FUSS & O'NEILL

MEMORANDUM

TO: Ashley Fisher, Director of Natural Resources, Town of Mashpee

FROM: Erik Mas, P.E.; Diane Mas, PhD, REHS/RS, CC-P; Stefan Bengtson, MSc, MESM; Jonathon Havey, EIT, Fuss & O'Neill, Inc.

DATE: February 25, 2022

RE: Task 2 – Characterization of Watershed Pollutant Sources
Watershed-based Solutions to Increase Resilience to Harmful Algal Blooms in Santuit Pond in a Warmer and Wetter Climate

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1 Introduction

This technical memorandum summarizes current water quality conditions in Santuit Pond, watershed characteristics and pollutant sources, and preliminary recommendations regarding measures to address watershed sources of nutrient and sediment contributions to the pond. The summary of current pond and watershed characteristics is based on information from prior studies of the pond and watershed including the 2010 Santuit Pond Diagnostic Study,[1] updated to reflect more recent water quality assessments, land use and resource mapping, municipal drainage system mapping, and other information provided by Town staff. The existing information and data sources used in developing this memorandum are summarized in a previous technical memorandum prepared for Task 1 (Compilation and Review of Existing Data) and described in more detail below.

The memorandum also reflects the findings and recommendations of field assessments of the Santuit Pond watershed completed in November 2021 to further evaluate known or suspected watershed pollutant sources, the feasibility of potential stormwater retrofits, and areas targeted for non-structural source control measures and residential Low Impact Development (LID) practices.

This memorandum is the deliverable from Task 2 (Characterization of Watershed Pollutant Sources) for the ongoing FY22 MVP Action Grant project examining watershed-based solutions to increase resilience to Harmful Algal Blooms in Santuit Pond under changing climate conditions.

2 Background

2.1 Santuit Pond Diagnostic Study (2010)

In 2009, the Town of Mashpee contracted with AECOM to conduct a diagnostic/feasibility study of Santuit Pond to document pond conditions and to characterize and quantify the sources of excess nutrient levels in the pond, which are responsible for degraded water quality that impacts the ability of the pond to support

[1] Santuit Pond Diagnostic Study, Mashpee, Massachusetts, prepared for Town of Mashpee by AECOM, July 19, 2010. https://www.mashpeema.gov/sites/g/files/vyhlif3426/f/uploads/santuitpondreportfinalv2.pdf

contact recreation and aquatic life. Excess nutrient levels in the pond have resulted in low water transparency, frequent harmful algal blooms of cyanobacteria (i.e., cyanoHABs), and low dissolved oxygen in bottom waters. The findings of the diagnostic/feasibility study are documented in a 2010 Santuit Pond Diagnostic Study report.[1]

The 2010 Diagnostic Study report provides an overview of the pond's history and water quality condition, provides estimates of internal and external phosphorus loading sources from the pond and watershed, and suggests an in-lake phosphorus target to address Total Maximum Daily Load (TMDL) requirements that have been established. The report found that the majority (78%) of the annual phosphorus load to Santuit Pond is from internal recycling (i.e., phosphorus release from accumulated sediments at the bottom of the pond into the water column), with surface runoff and groundwater sources (i.e., external or watershed loads) contributing 5% and 3% of the annual phosphorus load, respectively. Septic systems were estimated to account for 5% of the annual phosphorus load to the pond.

The study recommends a phosphorus management strategy focused on both internal and external phosphorus sources through in-pond and watershed restoration actions, with the goal of improving water quality to minimize the frequency of algal blooms and to better support recreational uses and aquatic life. The report recommended several in-lake phosphorus reduction strategies including dredging, artificial circulation, and phosphorus inactivation. External source reduction measures recommended in the 2010 Diagnostic Study report include improved stormwater management, reduced fertilizer use, vegetated buffers, septic system maintenance and upgrades, cranberry bog best management practices, and waterfowl control. The report identified the following specific locations for installation of structural stormwater controls to reduce stormwater-related phosphorus loads:

1) The Town Landing access road and parking area
2) Non-bermed areas of Timberlane Drive
3) Locations in the Briant's Neck neighborhood
4) Beechwood Point Drive
5) Cranberry Lane.

2.2 Ongoing and Planned Actions to Address Santuit Pond Water Quality

The Town of Mashpee, the Mashpee Wampanoag Tribe, and other partner organizations have undertaken or are planning a variety of short-term and long-term actions consistent with the recommendations of the 2010 Diagnostic Study report to reduce internal and external loadings of nutrients to Santuit Pond and the impaired downstream receiving waters, including the Santuit River and Popponesset Bay.

Ongoing actions or short-term actions planned to be completed within the next 5 years are focused on reducing external watershed sources as well as interim in-pond strategies until longer-term in-pond measures can be implemented. These actions include:

- In-Pond Aeration – In 2012, the Town of Mashpee in conjunction with Friends of Santuit Pond and other project partners purchased and installed in-pond "SolarBee" aerator units at 6 locations throughout Santuit Pond. The units serve to aerate and circulate water in the pond during the summer months, thereby increasing dissolved oxygen levels in the pond and limiting release of phosphorus from bottom sediments to the water column. While the SolarBees have been successful at mitigating the influence of internal phosphorus loading during the summer months, rainfall events often trigger harmful algal blooms of cyanobacteria. Heavy precipitation events in 2017 and 2019 have been reported to mobilize excess nutrients to the pond via stormwater runoff, overwhelming the Town's remedial efforts and reactivating the toxic cyanobacteria blooms in this eutrophic system.[2]

- Chemical Treatment – The Town of Mashpee proposes the use of algaecide to control milfoil and other invasive aquatic weeds prevalent in Santuit Pond.

- Lawn Fertilization – The Town of Mashpee will institute a bylaw banning the use of lawn fertilizer around the periphery of all waterbodies. This "no fertilizer" zone will extend 300 feet from the shoreline of all fresh and marine waters. Controlling lawn fertilizer runoff will reduce the flow of nutrients to Santuit Pond and other waterbodies in Mashpee.

- Stormwater Retrofits – The Town of Mashpee Department of Public Works has installed infiltrating catch basins and other similar structural stormwater controls to capture and infiltrate stormwater runoff from portions of roads in the neighborhoods surrounding Santuit Pond.

- Town Enforcement of Septic System Maintenance – The Town of Mashpee is increasing efforts to enforce required inspections of septic systems within the Santuit Pond watershed, particularly those systems located within 300 feet of the pond, only half of which are being inspected and pumped regularly, according to a recent survey. In September 2021, the Mashpee Select Board and Board of Health ordered septic inspections and pumpings for 121 abutters whose property falls within 300 feet of Santuit Pond.

- MVP Action Grant Project – In 2021, the Town of Mashpee received an MVP Action Grant from the Massachusetts Executive Office of Energy and Environmental Affairs for a multi-pronged project to increase the resilience of Santuit Pond to a warmer and wetter climate. The ongoing project, which is the subject of the work described in this technical memorandum, will develop concept designs for nutrient pollution reduction at key wet weather input locations around Santuit Pond including the design and permitting of one project, provide recommended changes to municipal bylaws to reduce nutrient impacts, and implement a public education and outreach program.

- SNEP Network Technical Assistance – Also in 2021, the Mashpee Wampanoag Tribe was selected to receive technical assistance from the Southeast New England Program (SNEP) Network to provide training and evaluate and implement measures to address nutrient pollution in Santuit Pond. The project includes a feasibility study of interim measures to address water column phosphorus, development of a Watershed Based Plan for Santuit Pond, and development of stormwater retrofit designs.

[2] Municipal Vulnerability Preparedness (MVP) Workshop Summary of Findings Report, prepared for Town of Mashpee by Woods Hole Group, January 2020.

- Alum Treatment – Addition of aluminum sulfate, called alum, to lake or pond water can be used as a method to reduce release of phosphorus from bottom sediments into the water column. When alum is added to water it removes phosphates through precipitation, forming a heavier than water particulate known as a "floc." The floc settles to the pond bottom, creating a barrier to phosphorus release. Alum treatments typically are effective for 5 to 15 years (Welch and Cooke 1999). Given that the analysis of the pond bottom sediment, which indicated limited options for beneficial reuse or other upland disposal, may be cost-prohibitive at this time making dredging infeasible in the short-term (see dredging discussion below), the Town is moving forward with assessment of the necessary dosing for alum treatment in 2022

Long-term actions are those actions that are planned to be implemented over the next 10 years or more to address internal phosphorus recycling and eliminate septic systems as a major source of nutrients to the pond. Long-term actions include:

- Sewering – The Town of Mashpee is planning to replace on-site septic systems and cesspools with sewer collection and wastewater treatment that will be implemented over the next 10 to 20 years. The Town proposes to include the Santuit Pond area in its approved Phase 2 Plan. The implementation of sewer collection and treatment will address the major controllable loads of nitrogen to the coastal waterbodies in Mashpee as well as phosphorus sources from septic systems in close proximity to Santuit Pond and other freshwater ponds in Mashpee.

- Pond Dredging – The U.S. Army Corps of Engineers is evaluating the overall feasibility, costs, and benefits of dredging of accumulated, phosphorus-rich sediments from the bottom of Santuit Pond, which has been identified as the major source of phosphorus (78% of the annual load) to the pond through phosphorus recycling. Analysis of sediment samples collected as part of the USACE study indicated elevated levels of arsenic that are anticipated to limit options for reuse of dredged material and make disposal of the dredged material cost prohibitive. Until such time that financial support for dredged material management is identified, the Town, Mashpee Wampanoag Tribe, and partner organizations will focus on other potential interim measures to control nutrients and manage the ongoing water quality problems and public health threats caused by harmful algal blooms such as alum treatment.

- Cranberry Bog Management – The two remaining cranberry bogs that were active at the time of the 2009/2010 Diagnostic Study, Baker's Bog on the north shore and Brackett's Bog on the east shore, have been abandoned as active cranberry growing operations. In 2002, the Town of Mashpee purchased the historic cranberry bogs on the east and south shores of Santuit Pond in a 200-acre acquisition called the "Santuit Pond Preserve." The Town also received state funding in 2021 for a feasibility evaluation and concept development for a cranberry bog restoration project on the 11.7-acre Chop Chaque Bog on the eastern shore of Santuit Pond. The restoration project, if constructed, would potentially help to improve water quality in Santuit Pond and downstream areas by retaining nutrients and floodwaters.

3 Historic Conditions

A decline in water quality in the 170-acre Santuit Pond was initially noted in the 1990s when algal blooms were observed in the summer months and increased in frequency and duration over the following decades.[1] Changes in water quality coincided with an overall increase in population and development on Cape Cod, in Mashpee, and in the Santuit Pond watershed.[3]

3.1 Water Quality

In the 2010 Diagnostic Study of Santuit Pond,[1] historic reports of water quality going back to the 1930s indicated a well-mixed and oxygenated shallow pond. In 1948, growth of "pond weed" was noted over the entire pond bottom.[4] In 1980, the Massachusetts Division of Water Pollution Control noted elevated concentrations of phosphorus at both the surface and bottom of the Santuit Pond water column and also noted anoxic conditions below 2 meters (6.6 feet) and classified the pond as "mesotrophic" or moderately enriched.

The University of Massachusetts Dartmouth Cape Cod Pond and Lake Stewardship program (PALS) began volunteer water quality monitoring in 2000 and recorded elevated phosphorus concentrations, decreased water clarity, and increased chlorophyll a concentration. All of these factors point to a transition from an aquatic macrophyte dominated pond to an algal dominated one.[1]

In 2009, in response to chronic cyanobacteria blooms, the Massachusetts Department of Public Health (MDPH) included Santuit Pond as part of its Centers for Disease Control and Prevention-funded survey of cyanobacteria blooms in Massachusetts. From June 2009 through October 2018, MDPH collected 84 water quality samples for algal identification and enumeration. Median, mean, and maximum cyanobacteria cell counts over the period of time were 53,100; 58,129; and 278,800 cells per milliliter of water (cells/ml). Since 2008, MDPH has recommended that access to recreational waters be restricted when a visible scum or mat is present, the total cyanobacteria cell count exceeds 70,000 cells/ml, or the concentration of the algal toxin microsystin exceeds 14 parts per billion (ppb). Approximately 24% of the samples collected by MDPH from 2009-2018 exceeded the criteria based on cyanobacteria cell count.

3.2 Watershed and Pond Characteristics

The changes in water quality described above are no doubt a reflection of the changes in land use in the watershed surrounding the pond. As Figure 1 shows, population growth and development in Mashpee, which started in the 1960s, increased dramatically in the period 1980-2000, with a decrease and flattening of the growth curves after approximately 2005.

Within the Santuit Pond watershed, the changes in land use, especially immediately adjacent to the pond are evident in an examination of aerial photography from 1952 through 2014 (Figure 2). While residential development on the northwestern shore of Santuit Pond was barely evident in 1952 and somewhat increased

[3] Cape Cod Area Wide Water Quality Management Plan Update, Cape Cod Commission, June 2015.
[4] Santuit Pond Description, Mashpee/Barnstable, Barnstable County Cape Cod Watershed, Massachusetts Division of Fisheries and Wildlife, March 2007.

in extent in 1971, explosive residential grown on both the western and eastern sides of Santuit Pond occurred from 1971 to 1994. Development has been relatively stable from 1994 to the present, with little increase in additional development immediately adjacent to the pond.

