Appendix 5-1

Action Plan for the Barnstable Ponds

Action Plan for the Barnstable Ponds

EcoLogic LLC
Stearns & Wheler GHD

December 31, 2009

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Action Plan for the Town of Barnstable Ponds

1 Introduction and Scope

This report summarizes the current water quality and aquatic habitat conditions of many freshwater ponds located in the Town of Barnstable, Massachusetts, and recommends priority actions to ensure the ponds' protection and restoration. The Town of Barnstable is currently working with Stearns & Wheler GHD of Hyannis, Massachusetts to prepare a comprehensive nutrient management strategy that will guide the community's development in a manner that protects natural resources, 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 planning project.

As summarized in the July 2008 report to the Town of Barnstable Conservation Commission prepared by the Cape Cod Commission and the Coastal Resources Group of the UMASS School of Marine Science and Technology (Eichner et al. 2008), the Town of Barnstable has 182 freshwater ponds, totaling 1,856 acres. About half of the town's freshwater ponds are extremely small, occupying less than one acre. There are 93 ponds one acre or greater in surface area. Of these, only 25 are larger than 10 acres and are consequently classified as "Great Ponds" by the state. The location of the freshwater ponds is illustrated in Figure 1, which was prepared by Town of Barnstable GIS staff.

This report sets forth recommendations to the Town of Barnstable as they integrate management of the inland ponds into an overall nutrient management plan. The recommendations consider effectiveness (both short-term and long-term), cost, permitting issues and recreational impacts. The recommended actions include institutional, technical and public education components. Some recommendations are town-wide, while others are directed to specific ponds. An overall implementation strategy is presented that defines priority actions and sequencing of recommendations.

Hamblin Pond: Recreational use

In accordance with guidance from the Massachusetts Department of Environmental Protection (MA DEP), the analysis and recommendations in this report do not provide a foundation for defining a Total Maximum Daily Load for phosphorus input to the town's freshwater ponds.

Aerial Photo Taken April 19, 2008

Major Roads

Town Boundary

TOWN OF BARNSTABLE

MASSACHUSETTS

Comprehensive Wastewater and Nutrient Management Plan

Freshwater Ponds

Figure 1

SEAL OF THE TOWN OF BARNSTABLE, MASS. 1639. ADOPTED MAY 4, 1889

N W E S

Miles

0 0.25 0.5 1 1.5 2

CWNMP_Ponds_11x17.mxd J.A.B. 4/13/2010

TOWN OF BARNSTABLE GEOGRAPHIC INFORMATION SYSTEMS UNIT

FIGURE PREPARED FOR STEARNS & WHELER GHD

2 Nutrients and Eutrophication

"Lakes seem, on the scale of years or human life spans, permanent features of the landscape, but they are geologically transitory, usually born of catastrophe and mature and die quietly and imperceptibly" (Hutchinson 1957).

This often-cited quote from a classic limnology text provides excellent context for reviewing the current and future conditions of the ponds of Barnstable. The ponds may be arrayed along a continuum from open, clear, water with little visible algal growth to extremely shallow, productive systems well on their way to becoming wetlands.

Shubael Pond – Deep, with exceptionally clear water, sandy bottom.

Aunt Betty's Pond – Ultra-shallow, very productive with submerged and floating-leaved plants evident.

Eutrophication, the term for both the process and the effects of enrichment of surface water systems (including lakes, ponds, estuaries, and reservoirs), is a significant water quality concern for many aquatic ecosystems. As aquatic systems become increasingly enriched with plant nutrients, organic matter and silt, the result is increased biomass of algae and plants, reduced water clarity, and ultimately, a reduction in volume. Aesthetic quality and habitat conditions are degraded, and affected waters may no longer be suitable for drinking water or recreation.

While eutrophication is a natural process, it can be greatly accelerated by human activities. There are numerous lakes and ponds included in state compendia of impaired waters; most are listed due to excessive nutrient inputs from nonpoint sources such as agricultural or urban runoff, or seepage from on-site wastewater disposal systems. Less frequently, the impairment of surface waters is attributed to excessive discharge of nutrients from point sources; these may be piped discharges of inadequately treated wastewater from industrial or municipal sources.

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 MA 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.

Mystic Pond (Indian Ponds)

Middle Pond (Indian Ponds)

Hamblin Pond (Indian Ponds)

3 Kettle Pond Ecosystems

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. 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, invasions of exotic species, application of lime to raise the naturally low pH of the waters, and fisheries management practices.

Unlike most lakes and ponds, kettle ponds do not have prominent tributary streams (inlets) and outlets (**Figure 2**). Groundwater seepage 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.

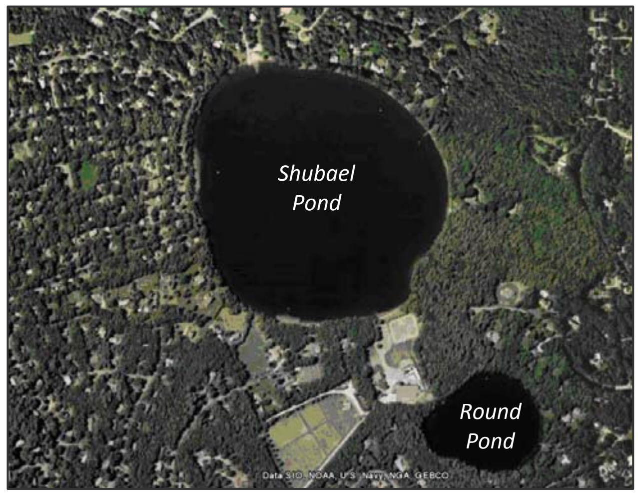

Figure 2. Aerial photograph of Shubael and Round Ponds illustrating hydrologic isolation of kettle ponds.

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 seepage 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 more productive over time, as there is little opportunity for particulate material to leave the system. The Cape Cod Commission compiled dissolved oxygen (DO) measurements in the lower waters of 41 kettle ponds; data were from 1948 and 2001. Comparison of the data revealed that 76% of the measurements were lower in 2001 than 1948. These data provide strong evidence of an increasing level of productivity in the ponds over the intervening five decades (Cape Cod Commission, May 2003 p. 46).

Round Pond

Another important consideration for the kettle ponds of Barnstable is that many of the ponds are shallow, with extensive wetland and 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.

Elizabeth Pond

4 Sources of Data and Information

A recent report summarizes the water quality status of the ponds of Barnstable (Eichner et al. 2008). After reviewing available data, the authors of this report concluded that:

> *"Available data for most ponds in Barnstable is limited. Other than the PALS Snapshots and sampling following the alum treatment at Hamblin Pond, sampling of most of the ponds has been sporadic. Given the sporadic available data and since the PALS Snapshots are designed to sample ponds during what is likely to be their worst water quality conditions, interpretation of available data must be approached with an understanding of these limitations."*

This Action Plan builds on the information provided in the 2008 report, and incorporates other data sources as summarized in **Table 1**. Of the 59 ponds listed in the table, data sources were available for 64% of the ponds.

Table 1. Data Sources Used to Develop Barnstable Ponds Action Plan

Named Pond[1]	CCC GIS ID[2]	Eichner, 2008[3]	Lake Wequaquet[4]	CCC Atlas: description[5]	Bathing beach bacteria testing[6]	2009 Visual Assessment[7]
1. Aunt Betty's	BA-756	✓				✓
2. Bearse	BA-617	✓		✓		
3. Bog	BA-802	✓				
4. Campground	BA-574					
5. Coleman	BA-819	✓				
6. Crystal	BA-878	✓				
7. Dunn's	BA-723	✓				
8. Eagle	BA-815	✓		✓		✓
9. Elizabeth	BA-795	✓				✓
10. Fawcett's	BA-748	✓				
11. Flax	BA-473					
12. Flint Rock	BA-614					
13. Flowing	BA-733					
14. Fresh	BA-701					
15. Garrett's	BA-510	✓		✓		✓
16. Hamblin	BA-668	✓		✓	✓	✓
17. Hathaway (North)	BA-565	✓		✓	✓	✓
18. Hathaway (South)	BA-594	✓				✓
19. Hinckley	BA-411	✓				
20. Israel	BA-585					
21. Joshua	BA-807	✓		✓	✓	✓
22. Lamson	BA-596					
23. Lewis	BA-881	✓				
24. Lewis (airport)	BA-670					
25. Little Israel	BA-608					
26. Little Parker	BA-841	✓				

Named Pond[1]	CCC GIS ID[2]	Eichner, 2008[3]	Lake Wequaquet[4]	CCC Atlas: description[5]	Bathing beach bacteria testing[6]	2009 Visual Assessment[7]
27. Little / Stony	BA-564	✓				
28. Long (C'ville)	BA-737	✓		✓		✓
29. Long (MM)	BA-675	✓		✓		✓
30. Lovell's	BA-759	✓		✓		✓
31. Lumbert	BA-719	✓				✓
32. Mary Dunn	BA-646	✓				
33. Micah	BA-797	✓		✓		
34. Middle	BA-640	✓				✓
35. Mill (MM)	BA-746	✓				✓
36. Mill (WB)	BA-391	✓				
37. Muddy	BA-694	✓				✓
38. Mystic	BA-584	✓				✓
39. Naomi	BA-812					
40. Neck	BA-874	✓				
41. No Bottom	BA-523	✓				
42. North (C'ville)	BA-752					
43. North (Ost)	BA-816					
44. Parker	BA-875	✓				
45. Patty's	BA-731					
46. Red Lily (North)	BA-782	✓				✓
Red Lily (South)	BA-782	✓				
47. Round (Bar)	BA-587					
48. Round (MM)	BA-691	✓				✓
49. Rushy Marsh	BA-914					
50. Sam	BA-820					
51. Sandy Hill	BA-542					
52. Schoolhouse	BA-806	✓				
53. Shallow	BA-626	✓				✓
54. Shubael	BA-664	✓		✓		✓
55. Simmons	BA-789					
56. Spruce	BA-535					
57. Upper Gate	BA-673					
58. Wequaquet	BA-605	✓	✓	✓	✓	✓
59. West	BA-764					

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

[2]CCC GIS ID: CCC GIS staff assigned a unique number to each waterbody digitized from a spring 1994 aerial photograph. The numbering system consisted of a two-letter town code and a unique number for each pond. These are presented in the CCC Atlas of 2003.

