakes and ponds. While phosphorus is the key to managing eutrophication of inland ponds, nitrogen is usually the limiting nutrient for primary production of coastal ecosystems. Nitrogen enrichment has resulted in degradation of estuarine and marine water quality and habitat conditions, and wastewater is a major source of nitrogen. Scientists and regulators from the EPA, the Mass DEP, the academic community and the Cape Cod Commission have supported the coastal municipalities in a systematic process to define the need for and extent of reductions in nitrogen loading (MA DEP 2003 "The Massachusetts Estuaries Project Embayment

Restoration and Guidance for Implementation Strategies”). Findings of this analysis are now being incorporated into land use and facilities decisions across Cape Cod.

Limnologists have developed guidelines to delineate the transition between trophic states based on phosphorus, water clarity, chlorophyll-a, and deep water dissolved oxygen concentrations (Table 3-2); these are applicable to freshwater bodies where the supply of phosphorus controls algal production. These guidelines will be used to assess the Town of Eastham ponds. ***Oligotrophic*** ponds are low in nutrients and aquatic plant and algal abundance; ***eutrophic*** ponds have a large supply of nutrients to support plants and algae. The term ***mesotrophic*** is used to describe ponds at an intermediate level of nutrients and production.

Table 3-2. Trophic State Indicator (TSI) Parameters

		TSI Calculation (where ln = natural logarithm)	***TSI(TP) = 14.42 ln(TP) + 4.15***	***TSI(CHL) = 9.81 ln(CHL) + 30.6***	***TSI(SD) = 60 – 14.41 ln(SD)***
Trophic State	**Calculated TSI Values**	**Attributes and Recreational Use**	**Total Phosphorus Concentration Range**	**Chlorophyll-a Concentration Range**	**Secchi disk transparency**
Oligotrophic	<30-40	Clear water, oxygen throughout the year in the hypolimnion. At TSI >30, hypolimnia of shallower lakes may become anoxic. Salmonid fisheries.	<6 to 12 µg/l	<0.95 to 2.6 µg/l	>8 to 4 m
Mesotrophic	40-50	Water moderately clear; increasing probability of hypolimnetic anoxia during summer. Hypolimnetic anoxia results in loss of salmonids.	12 to 24 µg/l	2.6 to 7.3 µg/l	4 to 2 m
Eutrophic	50-70	Anoxic hypolimnia, macrophyte problems possible. At TSI >60, blue-green algae dominate, algal scums and macrophyte problems. Warm-water fisheries only. Bass may dominate. At TSI >60, nuisance macrophytes, algal scum, and low transparency may discourage swimming and boating.	24 to 96 µg/l	7.3 to 56 µg/l	2 to 0.5 m
Hypereutrophic	>70	Light limited productivity. Dense algae and macrophytes. Rough fish dominate; summer fish kills possible.	96 to 384 µg/l	56 to >155 µg/l	0.5 to <0.25 m

after Carlson and Simpson (1996); Carlson TSI was developed using data from temperate lakes.

The USEPA has initiated an effort to develop *ecoregional criteria* for the trophic state parameters, designed to reflect the variability conditions of watershed geology, land use, climatic conditions, biological assemblages and hydrologic setting. These ecoregional criteria are used to define thresholds for impacted and non-impacted conditions, and represent starting points for states to develop more refined criteria and standards for nutrients. Ecoregional criteria for Cape Cod ponds have been described in the Cape Cod Pond and Lake Atlas (Cape Cod Commission, May 2003); the values (designated as subregion 84) were derived from a statistical evaluation of existing water quality conditions of pristine ponds located in coastal New England, including Cape Cod (USEPA 2001). The ecoregional criteria proposed for Cape Cod ponds (Table 3-3) were derived from the 2001 PALS data.

Table 3-3. Ecoregional Criteria

Parameter	Ecoregion XIV sub ecoregion 84 Reference Condition Threshold[1]	Cape Cod Ponds Thresholds based on 2001 PALS Data[2]
Secchi depth	≥2 m	Not calculated
Chlorophyll-a	≤6 µg/l	≤1.7 µg/l
Total Nitrogen	≤0.41 mg/l	≤0.31 mg/l
Total Phosphorus	≤9 µg/l	≤10 µg/l

[1] USEPA 2001, Table 3c. 25th percentile based on annual data for the decade; 75th percentile for Secchi disk transparency.

[2] Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

3.4 Current Water Quality and Trophic State Conditions

3.4.1 Sources of data and information

The Cape Cod Commission completed a detailed review of water quality conditions of the Eastham ponds, as measured between 2001 and 2006 (Eichner 2009). This report served as a primary reference for the characterization of the ponds and evaluation of the need for remedial measures. The CCC report was supplemented with review of recent water quality data (2008 – 2010), results of beach monitoring for bacterial counts, and a focused field monitoring effort in August, 2011 (Table 3-4).

Table 3-4. Data Sources Used to Develop Eastham Ponds Action Plan

Named Pond[1]	CCC GIS ID[2]	Eichner, 2009[3]	CCC Atlas: description[4]	CaCo WQ Data[5]	PALS WQ Data[6]	Beach bacteria testing[7]	2011 Field Assessment[8]
Bridge	EA-98	R	R	R	R		R
Depot	EA-96	★	R	R	R	R	R
Little Depot	EA-99		R	R	R		R
Great	EA-95	★	R	R	R	R	R
Herring	EA-103	★	R	R	R	R	R
Jemima	EA-100	R	R	R	R		R
Minister	EA-92	★	R	R	R	R	R
Molls	EA-91	R	R	R	R		R
Muddy	EA-102	★	R	R	R	R	R
Schoolhouse	EA-93	★	R	R	R		R
Widow Harding	EA-101	R	R	R	R		R

R – Reviewed: indicates a data review was conducted in this source for this pond; blank indicates no review was conducted.

★ *- Indicates a more detailed data analysis was performed in this source for this pond.*

[1]*Named ponds as listed in CCC Atlas 2003.*

[2]*CCC GIS ID: unique ID for each waterbody.*

[3]*Eichner, E. 2009. Eastham Freshwater Ponds: Water Quality Status and Recommendations for Future Activities. Coastal Systems Program, School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA. 155 pp.*

[4]*CCC Atlas description: Cape Cod Commission. 2003. Cape Cod Pond and Lake Atlas. Project 2000-02. Prepared by Cape Cod Commission for Massachusetts Executive Office of Environmental Affairs, Community Foundation of Cape Cod, and School of Marine Science and Technology at University of Massachusetts Dartmouth. May 2003.*

[5]*CaCo WQ Data 2006, 2008-2010 – Data provided by Eastham Water Quality Task Force, Cape Cod National Seashore, National Park Service, U.S. Department of Interior.*

[6]*PALS Water Quality Data 2008-2010 - Cape Cod Pond and Lake Stewardship (PALS) Program, Coastal Systems Group School for Marine Science and Technology, University of Massachusetts Dartmouth, New Bedford, MA*

[7]*Marine and Freshwater Beach Testing in Massachusetts, Annual Reports. 2007, 2008 and 2009. Massachusetts Department of Public Health, Bureau of Environmental Health, Environmental Toxicology Program. http://www.mass.gov/*

[8]*Field assessment conducted by EcoLogic staff, August 15-17, 2011.*

3.4.2 **Current conditions**

Since publication of the CCC evaluation of the Eastham Ponds, which reviewed water quality data collected between 2001 and 2006 (Eichner 2009), additional water quality data have been collected and analyzed through the PALS program and by Cape Cod National Seashore. The recent data support the earlier CCC findings regarding the trophic status of the Eastham ponds, as summarized in Table 3-5. Individual pond Fact Sheets are included in Appendix 1.

Table 3-5. Summary of data analysis, 2008-2010

(Notes: averages and minimums based on three years of summer data; upper waters represent measurements in top 1-meter of water column; lower waters represent measurements within 1 meter of the bottom.)

Criteria	Bridge	Depot	Little Depot	Great	Herring	Jemima	Minister	Molls	Muddy	Schoolhouse	Widow Harding
Fish community type (C=cold water; W= warm water)	W	C	W	C	C	W	W	W	W	W	W
Trophic Status (based on chlorophyll) (M = Mesotrophic; E = Eutrophic)	M	M	E	E	E	E	E	E	M	E	M
Dissolved Oxygen (anoxic conditions <2ppm) and Thermal Stratification											
• Were anoxic conditions observed in lower waters? (Yes/No)	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	Yes	No
• Was thermal stratification observed? (S/N/T)[1]	T	S	T	S	S	N	T	N	N	S	N
Secchi Transparency (minimum 4ft swimming safety guideline)											
• Did the average meet the swimming safety guideline? (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Did the minimum meet the swimming safety guideline? (Yes/No)	Yes	Yes	No	Yes	No	Yes	No	Yes	No	No	Yes
Total Phosphorus (TP) - (≤10 ppb = "healthy")											
• Was the average in upper waters more than 10ppb? (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Was the average in lower waters more than 10ppb? (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Were there indications of internal cycling of TP noted? (Yes/No)	Yes	No	No	Yes	Yes	No	Yes	No	No	Yes	Yes
Total Nitrogen (TN) – (≤0.31 ppm = "healthy")											
• Was the average in upper waters more than 0.31ppm? (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
• Was the average in lower waters more than 0.31ppm? (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
pH - Natural rain-water in equilibrium with CO2 in atmosphere: 5.65.											
• Was the pH within the range of 5.0-7.0? (Yes/No)	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Chlorophyll-a (≤1.7 ppb = "healthy")											
• Was the average more than 1.7 ppb? (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Source: PALS and Cape Cod National Seashore data, maintained by Town of Eastham

Notes:

Shaded cell indicates difference from 2001-2006 analysis (Eichner 2009); e.g. where the shaded cell indicates "Yes" for the 2008-2010 data set, the 2001-2006 data set indicated "No".

[1]Thermal stratification S=Stable thermal stratification; N=Not stratified; T= Transient stratification

In addition, bacteria samples were collected from five ponds to monitor suitability for bathing. Samples were collected weekly during beach season from 2007 through 2009 from seven public and semi-public beaches on Great Pond, Herring Pond, Depot Pond, Ministers Pond and Muddy

Pond. In 2009, one exceedance was reported on Depot Pond. Otherwise, no exceedances of bathing beach bacterial standards were reported.

3.4.3 **Summary of August 2011 field assessments**

In August 2011, EcoLogic scientists completed field assessments of the 11 ponds to observe water clarity and color, shoreline vegetation and development, public access and recreational uses, and the presence of algae and macrophytes. A summary of these observations is presented in Appendix 3.

Overall, the ponds exhibited high water clarity during the August, 2011 assessment, with the exception of Herring Pond, where waters were green-tinged and turbid. The majority of the pond shoreline areas are vegetated, interspersed with small clearings for access from residential properties. The shorelines were dominated by canopy trees and shrubs, with some emergent vegetation depending on water depth. Shoreline vegetation was typical of the outer Cape (representative list below). Again, Herring Pond was an exception; the invasive species purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*) were present.

Trees	Shrubs	Herbaceous/Emergents
Oak	Buttonbush	Wild grape
Pitch pine	Blueberry	Swamp loosestrife
Willow	Sweet pepper bush	Pickerel weed
Maple	Rose	Cattail
Black gum	Alder	Pipewort
Atlantic white cedar	Azalea	Rushes

The extent of shoreline development varies among the 11 ponds. Several ponds, including Great, Bridge, and Widow Harding, are adjacent to a conservation area, and portions of their shorelines are undeveloped except for the maintained woodland trails. Other ponds, notably Molls, Depot and Herring, have extensive residential development in their watersheds.

In Massachusetts, ponds larger than 10 acres (Great Ponds) are to be accessible for public use. Great Pond, Herring Pond, the Ministers/Schoolhouse complex, Depot Pond and Muddy Pond meet this size threshold for designation. There are town beaches on Great Pond and Herring Pond, and a boat launch on Schoolhouse Pond; public access to Depot Pond is by way of a fire road behind the library. Access to several of the smaller ponds is available through park and conservation lands.

Overall, the 11 Eastham ponds are used for both contact and non-contact recreation. Activities including fishing, non-motorized boating and swimming were either observed, or inferred by the presence of beaches, docks with boats, swimming platforms, or cleared areas leading from trails to the shoreline. Ponds are used by the general public (based on availability of access points) and by private landowners adjacent to the ponds.

During the August, 2011 survey, only Herring Pond was visibly impaired by the abundance of filamentous algae and phytoplankton. Macrophytes (rooted aquatic plants and algae) were prominent features of many ponds, notably shallow Muddy Pond, with extensive beds of bladderwort and broadleaf watermilfoil. In addition, nearshore areas of Great Pond support dense beds of a diverse macrophyte community. The field team noted extensive areas of gravel substrate in Depot Pond, which provides excellent spawning habitat for the pond's cold water fish community.

Rainbow, brown, brook and tiger trout are raised for stocking rivers, streams, lakes and ponds throughout the Commonwealth. In Eastham, Herring Pond is stocked by Mass Fish and Wildlife. http://www.mass.gov/dfwele/dfw/recreation/fishing/trout/trout_waters_sd.htm

Herring Pond and Bees River are included in the Area of Critical Environmental Concern (ACEC) encompassing Inner Cape Cod Bay.

3.4.4 **Summary of 2011 water and sediment testing**

In addition to the visual assessment and habitat evaluation, the August 2011 field program included water quality testing at all 11 Eastham ponds. Three deep ponds, Herring Pond, Great Pond and Depot Pond, were tested for phosphorus and alkalinity levels at 9 m. Sediment texture and mobile phosphorus content of sediments from the three deep ponds were tested as well. Results are tabulated in Appendix 4. The findings of the 2011 field sampling effort are summarized in this section.

Stratification regime. The 2011 sampling occurred in mid-August; this is typically the time when the ponds' heat content, and consequently degree of thermal stratification, reaches an annual maximum. Consistent with the results of previous sampling, Great Pond, Herring Pond and Depot Pond exhibited distinct thermal layering, with deep, cool water (the hypolimnion) isolated from the warmer upper water layer (the epilimnion). Dissolved oxygen depletion of the lower waters was evident.

Schoolhouse Pond, which had been reported as exhibiting thermal stratification, demonstrated only a very weak thermal gradient through the water column to the 4 m maximum depth. However, water samples from the deepest area of the pond did exhibit lower dissolved oxygen concentrations, indicating that these waters were isolated from atmospheric exchange. The stratification regime of Minister Pond was very similar to that of adjoining Schoolhouse Pond. Two other shallow ponds, Bridge Pond and Little Depot Pond, also had evidence of dissolved oxygen depletion in the only the very deepest sample.

Several of the smaller ponds were completely mixed. Molls Pond, Jemima Pond, Widow Harding Pond and Muddy Pond had water quality and temperature profiles that were essentially uniform through the water column.

Deep water phosphorus. The field team collected water from the hypolimnion of the three deepest ponds and measured total phosphorus (to evaluate the potential magnitude and importance of sediment phosphorus release) and total alkalinity (to estimate buffering capacity and guide alum dosage calculations). Results of the testing (Table 2-6) indicate that sediment phosphorus release is highest in Herring Pond. Concentrations in Great Pond and Depot Pond were substantially lower. Alkalinity levels indicate low acid neutralizing capacity in the three ponds, consistent with the nature of the watershed geology and soils.

Table 3-6. Results of testing deep waters for total phosphorus and alkalinity

Parameter (Units)	Eastham Ponds 8/16/2011		
	Great (9 meters)	***Herring (9 meters)***	***Depot (9 meters)***
Phosphorus as P (mg/l)	0.034	0.252	0.020
Total Alkalinity (mg/l CaCO3)	21.4	49.7	38.2
Samples analyzed by Spectrum Analytical, Inc. of Agawam MA			

Sediment phosphorus partitioning. Sediment samples were collected using a petite ponar dredge from multiple locations within the deepest portions of Herring Pond and Great Pond; the pond sediment samples were collected from areas overlain by low oxygen waters.

Results confirm that the sediment samples collected from the Eastham ponds contain a substantial reservoir of phosphorus (Table3-7). Sequential extraction of sediment phosphorus was conducted in order to estimate the mass of phosphorus that could be released from the sediments to the overlying waters under conditions of seasonal anoxia. Sediments from Great Pond and Herring Pond contain a substantial mass of loosely-sorbed and iron-phosphorus minerals, which represent the available phosphorus fraction within the sediment and would be released once oxygen is depleted from the lower waters. The sediments of Herring Pond were significantly higher in phosphorus. The average results of three samples from each pond are presented in Table3-7; complete results are included in Appendix 4.

Table 3-7. Results of sediment testing of Herring Pond and Great Pond

Parameter (Units)	Herring Pond Average	Great Pond Average
Iron (mg/kg dry)	74,233	14,717
Phosphorus as P (mg/kg dry)	3423	1114
Iron-bound Phosphorus as P (mg/kg dry)	288	20.3 J
Loosely-sorbed Phosphorus as P (mg/kg dry)	1.64 J	1.10 J
Percent Solids (%)	18.5	32.1
Grain Size (percent retained):		
Fractional % Sieve #4 (>4750 µm)	1.33	2.50
Fractional % Sieve #10 (4750-2000 µm)	29.1	20.0
Fractional % Sieve #20 (2000-850 µm)	21.0	19.4
Fractional % Sieve #40 (850-425 µm)	12.3	19.4
Fractional % Sieve #60 (425-250 µm)	7.77	14.07
Fractional % Sieve #100 (250-150 µm)	8.21	11.95
Fractional % Sieve #200 (150-75 µm)	10.7	8.4
Fractional % Sieve #230 (<75 µm)	9.64	4.30

Samples analyzed by Spectrum Analytical, Inc. of Agawam MA
"J" - Detected above the Method Detection Limit but below the Reporting Limit; therefore, result is an estimated concentration
"µm" –micron, or micrometer (1/1000 of a meter)

3.5 Use Attainment

In addition to grouping the ponds based on the degree to which human activities have altered them from their natural (pristine) condition, state and tribal agencies classify surface waters according to a designated "best use". This concept focuses on human uses, but incorporates the ecological condition of the resource as well. Examples of designated uses include public water supply, fishing, swimming (water contact recreation), aesthetic enjoyment and support of shellfish, wildlife and fisheries. The designated use of Eastham's inland kettle ponds is typically recreation (in and on the water) and fishing.

The fact that the Eastham ponds exceed regional guidelines for phosphorus and chlorophyll levels does not necessarily mean that the ponds are impaired with respect to their designated use. However, as discussed in Section 2.3, increasing nutrient enrichment will bring about changes in the ecology that will degrade water resources with respect to their designated uses, potentially affecting both human uses and the aquatic biota. States are required to assess whether designated uses are supported in the surface waters, and to develop a list of impaired waters. This list, termed the 303(d) list after the section of the Clean Water Act in which it is cited, is reported to EPA every two years. Massachusetts lists one pond in Eastham, Great Pond, as impaired for its designated uses (Figure 3-4). The pond is placed on the list for diminished oxygen resources in the deep waters, which can restrict available habitat for the cold water fish community. The elevated chlorophyll levels diminish the pond's aesthetic appeal, and the decomposition of the excessive algal biomass draws oxygen from the lower waters. Other

Eastham ponds, notably Herring Pond, may be added to the 2012 list of impaired waters once Mass DEP reviews the most recent data.

Figure 3-4 Listing of Great Pond in Massachusetts 2010 Compendium of Impaired Waters

Designated Uses		Status
Aquatic Life		IMPAIRED Cause: Low dissolved oxygen, elevated chlorophyll-a Source: Unknown Suspected source: Internal phosphorus recycling
Fish Consumption		NOT ASSESSED
Primary Contact		NOT ASSESSED
Secondary Contact		SUPPORT
Aesthetics		SUPPORT

The analysis of current water quality conditions indicates that the Eastham ponds exhibit various degrees of impairment, or are at risk of impairment of their designated uses (Table 3-8). Inclusion of the Nitrogen: Phosphorus ratio among these criteria merits additional explanation. Algae require many nutrients, and their nutritional requirements are within a relatively consistent range. When the ratio of available N and P in the water column declines below a critical level (variously cited as between 16 and 29), nitrogen becomes the limiting nutrient for algal growth. Many species of cyanobacteria are able to fix atmospheric nitrogen (i.e., convert nitrogen gas (N_2) to ammonia and other chemical forms more readily available for algal uptake). As a consequence, growth of these species is not limited by the availability of nitrogen in the water, and cyanobacterial have a competitive advantage over other groups of phytoplankton. Cyanobacteria can reach nuisance levels when phosphorus is abundant, due to their ability to use atmospheric nitrogen.

