Section 5
Assessment of Freshwater Ponds

5.1 Introduction

This section describes assessments conducted both as part of this CWMP and by others over the last several years to evaluate the health of freshwater ponds in Harwich. The section concludes with recommendations for enhanced watershed management and further evaluation of specific ponds.

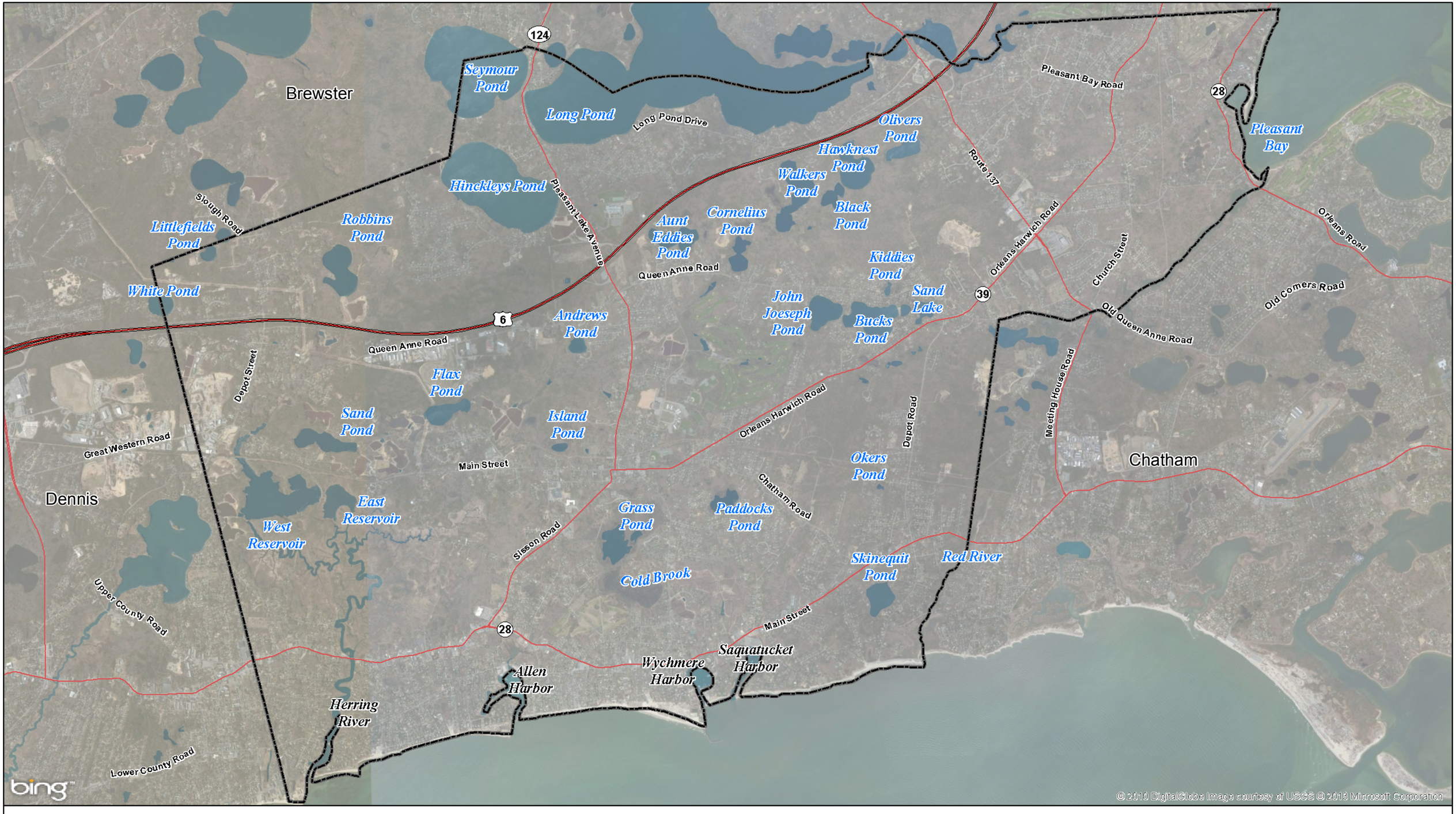
5.2 Pond Health Assessment

The Town of Harwich has approximately 22 ponds with a total area of several hundred acres. The Cape Cod Pond and Lake Stewardship (PALS) program has consistently sampled up to seventeen locations annually in sixteen of Harwich's ponds, typically in July, August, and/or September. Data from the PALS sampling program for 2006-2010 were reviewed for the analysis contained in this section. Discrete data for Long Pond and Seymour Pond were not provided for this assessment, but discussion regarding these ponds is included because they are partially within the town boundary of Harwich. Ponds with three years or more of sampling data are listed in Table 5-1. Figures 5-1 and 5-2 present several of the larger ponds in Harwich and show which ponds are impaired, high quality , or require additional data.

Table 5-1
Harwich Ponds Sampled by the PALS Program

Name	**Area** (Acres)	**Max Depth** (feet)	**PALS Sampling Years for Data Provided**
Andrews Pond	6.7	27	2006-2008
Aunt Edies Pond	22	7	2006-2010
Bucks Pond	34.3	30	2006-2010
Cornelius Pond	12.5	7	2006-2008
Flax Pond	17.3	20	2006-2010
Grass Pond	20.4	3	2007-2010
Hawksnest Pond	27.3	26	2006-2010
Hinckleys Pond	174.2	26	2006-2010
John Joseph Pond	21.8	55	2006-2010
Long Pond	734.7	66	*
Robbins Pond	33.1	12	2006-2010
Sand Pond	23	20	2006-2010
Seymour Pond	181.9	38	*
Skinequit Pond	18	32	2006-2010
Walkers Pond	35.6	26	2006-2010
White Pond	12.1	20	2006-2009

Note: (*) Data not provided



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Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 3,000 feet