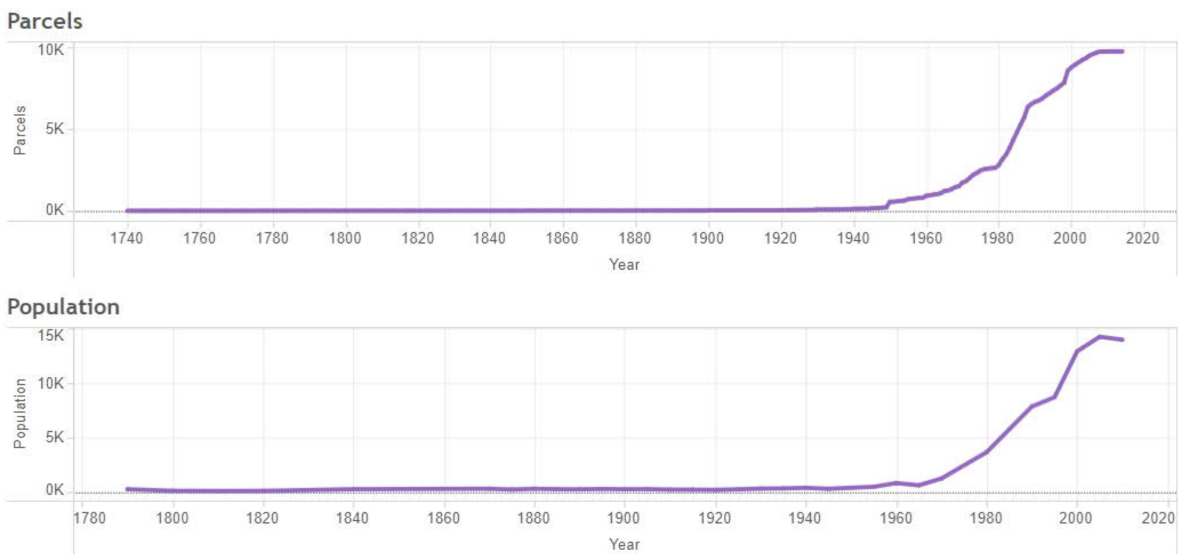

Figure 1. Parcel Count and Population Growth in Mashpee, MA
Source: Cape Cod Commission Chronology Viewer
(https://ww2.capecodcommission.org/chronology/)

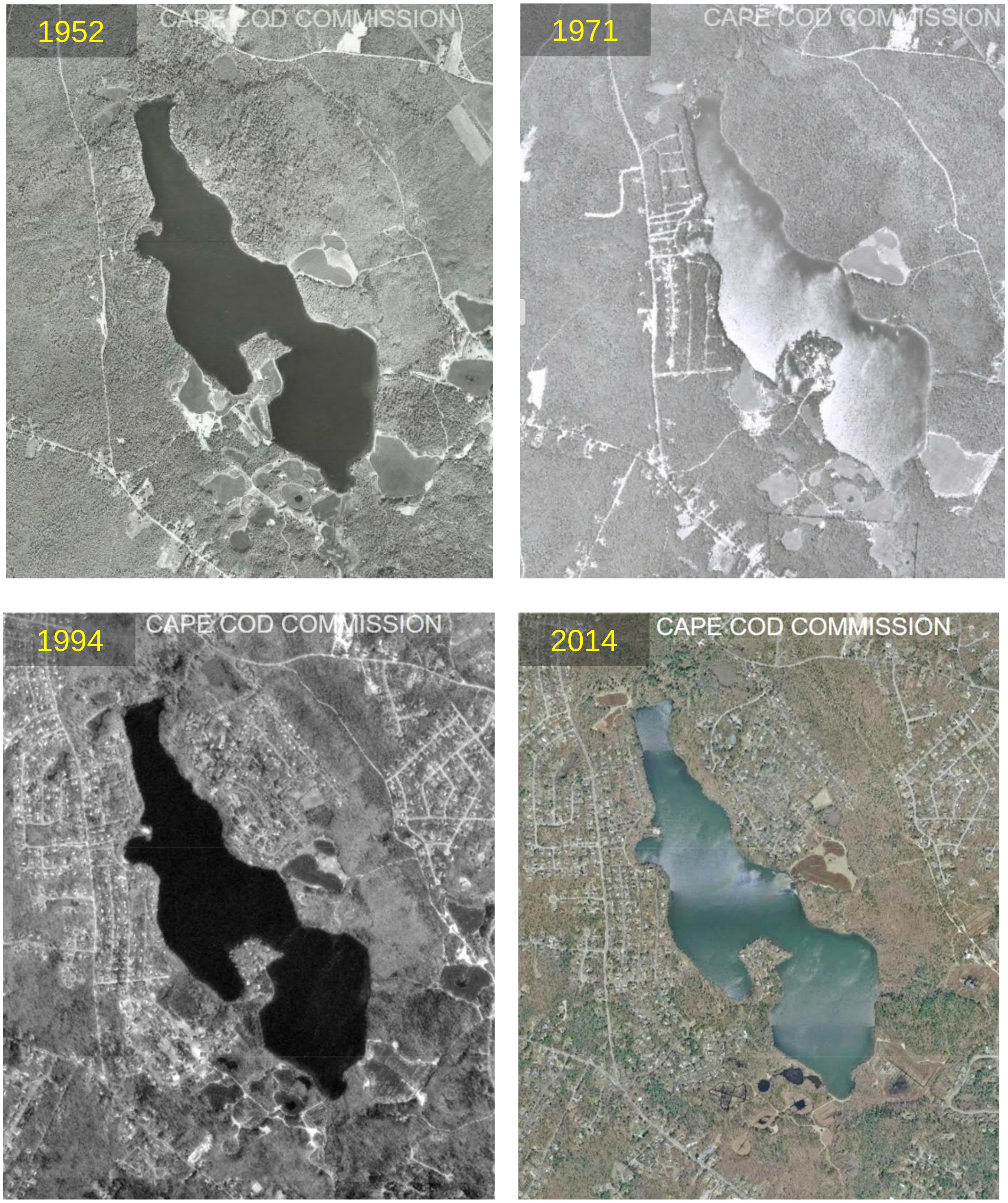

Figure 2. Aerial Views of the Santuit Pond Area Showing Development Between 1952 and 2014
Source: Cape Cod Commission Chronology Viewer (https://ww2.capecodcommission.org/chronology/)

4 Current Water Quality Conditions

4.1 Water Quality Impairments

In compliance with the Federal Clean Water Act (CWA), the Massachusetts Department of Environmental Protection (MADEP) must monitor and assess the quality of its surface and groundwater and provide periodic status reports to the U.S. Environmental Protection Agency (EPA), the U.S. Congress, and the public. Specifically, Section 305(b) of the CWA requires that waters are evaluated with respect to their capacity to support designated uses as defined in each of the states' surface water quality standards (SWQS). These uses include aquatic life support, fish and shellfish consumption, drinking water supply, and primary (e.g., swimming) and secondary (e.g., boating) contact recreation.[5] The latest report, the Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle (Integrated List), identifies Santuit Pond as impaired and requiring the development of a Total Maximum Daily Load or TMDL, which is a calculation of the maximum amount of a pollutant that a waterbody can accept and still meet water quality standards and provide a starting point for identifying ways to reduce the pollutants that are impacting water quality and causing the impairments observed.

In the Integrated List,[5] Santuit Pond water quality impairments are identified as high chlorophyll-a concentrations, presence of harmful algal blooms, elevated nutrients causing eutrophication, high pH, high phosphorus, and reduced total transparency/clarity. In addition, barriers to fish passage and abnormal fish deformities, erosions, lesions (DELTS) are noted in the Integrated List.[5]

4.2 Water Quality Summary

As discussed in Section 3.1, increased nutrient levels in Santuit Pond were noted in the 1980s and the pond was characterized as mesotrophic. Water quality conditions in the pond declined over the following four decades and water quality characteristics in the pond indicate that it is eutrophic/hypereutrophic. Eutrophic waterbodies are characterized by high concentrations of nutrients, low light penetration due to both rooted aquatic plants and algal blooms. Fish tend to be warm-water fish, but fish populations may be impacted by low dissolved oxygen levels, especially in summer (warm weather) (Gibson et al., 2000). Hypereutrophic waterbodies have even higher nutrient levels and lower light penetration that eutrophic waterbodies and represent the extreme of nutrient-impacted lakes and ponds.

Bi-weekly cyanobacteria water quality sampling in Santuit Pond is currently conducted during the warm weather season (approximately Memorial Day to late fall) by the Town of Mashpee and the Association to Preserve Cape Cod. Recent nutrient water quality sampling was conducted in 2018 and 2020 by the Cape Cod Ponds and Lakes Stewardship (PALS) Program.

In 2021, the Mashpee Department of Natural Resources characterized Santuit Pond as having the most impacted water quality of the five major ponds in Mashpee. Algal blooms are reported continuous throughout the warm-weather season, with an average cyanobacteria cell count of 70,475 cells/ml for the

[5] Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle, Massachusetts Department of Environmental Protection, November 2021.

period May 30, 2021 to November 3, 2021. The maximum 2021 cyanobacteria cell count was 169,288 cells/ml on August 25, 2021.

Water quality sampling for nutrient concentrations by PALS also indicated elevated and increasing nutrient concentrations. 2020 total nitrogen concentrations were reported as 1,129 ug/L and 1,222 ug/L in samples collected at the surface (0.5 m) and mid-water (2 m) column, respectively. Total phosphorus concentrations in 2020 were reported as 41.5 ug/L and 42.7 ug/L at the surface and mid-water column, respectively. Note that values above 24 ug/L of total phosphorus are typically considered indicative of eutrophic waters.

In summary, sampling for nutrients and cyanobacteria as well as visual evidence of water quality indicates continuing impacts to water quality in Santuit Pond. Continued nutrient loading to the pond from internal and external/watershed sources will further exacerbate the eutrophic conditions in the pond.

4.3 Climate Change Impacts and Future Water Quality

CyanoHABs are found in waterbodies with excess nutrients, especially phosphorus, combined with conditions of warm, still waters. Recent work by Ho and Michalak[6] found that summer temperatures drive total phytoplankton abundance and that the length of the summer drives cyanobacterial abundance. Projected climate change is anticipated to exacerbate cyanoHABs in the United States due to increased temperatures over a longer period of time combined with increases in both total precipitation and precipitation intensity, which favors runoff generation and subsequent transport of sediment and nutrients to receiving waters.

Projections for southeastern Massachusetts from the Northeast Climate Science Center at the University of Massachusetts Amherst (https://www.resilientma.org/) show that given a medium to high future emissions pathway, Mashpee could see as much as 2 inches of additional rainfall per year by the end of the century and average summer temperatures are expected to increase approximately 3-5 degrees by mid-century with average summer temperatures approximately 5-9 degrees higher than current conditions by the end of the century. In addition, the number of growing degree days, which can serve as a proxy for conditions that favor bloom formation, are projected to increase under a moderate emissions scenario (RCP4.5) by as much as 26% by the 2050s and by 69% by the 2090s under a high emissions (RCP8.5) scenario. Also important for the generation of runoff and the transport of nutrients into Santuit Pond is the number of days of precipitation over 1 inch, as well as the total amount of precipitation falling in the heaviest 1% of rainfall events (Figure 3), which is expected to continue to increase according to ResilientMA.org and the 4th National Climate Change Assessment.

The results of recent research funded by the U.S. EPA, shows that New England is anticipated to experience an increase in number of days with blooms sooner than other areas of the U.S.[7] While temperature change cannot be controlled, the secondary impacts of increased rainfall and rainfall intensity can be mitigated

[6] Exploring temperature and precipitation impacts on harmful algal blooms across continental U.S. lakes. Jeff Ho and Anna Michalak. 2019. Limnology and Oceanography. 65, 2020, 992-1009.
[7] Climate Change Impacts on Harmful Algal Blooms in U.S. Freshwaters: A Screening-Level Assessment. Steven C. Chapra, Brent Boehlert, Charles Fant, Victor J. Bierman, Jim Henderson, David Mills, Diane M. L. Mas, Lisa Rennels, Lesley Jantarasami, Jeremy Martinich, Kenneth M. Strzepek, and Hans W. Paerl. Environmental Science & Technology 2017. 51 (16), 8933-8943.

through stormwater controls, offering an adaptation measure to provide resilience to anticipated climate change.

As discussed above, phosphorus sources are a mix of internal and external sources and addressing both is part of a long-term solution to improving water quality. However, only addressing internal loading is a short-term solution since reduction and/or elimination of external loads is critical to reduce the introduction of additional phosphorus to the waterbody. While the majority of the existing annual load of phosphorus to Santuit Pond comes from internal recycling of nutrients, the 2010 Diagnostic Study[1] concluded that "addressing the internal load without reducing external loading…will result in re-accumulation of phosphorus in sediments over time and future internal loading." While the Town has been able to mitigate the influence of internal loading during the summer months through the use of in-pond aeration, rainfall events often trigger a cyanoHAB event. Heavy precipitation events in 2017 and 2019 have been reported to mobilize excess nutrients to the pond via stormwater runoff (Figure 4), overwhelming the Town's remedial efforts and reactivating the toxic cyanobacteria blooms in this eutrophic system (MVP Workshop Summary of Findings Report, January 2020). This situation is expected to become more frequent due to projected climate change.

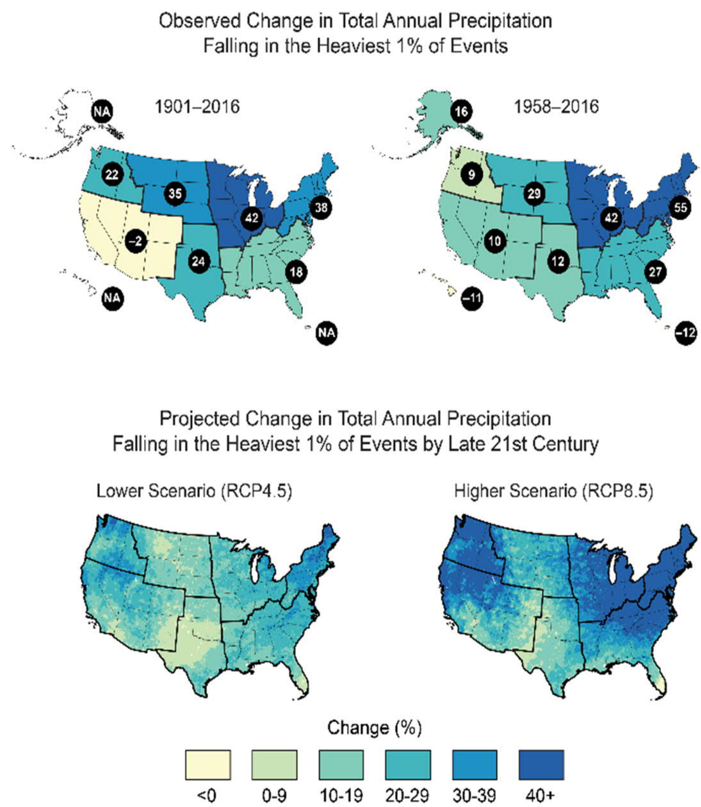

Figure 3. Observed and Predicted Extreme Precipitation (4th National Climate Assessment https://nca2018.globalchange.gov/chapter/2/)

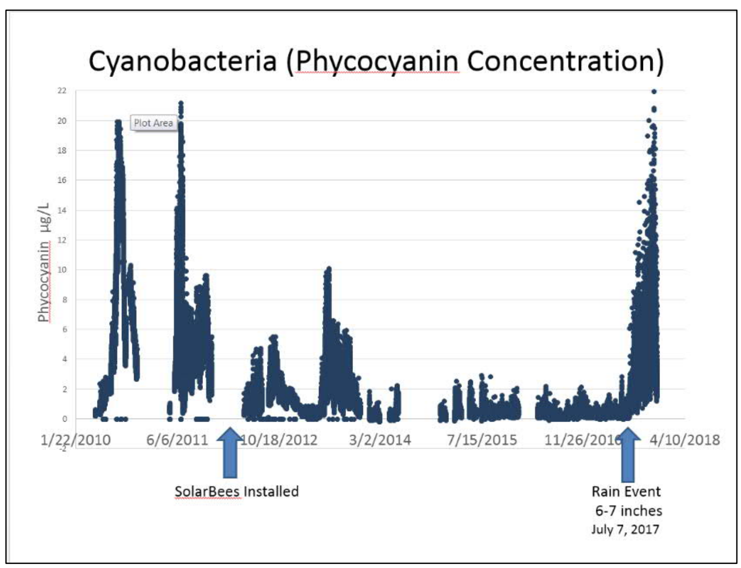

Figure 4. Cyanobacteria concentrations in Santuit Pond between 2010 and 2018 showing initial reductions in cyanoHABs following installation of in-pond aerators (SolarBees) and more recent cyanoHABs following major rain events (July 7, 2017 storm).