In addition to formation of unsightly blooms, certain species of cyanobacteria exude compounds that can be harmful to public health. *Cyanobacterial toxins* are the naturally produced poisons stored in the cells of certain species of cyanobacteria. These toxins fall into various categories. Some are known to attack the liver (hepatotoxins) or the nervous system (neurotoxins); others simply irritate the skin. These toxins are released into water when the cells rupture or die. It is estimated that about one-half of cyanobacterial species produce these harmful chemicals.

Table 3-8. Summary of potential use impairments, Eastham Ponds

Criteria	Ponds
Low dissolved oxygen in the deep waters, creating stress on cold water fish communities	Great Herring Depot
Low N:P ratio, increased risk of cyanobacterial (blue-green algae) blooms	Widow Harding Little Depot
Reduced water clarity from algal abundance, leading to diminished aesthetic and recreational quality	Minister Little Depot Herring Muddy Schoolhouse

3.6 Watershed Sources

The water quality of the kettle ponds of Eastham is largely governed by their natural assimilative capacity, which includes pond volume, depth and water residence time, and by the amount of development within the watersheds. On-site wastewater disposal systems, in particular, are implicated as the major sources of phosphorus to the inland kettle ponds. Phosphorus moves very slowly through the Cape Cod aquifer, and the conditions measured in the Eastham ponds through 2010 do not reflect steady-state conditions. Phosphorus loading will increase, and will contribute to further water quality decline in the ponds.

The Cape Cod Commission report (Eichner 2009) estimated the sources of phosphorus to six of the Eastham ponds (Table 3-9). The range associated with the contribution from wastewater disposal reflects variability in the estimated rate at which phosphorus migrates through the groundwater.

Table 3-9. Summary of estimated phosphorus sources (Eichner 2009)

Pond	Major Phosphorus Sources and Estimated Percent Loads
Great	Sediment (33-34%), precipitation (15-28%), septic (11-17%)
Depot	Septic (0-44%), birds (31-38%), roads (7-25%), roofs (7-25%), precipitation (2-6%)
Herring	Sediment (0-60%), roads (6-35%), precipitation (6-31%), roofs (3-18%), septic (0-16%)
Minister	Roads (29-60%), septic (0-45%); precipitation (4-10%), sediment (not quantified). ***Note that runoff from Highway 6 enters this pond, and is likely to be a significant source***
Schoolhouse	Birds (26-46%), roads (18-26%), precipitation (14-21%); input from Minister Pond (not quantified).
Muddy	Roads (21-45%), septic (0-38%), birds (17-21%), precipitation (10-21%)

Efforts to manage the ponds' water quality must ultimately address these phosphorus sources. Alternatives for reducing phosphorus sources, including the internal (sediment) source are reviewed in Section 4.

3.7 Fishery Resources

The diversity of pond size and depth, coupled with the extent to which the ponds are connected to the ocean, ultimately determines the nature of the fish community that can be sustained in the kettle ponds. As summarized in Table 2.5, Herring, Great and Depot Ponds are considered to support a cold water fishery. The other ponds are designated as warm water fisheries.

The Commonwealth of Massachusetts stocks ponds for recreational fishing. Only Herring Pond is cited on the Mass DEP web site as included in the annual stocking program; brook, brown, rainbow and tiger trout are stocked. Herring Pond supports a warm water fish community as well, with largemouth and smallmouth bass, chain pickerel, brown bullhead, yellow perch, white perch, pumpkinseed, golden shiners and banded killifish (source http://www.nefreshwater.com/article11.php). The annual spring spawning migration of river herring (*Alosa pseudoharengus* and *Alosa aestivalis*) into the pond through the Herring River represents an additional source of forage fish (that is, prey for game fish).

4 Potential Remedial Measures

4.1 Alternatives Considered

Over the decades, environmental engineers and scientists have devised a number of in-lake measures to mitigate the symptoms of eutrophication. These methods are most effectively used in addition to controls on external loading. As part of this Action Plan preparation, in-lake measures were screened for their potential applicability to Eastham conditions (Table 4-1, Appendix 2). The potential benefits, risks and permitting questions are summarized in Appendix 2 for a range of potential solutions, as compiled in *The Practical Guide to Lake Management in Massachusetts* (Wagner 2004) and supplemented with additional information.

Remedial measures are grouped in several categories, as described in the following sections:

- 4-1-1 - Dredging
- 4-1-2 – Control internal sediment phosphorus release (alum treatment)
- 4.1.3 - Enhanced mixing
- 4.1.4 - Herbicides
- 4.1.5 - Hypolimnetic aeration or oxygenation
- 4.1.6 - Small-scale measures to control aquatic vegetation

Additional information is provided for recommended technologies in Appendix 2.

Table 4-1. Summary of potential in-pond remedial measures and their applicability to Eastham ponds (*pg. 1 of 4*)

Remedial Measure	Description	Applicability to Eastham Ponds
Alum and Aeration Techniques		
Phosphorus (P) Inactivation (*Section 4.1.2*)	Application of alum (aluminum sulfate, mixed with sodium aluminate) to prevent soluble phosphorus release from sediments during anoxic (no oxygen) conditions.	Applicable to ponds with significant internal phosphorus loading from sediments: Herring, Great
Artificial Circulation (*Section 4.1.3*)	Whole lake circulation to eliminate anoxia in lower waters where sediment recycling of P occurs; thermal destratification also results.	Ponds that undergo stratification at least occasionally, support a warm water fish community: Bridge, Minister, Schoolhouse
Hypolimnetic Aeration (*Section 4.1.5*)	Aeration of lower waters to eliminate anoxia where sediment recycling of P occurs. Thermal stratification maintained.	Deep ponds with stable hypolimnion and a cold water fish community: Depot, Great, Herring
Sediment Manipulation Techniques		
Conventional Dry Dredging *(Section 4.1.1)*	Partial/complete draining of the pond and removal of exposed sediments using conventional excavation equipment. Dredge spoils require containment and disposal areas, preferably proximate to the pond.	Not applicable –ponds are ground-water flooded kettle holes with no significant inlet or outlet for water level control.
Conventional Wet Dredging *(Section 4.1.1)*	Removal of sediment under water using specialized excavation equipment. Dredge spoils will require dewatering prior to disposal. A containment/disposal area proximate to the pond may be required.	Shallow ponds with extensive macrophytes and organic sediment: Muddy, Herring, Minister, Schoolhouse and Little Depot. Siting dewatering/disposal sites challenging.
Hydraulic or Pneumatic Dredging *(Section 4.1.1)*	Removal of sediment using suction and agitation (hydraulic) or air pressure (pneumatic). Material is pumped to dewatering area prior to disposal.	Ponds impaired by shallow depths, extensive macrophyte growth and organic, P-rich sediment layers: Muddy, Herring, Minister, Schoolhouse and Little Depot. Siting dewatering/disposal sites challenging.
Reverse Layering	Uses hydraulic jetting to re-organize sediment layers – bring glacial sand to surface and bury organic surface layers. Experimental (Red Lily Pond, Barnstable)	More information needed regarding sediment profile (depth to reach sand layer). Smaller ponds with organic sediments: Bridge, Muddy, Widow Harding.

Table 4-1. Summary of potential in-pond remedial measures and their applicability to Eastham ponds (*continued – pg. 2 of 4*)

Remedial Measure	Description	Applicability to Eastham Ponds
Mechanical Aquatic Plant Control (Section 4.1.6)		
Drawdown	Water level lowered for a period of time (months) to expose sediment to air and to kill aquatic plants by drying/freezing.	Not applicable –ponds are ground-water flooded kettle holes with no significant inlet or outlet for water level control.
Hand Harvesting	Hand-pulling of unwanted plants by a diver.	Can be used to restore recreational access in relatively limited areas of ponds impaired by excessive growth of aquatic plants. Also used to help control invasive species.
Mechanical Harvesting	Cutting plants close to the sediment; may or may not involve removal of cut plants.	All ponds where excessive macrophyte growth impairs desired uses
Hydroraking	Hydroraking involves use of a floating backhoe, usually outfitted with a rake that is moved through sediment to rip out thick root masses and debris.	All ponds where excessive macrophyte growth impairs desired uses
Rotovation	A rotovator is a hydraulically operated tillage device mounted on a barge, typically for removal of dense growths of unwanted plants.	All ponds where excessive macrophyte growth impairs desired uses
Benthic Barriers	Use of natural or artificial material to cover the pond bottom to prevent plant growth	All ponds where excessive macrophyte growth impairs desired uses
Herbicide/Algaecide Controls (Section 4.1.4)		
Copper Treatment	Non-selective contact herbicide/algaecide, inhibits photosynthesis. Dependent on alkalinity, dissolved solids, suspended matter and water temperature. Approved for use in potable water supplies in Massachusetts.	Not recommended- algal blooms are not currently an impairment, ponds are not used for potable supply
Diquat Treatment	General purpose, broad-spectrum herbicide disrupts photosynthesis. Less effective in turbid, muddy waters, rapidly sorbs to sediments.	Not recommended at this time, likely to be significant public opposition to herbicide use
Endothall Treatment	Contact herbicide that inhibits use of oxygen for respiration. Does not kill roots, not very effective against milfoil. Dose limits to avoid impacts to non-target fauna.	Not recommended at this time, likely to be significant public opposition to herbicide use

Table 4-1. Summary of potential in-pond remedial measures and their applicability to Eastham ponds (*continued – pg. 3 of 4*)

Remedial Measure	Description	Applicability to Eastham Ponds
Herbicide/Algaecide Controls (continued)		
Glyphosate Treatment	Systemic, broad spectrum herbicide, disrupts plant's metabolic pathways. Most effective on emergent and floating-leaved plant species.	Not recommended at this time, likely to be significant public opposition to herbicide use
2,4-D Treatment	Systemic herbicide, absorbed by roots, leaves and shoots; and disrupts cell division. Useful for Eurasian watermilfoil.	Not recommended at this time, likely to be significant public opposition to herbicide use
Fluridone Treatment	Systemic herbicide that inhibits carotene synthesis, which exposes chlorophyll to photodegradation. Takes 30-90 days for die-off to occur. Some plants more susceptible than others.	Not recommended at this time, likely to be significant public opposition to herbicide use
Trichlopyr Treatment	Systemic herbicide, disrupts growth processes. Approved for use in Mass in 2004	Not recommended at this time, likely to be significant public opposition to herbicide use
Dyes and Covers	Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow or the total amount of light available for algal growth.	Not likely to be effective
Biological Controls		
Food Web Biomanipulation	Algal control options usually involving zooplankton and fish community structure	Unknown applicability to ponds, would require detailed fish community analysis
Herbivorous Fish	Grass carp (*Ctenopharyngodon idella*) is commonly used to control aquatic plants. However, grass carp are not approved for introduction in Massachusetts.	Not applicable, release of grass carp is not permitted in Massachusetts.
Herbivorous Invertebrates	Biological control using native invertebrates (mainly insects) that feed on the introduced target plant species. Two insects highlighted: native weevil (*Euhrychiopsis lecontei*) for the control of Eurasian milfoil and loosestrife beetle (*Galerucella* spp.), used to control purple loosestrife. Predator rarely eliminates prey, so population cycling will occur.	Purple loosestrife was observed in Herring Pond (Aug. 2011). Eurasian watermilfoil was not observed in the Eastham ponds.

Table 4-1. Summary of potential in-pond remedial measures and their applicability to Eastham ponds (*continued – pg. 4 of 4*)

Remedial Measure	Description	Applicability to Eastham Ponds
Biological Controls (continued)		
Plant Competition	Seeding and planting of native plant species to out-compete invasive plant species; experimental.	Based on August 2011 survey, macrophyte communities are dominated by native species
Barley Straw	Decomposition of the barley straw produces allelopathic compounds that act as algaecides. Competition for nutrients between heterotrophic decomposers and autotrophic algae appears to favor the heterotrophs after barley straw addition	Not recommended- experimental, significant permit barriers, algal blooms not yet problematic (except in Herring Pond).
Bacterial Additives	Add natural or engineered bacteria to the aquatic environment to out-compete algae for nutrients, reducing concentrations of N and P. It is not clear that a bacterial community capable of precluding algal blooms would not itself constitute an impairment of aquatic conditions.	Not recommended
Removal of Bottom-feeding Fish	Elimination of bottom feeders (common carp or bullheads) may reduce nutrient availability and improve transparency. This technique has not been practiced in many years in Massachusetts, except as a side effect of dry dredging or complete drawdown for structural dam repairs.	Fish community information lacking
Sonication	A floating sonicator breaks up algae and causes them to sink to the pond bottom over target areas that range from 150 to 15,500 square meters. No scientific tests of this apparatus have been reported in the lake management literature, and this product provides only short-term relief.	Algal blooms currently rare (except in Herring Pond), but may increase in future as additional wastewater P reaches ponds.

4.1.1 **Dredging**

Removal of material from the bottom of the ponds (sediment and vegetation) can be accomplished by mechanical or hydraulic dredging. Mechanical dredging uses a clamshell bucket on a boom. Sediment can be removed to a distance of 30 – 40 meters from the shoreline, or from a barge-mounted mechanical dredge. This technique can result in an uneven bottom profile. Production rates tend to be slow and sediment is suspended in the water column during dredging, creating high turbidity. Mechanical dredges are mobile and can easily be moved from between locations. The sediment removed by a mechanical dredge must be transported for dewatering and disposal.

Hydraulic dredges are popular due to their speed and ability to remove large quantities of sediment. There are several types of hydraulic dredges including the suction dredge, the hopper, the dustpan, and the cutter-head dredge. The cutter head dredge is the most practical and is the one most often used. The dredging machinery is incorporated onto a floating barge. A cutter with steel blades dislodges the sediments, and a centrifugal pump draws a mixture of sediment and water (called the slurry) into a pipe, which sends the slurry to an upland basin where the water is drained off and the sediments are left to dry. Hydraulic dredges create significantly less turbidity.

The objective of a dredging project, and the potential benefits and costs, would have to be clearly defined. Removal of phosphorus-rich sediment from the deep portions of lakes is unlikely to provide measureable water quality benefits in terms of improved water clarity and reduced risk of nuisance algal blooms. Removal of accumulated sediment and its associated vegetation from nearshore areas could improve recreational access and aesthetic conditions in some of the smaller ponds. The nearshore (littoral) zone in the ponds provides important habitat for the aquatic biota; it is likely that approvals for dredging would require detailed habitat evaluations and protection of areas to serve as a refuge and a seed bank for post-dredging colonization. Dredging is a temporary measure, and regrowth of aquatic vegetation will be rapid.

Dredging is a costly remedial alternative, and the location of a facility for sediment handling and/or dewatering is a key factor in the overall project cost. Sediment removed from the ponds can be placed for final disposal or managed for beneficial use. Based on the nature of the watersheds, it is expected that dredged material will be classified as free of contamination, and suitable for reuse. Options for its use include, but are not limited to: clean fill, landfill cover material, land reclamation, streambank construction, soil aggregate, landscape and garden amendment, and as a mix for creating topsoil (possibly composted with yard waste).

One factor affecting the range of potential alternatives for beneficial reuse is the sediment texture (particle size). Finer-grained materials are better suited for composting or landscape and farming applications. Coarser materials such as sand and gravel are better suited for construction projects. Based on sediment sampling for this project, sediment texture in areas proposed for dredging is variable, ranging from sands to clay, with mixtures of silt-sized particles as intermediate.

Once dewatered, sediment removed from the ponds can be used for projects designed to restore or enhance habitat. The nutrient content, percent organic matter and texture (particle size distribution) will affect how the dredged material can be used. Shoreline stabilization and restoration with plantings of native species can improve riparian habitat conditions, reduce shoreline erosion, and improve the overall aesthetic quality.

4.1.2 **Alum treatment program**

Alum (aluminum sulfate) has a long history in water treatment and lake restoration programs. The chemical compound is broken down in reaction with water, forming a *floc* (loose aggregation of small particles). As the floc settles to the sediment surface, it removes particulate material and dissolved phosphorus from the water column. The application rate is calculated to provide sufficient binding capacity at the sediment surface to continue to trap soluble and iron-bound phosphorus and prevent their release to the overlying waters. An alum treatment program will gradually lose its effectiveness as new organic material settles to the pond bottom.

This remedial alternative is appropriate for ponds that undergo stable thermal stratification and seasonal anoxia in the deep waters, and where sediments are a significant source of phosphorus to the pond. For poorly-buffered systems, such as the Cape Cod kettle ponds, a mixture of aluminum sulfate and sodium aluminate is applied. The ratio of the two chemicals is typically in the range of two parts alum to one part sodium aluminate when applied to ponds in this region (Aquatic Control Technologies, personal communication November 2011). Jar testing is performed immediately prior to treatment to calibrate the final chemical dosage and verify that ionic aluminum will not be released into the water column. Several Cape Cod ponds have been treated with alum, as summarized in Table 4-2.

Table 4 2. Summary of alum treatment programs on Cape Cod

Pond, Town and Surface Area	Year Treated	Results
Hamblin Pond, Barnstable *(115 acres)*	1995	Application not adequately buffered, resulted in fish kill. Water quality results have been excellent - low algae, high water clarity, high dissolved oxygen - and continue through 2011. Pond supports excellent trout fishery.
Ashumet Pond, Mashpee/Falmouth *(203 acres)*	2001 and 2010	25 acres treated in 2001. Barrier wall (to intercept wastewater plume high in phosphorus) constructed in 2004. Alum application repeated in 2010, results pending.
Long Pond, Brewster/Harwich *(716 acres)*	2007	370 acres treated with a mixture of alum and sodium aluminate, fall 2007. Water clarity increased the following summer, with no adverse impacts on lake biota.

Table 4 2. Summary of alum treatment programs on Cape Cod

Pond, Town and Surface Area	Year Treated	Results
Mystic Pond, Barnstable *(148 acres)*	2010	55 acres treated. Initial results indicate moderate success, with increased water clarity, elimination of blue-green algal blooms, and improved dissolved oxygen levels. Mass DEP restricted treatment area and dosage due to potential impacts on endangered mussels.
Lovers Lake (*37 acres*) & Stillwater Pond (*19 acres*) Chatham	2010	Treatment of 19 acres of Lovers Lake and 9 acres of Stillwater Pond, fall 2010. 2011 water quality results are pending.

A question has arisen regarding whether the addition of aluminum sulfate (alum) to the kettle ponds poses a risk of enhancing the methylation of mercury. Mercury methylation is a microbial process that converts ionic mercury to methyl mercury; sulfate reducing bacteria mediate this transformation. The methylated form of mercury accumulates in biota. The basis for the concern, therefore, is the potential for the sulfate addition to increase the rate of methylation and, ultimately, increase the flux of mercury into the food web.

Mercury methylation in the kettle ponds requires three conditions: elemental mercury, available sulfate and sulfate-reducing bacteria, and anoxic conditions at the sediment-water interface. The atmosphere is a source of both mercury and sulfate. In addition, the groundwater on Cape Cod contains sulfate; according to Harvey et al. 2010, concentrations are in the range of 7 mg/l in the uncontaminated aquifer; the concentration of sulfate increases with sewage plumes (Harvey et al. 2010).

To our knowledge, there has been no specific monitoring of an alum treatment program to evaluate whether methyl mercury levels have increased from baseline conditions. By reducing phosphorus flux from the sediments, an alum treatment program is designed to reduce algal production and biomass. Less algal biomass reaching the sediment surface will reduce oxygen demand and improve the dissolved oxygen status of the deep waters, as documented in Mystic Pond. With improved oxygen, the conditions that can lead to mercury methylation are mitigated.

4.1.3 Enhanced mixing

Several of the alternatives presented in Table 3-1 are designed to increase the mixing of the pond water column, in an effort to prevent oxygen depletion and the resulting phosphorus release at the sediment water interface. The required energy can be supplied through solar panels, as in the SolarBee® devices, wind turbines or shoreline generators.

Mixing the entire water column will increase water temperature in the ponds, and create uniform warm water habitat. A cold water fish community would not be supported. In theory, enhanced mixing can prevent the formation of surface scums and algal blooms. The technical literature documents inconsistent results for enhanced mixing. Overall, less than half of the projects have resulted in reduced algal blooms, or increased water clarity.

The enhanced mixing does not bring about a reduction phosphorus concentrations in the upper waters. The failure of artificial recirculation to improve water quality in many situations has been attributed to undersized equipment (Cooke et al. 2005).

The SolarBee® technology has been applied to many water bodies, as documented on the company web site **www.solarbee.com**. A summary of case studies is included in Appendix 2. In general, the units appear to be more effective on smaller waterbodies. Several scientific evaluations of the water quality impacts of the SolarBee® have been completed through cooperative projects that teamed scientists from academic institutions and regulatory agencies with staff engineers and scientists from SolarBee®, as briefly noted below.