[3]Eichner, 2008: Eichner, E. 2008. Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities. School of Marine Science and Technology, University of Massachusetts Dartmouth and Cape Cod Commission. New Bedford and Barnstable, MA.

[4]Lake Wequaquet: SMAST. 2008. Lake Wequaquet Water Quality Assessment draft FINAL REPORT October, 2008 for the Town of

Named Pond[1]	CCC GIS ID[2]	Eichner, 2008[3]	Lake Wequaquet[4]	CCC Atlas: description[5]	Bathing beach bacteria testing[6]	2009 Visual Assessment[7]

Barnstable and Cape Cod Commission. Prepared by Coastal Systems Group School of Marine Science and Technology University of Massachusetts Dartmouth.

[5]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.

[7]Visual assessment conducted by EcoLogic staff on July 29, 2009.

4.1 Cape Cod Commission Reports

Barnstable Ponds: Current Status, Available Data, and Recommendations for Future Activities (Eichner et al. 2008). In 2008, the Cape Cod Commission, in cooperation with the Coastal Systems Group School of Marine Science and Technology University of Massachusetts Dartmouth, issued a report on the current status, available data, and recommendations for future activities for the Barnstable Ponds. Data from 38 ponds were identified, which generally focused on two sources: 1) individual pond studies with intensive year-long data collection; and 2) data collect through the Pond and Lake Stewardship (PALS) Snapshots conducted through the CCC and the SMAST between 2001 and 2007. The report concluded that available datasets for Barnstable’s ponds were generally insufficient for drawing conclusions regarding the sources of nutrients and other factors affecting water quality and habitat conditions in individual ponds, but were sufficient for comparing conditions among ponds.

Lake Wequaquet Water Quality Assessment draft FINAL REPORT October, 2008 for the Town of Barnstable and Cape Cod Commission (SMAST, 2008). The Town of Barnstable contracted with the Coastal Systems Program, School of Marine Science and Technology (SMAST), University of Massachusetts Dartmouth through the Cape Cod Commission (CCC) to update the analysis of water quality conditions in Lake Wequaquet and connecting waterways. Sampling was conducted in summer 2007. This report documents the sampling results and their interpretation, as well as an evaluation of the relationship of the lake to its watershed through water, nitrogen, and phosphorus budgets.

Cape Cod Pond and Lake Atlas, Final Report (CCC Water Resources Office, 2003). The Cape Cod Commission Water Resources Office published the Cape Cod Pond and Lake Atlas in May 2003; this document presents a summary and analysis of water quality status of twelve of the Barnstable ponds. The summaries provide an overview, indicating location, the nature of the shoreline, and predominant land uses. The fish community and stocking activities are described. Results of an August 2001 sampling program are tabulated for 35 ponds; chlorophyll-*a*, phosphorus and nitrogen concentrations are compared with thresholds for impaired ponds.

4.2 Visual field assessment

In July 2009, EcoLogic LLC conducted a field visit of 20 of the Barnstable ponds to observe water clarity and color, shoreline vegetation and development, public access and recreational uses, and the presence of algae and macrophytes.

4.3 Delineation of contributing areas

The Town of Barnstable GIS Unit developed a draft map delineating the recharge areas and land use in the Town. Information on this map included acreage of the recharge areas, number of parcels, existing residential units, and existing commercial building square footage. A build-out analysis was conducted to estimate the total extent of development possible under existing zoning regulations.

5 Inventory of ponds

The Barnstable ponds exhibit a range of physical characteristics (**Table 2**). Additional details are presented in Appendix A.

Table 2. Physical Characteristics of the Barnstable Ponds

Pond	Area (acres)	Access	Water Clarity	Shoreline	Aquatic Plants
Aunt Betty's	7.1	Very limited	--	Developed	Present
Fawcett's	11.9	--	--	Developed	--
Lumbert	9.7	Private	Tannic	Developed	Present
Mary Dunn	18	--	--	Undeveloped	--
Mill (Marstons Mills)	6.0	--	Clear	Undeveloped	Present
Mill (West Barnstable)	16.7	--	--	--	--
Red Lily	4.5	Very limited	--	Vegetated	Present
Bearse	66.8	Permission	Clear	Developed	--
Eagle	8.5	Conservation	Clear	Undeveloped	Present
Elizabeth	6.3	Very limited	--	--	Present
Garrett's	27.9	Permission	Tannic	Developed	Present
Hinckley	10.3	--	--	Developed	--
Joshua	14.7	Public	Clear	Undeveloped	--
Long (Centerville)	51	Limited	Clear	Developed	Not evident
Long (Marstons Mills)	54.8	Conservation	Clear	Developed	Not evident
Muddy	24.6	None	--	Developed	--
Parker	10.9	--	--	Developed	--
Round (Marstons Mills)	9.8	Private	Clear	Developed	Present
Shallow	78.4	--	Clear	Developed	Not evident
Crystal	10.1	--	--	Developed	--
Hamblin (Indian Ponds)	115.4	Public	V. Clear	Developed	Present
Hathaway (North)	20.9	Public	V. Clear	Undeveloped	--
Lovell's	55.5	Public	--	Developed	Not evident
Micah	16.0	Conservation	--	Undeveloped	--
Middle (Indian Ponds)	104.6	Public	V. Clear	Developed	Minimal
Mystic (Indian Ponds)	148.4	Public	Clear	Developed	Present
Neck	13.6	--	--	Developed	--
Shubael	55.1	Public	V. Clear	Developed	Present
Wequaquet	596.3	Public	--	Developed	--
Lamson	12.3	--	--	Undeveloped	--
West	10.1	--	--	--	--

5.1 Current Water Quality and Habitat Conditions

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

The shallowest 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.

Eagle Pond

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. As a result of these chemical changes, phosphorus is released from sediments to the overlying waters. In some lakes, wind-induced mixing and internal waves (seiches) may draw the phosphorus-rich water into the upper sunlit layer where the nutrient can support algal growth (the photic zone) during the summer. Several of the shallower ponds are 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.

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**). However, assigning a lake or pond to one category still requires professional judgment considering the cumulative evidence of water quality conditions and the level of productivity (**Table 4**).

Lovell's Pond, with algal bloom
July 2009

Table 3. Trophic State and Indicator Parameters

Trophic State	TSI Values	Attributes and Recreational Use *TSI Calculation*	*TSI(TP) = 14.42 ln(TP) + 4.15* Total Phosphorus	*TSI(CHL) = 9.81 ln(CHL) + 30.6* Chlorophyll-a	*TSI(SD) = 60 – 14.41 ln(SD)* 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 developed in algal dominated, northern temperate lakes

Table 4. Summary of Trophic State Parameters, Barnstable Ponds

Trophic State	Depth Class		
	Ultra-Shallow	**Shallow**	**Deep**
Oligotrophic	Hathaway (South) Mary Dunn Mill (MM) Red Lily	Garrett's Joshua	Hamblin Hathaway (North) Micah Middle Neck Shubael
Mesotrophic	Aunt Betty's Bog Fawcett Lumbert	Bearse Coleman No Bottom Shallow	Crystal Lovell's Mystic Wequaquet
Eutrophic	Dunn's Little/Stony Mill (WB)	Eagle Elizabeth Hinckley Long (C'ville) Long (MM) Muddy Parker Round (MM)	
Hypereutrophic	Little Parker	Schoolhouse	

based on Eichner, 2008

The visual assessment conducted by EcoLogic in July 2009 confirmed that the Barnstable Ponds are in various stages of eutrophication.

While data are limited, they do provide a basis for making an assessment of trophic state using the standard indicators described in **Table 3**. Note that the concentrations of chlorophyll-a and phosphorus used to delineate trophic state (**Table 3**) are not the same as the concentrations used to define ecoregional reference lake conditions (**Table 5**). The ecoregional criteria are based on water quality conditions measured in eight pristine Cape Cod ponds.