5 Current Watershed Conditions

This section summarizes the current physical characteristics, land uses, and relevant infrastructure in the Santuit Pond watershed. The summary of current watershed conditions builds upon information presented in the 2010 Santuit Pond Diagnostic Study Report, which has been updated to reflect existing GIS data layers and other watershed characteristics, including observations from the November 2021 field assessments described in Section 7 and interviews with Town staff.

5.1 Santuit Pond Description

Santuit Pond is a 170-acre shallow kettle hole pond[8] located in the northeast portion of the Town of Mashpee, situated between Mashpee and Wakeby Ponds to the west and the town boundary with Sandwich to the north and Barnstable to the east. The freshwater pond is classified as a Great Pond, which is a pond that contained more than 10 acres in its natural state, with a maximum depth of 9 feet, an average depth of 5 feet, and an average flushing rate of 3 times per year. Santuit Pond supports a variety of recreational uses (boating, fishing, swimming) and ecological functions, and also holds cultural significance to the Mashpee Wampanoag tribe.

There is substantial residential development along the eastern and western sides of the pond, including the Briant's Neck neighborhood which is situated on a peninsula that extends into the center of the pond. The Mashpee Town Landing public boat launch, which is used for fishing and boating, is located off of Timberlane Drive on the western shore of Santuit Pond. Former cranberry bogs, several of which are now part of preserved conservation land, are situated around the north, east, and south shores of the pond.

There are no major stream inlets to Santuit Pond because of the high permeability of the soils in the watershed. Most incoming water reaches the pond as groundwater inflow or direct precipitation. Stormwater runoff primarily from impervious surfaces also discharges to the pond in some areas. The pond's only outlet, located at the southern end of the pond, consists of a dam, which partially maintains water levels in the impoundment, and a fish ladder. The pond discharges to the Santuit River (also known as the Cotuit River), which supports an important herring run and flows south to Popponesset Bay, ultimately joining Nantucket Sound on the southern side of the Lower Cape Cod peninsula. Figure 5 shows the location of Santuit Pond within the Town of Mashpee and the larger regional context.

As described in greater detail in Section 4, Santuit Pond is a nutrient enriched (eutrophic) pond with high phosphorus concentrations and reduced water clarity, and experiences regular occurrences of harmful algal (cyanobacteria) blooms. In addition to the water quality impairments within the pond itself, water quality in the tidal portion of the Santuit River is impacted by elevated levels of fecal indicator bacteria (fecal coliform), and Popponesset Bay water quality is impacted by excess nitrogen loadings.

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[8] As glaciers retreated from Cape Cod, large chunks of ice were left behind. As these chunks of ice melted, the landscape above them collapsed, forming large depressions called kettle holes. Where these depressions dip below the groundwater table, they are filled with water and create the hundreds of ponds that exist on Cape Cod today (Cape Cod Area Wide Water Quality Management Plan Update, Cape Cod Commission, June 2015).

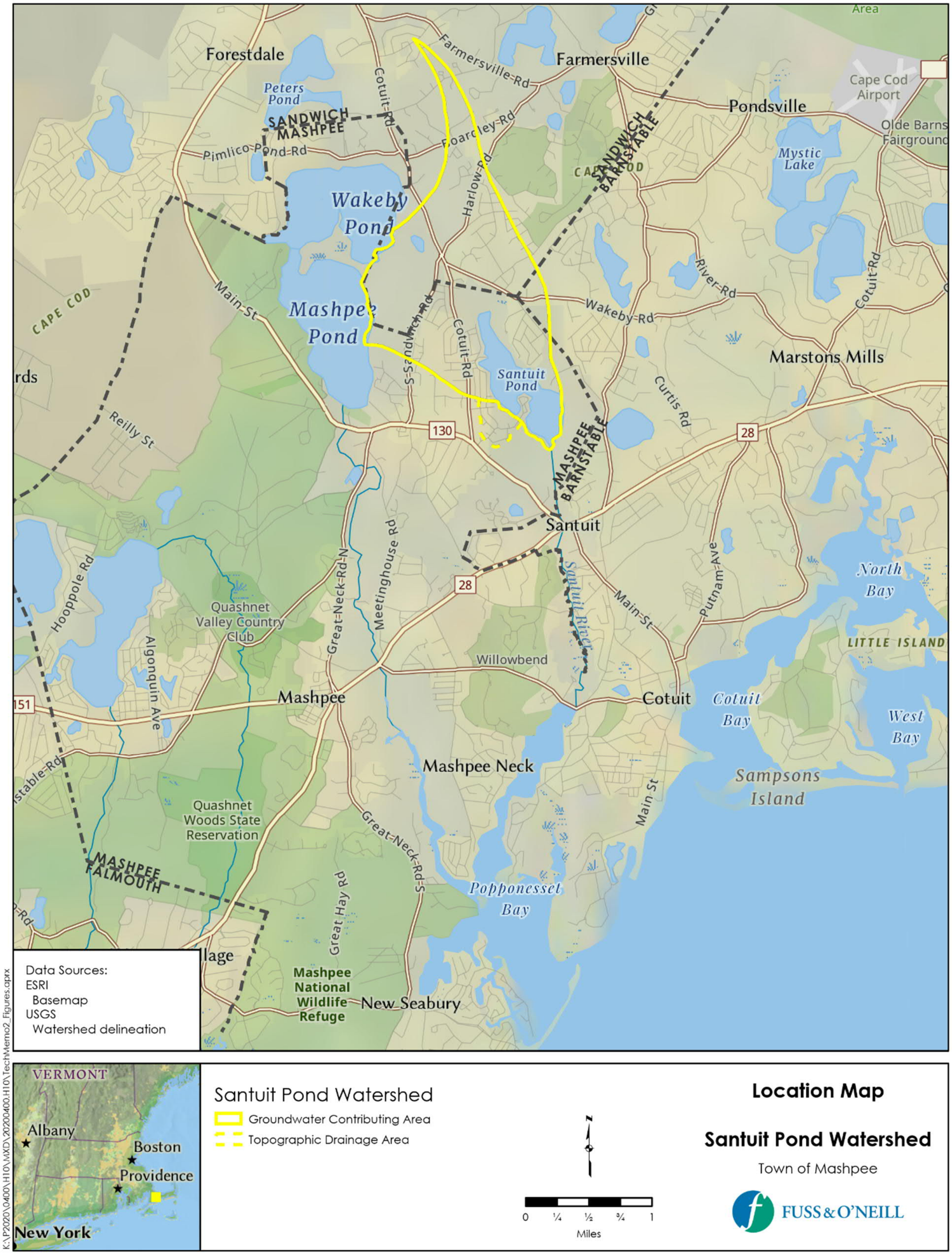

Figure 5. Santuit Pond Watershed Regional Context

5.2 Watershed Description

In general, subwatersheds on Cape Cod are determined not by the topography of the land, but by the elevation and flow direction of groundwater. Santuit Pond is located in the Sagamore Flow Lens, the largest of six groundwater flow lenses that comprise the Cape Cod Aquifer. In the area around Santuit Pond, groundwater generally flows in a southeasterly direction toward Popponesset Bay and Nantucket Sound. The Santuit Pond watershed is defined as: 1) the area of land where precipitation recharges groundwater (via infiltration) that eventually flows to the pond, 2) the pond water surface itself (which receives direct precipitation), and 3) the land area around the pond that contributes surface runoff via storm drainage systems or direct overland flow before it has a chance to infiltrate into the soil.

The Santuit Pond watershed was previously delineated by MassDEP based on groundwater contours and groundwater flow directions. The groundwater-based watershed boundary, which was used in the 2010 Santuit Pond Diagnostic Study and more recently in the Massachusetts Watershed Based Plan web application,[9] is shown as a solid yellow line in Figure 6.

The impervious surfaces (i.e., roads and driveways) within the pond's topographic drainage area but outside the groundwater contributing area are additional potential sources of stormwater runoff to the pond when they are hydrologically connected to the pond via stormwater outfalls, ditches, or other concentrated flow channels, or direct overland flow. The groundwater-based watershed boundary for Santuit Pond was modified slightly to include an additional 51-acre area on the southwest side of the pond, as delineated by the yellow dashed line on the map in Figure 6. This area encompasses the western portion of Shields Road, Tobisset Street, Nobska Road, and Pequot Road and the associated residential lots. The impervious surfaces within this area likely contribute stormwater runoff to Santuit Pond or the wetlands directly adjacent to the pond, which are believed to be hydraulically connected to the pond. Therefore, this additional 51-acre area is included as part of the Santuit Pond watershed and is shown on the watershed maps in this technical memorandum.

The Santuit Pond watershed (inclusive of the additional "topographic" drainage area described above) encompasses a land area of approximately 1,430 acres (including the 170-acre pond). Roughly 46% of the watershed (694 acres) lies within the Town of Mashpee and 50% (748 acres) is within the Town of Sandwich to the north. Approximately 3% of the watershed land area (42 acres) is located within the Town of Barnstable along the eastern limits of the watershed.

[9] Massachusetts Watershed Based Plan web application, Massachusetts Department of Environmental Protection and Geosyntec Consultants, https://prj.geosyntec.com/MassDEPWBP

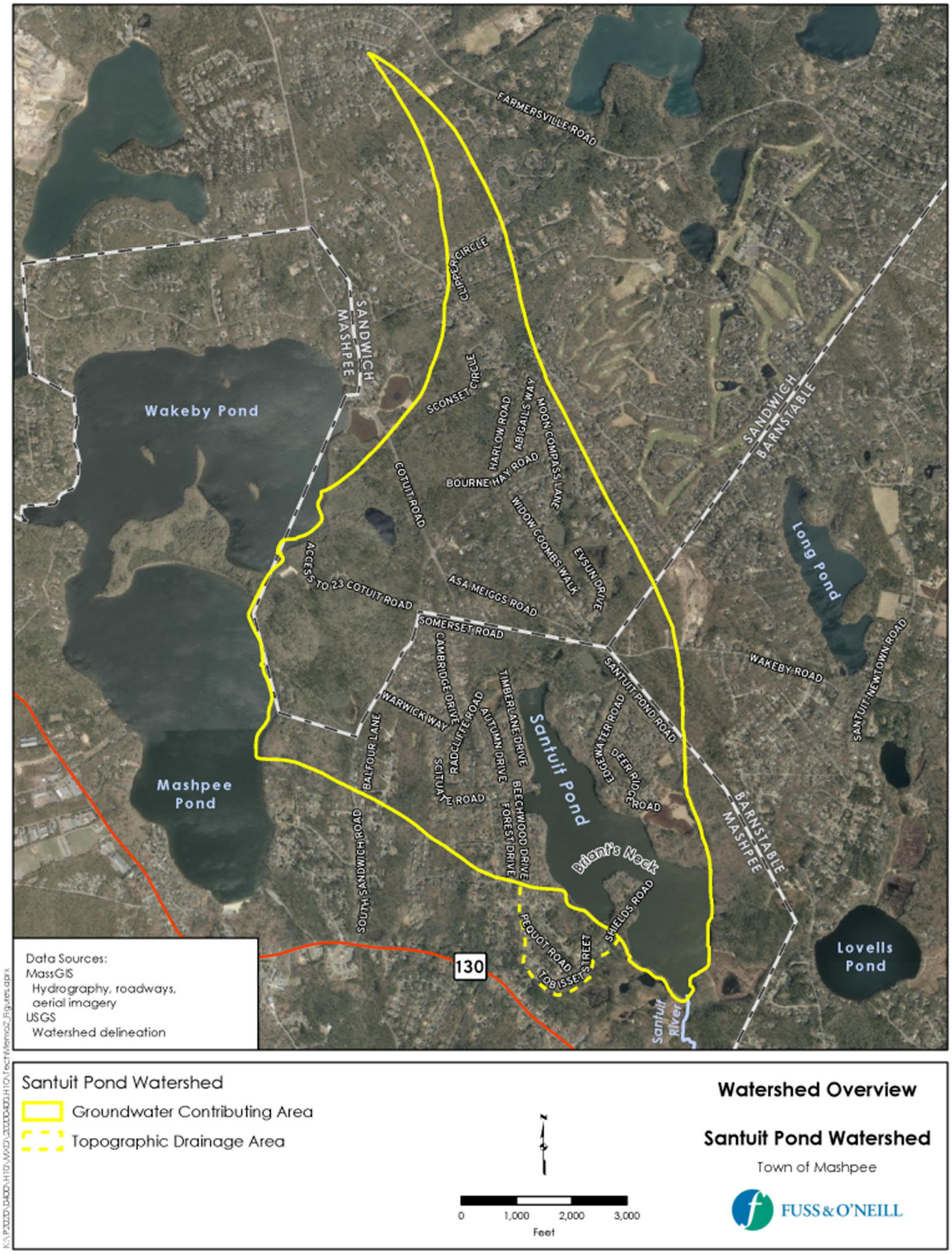

Figure 6. Santuit Pond Watershed

5.3 Land Use

The map in Figure 7 shows existing land use in the Santuit Pond watershed. The land use data is from the statewide dataset containing a combination of land cover mapping from 2016 aerial imagery and land use derived from standardized assessor parcel information for Massachusetts. Table 1 summarizes the percentage of each land use category within the watershed. Overall, the watershed is approximately 65% undeveloped, with developed land uses comprising approximately 23% of the watershed and open water (primarily Santuit Pond) accounting for approximately 12% of the area.