- Tufts University/ Mass DEP evaluation : Lake Cochituate, Natick MA
  Two units installed in 2006, removed in 2007 - no effect on Eurasian water milfoil.
- State University of NY/ Livingston County Planning Department evaluation: Conesus Lake, NY
  Two units installed in 2006, removed in 2007 - no discernible effect on Eurasian water milfoil, water clarity, dissolved oxygen or chlorophyll-a.
- Vermont Agency for Natural Resources
  Three units placed in St. Albans Bay, 2007. No evidence that the SolarBee® installation in St. Albans Bay reduced algal concentrations, improved water clarity, or inhibited blue-green algal growth.
- University of Wisconsin/ City of Madison evaluation: Monona Bay, Madison WI
  Five units placed in 2005 and 2006, terminated after no water quality improvement.

There has been interest in using these devices to improve water quality conditions in Cape Cod kettle ponds. Residents around the 15-acre Skinequit Pond in Harwich installed a SolarBee® in 2007. There has been no statistical improvement in water clarity or reduction in algal abundance, according to the Town of Harwich Water Quality Task Force. As displayed in Figure4-1, water clarity in Skinequit Pond increased in 2007, but conditions in 2008 – 2010 are comparable to those prior to installation of the unit.

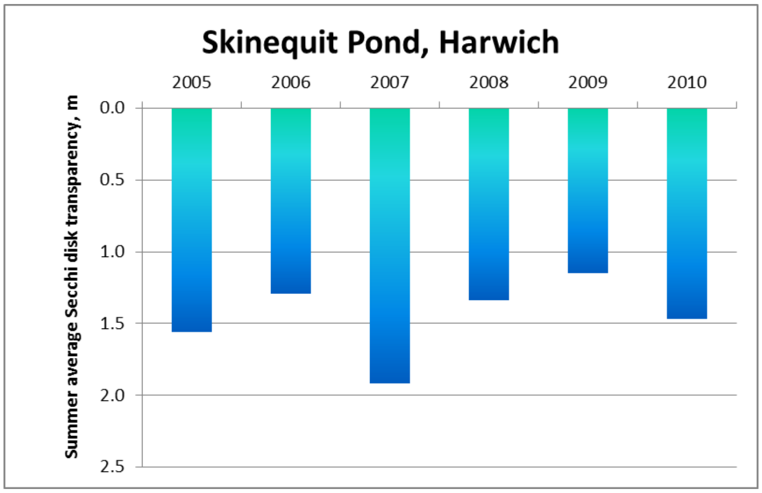

Figure 4-1 Summer average Secchi disk transparency, Skinequit Pond (Harwich), 2005-2010. ***SolarBee® installation was in 2007.***

Data source: Harwich Water Quality Task Force

The Town of Mashpee has recently approved funding for the installation of four solar-powered mixing devices on Santuit Pond, which has a surface area of 174 acres. This project will begin in 2012.

4.1.4 **Herbicides**

Several aquatic herbicides are identified as techniques for lake and pond management (Table 4-1). Herbicides can be an important tool for controlling aquatic macrophytes, particularly invasive species. Long Pond (Centerville), Town of Barnstable has been treated with the aquatic herbicide Sonar® to control fanwort; the pond is also quarantined to prevent spread of this plant to other ponds. Spot applications of aquatic herbicides are also periodically applied to Lake Wequaquet in Barnstable to maintain recreational access.

In order to be registered for use, aquatic herbicides are tested for their effectiveness on target organisms, potential toxicity to non-target organisms, and persistence in the aquatic environment. Both contact herbicides (which work quickly and kill plants on contact) and systemic herbicides (which work more slowly and kill plants by interfering with biochemical pathways) are approved for use in Massachusetts waters. All herbicide applications require a permit and must be completed by a licensed applicator.

The use of aquatic herbicides in kettle ponds poses special challenges, as nutrients released by dying vegetation tend to remain in the system. Killing the aquatic vegetation may result in algal blooms as soluble nitrogen and phosphorus are released and remain in the pond. Although the ponds are not used for domestic drinking water supply, the connection to the groundwater resource is a potential concern.

The effects of aquatic herbicides are temporary; plants will begin to recolonize suitable habitat as early as the next growing season. A potential longer-term benefit may be realized if herbicides are used to control invasive species, and recolonization is by native species with diminished potential for impairing desired uses.

4.1.5 **Hypolimnetic aeration or oxygenation**

As described in Section 4.1.3, bringing oxygenated water into the lake's deeper layers can help prevent the chemical changes at the sediment surface that lead to sediment phosphorus release. Hypolimnetic aeration and oxygenation are variations of this approach. These measures oxygenate the deep waters while avoiding the potential loss in cool and cold water aquatic habitat resulting from enhanced mixing. There is no longevity or residual benefit associated with these techniques. Once the aeration system is turned off, oxygen will be consumed by microorganisms in the deep water as they decompose the pond's organic material.

Ponds that are suitable for this alternative have the following characteristics:

- A significant fraction of the phosphorus budget is due to sediment release
- External loading is low
- Sediments are high in iron to immobilize phosphorus under oxygenated conditions
- Water clarity does not extend below the epilimnion, to minimize the potential effects of circulation of deep nutrient-rich water upward to within the region of the lake with enough light to support photosynthesis (the photic zone)
- Need to maintain habitat for a cold water fishery

4.1.6 **Small-scale measures to control aquatic vegetation**

Included in Table 4-1 are several remedial measures to control macrophyte growth that can be implemented by residents and groups of interested homeowners. Hand pulling and use of benthic mats can help restore recreational use, with a minimal potential for adverse environmental impacts. These alternatives are suitable for all the Eastham ponds. A fact sheet outlining these methods is included in Appendix 2. Note that these individual measures to control aquatic vegetation will require Conservation Commission approval.

4.2 Criteria for Recommendations

Criteria for selecting among potential solutions were discussed at the first community meetings, held in August, 2011. The following criteria were considered to be most applicable to the Eastham ponds.

- Technical feasibility for addressing specific impairment
- Track record of the method, specifically on Cape Cod
- Likelihood of success
- Duration of effectiveness (longevity)
- Risks to human health and the environment
- Potential impacts on fish and wildlife
- Ease of permitting

- Public acceptance
- Relative cost and benefit

A preliminary assessment of the potential applicability of the remedial measures to the Eastham Ponds is presented as a matrix evaluating these criteria against the six classes of remedial measures (Table 4-3). A ranking factor, scaled from 1 to 5 was applied, with higher values representing more feasible, less costly, or more environmentally benign alternatives.

Table 4 3. Assessment of remedial measures appropriate for the Eastham Ponds

Pond	Class of Remedial Measures (*Report Section Reference*)					
	Dredging (*3.1.1*)	Alum (*3.1.2*)	Mixing (*3.1.3*)	Herbicides (*3.1.4*)	Hypolimnetic aeration (*3.1.5*)	Macrophyte controls (*3.1.6*)
Bridge	2	1	4	1	1	4
Depot	2	4	2	1	3	4
Little Depot	2	1	4	1	1	4
Great	2	5	1	1	4	4
Herring	2	5	2	1	4	4
Jemima	2	1	3	1	1	4
Minister	2	4	4	1	1	4
Molls	2	1	3	1	1	4
Muddy	2	1	3	1	1	4
Schoolhouse	2	1	4	1	1	4
Widow Harding	2	1	3	1	1	4

Higher values represent more feasible, less costly, or more environmentally benign alternatives.

4.3 Additional Protective Measures

The focus of the assignment from the Town of Eastham has been to identify remedial measures that can effectively address current degraded water quality conditions. There are also protective measures to help reduce future movement of phosphorus toward the ponds. The following measures will help protect the Eastham Ponds from further degradation in water quality and habitat conditions. These measures are implemented in the watershed surrounding the ponds, rather than within the pond itself. These protective measures may be applied to all the ponds. More information regarding storm water infrastructure could help the Town refine priorities.

- Storm water management. Stormwater basins with water quality controls; operations and maintenance are critical. Improved stormwater management on parking lots adjacent to ponds. Runoff from State Highway 6 into Minsters Pond should be abated.

- Septic discharge. For new systems, the goal of a 300 ft. setback from surface waters is an effective approach. In addition to setbacks, there are alternative technologies, some of which show promise for enhanced phosphorus removal. The Massachusetts Alternative Septic Systems Test Center and the Barnstable County Department of Health are an informational resource

- Public Education. Conduct forums to discuss pond ecology, range of conditions in Town ponds, and effective measure for improving water quality conditions. Educate the public regarding the importance of remaining on trails and protecting riparian (shoreline) areas. Also, educate land owners about the impacts of fertilizer and pesticide applications adjacent to ponds.

- Land acquisition. Identify and acquire open space parcels, incorporating resource-based priorities into decisions. Place a priority for acquisition of properties in riparian areas.

- Bioengineering. Revegetation of shoreline areas to reduce erosion. Plan, install and maintain trails through public lands to reduce potential for erosion.

- Other structural measures. Wastewater collection to reduce phosphorus loading from individual on-site wastewater disposal systems. Install public toilet facilities for beach areas, and keep them cleaned and maintained to encourage their use.

- Inspection. Inspection and maintenance of onsite wastewater disposal systems.

- Monitoring. Continue to participate in volunteer (PALS) water quality monitoring program.

5 Implementation Strategy

As evident from the evaluation of alternatives discussed in Section 4, only a few in-lake measures would be effective for the Eastham ponds. Town officials will define their priorities among the 11 ponds, and decide what actions are to be undertaken immediately.

Suggested criteria and assigned ranks (Table 5-1) emphasize the current and projected water quality status of the ponds and the extent to which remedial actions will be of most public benefit. Higher numbers are associated with higher relative priority ranking for expenditure of Town funds.

Table 5-1. Proposed criteria for ranking ponds for remedial measures

Criteria	Values		
	1	2	3
Documented impairment	Slightly impaired (summer chlorophyll average below 8 µg/L)	Impaired (summer chlorophyll average above 8 µg/L, no measurements above 15 µg/L)	Highly impaired (summer chlorophyll average above 15 µg/L)
Outlook for future, without intervention	Improving	Stable	Declining
Ownership	Private	Public and private	Public
Access	None	Limited	Public beach or launch site
Size of ponds (surface area)	Less than 5 acres	5 – 10 acres	Larger than 10 acres (Great Pond)
Previously treated by Town	Yes, within 5 years	Yes, within 10 years	Never

Results of the preliminary ranking exercise are displayed in Table 5-2.

Table 5-2. Results of ranking exercise, based on recommended criteria

Pond	Recommended Criteria						Sum	Priority
	Impairment	Future	Ownership	Access	Size	Treatment		
Bridge	1	3	2	2	2	3	13	Low
Depot	1	2	3	2	3	3	14	Medium
Little Depot	3	3	2	2	1	3	14	Medium
Great	**2**	**3**	**3**	**3**	**3**	**3**	**17**	**High**
Herring	**3**	**3**	**3**	**3**	**3**	**3**	**18**	**High**
Jemima	2	3	2	3	2	3	15	Medium
Minister	3	3	3	3	3	3	**18**	**High**
Molls	2	3	2	2	1	3	13	Low
Muddy	1	3	3	2	3	3	15	Medium
Schoolhouse	3	2	3	3	3	3	**17**	**High**
Widow Harding	1	2	2	2	2	3	12	Low

Higher numbers are associated with higher relative priority ranking for expenditure of Town funds

The outcome of this exercise confirms that the priority ponds for immediate action are Herring, and the Schoolhouse/Ministers complex.

An alum treatment program is recommended for Herring Pond (highest priority) and Great Pond. Both ponds scored high on the documentation of impairment and their regional importance as large water bodies with public access. Herring is the priority because of its significant impairment. Enhanced mixing is recommended for the Minister/Schoolhouse complex. Abating the storm water runoff from Route 6 into Ministers Pond is recommended as a priority action as well.

The second phase of this assignment for the Town of Eastham will move the recommended actions, as amended or modified after review by town officials and the public, toward implementation.

6 References

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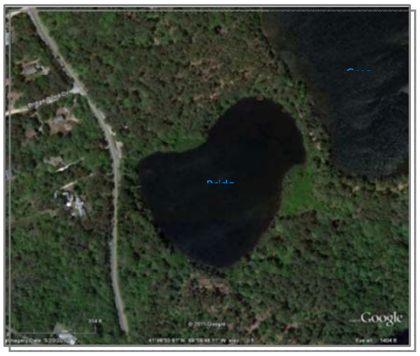
Appendix 1 – Eastham Pond Fact Sheets

Bridge Pond, Eastham MA



Setting

Pond Size: 6.7 acres; Maximum Depth: 20 ft.

Watershed Size: 7.9 acres

Public Access: Herring Brook Road to walking trails in conservation area and Wiley Park.

Uses: Wildlife viewing; herring run; fishing. No boat launches or developed beaches.

Fish community: warm water

Data: PALS, Eichner (2009), EcoLogic 2011

Current Conditions

- Impacted/at risk from human activities
- Hydrologically connected to Great Pond (inflow) and Herring Brook (outflow).
- Estimated 10.6 – 14.7 kg of annual phosphorus loading from Great Pond.
- Land use is park/conservation land around the pond, except for Herring Brook Road. No residences within 100 m of pond.
- Deep waters have low DO (transient)
- Possible sediment release of phosphorus
- Most likely phosphorus sources: birds, precipitation, roads, Great Pond

Outlook for Future

- Watershed likely to remain undeveloped
- Will be affected by conditions in Great Pond

Recommended Actions

Watershed Best Management Practices

- Control phosphorus levels in Great Pond.
- Maintain vegetated shoreline.
- Discourage large flocks of birds
- Control road runoff

Bridge Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	17 µg /l	≤10 µg/l
	Chlorophyll-a	2.8 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	2.3 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	44 µg /l	--
	Dissolved Oxygen *(minimum average)*	0.30 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Depot Pond, Eastham MA

Setting

Pond Size: 27.9 acres; Maximum Depth: 33 ft

Watershed Size: 64.9 acres

Public Access: Unmarked fire road

Uses: Swimming, fishing, non-motorized boating

Fish community: cold water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- At risk from human activities
- Oxygen depletion in deep waters during summer
- Major phosphorus sources: Septic (0-44%), birds (31-38%), roads (7-25%), roofs (7-25%)
- 6 residences within 300 ft. up-gradient of pond, with one other developable parcel.

Outlook for Future

- Septic system contribution may increase as discharges slowly reach the pond
- Sediment phosphorus release

Recommended Actions

In-pond measures:

- Alum treatment program

Watershed Best Management Practices (BMPs):

- Septic system maintenance

Depot Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	19 µg /l	≤10 µg/l
	Chlorophyll-a	1.7 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	5.0 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	36 µg /l	--
	Dissolved Oxygen *(minimum average)*	0.27 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Great Pond, Eastham MA

Setting

Pond Size: 109.7 acres; Maximum Depth: 36 ft.

Watershed Size: 226 acres

Public Access: Town Beach, Wiley Park, and Nickerson Conservation Area

Uses: Swimming, fishing, non-motorized boating (motorized boating by permit)

Fish community: cold water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Low dissolved oxygen levels in deep water during summer
- Major phosphorus sources: Sediment (33-34%), precipitation (15-28%), septic (11-17%)
- 22 properties within 300 ft. upgradient
- Discharges to Bridge Pond; herring run from Herring Brook through Bridge Pond.

Outlook for Future

- Sediment phosphorus release will continue
- Septic system contribution will increase as discharges slowly reach the pond (time of travel estimated 35-81 years)
- Phosphorus concentrations stable; will increase as wastewater input increases.

Recommended Actions

In-pond measure:

- Alum treatment program

Watershed Best Management Practices:

- Septic system maintenance/upgrades
- Replace septic systems with sewers
- Maintain shoreline vegetative buffers

Great Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	18 µg /l	≤10 µg/l
	Chlorophyll-a	12.1 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	2.7 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	43 µg /l	--
	Dissolved Oxygen *(minimum average)*	0.43 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.

[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Herring Pond, Eastham MA

Setting

Pond Size: 44.2 acres; Maximum Depth: 35 ft.

Watershed Size: 79.8 acres

Public Access: Town Beach

Uses: Swimming, fishing, boating

Fish community: cold water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted - Abundant algae
- Dissolved oxygen depletion in deep waters
- Increasing phosphorus
- Major phosphorus sources: Sediment (0-60%), roads (6-35%), precipitation (6-31%), roof (3-18%), septic (0-16%)
- 20 leach fields within 300 ft. (upgradient)

Outlook for Future

- Sediment phosphorus will continue to be important
- Septic system contribution will increase as discharges slowly reach the pond (time of travel estimated 35-81 years)
- Phosphorus concentrations will continue to increase

Recommended Actions

In-pond treatment:

- Alum application
- Aquatic plant controls

Watershed Best Management Practices (BMPs):

- Septic system maintenance
- Residential and lawn practices

Herring Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	19 µg /l	≤10 µg/l
	Chlorophyll-a	7.5 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	1.8 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	86.9 µg /l	--
	Dissolved Oxygen *(minimum average)*	0.26 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.

[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Jemima Pond, Eastham MA

Setting

Pond Size: 6.4 acres; Maximum Depth: 15 ft.

Watershed Size: 17.9 acres

Public Access: Samoset Road bathing beach

Uses: Swimming, fishing, non-motorized boating

Fish community: warm water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Well-mixed water column
- Six residences within 300 ft. upgradient
- Most likely phosphorus sources: birds, septic, precipitation, road runoff

Outlook for Future

- Phosphorus concentrations in pond may increase as discharges from septic systems reach the pond (time of travel in groundwater estimated 35-81 years)
- Phosphorus concentrations in pond may increase if road runoff is not controlled.

Recommended Actions

Watershed Best Management Practices (BMPs):

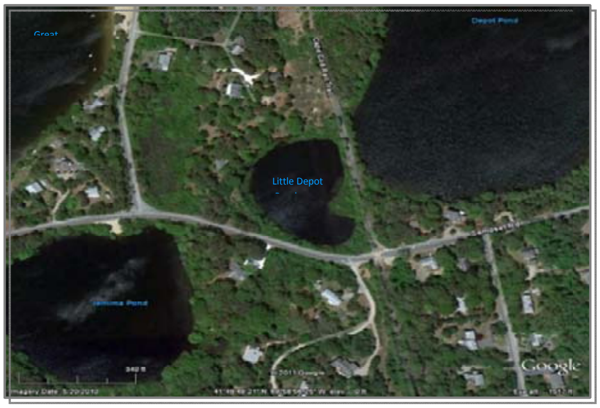
- Maintain or upgrade septic systems
- Maintain vegetated shoreline
- Discourage large flocks of birds
- Control road runoff

Jemima Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	18 µg /l	≤10 µg/l
	Chlorophyll-a	7.8 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	2.6 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	24 µg /l	--
	Dissolved Oxygen *(minimum average)*	6.1 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Little Depot Pond, Eastham MA



Setting

Pond Size: 2.3 acres; Maximum Depth: 10 ft.

Watershed Size: 2.3 acres

Public Access: Samoset Road or Rail Trail.

Uses: Wildlife observation, aesthetics, swimming, fishing, non-motorized boating

Fish community: warm water

Data sources: PALS 2008-2010, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Water column well-mixed
- Three residences within 300 ft. upgradient
- Most likely phosphorus sources: birds, septic, precipitation, road runoff (Samoset)
- No information on future build-out potential.

Outlook for Future

- Phosphorus concentrations in pond may increase as discharges from septic systems less than 35 years old slowly reach the pond (time of travel in groundwater estimated 35-81 years)
- Phosphorus concentrations in pond may increase if road runoff is not controlled.

Recommended Actions

Watershed Best Management Practices:

- Maintain or upgrade septic systems
- Maintain vegetated shoreline
- Discourage large flocks of birds
- Control road runoff

Little Depot Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	26 µg /l	≤10 µg/l
	Chlorophyll-a	18 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	1.7 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	40 µg /l	--
	Dissolved Oxygen *(minimum average)*	5.3 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Minister Pond, Eastham MA

Setting

Pond Size: 16.8 acres; Maximum Depth: 13 ft.

Watershed Size: 151 acres

Public Access: "Fisherman's Launch" at Schoolhouse Pond.

Uses: Swimming, fishing, non-motorized boating

Fish community: warm water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Dissolved oxygen loss in deep waters
- Major phosphorus sources: Roads (29-60%), septic (0-45%); sediment not quantified
- 16 residences within 300 ft. upgradient, 2 developable parcels
- Minister Pond receives phosphorus load from watershed upstream of Schoolhouse.

