# SAGAMORE CREEK

## WATER QUALITY SAMPLING PROGRAM

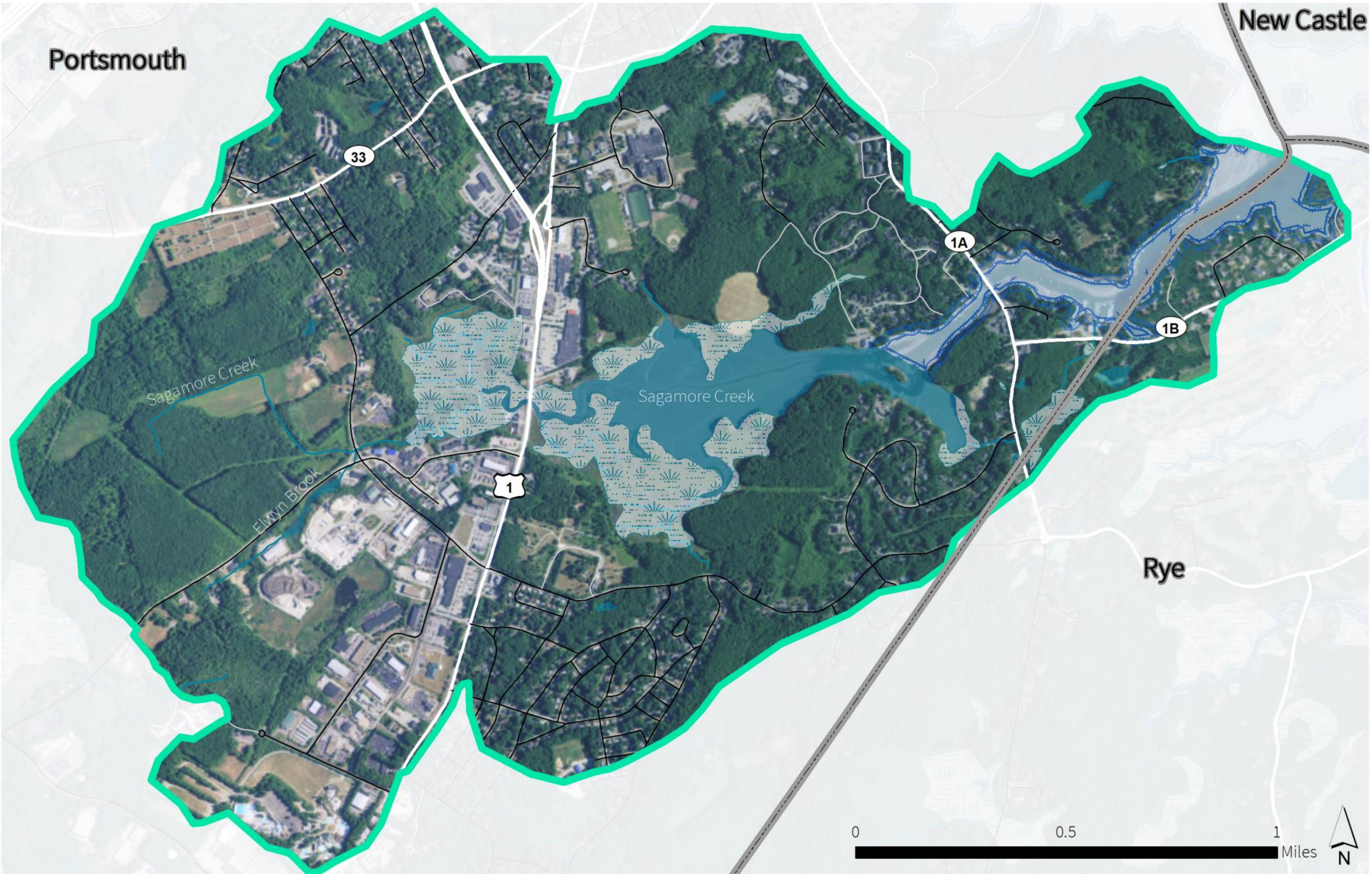
FINAL JULY 2018


FB environmental

University of New Hampshire

clf conservation law foundation

NEW HAMPSHIRE DEPARTMENT OF Environmental Services




FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com

Prepared by L. Diemer, FBE 10-5-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI

Project Area
NH

Stream
Open Water
Marsh
Estuary
Towns
State Road
Local Road
Private Road

# Sagamore Creek Watershed
## General Map

# SAGAMORE CREEK

## WATER QUALITY SAMPLING PROGRAM

Prepared by FB ENVIRONMENTAL ASSOCIATES
*in cooperation with the City of Portsmouth*

FINAL | JULY 2018

CONTACT
City of Portsmouth
680 Peverly Hill Road
Portsmouth, NH 03801
(603) 766-1421
www.cityofportsmouth.com

# Acknowledgements


### Technical Advisory Committee

Peter Rice, Director of Public Works, City of Portsmouth
Terry Desmarais, City Engineer, City of Portsmouth
Peter Britz, Environmental Planner/Sustainability Coordinator, City of Portsmouth
Brian Goetz, Deputy Director of Public Works, City of Portsmouth
Jessica Pearce, Water Quality & Resource Protection Specialist, City of Portsmouth
Suzanne Woodland, Deputy City Attorney, City of Portsmouth
William McDowell, Professor, Ph.D., University of New Hampshire
Wilfred Wollheim, Professor, Ph.D., University of New Hampshire
Melissa Paly, Great Bay WaterKeeper, Conservation Law Foundation
Ted Diers, Watershed Management Bureau Administrator, NHDES
Steve Couture, Coastal Program Administrator, NHDES
Matthew Wood, Water Quality Assessment Program Coordinator, NHDES
Sally Soule, Coastal Watershed Supervisor, NHDES

### FB Environmental Associates Technical Staff

Forrest Bell, Principal & Senior Scientist
Laura Diemer, Project Manager
Margaret Burns, Project Manager
Richard Brereton, Ph.D., Project Scientist
Jaqueline Boudreau, Project Scientist

### Additional Partners / Special Thanks To

James McCarty, GIS Coordinator, City of Portsmouth
Karl Snyder, Utilities Inspection & Maintenance Foreman, City of Portsmouth
Al Pratt, Water Resources Manager, City of Portsmouth
Kim McNamara, Health Officer, City of Portsmouth
Tom Irwin, Vice President & Director, Conservation Law Foundation
Chris Nash, Shellfish Program Manager, NHDES
Peter Rowell, Building Inspector/Code Enforcement Officer, Town of Rye
Vicky Nelson, Assistant District Manager, Rockingham County Soil & Water Conservation District
Jennifer Rowden, Senior Planner, Rockingham County Soil & Water Conservation District
Carolyn Marvin, Research Librarian, Portsmouth Athenaeum
Stephen Jones, Associate Director & Professor, Ph.D., Jackson Estuarine Laboratory & UNH
Deirdre Barrett, Science teacher, Portsmouth High School
Thomas Gregory, Research Scientist, University of New Hampshire
Larry Mayer, Center for Coastal & Ocean Mapping/Joint Hydrographic Center Director, Ph.D., UNH
Shachak Pe'eri, Affiliate Associate Professor, Ph.D., NOAA & UNH
Paul Johnson, Center for Coastal & Ocean Mapping/Joint Hydrographic Center Data Manager, UNH
Kalle Matso, Coastal Science Program Manager, Piscataqua Region Estuaries Partnership

Seth Barker, Independent Contractor, Piscataqua Region Estuaries Partnership
Frederick Short, Professor, Ph.D., Jackson Estuarine Laboratory & UNH
David Burdick, Interim Director & Professor, Ph.D., Jackson Estuarine Laboratory & UNH
Kevin Nyhan, Administrator, NHDOT
Andy Chapman, Biomonitoring Program Coordinator, NHDES
Alison Watts, Research Assistant Professor, Ph.D., UNH
Pamela Hunt, Senior Biologist in Avian Conservation, NH Audubon
Mike Doan, Research Associate, Friends of Casco Bay

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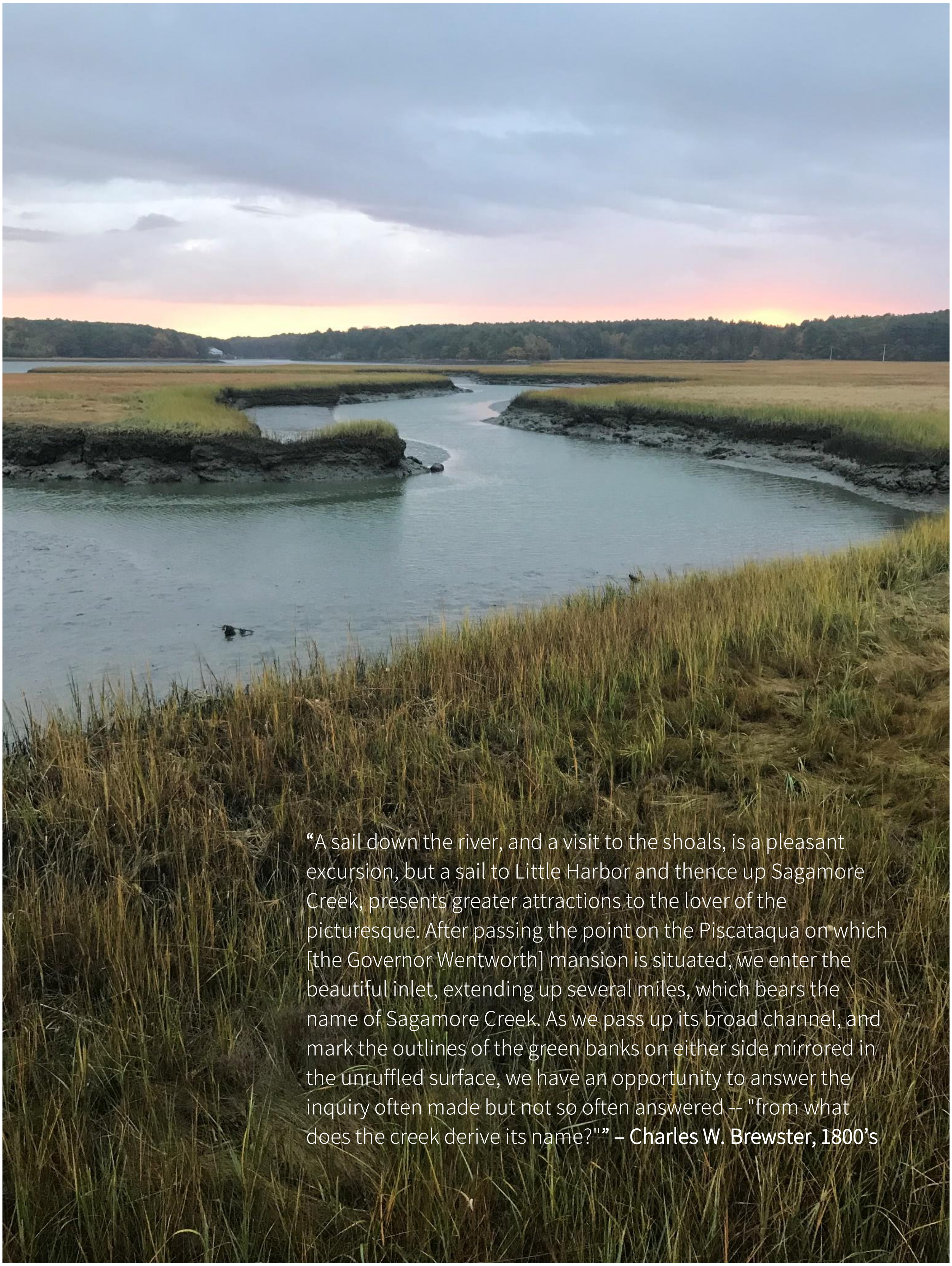
"A sail down the river, and a visit to the shoals, is a pleasant excursion, but a sail to Little Harbor and thence up Sagamore Creek, presents greater attractions to the lover of the picturesque. After passing the point on the Piscataqua on which [the Governor Wentworth] mansion is situated, we enter the beautiful inlet, extending up several miles, which bears the name of Sagamore Creek. As we pass up its broad channel, and mark the outlines of the green banks on either side mirrored in the unruffled surface, we have an opportunity to answer the inquiry often made but not so often answered -- "from what does the creek derive its name?"" – **Charles W. Brewster, 1800's**

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# Introduction

Located along the New Hampshire coastline near the outlet of the Piscataqua River, Sagamore Creek is a tidally-influenced waterbody, largely characterized by its salt marshes and mudflats that serve as critical habitat for numerous and diverse aquatic and terrestrial species. The Creek is enjoyed by boaters and paddlers alike with several public access points and recreational opportunities along the shoreline.

Although large tracts of conserved land exist within the watershed and help protect important natural resources, the Creek is also intersected by multiple high-traffic roads, including Route 1 and 1A, which are lined with a dense mix of residential, commercial, and industrial buildings largely serviced by municipal storm sewer systems (though septic systems are used at some residences and businesses in the area). Because of the diffuse pollution coming from these developed areas or from legacy human activities in the watershed, the freshwater and estuarine portions of Sagamore Creek are considered impaired waters in the State of New Hampshire. Sagamore Creek does not meet state criteria for the designated uses of aquatic life, fish consumption, and shellfishing due to elevated levels of various contaminants and/or poor estuarine bioassessments. Other assessment units include Elwyn Brook, a headwater tributary to Sagamore Creek, along with its one-acre impoundment bordering the Department of Public Works (DPW) lot, and an unnamed brook draining to the lower portion of the Creek, crossing under Wentworth Road. Not included in the New Hampshire Department of Environmental Services (NHDES) assessments are two unnamed freshwater, headwater tributaries: one originating just east of Route 1 and entering the upper salt marsh to the west after flowing under Greenleaf Avenue and the other originating from the Portsmouth High School area and flowing south past the Winchester Place Apartments before emptying into the upper estuarine portion of Sagamore Creek.

The following document describes a multi-year water quality sampling program that will characterize and quantify the type, amount, and location of pollutant input sources to Sagamore Creek and provide a broader understanding of the water quality of Sagamore Creek. The work accomplished for the program will help inform NHDES 303(d) listing assessments and achieve Great Bay 2020 vision goals through this project's collaboration with the scientific community to strategically identify and address major sources of pollution to the Creek, as well as gathering information to better understand the health of the Creek.

The genesis for this work arises from the City's obligations under the Consent Decree, Second Modified, in *United States et. al. v. City of Portsmouth*, No. 09-cv-283-PB (hereafter, Consent Decree). The Consent Decree requires mitigation for the delayed implementation of secondary treatment at the Peirce Island wastewater treatment facility. The City will provide $100,000 annually for a period of five years to support water quality and ecosystem health efforts related to the Great Bay estuary. A portion of that annual financial commitment is being used to support the Sagamore Creek sampling effort. Sagamore Creek was selected partly because the City will also be undertaking sewer system improvements and stormwater projects in the Sagamore Creek watershed over the next three to six years, as part of the same

Consent Decree. The City and other stakeholders have a unique opportunity to measure changes in water quality because of these infrastructure improvements.

# Technical Advisory Committee

A highly-qualified team of technical advisors was assembled for the development of the Sagamore Creek water quality sampling program. Technical Advisory Committee (TAC) members represented the following organizations: City of Portsmouth, University of New Hampshire (UNH), Conservation Law Foundation (CLF), and NHDES. FB Environmental Associates (FBE) was contracted to conduct this assessment and coordinate four TAC meetings to discuss the project.

- On October 25, 2017, FBE hosted a kick-off meeting to introduce project details to TAC members and solicit discussion of known issues in the watershed and identification of additional data sources for review.
- On December 13, 2017, FBE presented a summary of legacy and current potential pollutant sources in the Sagamore Creek watershed. TAC members provided feedback on information.
- On February 6, 2018, FBE presented a draft outline of the proposed water quality sampling program. TAC members provided feedback on the proposed plan and contacts for FBE to follow-up on for further information.
- On March 6, 2018, FBE presented a review of information gained from follow-up with contacts identified at previous meeting (refer to Appendix 1). TAC members agreed on a revised scope for the water quality sampling program based on this information.

FBE sent the draft report to TAC members for review and incorporated feedback in the final report.

# Watershed Characterization

This section provides information on the local climate, demographic history, underlying soil, habitat, and geographical characteristics, and past and present land cover, including stormwater infrastructure, in the Sagamore Creek watershed.

### Description, Location, & Climate

Located in the coastal region of southern New Hampshire, the 3.6-square-mile (2,314-acre) watershed to Sagamore Creek spans across two towns, with 96% (2,210 acres) in Portsmouth and 4% (104 acres) in Rye. The headwaters of Sagamore Creek begin in a forested-agricultural area west of Peverly Hill Road, where a tributary, Elwyn Brook, joins the Creek before continuing to flow east into a salt marsh. Another headwater tributary flows from the northeast side of the Route 1 (Lafayette Road) bridge crossing and travels under Greenleaf Avenue before entering the salt marsh. The Creek widens as flows from the north above Greenleaf Avenue converge with the main stem just upstream of Route 1. Downstream of Route 1, the salt marsh system opens to a navigable estuary with unrestricted tidal influence. The Creek then empties into the Piscataqua River west of New Castle, NH and between Back Channel to the north and Little Harbor to the south. Hydrodynamic studies of the area show that most of the water volume from Sagamore Creek flows into and out of Little Harbor, though there is some tidal influence from the Back Channel as well.

The State of New Hampshire is situated within a temperate zone of converging weather patterns from the hot, wet southern regions and the cold, dry northern regions, which causes various natural phenomena such as severe thunder and lightning storms, hurricanes, and heavy snowfalls. The low-lying, coastal areas of New Hampshire experience moderated climate due to the ocean influence. The coastal area near Portsmouth experiences moderate to heavy rainfall and snowfall, averaging 50.09 inches of precipitation annually (data collected from 1981-2010 at the North Hampton, NH weather station; NOAA NCEI, 2017). Temperature generally ranges from -12 °C to 14 °C with an average of -6 °C in winter and 18 °C in summer (NOAA NCEI, 2017).

While precipitation (as rain and snow) in the area steadily increased from the 1970's to the early 2000's, the area has experienced a slight decrease in total annual precipitation, total annual snowfall, and average snow depth in the last decade (Figures 1-3). The region overall has seen an increase in extreme rainfall events (e.g., the frequency of 2-inch rain events has increased since the 1950's and storms once considered a 1-in-100-year event are now more likely to occur nearly twice as often) (NRCC & NRCS, 2018). In addition, the annual average temperature has become cooler and the annual minimum temperature has become warmer from 1973-2017 (Figure 4). These trends are likely the result of human-induced climate change, which will impact the water quality and habitats of Sagamore Creek as the environment responds to these external climate forces.

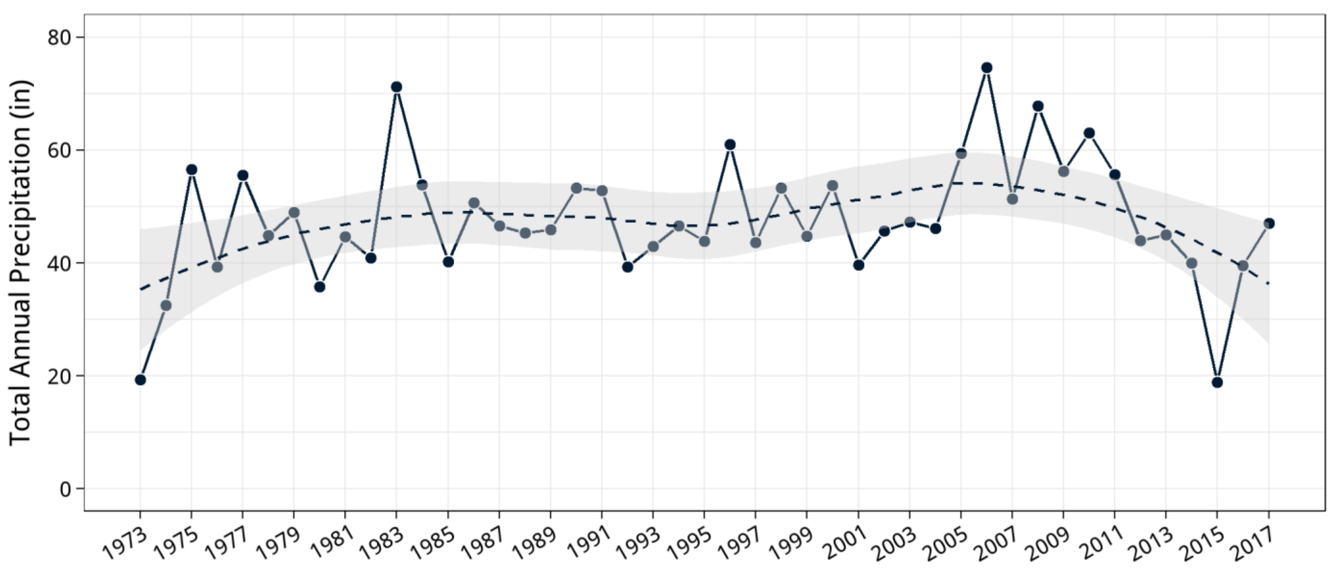



**Figure 1.** Total annual precipitation from 1973-2017. Data taken from the NOAA National Centers for Environmental Information (NCEI) for station GREENLAND, NH US (ID# USC00273626). Daily data were summarized by month then year using R statistical software. Mann-Kendall trend tests were performed. No statistically-significant trends were found. Dotted line and grey shading denote LOESS (locally-weighted smoothing) and its confidence intervals.

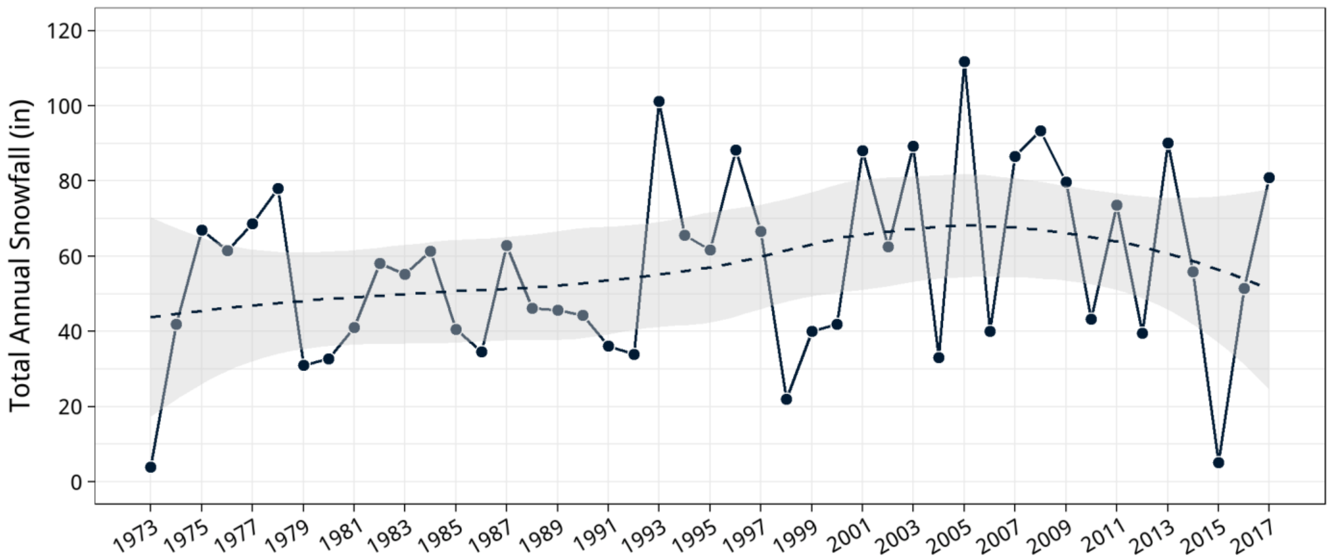



Figure 2. Total annual snowfall from 1973-2017. Data taken from the NOAA National Centers for Environmental Information (NCEI) for station GREENLAND, NH US (ID# USC00273626). Daily data were summarized by month then year using R statistical software. Mann-Kendall trend tests were performed. No statistically-significant trends were found. Dotted line and grey shading denote LOESS (locally-weighted smoothing) and its confidence intervals.

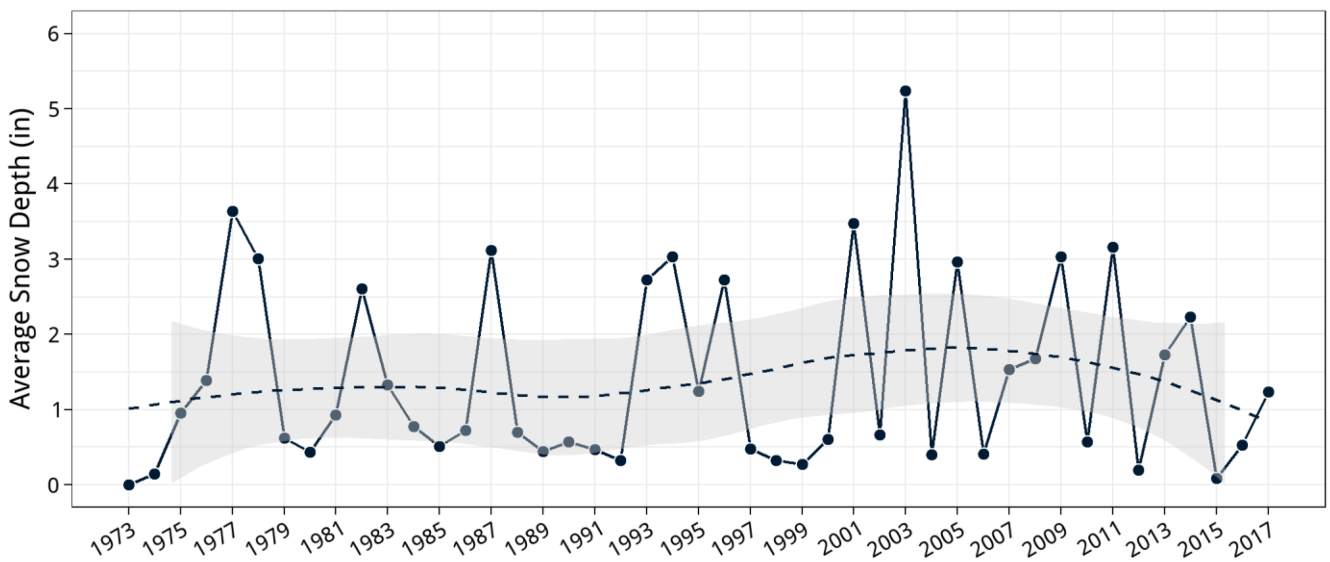



Figure 3. Average annual snow depth (water equivalent) from 1973-2017. Data taken from the NOAA National Centers for Environmental Information (NCEI) for station GREENLAND, NH US (ID# USC00273626). Daily data were summarized by month then year using R statistical software. Mann-Kendall trend tests were performed. No statistically-significant trends were found. Dotted line and grey shading denote LOESS (locally-weighted smoothing) and its confidence intervals.

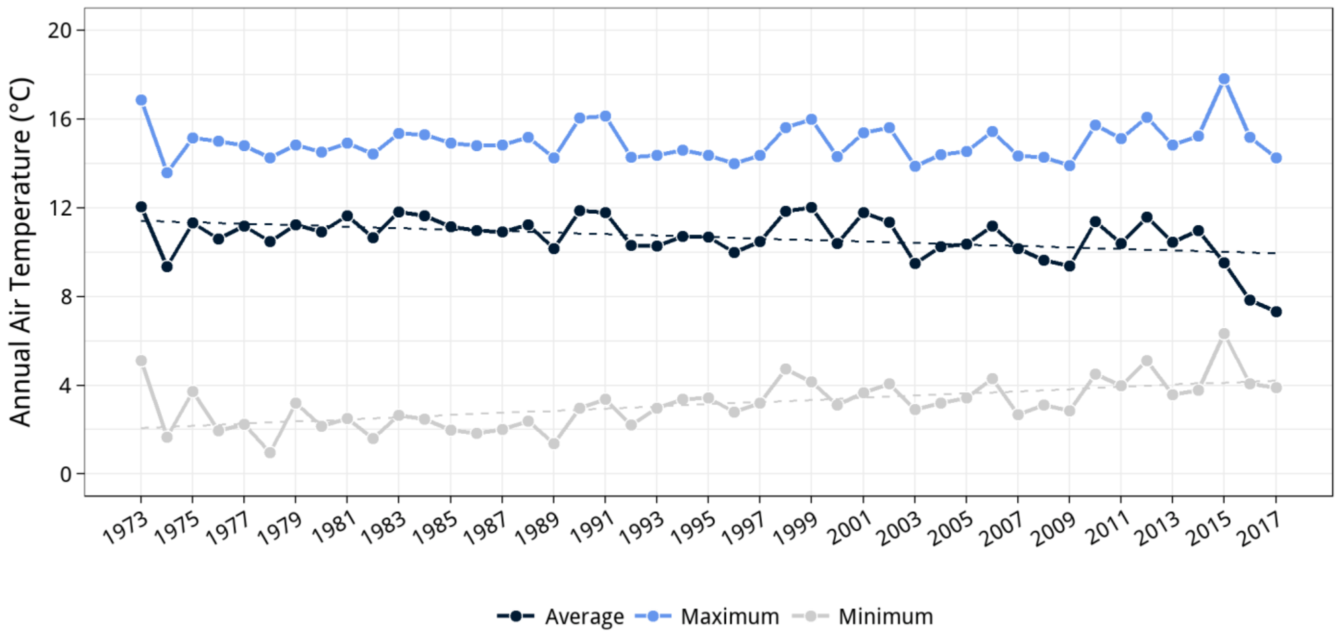



Figure 4. Annual maximum, average, and minimum air temperature from 1973-2017. Data taken from the NOAA National Centers for Environmental Information (NCEI) for station GREENLAND, NH US (ID# USC00273626). Daily data were summarized by month then year using R statistical software, so maximum and minimum values are the average of monthly maximums and minimums for an individual year. Mann-Kendall trend tests were performed. Statistically-significant trends were found for average and minimum air temperatures.

## Population & Growth Trends

Before European settlement, the area was inhabited by Native Americans. Sagamores were the heads of Native American families governing certain territories, including the Piscataqua River. It is assumed that the Creek's name was derived from the fact that the region's "Sagamore" lived along the Creek (Brewster, 2000). Portsmouth was first settled by colonists around 1622 when a handful of men put up homes and began fishing, sawing lumber, and trading with Native Americans. More people arrived by 1630 under the employment of the Laconia Company, owned by Captain John Mason. Plantations were established, and the first cattle arrived from Europe by 1635 (Adams, 1825). The Wentworth Coolidge estate (also known as Creek Farm) was first settled by Nicholas Rowe in 1640 and is considered one of the earliest European-cultivated lands in New Hampshire (Society for the Protection of New Hampshire Forests, n.d.). In the early to mid-1800's, the area saw roads widen and bridges constructed over large waterbodies, including Route 1A over Sagamore Creek, to accommodate the influx and transport of increasing development and population to the area (Adams, 1825). Portsmouth experienced exponential growth from 1940-1960 as commercial and industrial businesses came to the area and suburban neighborhoods were developed.

Understanding population growth and demographics and ultimately development patterns, provide critical insight to the status of water quality in the area. According to the U.S. Census Bureau, the population of Rockingham County in 2010 was 295,223, representing a 4% increase in population since the 1960 census (NHOEP, 2011; Figure 5; Table 1). Following a dramatic increase in population from 15,000 in 1940 to nearly 27,000 in 1960, Portsmouth has since experienced a decline in population to a low of over 20,000 in 2000, likely due to the closure of Pease Air Force Base (NHOEP, 2011; Figure 5; Table 1). Rye has experienced a steady increase in population, rising from over 1,200 in 1940 to nearly 5,300 in 2010 (NHOEP, 2011; Figure 5; Table 1).