Table 5. Ecoregional Criteria

Parameter	Subecoregion 84 Reference Condition Threshold	Cape Cod Ponds based on 2001 PALS Data
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

EPA is encouraging development of ecoregional criteria, designed to reflect site-specific conditions of watershed geology, land use, and hydrologic setting. These values are used to define thresholds for impacted and non-impacted conditions and thus target levels. Ecoregional criteria for Cape Cod ponds have been described in the Cape Cod Pond and Lake Atlas (Cape Cod Commission, May 2003); the ecoregional values (designated as subregion 84) are derived from a statistical evaluation of existing water quality conditions of "unimpacted" ponds for coastal New England, including Cape Cod. The 2001 PALS data were used to calculate thresholds for reference conditions using eight Cape Cod ponds. The eight ponds included a range of deep and shallow ponds; all were characterized with low nutrient and chlorophyll concentrations. One of these eight reference ponds was Barnstable's Micah Pond.

The status of the Barnstable Ponds with respect to the ecoregional criteria is summarized in **Table 6**, based on the data summaries provided by Eichner (2008).

Table 6. Status of Barnstable Ponds, based on Cape Cod Ponds Thresholds.

Pond	Impacted Criteria (Affected by Human Activities)		
	Chlorophyll-a >1.7 µg/l	**Total N > 0.31 mg/l**	**Total P > 10 µg/l**
Ultra-Shallow (0.5 and 1.2 m)			
Aunt Betty's	Impacted	Impacted	At Risk
Bog	Impacted	Impacted	At Risk
Dunn's	Impacted	Impacted	Impacted
Fawcett	Impacted	Impacted	At Risk
Hathaway (South)	Unimpacted	Unimpacted	Unimpacted
Little Parker	Impacted	Impacted	Impacted
Little/Stony	Impacted	Impacted	At Risk
Lumbert	Impacted	Impacted	At Risk
Mary Dunn	Impacted	Impacted	At Risk
Mill (MM)	Impacted	Impacted	Impacted
Mill (WB)	Impacted	Impacted	Impacted
Red Lily (North)	Impacted	Impacted	At Risk
Red Lily (South)	Impacted	Impacted	At Risk
Shallow (2.1 and 8.6 m)			
Bearse	Impacted	Impacted	At Risk
Coleman	Impacted	Impacted	Impacted
Eagle	At Risk	Impacted	At Risk
Elizabeth	Impacted	Impacted	Impacted
Garrett's	Impacted	Unimpacted	At Risk
Hinckley	Impacted	Impacted	Impacted
Joshua	At Risk	At Risk	At Risk
Long (C'Ville)	Impacted	Impacted	At Risk
Long (MM)	Impacted	Impacted	Impacted
Muddy	Impacted	At Risk	Impacted
No Bottom	Impacted	Impacted	Impacted
Parker	Impacted	Impacted	Impacted
Round (MM)	Impacted	Impacted	At Risk
Schoolhouse	Impacted	Impacted	Impacted
Shallow	Impacted	Impacted	At Risk

Table 6. Status of Barnstable Ponds, based on Cape Cod Ponds Thresholds.

Pond	Impacted Criteria (Affected by Human Activities)		
	Chlorophyll-a >1.7 µg/l	Total N > 0.31 mg/l	Total P > 10 µg/l
<u>**Deep (9.3 and 17.3 m)**</u>			
Crystal	Impacted	Impacted	Impacted
Hamblin	Impacted	At Risk	At Risk
Hathaway (North)	Impacted	Unimpacted	Impacted
Lovell's	Impacted	Impacted	Impacted
Micah	Impacted	At Risk	Impacted
Middle	Impacted	At Risk	At Risk
Mystic	Impacted	At Risk	Impacted
Neck	At Risk	Impacted	Impacted
Shubael	Impacted	Impacted	Impacted
Wequaquet	Impacted	Impacted	Impacted

In addition to grouping the ponds based on the degree to which human activities have altered them from their natural (pristine) condition, each state classifies surface waters for a desired "best use". This concept focuses on human use of the resource, but incorporates the ecological condition of the resource as well. Examples of designated use include public water supply, fishing, swimming (water contact recreation), aesthetic enjoyment and support of shellfish, wildlife and fisheries. The best use of Barnstable's inland kettle ponds is typically recreation in and on the water and fishing. It is important to note that the designation of a pond as showing evidence of impact by humans (i.e., "impacted" or "at risk") does not imply that the pond's designated uses are not being supported. Overall, the town's inland ponds fully support their designated use.

Based on this analysis, the Barnstable Ponds may be grouped into categories describing current water quality and habitat conditions. This grouping is presented in **Table 7.**

Table 7. Summary of Current Water Quality Conditions and Use Attainment.

Depth Categories:	Water Quality and Aquatic Habitat Status		
	Supports Desired Uses	**Currently Supports Desired Uses, with Evidence of Degradation**	**Does Not Support Desired Uses**
Ultra-shallow (less than 1.2 m maximum depth)	Aunt Betty's Hathaway (South) Lumbert Mary Dunn Mill (MM)	Red Lily Bog Dunn's Fawcett Little/Stony Mill (WB)	Little Parker
Shallow (from 2.1 to 8.6 m maximum depths)	Garrett's Joshua Eagle	Bearse Coleman Long(MM) Elizabeth No Bottom Round (MM) Shallow	Hinckley Long (C'ville) Muddy Parker Schoolhouse
Deep (from 9.3 to 17.3 m maximum depths)	Hathaway (North) Micah Middle Neck	Chrystal Hamblin Mystic Shubael Wequaquet	Lovell's

The nitrogen: phosphorus (N: P) ratio is another measure of pond conditions. Algae require many nutrients, and their nutritional requirements are within a relatively consistent range. As a general rule, higher N:P ratios are associated with lower productivity. When the elemental N:P ratio in the water column falls below about 16, 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 more readily useable forms of nitrogen). As a consequence, growth of these species is not limited by the availability of nitrogen in the water, and cyanobacterial abundance can reach nuisance levels in eutrophic lakes.

The N:P ratio of the Barnstable ponds (**Table 8)** tends to be high. The N:P ratio, on average, decreases from more than 100 for the less productive ponds to less than 10 for the most nutrient-rich and productive ponds. Lovell's Pond, which was closed for swimming in July 2009 due to a cyanobacterial bloom, exhibited a relatively low N: P ratio of 25:1 in 2001.

Table 8. Nitrogen:Phosphorus Ratios, Barnstable Freshwater Ponds, 2001

Ultra-Shallow		**Shallow**		**Deep**	
Oligotrophic (>100)		*Oligotrophic (>100)*		*Oligotrophic (>100)*	
Red Lily (Lower)	179:1	Long (August)	112:1		
Mid-Range (<100 and >10)		*Mid-Range (<100 and >10)*		*Mid-Range (<100 and >10)*	
Aunt Betty's	29:1	Bearse	19:1	Crystal	52:1
Bog	26:1	Coleman	25:1	Hathaway North	65:1
Fawcett's	61:1	Elizabeth	16:1	Lovell's	25:1
Hathaway (South)	29:1	Garrett's	44:1	Micah	53:1
Little	51:1	Long (Sept.)	31:1	Middle	46:1
Mary Dunn	33:1	Muddy	22:1	Mystic	23:1
		Parker	72:1	Shubael	73:1
		Round	45:1	Wequaquet Middle	22:1
		Shallow	32:1		
Eutrophic (<10)		*Eutrophic (<10)*		*Eutrophic (<10)*	
Dunns	9:1	Schoolhouse	8:1		

Based on data from Cape Cod Pond and Lake Atlas, May 2003.

5.2 Data Gaps

The evaluation of the data in Eichner (2008) repeatedly emphasized that only limited data were available to analyze the status and trends of the Barnstable ponds.

> *"When looking at all of this data, there are two significant factors that must also be considered: all of these characterizations are based on very limited data and there are a number of Barnstable ponds that do not have any data. Except for Mystic, Middle, and Hamblin, the rest of the ponds have not had water quality samples collected since 1986 except for PALS Snapshots. The PALS Snapshot data is useful for what it was designed for, a Cape-wide picture of pond water quality, but it is not sufficient for definitively stating the status of individual ponds or designing remedial strategies." (Eichner, 2008)*

5.3 Land Use and Phosphorus Sources

Phosphorus can reach the inland kettle ponds from several sources. Runoff from impervious surfaces, such as roadways, can transport dissolved and particulate material, including phosphorus, to the ponds. Eroding shorelines can contribute particulate material as well. Groundwater seepage transports dissolved nutrients into ponds; the concentrations of dissolved nutrients can be elevated when groundwater is affected by sewage disposal. There are biological sources as well, including waterfowl and humans.

Maps of current land use, depicting the number and location of residences, were reviewed during preparation of this Action Plan for Barnstable. This coverage area of impervious surfaces is important to consider in quantifying phosphorus loading to the ponds from the surrounding watershed due to surface runoff. The density of development is a factor in phosphorus loading from septic systems.

Mill Pond – Conservation Area visitor location map.

Review of the map of government-owned land and protected open space (Town of Barnstable, 2009) indicates that the majority of parcels within the town are in private ownership and not under conservation protection. However, many of the smaller ponds have a substantial portion of the watershed in town-owned or conservation lands.

Most of the town is not served by sanitary sewers. Therefore, septic effluent is likely a contributing factor in phosphorus loading to most of the Barnstable ponds. Once the contributing area of groundwater flow into each pond is delineated, these data can be used to help quantify the potential contribution of septic effluent to each pond.