Outlook for Future

- Sediment phosphorus will continue to be important
- Septic system contribution will increase as discharges slowly reach the pond (time of travel estimated 35-81 years)
- Phosphorus concentrations are presently stable, but may increase over time as septic system contributions increase.

Recommended Actions

Watershed Best Management Practices (BMPs):

- Septic system maintenance
- Maintain vegetated shoreline
- Mitigate roadway runoff

Minister Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	28 µg /l	≤10 µg/l
	Chlorophyll-a	21 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	1.3 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	43 µg /l	--
	Dissolved Oxygen *(minimum average)*	0.13 mg/l	--

Molls Pond, Eastham MA

Setting

Pond Size: 3.4 acres; Maximum Depth: 12 ft.

Watershed Size: 8.1 acres

Public Access: None

Uses: Swimming, fishing, non-motorized boating

Fish community: warm water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted/at risk by human activities
- Occasional occurrence of low oxygen conditions in deeper waters
- Most likely phosphorus sources: birds, septic, precipitation, road runoff
- Approximately 18 residences within 300 ft. upgradient

Outlook for Future

- Septic system contribution will increase as discharges slowly reach the pond (time of travel estimated 35-81 years)

Recommended Actions

Watershed Best Management Practices (BMPs):

- Maintain or upgrade septic systems
- Maintain vegetated shoreline
- Discourage large flocks of birds
- Control road runoff

Molls Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	19 µg /l	≤10 µg/l
	Chlorophyll-a	12 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	2.9 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	16 µg /l	--
	Dissolved Oxygen *(minimum average)*	1.3 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Muddy Pond, Eastham MA

Setting

Pond Size: 10.5 acres; Maximum Depth: 5 ft.

Watershed Size: 39.9 acres

Public Access: None; private beach

Uses: Swimming, fishing, non-motorized boating

Fish community: warm water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Dense aquatic plant growth.
- Major phosphorus sources: Roads (21-45%), septic (0-38%), birds (17-21%), precipitation (10-21%)
- 5 residences within 300 ft. upgradient of the pond

Outlook for Future

- Septic system contribution will increase as discharges slowly reach the pond (time of travel estimated 35-81 years)
- Phosphorus concentrations will continue to increase

Recommended Actions

In-pond measures:

- Aquatic plant controls
- Increased circulation

Watershed Best Management Practices (BMPs):

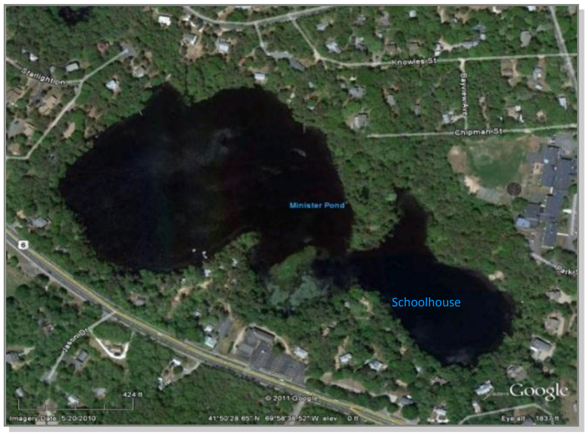
- Septic system maintenance

Muddy Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	21 µg /l	≤10 µg/l
	Chlorophyll-a	3.3 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	1.3 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	25 µg /l	--
	Dissolved Oxygen *(minimum average)*	5.9 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Schoolhouse Pond, Eastham MA



Setting

Pond Size: 6.8 acres; Maximum Depth: 13 ft.

Watershed Size: 5.7 acres

Public Access: Launch off Schoolhouse Road.

Uses: Swimming, fishing non-motorized boating

Fish community: warm water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Occasional stratification and low oxygen may allow sediment phosphorus release.
- Major phosphorus sources: Birds (26-46%), roads (18-26%), precipitation (14-21%); input from Minister Pond (amount not known)

One septic leach field within 300 ft. upgradient.

- Minister Pond receives phosphorus load from watershed upstream of Schoolhouse Pond

Outlook for Future

- Occasional stratification and low oxygen conditions will continue to allow sediment phosphorus release.
- Phosphorus concentrations appear stable.

Recommended Actions

Watershed Best Management Practices (BMPs):

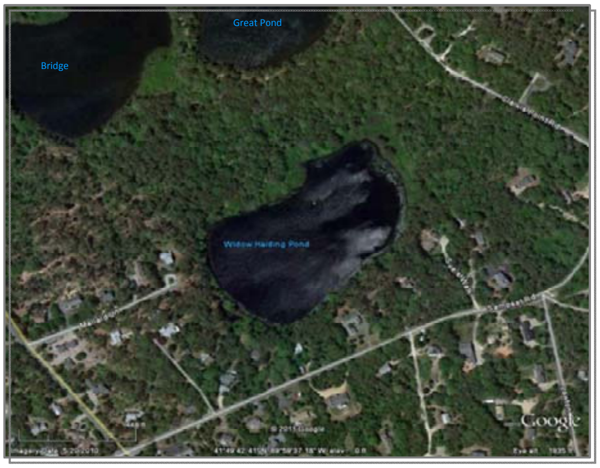
- Very limited watershed area, affected by conditions in Minister Pond
- Septic system maintenance

Schoolhouse Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	23 µg /l	≤10 µg/l
	Chlorophyll-a	22 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	1.3 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	65 µg /l	--
	Dissolved Oxygen *(minimum average)*	0.20 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Widow Harding Pond, Eastham MA



Setting

Pond Size: 8.7 acres; Maximum Depth: 13 ft.

Watershed Size: 25.9 acres

Public Access: Walking trails in conservation area and Wiley Park.

Uses: Wildlife viewing, swimming, fishing, non-motorized boating.

Fish community: warm water

Data: PALS, Eichner 2009, EcoLogic 2011

Current Conditions

- Impacted by human activities
- Occasional stratification and seasonal low oxygen
- 11 residences within 300 ft. upgradient
- Most likely phosphorus sources: birds, septic, precipitation, roads.

Outlook for Future

- Stable land use
- Septic system contribution will increase as discharges slowly reach the pond (time of travel estimated 35-81 years)

Recommended Actions

Watershed Best Management Practices (BMPs):

- Maintain or upgrade septic systems
- Maintain vegetated shoreline, minimize open lawn areas leading to water's edge.
- Discourage large flocks of birds.
- Control road runoff.

Widow Harding Pond Water Quality Summary

Water Column	Parameter	Result[1]	"Healthy" Ponds Thresholds[2]
Upper Waters	Total Phosphorus	21 µg /l	≤10 µg/l
	Chlorophyll-a	3.0 µg /l	≤1.7 µg/l
	Secchi Disk Transparency	3.1 m	Not calculated
Lower Waters	Total Phosphorus *(maximum average)*	38 µg /l	--
	Dissolved Oxygen *(minimum average)*	4.6 mg/l	--

[1]Annual average results; Total phosphorus and chlorophyll-a, 2008-2010; Secchi disk transparency and dissolved oxygen, 2007-2010.
[2]Cape Cod Commission 2003. Table 5. Based on lower 25th percentile of 2001 Snapshot (all ponds). Secchi disk transparency not calculated due to multiple observations of disk visible on the bottom.

Part I – Summary of Method Review

Part II – Method Fact Sheets

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds.

	Phosphorus (P) Inactivation	Artificial Circulation	Hypolimnetic Aeration
Description	Application of alum (aluminum sulfate) to keep phosphorus from leaching from sediments during anoxic conditions.	Whole lake circulation to eliminate anoxia in lower waters where sediment recycling of P occurs; thermal destratification also results.	Aeration of lower waters to eliminate anoxia where sediment recycling of P occurs. Thermal stratification maintained.
Benefits	• Rapid removal of P from water column • Minimize internal P loading	• Minimize P release from sediments • Increase in oxygen levels throughout pond may enhance habitat • Increase die-off rate of bacteria	• Minimize P release from sediment without eliminating thermal stratification • Increase in oxygen levels in lower waters may enhance habitat
Potential Drawbacks	• Potential impact to aquatic life in ponds with low alkalinity, as pH will decrease unless application is buffered; low pH can allow aluminum to be present in a toxic form. • Limited longevity if external loading is not controlled.	• May re-suspend sediment and increase turbidity if not controlled • May increase algal growth in some cases, if water rich in nutrients mixes into photic zone (zone of light penetration) • Can modify thermal conditions for fish community	Theoretically possible to induce gas bubble disease in fish if super saturation of nitrogen occurs.
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • Permit to Apply Chemicals from DEP • Possible 401 WQ permit through the DEP	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • Chapter 91 Permit through DEP may be required for Great Ponds	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • Chapter 91 Permit through DEP may be required for Great Ponds
Impacts Specific to Wetlands Protection Act (WPA)	• Water supply protection benefit from water quality improvement • Wildlife habitat and fisheries benefit from water quality improvement, but possible detriment through reduced fertility. • No impact to flood control, storm damage prevention or groundwater supply protection	• Water supply protection benefit from water quality improvement • Wildlife habitat and fisheries benefit from extended oxygenation, but possible detriment through loss of coldwater habitat. • No impact to flood control, storm damage prevention or groundwater supply protection	• Water supply protection benefit from water quality improvement • Wildlife habitat and fisheries benefit from extended oxygenation • No impact to flood control, storm damage prevention or groundwater supply protection
Relative Cost	Typically $500-$1000/acre	Capital: $200-$3000/acre Annual: $50-$800/acre	Capital: $750-$3000/acre Annual: $55-$220/acre
Applicable to Eastham Ponds	Applicable to ponds with significant internal P loading from sediments: Herring, Great, Depot	Ponds that undergo stratification at least occasionally, support a warm water fish community: Bridge, Minister, Schoolhouse, Widow Harding, Jemima	Deep ponds with stable hypolimnion and a cold water fish community: Depot, Great and Herring

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Drawdown	Conventional Dry Dredging	Conventional Wet Dredging
Description	Water level lowered for a period of time (months) to expose sediment to air and to kill aquatic plants by drying/freezing.	Partial/complete draining of the pond and removal of exposed sediments using conventional excavation equipment. Dredge spoils require containment and disposal areas, preferably proximate to the pond.	Removal of sediment under water using specialized excavation equipment. Dredge spoils will require dewatering prior to disposal. A containment/disposal area proximate to the pond may be required.
Benefits	• Kills vegetative portions of aquatic plants • Plant species richness may increase • Allows sediment oxidation and compaction to reduce available nutrients • May reduce fine sediments in drawdown zone, leaving coarser material behind • Protects shoreline from ice damage	• Deeper pond increases water storage, may improve recreational use • Reduces nutrient release from sediment by removing source • Controls distribution of rooted plants that require shallow waters and more light.	• Deeper pond increases water storage, may improve recreational use • Reduces nutrient release from sediment by removing source • Controls distribution of rooted plants that require shallow waters and more light.
Potential Drawbacks	• Will not kill seeds • If not flushed, nutrient release may fuel algal production • During drawdown, life stages of some fauna may be impacted • May impair nearby shallow well production	• Significant, short-term impacts to the habitat of the pond during disturbance • Sediment disposal may be costly; driven by sediment quality and quantity	• Significant, short-term impacts to the habitat of the pond during disturbance • Sediment disposal may be costly; driven by sediment quality and quantity • Potential for increased turbidity downstream during dredging • Difficult to visually appraise completeness
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)	• MEPA review • WPA permit (local CC/DEP) • Review by NHESP • Chapter 91 permit (DEP) for Great Ponds • 404 permit (Corps of Engineers) • 401 WQ permit (DEP) • Solid Waste permit (DEP)	• MEPA review • WPA permit (local CC/DEP) • Review by NHESP • Chapter 91 permit (DEP) for Great Ponds • 404 permit (Corps of Engineers) • 401 WQ permit (DEP) • Solid Waste permit (DEP) • Possible NPDES permit (EPA/DEP)
Impacts Specific to Wetlands Protection Act (WPA)	• Adverse impacts to water supply and groundwater • Neutral impacts to habitat and wildlife • Beneficial impacts to flood control	• Neutral impacts to groundwater supply, flood control, storm damage prevention • Beneficial impacts to water quality; long-term benefits wildlife habitat, fisheries	• Neutral impacts to groundwater supply, flood control, storm damage prevention • Beneficial impacts to water quality; long-term benefits wildlife habitat, fisheries
Relative Cost	Less expensive if water level control means are in place; more expensive if pumps are needed.	Generally $15/cubic yard, may range as high as $30/cubic yard for removal.	Generally $20/cubic yard.
Applicable to Eastham Ponds	Not applicable –ponds are ground-water flooded kettle holes with no significant inlet or outlet for water level control.	Not applicable –ponds are ground-water flooded kettle holes with no significant inlet or outlet for water level control.	Shallow ponds with extensive macrophytes and organic sediment. : Muddy, Herring, Minister, Schoolhouse and Little Depot. Siting dewatering/disposal sites challenging.

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Hydraulic or Pneumatic Dredging	Reverse Layering	Hand Harvesting
Description	Removal of sediment using suction and agitation (hydraulic) or air pressure (pneumatic). Material is pumped to dewatering area prior to disposal.	Uses hydraulic jetting to re-organize sediment layers – bring glacial sand to surface and bury organic surface layers. Experimental (Red Lily Pond, Barnstable)	Hand-pulling of unwanted plants by a diver.
Benefits	• Deeper pond increases water storage, may improve recreational use • Reduces nutrient release from sediment by removing source • Controls distribution of rooted plants that require shallow waters and more light. • Less disruption of biological components than conventional approaches.	• Controls some rooted plants by changing substrate to sand • Buries sediments that release P, limiting the P contribution to the water column • No dewatering or disposal area required.	• Selective plant control • Limited impact on non-target organisms • Prevention of infestations
Potential Drawbacks	• Upland disposal area required • May expose sediments equally enriched with P • Impacts habitat during process	• Fine sediment/sand may be suspended and dispersed. • Sand substrate may encourage growth of other nuisance aquatic plants • No permanent improvement to Red Lily Pond	• Incomplete harvesting may result in re-growth or dispersal of plants • Turbidity may be generated.
Permit Issues	• MEPA review • WPA permit (local CC/DEP) • Review by NHESP • Chapter 91 permit (DEP) for Great Ponds • 404 permit (Corps of Engineers) • 401 WQ permit (DEP) • Solid Waste permit sediment disposal (DEP) • Possible NPDES permit (EPA/DEP)	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)
Impacts Specific to Wetlands Protection Act (WPA)	• Neutral impacts: ground water supply, flood control, storm damage prevention • Beneficial impacts: water quality improvement, long-term habitat enhancement	• Neutral impacts: ground water supply protection, flood control, storm damage prevention. • Beneficial impacts: water quality improvement, long-term habitat improvement.	• Neutral impacts: water supply and groundwater supply protection; flood control; storm damage prevention; pollution prevention; protection of shellfish lands, fisheries, and wildlife habitat.
Relative Cost	Generally \$12/cy, as high as \$30/cy	\$10,000/acre (1991 figure)	Generally ranges \$100-\$500/acre
Applicable to Eastham Ponds	Ponds impaired by shallow depths, extensive macrophyte growth and organic, P-rich sediment layers: Muddy, Herring, Minister, Schoolhouse and Little Depot. Siting dewatering/disposal sites challenging.	More information needed regarding sediment profile (depth to reach sand layer). Smaller ponds with organic sediments: Bridge, Muddy, Widow Harding.	Can be used to restore recreational access in relatively limited areas of ponds impaired by excessive growth of aquatic plants. Also used to help control invasive species.

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Mechanical Harvesting	Hydroraking	Rotovation
Description	Cutting plants close to the sediment; may or may not involve removal of cut plants.	Hydroraking involves use of a floating backhoe, usually outfitted with a rake that is moved through sediment to rip out thick root masses and debris.	A rotovator is a hydraulically operated tillage device mounted on a barge, typically for removal of dense growths of unwanted plants.
Benefits	• Clears plant biomass in select areas • Does not kill most plants through single cutting • Repeated harvest may reduce abundance of seed-producing species	• Removes vegetation difficult to harvest by other means • Allows removal of stumps or other obstructions	• Disrupts the entire plant, especially roots.
Potential Drawbacks	• Minimally selective • May encourage expansion of plants propagating vegetatively • Regrowth may occur quickly, requiring more frequent harvesting	• Very disruptive in areas applied; may generate high turbidity and drastically alter habitat • May spread plants that reproduce by fragmentation	• Very disruptive in areas applied; may generate high turbidity and drastically alter habitat • May spread plants that reproduce by fragmentation • Decay of damaged plants may affect water quality
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)
Impacts Specific to Wetlands Protection Act (WPA)	• Neutral impacts: water supply protection, groundwater supply protection, flood control, storm damage prevention, pollution prevention, protection of shellfish lands, protection of fisheries, protection of wildlife habitat.	• Adverse impacts: shellfish areas • Neutral impacts: water supply protection, groundwater supply protection, flood control, storm damage prevention, fisheries • Beneficial impacts: wildlife habitat	• Adverse impacts: shellfish areas • Neutral impacts: water supply protection, groundwater supply protection, flood control, storm damage prevention, fisheries • Beneficial impacts: wildlife habitat
Relative Cost	Generally $200-$2,000/acre depending on plant density	Generally $1,500-10,000/acre depending on plant growth and density	Generally, $500-2,000/acre
Applicable to Eastham Ponds	All ponds where excessive macrophyte growth impairs desired uses	All ponds where excessive macrophyte growth impairs desired uses	All ponds where excessive macrophyte growth impairs desired uses

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Benthic Barriers	Herbicide/Algaecide: Copper Treatment	Herbicide/Algaecide: Diquat Treatment
Description	Use of natural or artificial material to cover the pond bottom to prevent plant growth.	Non-selective contact herbicide/algaecide, inhibits photosynthesis. Dependent on alkalinity, dissolved solids, suspended matter and water temperature. Approved for use in potable water supplies in Massachusetts.	General purpose, broad-spectrum herbicide disrupts photosynthesis. Less effective in turbid, muddy waters, rapidly sorbs to sediments.
Benefits	• Elimination of plants in target area with proper application and maintenance • Re-usable barrier materials • Creates edge effect and habitat enhancement • May foster improved assemblage after removal, by seeds or selective planting	• Rapid kill of susceptible algae • Rapidly eliminated from water column, minimizing prolonged adverse impacts	• Effective against a wide variety of species • Relatively rapid kill of targeted vegetation • Can be used for spot treatments; limited drift or impact outside target area
Potential Drawbacks	• Non-selective technique; all plants under barrier will be killed • Effectiveness declines without labor-intensive maintenance	• Toxic to many non-target organisms • Releases contents of most killed algal cells into water column, including nutrients, taste/odor compounds, and toxins • Ineffective on some algae; resistant nuisance algal species may benefit • Accumulates in sediments; long-term impacts may not be severe	• Not very selective; kills most species contacted • Does not damage portions of plants with which it does not contact; regrowth from roots is common • Potential for toxicity to fauna, but uncommon in practice
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP
Impacts Specific to Wetlands Protection Act (WPA)	• Neutral impacts: water supply protection, groundwater supply protection, flood control, storm damage prevention, pollution prevention, protection of shellfish lands, protection of fisheries, protection of wildlife habitat.	• Adverse impacts: food source alteration shellfish, wildlife • Neutral impacts: groundwater supply, storm damage prevention • Beneficial impacts: habitat enhancement	• Adverse impacts: food source alteration shellfish, wildlife • Neutral impacts: groundwater supply, storm damage prevention • Beneficial impacts: habitat enhancement
Relative Cost	Generally \$20,000-\$50,000/acre	Generally \$50-\$100/acre	Generally \$200-\$500/acre
Applicable to Eastham Ponds	All ponds where excessive macrophyte growth impairs desired uses	Not recommended- algal blooms are not currently an impairment, ponds are not used for potable supply	Not recommended at this time, likely to be significant public opposition