0 1,500 3,000 6,000 Feet

Figure 5-1
Harwich Ponds

CDM Smith

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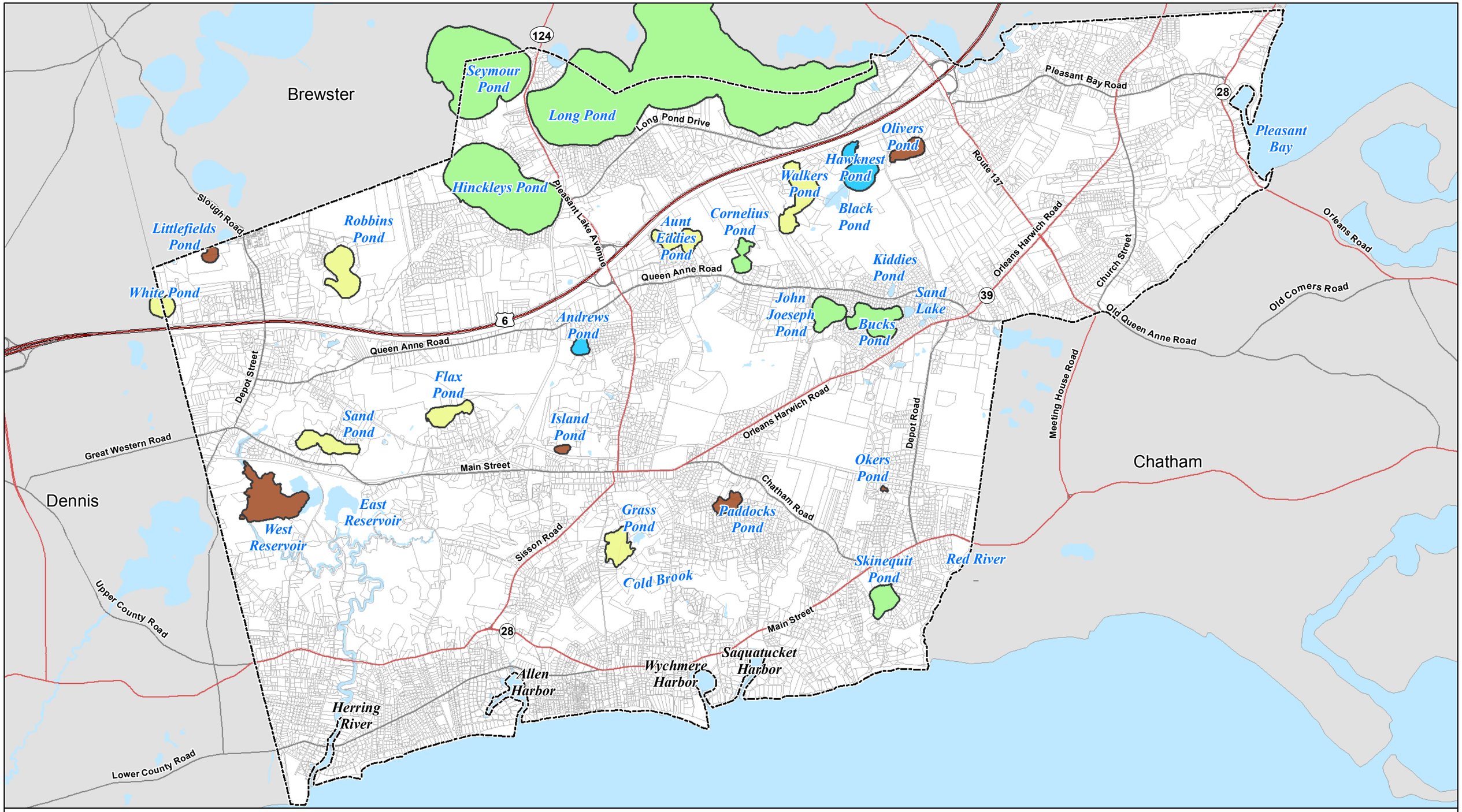

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Legend

- Additional Data Required
- High Quality Pond
- Pond With Some Water Quality Impairment
- Impaired Pond Water Quality

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 3,000 feet

0 1,500 3,000 6,000 Feet

Figure 5-2
Impairment Status of
Fresh Water Ponds in Harwich

CDM Smith

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Data from the PALS program and previous water quality analyses have been reviewed to prepare an overall assessment of pond health. This assessment can be used to suggest if construction of a wastewater collection network in the vicinity of the ponds might improve pond health. As discussed below, data on pond water quality alone may not be sufficient to determine if sewering of properties near a pond will improve pond health. This is because wastewater is only one source of phosphorus, typically the limiting nutrient in freshwater ponds. Other potentially significant sources include runoff from impervious surfaces, excess fertilizer application, runoff from cranberry bogs, birds and other wildlife, and regeneration of phosphorus from the bottom sediments of ponds.

Thus, in this section, we consider available water quality data along with the degree of development near the pond to suggest if actions are needed to improve pond health. In general, actions are either watershed-based measures to address external sources of phosphorus, or in-lake measures to address internal loading (from sediment regeneration). It is important to understand the relative magnitude of internal versus external loads because action taken to address one may not successfully improve pond health if it is not the dominant load to a pond. In some instances it could be necessary to take both watershed and in-lake actions.

5.2.1 Water Quality in Kettle Ponds

The ponds in Harwich are primarily kettle ponds, formed as depressions left by ice blocks following the retreat of the glaciers. In their original state, the ponds on Cape Cod are naturally clear and acidic due to few sources of nutrients and soils of granitic origin. The pond water surface is often a reflection of the groundwater table.

The typical physical setting of the ponds on Cape Cod aids both to protect and threaten their water quality. The protection is offered by the relatively high permeability soils of the ponds' watersheds. These soils soak up precipitation resulting in limited runoff in an unaltered watershed. The soils also tend to bind phosphorus, making it unavailable for transport through groundwater into the ponds; though with sufficient time (several decades or longer) and/or with a very large source (such as a discharge of effluent from a wastewater treatment plant that does not treat for phosphorus), the binding sites will be occupied and continued addition of phosphorus will move through the soils.

The introduction of phosphorus to ponds is important because an increase in phosphorus will increase plant growth (typically as algae), which can lead to degraded water quality through loss of water transparency, noxious algal blooms, and impairment or death of aquatic life through loss of oxygen.

Kettle ponds are sensitive to anthropogenic phosphorus loadings, and it only takes a small increase in phosphorus to alter the pond's water quality. The physical setting is thus a threat to water quality because most kettle ponds have long residence times (slow flushing rates). This means that additional phosphorus that reaches the ponds will remain in the ponds unless lost through an outlet stream (for those few ponds with outlets) or by deep burial. Thus, many kettle ponds have their principal source of phosphorus generated from within the pond, typically through regeneration of phosphorus at the sediment-water interface under no oxygen (anoxic) conditions. In kettle ponds, historic sources of phosphorus (such as fertilizer runoff from agricultural activities or large waterfowl populations) can continue to affect pond water qualit

5.2.2 Indicators of Pond Health

The PALS sampling program involved collecting Secchi depth readings, vertical profiles (multiple readings with depth) of temperature, pH, and dissolved oxygen (DO), and two discrete samples (top and near bottom of the pond) for analysis of phosphorus, total nitrogen (TN), and chlorophyll-a concentrations. The use of these parameters in assessing pond health is discussed below.

- **Secchi depth**: Secchi depth is a measure of water clarity. It is the depth at which a Secchi disk can no longer be seen as it is lowered through the water column. Waters with low Secchi depth readings can occur naturally (e.g., if wind/waves suspend bottom sediment) or be an indicator of degraded pond health (e.g., high concentrations of algae). A Secchi depth of 4 feet or more generally indicates suitability for swimming based on water clarity.