Table 1. Land Use Composition of the Santuit Pond Watershed

2016 Land Use	Percentage of Watershed	Acres
Undeveloped (65.2%)		
Deciduous Forest	24.22	359.2
Evergreen Forest	6.15	91.2
Open Space	27.16	402.7
Wetland	7.52	111.5
Grassland	0.15	2.2
Scrub/Shrub	0.03	0.4
Developed (22.5%)		
Single-Family Residential	12.71	188.4
Multi-Family Residential	0.70	10.4
Other Residential	0.04	0.6
Developed Open Space	0.51	7.6
Agriculture	2.40	35.6
Bare Land	0.06	0.8
Other Impervious	0.38	5.6
Right of Way	5.67	84.0
Water (12.3%)	12.32	182.8
Total	100.00	1,483.0

Undeveloped lands in the watershed consist primarily of forest, wetlands, municipal open space/conservation land, and historic cranberry bogs that are transitioning to wetlands. Residential development (primarily single-family residential) and the associated road network is the major developed land use in the watershed. Higher density residential development is concentrated on the east and west sides of the pond, with lower density residential in the northern portion of the watershed in Sandwich. Most of the residential development along the eastern and western shoreline of Santuit Pond is buffered by vegetated steep slopes. The residential neighborhoods surrounding the pond are 30-50 years old and are generally wooded with mature trees and moderate to high levels of lot and street tree canopy, which generates large amounts of leaf litter in the fall. Undeveloped forestland and forested wetlands are the predominant land uses adjacent to the north and south ends of the pond.

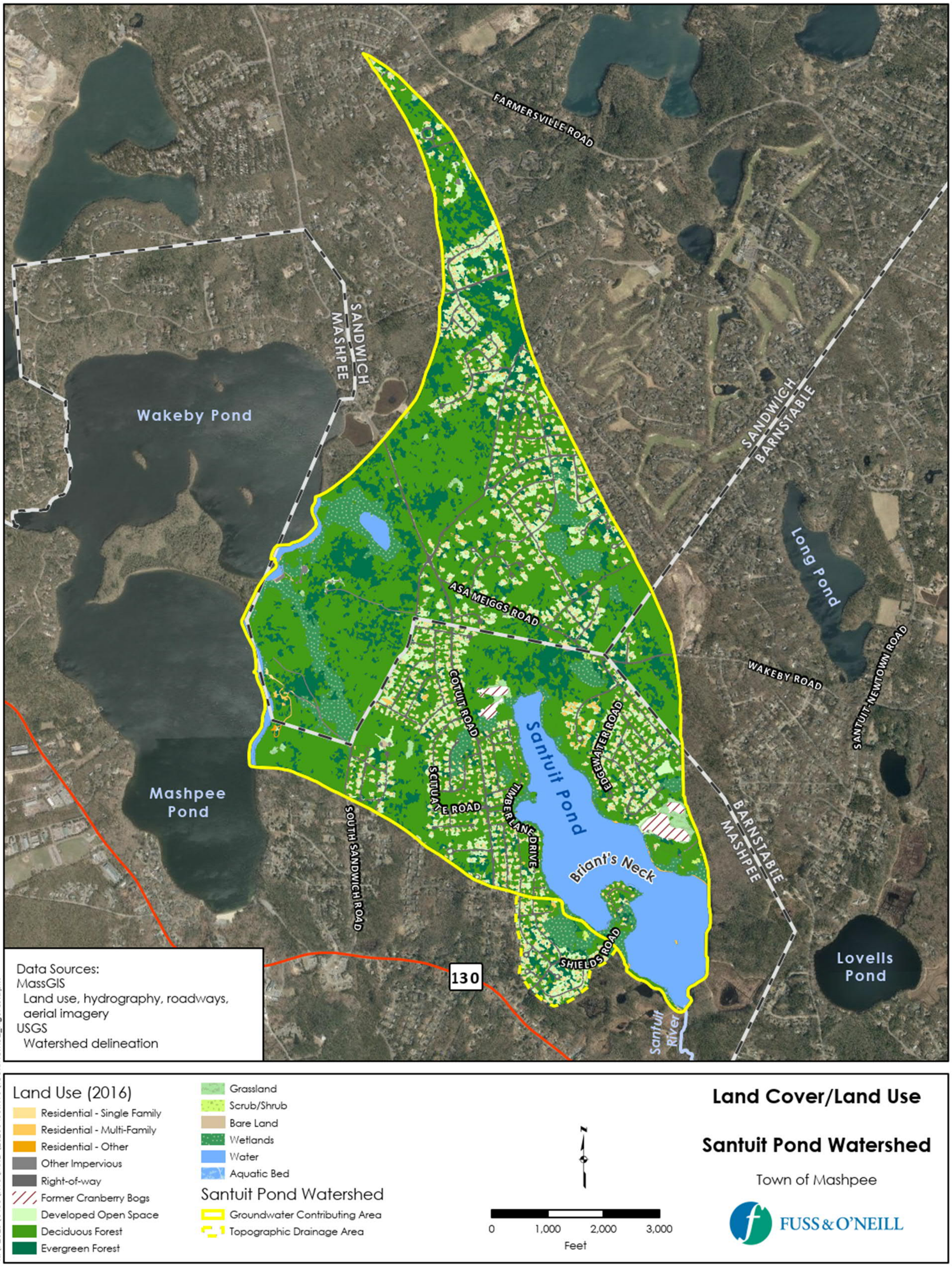

Figure 7. Land Cover-Based Land Use in Santuit Pond Watershed

Most of the roads in the watershed are owned and maintained by the watershed municipalities. There are several privately-owned and maintained roads immediately surrounding the pond, including Shields Court, the Briant's Neck neighborhood (Shields Road, Shields Lane, Santuit Lane, and South Shields Avenue), Santuit Pond Way in the Beechwood Point neighborhood, and the roads associated with the former Chop Chaque cranberry bog. A short segment of State Route 130 (Main Street) passes through the southwest corner of the watershed, while Cotuit Road, another primary north-south route, traverses the western half of the watershed.

5.4 Soils and Topography

The Santuit Pond watershed is characterized by well-drained sandy soils, which is typical of most soils on Cape Cod. The predominant USDA soil textural classifications are coarse sand, loamy coarse sand, fine sandy loam, and silt loam. These soils have high infiltration rates and low runoff potential, classified as Hydrologic Soil Group A and B soils (see Figure 8), with depth to water table of 6 feet or more. Due to the permeable nature of the soils, the vast majority of precipitation that falls on pervious surfaces in the watershed infiltrates into the ground and reaches the pond as shallow groundwater flow. Only overland flow within 300 feet of the pond is believed to contribute water to Santuit Pond,[1] with the exception of stormwater runoff from impervious surfaces that reaches the pond as channelized or concentrated flow and precipitation directly onto areas of poorly drained soils such as wetlands.

Most of the soils in the watershed are generally conducive to artificial recharge using stormwater infiltration systems and LID disconnection techniques (i.e., directing runoff from impervious surfaces to adjacent vegetated areas). Soils with very high infiltration rates, such as the sandy Cape Cod soils in the Santuit Pond watershed, typically have diminished ability to attenuate stormwater pollutants due to the relatively short contact time between the soil and infiltrated stormwater, lower soil adsorption potential, and a higher potential for rapid contaminant transport to groundwater. Use of vegetation and other treatment mechanisms prior to infiltration of stormwater into these sandy soils is important for adequate removal of phosphorus and nitrogen.

Soil erodibility – e.g., the susceptibility of a soil to sheet and rill erosion by water – varies across the watershed depending on the soil particle size, infiltration capacity, and the amount of fine-grained material present in the soil. The Santuit Pond shoreline areas have soils with low to medium soil erodibility. The residential neighborhoods along the western shoreline, which are characterized by fine sandy loam soils, have moderate erodibility, while areas of coarse sand have low erodibility. Larger areas of fine sandy loam soils, which are present in the residential neighborhoods north of the pond and in the residential areas along the watershed's western boundary, have moderate to high erodibility.

The topography of the watershed is characterized by glacial landforms, which were formed by terminal moraine and outwash plains. The watershed is relatively flat, with areas of undulating and low-rolling topography. Much of the area immediately surrounding Santuit Pond (a kettle hole pond) consists of steeply sloped residential lots or woodland, with the steepest areas (10-13 degrees or 17-23% slope) located along the eastern and western shoreline (Figure 9). Steep slopes (generally slopes of 15% or more) generate more runoff and faster, more erosive flows, increasing the potential for soil erosion especially in developed areas with erodible soils and little or no vegetation.

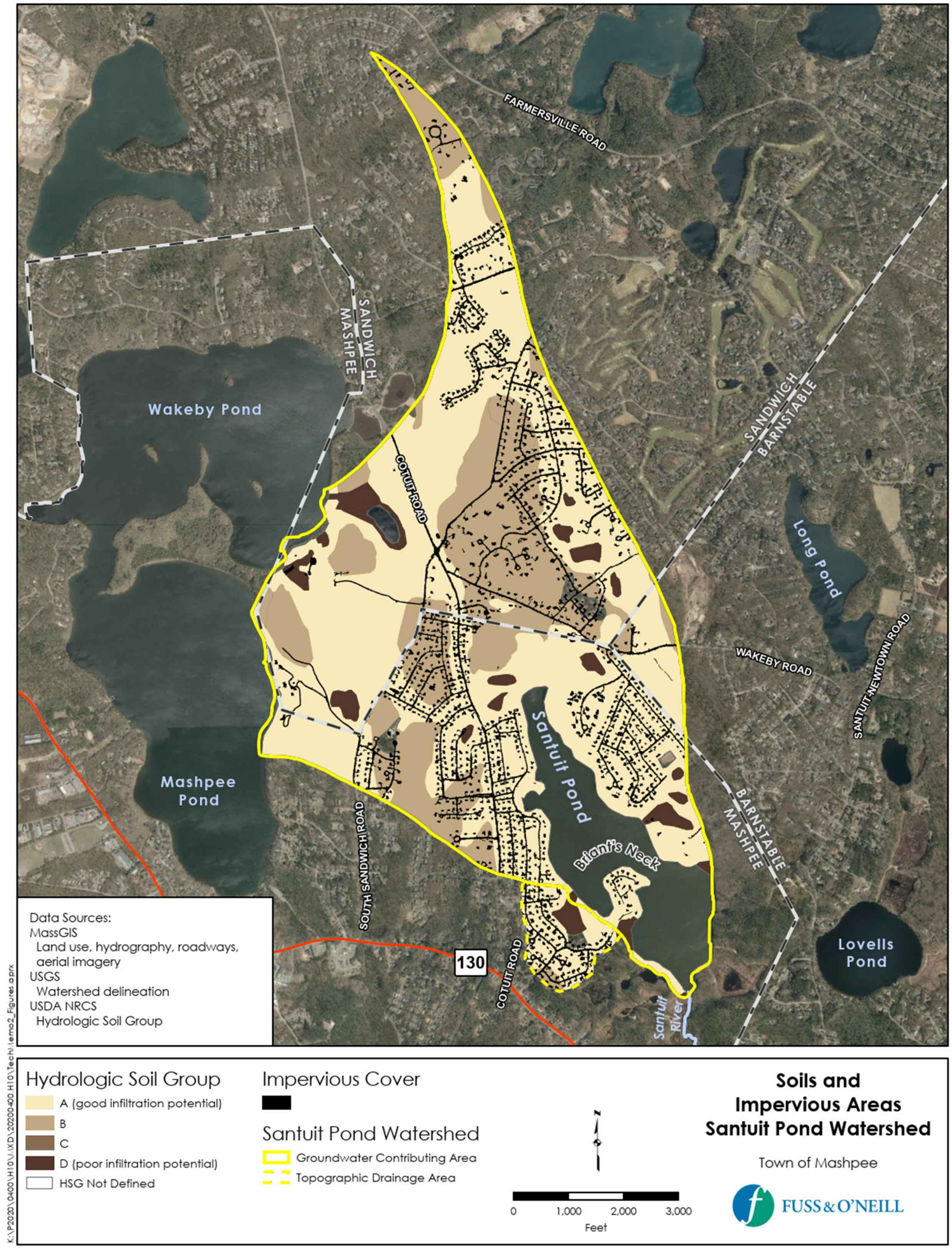

Figure 8. Hydrologic Soil Groups in Santuit Pond Watershed

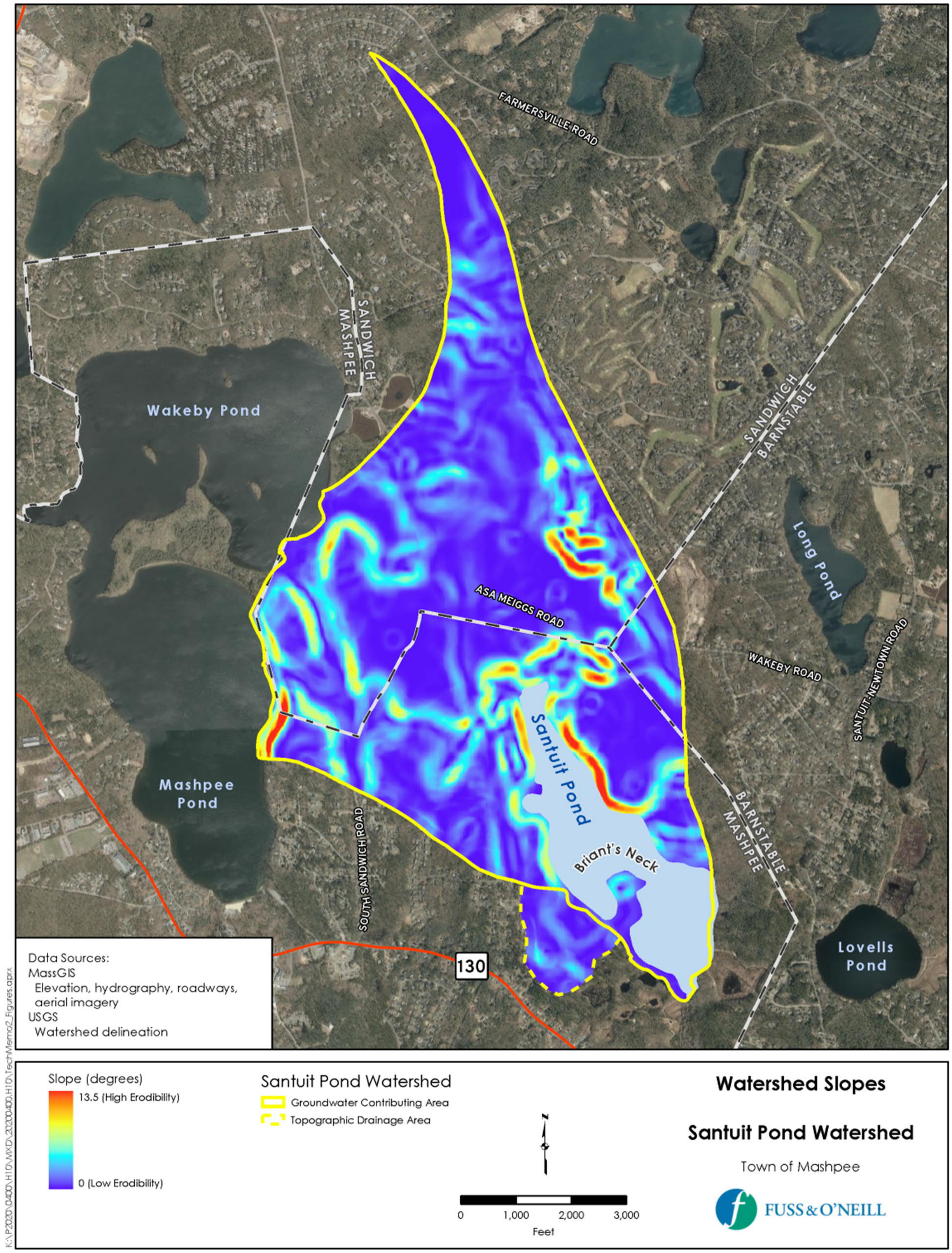

Figure 9. Santuit Pond Watershed Slope

5.5 Impervious Surfaces

Impervious cover is any impervious surface in the landscape that cannot effectively absorb and infiltrate rainfall including roads, parking lots, driveways, roofs, sidewalks, patios, and highly compacted soils. These surfaces disrupt the natural hydrologic cycle, increasing surface runoff and decreasing infiltration of rainfall into the soil. Runoff from impervious surfaces also mobilizes pollutants that build up on the land surface between storms and can cause erosion of exposed soils. Impervious cover is widely considered a key environmental indicator. A large body of scientific literature has shown that groundwater recharge and surface water quality measurably decrease as impervious cover increases.