Parcels in the Town of Barnstable that have sewer accounts have been mapped. According to a map[1] dated October 2007, these parcels are predominantly located on the eastern side of town, east of the Lake Wequaquet region. One would anticipate that parcels with sewer accounts would have fewer active septic systems, and that septic contributions of phosphorus to the ponds adjacent to these parcels would be reduced. Ponds in this region include:

Aunt Betty's	Fawcett's	Lewis
Crooked	Fresh	Mary Dunn
Duck	Fresh Hole	Upper Gate
Dunn's	Hathaway (South)	

5.4 Build-out Analysis

Changes in land use over time will have an impact on the Barnstable ponds. To estimate the amount of development possible in the town, and thereby identify ponds likely to be most affected, a build-out analysis was conducted. The analysis grouped 29 ponds into 17 areas around Barnstable, and tallied the existing and build-out quantities for residential dwelling units and commercial building square footage (**Table 9**).

[1] http://www.town.barnstable.ma.us/InformationSystems/GIS/SEWERED.PDF

Table 9. Build-out Analysis of Residential Dwelling Units and Commercial Building Square Footage, Town of Barnstable.

Pond(s)	Residential Dwelling Units			Commercial Bldg Sq Footage		
	Existing	Build-out	Change	Existing	Build-out	Change
Lovell	245	353	+108	0	0	0
Muddy, Long (MM)	138	143	+5	0	0	0
Eagle	60	61	+1	0	0	0
Mystic, Middle, Hamblin, Shubael, Little	756	823	+67	0	0	0
Mill (WB)	53	71	+18	0	0	0
Bog	82	104	+22	2,202	9,478	+7,276
Micah, Joshua	207	216	+9	316,330	316,330	0
West, Flowing	210	218	+8	0	0	0
Garrett's	132	158	+26	1,477	1,477	0
Wequaquet, Bearse, Shallow, Long (C'ville)	927	1,002	+75	22,737	31,569	+8,832
Hinckley	21	26	+5	0	0	0
Hathaway	0	23	+23	9,820	90,450	+80,630
Simmons, Ben	215	219	+4	6,728	23,073	+16,345
Fawcett's	205	239	+34	7,768	19,089	+11,321
[Number 15 on map]	0	0	0	43,192	180,657	+137,465
Mary Dunn	0	0	0	1,410	1,410	0
Israel, Lamson	0	0	0	119,114	464,441	+345,327

from draft GIS map "Town of Barnstable Freshwater Ponds Recharge Areas", August 2009

Ponds that have potential for extensive future residential development, based on this build-out analysis, are:

Lovell	Mystic-Middle-Hamblin-Shubael-Little
Fawcett	Wequaquet-Bearse-Shallow-Long (C'ville)
Garrett's	Hathaway[2]

Other ponds exhibiting potential for extensive future commercial development, based on this build-out analysis, include:

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[2] The lands around Hathaway Pond (both North and South) are predominantly owned by the Town and designated for conservation and recreation; therefore, the projected increase in development is unlikely.

Israel-Lamson	Wequaquet-Bearse-Shallow-Long (C'ville)
"Number 15"	Fawcett's
Simmons-Ben	

Given this assessment of potential for development, ponds which presently do not meet desired uses, and ponds with evidence of degradation are considered most at risk (**Table 10**).

Table 10. Water Quality Conditions of Ponds with Potential for Extensive Future Development.

Development	Water Quality and Aquatic Habitat Status		
	Meets Desired Uses	Meets Desired Uses, with Evidence of Degradation	Does Not Meet Desired Uses
Residential	Garrett's Middle	Bearse Fawcett Hamblin Little Mystic Shallow Shubael Wequaquet	Long (C'ville) Lovell's
Commercial		Bearse Fawcett Shallow Wequaquet	Long (C'ville)

Note: there were no data to categorize the water quality conditions of Israel, Lamson, "Number 15", Simmons or Ben.

5.5 Point and nonpoint sources of nutrients

There are no identified point sources of nutrients to the Barnstable Ponds; most of the nonpoint sources are direct inputs to the ponds: septic effluent, wildlife, swimmers, stormwater runoff, and shoreline erosion.

Septic effluent as a nonpoint source is the subject of investigation and debate. The extent to which phosphorus in septic effluent can reach surface waters is an issue of great importance to many communities. Research and monitoring indicates that subsurface phosphorus transport is influenced by depth to groundwater, soil texture, pH, geology, and groundwater quality, as well as by the nature of the on-site wastewater disposal systems (notably age, loading history, and maintenance).

5.6 Transport and attenuation from source to ponds

In general, phosphorus is considered relatively immobile in the subsurface environment. However, phosphorus transport through groundwater to surface waters has been documented; for example, phosphorus associated with the sewage plume from the Massachusetts Military Reservation on Cape Cod is reaching Ashumet Pond (McCobb et al 2003). Phosphorus from septic systems may reach surface waters when intervening distances and travel times are short, when the groundwater environment is reducing (anoxic), or when sites for sorption of phosphorus onto aluminum and iron oxides are already saturated with phosphorus (Portnoy et al 2001). The Ashumet Pond investigation by USGS documented that phosphorus can desorb from subsurface soils exposed to uncontaminated groundwater with low pH (McCobb et al. 2003). This implies that phosphorus from on-site systems remains a reservoir in the soil that may be slowly mobilized and transported to the ponds along with groundwater.

Controlled experiments by Cogger et al (1988) examined the movement of nutrients and bacteria from septic systems installed in the sandy soils of a coastal barrier island. They reported that phosphorus was most likely to be mobile in wet, sandy soils, and that both loading rate and water table location affected phosphorus concentrations in the groundwater surrounding the leach field. Data from this investigation were also consistent with two processes for adsorption occurring: a fast reaction and a slow reaction.

The ponds of Barnstable are situated in sandy soils, and the surrounding land areas have a variable depth to groundwater. Background pH is low, averaging 5.5 (McCobb et al. 2003). The sandy soils provide abundant iron and aluminum hydroxides for phosphorus adsorption. The reaction of soluble reactive phosphorus with sandy soil is described by two processes: a fast and reversible adsorption reaction on the surface of aluminum and iron oxides and a slow, diffusion-controlled process where the phosphorus either precipitates with aluminum or iron, or diffuses into micropores and becomes adsorbed to surfaces deep in the soil matrix (Shoumans and Breeuwsma 1997).

It appears that the soils of Barnstable have the cation exchange capacity and mineralogy to adsorb soluble phosphorus present in groundwater. However, phosphorus removal is not permanent. Under certain chemical conditions, phosphorus adsorbed to the surface aluminum and iron hydroxides may desorb and move with the groundwater towards the kettle ponds. Groundwater pH on Cape Cod is within the range where this desorption reaction will occur. Phosphorus movement from subsurface soils would be exacerbated by conditions such as high organic loading that contribute to microbial activity and de-oxygenation of the groundwater resource.

6 Summary of Findings

- **<u>Water Quality Conclusions (Eichner, 2008).</u>** The focus of the conclusions was centered on total phosphorus, chlorophyll-a, and dissolved oxygen as key data sets indicating pond health. In all cases, further data collection was recommended to refine the characterization of each pond. *Overall recommendation*: Standard best management practices to minimize stormwater runoff would help maintain/improve existing conditions.

    a. Ultra-shallow Ponds – Total phosphorus and chlorophyll-a concentrations were generally higher than threshold concentrations, while dissolved oxygen was compliant with the regulatory standards. Hathaway South and Mary Dunn Ponds are relatively pristine and undeveloped, and should be a priority for protection.

    b. Shallow Ponds – Total phosphorus and/or chlorophyll-a concentrations were excessively higher than threshold concentrations, while six of the 15 ponds exhibited dissolved oxygen concentrations in the deeper waters that were below the regulatory standards. Joshua was identified as a relatively pristine pond that should be protected.

    c. Deep Ponds - Total phosphorus and/or chlorophyll-a concentrations were higher than threshold concentrations, while eight of the 10 ponds exhibited dissolved oxygen concentrations in the deeper waters that were below the regulatory standard. None of the ponds may be considered relatively pristine, but several have only recently shown signs of water quality impairment: Micah, Middle and Neck. The alum treatment of Hamblin Pond continues to provide residual water quality benefits.

- **<u>Impacted Waters.</u>** The Barnstable Ponds are in various stages of eutrophication; many are considered "impacted waters" based on regional criteria developed from limited measurements of water quality conditions in eight pristine Cape Cod ponds. However, designated uses are generally met. The ponds are used for swimming, boating, recreational fishing and aesthetic enjoyment. While a few ponds exhibit visual degradation of water quality conditions, most are aesthetic assets and provide habitat for a diverse assemblage of aquatic plants and animals.

- **<u>Phosphorus Loading.</u>** Phosphorus is the limiting nutrient for primary production in the Barnstable Ponds, and therefore has an influence on water quality conditions and pond health.

    a. Unlike the nitrogen-limited coastal embayments, production of algae and macrophytes in inland ponds is limited by phosphorus. The ratio of nitrogen to phosphorus in ponds is likely to influence the species composition of the algal community, particularly the importance of blue-green algae.

b. Phosphorus enters the Barnstable Ponds from several sources; few (if any) of these sources are easily controlled. External sources of phosphorus include: groundwater influx; wastewater disposal (septic sewage plumes in groundwater); surface runoff; atmospheric deposition; shoreline erosion; and users of the ponds (swimmers and wildlife).

c. In deeper ponds subject to seasonal anoxia, phosphorus held in sediments can be released to the overlying waters; this internal loading can be a significant fraction of the annual supply of phosphorus available to support algal growth.

d. Kettle ponds are susceptible to phosphorus accumulation, due in part to the lack of surface outlets.

e. The watershed area of many of the Barnstable ponds includes parcels with on-site wastewater disposal systems. Installation of sewers to collect domestic wastewater before it enters the groundwater would likely reduce phosphorus loading to these ponds.

f. Build-out analysis was used to identify ponds where there is a high potential for future residential and commercial development. Such future development could increase phosphorus loading from surface runoff and groundwater seepage of sewage plumes.