- **Dissolved oxygen**: Adequate concentrations of dissolved oxygen are necessary to sustain fish and other aquatic organisms and prevent offensive odors.

  MassDEP's water quality standards require oxygen levels to be greater than either 5 or 6 mg/l depending on the characteristics of the pond. Some Harwich ponds are considered shallow ponds and thus must meet the 5 mg/l threshold to support warm-water fish.

  Waters are termed anoxic when oxygen levels drop below 1 mg/L. When a shallow pond has little to no oxygen at its bottom, this suggests that the decomposition of organic matter at the pond bottom is sufficient to use all available oxygen in between mixing. When a pond has anoxic bottom waters, phosphorus can be regenerated from the sediments to the overlying waters, which in shallow ponds is typically available to fuel algae or aquatic plant growth.

- **Phosphorus**: Phosphorus is a key nutrient influencing plant growth in ponds. Phosphorus is usually the limiting nutrient to freshwater ponds, such that increasing its concentration alone will result in greater plant productivity.

  Currently, MassDEP does not have a numerical criterion for phosphorus unless the water body is subject to a TMDL or site-specific criterion; however, discharges that result in excessive aquatic plant or algal growth (eutrophication) need to be controlled.

- **Nitrogen**: Nitrogen is an essential nutrient for plant growth; nitrogen is usually sufficiently abundant in freshwater systems and thus does not limit plant growth. In some highly eutrophic lakes (which have excess phosphorus – more than plants can use to grow), nitrogen can become the limiting nutrient for plant productivity. In these cases, an ecological advantage is afforded to certain blue-green algae that have the ability to obtain nitrogen from the atmosphere (called fixing nitrogen) and use this nitrogen as a nutrient source to fuel algal growth. Thus nitrogen limitation in ponds with excess phosphorus concentrations can be a factor in blue-green algal blooms.

  Currently, MassDEP does not have a numerical criterion for nitrogen unless the water body is subject to a TMDL (Total Maximum Daily Load) or site-specific criterion; however, discharges that result in excessive aquatic plant or algal growth (eutrophication) need to be controlled.

- **Chlorophyll-a**: Chlorophyll-a is a direct measure of a green pigment that transforms light energy into chemical energy in photosynthesis. Chlorophyll-a indicates the presence of phytoplankton (algae) biomass; the trophic status of ponds is often determined from the summer mean chlorophyll-a concentrations.

  Currently, MassDEP does not have a numerical criterion for chlorophyll-a unless the water body is subject to a TMDL or site-specific criterion. However, Mark Matteson of MassDEP indicated that the Commonwealth's water quality standards may be modified to include a new standard for chlorophyll-a. The standard would allow chlorophyll-a levels to exceed 16 µg/L only once during a growing season.

There are two additional methods for using water quality data to evaluate pond health: trophic status and the guidelines for pond health established by the CCC.

- **Trophic Status**: This is an integrative measure typically considering at least one of the following parameters: Secchi depth, seasonal average phosphorus concentration, and chlorophyll-a concentration. A common trophic status index (TSI) was derived by Carlson from work on northern temperate lakes. Table 5-2 (www.Secchidipin.org/tsi.htm) provides values used to evaluate the TSI and gives examples how fisheries and recreation in these lakes can be affected as the trophic status moves from oligotrophic to mesotrophic to eutrophic.

Table 5-2
Carlson Trophic Status Index Metrics

TSI	Chloro-phyll (ug/l)	Secchi Depth (feet)	Total Phosphorus (ug/l)	Attributes	Fisheries & Recreation
<30	<0.95	>26	<6	Oligotrophy: Clear water, oxygen throughout the year in the bottom waters	Salmonid fisheries dominate
30-40	0.95-2.6	26-13	6-12	Bottom waters of shallower lakes may become anoxic	Salmonid fisheries in deep lakes only
40-50	2.6-7.3	13-7	12-24	Mesotrophy: Water moderately clear; increasing probability of no oxygen in bottom waters during summer	Lack of oxygen in bottom waters results in loss of salmonids.
50-60	7.3-20	7-3	24-48	Eutrophy: No oxygen in bottom waters, macrophyte problems possible	Warm-water fisheries only. Bass may dominate.
60-70	20-56	1.5-3	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating
70-80	56-155	0.8-1.5	96-192	Hypereutrophy: (light limited productivity). Dense algae and macrophytes	*
>80	>155	<0.8	192-384	Algal scums, few macrophytes	Rough fish dominate; summer fish kills possible

Note: (*) Data not provided

- **CCC guidelines:** The CCC has established guidelines for pond health for phosphorus, nitrogen, and chlorophyll-a concentrations. The guidelines are based on the statistical analysis of data from 195 ponds in the first PALS snapshot in 2001, and they establish threshold values to

"identify ponds minimally impacted by human activities." The threshold values were determined following a USEPA methodology for establishing eco-region reference values. The two threshold values developed by the CCC represent (1) the lower 25th percentile of all water quality data and (2) the upper 25th percentile of unimpacted ponds. The second reference value is based on 2001 water quality data of eight ponds across the Cape. The reference values are shown in Table 5-3 below.

Table 5-3
CCC Pond Water Quality Guidelines

Water Quality Indicator	Lower 25th Percentile of All Ponds	Upper 25th Percentile of Unimpacted Pond
Total Phosphorus (µg/l)	10	7.5
Total Nitrogen (mg/l)	0.31	0.16
Chlorophyll-a (µg/l)	1.7	1.0

5.2.3 Assessment of Pond Health

The 2006-2010 PALS data for Harwich ponds were reviewed and compared to indicators of pond health. In addition, 2001-2005 PALS data were analyzed in the Review and Interpretation of Harwich Ponds Volunteer Monitoring Data Final Report (Eichner, 2006) herein referred to as the Harwich Ponds Report. Additional information from the following sources was included in this summary:

- Harwich Ponds Ecologic Memoranda (Moran, 2008 and 2011) herein referred to as the Ecologic Memos
- Guidance Document and Case Study Report for The Great Sand Lakes (Stearns & Wheler LLC and Ecologic LCC, 2007) herein referred to as the GSL Report
- Harwich Ponds Fact Sheets (Harwich Water Quality Task Force, 2006) herein referred to as the HWQTF Fact Sheets
- Brewster Freshwater Ponds: Water Quality Status and Recommendations for Future Activities (SMAST, 2009) herein referred to as the Brewster Ponds Report

Andrews Pond

Andrews Pond is categorized as a deep, oligotrophic pond. The shoreline of Andrews Pond has fewer than ten housing units within a 300-ft buffer from the water's edge. The area upgradient of the pond is generally low density residential surrounded by minor roads. Limiting further development of the area upgradient of the pond and surrounding the western edge of the pond will help in protecting the water quality of Andrews Pond. In general, the water quality conditions of Andrews Pond appear stable based on PALS data available through 2008.