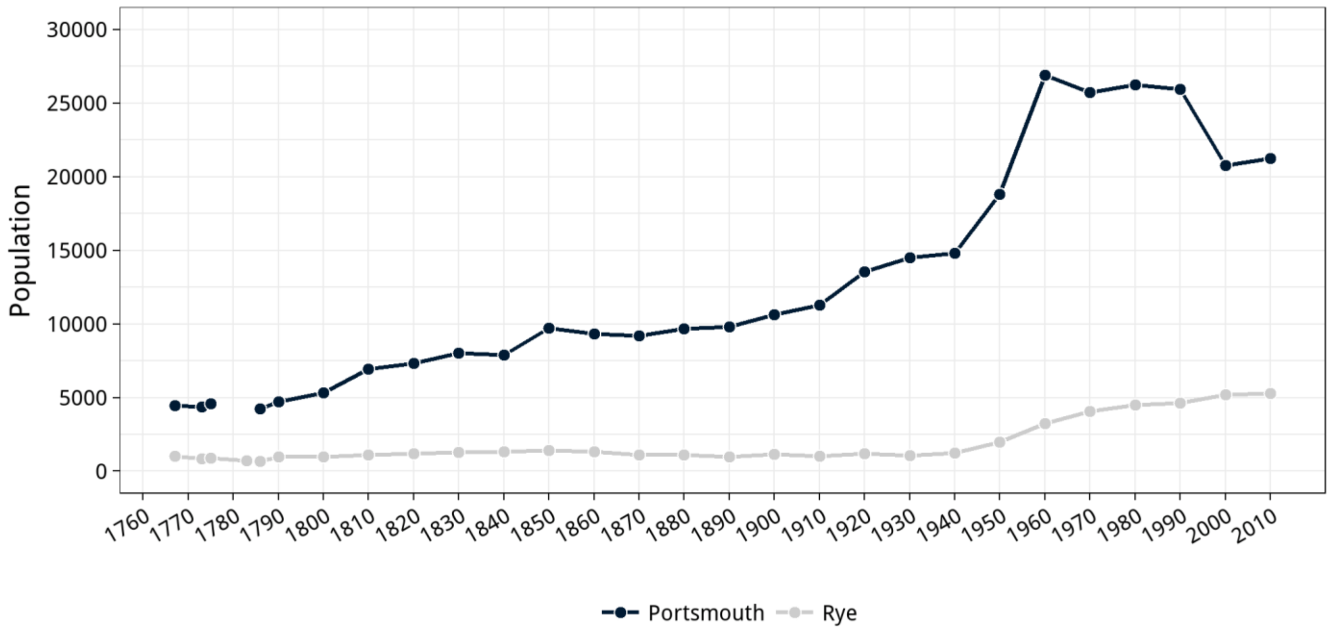



**Figure 5.** Historical demographic data for towns in the Sagamore Creek watershed. The population of Portsmouth has grown dramatically over the last 50 years. Data obtained from NHOEP (2011).

**Table 1.** Population growth rates for watershed communities in the Sagamore Creek watershed. Data obtained from NHOEP (2011).

| County/Town | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 | 50-Yr Annual Growth Rate (1960-2010) | 20-Yr Annual Growth Rate (1990-2010) | 10-Yr Annual Growth Rate (2000-2010) |
|---|---|---|---|---|---|---|---|---|---|
| Rockingham | 98,642 | 138,951 | 190,345 | 245,845 | 277,359 | 295,223 | 3.99% | 1.00% | 0.64% |
| Portsmouth | 26,900 | 25,717 | 26,254 | 25,925 | 20,784 | 21,233 | -0.42% | -0.90% | 0.22% |
| Rye | 3,244 | 4,083 | 4,508 | 4,612 | 5,182 | 5,298 | 1.27% | 0.74% | 0.22% |

Most of the population for Portsmouth and Rye fall within the 20-64 age category. Residences in these municipalities comprise a low percentage of seasonal (1-17%) and a high percentage of renter-occupied (16-46%) homes, though the residences in the Sagamore Creek watershed are likely year-round, owner-occupied homes as most rental homes are in downtown Portsmouth (Table 2).

**Table 2.** 2010 population demographics for Portsmouth and Rye compared to state and county data. Data obtained from NHOEP (2011).

| State/County/Town | Total pop | Aged 0-19 | Aged 20-64 | Aged 65+ | Total Housing Units | Total Occ. Houses[1] | Owner Occ. Houses[1] | Seasonal Houses[1] | Renter Occ. Houses[1] |
|---|---|---|---|---|---|---|---|---|---|
| New Hampshire | 1,316,470 | 325,802 | 812,400 | 178,268 | 614,754 | 84% | 60% | 10% | 25% |
| Rockingham County | 295,223 | 73,825 | 183,974 | 37,424 | 126,709 | 91% | 70% | 5% | 21% |
| Portsmouth | 20,779 | 3,722 | 13,752 | 3,305 | 10,625 | 94% | 48% | 1% | 46% |
| Rye | 5,298 | 1,147 | 3,105 | 1,046 | 2,852 | 79% | 63% | 17% | 16% |

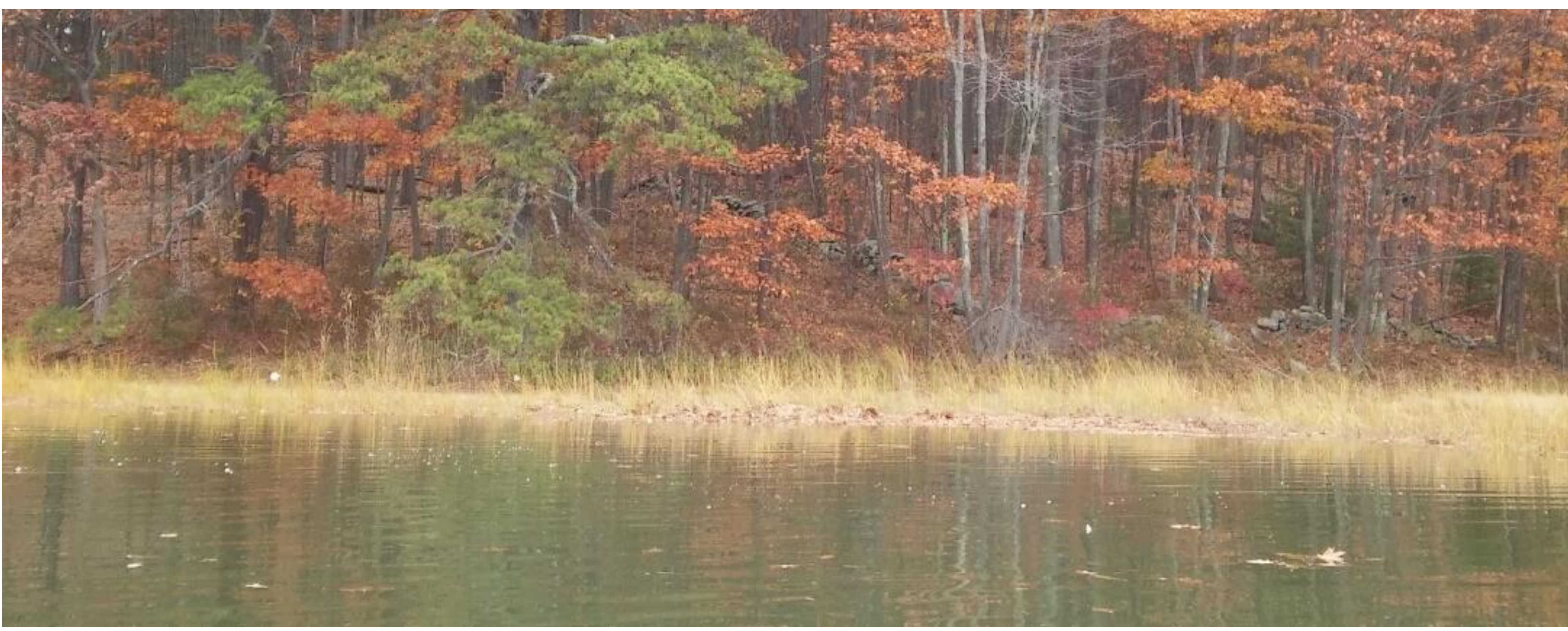
[1] *Percentage of total housing units*

The desirability of the New Hampshire Seacoast area as a primary residence, as well as a recreational destination, will likely stimulate continued population growth in the future. Growth figures and estimates suggest that communities within the Sagamore Creek watershed should consider the effects of current municipal land-use regulations on local water resources. As the region's watersheds are developed, pollutants from developed areas increase the potential for water quality decline.

## Land Cover

Land cover is the essential element in calculating pollutant loads contributing to a waterbody via stormwater runoff and groundwater. Characterizing both current and historical land cover within a watershed on a spatial and temporal scale can highlight potential sources of pollution that would otherwise go unnoticed in a field survey of the watershed.

Historically, the Sagamore Creek watershed was harvested for lumber and converted to agricultural land before the current commercial and industrial businesses moved in. Town meeting records in 1649 showed that a saw mill owned by Ambrose Lanne was in operation along Sagamore Creek. Mr. Lanne was permitted full liberty to fall any timber in common (Adams, 1825). By 1682, the primary exports to Europe were lumber, beef, fish, oil, and livestock. Ship building was also active along the shorelines. Early accounts showed that a dozen houses and a dozen more warehouses were erected in the area from Strawberry Bank to Sagamore Creek by 1682 (Adams, 1825). Livestock in the area expanded from cattle to sheep, goats, hogs, and horses. A map of the region in 1699 showed an orchard enclosed with stone walls on the northwest side of Sagamore Creek (The Thoresen Group, 1983).



Evidence of historic agriculture (stone walls) along the north shore of Sagamore Creek was noted during the 2017 shoreline survey. Photo: FBE.

The Wentworth Coolidge estate, which included a house, a warehouse, orchards, and wharves on 30 acres of land at the mouth of Sagamore Creek, was owned by Governor Benning Wentworth from 1663-1770. By the 1750's, the estate was considered a working farm with vegetable and flower gardens, hayfields, and pastures for grazing animals. An early 1800's advertisement provided evidence that there was about 100 acres of active agricultural land, plus two orchards enclosed by a stone wall. Tax records for the estate in 1823 showed 1 horse, 2 oxen, 5 cows, 1 acre of orchard, 4 acres of agricultural land, and 20 acres of pasture. A hennery was added to the estate in the 1870's and John T. Coolidge noted "there were so many hens there, there was no lawn in front of the mansion" (The Thoresen Group, 1983).

In the early to mid-1800's, the area saw roads widen and bridges constructed over large waterbodies, including Route 1A over Sagamore Creek, to accommodate the influx and transport of increasing development and population to the area. Other accounts described several active farms along the Creek by the 1850's, including a farm west of Sagamore Bridge (Route 1A) on the south side of the Creek that had cows, an apple orchard, and vegetable gardens (Brewster, 2000).

Between 1943 and 1962, large tracts of forest land in the southern portion of the watershed were converted to residential and commercial/industrial use (e.g., gravel pit; Figure 6). Between 1962 and 1974, most of the remaining active agricultural land in the watershed was converted to residential and commercial/industrial use (e.g., landfill; Figures 6 & 7). Developed area in the watershed continued to increase from 33% coverage in 1990 to 49% coverage in 2010 (Figure 8). Currently, agriculture covers 1%, developed areas cover 52% (impervious surfaces cover 21%), forests cover 27%, open water covers 7%, and wetlands cover 13% of the watershed (refer to Appendix 2, Maps 1 & 2).


Parking lot at the Dinnerhorn restaurant just upstream of the Route 1 bridge abuts the Creek and floods during very high tides. Photo: FBE.

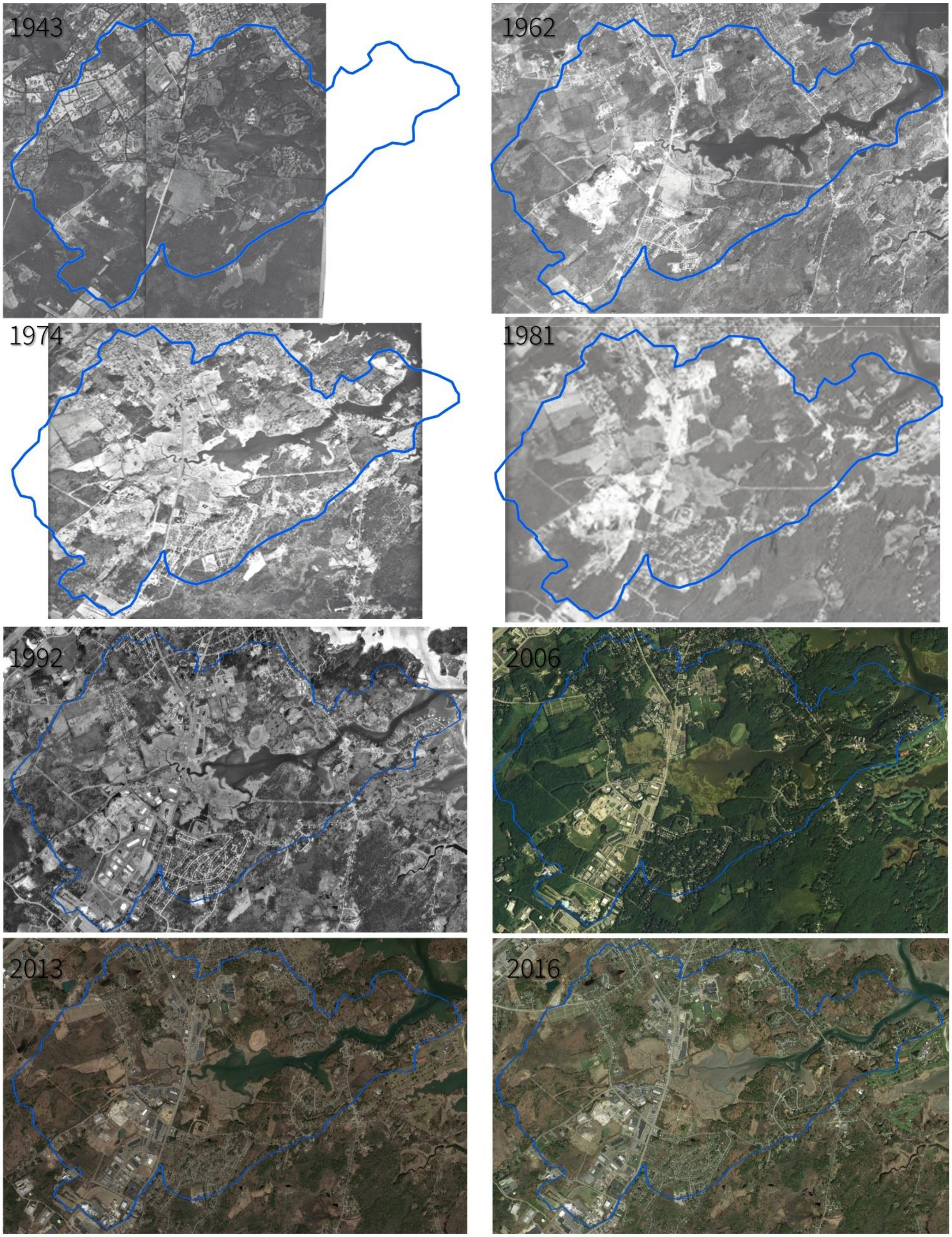



Figure 6. Historical aerials of the Sagamore Creek watershed from 1943-2016. Aerials from 1943, 1962, 1974, and 1981 were obtained from the Rockingham County Conservation District as scans of hardcopy prints. Overlaid watershed boundaries are approximate and leaf-off timing is unknown. Aerials from 1992, 2006, 2013, and 2016 were obtained from GoogleEarth Timelapse imagery (April leaf-off times shown only, when available).

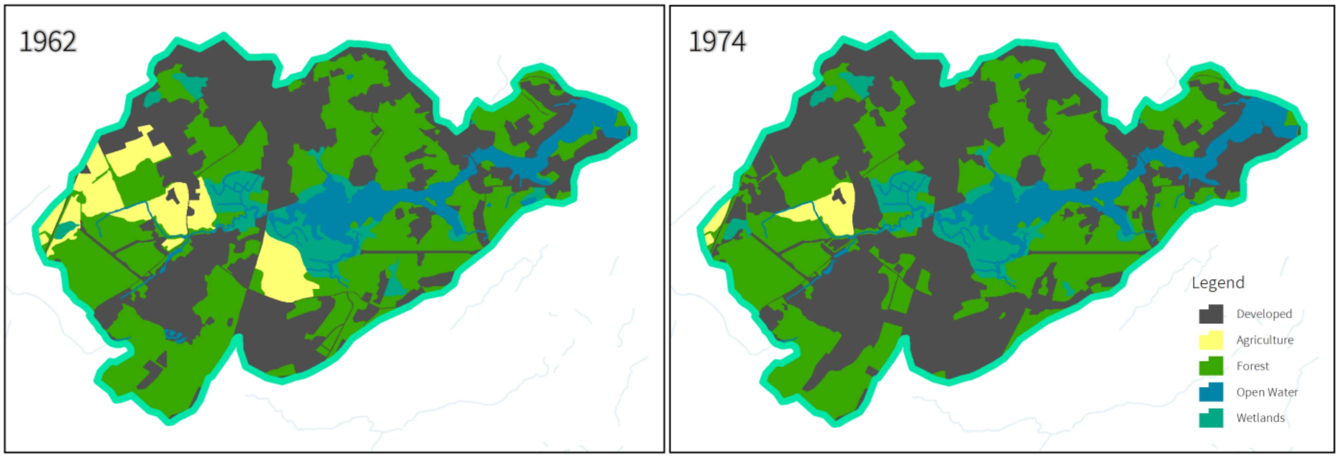



Figure 7. Change in general land cover types (developed, agriculture, forest, open water, and wetlands) in the Sagamore Creek watershed from 1962 to 1974. Photo-interpreted land use data was developed by the Complex Systems Research Center at the University of New Hampshire. Available online through GRANIT. Last revision March 2004.

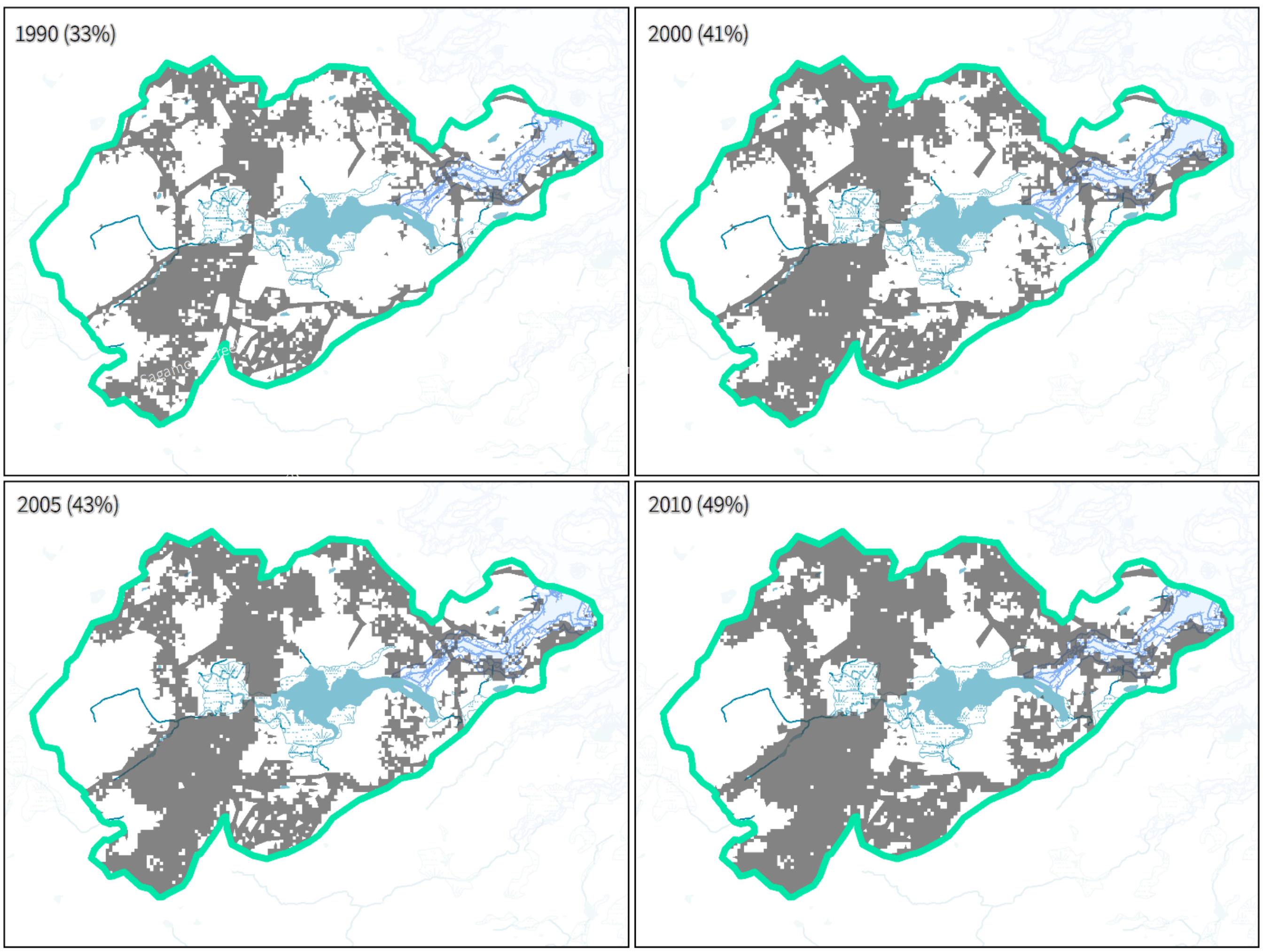



Figure 8. Change in developed area coverage (gray) in the Sagamore Creek watershed from 1990-2010 (33-49%). Data were developed from Landsat 5 Thematic Mapper imagery. Available online through GRANIT.

## Land Conservation

Nearly 19% (430 acres) of the Sagamore Creek watershed is in conservation. Major conservation properties include Creek Farm and the Wentworth Coolidge Historic Site located on the north shore at the outlet of Sagamore Creek, the Sagamore Creek Headlands located on the south shore west of Route 1A, Sagamore Creek Land located around the capped Jones Avenue Landfill on the north shore of the Creek, and the Urban Forestry Center located on the south shore east of Route 1 (Appendix 2, Map 3).

### Creek Farm and the Wentworth Coolidge Historic Site

Located near the outlet of Sagamore Creek, Creek Farm was one of the earliest agricultural settlements in New Hampshire. The 36-acre property was put in permanent conservation in 2000 and now serves as an outdoor education resource, tree farm, bird sanctuary, and wildlife reservation. Photo courtesy of the Society for the Protection of NH Forests.

### Sagamore Creek Headlands

Located on the south shore west of Route 1A, the Sagamore Creek Headlands is a 10-acre peninsula with significant rock outcroppings. The property was purchased in 2003 by the Trust for Public Land and the City of Portsmouth as open space for public recreational access. Photo courtesy of Geocaching.

### Sagamore Creek Land

Once the site of a municipal landfill and open burn pit until the 1970's (officially closed in 1990), the 79-acre, City-owned property is now being considered for better public access and recreational use. The Blue Ribbon Committee was appointed by the mayor in 2015 to begin design plans. Photo courtesy of GoogleEarth.

### Urban Forestry Center

Bequeathed to the State of New Hampshire in 1976, the Urban Forestry Center is a 172-acre property managed by the Division of Forests & Lands of the Department of Resources & Economic Development. The property is used as a tree farm, wildlife sanctuary, landscape demonstration site, and learning center for proper forest management. Photo courtesy of Wikipedia.

## Topography

Sagamore Creek is situated along the coast of New Hampshire, with the lowest point in the watershed at sea level. The highest point in the watershed (88 feet above sea level) is located along South Street directly northeast of the Portsmouth High School. The next highest points are located within the Sagamore Creek Land conservation area just northwest of the capped Jones Avenue Landfill, at the back of the DPW/Pike Industries properties, and at Water Country Water Park. Refer to Appendix 2, Map 4.

## Soils & Geology

### Surficial Geology

The composition of soils along the New Hampshire coastline reflects the dynamic geological processes that have shaped the landscape of New England over millions of years. Some 300 to 400 million years ago, much of the northeastern United States was covered by a shallow sea; layers of mineral deposition compressed to form sedimentary layers of shale, sandstone, and limestone (Goldthwait, 1951). Over time, the Earth's crust then folded under high heat and pressure to change the sedimentary rocks into metamorphic rocks (quartzite, schist, and gneiss parent material). This metamorphic parent material has since been modified by bursts of molten material intrusions to form igneous rock, including granite for which New Hampshire is famous for (Goldthwait, 1951). Erosion has further modified and shaped this parent material over the last 200 million years.

The current landscape formed 12,000 years ago, at the end of the Great Ice Age, as the mile-thick glacier over half of North America melted and retreated, scouring bedrock and depositing glacial till to create the deeply scoured basins of the region's waterbodies. The retreating action also eroded mountains and left behind remnants of drumlins and eskers from ancient stream deposits. The glacier deposited a layer of glacial till more than three feet deep. Glacial till is composed of unsorted material, with particle sizes ranging from loose and sandy to compact and silty to gravely. This material laid the foundation for invading vegetation and meandering streams as the depression basins throughout the region began to fill with water (Goldthwait, 1951). Along the coast, silts and clays deposited by glacial meltwater formed a submarine, blue-gray clay known as the Presumpscot Formation.

The surficial geology of the Sagamore Creek watershed is characterized largely by the Presumpscot Formation (38%), wave-modified marine delta deposits (26%), and glacial till (21%), along with smaller areas of salt marsh deposits (7%), artificial fill (1%), bedrock (<1%), and freshwater wetland deposits (<1%). Salt marsh deposits are a mix of sand and gravel and/or sand with minor silt. The Presumpscot Formation is undifferentiated sand, silt, and clay. Refer to Appendix 2, Map 5.

### Soils

The most prevalent soil group in the Sagamore Creek watershed is Chatfield-Hollis-Canton complex, a well-drained, very stony till at 3-8% slopes (22%) and 8-15% slopes (10%), closely followed by Urban land-Canton complex (18%). Generally, poorly-drained, organic soils (some from silt and clay marine deposits) cover 18% (427 acres) of the watershed; disturbed urban lands cover 32% (734 acres); and open water covers 7% (156 acres). The remaining areas are largely well-drained, sandy outwash and tills, covering 43% (996 acres) of the watershed. Refer to Appendix 2, Map 6 and Appendix 3.

### Soil Erosion Potential

Soil erosion potential is dependent on a combination of factors, including land contours, climate conditions, soil texture, soil composition, permeability, and soil structure (O'Geen et al., 2006). Soil erosion potential can identify areas more vulnerable to soil loss in developed areas. Soils with negligible soil erosion potential are primarily low-lying, clay and organic matter-dominated wetland areas near abutting streams. The soil erosion potential was determined from the associated whole soil erosion factor $K_w$[1] used in the Universal Soil Loss Equation (USLE). The USLE predicts the rate of soil loss by sheet or rill erosion in units of tons per acre per year.

Low and moderate soil erosion potential areas cover 8% and 11% of the Sagamore Creek watershed, respectively. These areas are largely in the forested headwaters of the watershed. The rest of the watershed is unclassified, especially in the developed areas. Disturbed areas are difficult to assign ratings to because it may be unclear what the soil composition is (e.g., depletion of organic matter or exposure/compaction of surface materials from construction can elevate soil erosion potential). As such, there may be more moderate or high soil erosion potential areas in the watershed because of human activities, but the extent is unknown. Refer to Appendix 2, Map 7.

## Habitats & Wildlife

New Hampshire Fish and Game Department (NHFGD) ranks habitat based on value to the State, biological region (areas with similar climate, geology, and other factors that influence biology), and supporting landscape. These habitat rankings are published in the State's 2015 Wildlife Action Plan, which serves as a blueprint for prioritizing conservation actions to protect Species of Greatest Conservation Need in New Hampshire.

[1] $K_w$ = the whole soil k factor. This factor includes both fine-earth soil fraction and large rock fragments.

Most of the watershed is characterized by barren or developed land (40%), followed by Appalachian oak-pine forests (25%), marsh and shrub wetlands (7%), temperate swamps (7%), salt marsh (6%), open water (6%), grassland (6%), and hemlock-hardwood-pine forests (3%). Coastal islands and dunes make up less than 1% of habitat types in the watershed.

About 7% (162 acres) of the Sagamore Creek watershed is considered Tier 1 habitat (highest ranked habitat in New Hampshire). Tier 1 habitat covers the entire salt marsh area. Only 2% (55 acres) of the watershed is considered Tier 2 habitat (highest ranked in the biological region). Tier 2 habitat covers the Appalachian oak-pine forests of the Creek Farm-Wentworth Coolidge Historic Site area, the grassland habitat covering the capped Jones Avenue Landfill, and wetlands at the headwaters of Sagamore Creek, north of Banfield Road. Supporting landscapes (covering 249 acres or 11%) abut these high priority habitats and large forest blocks in the headwaters. Refer to Appendix 2, Map 8.

These forested, wetland, marsh, and open water estuarine habitats offer diverse habitats for freshwater and estuarine, aquatic and terrestrial fauna and flora. Most of the Creek is tidal with head-of-tide at Peverly Hill Road and Greenleaf Avenue. Nelson's and Saltmarsh Sparrows have been observed in the marsh area below Route 1. Both are considered "Special Concern" by NH Fish and Game and are highly vulnerable to sea level rise. A more detailed data request from the Natural Heritage Bureau Database for the location of rare and endangered species in the Sagamore Creek watershed will be made in the future during watershed management plan development. In addition, the NH Coastal Viewer shows that some eelgrass habitat is present in small patches near the outlet, downstream of Route 1A, but the relatively minimal eelgrass coverage and biomass in Sagamore Creek have been declining since 1996 (PREP, 2012).

### Stormwater Infrastructure

The Sagamore Creek watershed area accounts for overland flow collected and conveyed to Sagamore Creek via the municipal stormwater drainage system. Stormwater passes through catchbasins (771), drain manholes (111), drain separators (33), drain inlets/outlets or culverts (396), drain outfalls (28), City drain pipes (18 miles), private drain pipes (< 1 mile), and City drain laterals (3 miles) before discharging to Sagamore Creek. Outfalls are locations in which stormwater is delivered directly to the stream via a ditch or pipe. These estimates reflect spatial data given to FBE by the City in 11/2017 (Appendix 2, Map 9).

# Water Quality Analysis

This section provides an overview of the water quality standards that apply to Sagamore Creek, the methodology used to assess water quality, and the current state of water quality in the Creek.

### Applicable Water Quality Standards & Criteria

The State of New Hampshire is required to follow federal regulations under the Clean Water Act (CWA) with some flexibility as to how those regulations are enacted. The main components of water quality regulations include designated uses, water quality criteria, and antidegradation provisions. The Federal

CWA, the NH *RSA 485-A Water Pollution and Waste Control*, and the NH Surface Water Quality Regulations (Env-Wq 1700) are the regulatory bases for governing water quality protection in New Hampshire. These regulations form the basis for New Hampshire's regulatory and permitting programs related to surface waters, as defined by the Clean Water Act. States are required to submit biennial water quality status reports to Congress via the USEPA. The reports provide an inventory of all waters assessed by the state and indicate which waterbodies exceed the state's water quality standards. These reports are commonly referred to as the "Section 303(d) list" and the "Section 305(b) report."

## Designated Uses & Water Quality Classification

The CWA requires states to determine designated uses for all surface waters within the state's jurisdiction. Designated uses are the desirable activities and services that surface waters should be able to support, and include uses for aquatic life, fish consumption, shellfish consumption, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating and fishing), and wildlife (Table 3). Surface waters can have multiple designated uses.

In New Hampshire, all surface waters are also legislatively classified as Class A or Class B, most of which are Class B (Env-Wq 1700). A brief description of these classes is provided in Table 4 (NHDES, 2016a). Water quality criteria are then developed to protect these designated uses. Depending on the designated use and type of waterbody, water quality criteria can become more or less strict if the waterbody is classified as either Class A or B. Sagamore Creek is considered a Class B waterbody.