7 Recommendations

Given the nature of the kettle ponds and the sources of phosphorus to the Barnstable Ponds, there are no simple answers to long-term water quality protection and improvement. Strategies fall into several categories: reducing the inputs of nutrients and sediment, altering internal cycling, increasing the output of nutrients and sediment, and/or mitigating the symptoms of eutrophication. Feasible alternatives for protection and restoration of the Barnstable Ponds are summarized in **Appendix B**. The following actions are recommended.

- **Develop town-wide strategies for water quality protection.**

  Some of these strategies would be implemented through Town Codes and regulation, while other strategies could be implemented without regulatory involvement. Storm water runoff controls would be one example of a regulatory action. Public education would be an example where regulatory involvement is not required.

- **Develop pond-specific strategies to protect and/or restore individual Barnstable Ponds.**

  Each pond has its own unique situation, based on its size and depth, the nature of the surrounding watershed, and the extent of groundwater influences. With a more detailed understanding of the individual pond through additional data collection, it will become more apparent whether actions such as alum treatment or weed harvesting are appropriate in a given pond.

- **Obtain more detailed data on priority ponds.**

  As noted above, there are very limited recent data to characterize water quality and habitat conditions of the town's ponds Additional data collection should be prioritized to ponds that are the most impaired, and that provide the greatest opportunity for public uses. Moreover, data collection should be focused on closing data gaps needed to make effective management decisions.

7.1 Priority Ponds

An assessment of the priority status of the Barnstable Ponds **(Table 11) includes** Barnstable inland ponds reviewed as part of this assignment; the list is not inclusive of all town ponds.

Table 11. Summary of existing conditions, recommended actions, and priorities for managing Barnstable Ponds

Pond	Priority (low-moderate-high-protect)	Findings (Trophic States: O, M, E, H)	Recommended Actions
Ultra-Shallow			
Aunt Betty's	Low	M; Limited public access	Education, watershed BMP
Bog	Low	M; Impacted/at risk	Education, watershed BMP
Dunn's	Moderate	E; Impacted	Education, watershed BMP
Fawcett's	Low	M; Impacted/at risk; potential for increased residential development	Education, watershed BMP; guide future development to minimize nutrient export
Hathaway (South)	Protect	O; Unimpacted	Low impact recreational use & education in protected watershed
Little Parker	High	H; Impacted; does not support desired uses	Watershed BMPs; mitigate symptoms to improve aesthetics and recreational use: hand-pulling, benthic barriers
Little/Stony	Moderate	E; Impacted/at risk	Education, watershed BMP
Lumbert	Low	M; Private; Impacted/at risk	Education, watershed BMP
Mary Dunn	Low	O; Impacted/at risk	Education, watershed BMP
Mill(MM)	Protect	O; Impacted; Conservation area	Low impact recreational use & education in protected watershed
Mill (WB)	Moderate	E; Impacted	Education, watershed BMP
Red Lily (North, South)	Low	O; Impacted/at risk; Limited public access	Education, watershed BMP
Shallow			
Bearse	Moderate	M; Impacted/at risk; fanwort; potential for increased residential development	Macrophyte survey, strategies to control exotics; consider reducing density of future development

Pond	Priority (low-moderate-high-protect)	Findings (Trophic States: O, M, E, H)	Recommended Actions
Coleman	Low	M; Impacted	Mitigate symptoms of eutrophication in recreational areas (benthic mats, hand harvesting); watershed BMPs
Eagle	Protect	E; At risk; watershed in land trust	Consider hand pulling emergent vegetation to improve shoreline access; maintain trails and prevent erosion
Elizabeth	Moderate	E; Impacted; Limited public access	BMPs, control stormwater on roadways
Garrett's	Low	O; At risk; limited public access	Education, watershed BMPs
Hinckley	High	E; Impacted	Stormwater management, septic inspections
Joshua	High	O; At risk; Town beach, natural vegetation; reference pond indicative of pristine conditions	Priority for protection, education, BMPs
Long (C'Ville)	High	E; Impacted; Town beach, highly developed; Does not support desired uses	Stormwater management, septic inspections, mitigating measures to improve recreational use: benthic mats, hand-pulling
Long (MM)	Moderate	E; Impacted; Conservation area; moderately protected	Education, watershed BMPs
Muddy	Moderate	E; Impacted/at risk	Education, watershed BMPs
No Bottom	Low	M; Impacted	Education, watershed BMPs
Parker	Moderate	E; Impacted	Education, watershed BMPs
Round (MM)	Moderate	E; Impacted/at risk; Private	Education, watershed BMPs
Schoolhouse	High	H; Impacted; does not support desired uses	

Pond	Priority (low-moderate-high-protect)	Findings (Trophic States: O, M, E, H)	Recommended Actions
Shallow	Moderate	M; Impacted/at risk; vegetated shoreline; potential for increased residential development	Controls on future density and/or BMPs to minimize phosphorus migration to pond from surface runoff and groundwater
Deep			
Crystal	Low	M; Impacted	Education, watershed BMPs
Hamblin	High	O; At risk; Town Beach, conservation land; alum-treated; potential for increased residential development	Monitor for effectiveness of alum treatment; controls on future density and/or BMPs to minimize phosphorus migration to pond from surface runoff and groundwater
Hathaway (North)	High	O; At risk; Town beach, mix of conservation land and development	Continue acquisition of hydrologically important parcels in watershed
Lovell's	High	M; Impacted; Town beach closed; blue-green algal bloom; does not support desired uses	Priority for monitoring deep water phosphorus levels and N/P ratio; consider nutrient inactivation
Micah	Protect	O; At risk; Undeveloped, reference pond	Priority for monitoring deep water phosphorus levels
Middle	Protect	O; At risk; Public access, very clear	Priority for monitoring deep water phosphorus levels; consider acquisition of key parcels to control density
Mystic	High	M; Impacted/at risk; Public access, endangered mussels; permit phase for alum application; potential for increased residential development	Priority for alum treatment program; guide future development to minimize surface runoff and groundwater nutrient input

Pond	Priority (low-moderate-high-protect)	Findings (Trophic States: O, M, E, H)	Recommended Actions
Neck	Moderate	O; Impacted/at risk;	Period monitoring to detect symptoms of degradation; watershed BMPs;
Shubael	High	O; Impacted; Town beach, exceptionally clear water potential for increased residential development	Priority for monitoring deep water phosphorus levels; septic inspections; guide future development to minimize nutrient input from surface runoff and groundwater seepage
Wequaquet	High	M; Impacted; Town beach, potential for future residential and commercial growth	Priority for monitoring deep water phosphorus levels; septic inspection; consider density controls on future development

Trophic states: O – Oligotrophic; M – Mesotrophic; E – Eutrophic; H -Hypereutrophic
Higher priority assigned to ponds with town beach and/or public access
BMP- Best Management Practices

7.2 Protection Measures

The following are measures that may be taken to protect the Barnstable Ponds from further degradation in water quality and habitat conditions. These measures are typically implemented in the watershed surrounding the ponds, rather than within the pond itself. These protection measures may be applied to all the ponds, though more information regarding existing 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.

- Septic discharge. Regulatory programs for septic systems existing in similar environments to the Cape Cod area show a variety of setback requirements, as summarized in **Appendix C**. In addition to setbacks, there are alternative technologies, some of which show excellent phosphorus removal capabilities. The Massachusetts Alternative Septic Systems Test Center and the Barnstable County Department of Health are an informational resource. For a listing of current MADEP approved alternative systems, refer to the web site http://www.mass.gov/dep/water/wastewater/techsum.htm

- 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. Pursue and acquire open space, while incorporating resource-based priorities into decisions. Place a high priority for acquisition of properties in riparian areas.

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

- Other structural measures. Implement wastewater collection to reduce phosphorus loading via septic systems. Install public toilet facilities for beach areas, and keep them cleaned and maintained to encourage use.

- Inspection and Monitoring. Inspection and maintenance of onsite septic systems. Routine participation in volunteer (PALS) water quality monitoring program. Additional monitoring suggestions are summarized in **Appendix D**.

7.3 Restoration Options

The following are measures that may be taken to restore the impacted Barnstable Ponds. These measures would be implemented as needed on a pond-by-pond basis. Additional data from the impacted ponds is required before selecting an appropriate restoration option.

- Alum treatment to seal bottom sediments. Alum application to seal bottom sediments and prevent phosphorus release. This treatment option is applicable to deep ponds that develop stable thermal stratification, and where internal (sediment) phosphorus release is a significant component of the annual TP budget.

- Mixing. Use aerators or mixers to keep the water column oxygenated and accelerate the rate of decomposition of organic material.

- Benthic barriers. To prevent the excessive growth of vegetation, a symptom of eutrophication. This technique may be applicable to limited areas to restore recreational use.