Impervious surfaces account for approximately 10.6% of the entire land area in the Santuit Pond watershed (Figure 8), with higher percentages of impervious cover (20-30%) in the medium- and high-density residential neighborhoods surrounding the pond and other portions of the watershed. Most of these impervious surfaces consist of local roads and impervious features of residential lots (rooftops, driveways, walkways, patios, etc.). Given the permeable nature of the soils in the watershed, runoff from impervious surfaces that flows over adjacent pervious areas or is managed by stormwater recharge systems (infiltrating catch basins, underground infiltration systems, infiltration basins, etc.) effectively infiltrates into the ground and eventually discharges to the pond via groundwater but does not reach Santuit Pond as surface discharge. Therefore, the watershed's effective or "directly connected" impervious area – impervious area with a direct hydraulic connection to a storm drainage system or a waterbody – is much lower than the total impervious area.

As described previously, some impervious surfaces in the watershed contribute stormwater runoff to Santuit Pond or the wetlands directly adjacent to the pond via stormwater outfalls, ditches, concentrated flow channels, or other overland flow. Surface stormwater discharges to the pond are common during high-intensity rain events, when the ground becomes saturated and the resulting runoff bypasses the existing drainage system due to clogging or insufficient capacity of the storm drain inlets. These conditions also result in erosion of unvegetated areas along roads and portions of residential lots, transporting sediment and attached pollutants to the pond.

5.6 Stormwater Runoff

Stormwater runoff contributes sediment, nutrients, and other pollutants to Santuit Pond via surface discharge and shallow groundwater flow. Runoff from paved and unpaved roads is a source of sediment and attached phosphorus as well as dissolved nitrogen. Fertilizer containing phosphorus and nitrogen can be washed off of lawns and seep into the groundwater that feeds Santuit Pond or discharge directly to the pond as overland flow. Decomposing plant material such as grass clippings, yard waste, and the large amounts of leaf litter that is present in the watershed in the fall is another source of nutrients in stormwater runoff and leaching to groundwater. Based on the loading analysis performed as part of the 2010 Santuit Pond Diagnostic Study, stormwater runoff contributes an estimated 5% of the annual phosphorus load to Santuit Pond.

Stormwater in the Santuit Pond watershed is managed through a variety of structural and non-structural measures to address stormwater quantity and quality. Most of the public and private roads in the watershed have structural storm drainage systems consisting of curb-and-gutter drainage in some areas, country drainage (i.e., no curbs) in other areas, catch basins and storm manholes, and drainage pipes. The Town of Mashpee has installed infiltrating or leaching catch basins (i.e., catch basin or manhole structures with an open bottom and/or holes in the side walls of the structure) and other underground infiltration systems to capture and infiltrate road runoff. The Town's Stormwater Management Bylaw also requires new development and redevelopment projects, including such activities within the Santuit Pond watershed, to incorporate Low Impact Development (LID) site planning and design techniques and structural stormwater control measures to treat and infiltrate stormwater.

Several of the roads in the watershed that do not have curbing or that have insufficient curbing (i.e., curb lines that are too low and are frequently overtopped) contribute to rutting, channelization, and direct discharge of stormwater and sediment to abutting parcels, wetlands, or Santuit Pond. Site visits of the watershed performed in November 2021, during leaf fall and following a period with significant rainfall, noted that many of the catch basins in the neighborhoods surrounding the pond were clogged with leaves, sediment, and other debris, and likely had been clogged prior to the recent rainfall. The clogging of the catch basins contributed to significant over wash of curb lines and downstream catch basins, which was observed in both public and privately managed drainage systems, likely resulting in significant direct runoff into Santuit Pond or adjacent wetlands.

The watershed municipalities – Mashpee, Sandwich, and Barnstable – are regulated under the EPA Massachusetts Small Municipal Separate Storm Sewer System (MS4) General Permit. Each town implements a stormwater management program to comply with the requirements of the MS4 Permit, including public education and participation, illicit discharge detection and elimination programs, land use regulatory controls, good housekeeping and pollution prevention, and stormwater retrofits on municipal properties. The Town of Mashpee's stormwater management program also includes provisions for addressing specific water quality impairments including excess nutrient loadings that are impacting Santuit Pond.

5.7 Septic Systems

The Santuit Pond watershed is served entirely by on-site waste disposal systems including septic systems and cesspools, which are a source of phosphorus and nitrogen inputs to the pond via groundwater. Properly functioning septic systems that are inspected and maintained regularly can be effective at reducing loadings of bacteria but are not designed for phosphorus or nitrogen removal. Most of the systems in the Santuit Pond watershed were constructed during the period of rapid residential growth that occurred on the western and eastern sides of the pond between the early 1970s and the mid-1990s. As homes are sold, homeowners are required to upgrade systems to meet current Title 5 regulations. Septic systems in the watershed that have not been upgraded are potentially between 30 and 50 years old, which exceeds the average lifespan of a conventional septic system (20 to 30 years) that is properly designed and built, well-maintained, and not overloaded. Failing septic systems are a potentially greater source of nutrient loading to Santuit Pond. According to the 2010 Santuit Pond Diagnostic Study, septic systems account for 5% of the annual phosphorus load to Santuit Pond.

In 2021, the Town of Mashpee conducted a septic system survey of property owners that abut Santuit Pond to better understand the risk posed to water quality by the existing systems. The survey found that only half of the 121 septic systems located within 300 feet of Santuit Pond are inspected and pumped regularly. Of these 121 systems, 7 were identified as cesspools, including 1 within 100 feet of Santuit Pond. In September 2021, the Mashpee Select Board and Board of Health ordered septic system inspections and pumpings for

121 abutters whose property falls within 300 feet of the pond. The Town continues to enforce required inspections of septic systems within the Santuit Pond watershed.

Recognizing the need to address septic systems as a source of excess nutrient loadings to Santuit Pond and downstream waterbodies, the Town is proposing sewering of the Santuit Pond watershed in Phase 2 of its recently updated draft 2021 Mashpee Clean Water Plan.

5.8 Other Pollutant Sources

Other sources of sediment and nutrient loadings to Santuit Pond include the following, which is based on information presented in the 2010 Santuit Pond Diagnostic Study:

- Direct Precipitation and Atmospheric Deposition – Precipitation that falls directly onto the surface of Santuit Pond and atmospheric deposition of pollutants over the watershed contribute approximately 5% of the annual phosphorus load to the pond.

- Waterfowl – Waterfowl including resident and migrating birds account for an estimated 1% of the annual phosphorus load to Santuit Pond.

- Internal Loading – Phosphorus released from nutrient-rich bottom sediments during low oxygen periods throughout the summer is the largest source of annual phosphorus loading (78%) to Santuit Pond. As described previously, the Town of Mashpee, the Mashpee Wampanoag Tribe, and other partner organizations are evaluating options to address internal cycling of phosphorus through alum treatment, dredging, and other in-pond measures.

- Former Cranberry Bogs – Several former cranberry bogs located around Santuit Pond are no longer active and therefore are no longer a major source of nutrients to the pond. The Town is also evaluating the feasibility of restoring the Chop Chaque Bog on the eastern shore of Santuit Pond to improve water quality in Santuit Pond and downstream areas by retaining nutrients and floodwaters.

6 Watershed Field Assessments

6.1 Field Assessment Methodology

Fuss & O'Neill conducted field assessments of the Santuit Pond watershed on November 3 and 4, 2021 to evaluate known or suspected watershed sources of sediment and nutrient inputs to Santuit Pond, potential stormwater retrofit and improvement opportunities, and target areas for non-structural source control measures and residential Low Impact Development (LID) practices. The field assessment locations were initially selected based on review of existing watershed conditions and mapping (aerial photography and GIS data layers), priority stormwater retrofit sites identified in the 2010 Diagnostic Study Report, and areas recommended by Town staff. The areas immediately surrounding Santuit Pond, which are believed to have the greatest impact on pond water quality due to the presence of stormwater inputs via surface discharges and shallow groundwater flow, were prioritized over other more remote areas of the watershed. As a result, the field assessments focused on the areas of the watershed located primarily in the Town of Mashpee.

Field information was collected using tablets uploaded with aerial imagery and digital field data collection forms. Photographs were also taken to document field conditions. The field assessments were conducted during leaf fall and following a period of significant rainfall,[10] providing visible indicators of drainage patterns and source of debris, erosion, and sedimentation. During the field assessments, some residents also reported anecdotal information on localized drainage issues and associated problem areas.

6.2 Field Assessment Results

A total of 21 site-specific opportunities were identified in the residential neighborhoods surrounding Santuit Pond to reduce stormwater-related sediment and nutrient loadings (Figure 10). These include improved or enhanced maintenance of the existing drainage system, physical improvements to the drainage system to reduce erosion and sedimentation, non-structural residential source control and LID measures, and retrofitting the existing drainage system with stormwater control measures (also referred to as structural stormwater Best Management Practices or BMPs) designed for enhanced sediment and nutrient load reduction.

Table 2 provides a summary of the identified opportunities, including site ID[11] and associated photograph # from the photo log in Attachment A; a brief description of the existing pollutant sources/problems; the identified opportunities for stormwater retrofits, drainage system improvements, and improved maintenance; and relative priority of each retrofit/improvement opportunity. Retrofits or improvements classified as "High Priority" are expected to have the greatest benefits in terms of reducing sediment and nutrient loads to Santuit Pond. "Medium Priority" retrofits or improvements will have water quality benefits or address localized drainage problems but are expected to result in relatively smaller load reductions.

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[10] Approximately 5 inches of rainfall were recorded at Hyannis Barnstable Municipal Airport in a 9-day period between October 25 and November 2, including 0.35 inches on November 2, 2021.

[11] The site identification numbers listed in Table 2 correspond to the numbered sites shown on the map in Figure 10.

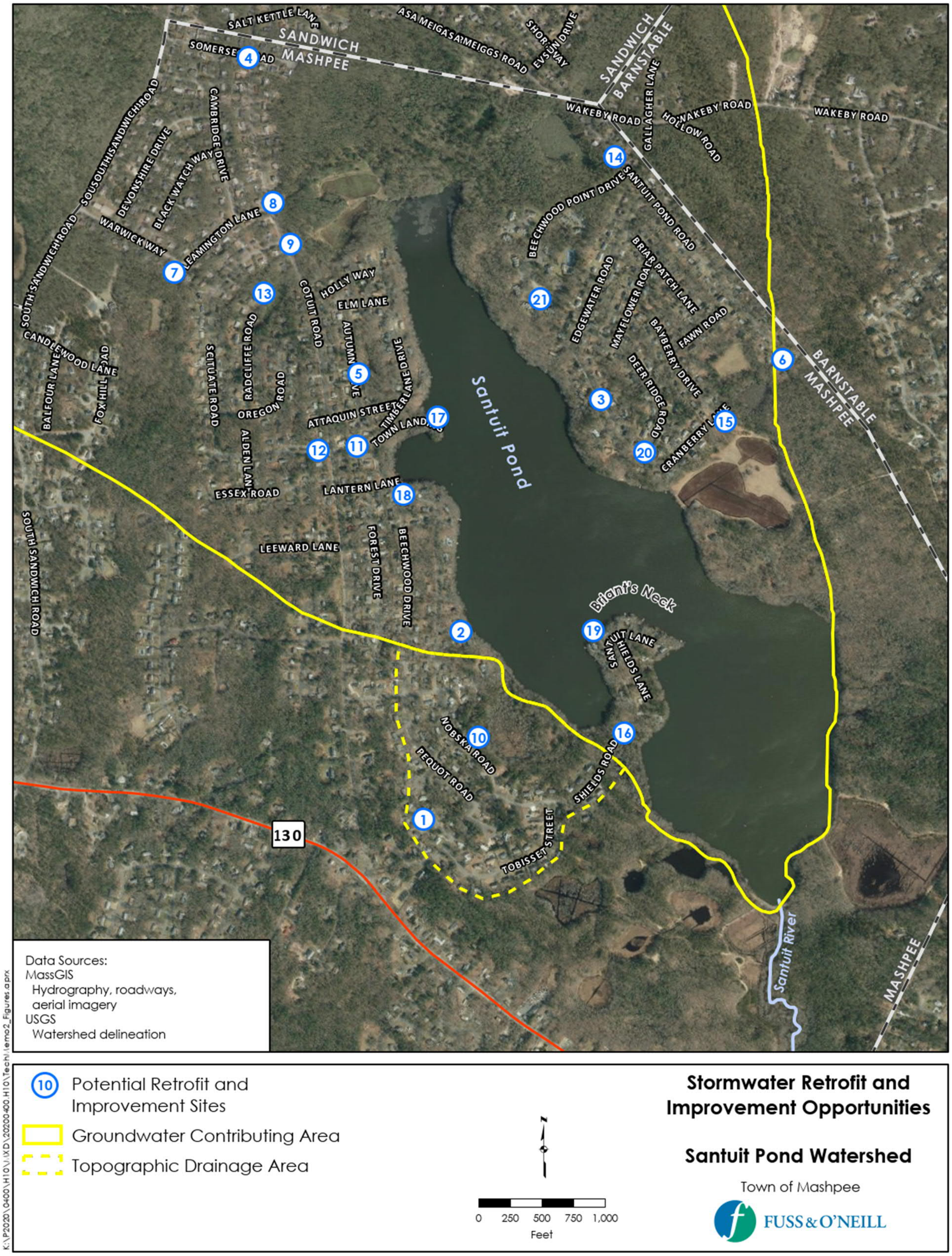


Figure 10. Stormwater Retrofit and Improvement Opportunities Identified from Field Assessments