**Table 3.** Designated uses for New Hampshire surface waters (adapted from NHDES, 2016a).

| Designated Use | NHDES Definition | Applicable Surface Waters |
|---|---|---|
| Aquatic Life | Waters that provide suitable chemical and physical conditions for supporting a balanced, integrated, and adaptive community of aquatic organisms. | All surface waters |
| Fish Consumption | Waters that support fish free from contamination at levels that pose a human health risk to consumers. | All surface waters |
| Shellfish Consumption | Waters that support a population of shellfish free from toxicants and pathogens that could pose a human health risk to consumers. | All tidal surface waters |
| Drinking Water Supply After Adequate Treatment | Waters that with adequate treatment will be suitable for human intake and meet state/federal drinking water regulations. | All surface waters |
| Primary Contact Recreation | Waters suitable for recreational uses that require or are likely to result in full body contact and/or incidental ingestion of water. | All surface waters |
| Secondary Contact Recreation | Waters that support recreational uses that involve minor contact with the water. | All surface waters |
| Wildlife | Waters that provide suitable physical and chemical conditions in the water and the riparian corridor to support wildlife as well as aquatic life. | All surface waters |

**Table 4.** New Hampshire surface water classifications (adapted from NHDES, 2016a).

| Classification | Description (RSA 485-A:8) |
|---|---|
| Class A | Class A waters shall be of the highest quality. There shall be no discharge of any sewage or wastes into waters of this classification. The waters of this classification shall be considered as being potentially acceptable for water supply uses after adequate treatment. |
| Class B | Class B waters shall be of the second highest quality. The waters of this classification shall be considered as being acceptable for fishing, swimming and other recreational purposes and, after adequate treatment, for use as water supplies. |

## Water Quality Criteria

New Hampshire's water quality criteria provide a baseline measure of water quality that surface waters must meet to support designated uses. These criteria are the "yardstick" for identifying water quality problems and for determining the effectiveness of state regulatory pollution control and prevention programs. If the existing water quality meets or is better than the water quality criteria, the waterbody supports its designated use(s). If the waterbody does not meet water quality criteria, then it is considered impaired for its designated use(s).

Water quality criteria for each classification and designated use in New Hampshire can be found in RSA 485 A:8, IV and in the state's surface water quality regulations. The designated uses for Sagamore Creek include Aquatic Life Use, Drinking Water After Adequate Treatment, Primary Contact Recreation, Secondary Contact Recreation, Fish Consumption, and Shellfishing. A list of the primary and secondary numeric water quality criteria used to assess each designated use for New Hampshire waterbodies is shown in Table 5. Refer to Table 7 for applicable designated uses by assessment unit for the Sagamore Creek watershed.

**Table 5.** List of primary and secondary numeric/narrative water quality criteria for each designated use in the Sagamore Creek watershed. Geo = geometric mean of multiple samples. Instan = instantaneous, single grab sample. Enterococci and E. coli units are in MPN/100mL.

| Designated Use | Primary Numeric/Narrative Criteria | Secondary Numeric/Narrative Criteria |
|---|---|---|
| Aquatic Life Use | Biological assessments (macros & fish)<br>DO < 5 ppm & 75% saturation<br>6.5 > pH > 8.0 | Habitat assessments<br>Stream channel stability<br>Chronic/acute toxics<br>Invasives, Turbidity, TP, Flow |
| Drinking Water* | Treatment technologies exist to produce safe drinking water | Chronic/acute toxics |
| Primary Contact Recreation | Freshwater (beach): E. coli > 88 (Instan), 47 (Geo)<br>Estuarine (beach): Entero > 104 (Instan), 35 (Geo)<br>Freshwater (no beach): E. coli > 406 (Instan), 126 (Geo)<br>Estuarine (no beach): Entero > 104 (Instan), 35 (Geo) | Freshwater: Chlorophyll-a > 15 ppb<br>Estuarine: Chlorophyll-a > 20 ppb<br>Discharge of untreated sewage<br>Presence of cyanobacteria or other scums |
| Secondary Contact Recreation | Freshwater: E. coli > 765 (Instan), 235 (Geo)<br>Estuarine: Entero > 520 (Instan), 175 (Geo) | Discharge of untreated sewage<br>Obstructions to boating by infill |
| Fish Consumption | Freshwater: Mercury in fish tissue<br>Estuarine: Mercury and PCBs in fish tissue | Other toxics in fish tissue<br>Toxics in water |
| Shellfishing | Fecal coliform > 14 (Geo), 43 (90th percentile)<br>Mercury and PCBs in fish tissue | |

**Note that both Class A and B waters shall be considered potentially acceptable for water supply uses after adequate treatment (even if not currently used as such).*

## Antidegradation Provisions

The Antidegradation Provision (Env-Wq 1708) in New Hampshire's water quality regulations serves to protect or improve the quality of the state's waters. The provision outlines limitations or reductions for future pollutant loading. Certain development projects (e.g., projects that require Alteration of Terrain Permit or 401 Water Quality Certification) may be subject to an Antidegradation Review to ensure compliance with the state's water quality regulations. The Antidegradation Provision is often invoked during the permit review process for projects adjacent to waters that are designated impaired, high quality, or outstanding resource waters. While NHDES has not formally designated high-quality waters, unimpaired waters are treated as high quality with respect to issuance of water quality certificates. Antidegradation requires that a permitted activity cannot use more than 20% of the remaining assimilative capacity of a high-quality water. This is on a parameter-by-parameter basis. For impaired waters, antidegradation requires that permitted activities discharge no additional loading of the impaired parameter.

## Water Quality Summary

Review of existing water quality data through the NHDES Environmental Monitoring Database (EMD) showed a dataset of 1,600 individual data points dating back to 1988. These samples (largely water, though some sediment and tissue samples) were collected under various programs for the freshwater and estuarine portions of Sagamore Creek (Table 6). Most of the water samples were fecal indicator bacteria collected through the NHDES Shellfish Program, as part of its routine monitoring; other water quality parameters were limited by small sample numbers. Two sites (LHPS075, LHPS076) were incorrectly labeled in the EMD as located within the lower Sagamore Creek assessment unit and were not included in the analysis.

Table 6. Summary of available water quality data for Sagamore Creek by major project or program.

| Project | Years Sampled | River/Stream | Estuary | Temperature | Dissolved Oxygen | SpCond/Salinity | pH | Turbidity/TSS | BOD | Nitrogen/Phosphorus | Chlorophyll | Bacteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shellfish Systematic Random Sampling Project | 1988 - 2014 | | ✓ | | | ✓ | | | | | | ✓ |
| Coastal Investigations | 1996 - 2009 | ✓ | ✓ | | | | | | | | | ✓ |
| Shellfish Shoreline Wet and Dry Weather Sampling | 1999, 2007, 2008 | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ |
| Shellfish Emergency Closure Sampling Project | 2000 - 2006 | | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ |
| National Coastal Assessment Probability Based Monitoring | 2000, 2002, 2004, 2006 | | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Shellfish Tidal Study Sampling Project | 2001 | | ✓ | ✓ | | ✓ | | | | | | ✓ |
| Ambient River Monitoring Program (ARMP) | 2001 - 2007 | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Little Harbor TMDL | 2003 - 2004 | ✓ | ✓ | ✓ | | ✓ | | | | | | ✓ |
| Shellfish Post Rainfall Sampling Project | 2003 - 2013 | | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ |
| Shellfish Rainfall Study Sampling Project | 2004 - 2005 | | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ |
| Shellfish Baseline Tissue Sampling Project | 2005 - 2010 | | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ |
| Shellfish Open Status Sampling Project | 2005 - 2013 | | ✓ | ✓ | ✓ | | ✓ | | | | | ✓ |
| Coastal Restoration | 2006 | ✓ | | ✓ | | ✓ | | ✓ | | | | |
| New Hampshire Estuaries Probability Based Monitoring Program | 2007 - 2008 | | ✓ | ✓ | ✓ | | ✓ | ✓ | | ✓ | ✓ | ✓ |
| Confirmation Sampling for Waterbody Assessments | 2012 | ✓ | | ✓ | | ✓ | ✓ | | | | | |
| Volunteer River Assessment Program (VRAP) | 2016-2017 | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |

The freshwater and estuarine (upper and lower) portions of Sagamore Creek are currently listed on the draft 2016 303(d) list of impaired waters in the State of New Hampshire (NHDES, 2016a). Sagamore Creek does not meet state water quality criteria for the designated uses of aquatic life, fish consumption, and shellfishing due to elevated levels of various contaminants in sediment[2] and shellfish tissue[3] and/or poor estuarine bioassessments (Figure 9, Table 7). The sources of these contaminants to the freshwater and tidal portions of the Creek are currently unknown, but the elevated levels of volatile organic compounds (VOCs) and metals likely stem from both existing and legacy human activities in the watershed. Because of elevated fecal indicator bacteria in water and tissue samples, elevated contaminants in sediment, as well as dye study results that indicate a high risk of sewage contamination following possible disinfection failure at the Pierce Island WWTF, the shellfish growing areas of Sagamore Creek were classified as Prohibited/Safety Zone.

Sample data for the freshwater portion of Sagamore Creek showed elevated chloride and fecal indicator bacteria (both of which are considered non-supporting for designated uses, along with pH) (Figure 10, Tables 8-10). An open water site in the upper estuary (NH08-0537) showed elevated fecal indicator bacteria. Several groundwater seeps and pipes in the lower estuary showed single samples elevated for fecal indicator bacteria (e.g., LHPS156 exceeded criteria at an average of 16,000 mpn/100mL for two samples). These sites were sampled by the NHDES Shellfish Program during a sanitary survey of the Sagamore Creek shoreline and were in an area serviced by septic systems. The NHDES Shellfish Program recommended follow-up investigation of the drainage to LHPS145 due to elevated fecal indicator bacteria and suspected human fecal contamination (NHDES, 2011).

Assessment units in the watershed with insufficient data to determine status include Elwyn Brook, a headwater tributary to Sagamore Creek, along with its one-acre impoundment bordering the Department of Public Works (DPW) lot, and an unnamed brook draining to the lower portion of the Creek, crossing under Wentworth Road (Figure 9, Table 7).

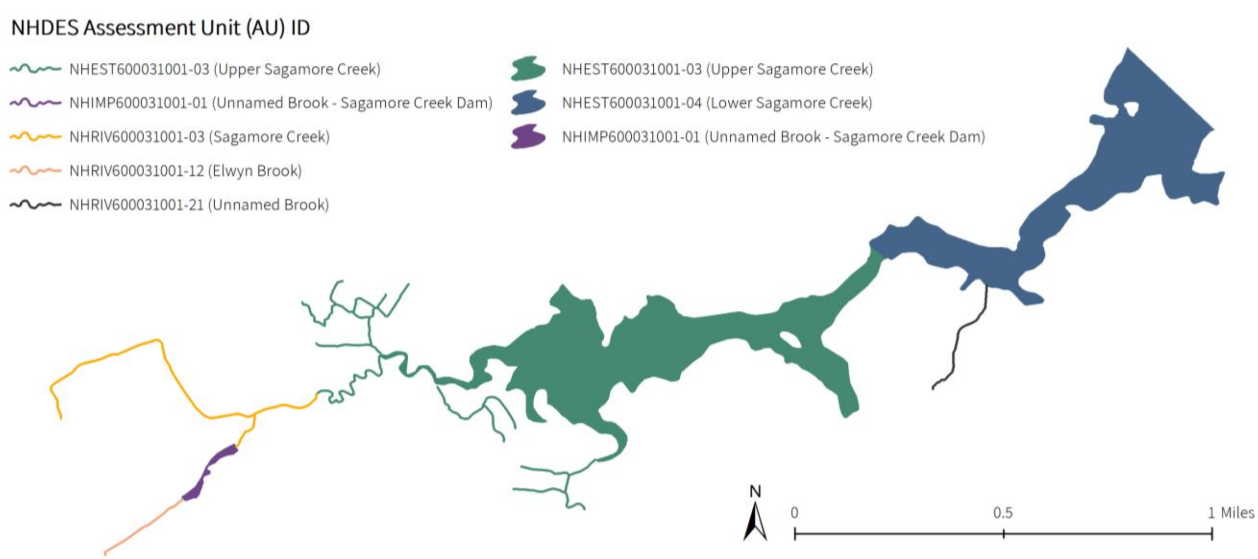



**Figure 9.** Map of NHDES Assessment Units (AU) for the Sagamore Creek watershed.

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[2] Sediment samples were collected from the upper estuary at NH00-0021A in 2000, NH04-0221A in 2004, and NH06-0039A in 2006.
[3] Tissue samples were collected from blue mussels and softshell clams from two sites at the mouth of Sagamore Creek from 2003-2013.

**Table 7.** Status of applicable water quality parameters for designated uses by NHDES Assessment Units (AU) for the Sagamore Creek watershed. Data taken from draft NHDES 2016 AU list. Parameter Level-NHDES Categories 5-M and 5-P are on the draft NHDES 303(d) list of impaired waters requiring a TMDL.

| Assessment Unit ID / Name / Size | Designated Use | Parameter Name | Parameter Level-NHDES Category |
|---|---|---|---|
| NHEST600031001-03, Upper Sagamore Creek, 0.15 sq. mi. | Aquatic Life | .alpha.-Endosulfan(Endosulfan 1) | 3-ND |
| | | .beta.-Endosulfan (Endosulfan 2) | 3-ND |
| | | 2-Methylnaphthalene | 3-ND |
| | | Acenaphthene | 3-ND |
| | | Acenaphthylene | 5-M |
| | | Aluminum | 5-M |
| | | Ammonia (Un-ionized) | 3-ND |
| | | Anthracene | 3-ND |
| | | Antimony | 3-ND |
| | | Arsenic | 5-M |
| | | Benzo(a)pyrene (PAHs) | 5-M |
| | | Benzo[a]anthracene | 5-M |
| | | Benzo[b]fluoranthene | 3-ND |
| | | Benzo[g,h,i]perylene | 3-ND |
| | | Benzo[k]fluoranthene | 3-ND |
| | | Biphenyl | 3-ND |
| | | Cadmium | 5-M |
| | | Chlorophyll-a | 3-PAS |
| | | Chrysene (C1-C4) | 5-M |
| | | Copper | 5-M |
| | | DDD | 3-ND |
| | | DDE | 3-ND |
| | | DDT | 3-ND |
| | | Dibenz[a,h]anthracene | 5-M |
| | | Dieldrin | 3-ND |
| | | Dissolved oxygen saturation | 3-ND |
| | | Endosulfan sulfate | 3-ND |
| | | Endrin | 3-ND |
| | | Estuarine Bioassessments | 5-P |
| | | Fluoranthene | 5-M |
| | | Fluorene | 3-ND |
| | | Hexachlorobenzene | 3-ND |
| | | Indeno[1,2,3-cd]pyrene | 3-ND |
| | | Iron | 3-ND |
| | | Lead | 5-M |
| | | Light Attenuation Coefficient | 3-ND |
| | | Lindane | 3-ND |
| | | Mercury | 5-M |
| | | Naphthalene | 3-ND |
| | | Nickel | 5-M |
| | | Nitrogen (Total) | 3-ND |
| | | Oxygen, Dissolved | 2-M |
| | | Phenanthrene | 5-M |
| | | Polychlorinated biphenyls | 3-ND |
| | | Pyrene | 5-M |
| | | Silver | 3-ND |
| | | Toxaphene | 3-ND |
| | | Zinc | 3-ND |
| | | pH | 3-PAS |
| | | trans-Nonachlor | 5-M |
| | Drinking Water | Escherichia coli | 3-PAS |
| | | Fecal Coliform | 3-PNS |
| | Fish Consumption | Mercury | 5-M |
| | | Polychlorinated biphenyls | 5-M |
| | Primary Contact Recreation | Chlorophyll-a | 3-ND |
| | | Enterococcus | 4A-P |

| Assessment Unit ID / Name / Size | Designated Use | Parameter Name | Parameter Level-NHDES Category |
|---|---|---|---|
| | Secondary Contact Recreation | Enterococcus | 4A-P |
| | Shellfishing | Dioxin (including 2,3,7,8-TCDD) | 5-M |
| | | Fecal Coliform | 3-PNS |
| | | Mercury | 5-M |
| | | Polychlorinated biphenyls | 5-M |
| NHEST600031001-04, Lower Sagamore Creek, 0.12 sq. mi. | Aquatic Life | Ammonia (Un-ionized) | 3-ND |
| | | Chlorophyll-a | 3-PAS |
| | | Dissolved oxygen saturation | 3-ND |
| | | Estuarine Bioassessments | 5-P |
| | | Light Attenuation Coefficient | 3-ND |
| | | Nitrogen (Total) | 3-ND |
| | | Oxygen, Dissolved | 2-M |
| | | pH | 3-PAS |
| | Drinking Water | Escherichia coli | 3-PAS |
| | | Fecal Coliform | 3-PNS |
| | Fish Consumption | Mercury | 5-M |
| | | Polychlorinated biphenyls | 5-M |
| | Primary Contact Recreation | Chlorophyll-a | 3-ND |
| | | Enterococcus | 4A-M |
| | Secondary Contact Recreation | Enterococcus | 4A-M |
| | Shellfishing | Dioxin (including 2,3,7,8-TCDD) | 5-M |
| | | Fecal Coliform | 3-PNS |
| | | Mercury | 5-M |
| | | Polychlorinated biphenyls | 5-M |
| NHIMP600031001-01, Unnamed Brook - Sagamore Creek Dam, 1.88 acres | Aquatic Life | Chlorophyll-a | 3-ND |
| | | Dissolved oxygen saturation | 3-ND |
| | | Oxygen, Dissolved | 3-ND |
| | | pH | 3-ND |
| | Fish Consumption | Mercury | 4A-M |
| | Primary Contact Recreation | Escherichia coli | 3-ND |
| | Secondary Contact Recreation | Escherichia coli | 3-ND |
| NHRIV600031001-03, Sagamore Creek, 0.98 mi. | Aquatic Life | Alkalinity, Carbonate as CaCO3 | 3-ND |
| | | Ammonia (Un-ionized) | 3-ND |
| | | Benthic-Macroinvertebrate Bioassessments (Streams) | 3-ND |
| | | Chloride | 5-M |
| | | Dissolved oxygen saturation | 3-ND |
| | | Fishes Bioassessments (Streams) | 3-ND |
| | | Oxygen, Dissolved | 3-ND |
| | | Phosphorus (Total) | 3-ND |
| | | Turbidity | 3-ND |
| | | pH | 5-M |
| | Drinking Water | Escherichia coli | 3-ND |
| | | Fecal Coliform | 3-ND |
| | Fish Consumption | Mercury | 4A-M |
| | Primary Contact Recreation | Chlorophyll-a | 3-ND |
| | | Escherichia coli | 4A-P |
| | Secondary Contact Recreation | Escherichia coli | 3-ND |
| NHRIV600031001-12, Elwyn Brook, 0.23 mi. | Aquatic Life | Benthic-Macroinvertebrate Bioassessments (Streams) | 3-ND |
| | | Dissolved oxygen saturation | 3-ND |
| | | Fishes Bioassessments (Streams) | 3-ND |
| | | Oxygen, Dissolved | 3-ND |
| | | pH | 3-ND |
| | Fish Consumption | Mercury | 4A-M |
| | Primary Contact Recreation | Escherichia coli | 3-ND |
| | Secondary Contact Recreation | Escherichia coli | 3-ND |

| Assessment Unit ID / Name / Size | Designated Use | Parameter Name | Parameter Level-NHDES Category |
|---|---|---|---|
| NHRIV600031001-21, Unnamed Brook, 0.31 mi. | Aquatic Life | Benthic-Macroinvertebrate Bioassessments (Streams) | 3-ND |
| | | Dissolved oxygen saturation | 3-ND |
| | | Fishes Bioassessments (Streams) | 3-ND |
| | | Oxygen, Dissolved | 3-ND |
| | | pH | 3-ND |
| | Fish Consumption | Mercury | 4A-M |
| | Primary Contact Recreation | Escherichia coli | 3-ND |
| | Secondary Contact Recreation | Escherichia coli | 3-ND |

| | |
|---|---|
| 2-M | All samples for a given parameter meet water quality standards, but only marginally. |
| 3-PAS | There is some but insufficient data to assess the parameter per the CALM, however, the data that is available suggests that the parameter is Potentially Attaining Standards (PAS). |
| 3-ND | There is no data available for the parameter. |
| 3-PNS | There is some but insufficient data to assess the parameter per the CALM, however, the data that is available suggests that the parameter is Potentially Not Supporting (PNS) water quality standards (e.g., there is one exceedance). |
| 4A-M | The parameter is a pollutant which is assessed as an impairment per the CALM, and an EPA-approved TMDL has been completed, however, the impairment is relatively slight or marginal. |
| 4A-P | The parameter is a pollutant which is assessed as an impairment per the CALM, and an EPA-approved TMDL has been completed, however, the impairment is more severe and causes poor water quality conditions. |
| 5-M | Parameter is a pollutant that requires a TMDL, however, the impairment is marginal. |
| 5-P | Parameter is a pollutant that requires a TMDL, and the impairment is more severe and causes poor water quality. |

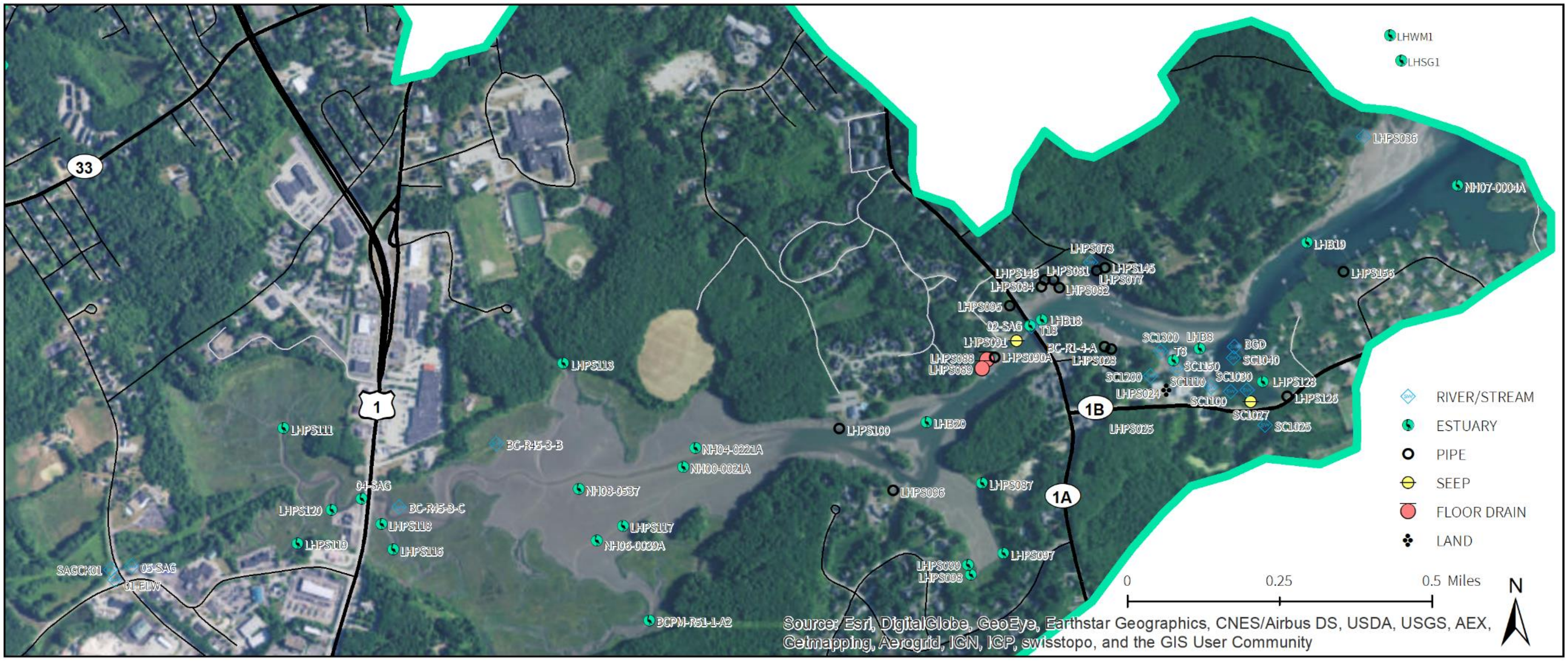



Figure 10. Map of water quality sampling sites for Sagamore Creek.

**Table 8.** Summary of chemical water quality data for Sagamore Creek. Data were obtained from NHDES EMD and were averaged by day, month, and site. Data includes 2016-17 results in preliminary status. Red text indicates exceedance of criteria or recommended guideline. Highlighted cells identify sites in the following assessment units: the freshwater headwaters of Sagamore Creek (yellow), the estuarine upper Sagamore Creek (green), and the estuarine lower Sagamore Creek (blue).

| SITE ID | STATION TYPE | START YEAR | END YEAR | DATA TYPE | ALKALINITY, CARBONATE AS CACO3 (PPM) | CHLORIDE (PPM) | BIOCHEMICAL OXYGEN DEMAND (BOD) (PPM) | CARBON, DISSOLVED ORGANIC (PPM) | CARBON, TOTAL SUSPENDED (PPM) | COLORED DISSOLVED ORGANIC MATTER (CDOM) (PPM) | NITROGEN, AMMONIA AS N (PPM) | NITROGEN, TOTAL DISSOLVED (PPM) | NITROGEN, TOTAL KJELDAHL (PPM) | NITROGEN, NITRATE (NO3) AS N (PPM) | NITROGEN, NITRITE (NO2) + NITRATE (NO3) AS N (PPM) | NITROGEN, NITRITE (NO2) AS N (PPM) | NITROGEN, DISSOLVED ORGANIC (PPM) | NITROGEN, TOTAL SUSPENDED (PPM) | PHOSPHORUS, TOTAL AS P (PPM) | PHOSPHORUS, ORTHOPHOSPHATE AS P | SILICA AS SI (PPM) | SILICA AS SIO2 (PPM) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Criteria / Recommended Guideline | 20 | 230 | 2.0 | | | | | | | | | | | | | | | |
| 01-ELW | RIVER/STREAM | 2006 | 2006 | RESULT | | 167 | | | | | | | | | | | | | | | | |
| | | | | COUNT | | 3 | | | | | | | | | | | | | | | | |
| 05-SAG | RIVER/STREAM | 2001 | 2017 | RESULT | 189 | 250 | 1.7 | | | | 0.07 | | 0.49 | 0.04 | 0.06 | 0.03 | | | 0.03 | | | |
| | | | | COUNT | 1 | 13 | 49 | | | | 64 | | 66 | 12 | 61 | 2 | | | 70 | | | |
| SAGCK01 | RIVER/STREAM | 2006 | 2006 | RESULT | | 6 | | | | | | | | | | | | | | | | |
| | | | | COUNT | | 3 | | | | | | | | | | | | | | | | |
| 04-SAG | ESTUARY | 2003 | 2017 | RESULT | | 10,144 | | | | | | | 0.30 | 0.19 | 0.21 | 0.03 | | | 0.05 | | | |
| | | | | COUNT | | 1 | | | | | | | 5 | 1 | 5 | 1 | | | 5 | | | |
| NH00-0021A | ESTUARY | 2000 | 2000 | RESULT | | | | | | | 0.17 | | | | 0.07 | 0.00 | | | | 0.02 | 0.2 | |
| | | | | COUNT | | | | | | | 1 | | | | 1 | 1 | | | | 1 | 1 | |
| NH04-0221A | ESTUARY | 2002 | 2004 | RESULT | | | | | 0.2 | | 0.02 | 0.18 | | 0.01 | 0.03 | 0.00 | 0.10 | 0.02 | 0.02 | 0.03 | 0.3 | |
| | | | | COUNT | | | | | 1 | | 2 | 1 | | 1 | 2 | 2 | 1 | 1 | 1 | 2 | 2 | |
| NH06-0039A | ESTUARY | 2006 | 2006 | RESULT | | | | | 0.5 | | 0.09 | 0.11 | | | 0.00 | 0.00 | | 0.06 | 0.02 | 0.01 | 0.2 | |
| | | | | COUNT | | | | | 1 | | 1 | 1 | | | 1 | 1 | | 1 | 1 | 1 | 1 | |
| NH08-0537 | ESTUARY | 2008 | 2008 | RESULT | | | | 6.2 | 5.1 | 2.1 | 0.24 | 0.98 | | | 0.43 | | | 0.53 | 0.09 | 0.01 | | 6.9 |
| | | | | COUNT | | | | 1 | 1 | 1 | 1 | 1 | | | 1 | | | 1 | 1 | 1 | | 1 |
| 02-SAG | RIVER/STREAM | 2016 | 2017 | RESULT | | 17,711 | | | | | | | 0.20 | 0.03 | 0.03 | 0.03 | | | 0.05 | | | |
| | | | | COUNT | | 1 | | | | | | | 5 | 1 | 5 | 1 | | | 5 | | | |
| NH07-0004A | ESTUARY | 2007 | 2007 | RESULT | | | | 2.1 | 0.2 | 0.4 | 0.02 | 0.14 | | | 0.01 | 0.00 | | 0.01 | 0.02 | 0.03 | | 0.3 |
| | | | | COUNT | | | | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | | 1 | 1 | 1 | | 1 |

**Table 9.** Summary of physical water quality data for Sagamore Creek. Data were obtained from NHDES EMD and were averaged by day, month, and site. Data includes 2016-17 results in preliminary status. Red text indicates exceedance of criteria or recommended guideline. Highlighted cells identify sites in the following assessment units: the freshwater headwaters of Sagamore Creek (yellow), the estuarine upper Sagamore Creek (green), and the estuarine lower Sagamore Creek (blue).