- Mechanical or hand removal of weeds. To eliminate invasive species and reduce the excessive growth of aquatic plants that impairs desired uses of the pond.

- Water level management (drawdown) to control aquatic plants.

8 Priority Actions Recommended for the Town of Barnstable for 2010-2011

Convene a public educational forum to discuss current water quality and habitat conditions of the ponds of Barnstable. Solicit public input on the desired future for the ponds (overall and for individual ponds). Major topics include:

- The eutrophication process
- The unique nature of the kettle ponds in nutrient cycling
- How conditions have changed in recent decades
- Alternatives for protection and restoration
- Why each pond requires a different strategy (no action, protection, active intervention) based on its physical characteristics, current conditions, and desired use
- The costs and benefits associated with alternatives
- How overall wastewater and facilities decisions may affect the ponds

Initiate a focused monitoring program to evaluate use attainment, confirm priorities for intervention, and assess the effectiveness of control measures.

The recommended monitoring plan is included as Appendix D.

Prepare an annual Pond Report Card to enhance public understanding of water quality conditions and contributing factors.

Consider a local law requiring periodic inspection and pump out of individual on-site wastewater treatment systems. The frequency can be linked to distance to ponds, with more stringent requirements within a defined buffer zone.

Review local erosion and sedimentation control laws and determine if they could be improved to prevent sediment loss to the ponds. If warranted, propose revisions for approval.

Convene technical committee (or engage a consultant) to initiate detailed planning and cost estimating, identify funding sources, secure non-local funding as available, and acquire permits for alum application to ponds as identified by the Town based on new data.

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10 Appendices

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Appendix B. Summary of Pond Management Alternatives

Appendix C. Summary of Regulatory Setbacks and Recommendations for Septic Systems in Coastal Areas

Appendix D. Recommended Water Quality Monitoring Program

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Pond	Surface Area (acres)	Delineated Watershed[1] (Y/N)	Physical Characteristics[2]				
			Access/ Use[3]	Water clarity and color	Shoreline	Macrophytes	Comments
<u>Ultra-shallow Ponds - depths between 0.5 and 1.2 m</u>							
Aunt Bettys	7.1	N	VL		Buildings encroach, most of shoreline remains undisturbed	Submerged and yellow lilies	Very limited public access and recreational use
Fawcetts	11.9	Y	na	na	na	na	na
Lumbert	9.7	Y	Pv	Brown-tannin	Fully vegetated (from vantage point of survey)	More surface growth	Roadway pulloff Private
Mary Dunn	18	Y	na	na	na	na	na
Mill (Marston Mills)	6.0	N		Clear	Natural	Emergents	Roadway historical marker; impoundment. Conservation area.
Mill (West Barnstable)	16.7	N	na	na	na	na	na
Red Lily	4.5	N	VL		Vegetation mostly intact; few large homes	Extensive lilies	Connected to Elizabeth (to the south)

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Pond	Surface Area (acres)	Delineated Watershed[1] (Y/N)	Physical Characteristics[2]				
			Access/ Use[3]	Water clarity and color	Shoreline	Macrophytes	Comments
Shallow Ponds: depths between 2.1 and 8.6 m							
Bearse	66.8	Y	Pm (2003)	2.3m Secchi (2003)	Residential development (2003)	Treated to limit growth of fanwort (2003)	Connected to Wequaquet High TP and chlorophyll suggest productive algal population (2003)
Eagle	8.5	Y	CA	Clear	Intact. Undeveloped	Pink water lilies, black benthic mat	Walking trails, full-land trust (Mary Barton Land Trust) "relatively clean, largely unimpacted lake" (2003)
Elizabeth	6.3	N	VL			Extensive lilies	Connected to Red Lily (to the north)
Garretts	27.9	N	Pm	Tannins	Some development, few cleared lawns	Yellow lilies	"relatively clean lake with uncertain deep water quality concerns" (2003)
Hinckley	10.3	N	na	na	na	na	na
Joshua	14.7	Y	TB	Clear water; brown benthic layer	Completely natural vegetation		town beach and bath house "relatively clean, largely unimpacted lake" (2003)

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Pond	Surface Area (acres)	Delineated Watershed[1] (Y/N)	Physical Characteristics[2]				
			Access/ Use[3]	Water clarity and color	Shoreline	Macrophytes	Comments
Shallow Ponds: (continued)							
Long (Centerville)	51.0	Y	WTW; Limited	Clear	Highly developed, lots of clearing	Not evident (Sonar treatment)	Hydrilla, restricted access to reduce spread of this invasive Town Beach (2003) "impacted with water quality problems" (2003)
Long (Marstons Mills)	54.8	Y	CA	Clear	Mostly intact, some developed shoreline. Moderately protected	None evident	LI conservation area "impacted with water quality concerns" (2003)
Muddy	24.6	Y	None	--	--	--	Sand pile along shoreline
Parker	10.9	Y	na	na	na	na	na
Round (Marston Mills)	9.8	N	WTW	Clear	Vegetation present	Benthic algal mat, emergents (cattails)	Private. Good setbacks in riparian zone.
Shallow	78.4	Y	na	Clear	Shoreline mostly vegetated. Developed	Sandy bottom	Benthic detrital/ algal mat

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Pond	Surface Area (acres)	Delineated Watershed[1] (Y/N)	Physical Characteristics[2]				
			Access/ Use[3]	Water clarity and color	Shoreline	Macrophytes	Comments
Deep Ponds: depths between 9.3 and 17.3 m							
Crystal	10.1	N	na	na	na	na	na
Hamblin (Indian Ponds)	115.4	Y	Yes	Very clear	Mostly intact, some cleared lawns. (2009) Beach conservation land (2003)	Emergent (fringe) Cranberry bog (2003)	Bath house, swimming, kayak access. 1995 alum treatment; 10hp motor limit. (2009) “clearly impacted” (2003)
Hathaway (North)	20.9	N	TB	Very clear	Extensive, overhanging vegetation. Development surrounds pond. (2009) Town-owned conservation land (2003)	sandy bottom; some benthic macroalgae	Town beach, bath house, swimming area. Stocked with fish (smallmouth and largemouth bass, perch, pickerel, and sunfish). (2009) “relatively clean, largely unimpacted lake” (2003)
Lovells	55.5	Y	TB	Evidence blue-green algal bloom	Mostly intact; some cleared lawns	Sandy bottom, little vegetation visible	Town beach (closed on 7/30/09 due to algal bloom) and bath house; “impacted with water quality concerns” (2003)

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Pond	Surface Area (acres)	Delineated Watershed[1] (Y/N)	Physical Characteristics[2]				
			Access/ Use[3]	Water clarity and color	Shoreline	Macrophytes	Comments
Deep Ponds: (continued)							
Micah	16.0	Y	CA (2003)	--	Undeveloped public land (2003)	--	Selected as one of 8 reference ponds for Cape Cod during development of Cape Cod thresholds; "relatively clean, largely unimpacted" (2003)
Middle (Indian Ponds)	104.6	Y	Yes	Very clear		Minimal	Boating
Mystic (Indian Ponds)	148.4	Y	Yes	Clear	Mostly intact, more lawns than other ponds in the Indian Ponds group.	Pondweed	Public access, swimming and boating. Permit phase, alum. Endangered mussels.
Neck	13.6	N	na	na	na	na	na
Shubael	55.1	Y	TB	Exceptionally clear	Some Phragmites and cattails.	Sandy bottom, minimal benthic algal	Beaches, small boats. Horse farm (2009) Well-developed, stocked with fish; "impacted with water quality concerns" (2003)

Appendix A. Summary of Physical Characteristics: Barnstable Ponds

Pond	Surface Area (acres)	Delineated Watershed[1] (Y/N)	Physical Characteristics[2]				
			Access/ Use[3]	Water clarity and color	Shoreline	Macrophytes	Comments
Deep Ponds: (continued)							
Wequaquet	596.3	Y	TB		Densely developed (2003)		Bath house, beach, sailing, boat launch (2009) "relatively clean but impacted" (2003)
No depth information							
Lamson	12.3	Y	na	na	na	na	na
West	10.1	Y	na	na	na	na	na

[1]Delineated watershed based on information provided in Eichner, 2008.

[2]Physical characteristics are primarily from the 2009 field visual assessment conducted by EcoLogic, unless noted by "(2003)" to indicate the information was obtained from the CCC Lakes and Ponds Atlas published in May, 2003.

[3]CA – Conservation Area; Pm – Permission granted for public access; Pv – Private access; TB – Town Beach; VL – very limited access and/or recreational use; na – no information available; WTW – Way to Water posted.