Satellite Image of Andrews Pond, Harwich, MA

Discrete data from 2006-2008 are summarized below:

- 22 out of 23 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds, indicating healthy DO levels overall. The Harwich Ponds Report states that Andrews Pond had a low DO reading of 1 mg/L at the pond bottom, which qualifies the pond as being impaired for DO. However, the single DO measurement is likely an outlier and does not indicate a water quality trend or a cause for concern.
- Total phosphorus concentrations were generally low and were within the oligotrophic range.
- The average Secchi depth reading was 21 feet, which makes the pond's clarity exceptionally suitable for swimming.
- Concentrations of chlorophyll-a did not exceed 16 µg/l at any depth.

Aunt Edies Pond

Aunt Edies Pond is categorized as a shallow, mesotrophic pond. The Harwich Ponds Report states that the average TSI for Aunt Edies Pond is classified as mesotrophic, but the data variability for all indicators spans across oligotrophic and eutrophic categories. The northern, upgradient shoreline of Aunt Edies Pond has fewer than five housing units. The pond's westernmost edge is approximately 300 feet from Route 6, and road runoff may be a source of contamination. In addition, the WQMTF developed a fact sheet for Aunt Edies Pond and identified two abandoned cranberry bogs.

Satellite Image of Aunt Edies Pond, Harwich, MA

At one point in time in either the late 1980's or early 1990's, the Sandy Shore Association limed Aunt Edies Pond in an attempt to improve the pond's water quality. The residual impact of liming is difficult to quantify without information before and after the lime application. The pond water quality is not improving with reports of milfoil infestation and nuisance algal blooms.

Discrete data from 2006-2010 are summarized below.

- 18 out of 18 DO measurements were greater than the state DO threshold of 5 mg/l for shallow, warm-water ponds.
- Total phosphorus concentrations were within the mesotrophic range. Average phosphorus concentrations at the pond bottom were higher compared to surface readings, indicating that bottom sediments may be an additional nutrient source.
- The average Secchi depth reading was 7 feet, which is approximately the total depth of the pond.

- Though concentrations of chlorophyll-a at any depth did not exceed 16 µg/l, the Ecologic Memo states that Aunt Edies Pond chlorophyll-a measurements did indicate a diminished water quality for recreational use because of concentrations averaging 7 µg/l compared to 4 ug/l in previous years. However, true data trends could not be identified due to the limited number of samples.

Bucks Pond

Bucks Pond is categorized as a deep, oligotrophic pond. The Harwich Ponds Report provides analysis of Bucks Pond to a depth of 26 feet, whereas the discrete data reports measurements up to a depth of 32 feet. Bucks Pond has the largest surface area of the four ponds in the Great Sand Lake system. It is directly connected on its eastern border with Kiddies Pond and its western border with John Joseph Pond. The entire pond system is surrounded by medium-to-high density residential development, connected by a network of minor roads.

Satellite Image of Bucks Pond, Harwich, MA

The Great Sand Lake pond system was extensively studied in June 2007 as part of the Evaluation of Wastewater Management Options for Freshwater Ponds for the Town of Harwich (GSL Report). Detailed phosphorus loads were evaluated and specific recommendations for phosphorus reduction included educational materials to reduce private phosphorus inputs, management of water fowl, and design enhancements to septic systems. As a potential long-term option to address future phosphorus loading to the watershed, the implementation of a wastewater collection and treatment system was discussed. In order to protect this pond system from degradation, action towards phosphorus reduction must be taken.

Discrete data from 2006-2010 are summarized below. Inconsistencies in reporting of blank and non-detect measurements are a cause of data uncertainty.

- 78 out of 111 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds. Low DO measurements and non-detect readings were at depths of 23 feet and greater, indicating that approximately the bottom third of the pond strata can be anoxic. The Ecologic Memo states that Bucks Pond is weakly stratified and therefore has periods of both stratification and of complete mixing.

- Total phosphorus concentrations were generally low and were within the oligo-mesotrophic range. The Ecologic Memo states that there continue to be elevated total phosphorus concentrations towards the pond bottom due to sediment-bound phosphorus, which can be released during periods of mixing.

- The average Secchi depth reading was 16 feet, which makes the pond's clarity exceptionally suitable for swimming.

- Average concentrations of chlorophyll-a did not exceed 16 µg/l. The 2006-2010 dataset contained recorded measurements at the pond bottom that exceeded 30 µg/l, indicating the presence of plant life.

Cornelius Pond

The Harwich Ponds Report categorized Cornelius Pond as a shallow, oligotrophic pond based on the average TSI for chlorophyll-a, but stipulated that Cornelius Pond had a large TSI range across the typical indicators. The Ecologic Memo categorized Cornelius Pond as a eutrophic pond based on a mean TSI from chlorophyll-a, total phosphorus, and Secchi disk measurements.

Satellite Image of Cornelius Pond, Harwich, MA

The shoreline of Cornelius Pond is relatively undeveloped with all residential units on the southern, downgradient edge of the pond. Limiting development in the northern, upgradient area will help protect the water quality of Cornelius Pond. Based on an orthophotographic survey, there appear to be two bogs that are directly connected via a culvert or channel into the northern section of the pond. There also appears to be a slag or sediment dump location to the northwest of the pond. Historic orthophotography also reveals persistent algal blooms.

Discrete data from 2006-2008 supporting a degraded water quality are summarized below.

- 5 out of 14 DO measurements were greater than the state DO threshold of 5 mg/l for shallow, warm-water ponds.
- Total phosphorus concentrations were elevated and were within the eutrophic range.
- The average Secchi depth reading was 3 feet, which does not satisfy the state water clarity swimming standard.
- Average concentrations of chlorophyll-a did not exceed 16 µg/l. The 2006-2008 dataset did contain recorded measurements at the surface that exceeded 16 µg/l, which are likely due to existence of algae.

Flax Pond

Satellite Image of Flax Pond, Harwich, MA

Samples for Flax Pond were taken on both the western and eastern portions of the pond. The western portion of the pond is deeper than the eastern portion of the pond. Discrete data were summarized separately for each monitoring location and analyzed separately in the Ecologic Memo. The Harwich Ponds Report categorized Flax Pond as a deep, oligotrophic pond based on the average TSI for chlorophyll-a, but stipulated that there was a large TSI range across the indicators. The Ecologic Memo categorized Flax Pond as a mesotrophic pond based on an average calculated TSI.

Flax Pond is connected on both the western and eastern sides for irrigation of nearby cranberry bogs. Historic orthophotography of the pond shows evidence of algal blooms. The area north of the pond is a capped landfill. In the mid-1990s, the Town initiated a project to restore Flax Pond after it was identified that leachate from the landfill and septage lagoons were impacting the pond's water quality. Water quality in Flax Pond has improved since the 1990s, but monitoring data for Flax Pond indicates that it still has some significant water quality concerns.