| SITE ID | STATION TYPE | START YEAR | END YEAR | DATA TYPE | SALINITY (PPS) | SECCHI DISK TRANSPARENCY (M) | DISSOLVED OXYGEN (PPM) | DISSOLVED OXYGEN SATURATION (%) | SOLIDS, TOTAL SUSPENDED (PPM) | SOLIDS, TOTAL (PPM) | SPECIFIC CONDUCTANCE (US/CM) | TEMPERATURE WATER (C) | TURBIDITY (NTU) | PH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Criteria / Recommended Guideline | | | 5.0 | 75 | | | 835 | 28.0 | | 6.5-8.0 |
| 01-ELW | RIVER/STREAM | 2006 | 2006 | RESULT | | | | | | | 748 | 19.6 | 2.9 | |
| | | | | *COUNT* | | | | | | | *3* | *2* | *2* | |
| 05-SAG | RIVER/STREAM | 2001 | 2017 | RESULT | | | 9.1 | 84 | 6 | 845 | 918 | 13.7 | 6.8 | 7.0 |
| | | | | *COUNT* | | | *64* | *63* | *55* | *1* | *71* | *71* | *70* | *69* |
| SAGCK01 | RIVER/STREAM | 2006 | 2006 | RESULT | | | | | | | 159 | 18.5 | 2.2 | |
| | | | | *COUNT* | | | | | | | *3* | *2* | *2* | |
| LHPS024 | SEEP | 1999 | 2001 | RESULT | | | | | | | | 15.0 | | 7.8 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS025 | SEEP | 1999 | 2001 | RESULT | | | | | | | | 14.0 | | 7.5 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS096 | PIPE | 1999 | 2001 | RESULT | | | | | | | | 14.0 | | 7.2 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS156 | PIPE | 2013 | 2013 | RESULT | 0.2 | | | | | | | 11.3 | | |
| | | | | *COUNT* | *1* | | | | | | | *1* | | |
| 04-SAG | ESTUARY | 2003 | 2017 | RESULT | 30.6 | | 7.4 | 87 | | | | 21.4 | 7.5 | 7.4 |
| | | | | *COUNT* | *4* | | *4* | *4* | | | | *4* | *3* | *4* |
| LHB18 | ESTUARY | 2003 | 2013 | RESULT | 28.1 | | | | | | | 10.2 | | |
| | | | | *COUNT* | *81* | | | | | | | *81* | | |
| LHB20 | ESTUARY | 2007 | 2013 | RESULT | 27.8 | | | | | | | 10.3 | | |
| | | | | *COUNT* | *77* | | | | | | | *77* | | |
| LHPS087 | ESTUARY | 1999 | 2008 | RESULT | 21.7 | | | | | | | 15.4 | | 7.6 |
| | | | | *COUNT* | *1* | | | | | | | *3* | | *1* |
| LHPS097 | ESTUARY | 1999 | 2007 | RESULT | | | | | | | | 16.5 | | 6.7 |
| | | | | *COUNT* | | | | | | | | *2* | | *1* |
| LHPS098 | ESTUARY | 1999 | 2007 | RESULT | | | | | | | | 16.0 | | 7.4 |
| | | | | *COUNT* | | | | | | | | *2* | | *1* |
| LHPS099 | ESTUARY | 1999 | 2007 | RESULT | | | | | | | | 16.0 | | 7.4 |
| | | | | *COUNT* | | | | | | | | *2* | | *1* |
| LHPS111 | ESTUARY | 1999 | 2001 | RESULT | | | | | | | | 19.0 | | 7.5 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS113 | ESTUARY | 1999 | 1999 | RESULT | | | | | | | | 28.0 | | 6.7 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS116 | ESTUARY | 1999 | 1999 | RESULT | | | | | | | | 15.0 | | 7.2 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS117 | ESTUARY | 1999 | 2001 | RESULT | | | | | | | | 18.0 | | 7.2 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS118 | ESTUARY | 1999 | 2001 | RESULT | | | | | | | | 17.0 | | 7.2 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS119 | ESTUARY | 1999 | 2001 | RESULT | | | | | | | | 20.0 | | 7.0 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS120 | ESTUARY | 1999 | 1999 | RESULT | | | | | | | | 21.5 | | 6.1 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| NH00-0021A | ESTUARY | 2000 | 2000 | RESULT | 31.0 | | 8.4 | | | | | 14.8 | | |

| SITE ID | STATION TYPE | START YEAR | END YEAR | DATA TYPE | SALINITY (PPS) | SECCHI DISK TRANSPARENCY (M) | DISSOLVED OXYGEN (PPM) | DISSOLVED OXYGEN SATURATION (%) | SOLIDS, TOTAL SUSPENDED (PPM) | SOLIDS, TOTAL (PPM) | SPECIFIC CONDUCTANCE (US/CM) | TEMPERATURE WATER (C) | TURBIDITY (NTU) | PH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Criteria / Recommended Guideline | | | 5.0 | 75 | | | 835 | 28.0 | | 6.5-8.0 |
| | | | | *COUNT* | *1* | | *1* | | | | | *1* | | |
| NH04-0221A | ESTUARY | 2002 | 2004 | RESULT | 29.3 | | 8.0 | | 7 | | | 15.0 | | 8.1 |
| | | | | *COUNT* | *5* | | *5* | | *2* | | | *5* | | *5* |
| NH06-0039A | ESTUARY | 2006 | 2006 | RESULT | 28.3 | | 8.3 | | 8 | | | 21.3 | | 7.9 |
| | | | | *COUNT* | *1* | | *1* | | *1* | | | *1* | | *1* |
| NH08-0537 | ESTUARY | 2008 | 2008 | RESULT | 4.0 | 0.2 | 7.0 | | 122 | | | 18.8 | | 7.9 |
| | | | | *COUNT* | *1* | *1* | *1* | | *1* | | | *1* | | *1* |
| LHPS090A | PIPE | 1999 | 1999 | RESULT | | | | | | | | 15.0 | | 7.8 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS091 | SEEP | 1999 | 1999 | RESULT | | | | | | | | 11.0 | | 7.8 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| 02-SAG | RIVER/STREAM | 2016 | 2017 | RESULT | 47.5 | | 6.6 | 88 | | | | 20.5 | 2.5 | 7.7 |
| | | | | *COUNT* | *3* | | *3* | *3* | | | | *3* | *3* | *3* |
| LHPS036 | RIVER/STREAM | 1999 | 1999 | RESULT | | | | | | | | 18.5 | | 7.9 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS073 | RIVER/STREAM | 1999 | 1999 | RESULT | | | | | | | | 17.5 | | 7.0 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHB19 | ESTUARY | 2003 | 2003 | RESULT | 31.1 | | | | | | | 16.0 | | |
| | | | | *COUNT* | *2* | | | | | | | *2* | | |
| LHB8 | ESTUARY | 2001 | 2017 | RESULT | 28.8 | | | | | | | 9.3 | | 7.8 |
| | | | | *COUNT* | *146* | | | | | | | *146* | | *47* |
| LHPS128 | ESTUARY | 1999 | 2001 | RESULT | | | | | | | | 18.0 | | 7.4 |
| | | | | *COUNT* | | | | | | | | *2* | | *2* |
| LHSG1 | ESTUARY | 2003 | 2010 | RESULT | 27.4 | | | | | | | 6.5 | | 7.8 |
| | | | | *COUNT* | *25* | | | | | | | *25* | | *14* |
| LHWM1 | ESTUARY | 2005 | 2013 | RESULT | 26.5 | | | | | | | 5.9 | | 7.9 |
| | | | | *COUNT* | *31* | | | | | | | *31* | | *14* |
| NH07-0004A | ESTUARY | 2007 | 2007 | RESULT | 33.0 | | 8.6 | | 14 | | | 15.3 | | 7.9 |
| | | | | *COUNT* | *1* | | *1* | | *1* | | | *1* | | *1* |
| T8 | ESTUARY | 1988 | 2001 | RESULT | 28.1 | | | | | | | 9.3 | | 7.7 |
| | | | | *COUNT* | *40* | | | | | | | *101* | | *32* |
| LHPS028 | PIPE | 2003 | 2013 | RESULT | 0.4 | | | | | | | 13.0 | | |
| | | | | *COUNT* | *1* | | | | | | | *1* | | |
| LHPS081 | PIPE | 1999 | 2003 | RESULT | | | | | | | | 12.0 | | 7.5 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS084 | PIPE | 1999 | 1999 | RESULT | | | | | | | | 12.0 | | 6.9 |
| | | | | *COUNT* | | | | | | | | *1* | | *1* |
| LHPS126 | PIPE | 1999 | 2013 | RESULT | 16.8 | | | | | | | 19.0 | | 7.7 |
| | | | | *COUNT* | *2* | | | | | | | *6* | | *1* |
| LHPS145 | PIPE | 2003 | 2008 | RESULT | 0.1 | | | | | | | 15.2 | | |
| | | | | *COUNT* | *2* | | | | | | | *2* | | |

**Table 10.** Summary of biological water quality data for Sagamore Creek. Data were obtained from NHDES EMD and were averaged by day, month, and site. Data includes 2016-17 results in preliminary status. Red text indicates exceedance of criteria or recommended guideline. Highlighted cells identify sites in the following assessment units: the freshwater headwaters of Sagamore Creek (yellow), the estuarine upper Sagamore Creek (green), and the estuarine lower Sagamore Creek (blue).

| SITE ID | STATION TYPE | START YEAR | END YEAR | DATA TYPE | CHLOROPHYLL A (PROBE) (PPB) | CHLOROPHYLL A, CORRECTED FOR PHEOPHYTIN (PPB) | CHLOROPHYLL A, UNCORRECTED FOR PHEOPHYTIN (PPB) | ENTEROCOCCUS (MPN/100ML) | ESCHERICHIA COLI (MPN/100ML) | TOTAL FECAL COLIFORM (MPN/100ML) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Criteria / Recommended Guideline | | 15-20 | | 35 | 126 | 14 |
| 05-SAG | RIVER/STREAM | 2001 | 2017 | RESULT | 5.7 | | 4.6 | 176 | 28 | 219 |
| | | | | *COUNT* | *4* | | *60* | *3* | *67* | *3* |
| LHPS024 | SEEP | 1999 | 2001 | RESULT | | | | | 179 | 400 |
| | | | | *COUNT* | | | | | *2* | *1* |
| LHPS025 | SEEP | 1999 | 2001 | RESULT | | | | | 126 | 400 |
| | | | | *COUNT* | | | | | *2* | *1* |
| BC-R1-4-A | PIPE | 2005 | 2005 | RESULT | | | | | 9 | |
| | | | | *COUNT* | | | | | *1* | |
| LHPS096 | PIPE | 1999 | 2001 | RESULT | | | | | 110 | 81 |
| | | | | *COUNT* | | | | | *2* | *1* |
| LHPS146 | PIPE | 2003 | 2003 | RESULT | | | | | | 16,984 |
| | | | | *COUNT* | | | | | | *2* |
| LHPS156 | PIPE | 2013 | 2013 | RESULT | | | | | | 50 |
| | | | | *COUNT* | | | | | | *1* |
| BC-R45-3-B | RIVER/STREAM | 2001 | 2001 | RESULT | | | | | 5 | |
| | | | | *COUNT* | | | | | *1* | |
| BC-R45-3-C | RIVER/STREAM | 2001 | 2001 | RESULT | | | | | 5 | |
| | | | | *COUNT* | | | | | *1* | |
| 04-SAG | ESTUARY | 2003 | 2017 | RESULT | | | | 295 | 50 | 2,342 |
| | | | | *COUNT* | | | | *6* | *2* | *3* |
| BCPM-R51-1-A2 | ESTUARY | 2001 | 2001 | RESULT | | | | | 220 | |
| | | | | *COUNT* | | | | | *1* | |
| LHB18 | ESTUARY | 2003 | 2013 | RESULT | | | | | | 15 |
| | | | | *COUNT* | | | | | | *81* |
| LHB20 | ESTUARY | 2007 | 2013 | RESULT | | | | | | 18 |
| | | | | *COUNT* | | | | | | *77* |
| LHPS087 | ESTUARY | 1999 | 2008 | RESULT | | | | | 25 | 18 |
| | | | | *COUNT* | | | | | *1* | *2* |
| LHPS097 | ESTUARY | 1999 | 2007 | RESULT | | | | | 1 | 2 |
| | | | | *COUNT* | | | | | *1* | *2* |
| LHPS098 | ESTUARY | 1999 | 2007 | RESULT | | | | | 1 | 8 |
| | | | | *COUNT* | | | | | *1* | *2* |
| LHPS099 | ESTUARY | 1999 | 2007 | RESULT | | | | | 8 | 20 |
| | | | | *COUNT* | | | | | *1* | *2* |
| LHPS111 | ESTUARY | 1999 | 2001 | RESULT | | | | | 93 | 264 |
| | | | | *COUNT* | | | | | *2* | *1* |

| SITE ID | STATION TYPE | START YEAR | END YEAR | DATA TYPE | CHLOROPHYLL A (PROBE) (PPB) | CHLOROPHYLL A, CORRECTED FOR PHEOPHYTIN (PPB) | CHLOROPHYLL A, UNCORRECTED FOR PHEOPHYTIN (PPB) | ENTEROCOCCUS (MPN/100ML) | ESCHERICHIA COLI (MPN/100ML) | TOTAL FECAL COLIFORM (MPN/100ML) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Criteria / Recommended Guideline | | 15-20 | | 35 | 126 | 14 |
| LHPS113 | ESTUARY | 1999 | 1999 | RESULT | | | | | 6 | 6 |
| | | | | *COUNT* | | | | | *1* | *1* |
| LHPS116 | ESTUARY | 1999 | 1999 | RESULT | | | | | 4 | 4 |
| | | | | *COUNT* | | | | | *1* | *1* |
| LHPS117 | ESTUARY | 1999 | 2001 | RESULT | | | | | 247 | 255 |
| | | | | *COUNT* | | | | | *2* | *1* |
| LHPS118 | ESTUARY | 1999 | 2001 | RESULT | | | | | 36 | 400 |
| | | | | *COUNT* | | | | | *2* | *1* |
| LHPS119 | ESTUARY | 1999 | 2001 | RESULT | | | | | 130 | 316 |
| | | | | *COUNT* | | | | | *2* | *1* |
| LHPS120 | ESTUARY | 1999 | 1999 | RESULT | | | | | 1 | 3 |
| | | | | *COUNT* | | | | | *1* | *1* |
| NH00-0021A | ESTUARY | 2000 | 2000 | RESULT | | 1.1 | | | | |
| | | | | *COUNT* | | *1* | | | | |
| NH04-0221A | ESTUARY | 2002 | 2004 | RESULT | | 0.7 | | 2 | 6 | 6 |
| | | | | *COUNT* | | *2* | | *2* | *2* | *2* |
| NH06-0039A | ESTUARY | 2006 | 2006 | RESULT | | 0.8 | | 2 | 12 | 12 |
| | | | | *COUNT* | | *1* | | *1* | *1* | *1* |
| NH08-0537 | ESTUARY | 2008 | 2008 | RESULT | | 1.6 | | 41,200 | 8,800 | 47,200 |
| | | | | *COUNT* | | *1* | | *1* | *1* | *1* |
| T18 | ESTUARY | 1996 | 2004 | RESULT | | | | 5 | 9 | 18 |
| | | | | *COUNT* | | | | *1* | *2* | *3* |
| LHPS091 | SEEP | 1999 | 1999 | RESULT | | | | | 2 | 2 |
| | | | | *COUNT* | | | | | *1* | *1* |
| LHPS090A | PIPE | 1999 | 1999 | RESULT | | | | | 5 | 7 |
| | | | | *COUNT* | | | | | *1* | *1* |
| 02-SAG | RIVER/STREAM | 2016 | 2017 | RESULT | | | | 13 | 5 | |
| | | | | *COUNT* | | | | *5* | *1* | |
| BGD | RIVER/STREAM | 1996 | 1996 | RESULT | | | | | 6 | |
| | | | | *COUNT* | | | | | *1* | |
| LHPS036 | RIVER/STREAM | 1999 | 1999 | RESULT | | | | | 5 | 5 |
| | | | | *COUNT* | | | | | *1* | *1* |
| LHPS073 | RIVER/STREAM | 1999 | 1999 | RESULT | | | | | 3,800 | 4,000 |
| | | | | *COUNT* | | | | | *1* | *1* |
| SC1025 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 50 | |
| | | | | *COUNT* | | | | | *1* | |
| SC1030 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 180 | |
| | | | | *COUNT* | | | | | *1* | |
| SC1040 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 5 | |
| | | | | *COUNT* | | | | | *1* | |

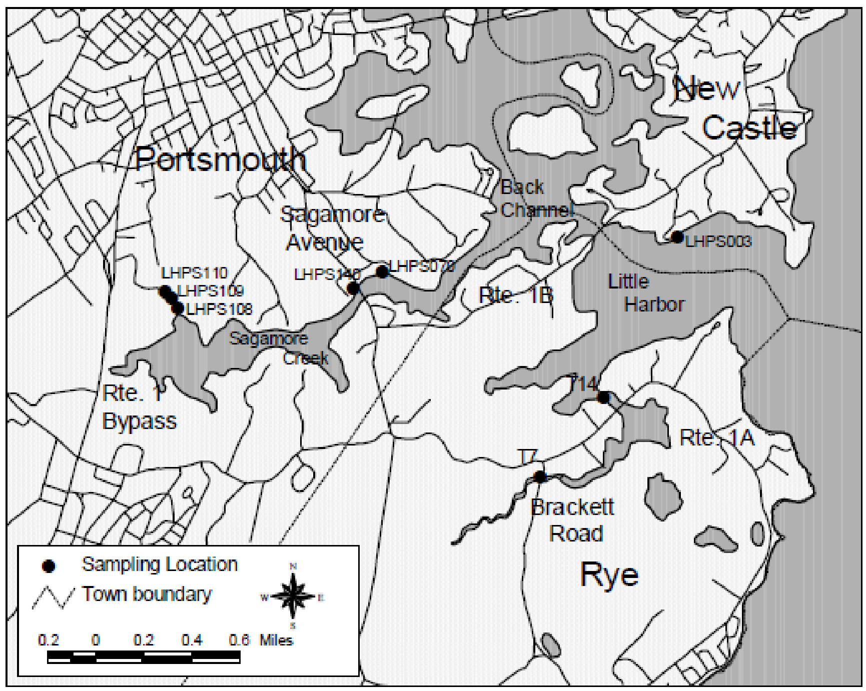
| SITE ID | STATION TYPE | START YEAR | END YEAR | DATA TYPE | CHLOROPHYLL A (PROBE) (PPB) | CHLOROPHYLL A, CORRECTED FOR PHEOPHYTIN (PPB) | CHLOROPHYLL A, UNCORRECTED FOR PHEOPHYTIN (PPB) | ENTEROCOCCUS (MPN/100ML) | ESCHERICHIA COLI (MPN/100ML) | TOTAL FECAL COLIFORM (MPN/100ML) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Criteria / Recommended Guideline | | 15-20 | | 35 | 126 | 14 |
| SC1100 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 187 | |
| | | | | *COUNT* | | | | | *1* | |
| SC1110 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 5 | |
| | | | | *COUNT* | | | | | *1* | |
| SC1150 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 180 | |
| | | | | *COUNT* | | | | | *1* | |
| SC1200 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 240 | |
| | | | | *COUNT* | | | | | *1* | |
| SC1300 | RIVER/STREAM | 2009 | 2009 | RESULT | | | | | 30 | |
| | | | | *COUNT* | | | | | *1* | |
| LHB19 | ESTUARY | 2003 | 2003 | RESULT | | | | | | 21 |
| | | | | *COUNT* | | | | | | *2* |
| LHB8 | ESTUARY | 2001 | 2017 | RESULT | | | | | | 13 |
| | | | | *COUNT* | | | | | | *162* |
| LHPS128 | ESTUARY | 1999 | 2001 | RESULT | | | | | 116 | 571 |
| | | | | *COUNT* | | | | | *3* | *2* |
| LHSG1 | ESTUARY | 2003 | 2010 | RESULT | | | | | | 9 |
| | | | | *COUNT* | | | | | | *25* |
| LHWM1 | ESTUARY | 2005 | 2013 | RESULT | | | | | | 10 |
| | | | | *COUNT* | | | | | | *31* |
| NH07-0004A | ESTUARY | 2007 | 2007 | RESULT | | 0.8 | | 5 | 7 | 9 |
| | | | | *COUNT* | | *1* | | *1* | *1* | *1* |
| T8 | ESTUARY | 1988 | 2001 | RESULT | | | | | | 16 |
| | | | | *COUNT* | | | | | | *102* |
| SC1027 | SEEP | 2009 | 2009 | RESULT | | | | | 210 | |
| | | | | *COUNT* | | | | | *1* | |
| LHPS028 | PIPE | 2003 | 2013 | RESULT | | | | | | 4,505 |
| | | | | *COUNT* | | | | | | *3* |
| LHPS081 | PIPE | 1999 | 2003 | RESULT | | | | | 2 | 488 |
| | | | | *COUNT* | | | | | *1* | *4* |
| LHPS084 | PIPE | 1999 | 1999 | RESULT | | | | | 4 | 4 |
| | | | | *COUNT* | | | | | *1* | *1* |
| LHPS126 | PIPE | 1999 | 2013 | RESULT | | | | 20 | 106 | 188 |
| | | | | *COUNT* | | | | *1* | *3* | *8* |
| LHPS145 | PIPE | 2003 | 2008 | RESULT | | | | | | 7,023 |
| | | | | *COUNT* | | | | | | *5* |

# Pollutant Source Inputs

## Total Maximum Daily Load Study

A Total Maximum Daily Load (TMDL) study was completed for Little Harbor and adjacent waterbodies: Back Channel, Lower Sagamore Creek, and Upper Sagamore Creek (NHDES, 2006). Data for the study were collected from 2001-2004 at multiple sites within Sagamore Creek. Using a Watershed Treatment Model, the study found that urban areas within the Sagamore Creek watershed were contributing 87,397 billion fecal coliform organisms per year from MS4 stormwater, 322 billion fecal coliform organisms per year from MS4 illicit discharges, and 5,072 billion fecal coliform organisms per year from failing septic systems. Sagamore Creek contributes about 40% of the fecal coliform load to Little Harbor, which means that Sagamore Creek has significant ecological and economic impacts to waters outside the Creek itself.

## Ribotyping Study




Sampling site locations for ribotyping study (Jones & Landry, 2004).

NHDES teamed up with the Jackson Estuarine Laboratory to conduct a ribotyping study of Sagamore Creek to determine specific sources of fecal indicator bacteria (Jones & Landry, 2004). Five sites (LHPS070, LHPS110, LHPS109, LHPS108, LHPS140) were sampled eight times in June 2001 and June-September 2002 under dry weather conditions. Although the dominant source of fecal indicator bacteria was found to be wildlife (i.e., otter, seagull, raccoon, rabbit, deer, skunk, and turkey), human and cow were also present; about 8% of isolates from all five sites were sourced from humans. Sources of human waste can come from leaky sewer lines or malfunctioning septic systems.

## Wastewater Treatment Systems

### Pierce Island Wastewater Treatment Facility

Most residences and businesses in the Sagamore Creek watershed are serviced by the municipal sewer system. Wastewater from Portsmouth, New Castle, and portions of Rye and Greenland is treated at the Pierce Island Wastewater Treatment Facility (WWTF), an advanced primary treatment facility with a design flow of 4.8 million gallons per day (MGD). The facility's outfall is located on the east side of the island, which is in the main channel of the Lower Piscataqua River.

Two dye studies have been conducted to determine the rate and extent of wastewater dilution of effluent from the outfall should a disinfection failure occur.

The US EPA and NH Department of Health and Human Services conducted the first dye study in spring 1999. Based on results of the study, the shellfish growing areas of Back Channel and Lower Sagamore Creek were classified as Prohibited/Safety Zone. These areas are closest to the facility's outfall and would not dilute sufficiently to 14 fecal coliform organisms per 100mL following a disinfection failure. The shellfish growing areas of Little Harbor, being adjacent to a Prohibited/Safety Zone, were classified as Conditionally Approved.

The US EPA, NHDES, and US Food & Drug Administration conducted the second dye study in spring 2012. Unlike the 1999 dye study, the 2012 dye study directly measured dye fluorescence and deployed shellfish cages (with oysters and blue mussels) and water quality sensors at the mouth of the Creek. Following dye injection on 12/11/2012, the dispersed dye was tracked to Little Bay, Back Channel, Little Harbor, and Sagamore Creek using a combination of fixed and mobile fluorescent monitoring stations. A subset of areas was checked for fluorometry at different depths. The dispersion dynamics observed at Sagamore Creek remain unclear. As expected, surface water came from Little Harbor on the flooding tide; however, a bottom profile reading at the mouth of Sagamore Creek on the ebbing tide showed injected dye from the facility's outfall. Based on results of the study, the Prohibited/Safety Zone classification was expanded from Back Channel and Lower Sagamore Creek to the entire stretch from the lower Little Bay and upper Piscataqua River to the mouth of the Piscataqua River. The study found that the existing WWTF effluent had high concentrations of pathogens that were bioaccumulating in shellfish.

Per the Consent Decree, the City of Portsmouth is required to upgrade its facility from primary to secondary treatment with a design flow of 6.1 MGD by December 2019. The upgrade is expected to greatly reduce the number of bacterial and viral pathogens in effluent. This will likely allow reopening of administratively-closed shellfish beds. Lowering that contamination risk could result in a complete reclassification of the area following reinstatement of sanitary surveys and monitoring by the NHDES Shellfish Program.

### Sewer Infrastructure

The City of Portsmouth maintains 110 miles of sewer pipe, 20 wastewater pumping stations, and 3 combined sewer overflows (CSOs). Many of the sewer pipes are 50-100 years old and need replacing. The City replaces old sewer pipes annually as part of sewer-specific capital improvement projects or road reconstructions. In the Sagamore Creek watershed, 19.6 miles of sewer pipe (17.2 miles of City and 2.4 miles of private lines) and 426 sewer manholes (381 City and 45 private) carry wastewater for 82% of residences and businesses. Sewer pipes are primarily made of asbestos cement, ductile iron pipe, polyvinyl chloride, or vitrified clay pipe. Sewer manholes are made of mortared brick or precast concrete. There are also five sewer pumping stations (two of which are private) located within the watershed.

The City operates CCTV in house or via outside engineers to inspect sewer line condition and prioritize sewer lines for replacement. A sewer study completed in 2017 showed that 913,000 gallons per day of groundwater and stormwater may be entering the City sewer system via infiltration[4] or inflow[5] (Woodard & Curran, 2017). Many locations that were part of the study showed high volume infiltration issues that caused surcharged pipes and manholes. Of the 33,359 linear feet of sewer lines and 403 manholes inspected, 74% and 40%, respectively, had infiltration, structural, and maintenance defects that must be addressed. Of the additional 14,500 linear feet of sewer lines inspected by the City, 27% need to be addressed. Woodard & Curran (2017) applied the National Association of Sewer Service Companies (NASSCO) Pipeline Assessment Certification Program (PACP) condition scoring to rate the severity of sewer lines and manholes and prioritize sewer lines and manholes for replacement by the City. Sewer lines and manholes with the most severe issues are provided in Tables 11-12 and highlighted as vulnerabilities in Appendix 2, Map 10. Issues found include fractures, holes, severe root or rock protrusions, broken pipes, heavy grease, and debris build-up.

Other significant findings include the following:

- According to Woodard & Curran (2017), the sewer lines along West Road have significantly reduced infiltration following an upgrade by the City in 2017; however, there are still some line bulges and horizontal deformations.
- Grease was noted by both Woodard & Curran (2017) and the City as an issue for some sewer line segments. Some lines, notably in the Odiorne Point Road area and behind the Lafayette Plaza Shopping Center, must be cleaned regularly by the City to remove build-up of restaurant grease.
- There may be a failure potential of sewer lines extending from Odiorne Point Road to homes along the shoreline that must pump up to the pumping station.
- Clay sewer pipes feeding from Hillside Drive are in poor condition and need replacement.
- High water inflow and infiltration was found in sewer lines that extend into the marsh off Greenleaf Woods Drive. This is an old clay pipe with grated manholes that were sealed in 2015.
- The sewer line running through the Urban Forestry Center is low-lying and used to need regular clean-outs after heavy rains. The City noted that this hasn't been an issue in over five years.
- An inverted syphon at the Route 1 crossing may be a possible problem.

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[4] Infiltration is groundwater that enters the sewer system through leaking pipes or manholes because of material degradation.
[5] Inflow is stormwater or river water that enters the sewer system through open manholes, manhole covers, frame seals or indirect connections with storm sewers.

**Table 11** Summary of CCTV inspections of severely-rated sewer lines (adapted from Woodard & Curran (2017)). Refer to Appendix 2, Map 10 for spatial reference of identified areas.

| Sewer ID | US MH | DS MH | Metering Basin | Street | Diameter (in.) | Material | Pipe length (LF) | Observation |
|---|---|---|---|---|---|---|---|---|
| 555 | 1056 | 1047 | LR4 | Greenleaf Ave | 8 | Asbestos-cement | 305 | Fractures and infiltration stains throughout pipe. Clear water running from laterals 24.5' and 90' DS. Clear water coming from lateral at 217.2' US (unknown source). |
| 1881 | 394 | 392 | LR4 | Greenleaf Ave | 10 | Asbestos-cement | 321 | Infiltration stains throughout pipe with gusher and runner at 238 and 248' DS, respectively. Protruding lateral at 256.8' DS |
| 640 | 562 | 565 | LR4 | Sylvester St | 8 | Asbestos-cement | 199 | Clear water coming from lateral at 160.3' DS. Infiltration gusher from hole in pipe at 190' DS. |
| 1834 | 372 | 5872 | LR4 | Greenleaf Ave XC | 10 | Asbestos-cement | 184 | Clear water dripping from lateral at 22.2' DS, Infiltration runner at DS MH connection |
| 1892 | 374 | 375 | LR4 | X-Country Greenleaf Woods Dr | 10 | Asbestos-cement | 231 | Infiltration runner joint at 116' US. Roots at US MH Connection. |
| 1845 | 545 | 420 | LR4 | X-Country | 8 | Asbestos-cement | 195 | Infiltration gusher at US MH Connection, roots at DS MH Connection |
| 1153 | 599 | 600 | HS15 | Sims Ave | 8 | Vitrified Clay Pipe | 80 | Infiltration runner at DS MH Connection |
| 1916 | 1046 | 1069 | LR5 | Lafayette Rd XC | 10 | Asbestos-cement | 135 | Infiltration runner at 30.3' DS, MH 1069 has infiltration at walls (1.5 gpm) |
| 1833 | 395 | 372 | LR4 | Greenleaf Ave XC | 10 | Asbestos-cement | 216 | Survey abandoned at 214' DS due to severe root ball. Infiltration dripper at MH372. |
| 1163 | 581 | 580 | HS15 | Sheffield Rd | 8 | Vitrified Clay Pipe | 242 | Hinge fracture 3 with broken pipe at 2' DS. Fractures throughout remainder of pipe. Intruding laterals at 58.6', 136', 145.4', and 167.5' DS. Clear water running from lateral at 167.5' DS (Unknown Source). Hole soil visible at 57.5' DS. Infiltration stains and mineral deposits throughout pipe with infiltration runner from joint at 156.1' DS. |
| 1915 | 1045 | 1046 | LR5 | Ledgewood Drive | 10 | Asbestos-cement | 167 | Broken pipe at 17.4' US. Hole soil visible at 40' US. Infiltration stains throughout pipe, infiltration runner joint at 224' US. Survey abandoned due to high water level in pipe at 226' US (no reversal attempted) |
| 4554 | 1382 | 1383 | HS15 | US Rt 1 Bypass | 12 | Vitrified Clay Pipe | 290 | Includes pipe sewer ID 4555. Infiltration stains and drippers throughout pipe. Clear water running from laterals at 190.7 and 191.3' DS. Lateral intruding at 190.7' DS. Survey abandoned at 290' DS due to high water level (no reversal attempted) |
| 547 | 1423 | 1382 | HS15 | US Rt 1 Bypass | 8 | Vitrified Clay Pipe | 83 | Infiltration stains throughout pipe. Crack longitudinal at 21' US. Broken pipe void visible at 56.8' US, Large rock intruding into broken pipe at 79.9' US with infiltration runner around rock. Roots medium joint at 82.1' US. |
| 4172 | 587 | 1381 | HS15 | Hampshire Rd | 10 | Vitrified Clay Pipe | 153 | Infiltration and fractures throughout, broken pipe void visible at 35.2'. |
| 5120 | 5421 | 5422 | LR4 | Parking Lot | 8 | Asbestos-cement | 237 | Clear water coming from laterals at 59', 75', and 154.9' US (Unknown Source). Broken pipe void visible with infiltration dripper at 65' US. Infiltration drippers and stains throughout pipe. |
| 1681 | 394 | 392 | LR4 | Greenleaf Ave | 10 | Asbestos-cement | 321 | Infiltration stains throughout pipe with gusher and runner at 238 and 248' DS, respectively. Protruding lateral at 256.8' DS |
| 1587 | 2641 | 136 | LR6 | Heritage Rd | 8 | Asbestos-cement | 285 | Heavy grease and debris buildup in pipe. Infiltration stains at 127' DS |
| 1640 | 237 | 236 | LR6 | Constitution Ave | 8 | Asbestos-cement | 230 | Clear water coming from lateral at 97.1' US (Unknown Source). Roots medium barrel at 104' |

| Sewer ID | US MH | DS MH | Metering Basin | Street | Diameter (in.) | Material | Pipe length (LF) | Observation |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | US. Infiltration gusher at 107' US. Roots fine joint at 118' US. |
| 194 | 1383 | 1384 | HS15 | US Rt 1 Bypass | 10 | Vitrified Clay Pipe | 399 | Fracture spiral at 22' US. Infiltration drippers throughout pipe. |
| 4163 | 581 | 580 | HS15 | Sheffield Rd | 8 | Vitrified Clay Pipe | 242 | Hinge fracture 3 with broken pipe at 2' DS. Fractures throughout remainder of pipe. Intruding laterals at 58.6', 136', 145.4', and 167.5' DS. Clear water running from lateral at 167.5' DS (Unknown Source). Hole soil visible at 57.5' DS. Infiltration stains and mineral deposits throughout pipe with infiltration runner from joint at 156.1' DS. |
| 202 | 2728 | 596 | HS15 | Melbourne St | 8 | Vitrified Clay Pipe | 248 | Roots and fractures throughout pipe, hole with soil visible at 210' DS. Chipped bell at 233' DS. |
| 1893 | 375 | 376 | LR4 | X-Country Greenleaf Woods Dr | 10 | Asbestos-cement | 214 | Broken pipe at 34.8' US. |
| 1908 | 1040 | 1062 | LR5 | Ledgewood Drive | 8 | Vitrified Clay Pipe | 134 | Deposits attached grease throughout pipe. Survey abandoned at 86.5' due to grease blockage (no reversal attempted) |
| 4165 | 2211 | 587 | HS15 | Hampshire Rd | 10 | Vitrified Clay Pipe | 89 | Infiltration stains at 11.1' US. Survey abandoned at 68.8' US due to high grease and water level (reversal incomplete) |
| 4156 | 593 | 580 | HS15 | Essex Ave | 8 | Vitrified Clay Pipe | 318 | Infiltration stains and roots throughout pipe. Fracture at 47.4 |
| 4153 | 599 | 600 | HS15 | Sims Ave | 8 | Vitrified Clay Pipe | 80 | Infiltration runner at DS MH Connection |

**Table 12** Summary of CCTV inspections of severely-rated manholes (adapted from Woodard & Curran (2017)). Refer to Appendix 2, Map 10 for spatial reference of identified areas.

| Manhole # | Metering Basin | Street | MH Depth (ft.) | Material | Observations |
|---|---|---|---|---|---|
| 377 | LR4 | Greenleaf Woods Drive | 14 | Precast | Mineral deposits at pipe connections (primary in/out) with active filtration |
| 378 | LR4 | Greenleaf Woods Drive | 15 | Precast | Active infiltration from wall |
| 380 | LR4 | Greenleaf Woods Drive | 14 | Precast | Chipped frame, active filtration and mineral deposits at wall |
| 396 | LR4 | Greenleaf Woods Drive | 7 | Precast | Incoming pipe connection leak, voids visible around inlet and outlet pipe connections |
| 397 | LR4 | Greenleaf Ave | 8 | Precast | Corbel missing bricks and mortar, light debris on bench. 6 gpm leak observed during flow isolation |
| 406 | LR4 | Peverly Hill Rd | 7 | Precast | Incoming and outgoing pipe connection leaks |
| 407 | LR4 | Peverly Hill Rd at McClintock Ave | 8 | Precast | Outgoing pipe connection leak |
| 554 | LR4 | Middle Road at Levitt Ave | 5 | Block | No bench and invert, heavy debris buildup, corbel missing/deteriorating |
| 563 | HS15 | Marjorie Street at Middle Street | 7 | Block | Heavy debris in bench and invert |
| 577 | HS15 | Middle Road | 6 | Block | Heavy debris in bench and invert |
| 578 | HS15 | Middle Road | 10 | Block | Heavy debris in bench and invert |
| 584 | HS15 | Hampshire Rd | 7 | Block | No bench and invert, heavy debris buildup, corbel missing mortar |
| 586 | HS15 | Hampshire Rd | 7 | Block | No bench and invert, heavy debris |
| 587 | HS15 | Hampshire Rd | 10 | Block | Mineral deposits at wall, no bench and invert, heavy debris buildup |
| 593 | HS15 | Essex Ave | 12 | Block | Broken and missing bricks from wall, loose bricks in corbel, no bench or invert, heavy debris buildup |
| 598 | HS15 | Sims Ave | 9 | Block | Heavy debris in bench and invert |
| 599 | HS15 | Sims Ave at Benson St | 8 | Precast | Infiltration at manhole wall |
| 961 | LR4 | Middle Road | 6 | Block | Heavy debris in bench and invert |
| 1044 | LR5 | Ledgewood Drive | 5 | Precast | No bench and invert, heavy debris buildup, active infiltration at wall, frame chipped |
| 1045 | LR5 | Ledgewood Drive | 8 | Precast | Infiltration staining and mineral deposits at wall. Active infiltration from wall joints |

| Manhole # | Metering Basin | Street | MH Depth (ft.) | Material | Observations |
|---|---|---|---|---|---|
| 1064 | LR5 | Lafayette Rd | 11 | Precast | Active filtration with mineral deposits at wall |
| 1382 | HS15 | US Rt 1 Bypass | 11 | Block | Active infiltration at wall, roots in corbel, loose bricks and debris on bench. Collapsed pipe connection found during flow isolation. Possible industrial connection/service infiltration. |
| 5685 | HS15 | Shefield Rd | 7 | Block | Mineral deposits at wall |

## Septic Systems

Septic systems serve the wastewater treatment needs of 18% of the residences and businesses in the Sagamore Creek watershed (Appendix 2, Map 10). Although there is a thorough state-level permitting and inspection process to ensure that new septic systems are properly designed and built, there is no program that checks whether a system continues to function properly over its 30-year service life. Research and real-world experience shows that systems of all ages sometimes malfunction for a wide variety of reasons, including poor maintenance, excessive loading with fats or solids, overloading due to water supply leaks, damage from tree roots or vehicles, old age, and even occasional errors in the design and/or installation. Sometimes malfunctions may persist for years with or without the homeowner's knowledge, potentially releasing untreated wastewater laden with fecal matter and excess nutrients to nearby waterbodies. It is also important to note that even a well-maintained and properly-functioning septic system can contribute nutrients, bacteria, and/or pathogens to groundwater and surface waters.