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Herbicide/Algaecide: Endothall Treatment	Herbicide/Algaecide: Glyphosate Treatment	Herbicide/Algaecide: 2,4-D Treatment
Description	Contact herbicide that inhibits use of oxygen for respiration. Does not kill roots, not very effective against milfoil. Dose limits to avoid impacts to non-target fauna.	Systemic, broad spectrum herbicide, disrupts plant's metabolic pathways. Most effective on emergent and floating-leaved plant species.	Systemic herbicide, absorbed by roots, leaves and shoots; and disrupts cell division. Useful for Eurasian watermilfoil.
Benefits	• Effective against a wide variety of species • Relatively rapid kill of targeted vegetation • Areally selective; limited drift or impact outside target area	• Effective on emergent vegetation • Kills entire plant for susceptible species • Selective by area and vegetation type (emergent/floating vs. submergent)	• Complete kill of susceptible vegetation, typically multiple years of control • Acts relatively quickly in the aquatic environment; sufficient uptake occurs within 3 days • Can be used selectively on certain major invasive species at low doses, and for partial (shoreline) pond treatments
Potential Drawbacks	• Not very selective; kills most species contacted • Does not damage portions of plants with which it does not contact; regrowth from roots is common • Potential for toxicity to fauna, but uncommon in practice	• Ineffective against submergent species • Precipitation (rain) interferes with uptake	• Potential for toxicity to fauna, but a rare occurrence in practice • Use restrictions in or near drinking water supplies (surface or wells) limits application
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP
Impacts Specific to Wetlands Protection Act (WPA)	• Adverse impacts: food source alteration, loss of cover (shellfish, wildlife) • Neutral impacts: groundwater supply, storm damage prevention • Beneficial impacts: habitat enhancement	• Adverse impacts: water supply, food source alteration, loss of cover (shellfish, wildlife) • Neutral impacts: groundwater supply, storm damage prevention, pollution prevention • Beneficial impacts: habitat enhancement	• Adverse impacts: water and groundwater supplies, food source alteration, loss of cover (wildlife) • Neutral impacts: storm damage prevention, pollution prevention, shellfish • Beneficial impacts: habitat enhancement
Relative Cost	Generally $400-$700/acre	Generally $500-$1,000/acre	Generally $300-$800/acre
Applicable to Eastham Ponds	Not recommended at this time, likely to be significant public opposition	Not recommended at this time, likely to be significant public opposition	Not recommended at this time, likely to be significant public opposition

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Herbicide/Algaecide: Fluridone Treatment	Herbicide/Algaecide: Triclopyr Treatment	Dyes and Covers
Description	Systemic herbicide that inhibits carotene synthesis, which exposes chlorophyll to photodegradation. Takes 30-90 days for die-off to occur. Some plants more susceptible than others.	Systemic herbicide, disrupts growth processes. Approved for use in Mass in 2004	Dyes are used to limit light penetration and therefore restrict the depth at which rooted plants can grow or the total amount of light available for algal growth.
Benefits	• Complete kill of susceptible vegetation • Can be used selectively on certain major invasive species at low doses • Slow death of plants minimizes oxygen demand and nutrient release • Minimal risk of any direct impacts on fauna	• Specific to dicots, notably Eurasian watermilfoil • Slow death of plants minimizes oxygen demand and nutrient release • Very low toxicity to fish and aquatic animals	• Change plant community without physical disruption or toxic reactions • Localized control on a temporary basis • Dyes can mask algal discoloration, create the illusion of greater depth; aesthetic appearance is often enhanced
Potential Drawbacks	• Acts slowly in the aquatic environment; exposure time of up to 90 days needed • Highly diffusive; dilution will limit effectiveness in areas of high flushing activity	• Half-life, approximately 20 days • Effective at relatively low concentrations	• Dyes may be ineffective in shallow water • Altered color may not appear natural • Increased heat absorption may cause thermal stratification • Surface covers interfere with recreation • Wind and waves compromise covers • Not for use in water bodies with active outflows
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • License to Apply Chemicals from DEP (dyes unless pond is private and has no flowing outlet) • Chapter 91 Permit through DEP may be required for Great Ponds (surface covers only)
Impacts Specific to Wetlands Protection Act (WPA)	• Adverse impacts: food source alteration, loss of cover (fish, wildlife) • Neutral impacts: water and groundwater supplies, storm damage prevention, pollution prevention, shellfish lands • Beneficial impacts: habitat enhancement	• Adverse impacts: food source alteration, loss of cover (fish, wildlife) • Neutral impacts: water and groundwater supplies, storm damage prevention, pollution prevention, shellfish lands • Beneficial impacts: habitat enhancement	• Adverse impacts: food source alteration, loss of cover (fish, wildlife) • Neutral impacts: water and groundwater supplies, storm damage prevention, pollution prevention, shellfish lands • Beneficial impacts: habitat enhancement
Relative Cost	Generally $500-$2,000/acre	$1000/acre, includes monitoring costs	Generally $100-$500 per acre.
Applicable to Eastham Ponds	Not recommended at this time, likely to be significant public opposition	Not recommended at this time, likely to be significant public opposition	Not likely to be effective

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Food Web Biomanipulation	Herbivorous Fish	Herbivorous Invertebrates
Description	Algal control options usually involving zooplankton and fish community structure	Grass carp (Ctenopharyngodon idella) is commonly used to control aquatic plants. However, grass carp are not approved for introduction in Massachusetts.	Biological control using native invertebrates (mainly insects) that feed on the introduced target plant species. Two insects highlighted: native weevil (Euhrychiopsis lecontei) for the control of Eurasian milfoil and loosestrife beetle (Galerucella spp.), used to control purple loosestrife. Predator rarely eliminates prey, so population cycling will occur.
Benefits	• Harnesses natural processes to develop desirable conditions • May be self-sustaining or require only limited maintenance • May produce both clearer water and better fishing	• Potential control of aquatic plants from a single introduction of an appropriate density of fish for perhaps 5 years	• Potential control with native (or carefully researched and approved non-native) species that may be self-perpetuating • Harnesses natural processes to control nuisance or invasive species
Potential Drawbacks	• High variability of results; not especially reliable	• Massachusetts Fisheries and Wildlife Board has not issued permits to introduce grass carp	• High variability in results; not especially reliable • Generally slow in achieving desired results
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)	• The importation of grass carp is currently illegal in Massachusetts. No permits are granted for the introduction of this fish.	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)
Impacts Specific to Wetlands Protection Act (WPA)	• Neutral impacts: groundwater supply, flood control, storm damage prevention, shellfish lands • Beneficial impacts: water supply, pollution prevention, fisheries.	•	• Neutral impacts: water and groundwater supplies, flood control, storm damage prevention, pollution prevention, shellfish lands • Beneficial impacts: habitat enhancement (fisheries and wildlife).
Relative Cost	Piscivore stocking - $500-$1500/acre Planktivore removal - $1,000-$5,000/acre		Generally $300-$3,000
Applicable to Eastham Ponds	Unknown applicability to ponds, would require detailed fish community analysis	Not applicable, release of grass carp is not permitted in Massachusetts.	Purple loosestrife – only Herring Pond (Aug. 2011). Eurasian watermilfoil was not observed in the Eastham ponds.

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Plant Competition	Barley Straw	Bacterial Additives
Description	Seeding and planting of native plant species to out-compete invasive plant species; experimental.	Decomposition of the barley straw produces allelopathic compounds that act as algaecides. Competition for nutrients between heterotrophic decomposers and autotrophic algae appears to favor the heterotrophs after barley straw addition	Add natural or engineered bacteria to the aquatic environment to out-compete algae for nutrients, reducing concentrations of N and P. It is not clear that a bacterial community capable of precluding algal blooms would not itself constitute an impairment of aquatic conditions.
Benefits	• Harnesses natural processes to develop desired conditions • May be self-perpetuating • Augments other techniques for plant control	• Possible control of selected algae (notably blue-greens) at low cost	• Reduced algal abundance through competition with bacteria
Potential Drawbacks	• May not prevent invasions over a long time period • Requires ongoing effort to keep up with natural disturbances • Indigenous species may become nuisances in some cases • Likely to require application of a major control technique prior to planting	• Possible oxygen depression and related biotic impacts • Highly variable results; not especially reliable	• Possible bacterial biomass build-up • Favorable conditions for blue-green algae
Permit Issues	• Possible WPA permit through local CC/DEP • Possible review by NHESP (further action if protected species are present)	• Possible WPA permit through local CC/DEP • Possible Review by NHESP (further action if protected species are present) • EPA classifies as an unregistered herbicide	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present)
Impacts Specific to Wetlands Protection Act (WPA)	• Neutral impacts: water and groundwater supplies, flood control, storm damage prevention, pollution prevention, shellfish lands • Beneficial impacts: habitat enhancement (fisheries, wildlife).	• Neutral impacts: groundwater supplies, flood control, storm damage prevention, shellfish lands • Beneficial impacts: water supply, pollution prevention, habitat enhancement (fisheries, wildlife).	• Neutral impacts: groundwater supplies, flood control, storm damage prevention, shellfish lands • Beneficial impacts: water supply, pollution prevention, habitat enhancement (fisheries, wildlife).
Relative Cost	Unknown	Unknown	Unknown
Applicable to Eastham Ponds	Based on August 2011 survey, macrophyte community dominated by native species	Not recommended- experimental, significant permit barriers, algal blooms not yet problematic	Not recommended

Appendix 2-1 Summary Review of potential in-pond management techniques and their applicability to Eastham ponds. (continued)

	Removal of Bottom-feeding Fish	Sonication
Description	Elimination of bottom feeders (common carp or bullheads) may reduce nutrient availability and improve transparency. This technique has not been practiced in many years in Massachusetts, except as a side effect of dry dredging or complete drawdown for structural dam repairs.	A floating sonicator breaks up algae and causes them to sink to the pond bottom over target areas that range from 150 to 15,500 square meters. No scientific tests of this apparatus have been reported in the lake management literature, and this product provides only short-term relief.
Benefits	• Reduces populations of fish that add turbidity and nutrients to the water • May improve water clarity and algal community features • May improve plant community features	• Rapid reduction in algal biomass without chemical addition
Potential Drawbacks	• Difficult to accomplish at significant level, especially in absence of approved fish poison in Massachusetts • May not be effective if nutrient loading from other sources is high	• Will result in release of algal cell contents to the water, increasing soluble nutrients • Safety issue associated with power cables in ponds
Permit Issues	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • Permit from MDFW for collection of fish	• WPA permit through local CC/DEP • Review by NHESP (further action if protected species are present) • Chapter 91 Permit through DEP may be required for Great Ponds, due to navigational hazard
Impacts Specific to Wetlands Protection Act (WPA)	• Neutral impacts: groundwater supplies, flood control, storm damage prevention, shellfish lands • Beneficial impacts: water supply, pollution prevention, habitat enhancement (fisheries, wildlife).	• Neutral impacts: groundwater supplies, flood control, storm damage prevention, shellfish lands • Beneficial impacts: water supply, pollution prevention, habitat enhancement (fisheries, wildlife).
Relative Cost	Unknown	Generally $1,000-$3,000 per unit to influence a few acres; operational costs unknown.
Applicable to Eastham Ponds	Fish community information lacking	Algal blooms currently rare, but may increase in future as additional wastewater P reaches ponds.

Abbreviations:

- CC = Conservation Commission
- DEP = Massachusetts Department of Environmental Protection
- MDFW = Massachusetts Division of Fisheries and Wildlife
- MEPA = Massachusetts Environmental Policy Act
- NHESP = Natural Heritage and Endangered Species Program
- NPDES = National Pollutant Discharge Elimination System
- P = Phosphorus
- WPA = Wetlands Protection Act
- WQ = Water Quality

Pond Management: Phosphorus Inactivation Using Alum

Phosphorus is a nutrient which, if present in high concentrations, can foster the excessive growth of algae. As algal abundance increases, the amount of organic material produced within the pond increases. Ultimately, decay of this organic material can deplete the deep waters of their oxygen supply. Chemical changes at the sediment surface occur once oxygen is lost. These chemical changes can result in phosphorus flux from the sediments back to the water column. An alum treatment program can be an effective pond restoration technique.

This approach accomplishes several objectives:

- Removes phosphorus rapidly from the water column during application
- Reduces internal loading of phosphorus by binding sediment phosphorus and containing it in the sediment.

Alum application is applicable to deep pond, with a substantial internal phosphorus load.

Methods

A mixture of alum and aluminum sulfate is applied to the pond from a boat. Once in the water, the alum forms a *floc* (loose aggregation of small particles), and settles to the bottom.

As the floc settles through the water column, phosphorus and suspended solids are removed from the water. Once on the bottom, the floc forms a layer that acts as a phosphorus barrier, binding the phosphorus released from the sediments before it can reach the water above.

High alkalinity in the pond is desirable to buffer the reaction of alum with the phosphorus and minimize lowering of pH. Where ponds do not have high alkalinity, the alum would be applied with a basic salt to provide buffering.

Cape Cod Alum Projects

Hamblin Pond, Barnstable, 1995

The pond's low buffering capacity caused some mortality to fish during the application; the fish community has recovered and Hamblin Pond now supports a high quality trout fishery. Water quality has been excellent for 16 years post treatment. Algal abundance is low, and water clarity and dissolved oxygen are high.

Ashumet Pond, Mashpee/Falmouth, 2001-2010

25 acres of Ashumet Pond were treated with alum in 2001. In 2004, a barrier wall was constructed to intercept the phosphorus plume in ground water. In 2010, alum treatment was repeated; results are pending.

Long Pond, Brewster/Harwich, 2007

370 acres were treated with a mixture of alum and sodium aluminate, fall 2007. Water clarity increased the following summer, with no adverse impacts on lake biota.

Mystic Pond, Barnstable, 2010

Initial results indicate moderate success, with increased water clarity, elimination of blue-green algal blooms, and improved dissolved oxygen in lower waters. Mass DEP applied permit restrictions on treatment area and dosage due to potential impacts on endangered mussels.

Lovers Lake, Chatham, 2010

Fall alum treatment, 2011 results pending.

Stillwater Pond, Chatham, 2010

Fall alum treatment, 2011 results pending.

Pond Management: Dredging

Dredging involves removing sediment from ponds using heavy equipment. Sediment removal accomplishes several objectives:

- Increases water depth
- Controls aquatic plants, both by:
    - removal during dredging, and
    - by the reduction of light reaching the bottom due to increased water depth.
- Reduces internal loading of nutrients, which in turn leads to less algal growth

Methods

Dredging is accomplished by several different methods:

Conventional dry dredging

Requires partial/complete draining of the pond and removal of exposed sediments using conventional excavation equipment. Dredge spoils require containment and disposal areas, preferably proximate to the pond.

Conventional wet dredging

Removal of sediment under water using specialized excavation equipment. Dredge spoils will require dewatering prior to disposal, and a containment/disposal area proximate to the pond.

Hydraulic or pneumatic dredging

Removal of sediment using suction and agitation (hydraulic) or air pressure (pneumatic). Material is pumped from the pond to a dewatering area proximate to the pond prior to final disposal.

Projects on Cape Cod

Maintenance dredging has been performed for decades on Cape Cod and the islands to maintain recreational access to inlets and marinas in coastal areas. Typically, dredged material is sandy in texture and is used in beach nourishment projects.

Dredging inland ponds is more challenging, due to costs and restrictions on placement of dredged materials.

Kettle Pond Dredging

The Town of Barnstable applied to Mass DEP for a permit to dredge Mill Pond (Marston Mills). The potential impact of a dredging project on the bridle shiner minnow, a state-listed species of special concern, complicated the permitting effort. Funding to implement the dredging project was allocated in the Town of Barnstable's FY2012 budget.

Hydraulic dredge

Aquatic Plant Control
Suggested Methods for Homeowners

There are several methods homeowners can use to control the overgrowth of aquatic plants. These methods work best in small areas, near docks or beaches. They may be implemented using easy-to-obtain tools and materials, and an investment of time and attention.

Dense aquatic plant growth.

Benthic Barriers

A *benthic barrier* is a natural or artificial material used to cover the pond bottom to prevent plant growth. A sheet of material is spread across the area to be treated, and anchored securely in place.

Pros:

- Eliminates plants in target area in one or two months.
- Re-usable barriers can be moved to a new location every couple of months.

Cons:

- Non-selective technique; all plants under barrier will be killed
- Effectiveness declines without labor-intensive maintenance

Hand Pulling

Hand pulling is the process of pulling out individual plants by hand. This method is labor-intensive, but allows for more selective plant removal – for example, where undesirable invasive plants are mixed in with desirable plants.

Pros:

- Selective plant control
- Limited impact on non-target plants and animals
- Prevention of infestations

Cons:

- Incomplete harvesting may result in re-growth or dispersal of plants
- Turbidity may be generated.

Mechanical Harvesting

Mechanical harvesting requires use of tools to cut or pull plants off close to the sediment. The cuttings may or may not be removed. A steel garden rake would be a useful tool for this application.

Pros:

- Clears plants in select areas
- Does not kill most plants through single cutting
- Repeated harvest may reduce abundance of seed-producing species

Cons:

- Minimally selective
- May encourage expansion of plants with vegetative propagation
- Regrowth may occur quickly, requiring frequent harvesting

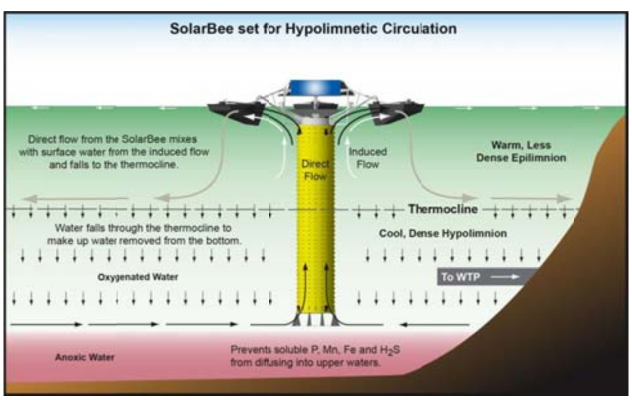
Pond Management: SolarBee®

Release of phosphorus from sediments occurs most readily under low-oxygen (anoxic) conditions. Deeper kettle ponds are known to thermally *stratify* during summer months – when ponds are stratified, the cooler, lower waters in the pond do not mix with the warmer, upper waters. Over the summer, the oxygen is depleted in lower waters, and phosphorus is released from the sediments. In the fall, as the upper waters cool, stratification breaks down and *turnover* occurs, mixing the phosphorus-rich lower waters with the upper waters. This upward flux of nutrients can result in algal blooms.

If the stratification can be disrupted by mixing the upper and lower waters, then more oxygen will be available in lower waters and less phosphorus will be released from the sediments.

Methods

SolarBee, Inc has developed solar-powered water circulators. According to the manufacturer, these solar-powered circulators can impact up to 35 acres per unit, require minimal maintenance and no infrastructure.



Projects on Cape Cod

Several SolarBee® projects have been completed in Cape Cod kettle ponds.

Skinequit Pond, Harwich, 2007

One unit was installed to treat 15 acres in 2007.

Santuit Pond, Mashpee, 2011

The town issued a Request for Quote, due October 2011, for solar-powered mixing devices to treat this pond, surface area 174 acres.

Case Study Summary
SolarBee Applications
Source: SolarBee web site and product information
updated September 27, 2011

Lake or Pond	State	Size (acres)	Units installed	Water quality or habitat concerns	Documented results
Chadwick Lake (reservoir)	NY	210	4	Stratification, Fe and Mn in water supply reservoir	No improvement in water quality, units not successful in affecting stratification
East Gravel Lake (reservoir)	CO	115	3 initially, then 4	Stratification, blue-green algal blooms in water supply reservoir	Units were not able to prevent stratification from developing, lower algal counts and fewer blue-greens. Reservoir also treated with copper sulfate.
Sylvan Lake	SD	17.3	1	Algal blooms, anoxic waters extending within 5-9 ft of surface in some years.	Oxygen to 16 ft in water column, reported fewer blue-green and more green algae. 2005 update reports control of blue-green blooms.
Palmdale Lake	CA	234	7	Algal blooms	Lower algal abundance (average chlorophyll decreased from 13.5 in 2002 to 6.6 µg/l in 2003)
Wastewater lagoon	OH	1.9	1	Test of circulation induced by SolarBee	Investigation supports SolarBee claim that mixing devices influence circulation in wastewater lagoon.
Highland Lake (reservoir)	NY	7.5	2	Eurasian water milfoil and blue-green algal blooms	Operators report no milfoil and acceptable water quality
Marina at Lake Tahoe	CA	Not specified	Not specified	Eurasian water milfoil (EWM)	"appears to have significantly reduced the need to use a harvester to control EWM" (quote from SolarBee web site)

Redwood Valley water district	CA	3	2	Blue-green algal blooms, taste& odor, macrophytes	Owner reported substantial reduction in blue-green blooms and macrophytes
Laguna Lakes West (lake #2)	CA	4 (chain of lakes, total 68)	1	Blue-green algal blooms, surface mats, macrophytes	Improved water quality. Installed units in other areas.
Goosehaven reservoir (City of Lafayette)	CO	45	1, later added a second unit	Blue-green algal blooms, taste& odor,	Reduction in blue greens
Lakewood school water holding pond	CO	2	1	Algae and biosolids (sludge) accumulation	Reduced algae and sludge in holding pond
Hidden Valley Lake	CA	102	4	Weeds and algae	Residents report greatly improved water quality conditions (units were used in conjunction with chemical treatment)
Gaynor Lake	CO	66	1	Anoxia, H_2S, fish kills, algal blooms	Improved oxygen, better fish habitat, diminished algal blooms
Englewood storage reservoir (raw water)	CO	18	1	Algal blooms	City no longer forced to use copper sulfate. Unit also successful in reducing Mn concentration and sludge accumulation
Dairyland Power reservoir	WI	27	1	Anoxia, H_2S, algal blooms	Improved oxygen
Conyers man-made storage reservoir	GA	6	2	Elevated Fe and Mn, low dissolved oxygen, poor circulation	Improved DO, reduced Fe and Mn concentrations in water
Camp Pendleton, Lake O'Neill	CA	125	3	Blue-green algal blooms, anoxia, fish kills. Elevated coliform bacteria counts, turbidity, heavy metals	Reduced algal blooms, improved oxygen, fewer coliform bacteria, improved fish community, improved water clarity

Pond Management: Sonication

Sonication is a process whereby cycles of low and high frequency sound waves disrupt and break down algal cells. This approach may be used instead of chemical treatments to kill algae and inhibit algal reproduction.