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 1: Control Inputs from Watershed

	Option 1 – Wastewater Collection	Option 2 – Modifications to on-site wastewater disposal systems	Option 3 – Inspect/Maintain on-site wastewater disposal systems
Method	Reduce phosphorus from on-site wastewater disposal systems by centralized collection and disposal outside of watershed zone of influence	Various engineering alternatives to enhance removal of nitrogen, BOD, solids, and phosphorus (in various combinations) from domestic wastewater	Reduce phosphorus from on-site wastewater disposal systems by requiring frequent inspections and maintenance of systems
How does it work?	Collection system and treatment/disposal	Alternatives to conventional on-site wastewater disposal systems	Modification to local laws
Potential Benefits	Decreased loading of all wastewater contaminants, including pathogens	Decreased loading of nutrients and organic material to subsurface	Decreased loading of all wastewater contaminants, including pathogens
Potential Drawbacks	Could increase development pressure	More complex systems, more maintenance.	Public acceptance needs to be very high
Data gaps to make decision	Integrated with rest of wastewater decisions. Existing data do not define extent of problem	Existing data do not define extent of problem	Existing data do not define extent of problem
Costs (Relative)	High (likely to receive some public funds)	Moderate (may receive approval to install as a pilot system)	Low (borne by homeowners)
Permitting issues	Collection system will have environmental impact. Need to identify acceptable site for disposal to groundwater. Conservation Commission approval needed.	Massachusetts Alternative Septic System test center is in Sandwich, on Otis Air National Guard base. This is a cooperative program of the state, Barnstable County and SMAST	Dept. of Health & Conservation Commission approvals
Longevity	High	Moderate	Moderate
Ponds appropriate for this alternative	Ponds with high number of on-site systems. Insufficient data.	Impaired ponds with >20 residences. Non-impaired ponds, at least 15 residences. Based on water quality.	All ponds

*Source for cost estimates: *Holdren et al. 2001; **NYSFOLA, 2009*

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 1: Control Inputs from Watershed (continued)

	Option 4 – Infiltration Basins	**Option 5 – Public Education**	**Option 6 – Wildlife Control**
Method	Water quality inlets to stormwater infiltration basins	Public education and outreach	Discourage high populations of wildlife (especially gulls, geese) from spending long periods of time in ponds.
How does it work?	Stormwater collection and treatment prior to groundwater discharge	Educate public on importance of landscaping, erosion controls, beach sanitation	By using scare techniques to scare away birds, attain reduction of nutrient deposition from birds
Potential Benefits	Reduced loading	Reduced loading. Increase public awareness of ponds and their vulnerability	Reduced loading of nutrients and bacteria
Potential Drawbacks	Most systems designed to capture sediment. Higher maintenance	None	Scare tactics can be disruptive to human community.
Data gaps to make decision	No estimate of the contribution of soluble P from stormwater	None	Estimate maximum number of gulls, use research reported in Portnoy (1990)
Costs (Relative)	Low	Low	Low
Permitting issues	Requires siting, Conservation Commission approval needed.	None	Needs approvals from Fish and Wildlife, MADEP. Conservation Commission approval needed.
Longevity	Moderate	Moderate (prevention of incremental source likely to be a small source)	Likely to be effective only while active measures are taken, although birds may move to other areas
Ponds appropriate for this alternative	All, especially those with developed watersheds and evidence of sediment deposition from runoff. Insufficient data.	All	Insufficient data.

*Source for cost estimates: *Holdren et al. 2001; **NYSFOLA, 2009*

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 2: Alter Internal Cycling of Nutrients in Pond

	Option 1 – Alum Application	Option 2 – Sediment Oxidation	Option 3 - Circulation
Method	Alum application to remove phosphorus from water column	Sediment oxidation	Artificial circulation.
How does it work?	Alum hydrolyzes in water, forming a floc. As the floc settles it removes particulate material as well as any dissolved P. If applied properly, forms a barrier on sediment surface that continues to trap P.	Procedure injects calcium nitrate into top 10" sediment to break down organics and promote denitrification, and injecting ferric chloride to bind available phosphorus released from sediments.	Compressed air is injected into the lower waters. Eliminates thermal stratification. Oxygenates lower waters, more oxygen available to break down organic material.
Potential Benefits	Long history of use. Does not seem to affect other aquatic organisms. May create layer over sediments retarding future sediment P release. Long-term results. Readily available.	If successful will greatly reduce internal P loading from sediments	Reduces surface algal blooms, improved habitat for aquatic biota, may retard sediment P release
Potential Drawbacks	Low pH ponds, need buffering (sodium aluminate). Potential for aluminum toxicity if pH declines. Loss of benthic organisms.	Optimal pH of sediments 7 – 7.5; would require liming. Considered an experimental technique.	Results may be subtle. Requires energy source to power. May increase algal production throughout water column.
Data gaps to make decision	Sediment testing to estimate optimal dose	Sediment testing to calculate dose	DO profiles over growing season, history
Costs (Relative)	Can be high, application rate estimated at $70 per 40-lbs.(40 lbs. treats 1 acre-ft) * High initial cost - $100-$500 per acre.**	Can be high, $8,000 – $12,000 per acre *	Approximately $150/acre**. Variable, depending on power source. Solar-powered mixing devices: $25,000.
Permitting issues	Requires permit, testing for optimal dose. Conservation Commission approval needed.	Requires permit, testing for optimal dose. Conservation Commission approval needed.	Conservation Commission approval needed.
Longevity	Moderate (at least several years)	Moderate (at least several years)	Only effective when mixers working
Ponds appropriate for this alternative	Deeper ponds with elevated TP in lower waters. Insufficient data.	Impaired ponds with DO depletion. Insufficient data.	Insufficient data.

*Source for cost estimates: *Holdren et al. 2001; **NYSFOLA, 2009*

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 2: Alter Internal Cycling of Nutrients in Pond (continued)

	Option 4 - Dredging	Option 5 – Pond Drawdown
Method	Dredging	Drawdown of pond water level to expose sediments
How does it work?	Sediment is physically removed, also removing accumulated nutrients and organic material	Lowering water level will dry sediments and allow sediments to oxidize and compact.
Potential Benefits	Reduced internal nutrient supply, increases water depth, can reduce sediment oxygen demand	May alter nutrient availability for the better. Opportunity for shoreline cleanup. Nuisance plant species may die back.
Potential Drawbacks	Expensive if disposal site not nearby. Temporary turbidity, removes macroinvertebrates, temporarily interferes with recreation. Might reduce ponds' natural capacity for denitrification and thus allow more soluble nitrogen to make its way to coastal embayments.	Possible impacts on contiguous wetlands, may change habitat for amphibians. Desirable species of plants may die. Ponds with water level controls may be managed for herring. Temporary loss of waterfowl habitat. Potential to create highly unappealing aesthetic conditions for neighbors.
Data gaps to make decision	Quality of sediments affects disposal options and costs (e.g. hazardous waste). Detailed bathymetry required to estimate volumes and costs.	Water level control needed, therefore not feasible for most kettle ponds which lack such controls
Costs (Relative)	$15,000 - $50,000/acre*, depending on transportation needs to remove dredge spoils from site.	<$100/acre if structures adequate*
Permitting issues	Requires permit for dredging and disposal Conservation Commission approval needed.	Permit required, complexity depends on impacts on wetland and other ponds. Conservation Commission approval needed.
Longevity	Moderate to long-term	Moderate to long-term
Ponds appropriate for this alternative	Insufficient data.	Insufficient data.

*Sources for cost estimates: *Holdren et al. 2001; ** NYSFOLA, 2009*

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 3: Mitigate Symptoms of Eutrophication - Weeds and Algae

	Option 1 – Mechanical Harvesting of Weeds	Option 2 – Mechanical Weed Removal	Option 3 – Hand-Harvesting Weeds
Method	Mechanical harvesting of weeds	Mechanical removal of weeds, by rotovating (rototilling) or hydroraking.	Removal of plants by hand.
How does it work?	Upper part of plants cut in place, deeper waters; roots are not harvested. Cuttings collected and removed from pond.	Removes rooted aquatic plants from targeted areas by means of large cutters that dislodge roots and plants from sediment.	Removes rooted aquatic plants from targeted areas, using human labor.
Potential Benefits	Immediate results. Improved recreational access. Remaining lower part of plants continues to provide habitat.	More effective than mechanical harvesting, as the roots as well as plants are removed.	Effective rapid-response to invasive species. Selective plant management.
Potential Drawbacks	Non-selective, may alter plant communities, may remove native insects that help control plants.	Creates turbidity, disturbs the sediment, may spread some plants by fragmentation. Not selective; cuts all plants.	Labor intensive, restricted to small areas. May spread some plants by fragmentation.
Data gaps to make decision	Species and habitat affected, water depth. Equipment access, disposal.	Useful for shallower areas where recreational access is limited by weeds	Useful for small areas where recreational access is limited by weeds
Costs (Relative)	Leasing a harvester, $600-$2,400/acre**, depending on size of harvester.	Hydroraking or rotavation services $1,000** to $2,000* per acre	$100/acre* up to $1,000/acre**
Permitting issues	Minor, need to develop plan for harvesting and upland disposal sites. Conservation Commission approval needed.	Turbidity, avoidance of critical habitat areas and spawning/early life stages of fish community Conservation Commission approval needed.	Minimal; Conservation Commission approval needed.
Longevity	Two or more harvests during the recreational season.	Usually needs to be repeated several times year	Usually needs to be repeated once or twice a year
Ponds appropriate for this alternative	Insufficient data.	Insufficient data.	Areas where homeowners' access is diminishing. Insufficient data.