Table 2. Summary of Stormwater Retrofit and Improvement Opportunities Identified During Field Assessments

Site ID and Description	Photo #	Existing Condition	Retrofit or Improvement Opportunity	Relative Priority
1. Tricia Lane Cul-de-Sac	1	Large area of excess pavement in front of the cul-de-sac island. Leaching catch basin located in front of island provides limited nutrient removal prior to recharging groundwater. Area appears to be used for recreation by the neighborhood residents (i.e., basketball hoop set up at edge of island).	• Expand the cul-de-sac island to create a "teardrop" shaped island, thereby reducing the paved area. • Convert the expanded island into a bioretention cell to collect sheet flow from the remaining paved drive, using the existing catch basin as an overflow structure within the bioretention cell. • Maintain sufficient clearance and turning radius around the modified cul-de-sac for emergency vehicle access.	Medium
2. Fir Court Cul-de-Sac	2	Leaching catch basin not located at low point in cul-de-sac. Stormwater runoff appears to bypass the catch basin and potentially discharges directly to the pond (depending on storm magnitude) by flowing over the downgradient curb. Relocating existing leaching catch basin to low point along curb line would result in insufficient separation distance to the steep embankment along the pond shoreline, which could cause slope instability due to seepage of infiltrated stormwater.	• Re-grade end of cul-de-sac so that pavement drains to the existing catch basin, OR • Install mountable berm behind existing catch basin and/or eliminate pavement at end of cul-de-sac and move curb line to downgradient edge of existing catch basin, OR • Install standard closed-bottom deep sump, hooded catch basin at low point along curb line with an outlet connected to the existing leaching catch basin. • For improved nutrient removal, install closed-bottom tree filter at low point along curb line with underdrain and overflow connected to the existing leaching catch basin.	Medium
3. Edgewater Road Cul-de-Sac(s)	3-4	Cul-de-sac on west side of Edgewater Road (near 91 Edgewater residence) constructed to provide the necessary frontage to maximize number of lots, resulting in excess pavement. Conventional catch basins located at terminal cul-de-sac at end of Edgewater Road.	• Remove or convert excess pavement to a permeable surface (91 Edgewater Road). • Convert existing catch basins at terminal cul-de-sac at end of Edgewater Road to leaching catch basins. Install roadside water quality swales or linear bioretention cells, and/or expand island to incorporate a new bioretention cell, to intercept and treat runoff for nutrient removal prior to entering or overflowing to leaching catch basins.	Medium
4. Somerset Road/ Cotuit Road Intersection	5-6	Existing catch basin grates covered with sediment and leaf litter. Somerset Road is privately owned.	• Improve maintenance of drainage structures on Somerset Road. • Install linear bioretention and/or bioretention cell in open space at northwest corner of Cotuit Road/Somerset Road intersection for improved nutrient removal. Use existing catch basin as an overflow.	Medium
5. 5 Autumn Drive	7-8	Existing conventional catch basin directed to a leaching manhole structure in road. Catch basin grate covered with sediment and leaf litter. Low-profile wooden retaining wall in disrepair. Evidence of stormwater bypass down steeply sloped driveway of adjacent property.	• Improve maintenance of drainage structures on both sides of road. Repair wooden retaining wall to minimize stormwater bypass.	Medium
6. Deerfoot Circle Cul-de-Sac	9-10	Very flat pavement around conventional catch basin at edge of cul-de-sac island. Low point not directly identifiable. Pavement and catch basin grate routinely covered with leaf litter and debris due to mature stand of trees and overhanging tree canopy in cul-de-sac island and adjacent properties.	• Improve maintenance around cul-de-sac (street sweeping and catch basin cleaning). • Replace or retrofit existing catch basin with deep sump-and hood (for pretreatment) and install leaching manhole/catch basin to receive discharge from existing catch basin.	Medium
7. Cambridge Drive/ Leamington Lane	11-13	Catch basin grates covered with sediment and debris resulting in significant stormwater bypass. Stormwater bypasses curb lines and runs down driveways, through residential properties affecting downgradient areas including Scituate Road, Cotuit Road, and Radcliffe Road. According to local residents, the catch basins have not been maintained in at least 5 years. Roads in these neighborhoods are privately owned.	• Town of Mashpee should consider accepting roads in the Cambridge Drive/Leamington Lane neighborhoods as Town roads. Improve maintenance of road and drainage structures including street sweeping and catch basin cleaning. • Replace or retrofit existing upgradient conventional catch basins with leaching catch basins, or with tree filters for improved nutrient removal.	High

Site ID and Description	Photo #	Existing Condition	Retrofit or Improvement Opportunity	Relative Priority
8. Leamington Lane/ Cotuit Road	14-16	Flooding at intersection and adjacent residential properties (and downstream areas). Major washout of soil around catch basins. Evidence of heavy ponding of stormwater. Infiltrating catch basin installed close to steep slope may have also contributed to washout around catch basin. Stormwater flows across Cotuit Road and toward Scituate Road transporting significant sediment load.	• Town of Mashpee should consider accepting roads in the Cambridge Drive/Leamington Lane neighborhoods as Town roads. Improve maintenance of road and drainage structures including street sweeping and catch basin cleaning. • Install curbing and/or riprap upgradient of catch basins on Leamington Lane to address erosive velocity of stormwater flowing down Leamington Lane. • Install water quality swales or linear bioretention upgradient of existing catch basins at eastern end of Leamington Lane, where space allows. • Install bioretention basin at dead-end western end of Leamington Lane.	High
9. Scituate Road/ Cotuit Road	17-20	Receives stormwater runoff from Leamington Lane neighborhood, Scituate Road, and Cotuit Road. Major source of sediment across Cotuit Road and to Cotuit Road right-of-way. In area along paved trail near retaining wall (across from 492 Cotuit Road), existing beehive grate catch basin clogs; runoff bypasses catch basin and overtops retaining wall.	• Install deep sump hooded catch basins as pretreatment for existing leaching catch basins. • Install water quality swales or linear bioretention upgradient of existing catch basins at end of Scituate Road, where space allows. • Consider installing a water quality swale and bioretention basin on opposite side of Cotuit Road, on downgradient side of existing trail retaining wall, to manage excess runoff/overflow from Scituate Road/Cotuit Road.	Medium
10. Nobska Road	21-22	Low point that receives stormwater from Nobska Road, located next to municipally owned parcel and adjacent wetlands. Existing catch basin does not capture gutter flow due to its location several feet from edge of road. Evidence of substantial dumping of yard debris.	• At dumping area, install linear bioretention or water quality swale and install guard rail to restrict access to limit dumping. Don't limit access to conservation land or dog walking area.	High
11. Pocknomett Street and Hornbeam Lane	23-24	Wooded municipally owned parcel located between Pocknomett Street and Hornbeam Lane. Both streets are curbed with leaching catch basins located towards downgradient western end of streets above intersection with Timberlane Drive. Density of trees and vegetation within this parcel varies. East and west ends of the parcel are lightly wooded and areas of clearing exist along the street rights-of-way. Parcel is elevated/bermed in the middle.	• Parcel provides opportunity for large-scale linear stormwater practice to treat stormwater from Pocknomett Street, Hornbeam Lane, and Cotuit Road prior to infiltration. Would require significant tree clearing and re-grading. Possible conflicts with water lines (hydrant present on Pocknomett side of parcel). Would potentially eliminate visual screening provided by existing vegetation. • Consider installing water quality swales or linear bioretention along isolated portions of the right-of-way or at the eastern and western ends of the parcel at the Cotuit Road and Timberlane Drive intersections.	Medium
12. Scituate Road Median Strip	25-26	Two one-way traffic lanes separated by a vegetated median strip at western end of Scituate Road, resulting in excess pavement. Water line and hydrant present within median strip.	• Potential for reconfiguration of roadway and traffic patterns and reduction in impervious area. • Convert portions of median (e.g., western end just upgradient of existing catch basins or paved area between median and Cotuit Road) to water quality swale or linear bioretention for enhanced nutrient removal. Existing conventional catch basins near Cotuit Road could serve as overflow structures from bioretention area or swales. Convert catch basins to leaching structures using existing catch basins as pretreatment.	Medium
13. Radcliffe Road Cul-de-Sac	27	Observed dumping of trash. Significant buildup of debris on pavement at cul-de-sac (leaves, pine needles, sediment, etc.). Collection point for stormwater originating from Leamington Lane neighborhood, which flows overland through residential lots along Scituate Road and reaches Radcliffe Road. Adjacent to wetland and wooded buffer – shallow groundwater likely.	• Remove trash and perform regular maintenance (street sweeping and catch basin cleaning). • Install leaching catch basin (will only work if upgradient stormwater runoff from Leamington is addressed more broadly). • Space available for additional stormwater treatment on outside of cul-de-sac pavement (wet vegetated stormwater treatment system).	Medium

Site ID and Description	Photo #	Existing Condition	Retrofit or Improvement Opportunity	Relative Priority
14. Santuit Pond Road	28	Low point located near 23 Santuit Pond Road (Town of Mashpee property). Sediment accumulation and erosion/rutting occurring from runoff bypassing catch basin and entering adjacent wetlands.	• Repair and stabilize slope behind catch basin to dissipate erosive energy of runoff. • Install bioretention cell upgradient of catch basin to intercept runoff using catch basin as overflow. Potential to use portion of 23 Santuit Pond Road (Town property) for stormwater management.	Medium
15. Cranberry Lane/ Bayberry Drive	29	Intersection receives significant runoff and sediment from Bayberry Drive and Cranberry Lane. Road flooding at intersection with over wash noted at curb. Catch basins along Bayberry Drive become clogged with sediment and debris and stormwater bypasses catch basins and flows to intersection. Leaching catch basins at intersection covered in debris curb and discharges to wetlands. Cranberry Lane is a dead-end street with excess impervious area and adjacent former cranberry bogs.	• Improve maintenance of drainage structures on Cranberry Lane and Bayberry Drive. • Install water quality swales or linear bioretention along Bayberry Drive upgradient of catch basins. • Dead-end portion of Cranberry Lane or adjacent municipal parcels could be used for stormwater wetland or other vegetated treatment practice to better manage runoff from Cranberry Lane and Bayberry Drive.	High
16. Shields Road/ Briant's Neck	30-32	Stormwater runoff from the paved public portion of Shields Road and the unpaved private section of Shields Road discharges at low point in road to wetlands that are hydraulically connected to Santuit Pond. Runoff flows down unpaved side path off of Shields Road, causing erosion of path and likely discharge of sediment to adjacent wetlands.	• Install linear bioretention or water quality swales in road right-of-way or create a bioretention island/median near the end of the paved portion of Shields Road, in combination with leaching catch basins as overflow structures. • Install similar stormwater control measures if Town accepts Shields Road as a Town Road and paves the road. • Regrade side path and install water bars or rubber razors to direct runoff to swale, infiltration trench, or stone-lined edge on downgradient side of path.	High
17. Town Landing	33-37	Catch basin receives runoff from several hundred feet of Timberlane Drive, which bypasses onto dirt/gravel Town Landing access road, causing erosion, channelized flow, and sediment-laden stormwater discharge directly to Santuit Pond.	• Improve maintenance of drainage structures at intersection of Timberlane Drive and Town Landing access road. • Install bioretention or water quality swale upgradient of catch basins. • Relocate and reconfigure parking and traffic flow near entrance to Town Landing access road and incorporate bioswale along access path and educational signage. • Restrict boat access and convert parking to recreational use, stormwater management, or reduced impervious area.	High
18. Timberlane Drive/ Lantern Lane	38-45	Major collection point for stormwater runoff from surrounding road network, located immediately adjacent to Santuit Pond and wetlands. Catch basins at low point frequently clog with leaf litter, sediment, and debris transported from upgradient road network, resulting in stormwater bypass and discharge to pond. Significant road flooding in this location was noted by local resident. Erosion has occurred around the ends of the adjacent retaining wall between the road and pond.	• Improve maintenance of drainage structures on Timberlane Drive, Lantern Lane, and Beechwood Drive. • Install linear bioretention system or stormwater wetland in lawn area between road and retaining wall for improved nutrient removal, using existing catch basins as overflow. • Install roadside linear bioretention or water quality swales at locations upgradient of existing catch basins.	High
19. Briant's Neck	46-49	Residential area with shoreline/beach access located on peninsula at southwest corner of Santuit Pond. Road network is privately owned and maintained. Several sources of direct and channelized surface runoff discharge into Santuit Pond, especially from dirt/gravel roads. Limited or no vegetated buffers along portions of pond shoreline. Town staff indicated existence of active cesspools near pond shoreline/beach access point.	• Town should consider accepting and maintaining roads, paving roads, and managing stormwater from impervious surfaces through a combination of roadside bioretention or water quality swales and leaching catch basins. • Expand vegetated buffers along shoreline, especially in unvegetated/unstabilized areas and areas of observed erosion, balancing shoreline access with water quality protection.	High
20. Deer Ridge Road	50	Private beach access, potential collection point for stormwater discharge. During site visit, it was noted that stormwater was not discharging from beach access point, and a "grass pave" pervious surface had been installed for stabilization and erosion control. No concerns were noted. Several hundred feet to the south, a catch basin was noted to be too high, resulting in stormwater bypass.	• Lower catch basin grate elevation to improve stormwater capture and reduce stormwater bypass.	Medium

Site ID and Description	Photo #	Existing Condition	Retrofit or Improvement Opportunity	Relative Priority
21. Beechwood Point / Santuit Pond Way	51-53	Santuit Pond Way within the Beechwood Point neighborhood is privately owned and maintained. Drainage system has conventional catch basins (could not field locate outfall locations). Stormwater runoff from paved areas discharges directly to Santuit Pond in some areas. Stormwater bypasses conventional catch basins at end of townhouse parking lot (catch basin grate elevations too high) and discharges to wetlands, with severe erosion noted down the slope. Stormwater also bypasses catch basins at nearby dumpster enclosure. Large open cul-de-sac at end of Santuit Pond Way offers potential for surface vegetated stormwater retrofit.	• Improve maintenance of drainage structures on Santuit Pond Way and in Beechwood Point neighborhood. • Repair erosion gully downgradient of parking lot. • Install bioretention cell around catch basins at edge of townhouse parking lot to capture runoff from parking lot and use catch basins as overflow. Install bioretention cell at edge of pavement near dumpster enclosure. • Install bioretention cell in cul-de-sac island at end of Santuit Pond Way. Use curb cuts to direct stormwater into bioretention cell, with existing catch basins as overflow structures.	Medium

6.2.1 Summary of Findings

6.2.2 Drainage System Maintenance

Many of the drainage structures (catch basins, drain manholes, low points along curb lines, etc.) that were evaluated during the field assessments were clogged with leaves, sediment, and other debris. Catch basin grates were partially or completely blocked in many instances, and significant buildup of debris was noted inside the catch basin structures. Although the leaf fall conditions and significant rainfall in the days preceding the field assessments likely contributed to the observed drainage issues, these observations suggest that many structures were likely clogged and/or full of sediment and debris prior to the rainfall. The clogging of catch basins contributed to runoff bypassing catch basins and significant over wash of curb lines and downstream catch basins, which was observed in both public and privately managed drainage systems, likely resulting in significant direct runoff into Santuit Pond or adjacent wetlands. Heavy buildup of sediment and leaf litter was observed within areas of the roadway right-of-way, especially in neighborhoods with heavy tree canopy and steep topography. Decomposing leaves are also a source of phosphorus in urban stormwater runoff and leaching of nitrogen to groundwater.