For these reasons, information was gathered from online and hardcopy file databases from the state and town offices about the number and status of septic systems in the watershed. Excluding rights-of-way, roads, and open water/marsh areas, a total of 1,222 parcels in Portsmouth and 62 in Rye were identified within the watershed. Of these parcels and including vacant lots, 175 (14%) in Portsmouth and 62 (100%) in Rye are serviced by or potentially serviced by septic systems. The earliest septic system permit date on record was 1991 in Portsmouth and 1968 in Rye. For parcels with available permit information, 47% of the permits in Portsmouth and 36% in Rye were issued within the last 10 years.

Many failing septic systems have been identified, particularly along the shorelines of lower Sagamore Creek near Route 1A. The City identified failing systems at the Golden Egg and Seacoast Mental Health. The Golden Egg has a 3,000-gallon grease trap and a 3,500-gallon holding tank for sewage, which must be pumped out twice per week. The septic system at BJ's Boathouse was found in failure in 1996. Raw sewage was being discharged directly into Sagamore Creek. Microbial brown scum was noted as floating on the water surface in the cove.

Several other properties were found to be in failure:

- 0223-0011-0000: failed septic system found in 1992
- 24-24: failed septic system found in 2007
- 26-9: failed septic system (date unknown)

- ∅ 23-31: town received complaint on 8/31/2009 regarding sewage leakage from property into tidal area
- ∅ 24-40: septic system malfunction, contaminating abutters and salt marsh (no date)
- ∅ 24-73: septic failure found in 2003

Failing septic systems were also suspected along Shaw Road. Environmental Canine Services (ECS) investigated the northern shoreline of Sagamore Creek from the western side of Sagamore Ave bridge to the end of Walker Bungalow Road (FBE, 2013). The canine team sniffed outfalls, unknown pipes, tributaries, and seeps along the shoreline. Several locations behind two homes (36 Shaw Road and 212 Walker Bungalow Road) were found positive for the presence of human waste.

The location of these failing septic systems on the landscape determines how much impact released effluent may have on water quality. To determine this impact, the watershed was assessed for the potential risk to critical water resources in the event of a wastewater system failure. Environmental risk factors considered include flooding, water movement, ponding, depth to saturated zone, filtering capacity, seepage/bottom layer, depth to bedrock, slope, and distance to stream or wetland. Higher risk factors indicate a greater risk to water quality if a septic system should fail because fecal contamination and excess nutrients will have a more direct route to nearby waterbodies and swimming areas. These risk factors were determined using GIS, along with publicly-available data. Risk factors were spatially analyzed using the "Polygon in Polygon" component of Hawths Analysis package in ArcMap 9.2 to calculate an area-weighted rank for each parcel based on the underlying soil and environmental risk factors located within each individual parcel. Refer to Appendix 2, Map 11.

## Stormwater Infrastructure Inspections

Geospatial data and inspection reports or metadata from the City were reviewed for stormwater infrastructure condition within the Sagamore Creek watershed. Out of the identified 915 catchbasins or drain manholes in the watershed, the City inspected 363 (40%) in 2014. Condition ratings were given to each inspected structure; most structures (86%) were in excellent or good condition (Table 13). Structures with fair or poor ratings had infrastructure damage and/or needed maintenance cleaning.

- ∅ One drainage structure located on McKinley Road in a residential neighborhood was noted to have dumped paint.
- ∅ Two drainage structures located on the west corner of the DPW lot were noted to have oil and sediment.
- ∅ Two drainage structures located on West Road between CrossFit Portsmouth and New England Truck Tire Center were noted to have significant amounts of trash.

Out of the identified 424 drainage outfalls in the watershed (which includes streams and channelized drainage in addition to pipes), the City inspected 47 (11%) in 2014. Condition ratings were given to each inspected outfall; most outfalls (57%) were in excellent or good condition (Table 13). Sixteen (16) outfalls received a fair or poor rating and/or noted a condition that warrants further investigation (Table 14). For example, one outfall (noID) had a sewage odor during the 2014 site visit. Other outfalls had structural damage, clogged openings, or indicators of nutrient enrichment.

**Table 13.** Condition rating for drainage structures (i.e., catchbasins and manholes) and stormwater outfalls or culverts inspected by the City of Portsmouth in 2014.

| Condition Rating | No. Drainage Structures | Percent | No. Outfalls/Culverts | Percent |
|---|---|---|---|---|
| Excellent | 82 | 23% | 20 | 42% |
| Good | 228 | 63% | 15 | 15% |
| Fair | 38 | 10% | 7 | 32% |
| Poor | 15 | 4% | 5 | 11% |
| Total | 363 | 100% | 47 | 100% |

**Table 14.** Select outfalls inspected by the City in 2014 that received a fair or poor rating and/or noted a condition that warrants further investigation.

| City ID | Pipe Diam. (in) | Sediment Burial Within Pipe | Water Submersion Within Pipe | Notes | Photo |
|---|---|---|---|---|---|
| 5088 | 10 | Open | No | Pipe constricted by rock; trash debris and floating green scum noted |  |
| 5193 | 10 | 1/2 full | No | Pipe clogged with sediment and debris |  |
| noID | 15 | Open | No | Sewage odor noted; warrants follow-up investigation | No photo available. |
| 5182 | 15 | Open | Partially | Algae film growing inside and near pipe |  |

| City ID | Pipe Diam. (in) | Sediment Burial Within Pipe | Water Submersion Within Pipe | Notes | Photo |
|---|---|---|---|---|---|
| 1194 | 12 | Open | Partially | Excessive green algae growth |  |
| 3883 | 12 | 1/2 full | Partially | Pipe clogged with sediment and debris |  |
| 3884 | 15 | 1/2 full | Partially | Pipe clogged with sediment and debris |  |
| 3898 | 12 | 1/2 full | Partially | Pipe clogged with sediment and debris |  |
| noID | 12 | 1/2 full | No | Pipe clogged with sediment and debris |  |

| City ID | Pipe Diam. (in) | Sediment Burial Within Pipe | Water Submersion Within Pipe | Notes | Photo |
|---|---|---|---|---|---|
| 1830 | 15 | 3/4 full | Partially | Vegetation overgrowth around pipe; pipe clogged with sediment and debris |  |
| 4042 | 12 | 1/2 full | Partially | Pipe clogged with sediment and debris; milky sheen in water |  |
| 1168 | -- | -- | Fully | Completely submerged; unable to inspect | No photo available. |
| 11376 | 12 | 1/2 full | Fully | Pipe clogged with sediment and debris |  |
| 5435 | 6 | Plugged | No | Pipe clogged with sediment and debris |  |
| 2279 | 18 | 1/2 full | Fully | Pipe clogged with sediment and debris |  |

| City ID | Pipe Diam. (in) | Sediment Burial Within Pipe | Water Submersion Within Pipe | Notes | Photo |
|---|---|---|---|---|---|
| 2781 | 15 | Open | Fully | Pipe broken allowing water out before outfall |  |

## Marinas & Boats

One marina (Witch Cove Marina) is located along Sagamore Creek, along with many private docks and slips. The NHDES Shellfish Program also identified 38 moorings in the lower portion of the Creek. The Creek experiences recreational and commercial boating activity from May to October, and anecdotal accounts suggest an increase in boating activity in recent years. During the boating season, the risk of overboard discharge of sewage or spilled fuel from boats is high and threatens public and aquatic health. Seasonal closures of shellfish beds around marinas helps to minimize this risk to public health.

## Landfills

The Jones Avenue Municipal Landfill is situated along the northern shoreline of Sagamore Creek. The original 25-acre property was acquired by the City in 1896 and gradually expanded to a total of 79 acres today. By the mid-1960's, the property was used as a landfill and open burn pit. A teepee burner was built to incinerate trash until 1972. With the help of Hoyle Tanner & Associates, the landfill closure process began in 1985. About 34,000 cubic yards of incinerator ash from the Pease Air Base was taken to the landfill for disposal around that time. The ash had elevated levels of lead. By 1990, a geocomposite and HDPE double-lined ash containment area with leachate collection system was built, and by 1991, the landfill was officially closed and capped with sand, VLDPE liner, and topsoil. The entire containment area was surrounded by an underdrain system. The groundwater monitoring permit was instated soon thereafter. Groundwater and surface water quality testing is conducted semi-annually in accordance with the permit, and reports are submitted annually to NHDES for 30 years. Four monitoring wells were installed, three downgradient along the shoreline and one upgradient near the entrance. A suite of VOCs and metals are regularly sampled. Chromium, nickel, and lead were elevated for the first three years following closure, but since then no significant trends have been detected that would suggest landfill leachate is contaminating the surrounding environment.

Since closure, the City has considered the site for relocation of a school and expansion of parking lots or fields. In 2015, a Blue Ribbon Committee was appointed by the Mayor to create a plan for public recreational use of the parcel.

A small, uncapped and unlined landfill was used in the 1950's and 1960's in the area around Mirona Road and the former Iafolla property (currently owned by the Portsmouth DPW and PIKE Industries). Soil tests and groundwater monitoring have since revealed soil contamination from sludge and other refuse disposal.

### Industrial & Commercial Businesses

The Sagamore Creek watershed is dominated by industrial and commercial business development, especially along the Route 1 corridor. A windshield survey of the watershed was conducted in October 2017, identifying businesses by parcel. These businesses were grouped together by general business type or category. Out of a total of 229 businesses identified, most businesses were classified as office or retail spaces, followed by restaurants and auto shops or dealerships (Table 15). Several large construction companies, some with significant equipment and material storage areas, were identified, including PIKE Industries, an asphalt and aggregate producer. The City of Portsmouth DPW is also located within the watershed. The site contains the transfer station, along with sand/salt piles and large vehicle storage. Several medical facilities, offices, and therapy/treatment centers exist, along with gyms and recreational youth centers. Four gas stations were also noted. The activities that take place on these properties may generate water quality contaminants. Hazardous waste generators are registered with the state and are discussed in the next section.

**Table 15.** Count of general business categories identified in the Sagamore Creek watershed. A total of 229 businesses were inventoried.

| Business Category | Count | Business Category | Count |
|---|---|---|---|
| Office | 62 | Bike Repair Shop | 1 |
| Retail | 41 | Boat Club | 1 |
| Restaurant | 17 | Bowling Alley | 1 |
| Auto Shop / Dealership / Rental | 15 | Country Club | 1 |
| Construction Company | 8 | Energy Provider | 1 |
| Therapy/Treatment Center | 8 | Equipment Rental | 1 |
| Gym | 7 | Factory Automation Services | 1 |
| Medical Facility | 7 | Food Pantry | 1 |
| Youth Center | 7 | Garage Install Services | 1 |
| Church | 6 | Glass Supplier | 1 |
| Medical Office | 5 | Golf Course | 1 |
| Printing / Shipping Center | 5 | Hotel | 1 |
| Bank | 4 | Paint Supplier | 1 |
| Gas Station | 4 | Plastic Manufacturing | 1 |
| Grocery | 3 | Pool Supplier | 1 |
| Diving | 2 | Public Works Facility | 1 |
| HVAC Services | 2 | Storage | 1 |
| Landscaping Company | 2 | Trucking Company | 1 |
| Salon & Spa | 2 | Water Park | 1 |
| Shelter | 2 | Welding Company | 1 |

### Potential Contamination Sources

Potential Contamination Sources (PCS) registered and tracked by NHDES include the following: aboveground storage tanks, underground storage tanks, hazardous waste generators, initial spill responses, remediation sites, air facility systems, and solid waste facilities. Refer to Appendix 2, Map 12 for locations of these PCSs. Note that more hazardous waste generators were discovered during review of the NHDES OneStop database, but were not added to the map.

### Aboveground Storage Tanks

Aboveground storage tanks are locations of registered aboveground petroleum storage tanks. A total of 10 aboveground storage tanks were identified in the Sagamore Creek watershed, including 6 tanks at PIKE Industries, 1 at Portsmouth High School, 2 at PSNH substations, and 1 at Portsmouth Used Car Center.

### Underground Storage Tanks

Underground storage tanks are locations of registered underground storage tanks for motor fuels, heating oils, lubricating oils, other petroleum and petroleum liquids, and hazardous substances. A total of 38 underground storage tanks were identified in the Sagamore Creek watershed, including 5 at two auto dealerships, 1 at Lens Doctors, 1 at Ricci Construction, 3 at the US Coast Guard office, 21 at seven gas stations, 5 at the Portsmouth DPW, 1 at the Portsmouth swimming pool, and 1 at a PSNH substation.

### Hazardous Waste Generators

Hazardous waste generators are facilities with former or existing activities that generate, transport, store, or dispose hazardous wastes, such as batteries, pesticides, thermostats, lamps, antifreeze, mercury-containing devices, used oil, and cathode ray tubes). Hazardous waste generators are registered and monitored by NHDES. Documentation is filled out as to the type, quantity, and method of disposal for all hazardous waste (unless deemed non-acute). Original data extraction from NHDES spatial layers showed 47 former or existing hazardous waste generators in the watershed. Each permit was reviewed on the NHDES OneStop database for more detailed information about the type of hazardous wastes generated. Through this review process, several more hazardous waste generators were discovered in the watershed, for a new total of 67 (though this still may be an underestimate).

The following hazardous wastes were identified in the watershed (in order of most to least prevalent):

- Oil and gasoline
- Solvents (paints and thinners)
- Flammable liquids
- Silver (photo solution)
- Refrigerants (chloroform)
- Mercury (bulbs)
- Aerosols (paints, WD-40, cleaners)
- Lead
- Batteries (lithium)
- Corrosive liquids
- Disinfectants and bleach
- Fertilizers
- Polychlorinated biphenyls (PCBs)
- Anti-freeze
- Pesticides
- Latex and silicates (coating and adhesives)
- Unknown chemical solid waste
- Asphalt
- Asbestos
- Staining agents

- ∅ Arsenic
- ∅ Vinyl manufacture byproducts
- ∅ Coagulants
- ∅ Plating and steelmaking byproducts

Refer to Table 16 for a complete list of hazardous wastes by permit.

### Initial Spill Responses & Remediation Sites

Initial spill responses are locations of reported hazardous waste spills or leaks, some of which may have evolved into remediation sites depending on the severity of the spill or leak. A total of 37 remediation sites were identified in the Sagamore Creek watershed, including gas stations, auto dealerships, Portsmouth DPW, the Jones Avenue Municipal Landfill, Wentworth Scrap Metal, Witch Cove Marina, restaurants, and residences. Thirty-one (31) remediation sites were assigned a risk to water supply value of “7” or “8”. A 7 indicates “low concentration, alternate water available” and a risk value of 8 indicates “no sources, no ambient groundwater quality standard violations onsite.” Four (4) remediation sites were scored at a risk of 2. A value of 2 indicates “in a wellhead protection area or within 1000’ of a well.” Two remediation sites were not assigned a risk value. Refer to Table 17 for descriptions of identified initial spill responses and/or remediation sites requiring a groundwater monitoring permit (GMP).

Most of the remediation sites involved removal of leaking underground storage tanks and surrounding contaminated soil. Several permits for properties along Mirona Road and the former Iafolla property (currently owned by the Portsmouth DPW and PIKE Industries) indicate that the area was used as a sand and gravel pit and then a disposal/landfill site (for sludge and other refuse materials) in the 1950’s and 1960’s. The Wentworth-By-The-Sea Country Club property was found to have elevated levels of Chlordane in 1997 and underwent remediation by stripping the first 4-6 inches of top soil. The persistence of Chlordane in soils suggests that it will be an ongoing issue for the foreseeable future.

### Air Facility Systems

Air facility systems are buildings, structures, facilities, or installations that emit regulated air pollutants into the ambient air. A total of 4 air facility systems were identified in the Sagamore Creek watershed, including the Portsmouth DPW, PIKE Industries, George’s Auto Body, and H.D. Baumann Inc. (inactive).

### Solid Waste Facilities

Solid waste facilities are facilities generating or storing solid waste. A total of 4 solid waste facilities were identified in the Sagamore Creek watershed, including the Portsmouth Transfer Station (operating), Wentworth Scrap Metal (inactive), Jones Avenue Municipal Landfill (capped), and former Country Motor Sales (not operating). The Jones Avenue Municipal Landfill was an unlined landfill operating from 1965-1972 and was capped in 1991. The former Country Motor Sales was also an unlined landfill located at 375 Banfield Road. No permit number or additional information was found.

**Table 16.** Summary of the types of hazardous wastes generated, stored, transported, or disposed in the Sagamore Creek watershed. Data were gleaned from permits and other documentation through the NHDES OneStop database.

| SITE NAME | ADDRESS | Active Timeframe | Status | Oil & Gasoline** | Solvents (Paints & Thinners)* | Silver (Photo Solution) | Refrigerants (Chloroform) | Aerosols (Paints, WD-40, Cleaners) | Flammable Liquids (General) | Corrosive Liquids (General) | Osmium Tetroxide (Staining Agent) | Polychlorinated Biphenyls (PCBs) | Mercury (Bulbs) | Anti-freeze (e.g., propylene glycol) | Asphalt | Disinfectants & Bleach*** | Pesticides^ | Batteries (e.g., Lithium) | Unknown Chemical Solid Waste | Arsenic | Lead | Dichloroethane, Muriatic Acid (Vinyl Manufacture) | Latex & Silicates (Coating & Adhesive) | Aluminum Hydroxide Chloride (Coagulant for Wastewater Effluent treatment) | Asbestos | Fertilizers (e.g., ammonium anhydrous, phosphoric acid, sulfuric acid) | Plating & Steelmaking (Calcium Carbide, Potassium Cyanide) | Non-acute hazardous waste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BENS AUTO BODY INC | 11 MIRONA RD | 1999-2017 | ACTIVE | | X | | | | | | | | | | | | | | | | X | | | | | | | |
| PORTSMOUTH AUTO BODY CENTER | 700 PEVERLY HILL RD | 1999-2016 | ACTIVE | X | X | | | | X | | | | | | | | | | | | | | | | | | | |
| KEY COLLISION CENTER | 4 MIRONA RD | 1987-2017 | ACTIVE | X | X | | | | X | | | | | | | | | | | | | | | | | | | |
| PORT CITY DODGE | 155 GREENLEAF AVE | 1999-2012 | ACTIVE | X | X | | | | X | | | | | X | | | | X | | | X | | | | | | | |
| PORTSMOUTH HIGH SCHOOL | 50 ALUMNI CIRCLE | 1987-2017 | ACTIVE | X | X | X | X | X | X | | | | X | | | X | | | | | | | | | | | | |
| ANANIAN STEPHEN E DMD | 278 LAFAYETTE RD | 1999-2017 | ACTIVE | | | X | | | | | | | | | | | | | | | | | | | | | | |
| PORTSMOUTH USED CAR CENTER | 180 MIRONA RD | 1999-2017 | ACTIVE | X | | | X | | | | | | | | | | | | | | | | | | | | | |
| PIKE INDUSTRIES INC | 650 PEVERLY HILL RD | 2004-2017 | ACTIVE | X | X | | | | | | | | | | X | | | | | | | | | | | | | |
| NATIONAL WRECKER INC | 295 WEST RD | 1997-2017 | ACTIVE | X | X | | | | | | | | | | | | | | | | | | | | | | | |
| TOYOTA OF PORTSMOUTH | 150 GREENLEAF AVE | 1999-2004 | ACTIVE | X | X | | | | | | | | | X | | | | | | | X | | | | | | | |
| UNITIL | 325 WEST RD | 1992-2008 | ACTIVE | X | X | | | | X | | | | X | X | | | | X | | | | | X | | X | X | | |
| PORTSMOUTH DPW | 680 PEVERLY HILL RD | 2000-2017 | ACTIVE | X | X | | | X | X | X | | | X | | | X | X | X | | | X | | | | X | | | |
| TRI RENT ALL OF PORTSMOUTH INC / THE SIGN PLACE | 10 MIRONA RD | 1989-1990; 2002-2006 | ACTIVE | X | X | | | | X | | | | | | | | | | | | | | | | | | | |

| SITE NAME | ADDRESS | Active Timeframe | Status | Oil & Gasoline** | Solvents (Paints & Thinners)* | Silver (Photo Solution) | Refrigerants (Chloroform) | Aerosols (Paints, WD-40, Cleaners) | Flammable Liquids (General) | Corrosive Liquids (General) | Osmium Tetroxide (Staining Agent) | Polychlorinated Biphenyls (PCBs) | Mercury (Bulbs) | Anti-freeze (e.g., propylene glycol) | Asphalt | Disinfectants & Bleach*** | Pesticides^ | Batteries (e.g., Lithium) | Unknown Chemical Solid Waste | Arsenic | Lead | Dichloroethane, Muriatic Acid (Vinyl Manufacture) | Latex & Silicates (Coating & Adhesive) | Aluminum Hydroxide Chloride (Coagulant for Wastewater Effluent treatment) | Asbestos | Fertilizers (e.g., ammonium anhydrous, phosphoric acid, sulfuric acid) | Plating & Steelmaking (Calcium Carbide, Potassium Cyanide) | Non-acute hazardous waste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEAD RIVER OIL | 100 WEST RD | 2002-2003 | ACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| BIG APPLE FOOD STORE | 800 Lafayette Rd | 2005-2011 | ACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| FA GRAY INC | 300 WEST RD, UNIT 4 | 2014-2015 | ACTIVE | | X | | | | | | | | | | | | | | | | | | | | | | | |
| COMCAST PORTSMOUTH | 180 GREENLEAF AVE | 2014-2017 | ACTIVE | | | | | X | | | | | | | | | | | | | | | | | | | | |
| HANSCOMS TRUCK STOP INC | 60 WEST RD | 1999-2017 | ACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| DYNATUNE / NAPA AUTO PARTS | 20 MIRONA RD | 1991-2001 | ACTIVE | X | X | | | | | | | | | | | | | | | | | | | | | | | |
| EVERSOURCE ENERGY | 1700 LAFAYETTE RD | 1994-2017 | ACTIVE | X | | | | X | | | | | X | | | | | X | | | | | | | | | | |
| SUNOCO SERVICE STATION | 1400 LAFAYETTE RD | 1993-1999 | DECLASSIFIED | X | | | X | | X | | | | | | | | | | | | | | | | | | | |
| BAUMANN H D INC | 35 MIRONA RD | 1997-2003 | DECLASSIFIED | X | X | | X | | | X | | | X | | | | | X | | | | | | | | | | |
| CORNING INC | 170 WEST RD | 1998-2002 | DECLASSIFIED | | X | X | X | X | | | X | | X | | | X | X | | | | | | X | | | | | |
| WENTWORTH SCRAP METAL | 246 JONES AVE | 1999-2003 | DECLASSIFIED | | | | | | | | | X | | | | | | | | | | | | | | | | |
| QUALITY FABRICATORS | 30 MIRONA RD EXT | 1999-2011 | DECLASSIFIED | X | X | | | | | | | | | | | | | | | | | | | | | | | |
| SEACOAST PRINTING INC | 140 WEST RD | 2001-2002 | DECLASSIFIED | | | X | | | | | | | | | | | | | | | | | | | | | | |
| RITE AID 10290 | 1500 LAFAYETTE RD | 2002-2013 | DECLASSIFIED | X | X | X | | | | | | | | | | | | | | | | | | | | X | | |
| BOURNIVAL JEEP | 720 LAFAYETTE RD | 1987-2006 | DECLASSIFIED | X | | | | | | | | | | | | | | | | X | X | | | | | | | |
| DOOLITTLE DOUG | 138 LEAVITT ST | 1987-1988 | DECLASSIFIED | X | | | | | | | | | | | | | | | | | | | | | | | | |

| SITE NAME | ADDRESS | Active Timeframe | Status | Oil & Gasoline** | Solvents (Paints & Thinners)* | Silver (Photo Solution) | Refrigerants (Chloroform) | Aerosols (Paints, WD-40, Cleaners) | Flammable Liquids (General) | Corrosive Liquids (General) | Osmium Tetroxide (Staining Agent) | Polychlorinated Biphenyls (PCBs) | Mercury (Bulbs) | Anti-freeze (e.g., propylene glycol) | Asphalt | Disinfectants & Bleach*** | Pesticides^ | Batteries (e.g., Lithium) | Unknown Chemical Solid Waste | Arsenic | Lead | Dichloroethane, Muriatic Acid (Vinyl Manufacture) | Latex & Silicates (Coating & Adhesive) | Aluminum Hydroxide Chloride (Coagulant for Wastewater Effluent treatment) | Asbestos | Fertilizers (e.g., ammonium anhydrous, phosphoric acid, sulfuric acid) | Plating & Steelmaking (Calcium Carbide, Potassium Cyanide) | Non-acute hazardous waste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEACOAST PRINTING CO | 129 MIRONA RD | 1992-1997 | DECLASSIFIED | | | | | | | X | | | | | | | | | | | | | | | | | | |
| US COAST GUARD ELECTRONIC SHOP | 195 GREENLEAF AVE | 1990-1999 | INACTIVE | X | X | | X | | X | | | X | | | | | | | | | | | | | | | | |
| OCEAN PROPERTIES LTD | 1150 SAGAMORE RD | 1987-2013 | INACTIVE | X | X | | | X | X | | | | | X | | | | | | | | | X | | | X | | |
| PISCATAQUA DENTAL PARTNERS PA | 288 LAFAYETTE RD | 1999-2006 | INACTIVE | | | X | | | | | | | | | | | | | | | | | | | | | | |
| K A I TECHNOLOGIES LLC | 170 WEST RD | 1998 | INACTIVE | X | | | | | X | X | | X | | | | X | | | | | | | | | | | | |
| H J LUDINGTON DDS | 288 LAFAYETTE RD | 1999-2015 | INACTIVE | | | X | | | | | | | | | | | | | | | | | | | | | | |
| FOUR SEASON FENCE | 10 BANFIELD Rd | 1998-1999 | INACTIVE | | | | | | X | | | | | | | | | | | | | | | | | | | |
| GOODY TWO SHOES | 1190 LAFAYETTE RD | 1999 | INACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| HALEY & ALDRICH INC | JONES AVE | 1989 | INACTIVE | | | | | | | | | | | | | | | | | | X | | | | | | | |
| LARUES FIREARMS INC | 150 SPAULDING TPKE | 1994-1999 | INACTIVE | | | | | | | | | | | | | | | | | | | | | | | | | X |
| JONES AVE MUNICIPAL LANDFILL | JONES AVE | 1989 | INACTIVE | | | | | | | | | | | | | | | | X | | | | | | | | | |
| ADVANCED ABSORBER PRODUCTS INC | 170 WEST ST | 1991 | INACTIVE | | X | | X | | X | | | | | | | | | | | | | | | | | | | |
| HARDWARE | 650 LAFAYETTE RD | 1994 | INACTIVE | | | | | | X | | | | | | | | | | | | | | | | | | | |
| Dead River Co | 72 MIRONA Rd | 1996-1999 | INACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |

| SITE NAME | ADDRESS | Active Timeframe | Status | Oil & Gasoline** | Solvents (Paints & Thinners)* | Silver (Photo Solution) | Refrigerants (Chloroform) | Aerosols (Paints, WD-40, Cleaners) | Flammable Liquids (General) | Corrosive Liquids (General) | Osmium Tetroxide (Staining Agent) | Polychlorinated Biphenyls (PCBs) | Mercury (Bulbs) | Anti-freeze (e.g., propylene glycol) | Asphalt | Disinfectants & Bleach*** | Pesticides^ | Batteries (e.g., Lithium) | Unknown Chemical Solid Waste | Arsenic | Lead | Dichloroethane, Muriatic Acid (Vinyl Manufacture) | Latex & Silicates (Coating & Adhesive) | Aluminum Hydroxide Chloride (Coagulant for Wastewater Effluent treatment) | Asbestos | Fertilizers (e.g., ammonium anhydrous, phosphoric acid, sulfuric acid) | Plating & Steelmaking (Calcium Carbide, Potassium Cyanide) | Non-acute hazardous waste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GRANITE STATE GAS | 375 WEST RD | 1995 | INACTIVE | | | | | | | | | | | | | | | | X | | | | | | | | | |
| NEW HAMPSHIRE GLASS | 1 MIRONA Rd | 1996 | INACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| C N Brown | 400 LAFAYETTE Rd | 1997-1999 | INACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| ROCKY COAST PRINT WORKS | 2080 LAFAYETTE RD | 1999 | INACTIVE | | | | | | | | | | | | | | | | X | | | | | | | | | |
| A H HARRIS & SON | 255 WEST RD | 2001-2012 | INACTIVE | | X | | | | | | | | | | | | | | | | | | X | | | | | |
| ABINGTON GROUP | 195 WEST RD | 2002-2005 | INACTIVE | X | X | | | X | | | | | X | | | | | X | | | | | | | | | | |
| SCOTTS LAWN SERVICE | 170 WEST RD | 2002-2003 | INACTIVE | X | | | | | | | | | | | | | | | | | | | | | | | | |
| BETTER SMILES DENTAL CARE | 278 LAFAYETTE RD | 2003-2010 | INACTIVE | | | X | | | | | | | | | | | | | | | | | | | | | | |
| MXI ENVIRONMENTAL SERVICES HHWC | 680 PEVERLY HILL RD | 2003-2014 | INACTIVE | X | X | | | X | | X | | | X | | | X | X | X | | | X | | | | | X | X | |
| MICRONICS INC | 200 WEST RD | 2003-2013; 2016 | INACTIVE | | X | | | | | | | | | | | | | | | | | | | X | | | | |
| A & M PAINT & WALLPAPER CORP | 620 PEVERLY HILL RD | 2004 | INACTIVE | | X | | | | | | | | | | | | | | | | | | | | | | | |
| CLEAR CHANNEL COMMUNICATION | 815 LAFAYETTE RD | 2003-2007 | INACTIVE | | | | | | | | | X | | | | | | | | | | | | | | | | |
| WASTECH INTERNATIONAL | 210 WEST RD | 2005 | INACTIVE | | X | | | | | | | | X | | | X | | | | | | | | | | X | | |
| PORTSMOUTH DPW | 915 SAGAMORE AVE | 2010 | INACTIVE | | | | | | | | | | | | | | | | | | X | | | | | | | |

| SITE NAME | ADDRESS | Active Timeframe | Status | Oil & Gasoline** | Solvents (Paints & Thinners)* | Silver (Photo Solution) | Refrigerants (Chloroform) | Aerosols (Paints, WD-40, Cleaners) | Flammable Liquids (General) | Corrosive Liquids (General) | Osmium Tetroxide (Staining Agent) | Polychlorinated Biphenyls (PCBs) | Mercury (Bulbs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HIGHET AND JAMES | 141 BANFIELD RD | 2012 | INACTIVE | | X | | | | | | | | |
| BOURASSA CONTRUCTION | 275 WEST RD | 2015 | INACTIVE | X | | | | | | | | | |
| IAFOLLA JOHN COMPANY INC | 650 PEVERLY HILL RD | 1987-1998 | INACTIVE | X | X | | X | | X | | | X | |
| RANDALL PRESS INC | 210 WEST RD | 1999-2007 | INACTIVE | | | X | | | | | | | |
| SHIELDING SYSTEMS CORP | 170 WEST RD | 1991 | INACTIVE | | | | | | X | | | | |
| ELWYN PARK EXXON / CONOCO PHILLIPS | 1533/1475 LAFAYETTE RD | 1988-2017 | INACTIVE | X | | | X | | | | | | |
| LAFAYETTE CLEANERS | 599 LAFAYETTE RD | 1989-1997 | INACTIVE | | X | | | | | | | | |
| SPORTS MEDICINE ATLANTIC ORTHOPAEDICS PA | 150 RTE 1 BYPASS | 1991-2004 | INACTIVE | X | | | | | | X | | | |
| SPIVEY DDS MS JAMES D | 278 LAFAYETTE RD | 1992-2004 | INACTIVE | | | X | | | | | | | |
| AD CETERA GRAPHICS | 692 SAGAMORE AVE | 1999-2010 | INACTIVE | | | X | | | | | | | |

| SITE NAME | Anti-freeze (e.g., propylene glycol) | Asphalt | Disinfectants & Bleach*** | Pesticides^ | Batteries (e.g., Lithium) | Unknown Chemical Solid Waste | Arsenic | Lead | Dichloroethane, Muriatic Acid (Vinyl Manufacture) | Latex & Silicates (Coating & Adhesive) | Aluminum Hydroxide Chloride (Coagulant for Wastewater Effluent treatment) | Asbestos | Fertilizers (e.g., ammonium anhydrous, phosphoric acid, sulfuric acid) | Plating & Steelmaking (Calcium Carbide, Potassium Cyanide) | Non-acute hazardous waste |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HIGHET AND JAMES | | | | | | | | | | | | | | | |
| BOURASSA CONTRUCTION | | X | | | | | | | | | | | | | |
| IAFOLLA JOHN COMPANY INC | X | | | X | | | | | | | | | | | |
| RANDALL PRESS INC | | | | | | | | | | | | | | | |
| SHIELDING SYSTEMS CORP | | | | | | | | | | | | | | | |
| ELWYN PARK EXXON / CONOCO PHILLIPS | | | | | | | | | X | | | | | | |
| LAFAYETTE CLEANERS | | | | | | | | | | | | | | | |
| SPORTS MEDICINE ATLANTIC ORTHOPAEDICS PA | | | | | | | | | | | | | | | |
| SPIVEY DDS MS JAMES D | | | | | | | | | | | | | X | | |
| AD CETERA GRAPHICS | | | | | | | | | | | | | | | |

* May include the following chemicals; Methyl Ethyl Ketone, Acetone, Chromium, Xylene, Toluene, Trichloroethylene, Tetrachloroethylene, Nitrobenzene, Chlorobenzene, Arsenic, Barium, Cadmium, Selenium, Titanium Sulfate, Potassium Hydroxide, Hydrofluoric Acid, Methylene Chloride, Nitric Acid, Phosphoric Acid, Hydrochloric Acid, Sodium Hydroxide, Hydrogen Fluoride, and/or Methanol

** May include the following chemicals: Benzene, Petroleum Naphthalene, Methyl Tertiary Butyl Ether (MtBE), Tert Butyl Alcohol (TBA), Sodium Hydroxide, and/or Tetrachloroethene

*** May include the following chemicals: Isopropyl Alcohol, Hydrogen Peroxide, Sodium Borohydride, Ammonium Persulfate, Sodium Hydroxide, Calcium Hypochlorite, and/or Sodium Hypochlorite

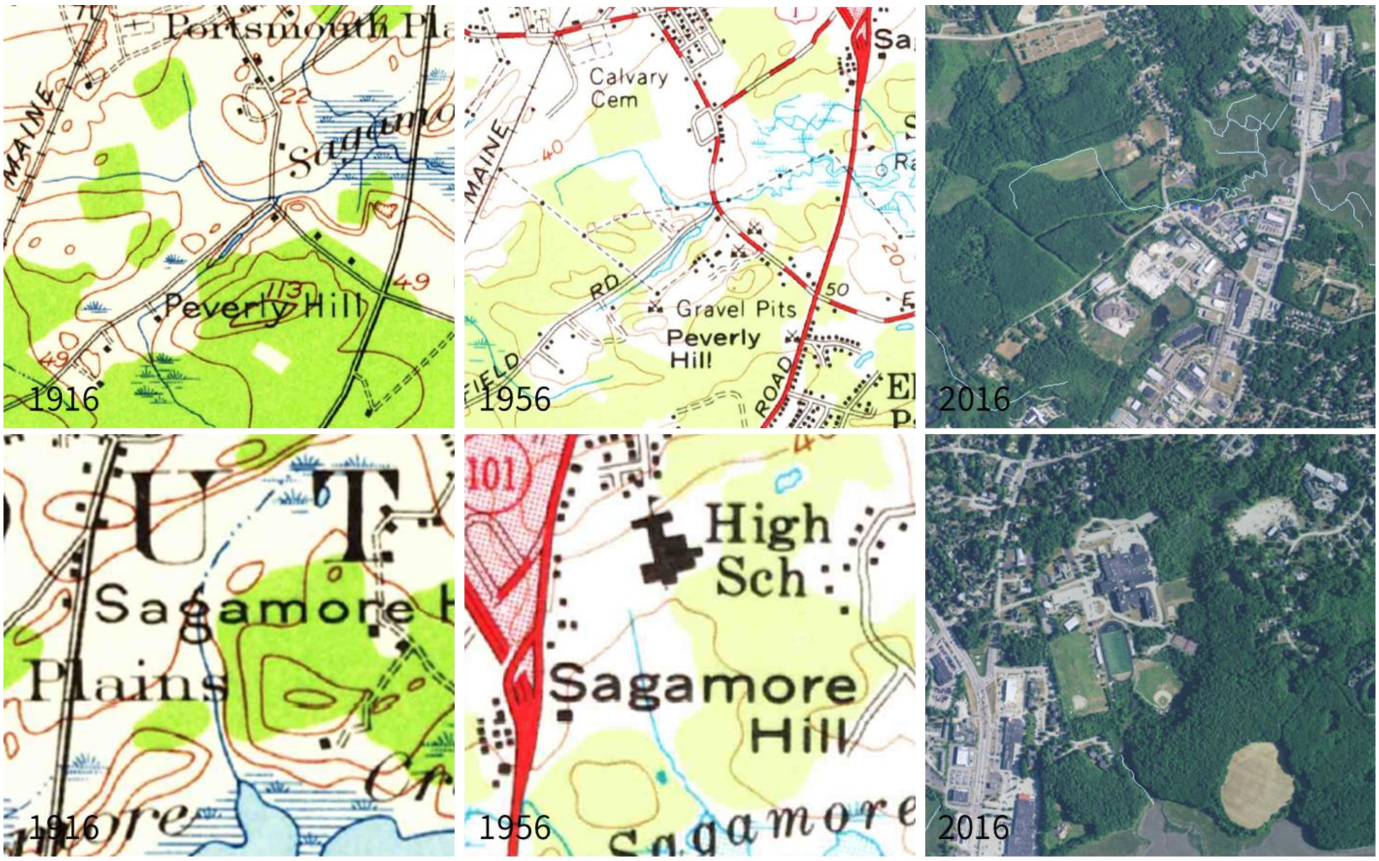
^ May include the following chemicals: Pentachlorophenol, Urethane, Calcium Cyanide, Malathion, Diazinon

**Table 17.** Summary of identified initial spill responses and/or remediation sites requiring groundwater monitoring permits (GMP). Data obtained from the NHDES OneStop database.

| Facility | Address | Date | Description |
|---|---|---|---|
| ARTISAN OUTLET | 72 MIRONA ROAD | 1997-2002 | GMP 1997-2002; monitored two wells for arsenic and lead; no violations found in 2000; file closed |
| BIG APPLE FOOD STORE | 800 LAFAYETTE RD | 9/10/1999 | Gas spill (3-5 gal) due to overfill at pump; spill contained on asphalt using speedy dri; disposed properly |
| BIG APPLE FOOD STORE | 800 LAFAYETTE RD | 12/11/2014 | Gasoline detected in a catch basin; Clean Harbors was hired to pump out the remaining fuel; a sheen was detected in the marsh behind the station; a boom was placed at the drain outlet |
| BIG APPLE FOOD STORE | 800 LAFAYETTE RD | 1988-present | High VOCs in GWM well observed in 1988; continue to monitor 10 GWM wells and same site comes up high in VOCs, confirming known soil contamination area; organic peat layer acting as major filtration of VOCs and VOCs are reducing at contaminated site |
| BOURNIVAL | 720 LAFAYETTE RD | 7/1/2010 | Leaking underground tank; GWM wells installed to monitor documented released associated with a former gas station on adjacent property to south and former kerosene and waste oil USTs off north side of site building; elevated VOCs indicating release from one or both USTs found; both removed; evidence of damage, holes, leaking; removed wastewater UST as well, samples with high arsenic; monitoring closed out 2012 |
| DEPT. OF PUBLIC WORKS | 680 PEVERLY HILL RD | 6/17/1997 | 55 gal of mixed flammable liquids spilled during household hazardous waste collection event; spilled on parking lot, contained quickly and diverted from nearby catch basins |
| DEPT. OF PUBLIC WORKS | 680 PEVERLY HILL RD | 1997-2016 | GMP monitored contaminants from former Iafolla property (buried sludge) |
| EXXON DIV OF CFI 70119 | 1475 LAFAYETTE RD | 2014 | Site redeveloped in 2014; replaced 1 UST; removed 3 USTs and 4 gas dispensers; currently has 2 USTs; remediation and removal of contaminated soil and semi-solid waste (source of contamination from former USTs installed in 1966); decreasing trend in petroleum products (by natural attenuation processes); naphthalene high; tetrahydrofuran one sample high in 2014 |
| EXXON DIV OF CFI 70119 | 1475 LAFAYETTE RD | 3/31/2014 | Gas spill (5 gal) due to overfill at pump; spill contained on asphalt using speedy dri; spent absorbant was removed from site |
| HORTON PROPERTY | 171 MUNROE ST EXT | 02/02/2007 | 2 gal of #2 fuel oil spilled under porch |
| IAFOLLA JOHN COMPANY INC / PIKE INDUSTRIES | 650 PEVERLY HILL RD | 1997-1999 | GMP 1997-1999; low VOCs, file closed for no further action; landfill closure |
| KEY COLLISION CENTER | 4 MIRONA RD | 1995-2014 | GMP 2012-2014; two monitoring wells for VOCs; elevated naphthalene in wells; formerly a sand and gravel pit, turned landfill for City in the 1950's and 60's; no known USTs; found refuse from former landfill in soil borings (1995); elevated VOCs from petroleum spills |
| LARUES FIREARMS INC | 150 SPAULDING TPKE | 7/5/2017 | Removed UST; found elevated naphthalene in surrounding soil |
| MICRONICS INC | 200 WEST RD | 1/31/2011 | Spilled 50 gal of hydraulic oil; spill contained on cement floor and cleaned up |
| PORTSMOUTH USED CAR CENTER | 180 MIRONA RD | 1998-present | Environmental site assessment and limited subsurface investigation performed in 1996; found impacts to soil and groundwater; associated contamination with prior use as a municipal landfill; concentrations of contaminants exceeding standards; 1998 GMP issued; found to be impacted by VOCs and arsenic; VOCs meeting standards since 2006; VOCs dropped in 2008; annual monitoring of arsenic continues; current permit through 2018 |
| ROADSIDE TRANSFORMER SPILL | WEST ROAD | 3/24/2010 | Pole top regulator damaged during wind storm and released 85 gal of mineral oil onto pavement and gravel road shoulder |
| TOYOTA OF PORTSMOUTH | 150 GREENLEAD AVE | 3/23/1987 | Removed two USTs; excavated trenth behind building and four interconnecting trenches on southwestern section of property in former UST location; low levels of VOCs, no groundwater contamination detected in area of 2 USTs; no VOCs in trenches; VOCs found in area of former UST |

## Hydrologic Alterations

Over the last 200 years, humans have significantly altered the landscape, including the stream network, by artificially straightening channels for agriculture, roads, or other development (Field, 2007). Sagamore Creek is no exception and there are several examples of human channel alteration. The most notable example is diversion and straightening of the headwaters of Sagamore Creek upstream of the Peverly Hill Road crossing. This was likely done to drain water away from agricultural land. A second example is at the headwaters of a small tributary to Sagamore Creek on the north shore east of Route 1. The wetland, headwater area was filled in for construction of the Portsmouth High School.



Historical USGS topos and GoogleEarth aerials depicting examples of human channel alterations in the Sagamore Creek watershed.

The NHDES OneStop registers human-created dams, of which three were identified in the Sagamore Creek watershed. The Sagamore Creek dam creates a one-acre impoundment bordering the DPW/PIKE Industries lot just before Elwyn Brook crosses under Banfield Road, then Peverly Hill Road. This impoundment was once used as a settling basin for treating runoff from the former gravel pit. Two other dams create the Riverbrook detention pond between Islington Street and Pearson Street near the northwest watershed boundary.

Historically, New England salt marshes were ditched for salt hay production and later for mosquito control. The altered hydrology has been shown to change marsh soil properties and elevation, reducing a marsh's ability to respond to rising sea levels. Further research into successful historic salt marsh ditch management and/or restoration examples is needed.

The salt marsh of Sagamore Creek provides evidence of historic ditching. Image obtained from GoogleEarth.

Other noted hydrologic alterations in the watershed include the following:

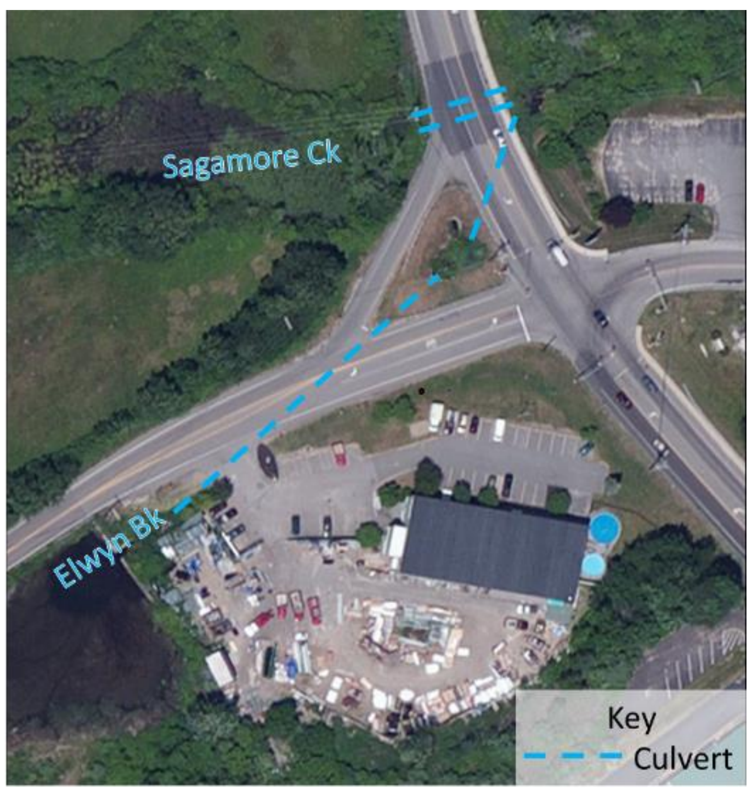
- ∅ The Army Corps of Engineers was planning to remove a sandy shoal from the bottom of Sagamore Creek in winter 2017, increasing the water depth by about 5 feet and allowing boats greater access to the Creek (Dinan, 2016).
- ∅ On the north side of Greenleaf Avenue on property formerly owned by James Boyle, Trustee for 150 Greenleaf Avenue Realty Trust and now owned by the City of Portsmouth pursuant to an eminent domain action, an extensive natural wetland with evidence of a perennial stream has a well-documented history of disturbance (Map/Lot 0243-0067-0002) (West Environmental, 2007 & 2006; Rockingham County Conservation District, 2016; Trial Tr., Mark West, 1145:1-14; Trial Tr., Lenny Lord, 1227:18-1236:20, 1238:15-21, 1243:21-1247:22).

## Field Assessments

### Culvert Survey

Undersized culverts represent a “fast change” in alluvial stream systems by causing a constriction of flow through a straightened area; this barrier to the natural flow of water increases channel slope, flow velocity, and the capacity of the stream to transport material. Stream adjustments resulting from the destabilizing effects of undersized culverts include deposition upstream and erosion downstream that can ultimately damage the culverts themselves. The eroded material can potentially be transported and deposited further downstream where it may increase flooding risks as the channel fills in with sediment. The magnitude of these impacts from undersized culverts can vary depending on site-specific characteristics, such as the width of the floodplain, size of the culvert, height of the road grace above the structure, floodplain/riparian vegetation, substrate type (grain size), and channel gradient.

Undersized culverts not only impact stream geomorphology, but may also impact fish passage, flow, and infrastructure safety. Perched culverts created by downstream scour and erosion impede upstream fish migration to spawning habitat and/or thermal refugia. Undersized culverts may impound water immediately upstream during storm events, causing a delay in the timing, magnitude, and duration of peak flow. Material can also collect in and clog inlet culverts, which may then impound water even during low-flow conditions. Impounded water during storm events can inundate roads and damage infrastructure, causing risk to public safety and economic burden to local governments. Infrastructure is becoming particularly vulnerable to an increase in the frequency and intensity of storm events because of climate change. Increased flows will cause flooding and exacerbate already-poor conditions for ecological function and infrastructure safety.



Depiction of flow routes for Sagamore Creek and Elwyn Brook through culverts under Banfield Road and Peverly Hill Road.

During the 2017 watershed survey, FBE technical staff noted water flow from Elwyn Brook to the headwaters of Sagamore Creek as they converge under Banfield Road and Peverly Hill Road. The freshwater reach of Sagamore Creek begins in a forested wetland north of Banfield Road and west of Peverly Hill Road before passing through a ponded area with cattails and under Peverly Hill Road through a double concrete culvert. Elwyn Brook flows parallel to Banfield Road through a historic, one-acre impounded settling basin (used to wash and separate gravel from a former gravel pit) and into a series of two culverts that pass directly under the intersection of Banfield Road and Peverly Hill Road. Elwyn Brook flows to Sagamore Creek east of Peverly Hill Road.

The Rockingham Planning Commission (RPC) provided data on culvert surveys completed by the RPC in 2017 and NHDOT in 2014. Results are summarized as follows:

- NHDOT surveyed the culvert outlet from an unnamed drainage (AUID NHRIV600031001-21) that crosses under Wentworth Road to Witch Cove Marina. Overall condition was noted as good with no further details.
- RPC surveyed a culvert downstream of the one-acre impoundment on Elwyn Brook, adjacent to Banfield Road. No issues were reported with culvert condition.
- RPC surveyed a culvert that crosses under Peverly Hill Road where Elwyn Brook and Sagamore Creek join. Field observations noted evidence of significant channelization and failure of downstream bank armoring.
- RPC surveyed a culvert crossing under Sagamore Avenue. Field observations noted sediment issues that covered the culvert structure opening by one-quarter. A sharp bend in the drainage to the culvert may be contributing to bank sediment erosion.

### Tidal Shoreline Protection Structures Inventory

NHDES completed a Tidal Shoreline Protection Structures Inventory of the entire New Hampshire shoreline (NHDES, 2016b). The inventory identified, characterized, and rated engineered shoreline protection structures, such as retaining walls, riprap, jetties, berms, etc. The information helps to determine infrastructure most at risk from sea-level rise or storm surge, as well as identify infrastructure that may be causing habitat erosion or loss adjacent to the structure. Living shoreline approaches are encouraged as a more effective means of shoreline protection and storm impact mitigation.

About 1.3 miles of shoreline protection structures were identified in the Sagamore Creek watershed. Roughly 0.8 miles (60%) and 0.5 miles (40%) were classified as riprap/revetment and wall, respectively (Appendix 2, Map 13).

### Sanitary Survey

As required by the National Shellfish Sanitation Program, the NHDES Shellfish Program must conduct a sanitary survey of shellfish management areas, such as Sagamore Creek. The sanitary survey evaluates pollution sources that may contribute bacteria, pathogens, and other contamination sources to the Creek and pose a threat to shellfish consumption. These surveys, along with assessment of water quality, are used to make classification decisions. The last sanitary survey of Sagamore Creek was conducted in 2010 and summarized in the 2011 Triennial Report (NHDES, 2011). NHDES documented changes in land use (following review of new alteration of terrain or wetland permits) and evaluated possible pollution sites along the shoreline. Ninety-one (91) pollution sources were identified, several of which were also sampled for fecal coliform. Of the 91 sites, 30 were pipes, 17 were within the tidal creek, 14 were groundwater seeps, 6 were from perennial streams, 5 were foundation drains, 4 were stormwater outfalls, 3 were lobster tank discharges, 2 were floor drains, 2 were land runoff, 2 were marinas, 2 were road culverts, 1 was an intermittent stream, 1 was an inactive pipe, 1 was uncategorized, and 1 was a salt marsh panne. NHDES discontinued sanitary surveys of Sagamore Creek until the Pierce Island WWTF is upgraded to secondary treatment and the area's shellfish growing beds can be reassessed for classification status.

## Shoreline Survey

On November 7, 2017, FBE technical field staff, Laura Diemer and Jacqueline Boudreau, along with the Great Bay WaterKeeper, Melissa Paly, conducted a shoreline survey of Sagamore Creek from the outlet to just upstream of the crossing under Route 1 (Lafayette Road). The team paddled along the shoreline and documented visible pipes, outfalls, suspect land use activities, erosion, and areas with minimal buffer. Sites previously identified by the NHDES Shellfish Program were revisited and re-evaluated, whenever possible. Forty-five (45) sites were documented, georeferenced, and photographed (Table 18; Appendix 2, Map 14). Two (2) sites were brought to the attention of the City of Portsmouth Zoning Enforcement Department for proper handling.

Example of collapsing retaining wall, lack of shoreline buffer, and green lawn (top left), eroding bank and unknown pipe discharge (top right), improper dumping area (bottom left), and trash/debris on marsh (bottom right). Photos taken by FBE on 11/7/2017 during the shoreline survey of Sagamore Creek.

**Table 18.** Summary of possible pollution sources identified during the 2017 shoreline survey of Sagamore Creek.

| 2017 Shoreline Survey Site ID | NHDES Shellfish Program Site ID | City Outfall ID | Lack of Shoreline Vegetation / Runoff Potential | Infrastructure Flooding / Failure Potential | Erosion from Flooding, Storms, Overland Flow | Fertilizer Use Likely | BMP Remediation Needed | Unknown Drainage Pipe Source | Improper Yard Waste Disposal / Dumping | Trash/Debris on Incoming-Outgoing Tide | Under Construction | No Visible Issues | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | LHPS024; LHPS023; LHPS022 | | | X | X | | | | | | | | Collapsing retaining wall and walkway; Storage building close to shoreline edge - using stilts to support back of building; Drainage seep coming from parking area and road |
| 2 | | | | X | X | | | | | | | | Degrading retaining wall supporting deck; Home at shoreline edge |
| 3 | LHPS163 | 12504 | | | | | | | | | | X | 12" green circular PVC outfall; trickle flow |
| 4 | LHPS168 | | | | | | | | | | | X | Foundation drain |
| 5 | | 12442 | | | | | | | | | | X | Black apron PVC outfall; no flow; new from bridge construction |
| 6 | LHPS087 | | | | | | | | | | | X | 4' wide tidal drainage which emerges from wooded area into a phragmites stand; Drains from large parking area and other development near road |
| 7 | | | | | | | X | | | | X | | Sand, gravel, and loam staging area located at steep edge before Creek; New home construction; Gaps in coir log sediment traps observed |
| 8 | | | | | | X | | | | | | | Large, clustered homes near Creek; Green lawns |
| 9 | | | X | | | X | | | | | | | Homes with minimal buffer; Green lawns |
| 10 | | | X | X | | | | | | | | | Boat ramp with degrading asphalt and concrete extending into Creek |
| 11 | LHPS096 | 12502 | X | | X | X | | | | | | | Large home with minimal buffer, collapsing retaining wall, green lawn; Outfall no longer visible; possibly removed during new home construction in 2009-10 |
| 12 | | | X | | | X | | | X | | | | Large home with minimal buffer, green lawn, yard waste pile on Creek edge. |
| 13 | | | | X | | | | | | | | | Parking lot of restaurant abutting Creek edge regularly floods |
| 14 | | | X | | | | | | | | | | Back parking area of commercial building close to shoreline edge; Shoreline buffer cleared; Dumpster in lot |
| 15 | | | | | | | | | | X | | | Plastic barrels and other trash debris found throughout marsh system |
| 16 | | | | | | | | | | X | | | Large wooden dock washed up on marsh surface |
| 17 | | | | | | | | | | | | X | Old rock walls from historical farming in area |
| 18 | | | | | | | | X | | | | | 4" white metal straight pipe leading from parking area and dumpster of Elks Lodge |
| 19 | | | | | | | | | X | | | | Trash and debris dumping area directly to Creek, included concrete cinder blocks, bricks, plastic, styrofoam, screens, etc. |
| 20 | | | X | X | X | X | | | | | | | Collapsed retaining wall; Concrete debris entering Creek; Building close to shoreline edge; Green lawn. |
| 21 | | | | | | | | | | | | X | Small black foundation pipe |
| 22 | | | | | | | X | | | | | | Private carry-in/out access; evidence of erosion; using blanket and crushed stone to stabilize; could benefit from some BMP improvements |

| 2017 Shoreline Survey Site ID | NHDES Shellfish Program Site ID | City Outfall ID | Lack of Shoreline Vegetation / Runoff Potential | Infrastructure Flooding / Failure Potential | Erosion from Flooding, Storms, Overland Flow | Fertilizer Use Likely | BMP Remediation Needed | Unknown Drainage Pipe Source | Improper Yard Waste Disposal / Dumping | Trash/Debris on Incoming-Outgoing Tide | Under Construction | No Visible Issues | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | LHPS093 | 12588 | | | | | | | | | | X | DES indicated site as channelized drainage from subdivision (2007); 2017 investigation showed stormwater outfall (likely installed since 2007) |
| 24 | LHPS090 | | | X | | | | X | | | | | Commercial fishing/lobstering operation; concrete structure with AC units likely for refrigeration located at water's edge (potential for contamination if fails); Noted large pipe extending into water (source or purpose unknown) |
| 25 | LHPS094A | | | | | | | | | | | X | Water intake pipe |
| 26 | LHPS084 | | | | | | | | | | X | | Installing new foundation or roof drain piping |
| 27 | LHPS146 | | X | | | X | | | | | | | Foundation drain; minimal buffer; steep, green lawn |
| 28 | | | | | X | | | | | | | | Collapsing bank with evidence of recent erosion; some riprap at top of bank |
| 29 | LHPS081 | 12533 | | | | | | X | | | | | 15" CMP stormwater outfall with small green PVC pipe inside; no flow at time of observation; possible foundation drain upslope to right lined with riprap |
| 30 | LHPS082 | | X | | X | X | | | | | | | Foundation drain; evidence of recent planting and mulching to combat steep bank erosion; green lawn |
| 31 | LHPS083 | | | | | | | | | | | X | Drain line for water spicket used to empty line in the winter |
| 32 | | | | X | | | | | | | | | House situated at low elevation; flooding potential high |
| 33 | LHPS069; LHPS170 | | X | | | | | X | | | | | House with minimal buffer and green lawn next to perennial stream; riprap stream bank with foundation drain and possibly other drainage pipe |
| 34 | LHPS167 | | X | | | | | | | | | | Foundation drain; minimal buffer; irrigation system for garden |
| 35 | | | X | | | X | | | | | | | Large homes with minimal buffer, green lawns |
| 36 | | | X | | | | | | | | | | Minimal shoreline buffer; small garden and mowing/haying |
| 37 | | | | | | | | | | | X | | New home construction near shoreline; BMPs in place |
| 38 | | | X | | | | | | | | | | Creek Farm; minimal shoreline buffer, extensive lawn |
| 39 | LHPS129 | | X | | | | | | | | | | Multiple large homes with minimal shoreline buffer |
| 40 | LHPS158 | | X | | | | | | | | | | Foundation drain; home close to shoreline with minimal buffer; riprap banking |
| 41 | | | X | | X | | | | | | | | Steep banks lined with riprap; non-riprapped sections were severely eroding |
| 42 | | | X | | | | | | | | | | House close to shoreline with minimal buffer |
| 43 | | | X | | | | | | | | | | Minimal buffer between Creek and road |
| 44 | | | X | X | | | | | | | | | BG's Boathouse immediately adjacent to water; minimal buffer from parking lot to Creek; low elevation, potential for flooding |

| 2017 Shoreline Survey Site ID | NHDES Shellfish Program Site ID | City Outfall ID | Lack of Shoreline Vegetation / Runoff Potential | Infrastructure Flooding / Failure Potential | Erosion from Flooding, Storms, Overland Flow | Fertilizer Use Likely | BMP Remediation Needed | Unknown Drainage Pipe Source | Improper Yard Waste Disposal / Dumping | Trash/Debris on Incoming-Outgoing Tide | Under Construction | No Visible Issues | Description |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45 | | 12503 | | | | | | | | | X | | Stormwater outfall under construction at time of survey; drains parking lot and boat storage building at Witch Cove Marina |

## Watershed Survey

On November 1, 2017, FBE technical field staff, Margaret Burns and Richard Brereton, conducted a watershed survey of the Sagamore Creek watershed. Fifteen (15) sites were identified during the survey, ranging from unmarked restaurant grease drums or dumpsters on pervious surfaces (no secondary containment), unstable and eroding banks, minimal shoreline buffer or distance from shoreline to parking lots or buildings, and horse pastures (Appendix 2, Map 14, Table 19).