Discrete data for Flax Pond West from 2006-2010 are summarized below. Inconsistencies in reporting of blank and non-detect measurements are a cause of data uncertainty.

- 33 out of 75 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds. Low DO measurements and non-detect readings were at depths of 13 feet and greater indicating an anoxic pond bottom.
- Total phosphorus concentrations were generally elevated and were within the mesotrophic range. Certain years of data exhibited higher total phosphorus concentrations at the pond bottom.
- The average Secchi depth reading was 10 feet, which makes the pond's clarity suitable for swimming.
- Average concentrations of chlorophyll-a did not exceed 16 µg/l. The Ecologic Memo determined that there was an outlier measurement in 2003 and that concentrations over time taken in the surface waters (between 2001-2005) were consistently less than 10 µg/l. The 2006-2010 dataset supports that finding.

Discrete data for Flax Pond East from 2006-2010 are summarized below.

- The Ecologic Memo indicated that Flax Pond East was undergoing a statistically significant decreasing trend of total phosphorus concentrations. Interpretation of the 2006-2010 dataset indicates insignificant fluctuation in total phosphorus concentrations.

- The average Secchi depth reading was 5 feet, which makes the pond's clarity suitable for swimming.
- Concentrations of chlorophyll-a at any depth did not exceed 16 µg/l.

Grass Pond

The Harwich Ponds Report and the 2008 Ecologic Memo categorized Grass Pond as a shallow, eutrophic pond, whereas the 2011 Ecologic Memo categorized the pond as mesotrophic. Flow from Grass Pond feeds the Bank Street Bogs Nature Preserve, which is a parcel preserved by the Harwich Conservation Trust. There is a small housing development to the north of the pond and a denser housing development to the west. Based on an orthophotographic survey, there appears to be at least one abandoned bog that is directly connected to the pond via a culvert or channel in the southern section of the pond. A second bog/marsh borders the northern edge of the pond. The pond's westernmost edge is approximately 100 feet from a minor arterial road, Forest Street. Road runoff may also be a source of contamination. Surface water from Grass Pond flows through a series of bogs and marshes until it reaches Saquatucket Harbor.

Satellite Image of Grass Pond, Harwich, MA

Discrete data from 2007-2010 supporting the assessment of water quality degradation are summarized below.

- 5 out of 8 DO measurements were greater than the state DO threshold of 5 mg/l for shallow, warm-water ponds.
- Total phosphorus concentrations were elevated in Grass Pond and were within the eutrophic range. The Ecologic Memo stated that Grass Pond has consistently elevated total phosphorus concentrations but because of the limited number of measurements, a statistical trend could not be identified of improving or worsening water quality. The discrete 2007-2010 data does include measurements that were taken at the outlet and at locations where the sample depth was not recorded.
- Only one Secchi depth measurement was reported in the 2007-2010 data set at a depth of 4.4 feet, which just meets the 4 foot pond clarity threshold for swimming.
- There were two measurements of chlorophyll-a that were exceptionally high and were likely taken during a period of elevated algal activity. All other measurements at any depth did not exceed 16 µg/l.

Hawksnest Pond

The Harwich Ponds Report and the 2008 Ecologic Memo categorized Hawksnest Pond as a deep, oligotrophic pond, whereas the 2011 Ecologic memo categorized the pond as mesotrophic. Hawksnest Pond is completely within Hawksnest State Park. The shoreline is entirely undeveloped except for one small cottage belonging to the Rod & Gun club. Three minor roads surround Hawksnest Pond. Spruce Road is approximately 100 feet from the water's edge. The larger arterial road, Route 6, is approximately 350 feet from the water's edge. Road runoff from either road may be a source of contamination. Limiting development surrounding Hawksnest Pond and eliminating road runoff inputs will preserve and protect the water quality of Hawksnest Pond.

Satellite Image of Hawknest Pond, Harwich, MA

Discrete data from 2006-2010 supporting an oligotrophic status are summarized below. Hawksnest Pond was the only pond listed in the 2011 Ecologic Memo that fully met the Cape Cod criteria related to trophic status conditions as detailed in Table 5-3 above.

- 58 out of 64 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds.
- Total phosphorus concentrations were low and were within the oligotrophic range.
- The average Secchi depth reading was 19 feet, which makes the pond's clarity exceptionally suitable for swimming.
- Concentrations of chlorophyll-a were among the lowest of Harwich's ponds with an average of 1.4 µg/l. Recorded measurements did not exceed 16 µg/l at any depth.

Hinckleys Pond

Hinckleys Pond was categorized as a deep, borderline eutrophic pond. Hinckleys Pond is surrounded by medium to high density residential units. It is also bounded by two active cranberry bogs and is less than 100 feet from Route 124. Recently, the water quality in Hinckleys Pond has degraded. In 2009, Hinckleys Pond was closed when state and local officials determined that toxic cyanobacteria algae were found and that concentrations were five times the allowable level. During the fall of 2011, a diagnostic assessment was performed specifically for Hinckleys Pond and its watershed (Evaluation of Hinckley's Pond, Harwich, Massachusetts,

Satellite Image of Hinkleys Pond, Harwich, MA

Draft March 2012, by Water Resource Services in Conjunction with CDM Smith). The purpose of the study was to understand nutrient sources and to recommend actions to mitigate adverse impacts of excess phosphorus to improve the pond's water quality. The evaluation determined that the largest source of phosphorus is internal.

Discrete data from 2006-2010 supporting the degradation in pond water quality and eutrophic status are summarized below.

- 64 out of 106 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds. Low DO measurements and non-detect readings were at depths of 16 feet and greater indicating an anoxic pond bottom.
- Total phosphorus concentrations were elevated and were within the eutrophic range. There was evidence of a trend of internal recycling of phosphorus due to elevated concentrations in deeper waters.
- The average Secchi depth reading was 5 feet with a minimum measurement of 2 feet demonstrating poor water clarity. The readings were consistently at or below the swimming standard.
- Average concentrations of chlorophyll-a did not exceed 16 µg/l. However, there were 14 measurements of chlorophyll-a concentrations greater than 16 µg/l.

Long Pond

Long Pond was categorized as a deep, mesotrophic pond and is split by the Town boundary between Brewster and Harwich. It is surrounded by medium-to-high density residential development and is less than 100 feet from Route 124 and Long Pond Drive. A cranberry bog is located on the northwestern edge of Long Pond.