More frequent and targeted catch basin cleaning, street sweeping, and fall leaf collection is recommended to maintain the effectiveness of the existing drainage system, alleviate drainage problems, and reduce sediment and nutrient loads to Santuit Pond. Sweeping of the streets within the neighborhoods surrounding the pond is recommended at a minimum of twice per year, in the spring after snow melt and in the fall during peak leaf falling season. A recent USGS study in Wisconsin demonstrated that enhanced street sweeping in the fall can achieve approximately 60-70% reduction in phosphorus loads, is more effective than structural stormwater practices for removing dissolved phosphorus, and improves the effectiveness of municipal leaf collection programs.[12] Enhanced fall street sweeping (weekly or once every two weeks) should be considered in catchment areas of major collection points and known problem areas such as:

- Leamington Lane/Cambridge Drive neighborhoods
- Neighborhoods bounded by Scituate Road and Cotuit Road
- Neighborhoods between Cotuit Road and Santuit Pond including the Timberlane Drive/Lantern Lane catchment area
- Neighborhoods on eastern side of Santuit Pond (Beechwood Point, Edgewood Road, Cranberry Lane, Bayberry Drive, etc.).

Before forecasted heavy rainfall events, the Town, privately contracted maintenance personnel, or homeowners with catch basins adjacent to their property should consider clearing the grates of catch basins that are prone to clogging. This could be an element of an "Adopt a Storm Drain" program for homeowners, which could complement routine catch basin cleaning by the Town and privately contracted maintenance.

[12] Selbig, W.R., Buer, N.H., Bannerman, R.T., and Gaebler, P., 2020, Reducing leaf litter contributions of phosphorus and
nitrogen to urban stormwater through municipal leaf collection and street cleaning practices: U.S. Geological Survey Scientific Investigations Report 5109, 17 p., https://doi.org/10.3133/sir20205109.

6.2.3 Curbing and Drainage Structures

Some roads in the watershed do not have curbing or have insufficient curbing (i.e., curbs that are too low and are frequently overtopped, especially when catch basins are clogged and in areas with steep slopes). This contributes to channelized flow and erosion along the edge of the road and stormwater flow overtopping the curb resulting in erosion of pervious areas behind the curb, drainage issues on residential lots, and direct discharge of stormwater and sediment to Santuit Pond or adjacent wetlands.

In some areas, catch basins are ineffective at capturing stormwater flow because they are not located at the low point in the area they were designed to serve, are not located along the curb line and do not intercept gutter flow, or have grates that are higher than the surrounding pavement due to settling of the pavement around the catch basin over time. These issues result in stormwater bypassing catch basins, which increases flow volumes and hydraulic loading to downgradient areas (catch basins, road intersections, residential lots, etc.).

Most of these issues can be resolved through isolated improvements to individual drainage structures (e.g., relocating a catch basin, re-setting a catch basin grate, minor grading). Roads with insufficient curbing should be addressed by raising or replacing existing curbing. Uncurbed roads with erosion issues are potential candidates for installation of new curbing and catch basins or the use of roadside vegetated swales.

The above issues, when combined with clogged catch basins due to insufficient maintenance, can result in significant drainage issues with entire neighborhoods. Many of these problems were observed in the Leamington Lane and Cambridge Drive neighborhoods, which impacts drainage in downgradient areas including homes along Scituate Road, Radcliffe Road, and Cotuit Road. More widespread drainage improvements and improved drainage system maintenance and street sweeping are recommended for these particular neighborhoods.

6.2.4 Leaching Catch Basins and Related Infiltration Structures

Much of the storm drainage network in the neighborhoods surrounding Santuit Pond is equipped with infiltrating or leaching catch basins and other underground infiltration systems to capture and infiltrate road runoff. The permeable, sandy soils in the watershed make these stormwater infiltration systems highly effective at reducing runoff volumes and loadings of sediment and pollutants attached to sediment particles.

Leaching catch basins and similar underground infiltration systems are not designed to remove dissolved pollutants such as dissolved phosphorus or nitrogen. When these systems are located in soils with very high infiltration rates, such as the sandy Cape Cod soils in the Santuit Pond watershed, there is greater potential for rapid transport of dissolved nutrients to groundwater due to the relatively short contact time between the soil and infiltrated stormwater and lower soil adsorption potential. The dissolved fraction of phosphorus and nitrogen in stormwater infiltrated through leaching catch basins may ultimately reach Santuit Pond through shallow groundwater flow. Use of vegetation and other treatment mechanisms prior to infiltration of stormwater into these sandy soils is important for adequate removal of phosphorus and nitrogen.

The Town of Mashpee has recognized the potential for stormwater infiltration systems to contribute nutrient loads to Santuit Pond and other waterbodies via groundwater. The Town's Stormwater Management Bylaw, which was updated in 2021, requires treatment of runoff for removal of nitrogen and phosphorus prior to recharge through the use of stormwater infiltration systems. Such treatment typically requires the use of stormwater control measures that rely on vegetation for nutrient removal including bioretention/rain gardens, tree filters, sand/organic filters, water quality swales, and stormwater wetlands. The bylaw also prohibits the use of dry wells and leaching catch basins except for overflow from stormwater treatment facilities (designed to remove phosphorus and nitrogen) and when there are no other feasible alternatives.

Many opportunities exist in the watershed to retrofit leaching catch basins to enhance nutrient removal efficiency and reduce nutrient loadings via groundwater. Vegetated stormwater practices such as linear bioretention systems or dry water quality swales can be installed along roadways or on adjacent land upgradient of existing leaching catch basins (or conventional catch basins that discharge to infiltration structures beneath the road) to intercept runoff using curb cuts prior to entering the catch basins. The intercepted runoff is then treated via vegetation and a layer of engineered soil media prior to infiltration into the soils beneath the system or collection by an underdrain/liner and discharge to the leaching catch basin system for subsequent infiltration of the treated stormwater. Stormwater flows that exceed the capacity of the bioretention system or water quality swale would overflow into the existing catch basins.

Table 2 identifies specific neighborhoods, roads, or sites that could benefit from these types of retrofits. Common installations include along the side of the road within the existing municipal right-of-way, within the existing paved area by creating "bump-outs" where the pavement width can be narrowed, or within adjacent pervious areas such as cul-de-sac islands and traffic medians. The configuration of the existing catch basins, ground slope, available space, land ownership, and potential underground utility conflicts (electric, water, gas) are important factors that can influence the feasibility of these type of retrofits at a given site.

6.2.5 Surface Discharges of Untreated Stormwater

As described previously, some impervious surfaces in the watershed contribute stormwater runoff to Santuit Pond or wetlands that are hydraulically connected to the pond via stormwater outfalls, ditches, concentrated flow channels, or other overland flow. During the watershed assessments, field staff were unable to confirm locations of stormwater outfall pipes through visual inspection, although outfalls are believed to exist in some areas due to the presence of conventional (i.e., non-leaching) catch basins with outlets located relatively close to the pond shoreline (e.g., Beechwood Point neighborhood on the eastern shoreline of the pond). More common are areas where stormwater discharges to the pond as concentrated or channelized overland flow during high-intensity rain events, especially when runoff bypasses existing clogged catch basins and the runoff overwhelms the downgradient drainage system. An example is the Timberlane Drive/Lantern Lane area where significant runoff from the upgradient catchment area causes road flooding and discharge of stormwater and sediment around the retaining wall and into the pond and adjacent wetlands. Surface stormwater discharges also occur at the Town Landing site, in the Briant's Neck and Shields Road area, and at a few other isolated locations around the pond.

Solutions for eliminating or reducing this direct discharge consist of physical retrofits/improvements and improved maintenance of the upgradient drainage system, combined with new structural stormwater BMPs near the discharge location to build redundancy into the system of controls. Similar to the leaching catch basin retrofits, vegetation-based stormwater treatment BMPs such as bioretention, water quality swales, and stormwater wetlands are most effective for nutrient load reduction. These installations are located near the low point in a catchment area and typically require more space to manage larger volumes of runoff.

For retrofits that employ bioretention or other filtering BMPs for treatment, the designs should incorporate filter media and/or an internal water storage zone to optimize phosphorus and nitrogen removal.

- Filter Media – Many of the earlier bioretention system designs incorporated compost as the organic component of the bioretention soil mix. Compost-based bioretention soil mixes have been shown to export nutrients and are therefore no longer recommended. Bioretention soil media can be specified to enhance pollutant removal, particularly phosphorus removal, by incorporating organic matter (sphagnum peat moss or wood derivatives such as shredded wood, wood chips, ground bark, or wood waste) or other soil amendments such as zerovalent iron and/or drinking water treatment residuals (alum). The University of New Hampshire Stormwater Center has developed a bioretention soil mix for enhanced phosphorus removal.

- Internal Water Storage – For enhanced removal of nitrogen, use an upturned or reverse-slope underdrain in combination with a liner to create a thicker saturated zone (also called an Internal Water Storage zone or Internal Storage Reservoir) that extends into the bottom of the bioretention soil media. This type of underdrain configuration increases infiltration and evapotranspiration and enhances removal of nitrogen through the creation of an anaerobic or anoxic zone. The University of New Hampshire Stormwater Center has developed a standard bioretention design with internal water storage zone, variations of which have been incorporated into other recently updated stormwater design manuals.

6.2.6 Residential Cul-de-sacs

Cul-de-sacs are common in the residential neighborhoods around Santuit Pond. Most of the cul-de-sacs are circular in shape and either completely paved or have a grass/landscaped island in the middle with conventional or leaching catch basins around the perimeter of the island to collect pavement runoff. Portions of these cul-de-sacs can be converted into bioretention cells by excavating the lawn area around the existing catch basins and using curb cuts to intercept and redirect pavement runoff into the bioretention cells, using the existing catch basin as overflow structures. Some of the cul-de-sacs also have excessive amounts of pavement (i.e., unused paved area or more pavement than necessary to accommodate emergency vehicles) and provide opportunities for impervious area reduction by enlarging the cul-de-sac island and installing bioretention. Specific sites where this type of retrofit is recommended include Tricia Lane, Fir Court, Edgewater Road, and Radcliffe Road.

6.2.7 Unpaved Roads

The roads in the Briant's Neck neighborhood and several other isolated locations around the pond (e.g., Town Landing access road, Shields Road side path) consist of unpaved, gravel/crushed stone surfaces that are susceptible to channelization and erosion by stormwater runoff. The Town of Mashpee should consider accepting, paving, and maintaining the roads on Briant's Neck as Town roads. Stormwater runoff could be managed through a combination of roadside bioretention or water quality swales and leaching catch basins. The Town should also consider paving the Town Landing access road and managing pavement runoff using similar stormwater controls. Erosion issues on existing dirt roads or paths could be addressed through a combination of re-grading and use of water bars or rubber razors to direct runoff to water quality swales or infiltration trenches along the edges of the road or path.

6.2.8 Gravel Driveways

Gravel driveways are fairly common in the residential neighborhoods surrounding Santuit Pond and are a potential source of erosion and sediment transport via stormwater runoff. The gravel driveways in the watershed vary significantly in their condition, slope, material, etc. Some are flat with a thick layer of gravel/stone and pose low potential for erosion, while others are on steeply sloping lots with insufficient cover, exposed underlying soil, and areas of runoff channelization and erosion. When sloped toward the road, sediment from gravel driveways that are susceptible to erosion can be transported to Santuit Pond and contribute to clogging of catch basins and stormwater bypass.

Residents can implement a number of measures to reduce erosion and sediment transport from gravel driveways, including:

- Installation of driveway infiltration trenches, which are stone-filled trenches along the edge of a driveway to collect water from the driveway, allowing it to soak into the ground and reducing erosion along the edge of the driveway.
- Installation of water bars along driveways to divert runoff into adjacent vegetated areas or to driveway infiltration trenches.
- Replacing lost or insufficient gravel/stone. Use of angular rocks with squared-off edges is recommended rather than smooth rock or round gravel, which is prone to sliding. Gravel should be placed in several layers, going from large gravel, to medium-sized gravel, to small gravel on top. Gravel grids can also be installed before placing gravel, which will help to lock in the gravel and reduce erosion. Gravel should be applied by forming a crown in the center of the driveway and tapering the driveway out to the sides, using driveway infiltration trenches along the sides.
- Converting gravel driveways to other types of permeable surfaces such as porous asphalt (Porous Pave), porous concrete (Perk-crete), permeable concrete pavers, grass pavers, plastic turf reinforcing grids, and geocells (cellular confinement systems).

Paved asphalt driveways are the most common type of driveway surface in the watershed. Paved asphalt driveways generate greater quantities of stormwater runoff. When sloped toward the road, driveways can be a significant source of stormwater runoff to the road drainage system. Disconnecting driveway surfaces from the drainage system through grading and adjacent permeable areas or converting paved driveways to a permeable surface, as described above, can be effective strategies for reducing the amount of connected impervious surfaces on residential lots.