Methods

SonicSolutions® is a product that uses sonication to control algae. The SonicSolutions® transducer, submerged just beneath the surface, is programmed to generate ultrasonic waves that inhibit the growth and spread of algae. The device uses high frequency ultrasonic sound waves to tear the cell membranes, rupture the little air pockets in algae called vacuoles and interrupt the reproductive cycle of the algae. It is the constant bombardment of the ultrasonic signal to the algae that keeps the algae from reproducing.

The SonicSolutions® device only kills and controls blue/green and filamentous algae. It will have no effect upon aquatic plants, such as duckweed, water meal, eelgrass, and milfoil. Nor will it affect plant-like algal species such as *Chara* or *Nitella*.

SonicSolutions® device installation using stakes.

The SonicSolutions® devices come in five sizes, where "size" is defined not by the dimensions of the device, but by the output power of the unit. The smallest unit is suitable for treating koi ponds (10 ft x 10 ft), while the largest unit can treat up to 6 acres. The units may be connected to an existing electrical system, or so solar power.

Projects on Cape Cod

To date, there have been no applications of the sonicator devices to Cape Cod ponds.

Appendix 3 – Summary of August Field Effort

Part I – Field Measurements

Part II - Visual Features

Eastham Ponds - Field water quality measurements

by EcoLogic LLC - August 15-16, 2011

Bridge Pond

8/15/2011 3:15 PM Heavy rain, very gusty winds

GPS (NAD83)

Latitude: 41° 49' 49.9"

Longitude: 069° 59' 50.4" Pond Depth: 21 ft

Secchi: 2.9 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	93.7	7.83	24.8	143.2	0.1
0.5	92.2	7.56	24.9	143.5	0.1
1.0	91	7.61	25	143.5	0.1
1.5	90.7	7.52	25	143.6	0.1
2.0	89.9	7.42	25	143.4	0.1
2.5	98.2	7.38	25	143.5	0.1
3.0	87.9	7.32	25	143.5	0.1
4.0	93.8	7.76	24.4	143	0.1
5.0	23.6	2.19	20	169.9	0.1

Depot (Long) Pond

8/16/2011 9:20 AM Overcast, breezy

Water quality sample collected from 9.0 m using Kemmerer for total phosphorus and alkalinity analyses.

GPS (NAD83)

Latitude: 41° 49' 52.8"

Longitude: 069° 58' 48.4" Pond Depth: 32 ft

Secchi: 5 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	93.6	7.59	24.3	108.8	0.1
0.5	91.3	7.6	24.3	108.8	0.1
1.0	90.3	7.54	24.4	108.7	0.1
1.5	89.2	7.45	24.4	108.7	0.1
2.0	88.7	7.43	24.4	108.7	0.1
2.5	87.9	7.32	24.4	108.7	0.1
3.0	86.7	7.16	24.4	108.7	0.1
5.0	91.8	7.72	23.9	106.7	0.1
7.0	60.1	5.53	19.1	108.2	0.1
9.0	23.3	2.37	14.9	119.6	0.1

%DOSat = % saturation dissolved oxygen; DO mg/l = dissolved oxygen concentration; Temp°C = temperature;

Conductivity µS = conductivity in microsiemens; Salinity ppt = salinity in parts per thousand

Eastham Ponds - Field water quality measurements

by EcoLogic LLC - August 15-16, 2011

Great Pond

8/16/2011 12:30 PM Mostly cloudy, breezy

Water quality sample collected from 9.0 m using Kemmerer for total phosphorus and alkalinity analyses; 3 sediment samples collected.

GPS (NAD83)

Latitude: 41° 49' 57.2"

Longitude: 069° 59' 06.7" Pond Depth: 37 ft

Secchi: 2.5 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	90.4	7.59	23.8	143.4	0.1
0.5	88.6	7.44	23.8	143.5	0.1
1.0	88.2	7.42	23.8	143.5	0.1
1.5	87.7	7.41	23.8	143.5	0.1
2.0	87.2	7.34	23.8	143.4	0.1
2.5	85.5	7.19	23.8	143.4	0.1
3.0	85.1	7.22	23.8	143.5	0.1
5.0	89.4	7.57	23.6	147.7	0.1
7.0	26.5	2.5	18.6	149.6	0.1
9.0	21.8	2.25	14.1	206	0.1

Herring Pond

8/16/2011 3:56 PM Mostly cloudy, breezy

Water quality sample collected from 9.0 m using Kemmerer for total phosphorus and alkalinity analyses; 3 sediment samples collected.

GPS (NAD83)

Latitude: 41° 49' 32.5"

Longitude: 069° 59' 13.6" Pond Depth: 35 ft

Secchi: 1.25 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	111.5	9.14	24.6	1352	0.7
0.5	110	9.12	24.6	1352	0.7
1.0	110	9.14	24.5	1351	0.7
1.5	111.3	9.33	24.2	1349	0.7
2.0	108.3	9.03	24.2	1350	0.7
2.5	108.3	9.03	24.1	1350	0.7
3.0	106.2	8.78	24.1	1350	0.7
5.0	99.2	8.37	23.7	1344	0.7
7.0	38	3.63	17.4	1539	0.8
9.0	21.3	2.18	14	1837	0.9

%DOSat = % saturation dissolved oxygen; DO mg/l = dissolved oxygen concentration; Temp°C = temperature;

Conductivity µS = conductivity in microsiemens; Salinity ppt = salinity in parts per thousand

Eastham Ponds - Field water quality measurements

by EcoLogic LLC - August 15-16, 2011

Jemima Pond

8/15/2011 2:00 PM Heavy rain

GPS (NAD83)

Latitude: 41° 49' 45.9"

Longitude: 069° 59' 05.4" Pond Depth: 15 ft

Secchi: 3.8 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	84	6.89	25.1	83.1	0
0.5	83.3	6.83	25.2	83.3	0
1.0	82.1	6.8	25.3	83.2	0
1.5	81.8	6.74	25.3	83.3	0
2.0	80.4	6.59	25.3	83.3	0
2.5	80.3	6.49	25.3	83.2	0
3.0	79.5	6.56	25.3	83.1	0
4.0	83.5	6.93	24.7	82.1	0

Little Depot Pond

8/15/2011 1:00 PM Heavy rain

GPS (NAD83)

Latitude: 41° 49' 50.1"

Longitude: 069° 58' 56.2" Pond Depth: 13 ft

Secchi: 2.7 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	80.8	6.67	24.7	120.2	0.1
0.5	78.3	6.55	24.7	120.4	0.1
1.0	78.3	6.56	24.7	120.5	0.1
1.5	77.6	6.46	24.7	120.5	0.1
2.0	77.2	6.41	24.7	120.5	0.1
2.5	75.1	6.24	24.7	120.5	0.1
3.0	27.4	2.9	24.2	123.6	0.1

%DOSat = % saturation dissolved oxygen; DO mg/l = dissolved oxygen concentration; Temp°C = temperature;

Conductivity µS = conductivity in microsiemens; Salinity ppt = salinity in parts per thousand

Eastham Ponds - Field water quality measurements

by EcoLogic LLC - August 15-16, 2011

Minister Pond

8/15/2011 11:00 AM Overcast, light rain, breezy

GPS (NAD83)

Latitude: 41° 50' 30.1"

Longitude: 069° 58' 41.7" Pond Depth: 16 ft

Secchi: 1.6 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	87.2	7.73	24.7	391	0.2
0.5	86.1	7.12	24.7	391	0.2
1.0	80.3	6.97	24.7	391	0.2
1.5	79.2	6.39	24.7	391	0.2
2.0	76	6.29	24.7	390.8	0.2
2.5	72.2	5.93	24.7	391	0.2
3.0	13.6	1.15	23.4	391.7	0.2
4.0	19.1	1.76	18.9	390.4	0.2

Moll Pond

8/15/2011 9:00 AM Overcast

GPS (NAD83)

Latitude: 41° 50' 42.2"

Longitude: 069° 58' 33.5" Pond Depth: 12.5 ft

Secchi: 3.75 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	81.9	6.66	25.7	75.2	0
0.5	80.5	6.57	25.7	75.3	0
1.0	80.3	6.58	25.7	75.3	0
1.5	79.4	6.46	25.7	75.3	0
2.0	77.5	6.32	25.7	75.3	0
2.5	77.5	6.3	25.7	75.3	0
3.0	73.7	6.03	25.7	75.3	0

%DOSat = % saturation dissolved oxygen; DO mg/l = dissolved oxygen concentration; Temp°C = temperature;

Conductivity µS = conductivity in microsiemens; Salinity ppt = salinity in parts per thousand

Eastham Ponds - Field water quality measurements

by EcoLogic LLC - August 15-16, 2011

Muddy (Mill) Pond

8/17/2011 8:20 AM Clear, sunny, calm

GPS (NAD83)

Latitude: 41° 49' 35.6"

Longitude: 069° 58' 34.8" Pond Depth: 6 ft

Secchi: 1.7 m (on bottom; hidden in vegetation)

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	89.3	7.8	22.5	64.8	0
0.5	87	7.53	22.6	64.7	0
1.0	87.8	7.57	22.6	64.6	0
1.5	86.8	7.38	22.6	64.6	0

Schoolhouse Pond

8/15/2011 10:10 AM Overcast, light rain, breezy

GPS (NAD83)

Latitude: 41° 50' 23.5"

Longitude: 069° 58' 30.9" Pond Depth: 16 ft

Secchi: 2.25 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	67.7	5.6	24.7	388.2	0.2
0.5	66.6	5.57	24.7	389.1	0.2
1.0	64.3	5.33	24.7	389.2	0.2
1.5	62.2	5.17	24.7	389.4	0.2
2.0	51.1	4.26	24.6	389.5	0.2
2.5	44.9	3.85	24.5	388.5	0.2
3.0	21.9	1.64	22.8	392.5	0.2
4.0	31.7	3.22	15.5	401	0.2

%DOSat = % saturation dissolved oxygen; DO mg/l = dissolved oxygen concentration; Temp°C = temperature;

Conductivity µS = conductivity in microsiemens; Salinity ppt = salinity in parts per thousand

Eastham Ponds - Field water quality measurements

by EcoLogic LLC - August 15-16, 2011

Widow Harding Pond

8/16/2011 5:58 PM Mostly cloudy, light breeze

GPS (NAD83)

Latitude: 41° 49' 41.0"

Longitude: 069° 59' 37.5" Pond Depth: 13 ft

Secchi: 3.1 m

Depth (m)	%DO Sat	DO mg/l	Temp°C	Conductivity µS	Salinity ppt
0.0	95.2	7.71	25.2	67.8	0
0.5	92.5	7.66	25.2	67.8	0
1.0	96.7	7.77	25.2	67.8	0
1.5	94.3	7.69	24.7	67.6	0
2.0	87.6	7.22	24.5	67.4	0
2.5	86.5	7.28	24.3	67.4	0
3.0	81.2	6.78	24.2	67.5	0

%DOSat = % saturation dissolved oxygen; DO mg/l = dissolved oxygen concentration; Temp°C = temperature;

Conductivity µS = conductivity in microsiemens; Salinity ppt = salinity in parts per thousand

Eastham Ponds - Sediment Sample GPS Coordinates (NAD83)

by EcoLogic LLC - August 15-16, 2011

Great Pond

	01	02	03
Latitude	41° 49' 57.2"	41° 49' 55.9"	41° 50' 01.5"
Longitude	069° 59' 06.7"	069° 59' 11.5"	069° 59' 18.5"

Herring Pond

	01	02	03
Latitude	41° 49' 32.8"	41° 49' 29.4"	41° 49' 26.2"
Longitude	069° 59' 13.7"	069° 59' 12.4"	069° 59' 10.6"

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond *Depth (ft)*[1] *Surface Area (acres)*[2] *Watershed (acres)*[3]	Physical Characteristics[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
Ultra-shallow Ponds *depths <10 ft (~3m)*						
Little Depot *Max Depth: 10 ft* *Surface Area: 2.3 acres* *Watershed: 2.3 acres*	Limited; access to pond over a fence from Samoset Road or bikeway trail.	Fishing. Aesthetic use as viewed from bikeway trail.	2.7m Secchi Clear/ pale yellowish-green	Densely vegetated, shrubs and trees. Observed: buttonbush, blueberry, sweet pepper bush, oak, pine, mixed deciduous	Limited emergent and floating leaved plants observed. Some white water lily along shoreline.	Few residences. Shoreline within 200 ft of bikeway trail and Samoset Road. Powerlines pass over eastern shore. During heavy rain, runoff was seen entering pond from Samoset Road. Wildlife observed: cormorants

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond ***Depth (ft)***[1] ***Surface Area (acres)***[2] ***Watershed (acres)***[3]	**Physical Characteristics**[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
Ultra-shallow Ponds (continued) *depths <10 ft (~3m)*						
Muddy *Max Depth: 5 ft* *Surface Area: 10.5 acres* *Watershed: 40 acres*	Unmarked; appears limited to residents of adjacent cottage colony	Swimming, fishing, nonmotorized boating	1.7m Secchi (on bottom) Clear/ pale yellowish-green	Densely vegetated, shrubs & trees, with some open beach/lawn areas. Observed: oak, pine, maple, willow, mixed deciduous, swamp loosestrife, buttonbush, wild grape, sweet pepper bush	Bottom appears carpeted with bladderwort. Observed: bladderwort, water lily (yellow & white), pickerel weed, sago pondweed, cattail, broadleaf water-milfoil (*Myriophyllum heterophyllum*)	Sparse shoreline development Wildlife observed: bluegill, pickerel, yellow perch, golden shiners, young of year *Lepomis* sp.

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond ***Depth (ft)***[1] ***Surface Area (acres)***[2] ***Watershed (acres)***[3]	**Physical Characteristics**[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
<u>Shallow Ponds</u> *depths 10-30 ft (~3-9m)*						
Bridge *Max Depth: 20 ft* *Surface Area: 6.7 acres* *Watershed: 7.9 acres*	Limited; from walking trails in Nickerson Conservation Area (accessed via Herring Brook Road or Wiley Park on Great Pond).	Fishing, aesthetic use as viewed from conservation area trails	2.9m Secchi Clear/ pale yellowish-green	Densely vegetated with trees and shrubs. <u>Observed</u>: pine, oak, willow, buttonbush, blueberry, rose, ferns, sweet pepper bush, swamp loosestrife	Emergents and floating-leaved plants limited. <u>Observed</u>: *Potamogeton* sp., bladderwort	Private dock observed; no housing units. A maintained herring run is present. Observed a group of about 20 dead eels and one live eel in the pond next to herring run.
Jemima *Max Depth: 15 ft* *Surface Area: 6.4 acres* *Watershed: 18 acres*	Parking area off Samoset Road, fishing access point, also clearly marked with Bathing Beach permit from Dept. of Health.	Fishing, swimming, unmotorized boating.	3.8m Secchi Clear/ light yellowish-green	Densely vegetated: trees, shrubs, vines <u>Observed</u>: buttonbush, blueberry, maple, wild grape	Emergents and floating-leaved dense in some places, absent in others. <u>Observed</u>: sago pondweed, water lily (white and yellow), bladderwort, pipewort,	Few private residences, predominantly forested. Fishermen landed chain pickerel, yellow perch. Said that the pond is a "great bass pond".

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond ***Depth (ft)***[1] ***Surface Area (acres)***[2] ***Watershed (acres)***[3]	**Physical Characteristics**[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
Shallow Ponds (continued) *depths 10-30 ft (~3-9m)*						
Minister *Max Depth: 13 ft* *Surface Area: 7.8 acres* *Watershed: 151 acres*	"Fisherman's Launch" marked on Schoolhouse Road; public access to Minister via Schoolhouse Pond. No other public access points observed.	Swimming, fishing, non-motorized boating	1.6m Secchi Clear/ light yellowish-green	Vegetated: trees, shrubs. Observed: oak, pine, mixed deciduous, buttonbush	Emergents and floating-leaved fairly dense along shore. Observed: water lily (white & yellow), bladderwort, rushes, watershield, coontail, cattails	Several private residences south and north; predominantly forested. Route 6 runs within 200 ft of west edge.
Molls *Max Depth: 12 ft* *Surface Area: 3.4 acres* *Watershed: 8.1 acres*	Unmarked; appears limited to pond residents.	Swimming, fishing, non-motorized boating	3.75m Secchi Very clear/ light yellowish-green	Vegetated: trees, shrubs, ground cover. North end has distinct wetland character. Observed: blueberry, oak, pine, sweet pepper bush	1 area of reed *Phragmites;* Emergents and floating-leaved along shore in places. Observed: water lily (white and yellow), *Eleocharis*, watershield, *Potamogeton* sp.	Private residences are fairly dense around shoreline. Wildlife observed: fish - bluegill, pumpkinseed, minnows, yellow perch, large-mouth bass (3 year classes); osprey

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond *Depth (ft)*[1] *Surface Area (acres)*[2] *Watershed (acres)*[3]	Physical Characteristics[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
<u>Shallow Ponds (continued)</u> *depths 10-30 ft (~3-9m)*						
Schoolhouse *Max Depth: 13 ft* *Surface Area: 6.8 acres* *Watershed: 5.7 acres*	"Fisherman's Launch" marked on Schoolhouse Road; public access.	Swimming, fishing, non-motorized boating	2.25m Secchi Clear/ light yellowish-green	Vegetated: trees, shrubs fairly dense. <u>Observed</u>: oak, pine, willow, buttonbush, swamp loosestrife	Emergents and floating-leaved common along shoreline. <u>Observed</u>: pickerel weed, water lily (white & yellow), watershield, *Potamogeton* sp.	Multiple private residences observed southern end, generally set back from shore hidden by dense vegetated buffer. Remainder forested. Small cleared area each property for water access.