Culverts at Banfield Road and Peverly Hill Road were assessed and appeared in good condition. No vertical drop was apparent at any of the downstream ends of the culverts. The eastern bank of Peverly Hill Road just north of the culvert outlets for Sagamore Creek and Elwyn Brook was slumping and eroding into the Creek.

Three neighborhood surveys[6] were completed for the Sagamore Creek watershed, including the following:

- ∅ Elwyn Road neighborhood immediately south of Elwyn Road and east of Route 1: 50% impervious, 40% grass, 10% mulched beds, 0% bare soil, not close to Sagamore Creek
- ∅ Harborview Road neighborhood just north of the Wentworth-By-The-Sea golf course in Rye: 40% impervious, 40% grass, 20% mulched beds, 0% bare soil, and 15 ft from Sagamore Creek; house lots with frontage had minimal vegetated buffer and grass up to the shoreline
- ∅ Tidewatch neighborhood east of Jones Avenue and west of Route 1A: 50% impervious, 40% grass, 10% mulched beds, 0% bare soil, and 30 ft from Sagamore Creek; house lots with frontage had some vegetated buffer

All three neighborhoods appeared to have new homes (20-50 years old) that were in good condition with no yard waste, junk, or exposed soil observed.

[6] A neighborhood survey is a method of assessing neighborhoods for potential risk of nonpoint source pollution to surface waterbodies. FBE technical staff followed methods described in the Urban Watershed and Site Reconnaissance: A User's Manual (2004) published by the Center for Watershed Protection.


Examples of potential contamination sources identified during the 2017 watershed survey: unmarked drums outside restaurant on pervious surface (top left), seepage from unknown source identified along building foundation (top right), former scrap metal yard close to water resources (bottom left), and a horse farm on Peverly Hill Road (bottom right).

Table 19. Summary of possible pollutant sources noted during the 2017 watershed survey.

| Site ID | Observations |
|---|---|
| SC-01 | 3 55-gallon, unmarked drums next to dumpster on pavement, appear to be filled with used restaurant grease |
| SC-02 | Recent tree removal along West Road north of waterpark |
| SC-03 | 6 dumpsters not located on impervious surfaces; appears to be water leaking down concrete wall of building |
| SC-04 | Historic settling basin created by artificial impoundment for former gravel pit operation, grown in with cattails |
| SC-05 | Double culvert carries Sagamore Creek under Peverly Hill Road north of intersection with Banfield Road; single culvert carries Elwyn Brook under intersection, emerges alongside double culvert of Sagamore Creek, eroded slope of Peverly Hill Road slumping into Creek |
| SC-06 | Mowed field, no horses present, but paddock observed, 2016 aerials show at least three horses |
| SC-07 | Dinnerhorn parking lot drains to Sagamore Creek through pipe to the upstream left of Route 1 bridge, parking lot abuts Creek and regularly floods during high high tides |
| SC-08 | Dumpsters on pervious surfaces behind Lafayette Plaza Shopping Center |
| SC-09 | Tidewatch neighborhood survey |
| SC-10 | Lack of buffer to Creek from Elks Lodge and parking lot |
| SC-11 | Landfill closed to foot traffic, trail network accesses surrounding area for dog walkers, no pet waste noticed, but potential issue |
| SC-12 | Large paved lot, some scrap visible in organized piles, City staff noted iron-reducing bacteria in stormwater runoff from this site |
| SC-13 | Gravel parking lot and boat ramp, evidence of rills/gullies in lot, boats stored outdoors, site under active construction during shoreline survey one week later (to replace outfall) |
| SC-14 | Harborview neighborhood survey |
| SC-15 | Elwyn Road neighborhood survey |

### Contaminants Outside the Watershed

Because of the tidal nature of Sagamore Creek, contaminants from outside the watershed may also impact the water quality of the Creek. The Creek is within the Prohibited/Safety Zone of the Pierce Island WWTF's outfall. The facility will upgrade by December 2019 and reduce the risk of effluent contamination to Sagamore Creek in the event of a disinfection failure. A portion of Sagamore Creek also falls within the seasonal Safety Zone of the Wentworth-By-The-Sea Marina, a 170-slip private marina on the northern shore of Little Harbor in New Castle. The marina hosts a fuel station and sewage pump-out system that is tied into New Castle's sewer system. During the boating season from May to October, there is a high risk of overboard sewage discharge or fuel spill from these docking and service areas that could make its way to Sagamore Creek.

### Climate Change

Climate change will impact Sagamore Creek largely through sea-level rise. Sea-level rise will cause the inundation of upland areas, increase flood risk from coastal storm surge, and force groundwater tables to rise. According to estimates by a UNH research group (Knott et al., n.d.), approximately 9% of the City of Portsmouth will be inundated by 2100, with half directly attributable to sea-level rise and half due to the subsequent rise in groundwater levels. Inundation will threaten infrastructure as low-lying wastewater systems near the shoreline flood more frequently and possibly generate illicit discharges to surface waters. Undersized culverts will deteriorate and fail under pressure from larger and more frequent flood events.

The City's Coastal Resilience Initiative and the Rockingham Planning Commission have mapped the projected extent of inundation from sea-level rise in Portsmouth. These reports identified specific infrastructure in the Sagamore Creek watershed at risk of flooding: 1) the wastewater pumping station at 630 Lafayette Road, and 2) culverts at Route 1/Lafayette Road, Peverly Hill Road, and Wentworth Rd (City of Portsmouth, 2013; RPC, 2015). While the Wentworth Road crossing is just southeast of the Sagamore Creek outlet, it may impact tidal dynamics in the Creek.

Ecological communities will also be impacted by sea-level rise. Freshwater and coastal wetlands provide natural flood protection, wildlife habitat, and nutrient cycling, but only if those wetlands can migrate inland freely with a changing environment from sea-level rise. The Sagamore Creek watershed was identified as a prime area for tidal marsh to migrate inland and upland, potentially into areas that are currently occupied by freshwater wetland (RPC, 2015). Freshwater wetlands will also expand and/or deepen due to rising groundwater tables.

## Data Gap Analysis

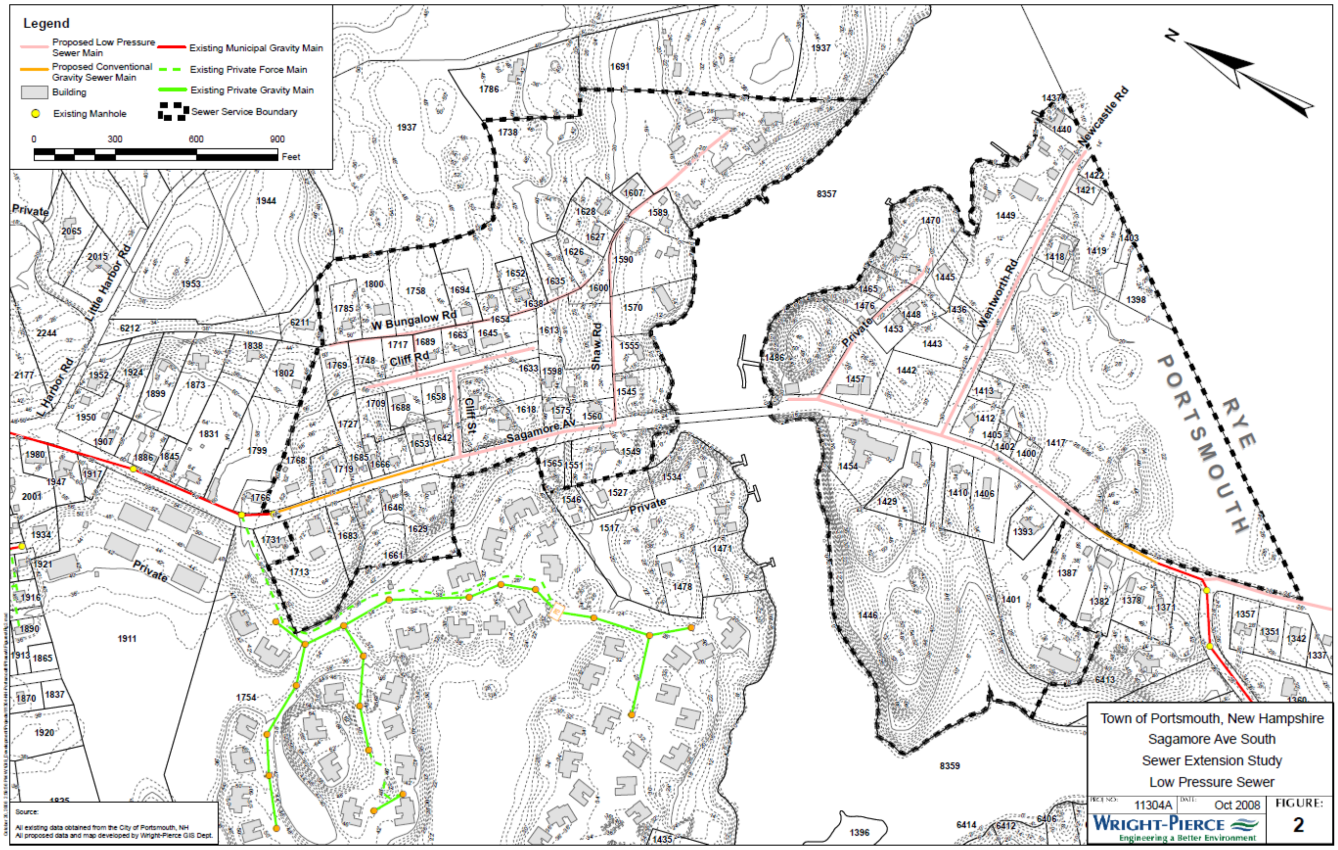
Review of all available information for Sagamore Creek revealed significant data gaps. Each of these data gaps were assessed carefully and incorporated to the monitoring program design to fill in those data gaps, allowing for a better understanding and characterization of the water quality and pollutant inputs to Sagamore Creek.

- Existing water quality data were largely fecal indicator bacteria collected by the NHDES Shellfish Program. Other water quality parameters (e.g., nutrients, organic matter, suspended sediments, fecal indicator bacteria DNA tracking) were limited in sample number and spatial coverage.
- Non-support status for shellfish consumption was based on contaminant exceedances in sediment samples collected in the upper Sagamore Creek estuary in 2000, 2004, and 2006, the last of which was over a decade ago. Resampling sediment over a greater spatial area is recommended.
- Data collected under different weather conditions and seasons across multiple years are needed to estimate average parameter loadings from the landscape.
- Lack of continuous logger data to help identify diel variations in key parameters at multiple sites.
- Lack of adequate tidal flux and other discharge data (from infrastructure and natural runoff) to help estimate volume and rate of waters moving into and out of Sagamore Creek. The 2012 dye study was relatively unclear as to the source of incoming water (which appeared to depend on depth and ebbing or flooding tide).
- Lack of baseline for climate change indicators.

# Anticipated Watershed Improvements

Sagamore Creek was selected largely because the City will be undertaking sewer system improvements and stormwater projects in the Sagamore Creek watershed over the next three to six years, as part of the Consent Decree. The City and other stakeholders have a unique opportunity to measure changes in water quality because of these infrastructure improvements. Examples of potential infrastructure improvements in the Sagamore Creek watershed are as follows:

- Restructuring of stormwater drainage along Peverly Hill Road with the installation of new sidewalks and multi-use paths that incorporate LID elements
- Conversion of land behind DPW property to municipal recreational/open space that incorporates LID elements
- Extension of the municipal sewer system along Sagamore Avenue (Route 1A) to areas with known failing septic systems. A low pressure municipal sewer line will be installed from Tidewatch Condominium to Cliff Road, Walker Bungalow Road, and Shaw Road on the north side of the Route 1A bridge, as well as from Odiorne Point Road to Wentworth Road and Sagamore Grove on the south side of the Route 1A bridge.




Map of proposed municipal sewer line extension along Route 1A (Sagamore Avenue).

# Preliminary Pollutant Load Modeling

Limited existing data prevented preliminary pollutant load modeling of Sagamore Creek. Implementation of the sampling plan over the next several years aims to build a robust baseline assessment of water quality for input to a model or series of models that simulate hydrologic and pollutant transport through the estuary. Significant time was spent researching and reviewing appropriate model options, which were presented to TAC members. Feedback from TAC members allowed for further refinement of possible model options, described as follows:

- Better Assessment Science Integrating Point & Nonpoint Sources (BASINS) is a GIS-based model that integrates environmental characteristics (e.g., soils, land cover, hydrography, etc.) for use in other plug-in models to simulate water flow and pollutant routing from defined sub-areas in the watershed. Plug-in options include WASP and/or AQUATOX, which utilize similar algorithms, but AQUATOX can also perform ecological risk assessments and has a better biological effects component. Both can be used for estuarine applications and incorporate sensitivity analyses.
    - Water Quality Analysis Simulation Program (WASP) is a dynamic, multi-dimensional model that simulates the transport and fate of various pollutants, including nitrogen phosphorus, organic chemicals, metals, and pathogens, and estimates their impact on a limited number of biological response indicators.

- AQUATOX is an ecological risk assessment model that simulates the fate and effects of pollutant loads to/from the water, sediments, and biota, including fish, invertebrates, and aquatic plants.

A watershed survey was completed for this project, but follow-up surveys of "hotspot" drainages identified during sampling efforts may be completed for development of a watershed management plan for Sagamore Creek. For those identified NPS sites, recommendations for best management practice (BMP) implementation will be made and estimates of pollutant reductions associated with each proposed BMP will be completed. In accordance with recommendations from the 2017 New Hampshire Small MS4 General Permit and the Great Bay Pollution Tracking and Accounting Pilot Project (PTAPP), EPA Region 1 BMP performance curves will be used to track and account for structural BMP performance. Methods are detailed in Appendix F of the 2017 New Hampshire Small MS4 General Permit. For gully and streambank stabilization projects that are not well accounted for in performance curves, use of the EPA Region 5 model is accepted.

Other useful stormwater modeling tools for the City to consider include:

- ∅ Storm Water Management Model (SWMM): a watershed hydrological transport model that simulates water quantity and quality through stormwater drainage networks.
- ∅ SUSTAIN: integrates hydraulics and pollutant loading from SWMM to aid in management decisions regarding stormwater flow and pollutant controls at the watershed scale.

# Conclusion & Next Steps

With guidance from the Technical Advisory Committee, a Water Quality Sampling Program was developed for the Sagamore Creek watershed based on information gained from the watershed characterization, water quality analysis, pollutant source input identification, and data gap analysis. A descriptive summary of the program is provided in Appendix 4. A detailed quality assurance project plan (QAPP) for the program is provided in Appendix 5.

The program addresses identified data gaps and details protocols for consistent, reliable data collection that can be used in statistical analysis and modeling to better understand the water quality of Sagamore Creek. The program seeks to achieve the following objectives with new data collection:

1) Perform statistical analysis and modeling for overall water quality understanding,
2) Apply state and federal water quality criteria for status determination,
3) Quantify of the type, amount, and location of pollutant sources to the Creek for follow-up investigation and remediation, and
4) Assess water quality following watershed improvements.

The Water Quality Sampling Program was divided into several major components that strategically build on the achievements of each successive year (see Appendix 4, Table A4-1). We will build a robust baseline dataset in the first two years to better inform the development of a watershed management plan for Sagamore Creek. Later investigative water quality sampling will target polluted sites identified during the baseline monitoring. Following development and approval of a watershed management plan, the City will then become eligible for federal grant funds to help cover implementation costs for remediation of identified polluted sites. The Water Quality Sampling Program was designed with the intent to provide a long-term management strategy for Sagamore Creek, beyond the scope of funded work generated by the Consent Decree.

# References

Adams, N. (1825) Annals of Portsmouth. Portsmouth, NH. pp. 9-390.

Brewster, C.W. (2000) Brewster's Rambles About Portsmouth #42: Many Residents of Sagamore Creek". Seacoast NH. Online at: http://www.seacoastnh.com/brewster/42.html

City of Portsmouth. (2013) Coastal Resilience Initiative: Climate Change Vulnerability Assessment and Adaptation Plan. Online: http://www.planportsmouth.com/cri/CRI-Report.pdf

Climate Change in the Piscataqua/Great Bay Region: Past, Present, and Future, Wake, C., E. Burkowski, E. Kelsey, K.Hayhoe, A.Stoner, C. Watson, E. Douglas, Earth Systems Research Center, University of New Hampshire (2011) available online by Carbon Solutions New England at http://www.carbonsolutionsne.org/.

Dinan, E. (2016) Boaters to benefit from dredging in Portsmouth's Sagamore Creek. Seacoast Online. Online at: http://www.seacoastonline.com/news/20161129/boaters-to-benefit-from-dredging-in-portsmouths-sagamore-creek

FB Environmental Associates. (2013). Bacteria Source Tracking and Canine Detection: North Mill Pond, Sagamore Creek, Colonial Drive, and Other Locations. Prepared for the City of Portsmouth.

Field, J.J. (2007) The recreation of meanders along artificially straightened stream channels. Geological Society of America Abstracts with Programs, v. 39, p. 243.

Goldthwait, J.W., Goldthwait, L., & Goldthwait, R.P. (1951). The Geology of New Hampshire. Part I: Surficial Geology. Concord, NH: State of New Hampshire State Planning and Development Commission.

Hoyle, Tanner & Associates, Inc. (2007) Jones Avenue Landfill Status Update Report. Prepared for the City of Portsmouth.

HydroQual. (2013) Calibration of Great Bay Estuary Hydrodynamic Model and Incremental Nitrogen Estimation. Technical Memorandum: File 337-200951-007. Prepared for the City of Portsmouth.

Jones, S. & Landry, N. (2004) Tracking Bacterial Pollution in Little Harbor and New Hampshire Atlantic Coast Tributaries.

Knott, J.F., Jacobs, J.M., Daniel, J.S., Kirshen, P. (n.d.) Modeling the effects of sea-level rise on groundwater levels in coastal New Hampshire. Online: https://www.unh.edu/erg/sites/www.unh.edu.erg/files/modeling_the_effects_of_sea-level_rise_on_groundwater_levels_in_coastal_nh.pdf

New Hampshire Department of Environmental Services (NHDES). (2006) TMDL Study for Bacteria in Little Harbor, NH. NHDES-R-WD-05-25.

New Hampshire Department of Environmental Services (NHDES). (2011) 2008-2010 Triennial Shellfish Management Area Update for Little Harbor/Back Channel, New Hampshire. Prepared by Chris Nash, DES Shellfish Program Manager.

New Hampshire Department of Environmental Services (NHDES). (2016a) DRAFT 2016 Section 305(b) and 303(d) Consolidated Assessment & Listing Methodology. R-WD-17-08, November 20, 2017. Online at: https://www.des.nh.gov/organization/divisions/water/wmb/swqa/2016/documents/r-wd-17-08.pdf

New Hampshire Department of Environmental Services (NHDES). (2016b) New Hampshire Inventory of Tidal Shoreline Protection Structures. Online at: https://www.des.nh.gov/organization/commissioner/pip/publications/documents/r-wd-16-09.pdf

New Hampshire Office of Energy and Planning (NHOEP). (2011). Historical census data for New Hampshire from 1767 to 2010. Retrieved from: http://www.nh.gov/oep/data-center/historical-census.htm

Northeast Regional Climate Center (NRCC) & Natural Resources Conservation Service (NRCS). (2018). Extreme precipitation in New York and New England: An Interactive Web Tool for Extreme Precipitation Analysis. Online at: http://precip.eas.cornell.edu/

O'Geen, A., Elkins, R., & Lewis, D. (2006). Erodibility of Agricultural Soils, With Examples in Lake and Mendocino Counties. Oakland, CA: Division of Agriculture and Natural Resources, University of California.

Piscataqua Region Estuaries Partnership (PREP). (2012) Final Environmental Data Report December 2012: Technical Support Document for the 2013 State of Our Estuaries Report. PREP Publications, 265. Online at: http://scholars.unh.edu/prep/265

Ransom Consulting. (2016) Sample Collection and Analysis (Fall 2016) Data Submittal, Jones Avenue Landfill and Ash Containment. Prepared for the City of Portsmouth for the NH Department of Environmental Services.

Rockingham County Conservation District. (2016) Wetland Analysis: 150 Greenleaf Avenue, Portsmouth, NH, Tax map 243, lot 67. Prepared for the City of Portsmouth.

Rockingham Planning Commission (RPC). (2015) City of Portsmouth, New Hampshire Vulnerability Assessment of projected sea-level rise and coastal storm surge flooding. TIDES TO STORMS: Preparing for New Hampshire's Future Coast, Assessing risk and vulnerability of coastal communiteis to sea-level rise and storm surge. Online: http://www.rpc-nh.org/application/files/9314/6920/2321/Portsmouth_Vulnerability_Assessment.pdf

Society for the Protection of New Hampshire Forests. (n.d.) Creek Farm. Online at: https://forestsociety.org/property/creek-farm

The Thoresen Group. (1983) State Coastal Properties Project: Part V Wentworth-Coolidge Property. Highland House Histories and Research Services. pp. 6-43.

The Trust for Public Land. (2016) Sagamore Creek Headlands. Online at: https://www.tpl.org/our-work/sagamore-creek-headlands#sm.0001dxhl73eg1dckw0w2rew0ene2u

US EPA (2015). BASINS 4.1 (Better Assessment Science Integrating point & Non-point Sources) Modeling Framework. National Exposure Research Laboratory, RTP, North Carolina. Online at: https://www.epa.gov/exposure-assessment-models/basins.

United States Food & Drug Administration. (2012) Hydrographic Study of Pierce Island Wastewater Treatment Plant Effluent in the Piscataqua River of Portsmouth, NH.

West Environmental. (2006) Portsmouth Toyota site, 150 Greenleaf Ave. Prepared for the City of Portsmouth.

West Environmental. (2007) City of Portsmouth vs. James Boyle, Trustee, 150 Greenleaf Ave Realty Trust Historic Aerial Photo Interpretation. Prepared for the City of Portsmouth.

West Environmental. (2017) Addendum to PULA Report. Prepared for the City of Portsmouth.

Woodard & Curran. (2017) Sewer System Evaluation Survey (SSES) Infiltration Study. Draft Report, Vols. I-II, to the City of Portsmouth, October 2017.

# A1. Notes & Justification

The following provides a summary of information gained from TAC members or external contacts in an applicable field to help guide rationale or justification for chosen components of the water quality sampling program.

### Steve Jones coordinates the Gulf Watch program that analyzes contaminants in shellfish tissue along the NH Coast. Unsure whether any sites in Sagamore Creek were sampled or could be sampled in the future.

The Gulfwatch Contaminant Monitoring Program, which is administered by the Gulf of Maine Council on the Marine Environment, has run analyses of blue mussel tissue since 1991, but never in Sagamore Creek. The closest sampling station to Sagamore Creek would be Little Harbor; the station is located on the harbor side of Jaffrey Point. Since they have found differences in contaminant levels in mussels even between sampling locations at sampling stations, using Little Harbor data for Sagamore Creek is not recommended. Funding for the Gulf Watch program is becoming problematic. Many 2017 samples are being archived until funding becomes available in the future for analyses. Steve plans to sample again in 2018, but these samples again may be archived. Funding would need to come from the City to add Sagamore Creek to the program and run analyses of the tissue samples. The program has a set protocol and QAPP that we could reference and use for the monitoring plan. The current program focuses on legacy contaminants, but recent analyses included emerging contaminants that expand the existing list of analyzed PAHs, PCBs, and metals to also include pesticides, pharmaceuticals, and pfos/pfoa, among others. NHDES expressed concern about the increasing difficulty in finding enough mussels for tissue analysis. The cause of this scarcity is unknown (suggested green crab predation), but this could make sampling in Sagamore Creek a challenge. An alternative method would be to deploy strings of mussels for a period of time that would allow for accumulation of toxins in the tissue. Because the NHDES Shellfish Program already conducts some shellfish tissue analysis in the area (and could target Sagamore Creek in the coming years with the advent of the treatment plant upgrade) and because of the challenge of collecting and interpreting tissue data, we decided this component of the sampling plan was low priority.

### A water level logger is deployed near the Elks Lodge and is maintained by a teacher at the Portsmouth High School. Unsure of its status.

Deirdre Barrett is a science teacher at Portsmouth High School that currently has a Vernier Logger Pro deployed in protective PVC housing that is attached to a dock piling at the Elks Lodge. The logger was surveyed in to a baseline elevation. It has been deployed since spring 2017 and has been downloaded a couple times. She is more than happy to share the data. These data can be used to help inform tidal dynamics in the estuary.

### The Great Bay Municipal Coalition has several data sondes. Unsure of their availability for this project.

Tom Gregory at the UNH Ocean Process Analysis Laboratory currently deploys, maintains, and stores these sondes. There are two Eureka Manta2 sondes in his possession that are owned by the Coalition. Three were purchased several years ago (circa 2011), but one failed catastrophically a couple of years ago. Concerns regarding these sondes are valid, and mostly relate to the effects of biofouling on individual Manta2 sensors. Most of the sensors on these sondes do not have any of the biofouling mitigation technologies that newer sondes employ. That said, the Manta2 sondes do work well when they are clean. There are newer YSI EXO2 sondes that include Total Algae and fDOM probes that were purchased in the last 18 months with funding from both the State of NH and NOAA. These have strengthened the fleet of existing EXO2, YSI 6600, and other Manta2 sondes. He does not foresee that these will be available for use in Sagamore Creek in 2018, but we could check their availability for 2019.

FBE obtained a quote from Onset for the City's direct purchase of HOBO loggers, amounting to roughly $11,000 to monitor 5 sites for temperature, dissolved oxygen, conductivity, and water level. By purchasing the loggers, the City would be able to deploy the loggers longer and use them for other projects in the future. TAC members were deterred by the high cost of logger deployment and maintenance and wanted to see a reduction in scope for data sonde use in the sampling plan.

FBE obtained a discounted quote from US Environmental for renting two multi-parameter sondes measuring temperature, dissolved oxygen, conductivity, water level, pH, and turbidity for 2-3 months per year (spring and late summer). Quoted at $700/month per sonde. This cost could be reduced further by using FBE's YSI sonde, EPA's short-term loan sonde (need to contact Tim Bridges or Jeannie Brochi), or the Coalition's sonde.

A suggested alternative approach would deploy YSI 556A handheld meters for 3-day deployments (that could be borrowed from UNH or other organizations). This would be very labor intensive for the benefit of minimal data.

### Unsure of existing data on bathymetry and tidal/current information for Sagamore Creek.

A hydrodynamic model was developed for the area, including Sagamore Creek. The data may include bathymetry and tidal/current information. The City will establish contact between FBE and the original modeler to obtain information and help inform further load modeling of Sagamore Creek.

Larry Mayer at the Center for Coastal & Ocean Mapping/Joint Hydrographic Center at UNH was unsure of available datasets for Sagamore Creek, so he forwarded our request to his colleagues. We were directed to the NGDC bathymetric data viewer (https://maps.ngdc.noaa.gov/viewers/bathymetry/) and the NOAA USGS LiDAR data (https://www.coast.noaa.gov/dataviewer/#/lidar/search/-7880848.708772385,5316940.578259788,-7871064.769151882,5322864.44795189), but neither sources had bathymetric data for Sagamore Creek. FBE received a response from Shachak Peeri at NOAA who directed us to https://coast.noaa.gov/digitalcoast/data/, which had topobathy for New England states, but not so far into Sagamore Creek. Paul Johnson also responded that no LIDAR and multibeam (http://bit.ly/2ExKMPi) data exist for Sagamore Creek, but data may be available here: https://viewer.nationalmap.gov/basic/?basemap=b1&category=ned,nedsrc&title=3DEP%20View#productSearch. We found some topobathy files that go down to -2.1 meters in the Creek. These files could be converted from tiff files to a bathy shapefile for further modeling.

**DES suggested adding total nitrogen (to include both dissolved and particulate forms) to the parameter list. Bill suggested that we run the components of TN and not TN directly for more accurate results.**

FBE contacted UNH WQAL for the analysis details and costs. They would run TSS and combust the filter for N (and C). This would be covered under CHN – Carbon and Nitrogen on solids ($20 per sample for the first 20 samples, then $12 per sample for 21+ samples).

**Chloride and *E. coli* could be run by Jesse Pearce through the City water treatment facility. DES did not have a problem with the data method accuracy and it may provide cost savings for the program.**

FBE contacted Jesse Pearce for more specifics on protocols and costs. The City would use the 24-hr Colilert with Quanti-Tray/2000 method for analyzing *E. coli* and Chloride test strips for analyzing chloride in freshwater sites. Going through the City instead of an accredited laboratory for these parameters could save about $1,700. DES confirmed that these methods would be acceptable to them for assessment purposes.

**Submerged Aquatic Vegetation (SAV) or eelgrass extent may be an important parameter to track in Sagamore Creek. Unsure of existing efforts and/or data.**

Fred Short at UNH leads the eelgrass monitoring program hosted by SeagrassNET. SeagrassNet teams, composed of scientists and managers from participating countries, conduct synchronous quarterly sampling of selected plant and environmental parameters to determine seagrass habitat status and trends. Fred has been monitoring eelgrass in Sagamore Creek annually since 1996. He maps low level aerial photography each year, together with low tide ground truth surveys every other year (to verify aerial results, determine max depths of beds, and ensure eelgrass is present). Data posted online is aggregated and labelled as Portsmouth Harbor. The City of Portsmouth has already put in a FOIA request to Fred Short to get raw data on Sagamore Creek and other Portsmouth areas tracked as part of the program. This request has gone unfulfilled for the last year. It is assumed that this information is not available for this project's purpose, other than what is made publicly-available online.

Fred Short used to be PREP's contractor for eelgrass/SAV monitoring, but PREP has since switched to using Seth Barker. Under the new protocol, eelgrass density is no longer calculated/estimated. The area of Great Bay, Portsmouth Harbor, and the Piscataqua River are surveyed annually for eelgrass presence/absence. Surveying includes a combination of aerial photography and field checks by boat. The 2017 aerial photography covered Sagamore Creek and the entire area was included in the review and screen digitizing for reporting. Only eelgrass beds with >10% coverage within 100 square meters are mapped and field checked. Several patches of eelgrass are located at the mouth of Sagamore Creek, but none were identified via aerial photography in the Creek itself, so the Creek was not visited by boat. If there are any eelgrass patches within Sagamore Creek, they may be too small or patchy to easily track and monitor. Because of the lack of historic eelgrass beds in Sagamore Creek and the existing effort in mapping beds by PREP, we marked SAV as a low priority parameter to include in the sampling plan.

Consider adding invasive species tracking and mapping (e.g., Phragmites extent).

David Burdick (Interim Director of the Jackson Estuarine Lab and Associate Research Professor at UNH) was not aware of any existing vegetation mapping in Sagamore Creek (other than what is available at coarser resolutions from larger databases, such as through the NH Wildlife Action Plan). He recommended that a botanist (Greg Moore) complete a floristic survey (three visits) of the salt marsh to identify invasive, rare, and endangered plant species. We could also do contour plots of salinity gradients using an electromagnetic induction tool to determine the possible extent of plant invasion (e.g., Phragmites). Plant surveys were marked as low priority for project funds but high priority for volunteer efforts.

The City of Portsmouth's Coastal Resiliency Plan used several sites (possibly in Sagamore Creek) to assess salt marsh migration. David Burdick was part of this plan development and studies salt marsh vegetation, migration, and accretion in the area (though not Sagamore Creek currently). DOT also collected marsh surface elevation and other data for some stormwater work. Check the availability of this data; may re-use sites for climate change baseline monitoring.

David Burdick (Interim Director of the Jackson Estuarine Lab and Associate Research Professor at UNH) was not aware of any other Sagamore Creek marsh monitoring data. He recommended that we establish 6-8 transects (extending from low to high marsh) throughout the salt marsh system, above and below Route 1, following NERR protocols. This would include plots at the creek and upland (upland plot may be larger to accommodate greater diversity in upland plant species - possibly 5x20m, to include trees and a tree health index). The transects would need to be surveyed in for X, Y, and Z (elevation) coordinates. Since the RTK system is plus or minus 2 cm, it is not always reliable, especially when considering disturbance to the field site (walking along the transect can cause compaction). Placement of points along the transect should consider ecotones, so that two plots are positioned above and below a critical transition (low to high marsh and high marsh to upland). In addition to RTK-elevation data, he recommends establishing 6 surface elevation tables (SET) in the high marsh (near the low-high marsh transition) that are permanently established in the bedrock and measure salt marsh height using specialized equipment (one-time cost of $2,500). This should be measured at each SET 3 times per year for 3 years to get a baseline. Subcontracting Greg Moore to complete RTK data collection and floristic surveys and David Burdick to complete SET and training would cost around $20,000.