Satellite Image of Long Pond, Harwich, MA

Satellite Image John Josephs Pond, Harwich, MA

Long Pond was treated with alum in the fall of 2007 because of degrading water quality. The limited available water quality data since the alum treatment suggest that the water quality has not returned to the highly impacted condition prior to the pond treatment, but it also suggests that elevated phosphorus levels are still present in the pond. The *Treatment Summary for Phosphorus Inactivation in Long Pond* (AECOM, 2009) provides water quality monitoring data for the year following the alum treatment. The phosphorus data during this year are ambiguous. After the initial drop in phosphorus levels in the month following the treatment, AECOM (2009) reports "the pattern that arose after October 2007 was unexpected. In essence, TP and DP [dissolved phosphorus] increased gradually between October 2007 and April 2008, with TP reaching levels similar to those of the upper layer from September 2007 in April and May 2008. DP levels did not recover to pre-treatment levels, but did increase to more than half the pre-treatment concentration." While the overall pond water quality has improved, additional data is needed to understand the efficacy of the pond treatment and in which category to place Long Pond.

John Joseph Pond

John Joseph Pond was categorized as a deep, mesotrophic pond in the Brewster Pond Report. It is the second largest pond of four ponds in the Great Sand Lake pond system. It is directly connected on its eastern border to Bucks Pond. According to the USGS topographic map for the area, John Joseph and Bucks Ponds are at the same water surface elevation. This entire Great Sand Lake system is surrounded by medium-to-high density residential development with a network of minor roads. As mentioned above regarding Bucks Pond, John Joseph Pond was also studied in detail in June 2007 and identified as an area requiring phosphorus load reduction to improve water quality.

Satellite Image of Robbins Pond, Harwich, MA

Discrete data from 2006-2010 are summarized below.

- 137 out of 197 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds. Low DO measurements and non-detect readings were at depths of 16 feet and greater indicating an anoxic pond bottom.
- Total phosphorus concentrations were elevated and were within the mesotrophic range.
- The average Secchi depth reading was 18 feet, which makes the pond's clarity suitable for swimming.
- Average concentrations of chlorophyll-a did not exceed 16 µg/l.

Robbins Pond

Robbins Pond was categorized as a shallow, mesotrophic pond. It has a relatively undeveloped shoreline with less than ten houses within a 300-ft buffer surrounding its shoreline. There is a large cranberry bog to the west and a smaller bog to the south of the pond. There appears to be no direct

connection from either bog to Robbins Pond, but water from the pond may be used as irrigation. Historic orthophotography also indicates that nuisance algal blooms do occur in Robbins Pond, especially in the thumb-like feature where mixing is limited.

Discrete data from 2006-2010 are summarized below.

- 23 out of 24 DO measurements were greater than the state DO threshold of 5 mg/l for shallow, warm-water ponds.
- Total phosphorus concentrations were elevated and were within the mesotrophic range. The Ecologic Memo indicates that Robbins Pond exhibited an increasing trend of annual average phosphorus in 2010 compared to data in 2000-2008. Inspection of the data indicates that the samples for total phosphorus taken in 2010 were primarily at depth whereas the average from past years included surface samples.
- The average Secchi depth reading was 7 feet, which makes the pond's clarity suitable for swimming.
- There was one measurement of chlorophyll-a concentration that was above the 16 µg/l threshold. All other measurements did not exceed 16 µg/l.

Sand Pond

Sand Pond was categorized as a deep, mesotrophic pond. The shoreline of Sand Pond has fewer than ten housing units within a 300-ft buffer from the water's edge. The northern area upgradient of the pond is generally low density residential connected by minor roads. Sand Pond has three direct connections from active cranberry bogs. Sand Pond is also approximately 300 feet from a minor arterial road, Great Western Road.

Satellite Image of Flax Pond, Harwich, MA

Discrete data from 2006-2010 are summarized below.

- 40 out of 74 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds.
- Total phosphorus concentrations were within the mesotrophic range.
- The average Secchi depth reading was 12 feet, which makes the pond's clarity suitable for swimming.
- Average concentrations of chlorophyll-a do not exceed 16 µg/l. However, there were 13 measurements of chlorophyll-a concentrations greater than 16 µg/l, most of which were taken at the pond bottom.

Seymour Pond

Seymour Pond was characterized as a deep, mesotrophic pond. The northeastern, upgradient watershed has a medium-to-high level of residential units with a network of minor streets. It is also less than 100 feet from Route 124. Seymour Pond is split by the Town boundary between Brewster and Harwich. The Brewster Ponds Report performed a detailed individual pond assessment for Seymour Pond and developed a water budget to account for flows entering and exiting the pond. They also performed a detailed phosphorus budget to determine the sources and magnitude of phosphorus loading.

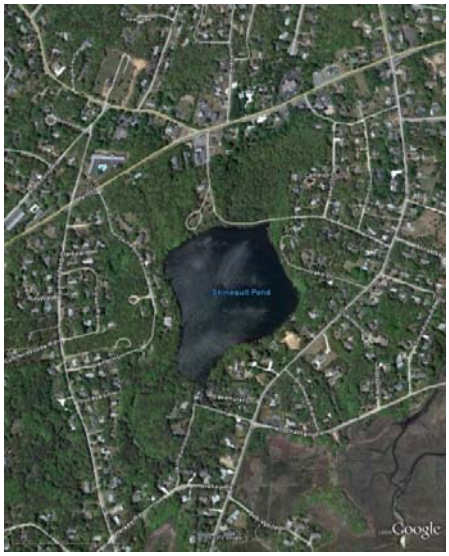
Satellite Image of Seymour Pond, Harwich, MA

The Brewster Ponds Report identified Seymour Pond as an impaired water body from analysis of PALS data from 2001-2007.

- DO measurements show decreasing concentrations with increasing depth and regular anoxic conditions during the summer months. Based on average DO concentrations, the bottom 16 feet of the pond was less than the state DO threshold of 6 mg/l for deep, cold-water ponds.
- Total phosphorus concentrations were within the mesotrophic range. The average deep total phosphorus concentrations were three times greater than surface concentrations indicating that there is phosphorus regeneration from sediments.
- The average Secchi depth reading was estimated to be 9 feet, which makes the pond's clarity suitable for swimming. However, the Brewster Ponds Report carefully reviewed historic Secchi depth readings and suggested that clarity and water quality conditions are worsening.
- Average concentrations of chlorophyll-a do not exceed 16 µg/l.

Skinequit Pond

Skinequit Pond was categorized as a deep, eutrophic pond. It is surrounded by medium-to-high residential units and a network of minor streets. The Town has also identified a manmade dam separating the pond from an abandoned cranberry bog to its northern border. Though Route 28 is approximately 700 feet from the pond's edge, it is suspected that road runoff can flow into the abandoned bog and eventually into Skinequit Pond. A study was conducted by the Harwich Department of Natural Resources on Skinequit Pond to mitigate the degradation of the pond's water quality. Currently, Skinequit Pond is being treated with Solar Bee technology to mix oxygenated water deeper into the water column.