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond *Depth (ft)*[1] *Surface Area (acres)*[2] *Watershed (acres)*[3]	Physical Characteristics[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
Shallow Ponds (continued) *depths 10-30 ft (~3-9m)*						
Widow Harding *Max Depth: 13 ft* *Surface Area: 8.7 acres* *Watershed: 25.9 acres*	Limited; from walking trails in Nickerson Conservation Area (accessed via Herring Brook Road or Wiley Park on Great Pond).	Fishing, swimming, nonmotorized boating, aesthetic use as viewed from conservation area trails	3.1m Secchi Clear/ light yellowish-green (copepods observed)	Densely vegetated, shrubs and trees with emergents. Some open beach and lawn space. Observed: pine, maple, mixed deciduous, buttonbush, sweet pepper bush, swamp loosestrife.	Emergents and floating leaved common. Observed: bladderwort, water lily (white & yellow), pipewort, pickerel weed, watershield, *Potamogeton* sp. (narrow-leaves)	Residences seen on southern side; northern side forested. Observed wildlife: largemouth bass, sunfish nests, yellow perch, bluegill, songbirds

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond *Depth (ft)*[1] *Surface Area (acres)*[2] *Watershed (acres)*[3]	Physical Characteristics[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
<u>Deep Ponds</u> *depths >30 ft (~9m)*						
Depot (Long) *Max Depth: 33 ft* *Surface Area: 27.9 acres* *Watershed: 65 acres*	Limited; unmarked fire road access behind library off Samoset Road. Also, access over the fence from bikeway trail	Swimming, fishing, unmotorized boating. Aesthetic use as viewed from bikeway trail.	5m Secchi Very clear/ light yellowish-green	Vegetated (trees, shrubs), with multiple open beach/lawn areas. Housing mostly on east side; west side bordered by bikeway trail and forest. <u>Observed</u>: oaks, pine, mixed deciduous, buttonbush, sweet pepper bush	Scattered areas of plant growth, gravel bottom along west side near bikeway. Noted centrarchid nests, good substrate for sunfish spawning. <u>Observed</u>: white water lily, *Potamogeton* sp., pickerel weed (two varieties), rush	Multiple private residences, some quite close to shore, others were set back behind trees. <u>Observed wildlife</u>: cormorants, kingbird, ducks, freshwater mussels (Eastern Floater *Pyganodon cateracta*, and Eastern Elliptio *Elliptio complanata*)

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond ***Depth (ft)***[1] ***Surface Area (acres)***[2] ***Watershed (acres)***[3]	**Physical Characteristics**[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
Deep Ponds (continued) *depths >30 ft (~9m)*						
Great *Max Depth: 43 ft* *Surface Area: 110 acres* *Watershed: 226 acres*	Town Beach off Great Pond Road; Wiley Park off Herring Brook Road. Also, access from trails in Wiley Park and Nickerson Conservation Area.	Swimming, fishing, nonmotorized boating and sailing (motorized watercraft by permit only)	2.5m Secchi Clear/ light yellowish-green	Densely vegetated, some with beach/lawn areas. Trees, shrubs, herbaceous. Observed: Pine, oak, willows, cedars, mixed deciduous, sweet pepper bush, buttonbush, wild grape, swamp loosestrife	Extensive macrophyte beds. Observed: *Potamogeton* sp., Elodea, eelgrass, coontail	Houses on west side generally set back while houses on side east are closer to shoreline. Western side low topography at conservation area. Wildlife observed: osprey, painted turtle, mussel Eastern Floater *Pyganodon cateracta*

Appendix 3 Part II
Eastham Ponds – Visual Observations from August 2011 EcoLogic LLC Field Survey

Pond *Depth (ft)*[1] *Surface Area (acres)*[2] *Watershed (acres)*[3]	Physical Characteristics[4]					
	Public Access Observed	**Uses Observed**	**Water clarity and color**	**Shoreline**	**Macrophytes**	**Comments**
Deep Ponds (continued) *depths >30 ft (~9m)*						
Herring *Max Depth: 39 ft* *Surface Area: 44.2 acres* *Watershed: 80 acres*	Town Beach on Herring Brook Road. Also appears to be pathways from upland, which may be private access.	Swimming, fishing, nonmotorized boating	1.25m Secchi Green, turbid	Residences surround most of pond. Shoreline generally vegetated with some beach/lawn areas. Observed: Willow, maple, pine, mixed deciduous, purple loosestrife, *Phragmites*, cattails	Very weedy to 12 ft. Observed: coontail, eelgrass, *Potamogeton* sp., filamentous algae	Some residences are at low elevation to pond while others are upslope Wildlife observed: largemouth bass, fish nests, cormorants, osprey

[1]Depths obtained from Eichner, 2009 (Table V-I and Appendix A), except for Little Depot which was obtained from PALS data set.
[2]Surface area from CCC Atlas, Eastham Pond Database table; acres for Ministers was derived by subtracting acres of Schoolhouse from acres of Ministers/Schoolhouse.
[3]Watershed areas provided by GHD.
[4]Physical characteristics observed in the field by EcoLogic scientists August 15-17, 2011.

Appendix 4 – Spectrum Analytical Lab Results

Report Date:
08-Sep-11 15:14

☑ Final Report
☐ Re-Issued Report
☐ Revised Report

SPECTRUM ANALYTICAL, INC.
Featuring
HANIBAL TECHNOLOGY

Laboratory Report

EcoLogic LLC
132 1/2 Albany Street
Cazenovia, NY 13035
Attn: Elizabeth Moran

Project: Herring Pond, Long/Depot Pond - Eastham, MA
Project #: Eastham Ponds

Laboratory ID	Client Sample ID	Matrix	Date Sampled	Date Received
SB33752-01	Herring 01	Sediment	16-Aug-11 16:30	17-Aug-11 10:03
SB33752-02	Herring 02	Sediment	16-Aug-11 16:45	17-Aug-11 10:03
SB33752-03	Herring 03	Sediment	16-Aug-11 17:00	17-Aug-11 10:03
SB33752-04	Herring T-Alk	Surface Water	16-Aug-11 16:00	17-Aug-11 10:03
SB33752-05	Herring TP	Surface Water	16-Aug-11 16:00	17-Aug-11 10:03
SB33752-06	Long/Depot T-Alk	Surface Water	16-Aug-11 10:00	17-Aug-11 10:03
SB33752-07	Long/Depot TP	Surface Water	16-Aug-11 10:00	17-Aug-11 10:03
SB33752-08	Great Pond 01	Sediment	16-Aug-11 14:00	17-Aug-11 10:03
SB33752-09	Great Pond 02	Sediment	16-Aug-11 14:15	17-Aug-11 10:03
SB33752-10	Great Pond 03	Sediment	16-Aug-11 14:30	17-Aug-11 10:03
SB33752-11	Great Pond T-Alk	Surface Water	16-Aug-11 13:30	17-Aug-11 10:03
SB33752-12	Great Pond TP	Surface Water	16-Aug-11 13:30	17-Aug-11 10:03

I attest that the information contained within the report has been reviewed for accuracy and checked against the quality control requirements for each method. These results relate only to the sample(s) as received.
All applicable NELAC requirements have been met.

Massachusetts # M-MA138/MA1110
Connecticut # PH-0777
Florida # E87600/E87936
Maine # MA138
New Hampshire # 2538
New Jersey # MA011/MA012
New York # 11393/11840
Pennsylvania # 68-04426/68-02924
Rhode Island # 98
USDA # S-51435

Authorized by:

Nicole Leja
Laboratory Director

Spectrum Analytical holds certification in the State of New York for the analytes as indicated with an X in the "Cert." column within this report. Please note that the State of New York does not offer certification for all analytes.
Please note that this report contains 13 pages of analytical data plus Chain of Custody document(s). When the Laboratory Report is indicated as revised, this report supersedes any previously dated reports for the laboratory ID(s) referenced above. Where this report identifies subcontracted analyses, copies of the subcontractor's test report are available upon request. This report may not be reproduced, except in full, without written approval from Spectrum Analytical, Inc.

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CASE NARRATIVE:

The samples were received 2.3 degrees Celsius, please refer to the Chain of Custody for details specific to temperature upon receipt. An infrared thermometer with a tolerance of +/- 2.0 degrees Celsius was used immediately upon receipt of the samples.

If a Matrix Spike (MS), Matrix Spike Duplicate (MSD) or Duplicate (DUP) was not requested on the Chain of Custody, method criteria may have been fulfilled with a source sample not of this Sample Delivery Group.

Due to possible microbial action or loss or gain of gases when the sample is exposed to air, the sampling recommendation for alkalinity or acidity suggests a separate bottle filled completely and capped tightly. When possible, testing for alkalinity or acidity is performed as soon as possible from the designated unopened, full container.

Phosphorus Fractionation Case Narrative

25 ml. aliquots of a 1 M solution of ammonium chloride (buffered to pH 7) were added to various sample weights and tumbled for a two hour period. This extract is tested for loosely-bound phosphorus using ASTM method D515-88 for reactive phosphorus.

The next extraction was performed by adding 25 ml. aliquots of the dithionite solution (0.11 M NaHCO3/0.11 M Na2S2O4 final pH 6.8) to the original samples. The samples were tumbled for 1 hour. This extract is tested for iron-bound phosphorus using ASTM method D515-88 for reactive phosphorus.
A spiked sample / sample duplicate were analyzed throughout the complete procedure. The total matrix spike recovery for SB33752-01 (Herring 01) MS/MSD exceeded laboratory acceptance criteria of 80-120% at 46 and 8% showing a matrix effect of the sample from this work order. No appreciable spike recovery for the loosely-bound portion was determined.

The negligible recovery of the loosely-bound phosphorus in SBSB33752-01 is typical of sediments normally seen at this laboratory. The corresponding elevated matrix spike recovery of the iron bound portion follows the typical pattern.

All samples for this procedure were air dried to a mousse-like or drier consistency and analyzed for %solids. All results have been reported on a dry weight basis based on the laboratory prepared %solid values.

See below for any non-conformances and issues relating to quality control samples and/or sample analysis/matrix.

ASTM D515-88(A)

Spikes:

1117918-MS1 *Source: SB33752-01*

The spike recovery was outside acceptance limits for the MS, MSD and/or PS due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

Loosely-sorbed Phosphorus as P

1117918-MSD1 *Source: SB33752-01*

The spike recovery was outside acceptance limits for the MS, MSD and/or PS due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

Loosely-sorbed Phosphorus as P

1117953-MS1 *Source: SB33752-01*

The spike recovery was outside acceptance limits for the MS, MSD and/or PS due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

Iron bound Phosphorus as P

1117953-MSD1 *Source: SB33752-01*

The spike recovery was outside acceptance limits for the MS, MSD and/or PS due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.

Iron bound Phosphorus as P

<u>EPA 200.7</u>

Spikes:

1116959-MS1 *Source: SB33752-01*

The RPD and/or percent recovery for this QC spike sample cannot be accurately calculated due to the high concentration of analyte inherent in the sample.

Iron

1116959-PS1 *Source: SB33752-01*

The RPD and/or percent recovery for this QC spike sample cannot be accurately calculated due to the high concentration of analyte inherent in the sample.

Iron

The spike recovery was outside of QC acceptance limits for the MS, MSD and/or PS due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.

Phosphorus as P

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Herring 01 SB33752-01	Eastham Ponds	Sediment	16-Aug-11 16:30	17-Aug-11

CAS No.	*Analyte(s)*	*Result*	*Flag*	*Units*	**RDL*	*MDL*	*Dilution*	*Method Ref.*	*Prepared*	*Analyzed*	*Analyst*	*Batch*	*Cert.*
Total Metals by EPA 200 Series Methods													
7439-89-6	Iron	**117,000**		mg/kg dry	21.4	14.6	1	EPA 200.7	23-Aug-11	01-Sep-11	EDT	1116959	
7723-14-0	Phosphorus as P	**5,450**		mg/kg dry	77.4	1.94	1	"	"	"	"	"	
General Chemistry Parameters													
	% Solids	**17.1**		%			1	SM2540 G Mod.	26-Aug-11	26-Aug-11	JLH	1117264	
	Iron bound Phosphorus as P	**394**		mg/kg dry dry	73.3		1	ASTM D515-88(A)	05-Sep-11	05-Sep-11	JOC	1117953	
	Loosely-sorbed Phosphorus as P	**2.12**	J	mg/kg dry dry	2.93		1	"	04-Sep-11	05-Sep-11	"	1117918	
Toxicity Characteristics													
Grain Size - Reported as % retained.													
Prepared by method General Preparation													
	Fractional % Sieve #4 (>4750μm)	**0.730**		% Retained			1	ASTM D422	02-Sep-11	07-Sep-11	VK	1117819	
	Fractional % Sieve #10 (4750-2000μm)	**36.1**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #20 (2000-850μm)	**24.3**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #40 (850-425μm)	**11.3**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #60 (425-250μm)	**6.20**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #100 (250-150μm)	**5.47**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #200 (150-75μm)	**7.48**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #230 (less than 75μm)	**8.39**		% Retained			1	"	"	"	"	"	

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Herring 02 SB33752-02	Eastham Ponds	Sediment	16-Aug-11 16:45	17-Aug-11

CAS No.	*Analyte(s)*	*Result*	*Flag*	*Units*	**RDL*	*MDL*	*Dilution*	*Method Ref.*	*Prepared*	*Analyzed*	*Analyst*	*Batch*	*Cert.*
Total Metals by EPA 200 Series Methods													
7439-89-6	Iron	**62,900**		mg/kg dry	22.1	15.1	1	EPA 200.7	23-Aug-11	01-Sep-11	EDT	1116959	
7723-14-0	Phosphorus as P	**3,100**		mg/kg dry	80.1	2.00	1	"	"	"	"	"	
General Chemistry Parameters													
	% Solids	**15.1**		%			1	SM2540 G Mod.	26-Aug-11	26-Aug-11	JLH	1117264	
	Iron bound Phosphorus as P	**398**		mg/kg dry dry	82.8		1	ASTM D515-88(A)	05-Sep-11	05-Sep-11	JOC	1117953	
	Loosely-sorbed Phosphorus as P	**1.83**	J	mg/kg dry dry	3.31		1	"	04-Sep-11	05-Sep-11	"	1117918	
Toxicity Characteristics													
Grain Size - Reported as % retained. Prepared by method General Preparation													
	Fractional % Sieve #4 (>4750µm)	**1.82**		% Retained			1	ASTM D422	02-Sep-11	07-Sep-11	VK	1117819	
	Fractional % Sieve #10 (4750-2000µm)	**36.1**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #20 (2000-850µm)	**21.3**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #40 (850-425µm)	**9.90**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #60 (425-250µm)	**6.11**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #100 (250-150µm)	**7.76**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #200 (150-75µm)	**8.58**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #230 (less than 75µm)	**8.42**		% Retained			1	"	"	"	"	"	

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Herring 03 SB33752-03	Eastham Ponds	Sediment	16-Aug-11 17:00	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
Total Metals by EPA 200 Series Methods													
7439-89-6	Iron	**42,800**		mg/kg dry	15.7	10.7	1	EPA 200.7	23-Aug-11	01-Sep-11	EDT	1116959	
7723-14-0	Phosphorus as P	**1,720**		mg/kg dry	57.1	1.43	1	"	"	"	"	"	
General Chemistry Parameters													
	% Solids	**23.4**		%			1	SM2540 G Mod.	26-Aug-11	26-Aug-11	JLH	1117264	
	Iron bound Phosphorus as P	**73.4**		mg/kg dry dry	53.5		1	ASTM D515-88(A)	05-Sep-11	05-Sep-11	JOC	1117953	
	Loosely-sorbed Phosphorus as P	**0.97**	J	mg/kg dry dry	2.14		1	"	04-Sep-11	05-Sep-11	"	1117918	
Toxicity Characteristics													
Grain Size - Reported as % retained.													
Prepared by method General Preparation													
	Fractional % Sieve #4 (>4750µm)	**1.43**		% Retained			1	ASTM D422	02-Sep-11	07-Sep-11	VK	1117819	
	Fractional % Sieve #10 (4750-2000µm)	**15.1**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #20 (2000-850µm)	**17.5**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #40 (850-425µm)	**15.6**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #60 (425-250µm)	**11.0**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #100 (250-150µm)	**11.4**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #200 (150-75µm)	**16.0**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #230 (less than 75µm)	**12.1**		% Retained			1	"	"	"	"	"	

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Herring T-Alk SB33752-04	Eastham Ponds	Surface Water	16-Aug-11 16:00	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
General Chemistry Parameters													
7723-14-0	Phosphorus as P	**0.252**		mg/l	0.0100	0.00493	1	ASTM D515-88(A)	29-Aug-11	29-Aug-11	GMA	1117403	X

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Herring TP SB33752-05	Eastham Ponds	Surface Water	16-Aug-11 16:00	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
General Chemistry Parameters													
	Total Alkalinity	**49.7**		mg/l CaCO3	2.00	0.970	1	SM2320B	25-Aug-11	26-Aug-11	GMA	1117148	X

* Reportable Detection Limit

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Long/Depot T-Alk SB33752-06	Eastham Ponds	Surface Water	16-Aug-11 10:00	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
General Chemistry Parameters													
7723-14-0	Phosphorus as P	**0.0200**		mg/l	0.0100	0.00493	1	ASTM D515-88(A)	29-Aug-11	29-Aug-11	GMA	1117403	X

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Long/Depot TP SB33752-07	Eastham Ponds	Surface Water	16-Aug-11 10:00	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
General Chemistry Parameters													
	Total Alkalinity	**38.2**		mg/l CaCO3	2.00	0.970	1	SM2320B	25-Aug-11	26-Aug-11	GMA	1117148	X

Sample Identification	Client Project #	Matrix	Collection Date/Time	Received
Great Pond 01 SB33752-08	Eastham Ponds	Sediment	16-Aug-11 14:00	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
Total Metals by EPA 200 Series Methods													
7439-89-6	Iron	**8,650**		mg/kg dry	7.13	4.86	1	EPA 200.7	23-Aug-11	01-Sep-11	EDT	1116959	
7723-14-0	Phosphorus as P	**563**		mg/kg dry	25.9	0.647	1	"	"	"	"	"	
General Chemistry Parameters													
	% Solids	**48.2**		%			1	SM2540 G Mod.	26-Aug-11	26-Aug-11	JLH	1117264	
	Iron bound Phosphorus as P	**18.3**	J	mg/kg dry dry	25.9		1	ASTM D515-88(A)	05-Sep-11	05-Sep-11	JOC	1117953	
	Loosely-sorbed Phosphorus as P	**0.85**	J	mg/kg dry dry	1.04		1	"	04-Sep-11	05-Sep-11	"	1117918	
Toxicity Characteristics													
Grain Size - Reported as % retained. Prepared by method General Preparation													
	Fractional % Sieve #4 (>4750µm)	**1.42**		% Retained			1	ASTM D422	02-Sep-11	07-Sep-11	VK	1117819	
	Fractional % Sieve #10 (4750-2000µm)	**6.38**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #20 (2000-850µm)	**13.0**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #40 (850-425µm)	**23.8**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #60 (425-250µm)	**21.6**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #100 (250-150µm)	**21.0**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #200 (150-75µm)	**10.4**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #230 (less than 75µm)	**2.41**		% Retained			1	"	"	"	"	"	

Sample Identification
Great Pond 02
SB33752-09

Client Project #	Matrix	Collection Date/Time	Received
Eastham Ponds	Sediment	16-Aug-11 14:15	17-Aug-11

CAS No.	*Analyte(s)*	*Result*	*Flag*	*Units*	**RDL*	*MDL*	*Dilution*	*Method Ref.*	*Prepared*	*Analyzed*	*Analyst*	*Batch*	*Cert.*
Total Metals by EPA 200 Series Methods													
7439-89-6	Iron	**16,800**		mg/kg dry	13.5	9.22	1	EPA 200.7	23-Aug-11	01-Sep-11	EDT	1116959	
7723-14-0	Phosphorus as P	**1,220**		mg/kg dry	49.0	1.23	1	"	"	"	"	"	
General Chemistry Parameters													
	% Solids	**25.9**		%			1	SM2540 G Mod.	26-Aug-11	26-Aug-11	JLH	1117264	
	Iron bound Phosphorus as P	**25.8**	J	mg/kg dry dry	48.2		1	ASTM D515-88(A)	05-Sep-11	05-Sep-11	JOC	1117953	
	Loosely-sorbed Phosphorus as P	**1.18**	J	mg/kg dry dry	1.93		1	"	04-Sep-11	05-Sep-11	"	1117918	
Toxicity Characteristics													
Grain Size - Reported as % retained.													
Prepared by method General Preparation													
	Fractional % Sieve #4 (>4750µm)	**3.26**		% Retained			1	ASTM D422	02-Sep-11	07-Sep-11	VK	1117819	
	Fractional % Sieve #10 (4750-2000µm)	**23.1**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #20 (2000-850µm)	**22.0**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #40 (850-425µm)	**18.1**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #60 (425-250µm)	**11.6**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #100 (250-150µm)	**9.35**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #200 (150-75µm)	**8.61**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #230 (less than 75µm)	**4.01**		% Retained			1	"	"	"	"	"	

Sample Identification
Great Pond 03
SB33752-10

Client Project #	Matrix	Collection Date/Time	Received
Eastham Ponds	Sediment	16-Aug-11 14:30	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
Total Metals by EPA 200 Series Methods													
7439-89-6	Iron	**18,700**		mg/kg dry	16.4	11.2	1	EPA 200.7	23-Aug-11	01-Sep-11	EDT	1116959	
7723-14-0	Phosphorus as P	**1,560**		mg/kg dry	59.6	1.49	1	"	"	"	"	"	
General Chemistry Parameters													
	% Solids	**22.1**		%			1	SM2540 G Mod.	26-Aug-11	26-Aug-11	JLH	1117264	
	Iron bound Phosphorus as P	**16.8**	J	mg/kg dry dry	56.7		1	ASTM D515-88(A)	05-Sep-11	05-Sep-11	JOC	1117953	
	Loosely-sorbed Phosphorus as P	**1.28**	J	mg/kg dry dry	2.27		1	"	04-Sep-11	05-Sep-11	"	1117918	
Toxicity Characteristics													
Grain Size - Reported as % retained.													
Prepared by method General Preparation													
	Fractional % Sieve #4 (>4750µm)	**2.82**		% Retained			1	ASTM D422	02-Sep-11	07-Sep-11	VK	1117819	
	Fractional % Sieve #10 (4750-2000µm)	**30.6**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #20 (2000-850µm)	**23.1**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #40 (850-425µm)	**16.3**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #60 (425-250µm)	**9.01**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #100 (250-150µm)	**5.49**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #200 (150-75µm)	**6.20**		% Retained			1	"	"	"	"	"	
	Fractional % Sieve #230 (less than 75µm)	**6.48**		% Retained			1	"	"	"	"	"	