Source for cost estimates: *Holdren et al. 2001 ; ** NYSFOLA, 2009

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 3: Mitigate Symptoms of Eutrophication - Weeds and Algae (continued)

	Option 4 – Benthic Barriers	Option 5 – Chemical Control Algae	Option 6 – Aquatic Herbicides
Method	Benthic barriers, benthic screens	Chemical control of algae (several copper-based and organic compounds approved for this use)	Chemical control of weeds (Diquat, 2,4-D, Endothol, Glyphosate, Fluridone, Trichlopyr, copper-based herbicides)
How does it work?	Mat of variable composition laid on bottom of target areas. Blocks light and restricts space for plant growth.	Algaecides kill algae by direct toxicity or by metabolic interference	Toxins in contact with or taken up by plant; biochemical pathways disrupted. Ultimately results in plant senescence and death.
Potential Benefits	Used effectively in a variety of lake conditions; can be sited by homeowners.	Rapidly eliminates algae from water column	Reduces density of macrophytes in treated areas.
Potential Drawbacks	Cumbersome to place and anchor. Require maintenance.	Toxic to other organisms; decaying algae may release nutrients, increase oxygen demand. May restrict water uses.	Toxic to other organisms; decaying plants may release nutrients, increase oxygen demand. May restrict water uses.
Data gaps to make decision	Useful for areas where recreational access is limited by weeds	Water pH, alkalinity, background concentrations of metals; sediment quality (AVS and TOC)	Detailed species inventories needed to select most appropriate chemicals
Costs (Relative)	Professional installation $20,000/acre**	Depends on compound: Chelated copper $150 – 300/acre per application*. Copper sulfate $5-$25/acre-foot**.	$200 to $1,500 per acre** Some treatments may need to be repeated. Cost vary with chemical, dose rate, etc.
Permitting issues	Minimal, need to avoid critical habitat Conservation Commission approval needed.	Requires permit and approvals from environmental and public health agencies, including Conservation Commission.	Requires permit and approvals from environmental and public health agencies, including. Conservation Commission
Longevity	Need to be replaced every 1 – 2 years	Short-term (weeks to months)	Annual
Ponds appropriate for this alternative	Areas where homeowners' access is diminishing. Insufficient data..	Insufficient data.	Insufficient data.

Source for cost estimates: *Holdren et al. 2001; **NYSFOLA, 2009

Appendix B. Summary of Pond Management Alternatives

Appendix B - Category 3: Mitigate Symptoms of Eutrophication - Weeds and Algae (continued)

	Option 7 – Biomanipulation	**Option 8 – Barley straw**
Method	Stocking or removing specific organisms to shift ecological conditions to improve lake for desired uses ("top-down" approach)	Dried barley straw
How does it work?	Stocking fish that eat plankton-eating fish to reduce predation on zooplankton. As a result, zooplankton species increase in size and abundance and feed on more algae, thus controlling algae populations and improving water clarity. Removing bottom-feeding fish that cause turbidity and increase nutrient concentrations by disturbing and consuming organic material at the bottom of the lake.	Dried barley straw, loosely netted to allow maximum oxygen exchange within the straw. Anchored floats hold the netted straw in place in the upper three to four feet of water. Not clearly understood how barley straw affects algae.
Potential Benefits	Serves to achieve multiple water quality objectives while increasing the population of desirable fish species.	Reduces algae levels in ponds and lakes, most effective in controlling new algae growth than at removing pre-existing algae. Public perception that it is "natural" method.
Potential Drawbacks	Results are not easily predictable. May cause unexpected side effects. May control palatable algae and leave blue-green algae.	Not practical for ponds greater than 100 acres. Inconsistent track record. Removing water-logged bales (150 lbs) labor-intensive.
Data gaps to make decision	Experimental procedure. Detailed food web analysis to evaluate appropriateness of using this method to achieve water quality objectives.	Experimental procedure. Water temperatures and temporal patterns of algal blooms during the growing season to optimize deployment of the bales..
Costs (Relative)	$100-$200 per hundred fish. Estimate 100 to 1,000 fish/acre**	Ranges from $20 to $400 per acre, depending on the cost and quantity of straw required.
Permitting issues	Class 2 public stocking license. Conservation Commission approval needed.	Uncertain
Longevity	Depends on whether stocked fish survive and reproduce.	30 to 90 days (based on rate of decomposition of bales)
Ponds appropriate for this alternative	Insufficient data.	Insufficient data.

Source for cost estimates: *Holdren et al. 2001; **NYSFOLA, 2009

Appendix C. Summary of Regulatory Setbacks and Recommendations for Septic Systems in Coastal Areas.

Buzzards Bay Watershed Management Plan	• Recommends 250 ft setback from surface waters and wetlands, (viral pollution) • Where this setback cannot be met, changes in system design and application rate are required to ensure removal of viruses.
New Hampshire's Shoreland Protection Act [3.10 Leach Field And Septic Tank Setback (Added 1990, Amended 1992)]	• "Where the naturally occurring receiving soil down-gradient of the leaching portions of a septic system is a porous sand and gravel material with a percolation rate faster than two (2) minutes per inch, the setback shall be at least 125 feet. • For naturally occurring receiving soils with restrictive layers within 18 inches of the surface, the setback shall be at least 100 feet; and • For naturally occurring receiving soils with any other characteristics the setback shall be at least 75 feet.."
CAMA Handbook For Development In Coastal North Carolina: Section 3	• Septic tanks and drainfields must be located at least 100 feet from waters classified as WS IV by the Environmental Management Commission. • No sewers, septic tank fields or other sources of pollution may be built within 500 feet of the edge of the Fresh Pond in the Nags Head/Kill Devil Hills Fresh Pond watershed. Between 500 feet and 1,200 feet from the pond, septic systems are limited to one system serving a single-family home with no more than four bedrooms (or an equivalent volume of sewage) on a tract of land at least 40,000 square feet in size.
Rhode Island towns:	
Burrillville:	200 ft from wetlands
Charlestown:	• 100 feet from a freshwater or coastal wetland. • 200 feet from a ten-foot-wide flowing body of water. • 100 feet from flowing bodies of water less than 10 feet wide. • 100 feet from intermittent streams. • 100 feet from floodplains.
Foster:	200 ft from any pond, stream, spring or brook
Glocester:	150 ft from ponds, streams or springs
Jamestown:	150 ft from any freshwater
Narrangasett:	Special use permits for septic systems within 150 ft. of coastal and freshwater wetlands.

Appendix C. Summary of Regulatory Setbacks and Recommendations for Septic Systems in Coastal Areas. (continued)

Rhode Island towns (continued):

New Shoreham:	• 150 feet of vegetated buffer shall be maintained from any septic system to a freshwater wetland or coastal feature. • 200 feet of vegetated buffer shall be maintained from any septic system to Sands Pond, Peckham Pond and Fresh Pond.
Scituate:	150 ft from surface waters
South Kingstown:	Requires special use permits for all septic systems located: • Within 50 feet of a bog, marsh, swamp or pond. • Within 200 feet of flowing bodies of water 10 feet or more in width. • Within 100 feet of flowing bodies of water less than 10 feet in width. • Within 150 feet of floodplains. • Within 150 feet of other freshwater wetlands
Warren:	150 ft from any body of water, including wetlands
West Greenwich:	200 ft from edge of any pond or stream

Appendix D. Recommended Water Quality Monitoring Program

As described in Eichner et al (2008), there is currently no on-going water quality monitoring program to track the condition of Barnstable's inland kettle ponds. Monitoring can be a costly and time-consuming endeavor; therefore, we recommend a focused monitoring program clearly linked to specific management objectives. This focused monitoring program will provide strategic information regarding the water quality and ecological status of the Barnstable freshwater ponds. Measuring various physical, chemical, and biological attributes of the inland ponds can help municipal leaders and other stakeholders evaluate use attainment, trends and the effectiveness of control measures.

- *Recommended Action: Conduct water quality monitoring using the established PALS protocol on a three-year rotation*

Objective: Develop a program to sample priority ponds on a three-year cycle. This will enable comparisons between ponds and within ponds over time.

- *Recommended Action: Measure water quality conditions in the upper and lower waters of Lovells, Wequaquet and Mystic Ponds from April – October, 2010*

Objective: Evaluate the magnitude and importance of sediment TP flux in deep ponds affected by increased productivity.

Rationale: Internal sediment TP can be remediated for a period of a decade or more with an alum treatment program. For this treatment to be effective, internal TP flux during summer anoxia must be a significant fraction of the TP budget. Moreover, TP released from sediment must reach the upper, sunlit waters where algal production occurs.

Parameter list:

Parameter	Depth	Frequency	Note
TP, TN, total alkalinity	3 m intervals through water column	Monthly (minimum) Biweekly(recommended)	Discrete samples
DO, temperature, pH, specific conductance	1 m intervals through water column	Monthly (minimum) Biweekly(recommended)	Field meter
Secchi disk transparency	From surface	Biweekly	Volunteer monitoring possibility
Chlorophyll-*a*	Composite sample through photic zone	Monthly (minimum) Biweekly(recommended)	

Recommended Action (2): Develop a surveillance program for cyanobacterial blooms

Objective: Adopt a reliable near-real time technique for evaluating whether the public is at risk from harmful algal blooms.

Rationale: Certain species of cyanobacteria (blue-green algae) can exude potentially harmful compounds. Restrictions on swimming during bloom conditions may be warranted to protect public health. Sampling and analysis of the algal community can be costly if in-house expertise is not available, and may extend over several days before results are received and interpreted. A field meter to screen for the presence and concentration of phycocyanin, a pigment associated with cyanobacterial blooms, may provide a screening tool.