Satellite Image of Skinequit Pond, Harwich, MA

The Ecologic Memo details observations regarding the total phosphorus concentrations. Skinequit Pond had a higher ratio of dissolved to total phosphorus, which suggests that a significant component of the water column is dissolved total phosphorus originating from the sediments. Surface concentrations may be lower because of the implementation of the Solar Bee technology. The water clarity in 2010 was an increase from previous years after installation of the Solar Bee based on Secchi depth measurements.

Discrete data from 2006-2010 are summarized below.

- 34 out of 68 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds. DO measurements on the pond bottom show a layer (at times, 9 feet or more) of anoxia.
- Total phosphorus concentrations were elevated across the entire water column and were within the eutrophic range. Total phosphorus concentrations at the pond bottom were exceptionally high.
- The average Secchi depth reading prior to the Solar Bee implementation was 4 feet. In 2010, the recorded Secchi depth ranged from 2 to 9 feet.
- The average concentration of chlorophyll-a for the discrete dataset was 37 µg/l. Skinequit Pond has much higher concentrations of chlorophyll-a than might be expected from the observed phosphorus concentrations, which diminishes suitability for recreational use.

Walkers Pond

The Harwich Ponds Report and the 2008 Ecologic Memo characterize Walkers Pond as a deep, oligotrophic pond, whereas the 2011 Ecologic Memo has characterized it as a mesotrophic pond. The Ecologic Memo states that Walkers Pond experienced nuisance algal blooms in 2007. The exact cause of the blooms was never determined. Historic orthophotos also show evidence of persistent algal blooms.

Satellite Image of Walkers Pond, Harwich, MA

The shoreline of Walkers Pond has approximately ten housing units within a 300-ft buffer from the water's edge. The northern area upgradient of the pond is low-to-medium density residential since residential units also surround Long Pond, which is just north of Walkers Pond. The pond's northernmost edge is less than 100 feet from Spruce Road and approximately 300 feet from Route 6. Road runoff from both roads may be a source of contamination. Based on an orthphotographic survey, there appears to be at least one bog that is directly connected to the pond via a culvert or channel in the southern section of the pond. There also appears to be another smaller bog that is connected to the west of the southern section of the pond.

Discrete data from 2006-2010 are summarized below.

- 50 out of 83 DO measurements were greater than the state DO threshold of 6 mg/l for shallow, warm-water ponds.
- Total phosphorus concentrations were within the mesotrophic range.
- The average Secchi depth reading was 14 feet, which makes the pond's clarity suitable for swimming.
- Concentrations of chlorophyll-a at any depth did not exceed 16 µg/l.

White Pond

The Harwich Ponds Report and the 2008 Ecologic Memo categorized White Pond as a deep, oligotrophic pond, whereas the 2011 Ecologic memo categorized the pond as mesotrophic based on an additional two years of data showing an increasing trend of total phosphorus. The shoreline of White Pond has approximately fifteen housing units within a 300-ft buffer from the water's edge. The northern area upgradient of the pond is relatively undeveloped except for a large horse stable approximately 500 feet from the water's edge.

Satellite Image of White Pond, Harwich, MA

Discrete data from 2006-2009 are summarized below.

- 9 out of 17 DO measurements were greater than the state DO threshold of 6 mg/l for deep, cold-water ponds.
- Total phosphorus concentrations were low and according to the Ecologic Memo, exhibiting an increasing trend within the past two years. The range of concentrations was within the oligio-mesotrophic range.
- The average Secchi depth reading was 17 feet, which makes the pond's clarity exceptional for swimming.
- Concentrations of chlorophyll-a at any depth did not exceed 16 µg/l.

5.3 Summary

The sixteen Harwich ponds in this pond health assessment are quite diverse in both physical and water quality characteristics. Harwich's ponds provide important habitat for aquatic life and are important natural resources for the community. The growing number of pond restoration actions on Cape Cod suggests that many ponds are reaching their tipping points, where further alterations to the environment will result in sometimes dramatic changes in water quality. These have included noxious and potentially harmful algal blooms at Hinckleys Pond and Skinequit Pond. The latter was treated by installing the Solar Bee mixing technology. Summary of water quality data was supported with

previous analyses from the Town of Harwich, WQMTF, Ecologic, LLC; and Stearns & Wheler, LLC. Below are some preliminary steps that should be taken to protect or restore Harwich's ponds.

1. Continue Monitoring

It is recommended that monitoring of all current ponds continue. It is also recommended to expand the PALS program to collect at least one sample annually from other Harwich ponds without historic water quality data including:

- Paddocks Pond, a shallow pond.
- West Reservoir, which experienced a toxic algal bloom in 2004 and East Reservoir, both of which feed the Herring River
- Olivers Pond and Black Pond, near Hawksnest Pond and currently in an area that may experience future residential development
- Smaller water bodies like Okers, Island, Abrams, and Littlefields Ponds to obtain a more detailed dataset to determine if these water bodies are experiencing similar trends in water quality

This expansion can be done gradually and adaptively. The additional monitoring of a handful of ponds each year would increase the knowledge database of the Town's ponds.

2. Perform an Inventory of All Stormwater Pipes Draining to Ponds

Road runoff as a potential source of contamination was identified in at least twelve ponds. Create an inventory incrementally with focus on ponds with water quality data. If found, divert or disconnect stormwater systems that directly discharge to ponds.

3. Investigate Other Potential Contaminant Sources

Phosphorus loads from the following sources should be considered: abandoned or active cranberry bogs, sediment dumping locations, farms, private impervious surface runoff, private landscape and fertilizer applications, and waterfowl.

Decreasing phosphorus loads to ponds that are currently affected by high phosphorus concentrations would improve pond health. For ponds that have evidence of phosphorus regeneration, expansion of monitoring points allows for a more accurate understanding of phosphorus regeneration. If phosphorus loads are coming from internal loading, then in-lake measures may be an option. For ponds that are on the border between mesotrophic and eutrophic conditions, it is important to act soon to determine the source(s) of phosphorus contributing to this degradation.

4. Investigate the Feasibility and Applicability of Alternative Wastewater Management Practices

Pond shorelines with medium-to-high levels of residential development could be candidates in determining the feasibility of alternative wastewater management practices. Pond Areas with upgradient high level development are more likely candidates for alternative waste water management than downgradient areas. In general, these actions are watershed-based measures to address external sources of phosphorus to a pond. The GSL Report recommends initial suggestions for watershed management options, which include: reduction of phosphorus-containing detergents,

elimination of sink garbage disposals to reduce phosphorus loads from food waste, and more rigorous enforcement of the Town Board of Health requirements for septic systems.

It is also extremely important to understand the relative magnitude of internal versus external loads. External actions taken to address one source of load may not successfully improve pond health if it is not the dominant load to a pond. In some instances it could be necessary to take both watershed and in-lake actions.