Sample Identification
Great Pond T-Alk
SB33752-11

Client Project #	Matrix	Collection Date/Time	Received
Eastham Ponds	Surface Water	16-Aug-11 13:30	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
General Chemistry Parameters													
7723-14-0	Phosphorus as P	**0.0340**		mg/l	0.0100	0.00493	1	ASTM D515-88(A)	29-Aug-11	29-Aug-11	GMA	1117403	X

Sample Identification
Great Pond TP
SB33752-12

Client Project #	Matrix	Collection Date/Time	Received
Eastham Ponds	Surface Water	16-Aug-11 13:30	17-Aug-11

CAS No.	Analyte(s)	Result	Flag	Units	*RDL	MDL	Dilution	Method Ref.	Prepared	Analyzed	Analyst	Batch	Cert.
General Chemistry Parameters													
	Total Alkalinity	**21.4**		mg/l CaCO3	2.00	0.970	1	SM2320B	25-Aug-11	26-Aug-11	GMA	1117148	X

Total Metals by EPA 200 Series Methods - Quality Control

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch 1116959 - EPA 200 Series										
Blank (1116959-BLK1)					Prepared: 23-Aug-11 Analyzed: 01-Sep-11					
Phosphorus as P	**14.2**	J	mg/kg wet	0.363						
Iron	< 2.73	U	mg/kg wet	2.73						
Duplicate (1116959-DUP1)			Source: SB33752-01		Prepared: 23-Aug-11 Analyzed: 01-Sep-11					
Phosphorus as P	**5600**		mg/kg dry	1.87		5450			3	20
Iron	**119000**		mg/kg dry	14.0		117000			2	20
Matrix Spike (1116959-MS1)			Source: SB33752-01		Prepared: 23-Aug-11 Analyzed: 01-Sep-11					
Phosphorus as P	**6190**		mg/kg dry	1.96	676	5450	109	75-125		
Iron	**120000**	QM2	mg/kg dry	14.8	676	117000	361	70-130		
Post Spike (1116959-PS1)			Source: SB33752-01		Prepared: 23-Aug-11 Analyzed: 01-Sep-11					
Phosphorus as P	**5540**	QM4X	mg/kg dry	1.94	667	5450	14	85-115		
Iron	**104000**	QM2	mg/kg dry	14.6	667	117000	-2020	85-115		
Reference (1116959-SRM1)					Prepared: 23-Aug-11 Analyzed: 01-Sep-11					
Iron	**4760**		mg/kg wet	2.73	6640		72	50.7-150		
Reference (1116959-SRM2)					Prepared: 23-Aug-11 Analyzed: 01-Sep-11					
Phosphorus as P	**207**		mg/kg wet	0.363	202		103	52.4-147.5		

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch 1117148 - General Preparation										
Blank (1117148-BLK1)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**1.41**	J	mg/l CaCO3	0.970						
Blank (1117148-BLK2)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**1.60**	J	mg/l CaCO3	0.970						
Blank (1117148-BLK3)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**1.80**	J	mg/l CaCO3	0.970						
Blank (1117148-BLK4)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**1.59**	J	mg/l CaCO3	0.970						
LCS (1117148-BS1)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**49.4**		mg/l CaCO3	0.970	50.0		99	90-110		
LCS (1117148-BS2)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**47.8**		mg/l CaCO3	0.970	50.0		96	90-110		
LCS (1117148-BS3)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**49.3**		mg/l CaCO3	0.970	50.0		99	90-110		
LCS (1117148-BS4)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**47.6**		mg/l CaCO3	0.970	50.0		95	90-110		
Duplicate (1117148-DUP1)			Source: SB33752-05		Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**51.9**		mg/l CaCO3	0.970		49.7			4	20
Matrix Spike (1117148-MS1)			Source: SB33752-05		Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**98.7**		mg/l CaCO3	0.970	50.0	49.7	98	80-120		
Matrix Spike Dup (1117148-MSD1)			Source: SB33752-05		Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**100**		mg/l CaCO3	0.970	50.0	49.7	101	80-120	2	20
Reference (1117148-SRM1)					Prepared: 25-Aug-11 Analyzed: 26-Aug-11					
Total Alkalinity	**37.0**		mg/l CaCO3	0.970	39.8		93	91-105		
Batch 1117264 - General Preparation										
Duplicate (1117264-DUP1)			Source: SB33752-01		Prepared & Analyzed: 26-Aug-11					
% Solids	**16.9**		%			17.1			0.9	20
Batch 1117403 - General Preparation										
Blank (1117403-BLK1)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	< 0.00493	U	mg/l	0.00493						
LCS (1117403-BS1)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**0.00500**	J	mg/l	0.00493	0.00500		100	90-110		
Calibration Blank (1117403-CCB1)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**-0.00200**	U	mg/l							
Calibration Blank (1117403-CCB2)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**-0.00100**	U	mg/l							
Calibration Blank (1117403-CCB3)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**0.00200**		mg/l							
Calibration Check (1117403-CCV1)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**0.197**		mg/l		0.200		98	90-110		
Calibration Check (1117403-CCV2)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**0.199**		mg/l		0.200		100	90-110		
Calibration Check (1117403-CCV3)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**0.197**		mg/l		0.200		98	90-110		
Reference (1117403-SRM1)					Prepared & Analyzed: 29-Aug-11					
Phosphorus as P	**0.197**		mg/l	0.00493	0.200		98	93-116		
Batch 1117918 - Phosphorus Fractionation										
Blank (1117918-BLK1)					Prepared: 04-Sep-11 Analyzed: 05-Sep-11					
Loosely-sorbed Phosphorus as P	**0.30**	J	mg/kg dry wet							
LCS (1117918-BS1)					Prepared: 04-Sep-11 Analyzed: 05-Sep-11					

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* Reportable Detection Limit

General Chemistry Parameters - Quality Control

Analyte(s)	Result	Flag	Units	*RDL	Spike Level	Source Result	%REC	%REC Limits	RPD	RPD Limit
Batch 1117918 - Phosphorus Fractionation										
LCS (1117918-BS1)					Prepared: 04-Sep-11 Analyzed: 05-Sep-11					
Loosely-sorbed Phosphorus as P	**45.7**		mg/kg dry wet		50.1		91	90-110		
Duplicate (1117918-DUP1)			Source: SB33752-01		Prepared: 04-Sep-11 Analyzed: 05-Sep-11					
Loosely-sorbed Phosphorus as P	**2.17**	J	mg/kg dry dry			2.12			2	35
Matrix Spike (1117918-MS1)			Source: SB33752-01		Prepared: 04-Sep-11 Analyzed: 05-Sep-11					
Loosely-sorbed Phosphorus as P	**2.06**	QM5, J	mg/kg dry dry		258	2.12	-0.02	80-120		
Matrix Spike Dup (1117918-MSD1)			Source: SB33752-01		Prepared: 04-Sep-11 Analyzed: 05-Sep-11					
Loosely-sorbed Phosphorus as P	**1.99**	QM5, J	mg/kg dry dry		222	2.12	-0.06	80-120	3	35
Batch 1117953 - Phosphorus Fractionation										
Blank (1117953-BLK1)					Prepared & Analyzed: 05-Sep-11					
Iron bound Phosphorus as P	**0.25**	J	mg/kg dry wet							
LCS (1117953-BS1)					Prepared & Analyzed: 05-Sep-11					
Iron bound Phosphorus as P	**53.2**		mg/kg dry wet		50.1		106	90-110		
Duplicate (1117953-DUP1)			Source: SB33752-01		Prepared & Analyzed: 05-Sep-11					
Iron bound Phosphorus as P	**390**		mg/kg dry dry			394			1	35
Matrix Spike (1117953-MS1)			Source: SB33752-01		Prepared & Analyzed: 05-Sep-11					
Iron bound Phosphorus as P	**512**	QM5	mg/kg dry dry		258	394	46	80-120		
Matrix Spike Dup (1117953-MSD1)			Source: SB33752-01		Prepared & Analyzed: 05-Sep-11					
Iron bound Phosphorus as P	**411**	QM5	mg/kg dry dry		222	394	8	80-120	22	35

Notes and Definitions

J	Detected above the Method Detection Limit but below the Reporting Limit; therefore, result is an estimated concentration (CLP J-Flag).
QM2	The RPD and/or percent recovery for this QC spike sample cannot be accurately calculated due to the high concentration of analyte inherent in the sample.
QM4X	The spike recovery was outside of QC acceptance limits for the MS, MSD and/or PS due to analyte concentration at 4 times or greater the spike concentration. The QC batch was accepted based on LCS and/or LCSD recoveries within the acceptance limits.
QM5	The spike recovery was outside acceptance limits for the MS, MSD and/or PS due to matrix interference. The LCS and/or LCSD were within acceptance limits showing that the laboratory is in control and the data is acceptable.
U	Analyte included in the analysis, but not detected
dry	Sample results reported on a dry weight basis
NR	Not Reported
RPD	Relative Percent Difference

Laboratory Control Sample (LCS): A known matrix spiked with compound(s) representative of the target analytes, which is used to document laboratory performance.

Matrix Duplicate: An intra-laboratory split sample which is used to document the precision of a method in a given sample matrix.

Matrix Spike: An aliquot of a sample spiked with a known concentration of target analyte(s). The spiking occurs prior to sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix.

Method Blank: An analyte-free matrix to which all reagents are added in the same volumes or proportions as used in sample processing. The method blank should be carried through the complete sample preparation and analytical procedure. The method blank is used to document contamination resulting from the analytical process.

Method Detection Limit (MDL): The minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte.

Reportable Detection Limit (RDL): The lowest concentration that can be reliably achieved within specified limits of precision and accuracy during routine laboratory operating conditions. For many analytes the RDL analyte concentration is selected as the lowest non-zero standard in the calibration curve. While the RDL is approximately 5 to 10 times the MDL, the RDL for each sample takes into account the sample volume/weight, extract/digestate volume, cleanup procedures and, if applicable, dry weight correction. Sample RDLs are highly matrix-dependent.

Surrogate: An organic compound which is similar to the target analyte(s) in chemical composition and behavior in the analytical process, but which is not normally found in environmental samples. These compounds are spiked into all blanks, standards, and samples prior to analysis. Percent recoveries are calculated for each surrogate.

Continuing Calibration Verification: The calibration relationship established during the initial calibration must be verified at periodic intervals. Concentrations, intervals, and criteria are method specific.

Validated by:
June O'Connor
Kimberly Wisk
Nicole Leja

SB33752 By

SPECTRUM ANALYTICAL, INC.
Featuring
HANIBAL TECHNOLOGY

CHAIN OF CUSTODY RECORD

Page 1 of 2

Special Handling:
- ☐ Standard TAT - 7 to 10 business days
- ☐ Rush TAT - Date Needed: ______
- All TATs subject to laboratory approval.
- Min. 24-hour notification needed for rushes.
- Samples disposed of after 60 days unless otherwise instructed.

Report To: Liz Moran
Ecologic, LLC
Cazenovia, NY 13035

Telephone #: 315 655-8305
Project Mgr. Kurt Jirka

Invoice To: Eco Logic, LLC
132 1/2 Albany Street
Cazenovia, NY 13035

P.O. No.: ______ RQN: 7216

Project No.: Eastham Ponds
Site Name: Herring Pond, Long/Depot Pond
Location: Eastham State: MA
Sampler(s): Kurt Jirka, Kerry Thurston

1=$Na_2S_2O_3$ 2=HCl 3=H_2SO_4 4=HNO_3 5=NaOH 6=Ascorbic Acid 7=CH_3OH
8= $NaHSO_4$ 9= Deionized Water 10=______ 11=______

List preservative code below:

DW=Drinking Water GW=Groundwater WW=Wastewater
O=Oil SW= Surface Water SO=Soil SL=Sludge A=Air
X1= Sediment X2=______ X3=______

G=Grab C=Composite

QA/QC Reporting Notes:
* additional charges may apply

MA DEP MCP CAM Report: Yes☐ No☒
CT DPH RCP Report: Yes☐ No☒

QA/QC Reporting Level
☐ Standard ☐ No QC ☐ DQA*
☐ NY ASP A* ☐ NY ASP B*
☐ NJ Reduced* ☐ NJ Full*
☐ TIER II* ☐ TIER V*
☐ Other ______

State-specific reporting standards:

Lab Id:	Sample Id:	Date:	Time:	Type	Matrix	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic Bags	# of Plastic Bottles	Total P	Grain Size	Total Fe	Fe-bound TP	Loosely-sorbed P	Total Alkalinity	Total P low level
33752.01	Herring 01	8-16-11	1630	G	X1				1		✓	✓	✓	✓	✓		
.02	Herring 02	8-16-11	1645	G	X1				1		✓	✓	✓	✓	✓		
.03	Herring 03	8-16-11	1700	G	X1				1		✓	✓	✓	✓	✓		
.04	Herring T-ALK	8-16-11	1600	G	SW					1						✓	
.05	Herring TP	8-16-11	1600	G	SW					1							✓
.06	Long/Depot T-ALK	8-16-11	1000	G	SW											✓	
.07	Long/Depot TP	8-16-11	1000	G	SW												✓

Relinquished by:	Received by:	Date:	Time:	Temp°C
Kurt Jirka [signature]	Fed Ex	8-17-11	1030	
FedEx	[signature]	8/17/11	1003	2.3

☐ EDD Format ______
☒ E-mail to ~~[illegible]~~ lmoran@ecologicllc.com

☐ Ambient ☒ Iced ☐ Refrigerated ☐ Fridge temp ___°C ☐ Freezer temp ___°C

SB33752 BH

SPECTRUM ANALYTICAL, INC.
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CHAIN OF CUSTODY RECORD

Page 2 of 2

Special Handling:
- ☐ Standard TAT - 7 to 10 business days
- ☐ Rush TAT - Date Needed: ________
- All TATs subject to laboratory approval.
- Min. 24-hour notification needed for rushes.
- Samples disposed of after 60 days unless otherwise instructed.

Report To: Liz Moran
Ecologic, LLC
Cazenovia, NY 13035

Telephone #: (315) 655-8305
Project Mgr. Kurt Jirka

Invoice To: Ecologic LLC
132 1/2 Albany Street
Cazenovia, NY 13035

P.O. No.: ________ RQN: 7216

Project No.: Eastham Ponds
Site Name: Great Pond
Location: Eastham State: MA
Sampler(s): Kurt Jirka, Kerry Thurston

1=Na_2S2O_3 2=HCl 3=H_2SO_4 4=HNO_3 5=NaOH 6=Ascorbic Acid 7=CH_3OH
8= $NaHSO_4$ 9= Deionized Water 10=________ 11=________

DW=Drinking Water GW=Groundwater WW=Wastewater
O=Oil SW= Surface Water SO=Soil SL=Sludge A=Air
X1= Sediment X2=________ X3=________

G=Grab C=Composite

List preservative code below:

Lab Id:	Sample Id:	Date:	Time:	Type	Matrix	# of VOA Vials	# of Amber Glass	# of Clear Glass	# of Plastic Bags	# of Plastic Bottles	Total P	Grain Size	Total Fe	Fe-bound TP	Loosely-sorbed P	Total Alkalinity	Total P low level
33752-08	Great Pond 01	8-16-11	1400	G	X1						✓	✓	✓	✓	✓	~~✓~~	
09	Great Pond 02	8-16-11	1415	G	X1						✓	✓	✓	✓	✓		
10	Great Pond 03	8-16-11	1430	G	X1						✓	✓	✓	✓	✓		
11	Great Pond T-ALK	8-16-11	1330	G	SW											✓	
12	Great Pond TP	8-16-11	1330	G	SW												✓

QA/QC Reporting Notes:
* additional charges may apply

MA DEP MCP CAM Report: Yes ☐ No ☒
CT DPH RCP Report: Yes ☐ No ☒

QA/QC Reporting Level
☐ Standard ☐ No QC ☐ DQA*
☐ NY ASP A* ☐ NY ASP B*
☐ NJ Reduced* ☐ NJ Full*
☐ TIER II* ☐ TIER V*
☐ Other ________

State-specific reporting standards:

Relinquished by:	Received by:	Date:	Time:	Temp°C
Kurt Jirka [signature]	Fed Ex	8-17-11	1030	
[signature]	[signature]	8/17/11	1003	2.3

☐ EDD Format ________
☒ E-mail to lmoran@ecologicllc.com

☐ Ambient ☒ Iced ☐ Refrigerated ☐ Fridge temp ___°C ☐ Freezer temp ___°C

FedEx® Express US Airbill

FedEx Tracking Number **8750 9382 5805**

Form ID No. 0200

Recipient's Copy

1 From [redacted]

Date: 8-17-11

Sender's Name: Kurt Jinka Phone: 315 655-8305

Company: Ecologic LLC

Address: 132 1/2 Albany St Dept./Floor/Suite/Room

City: Cazenovia State: NY ZIP: 13035

2 Your Internal Billing Reference

3 To

Recipient's Name: Sample Receiving Phone: 413 789-9018

Company: Spectrum Analytical Inc.

Address: 830 Silver St Dept./Floor/Suite/Room

We cannot deliver to P.O. boxes or P.O. ZIP codes.

Address: A

Use this line for the HOLD location address or for continuation of your shipping address.

City: Agawam State: MA ZIP: 01001

☐ HOLD Weekday — FedEx location address REQUIRED. **NOT available for** FedEx First Overnight.

☐ HOLD Saturday — FedEx location address REQUIRED. **Available ONLY for** FedEx Priority Overnight and FedEx 2Day to select locations.

8750 9382 5805

4a Express Package Service * To most locations. ***Packages up to 150 lbs.***

- ☐ FedEx Priority Overnight — Next business morning.* Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- ☒ FedEx Standard Overnight — Next business afternoon.* Saturday Delivery NOT available.
- ☐ FedEx First Overnight — Earliest next business morning delivery to select locations.*
- ☐ FedEx 2Day — Second business day.* Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- ☐ FedEx Express Saver — Third business day.* Saturday Delivery NOT available.

4b Express Freight Service ** To most locations. ***Packages over 150 lbs.***

- ☐ FedEx 1Day Freight — Next business day.** Friday shipments will be delivered on Monday unless SATURDAY Delivery is selected. FedEx 1Day Freight Booking No.
- ☐ FedEx 2Day Freight — Second business day.** Thursday shipments will be delivered on Monday unless SATURDAY Delivery is selected.
- ☐ FedEx 3Day Freight — Third business day.** Saturday Delivery NOT available.

5 Packaging * Declared value limit $500.

☐ FedEx Envelope* ☐ FedEx Pak* (Includes FedEx Small Pak and FedEx Large Pak.) ☐ FedEx Box ☐ FedEx Tube ☒ Other

6 Special Handling and Delivery Signature Options

☐ SATURDAY Delivery — **NOT available for** FedEx Standard Overnight, FedEx Express Saver, or FedEx 3Day Freight.

- ☒ No Signature Required — Package may be left without obtaining a signature for delivery.
- ☐ Direct Signature — Someone at recipient's address may sign for delivery. ***Fee applies.***
- ☐ Indirect Signature — If no one is available at recipient's address, someone at a neighboring address may sign for delivery. For residential deliveries only. ***Fee applies.***

Does this shipment contain dangerous goods?

One box must be checked.

☒ No ☐ Yes — As per attached Shipper's Declaration. ☐ Yes — Shipper's Declaration not required. ☐ Dry Ice — Dry Ice, 9, UN 1845 ____ x ____ kg

Dangerous goods (including dry ice) cannot be shipped in FedEx packaging or placed in a FedEx Express Drop Box.

☐ Cargo Aircraft Only

7 Payment ***Bill to:***

Enter FedEx Acct. No. or Credit Card No. below.

☒ Sender (Acct. No. in Section 1 will be billed.) ☐ Recipient ☐ Third Party ☒ Credit Card ☐ Cash/Check Obtain recip. Acct. No. ☐

[redacted]

Total Packages	Total Weight	Total Declared Value†	Credit Card Auth.
1	60 lbs.	$ .00	

†Our liability is limited to $100 unless you declare a higher value. See the current FedEx Service Guide for details.

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fedex.com 1.800.GoFedEx 1.800.463.3339