6.2.9 Yard Waste

Dumping of leaves, grass clippings, and other yard waste was observed on municipal or private property in several areas of the watershed. Heavy accumulations of leaf litter, grass clippings, and other debris were also observed in and covering many catch basins in the watershed, as described previously. The Mashpee Transfer Station accepts leaves and grass clippings for recycling. Chapter 85 of the Town of Mashpee's General Bylaws

(Illicit Connections and Discharges to the Municipal Storm Drain Systems) prohibits dumping or discharge of yard waste to the municipal drainage system. Enforcement of the Town's illicit connections and discharge bylaw can help reduce the occurrence of off-site dumping of yard waste, along with limiting public access to common dumping areas and homeowner education and outreach (i.e., proper management and disposal of leaves and grass clippings). While leaves are an issue when they accumulate in roads and drainage structures, homeowners should consider leaving fallen leaves in place on their property by raking or blowing and creating a leaf pile at the corner of the yard, allowing them to break down naturally or adding them to a compost pile over time.

6.2.10 Residential Landscapes

Residential landscapes in the Santuit Pond watershed vary considerably in their size, appearance, and level of maintenance, ranging from typical well-manicured grass lawns to yards with less grass and more natural vegetative ground cover, especially on heavily wooded and steeply sloping lots. Heavily maintained landscapes can be a source of nutrients (fertilizer) and chemicals (herbicides/pesticides) to stormwater runoff and groundwater, have greater water requirements, and provide fewer ecological benefits than natural landscaping. Alternative landscaping can be an effective strategy for enhancing resilience and reducing the water quality impacts of residential lots on Santuit Pond. Lower impact options include:[13]

- Use diverse selection of native plant species
- Create shade
- Preserve natural/wild areas
- Leave fallen leaves in place on residential lots (keep out of the road and the storm drainage system)
- Minimize lawn area and associated lawn maintenance
- Conserve water and manage stormwater on-site through the use of rain barrels, rain gardens, and roof downspout disconnection techniques
- Recycle, repurpose, and reuse yard materials
- Minimize soil disturbance.

6.2.11 Shoreline Vegetated Buffers

Vegetated buffers are vegetated areas along a waterbody that stabilize the shoreline and provide wildlife habitat and shade. Buffers help slow down and clean stormwater runoff. Minimum vegetated buffer widths of 25 feet are recommended, where space allows, although the wider the buffer, the greater the benefits, particularly in areas with steeper slopes.

Most of the Santuit Pond shoreline is steeply sloped and fairly well-vegetated. Exceptions include Briant's Neck, the Town Landing, and other backyard areas of shoreline homes along Timberlane Drive, portions of which have limited or no vegetated buffers. The Town should work with homeowners in these areas to establish and maintain shoreline vegetated buffers. Well-designed buffers on shorefront properties can enhance the view of the pond and can include paths to access the water.

[13] Landscape Choice for a Changing Climate: Climate-wise Best Practices, Kristen Andres, Associate Director for Education & Informational Services, Association to Preserve Cape Cod.

ATTACHMENT A

Photo Log
Santuit Pond Watershed Field Assessments
November 3 and 4, 2021

PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 1) Tricia Lane Cul-de-Sac (excess pavement in front of cul-de-sac island)

Photo 2) Fir Court Cul-de-Sac (runoff bypassing leaching catch basin)

Photo 3) Edgewater Road West Cul-de-Sac (near 91 Edgewater)

Photo 4) Edgewater Road Terminal Cul-de-Sac

PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 5) Somerset Road / Cotuit Road Intersection (looking east across Cotuit Road)

Photo 6) Somerset Road / Cotuit Road Intersection (clogged catch basin at northwest corner of intersection)

Photo 7) 5 Autumn Drive (clogged catch basin and evidence of stormwater bypass)

Photo 8) 5 Autumn Drive (flow path of stormwater bypass down driveway)

Photo 9) Deerfoot Circle Cul-de-Sac (catch basins clogged, heavy stormwater debris left on pavement)

Photo 10) Deerfoot Circle Cul-de-Sac (stormwater bypass of catch basin)

Photo 11) Western End of Leamington Lane (debris and stormwater accumulation area)

Photo 12) 38 Leamington Lane (stormwater bypass/clogged catch basin)

Photo 13) 38 Leamington Lane (clogged catch basin)

Photo 14) Leamington Lane/Cotuit Road Intersection (clogged catch basin and heavy debris on Leamington)

Photo 15) Leamington Lane/Cotuit Road Intersection (washout around leaching catch basin on Cotuit Road)

Photo 16) Leamington Lane/Cotuit Road Intersection (debris transported across Cotuit Road and path)

Photo 17) 114 Scituate Road Back / Side Yard (evidence of overland flow through residential lots)

Photo 18) 113 Scituate Road Catch Basin Bypass and Heavy Sediment Accumulation

Photo 19) Cotuit Road (south of Scituate Road, trail fence and retaining wall)

Photo 20) Cotuit Road (stormwater and sediment bypass of catch basin along path near Scituate Road)

Photo 21) Nobska Road Catch Basin (located away from road edge)

Photo 22) Nobska Road Yard Debris Dumping Site

Photo 23) Pocknomett Street and Hornbeam Lane (eastern end of municipal parcel at Timberlane Drive)

Photo 24) Pocknomett Street and Hornbeam Lane (western end of municipal parcel at Cotuit Road)

PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 25) Scituate Road Median Strip (looking west from Cotuit Road)

Photo 26) Scituate Road Median Strip (looking east from Scituate Road)

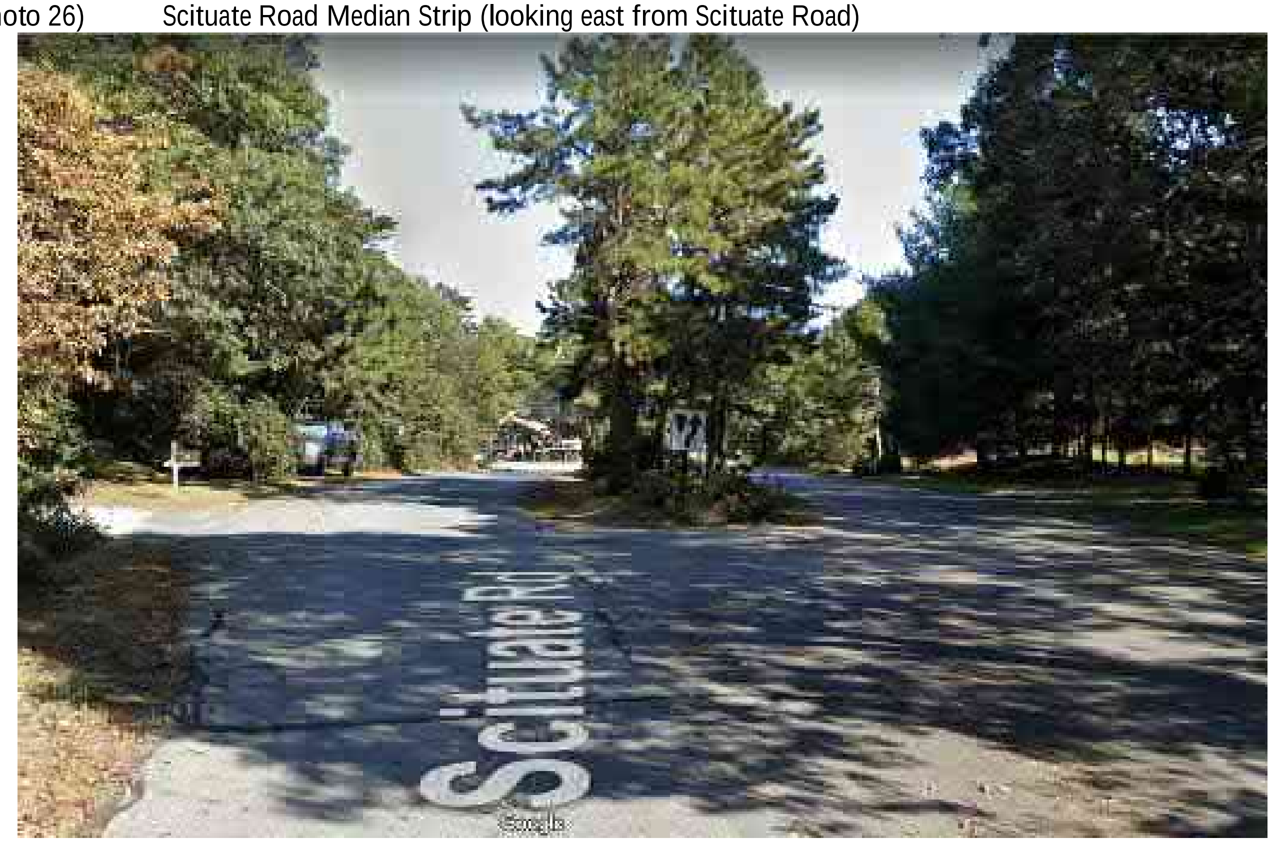


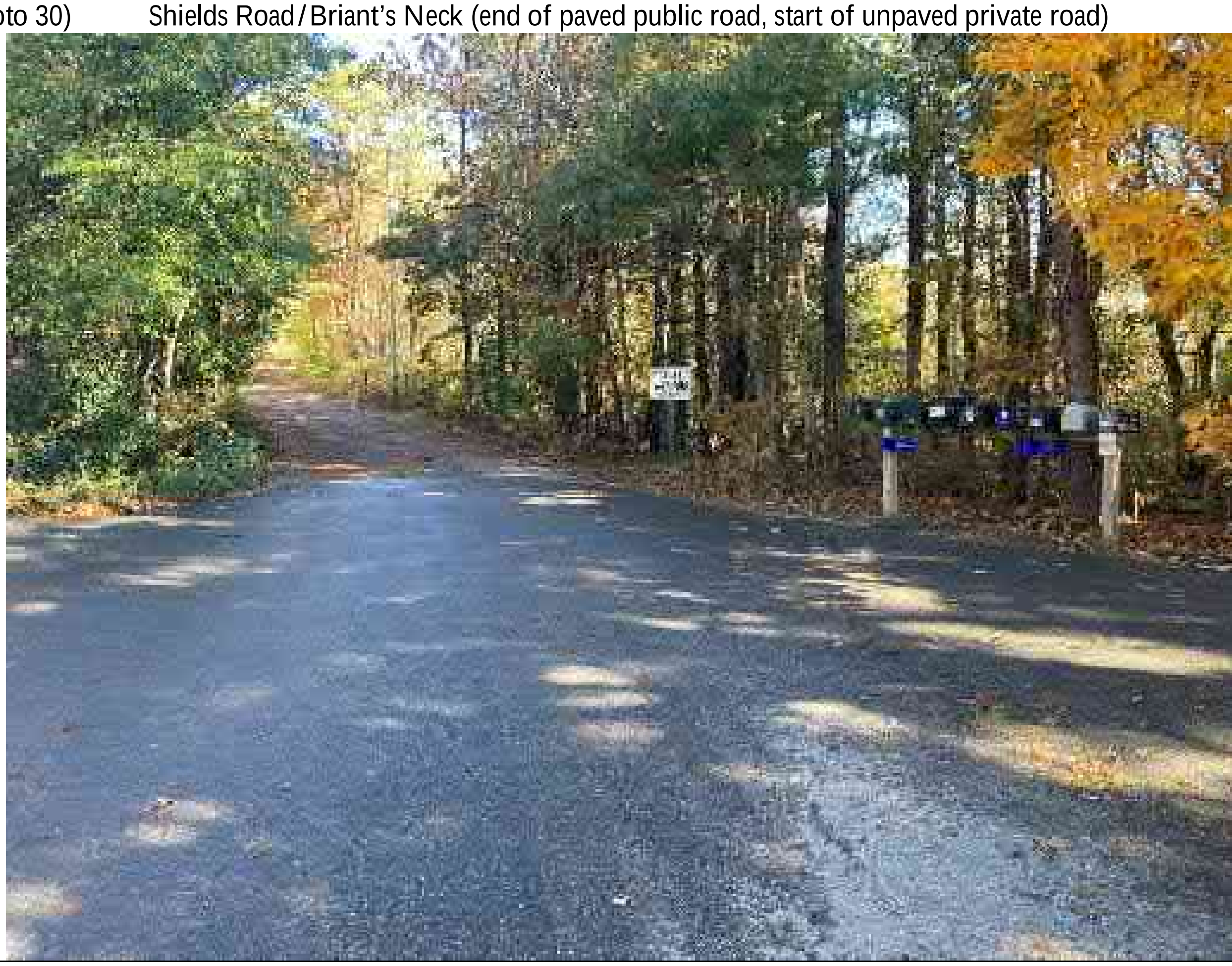
Photo 27) Radcliffe Road Cul-de-Sac (heavy debris on road and covering catch basin grates)

Photo 28) Santuit Pond Road (stormwater bypass of catch basin near 23 Santuit Pond Road)

PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 29) Cranberry Lane / Bayberry Drive (heavy accumulation of sediment and debris)

Photo 30) Shields Road / Briant's Neck (end of paved public road, start of unpaved private road)



PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 31) Shields Road/Briant's Neck (side path off leading to conservation land and adjacent wetlands)

Photo 32) Shields Road/Briant's Neck (end of paved portion of shields road, shoulder rutting)

Photo 33) Town Landing (erosion gulley in access road)

Photo 34) Town Landing (erosion along side of access road)

Photo 35) Town Landing (boat launch)

Photo 36) Town Landing (boat launch parking area)

Photo 37) Timberlane Drive / Town Landing Access Road Intersection

Photo 38) Timberlane Drive (catch basin with evidence of stormwater bypass and flow over curb)

Photo 39) Intersection of Timberlane Drive and Lantern Lane

Photo 40) Eagle Project Stairs (erosion/rutting around steps)

Photo 41) Timberlane Drive (erosion around ends of retaining wall due to stormwater bypass at catch basin)

Photo 42) Timberlane Drive (rutting and overland flow path towards pond)

Photo 43) Timberlane Drive / Lantern Lane Intersection (catch basin in center of photo)

Photo 44) Timberlane Drive Upgradient of Town Landing Access Road (stormwater bypass of catch basin)

Photo 45) Timberlane Drive (clogged catch basin)

Photo 46) Briant's Neck (facing north away from road)

Photo 47) Briant's Neck (beach access facing south towards road)

Photo 48) Briant's Neck (beach access)

Photo 49) Briant's Neck (road shoulder and adjacent wetland / water)

Photo 50) Deer Ridge Road Catch Basin (elevated too high, stormwater bypass)

PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 51) Beechwood Point/Santuit Pond Way (stormwater bypass at end of townhouse parking lot)

Photo 52) Beechwood Point/Santuit Pond Way (erosion gully to wetlands from edge of parking lot)

PHOTOGRAPHS – Santuit Pond Watershed Field Assessments (November 3 and 4, 2021)

Photo 53) Beechwood Point / Santuit Pond Way (erosion near dumpsters at townhouse parking lot)