5. Determine uses and ponds to support.

Fostering stakeholder and public participation is a key component in determining which ponds and which uses for each individual pond should be prioritized to keep or meet a high quality designation. An example would be to prioritize the protection of Olivers, Hawksnest, and Black Pond to prevent water quality degradation from affecting fish populations, if that is a priority for the community. Table 5-4 summarizes the analysis and recommendations for each of the sixteen ponds examined.

Table 5-4
Harwich Ponds Health Assessment Summary and Recommendations

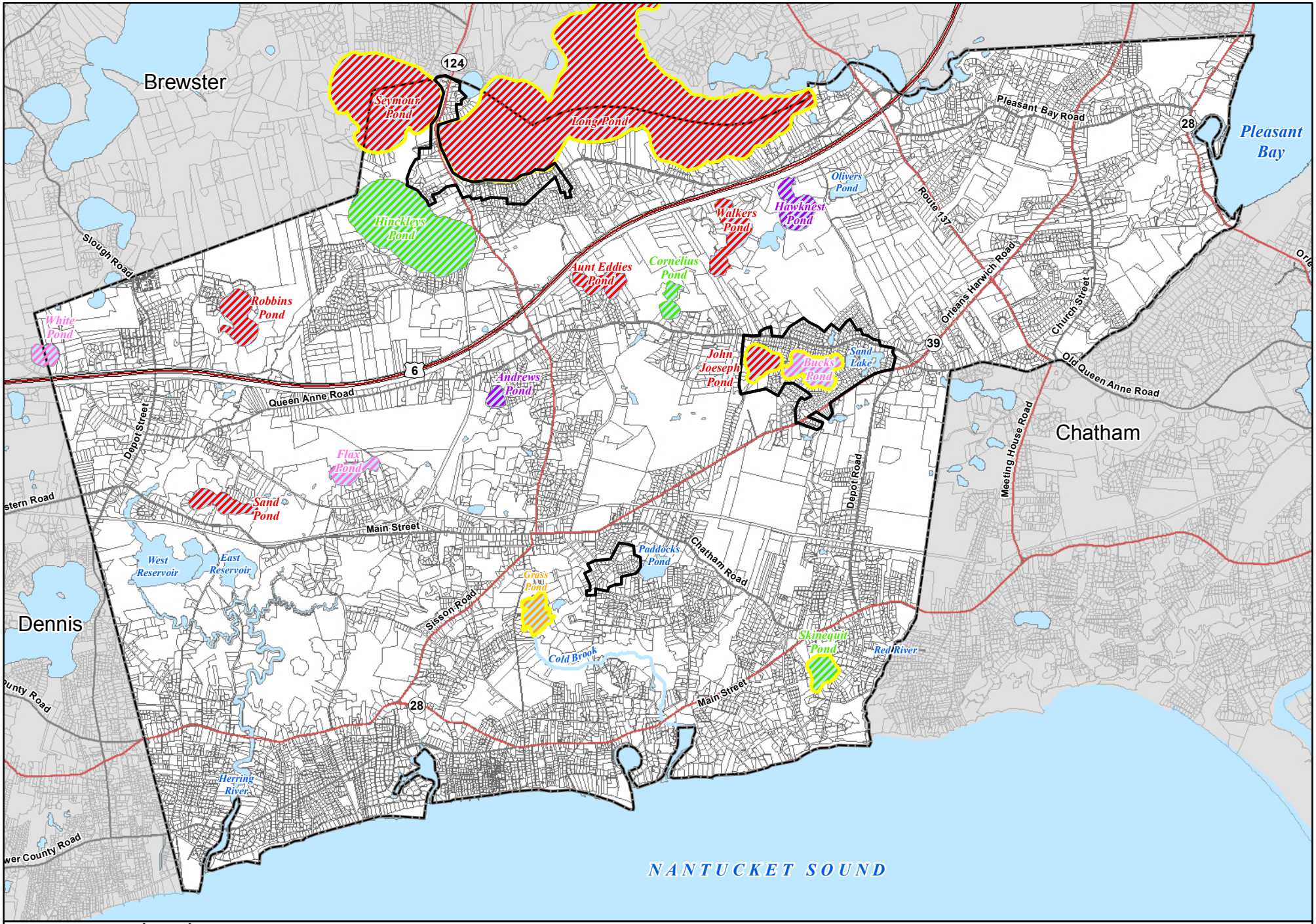
Name	Pond Trophic Status	Monitor	Investigate Road Runoff Contribution	Investigate Potential Contaminant Sources	Shoreline Development
Andrews Pond	Oligotrophic	X		X	Low
Aunt Edies Pond	Mesotrophic	X	X	X	Low
Bucks Pond	Oligo-mesotrophic	X	X	X	Medium to High
Cornelius Pond	Eutrophic	X		X	Low
Flax Pond	Oligo-mesotrophic	X	X	X	Low
Grass Pond	Meso-eutrophic	X	X	X	Low
Hawksnest Pond	Oligotrophic	X	X	X	Low
Hinckleys Pond	Eutrophic	X	X	X	Medium to High
Island Pond	*	X			*
John Joseph Pond	Mesotrophic	X	X	X	Medium to High
Littlefields Pond	*	X			*
Long Pond	Mesotrophic	X	X	X	Medium to High
Oilvers Pond	*	X			*
Okers Pond	*	X			*
Paddocks Pond	*	X			*
Robbins Pond	Mesotrophic	X		X	Low
Sand Pond	Mesotrophic	X	X	X	Low
Seymour Pond	Mesotrophic	X	X	X	Medium to High
Skinequit Pond	Eutrophic	X	X	X	Medium to High
Walkers Pond	Mesotrophic	X	X	X	Low
West Resevior	*	X			*
White Pond	Oligo-mesotrophic	X		X	Low

Note: (*) Data not provided

Red Fields indicate impaired water quality.

The highlighted ponds in Table 5-4 should be examined more closely to determine if providing sewers within the watersheds and thus removing septic system effluent phosphorus inputs would be appropriate to reduce degradation. Figure 5-3 presents several of the larger ponds in Harwich based on their trophic status.

Ponds that require additional analysis prior to determining sewering needs within their watersheds can be handled through an adaptive management approach during the implementation phase of the CWMP recommended program, as described in Section 13 of this report.



Legend

Pond Trophic Status

- Eutrophic
- Meso-eutrophic
- Mesotrophic
- Oligo-mesotrophic
- Oligotrophic

- Water Quality Degradation Possibly Related to Development
- Primary Areas of Concern for Pond Health

Town of Harwich
Comprehensive Wastewater
Management Plan

1 inch = 4,000 feet

0 1,000 2,000 4,000 Feet

Figure 5-3
Pond Water Quality

CDM Smith

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