Kevin Nyhan at DOT provided follow-up monitoring reports for 2014, 2015, and 2017, as well as the 2013 field monitoring protocol used to define their monitoring program. Immediately following construction of the drainage ditch through the salt marsh to the east of Lafayette Rd, DOT conducted spring 2013 monitoring of vegetation and water quality to establish a baseline against which to compare subsequent years' data. The monitoring protocol was then followed in 2014, 2015, and 2017. The vegetation monitoring consisted of transects of 1-m plots inside which vegetation was identified. The primary goal was to track the rare plant Salt Marsh Gerardia (*Agalinus maritima*) and the invasive common reed *Phragmites*.

It was determined that establishing a climate change baseline for Sagamore Creek is an important action that the City may pursue, but under a different funding mechanism.

### There may be opportunity to complete fish and macroinvertebrate assessments through NHDES.

FBE contacted Andy Chapman at DES to determine if Sagamore Creek is on the DES rotation for bioassessments. There are no estuarine bioassessment protocols that DES conducts. Sagamore Creek is up for synoptic sampling in 2019; this sampling is flexible and driven by local concerns or known impairments. The freshwater sections of Sagamore Creek are too small and likely dry up in summer, so the streams have never been monitored for macroinvertebrates or fish. This could be reassessed this summer if water levels are observed to be high enough. DES would also deploy temperature loggers and collect information on chemical/physical parameters. There is an opportunity for teaming up with DES on this for 2019. If a national-level biomonitoring protocol for estuaries is found, DES would consider helping us design and conduct the sampling. He recommended to contact Alison Watts at UNH who is working on an eDNA project that identifies fish/plant DNA in water samples for presence/absence. FBE contacted Alison Watts. She is working to develop methodology for use of eDNA in estuaries. The method is currently being used in the central US to track extent of carp. DNA is extracted from water samples for species-level identification. It is currently not ready for full implementation yet. They are still in research mode but would be interested in adding Sagamore Creek as a test site if adequate biological data are collected to compare DNA results to. Completing these biological assessments was marked as low priority for project funds but high priority for volunteer efforts.

### We could also consider instating citizen science monitoring.

Melissa Paly currently heads the NH Volunteer River Assessment Program that has regularly monitored three sites along Sagamore Creek for a few years. This program taps into a motivated group of volunteers, whose time may be redirected to other monitoring efforts such as bird surveys, plant surveys, and fish/macro assessments with DES (based on Volunteer Biological Assessment Program protocols).

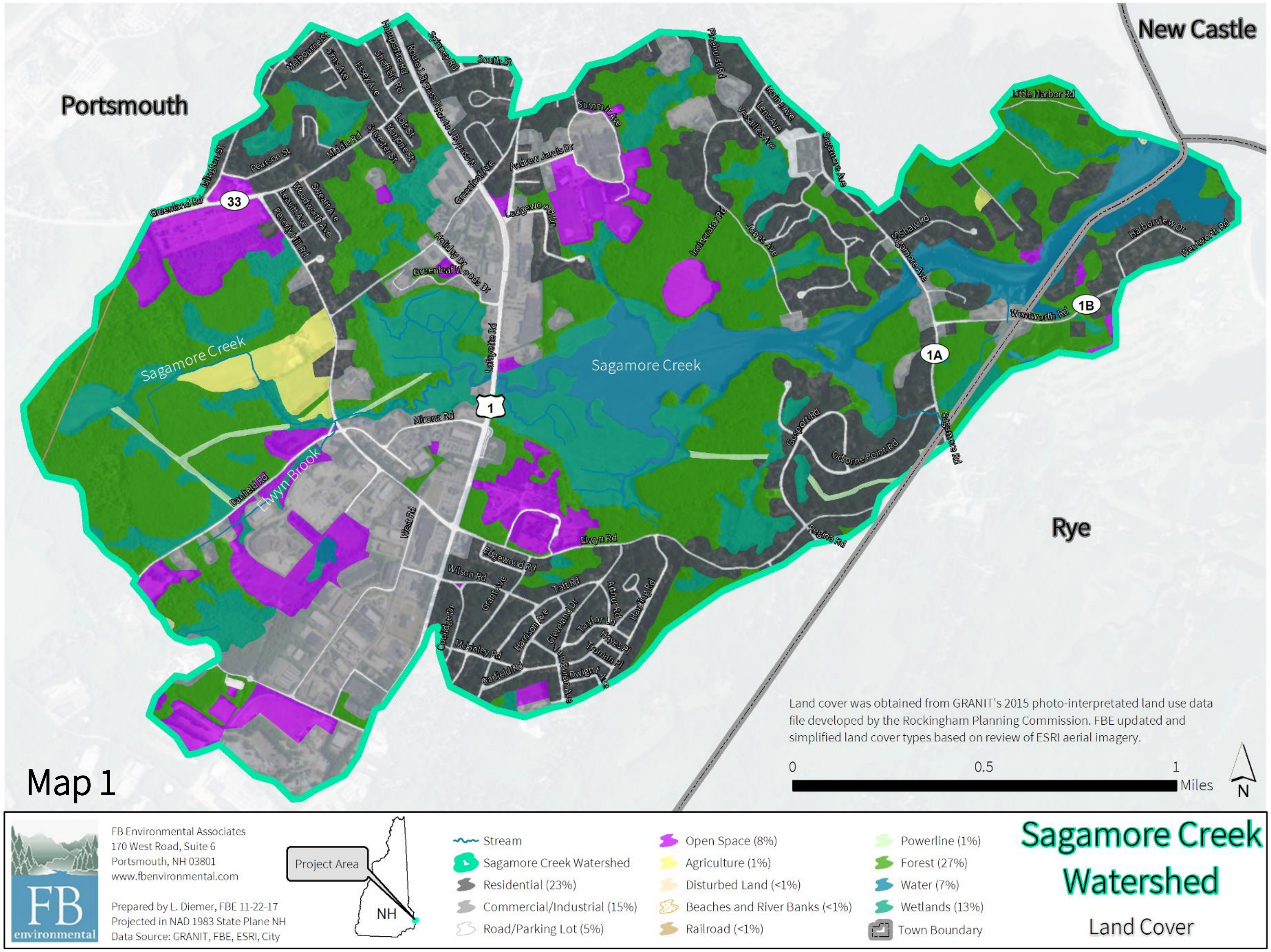
Wading bird or other bird census counts may be beneficial to track. Pam Hunt from Audubon would be the most knowledgeable on existing bird data for Sagamore Creek.

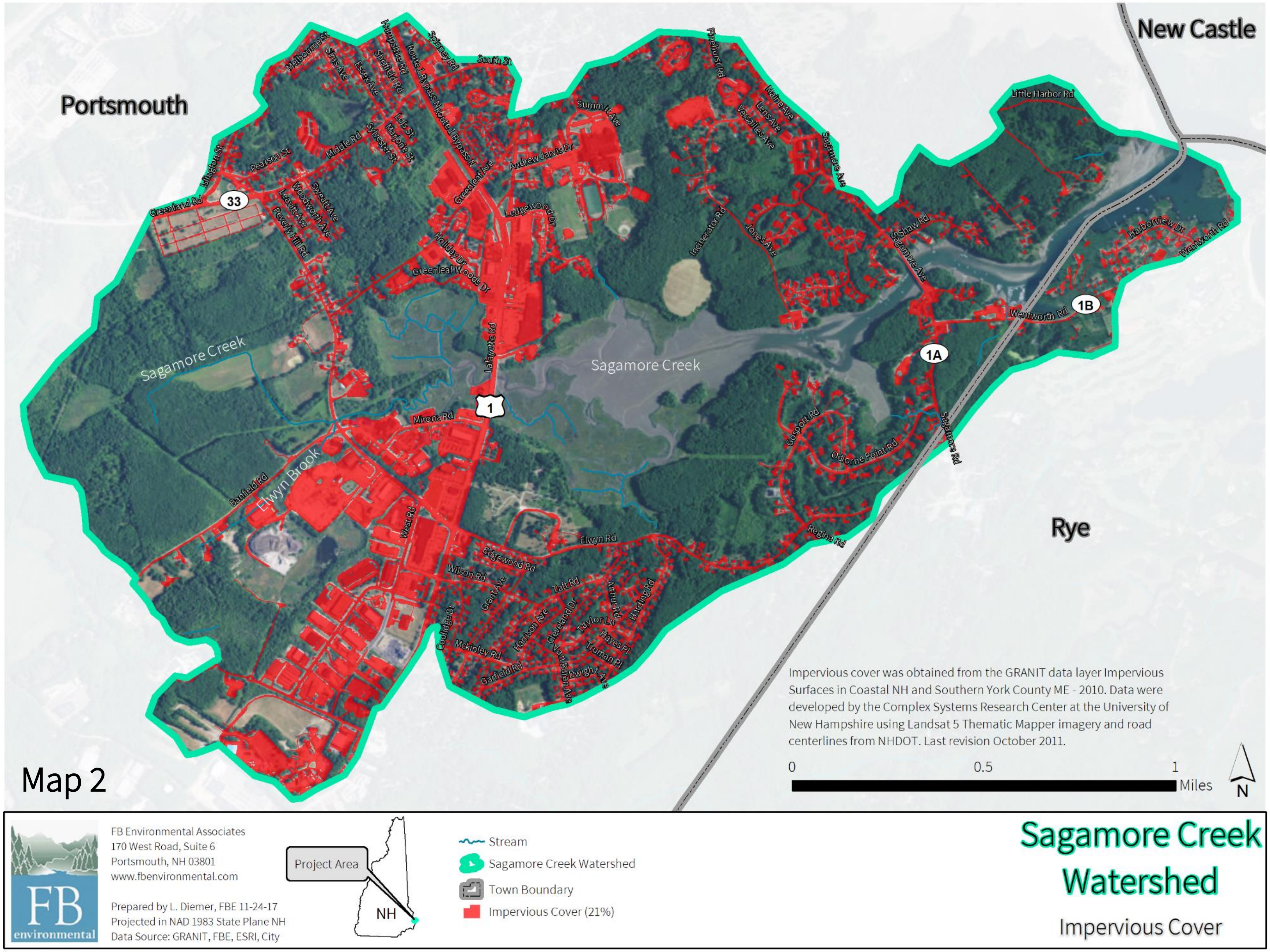
Pam Hunt from Audubon was not aware of any targeted bird survey efforts for the Sagamore Creek area. There were 1-2 point counts there for saltmarsh birds back in the early 2000s, but otherwise any data from the area would be incidental. Though there may be data available through the Urban Forestry Center and eBird, an online database managed by Cornell. The early 2000s saltmarsh surveys (conducted by a UNH graduate student working under Dr. Kimberly Babbitt) did find both Nelson's and Saltmarsh Sparrows in the area, presumably in the larger marsh area below Route 1. Both are considered "Special Concern" by NH Fish and Game and are considered highly vulnerable to sea level rise. A bird survey was marked as low priority but could easily be picked up by local volunteers.

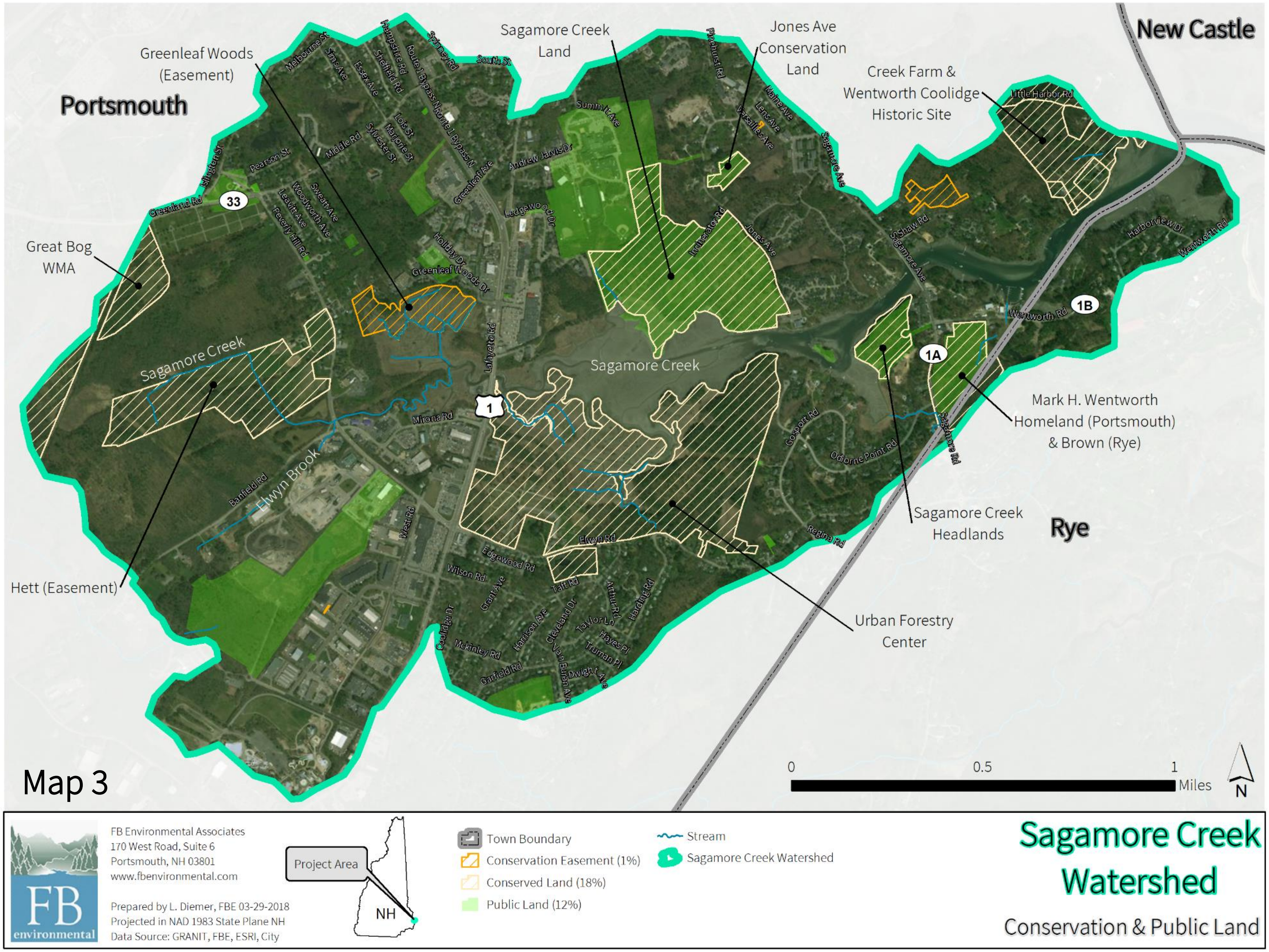
DES typically outsources sediment sampling in estuaries. Steve Jones has completed sediment sampling and analysis for DES before. Unsure of protocols and costs.

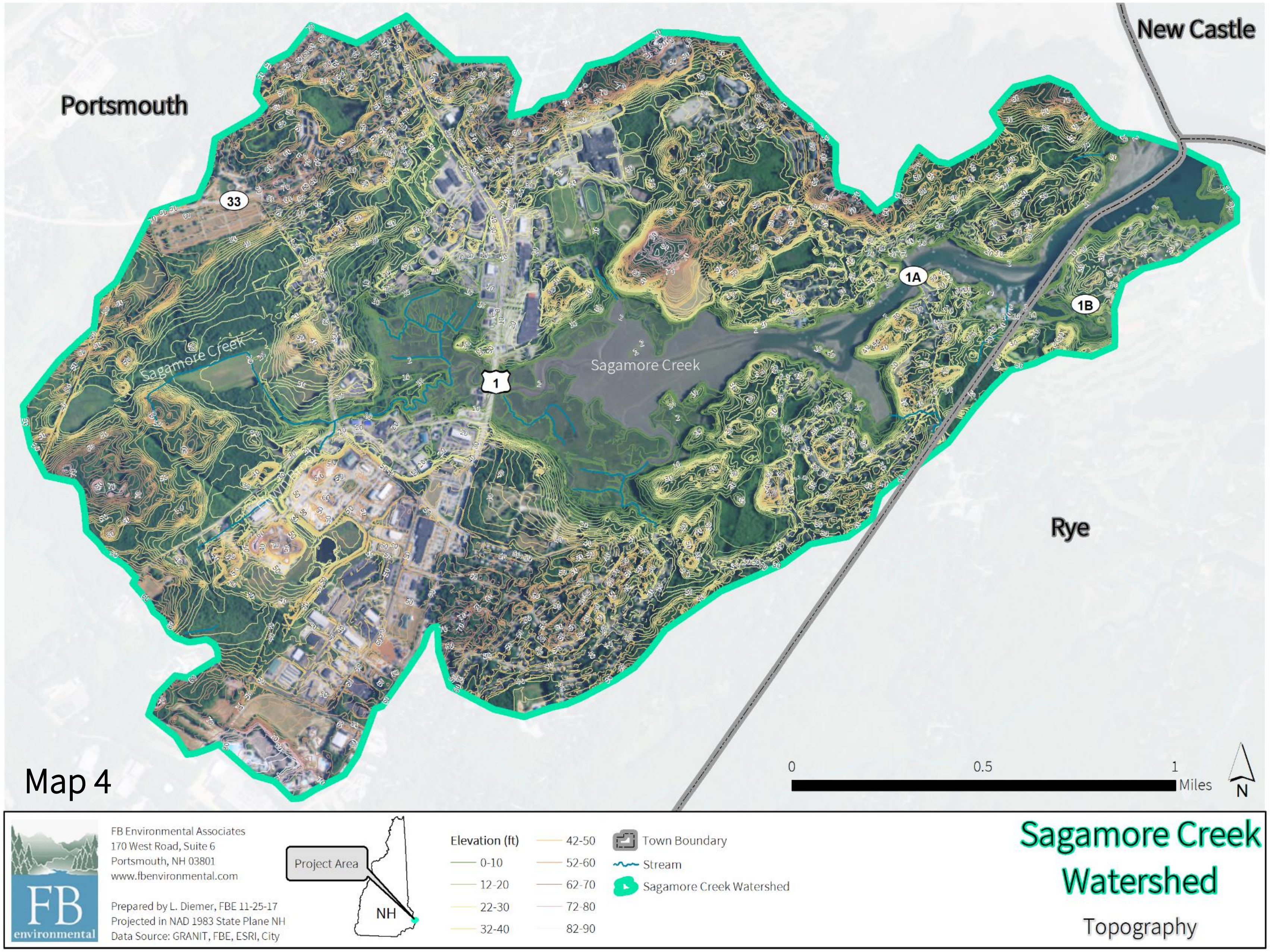
Sediment analyses was part of the National Coastal Condition Assessment Program, whose QAPP is an excellent reference for the monitoring plan. Steve recommends sampling 2-3 locations throughout the Creek for a variety of chemical, toxic, biological, and physical parameters. Because much of the existing impairment was based on historic sediment sample data, we marked repeated sediment sampling as high priority for re-assessing the Creek's impairment status.

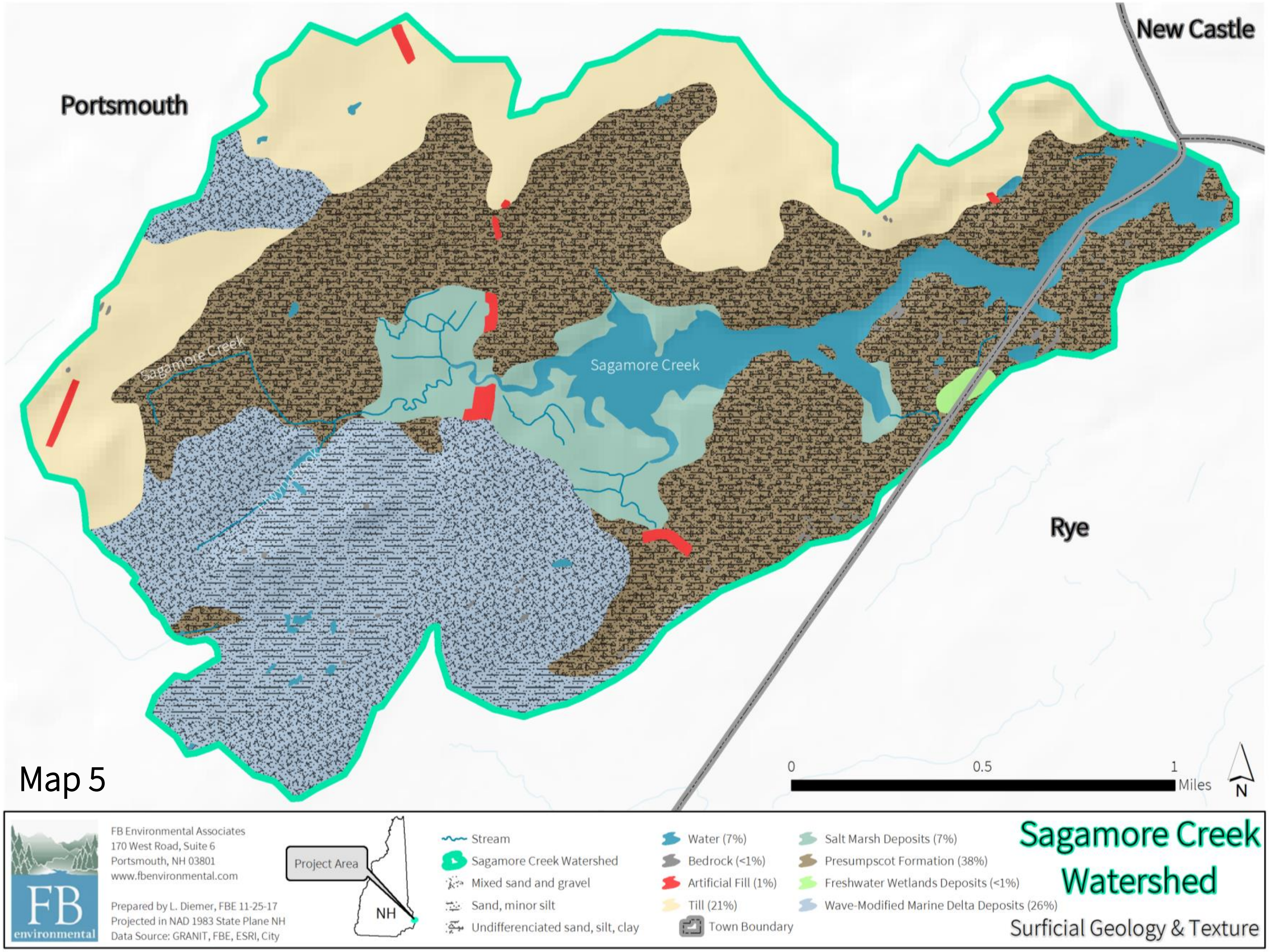
# A2. Maps

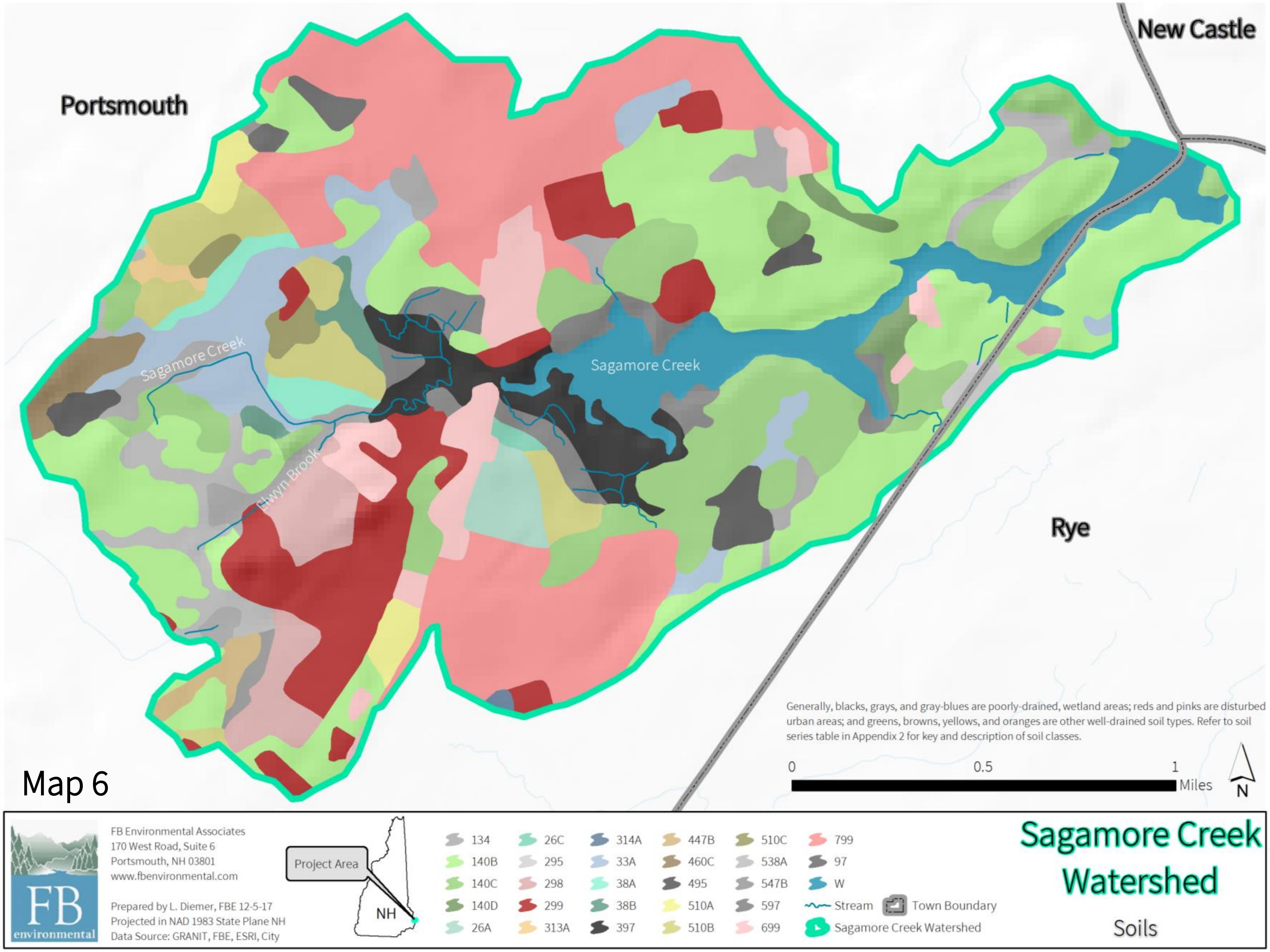

New Castle
Portsmouth
Rye
Sagamore Creek
Sagamore Creek
Elwyn Brook
Land cover was obtained from GRANIT's 2015 photo-interpretated land use data file developed by the Rockingham Planning Commission. FBE updated and simplified land cover types based on review of ESRI aerial imagery.
0
0.5
1
Miles
N
Map 1
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 11-22-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Stream
Sagamore Creek Watershed
Residential (23%)
Commercial/Industrial (15%)
Road/Parking Lot (5%)
Open Space (8%)
Agriculture (1%)
Disturbed Land (<1%)
Beaches and River Banks (<1%)
Railroad (<1%)
Powerline (1%)
Forest (27%)
Water (7%)
Wetlands (13%)
Town Boundary
Sagamore Creek Watershed
Land Cover

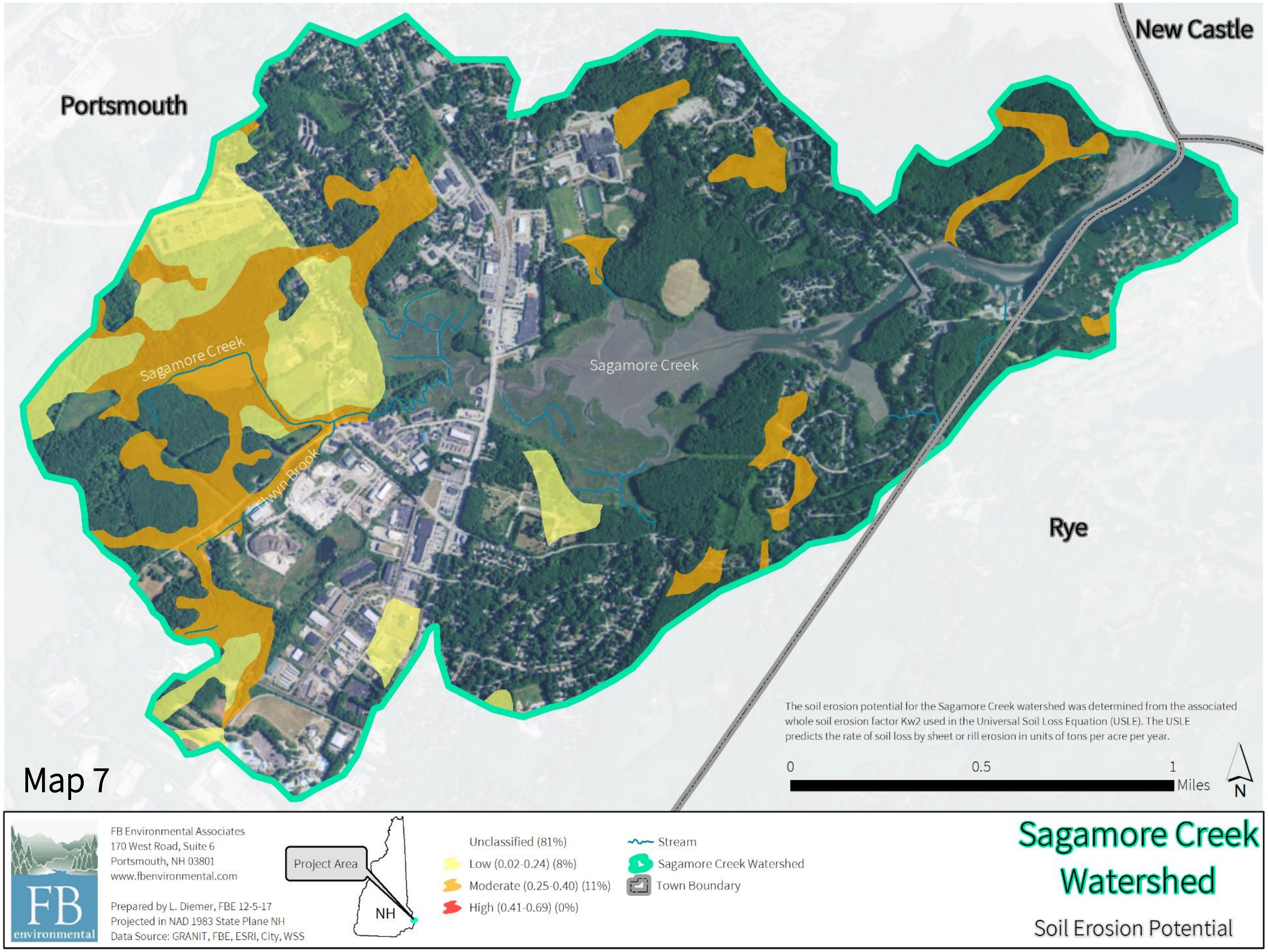

New Castle
Portsmouth
Rye
Sagamore Creek
Elwyn Brook
Map 2
1A
1B
33
1
Little Harbor Rd
Wentworth Rd
Odiorne Point Rd
Gosport Rd
Elwyn Rd
Mirona Rd
Lafayette Rd
Greenland Rd
Banfield Rd
Edgewood Rd
Wilson Rd
Andrew Jarvis Dr
Ledgewood Dr
Greenleaf Woods Dr
Holiday Dr
Sagamore Ave
Pleasant Rd
Incinerator Rd
Jones Ave
Harbour View Dr
Regina Rd
Impervious cover was obtained from the GRANIT data layer Impervious Surfaces in Coastal NH and Southern York County ME - 2010. Data were developed by the Complex Systems Research Center at the University of New Hampshire using Landsat 5 Thematic Mapper imagery and road centerlines from NHDOT. Last revision October 2011.
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 11-24-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Stream
Sagamore Creek Watershed
Town Boundary
Impervious Cover (21%)
Sagamore Creek Watershed
Impervious Cover

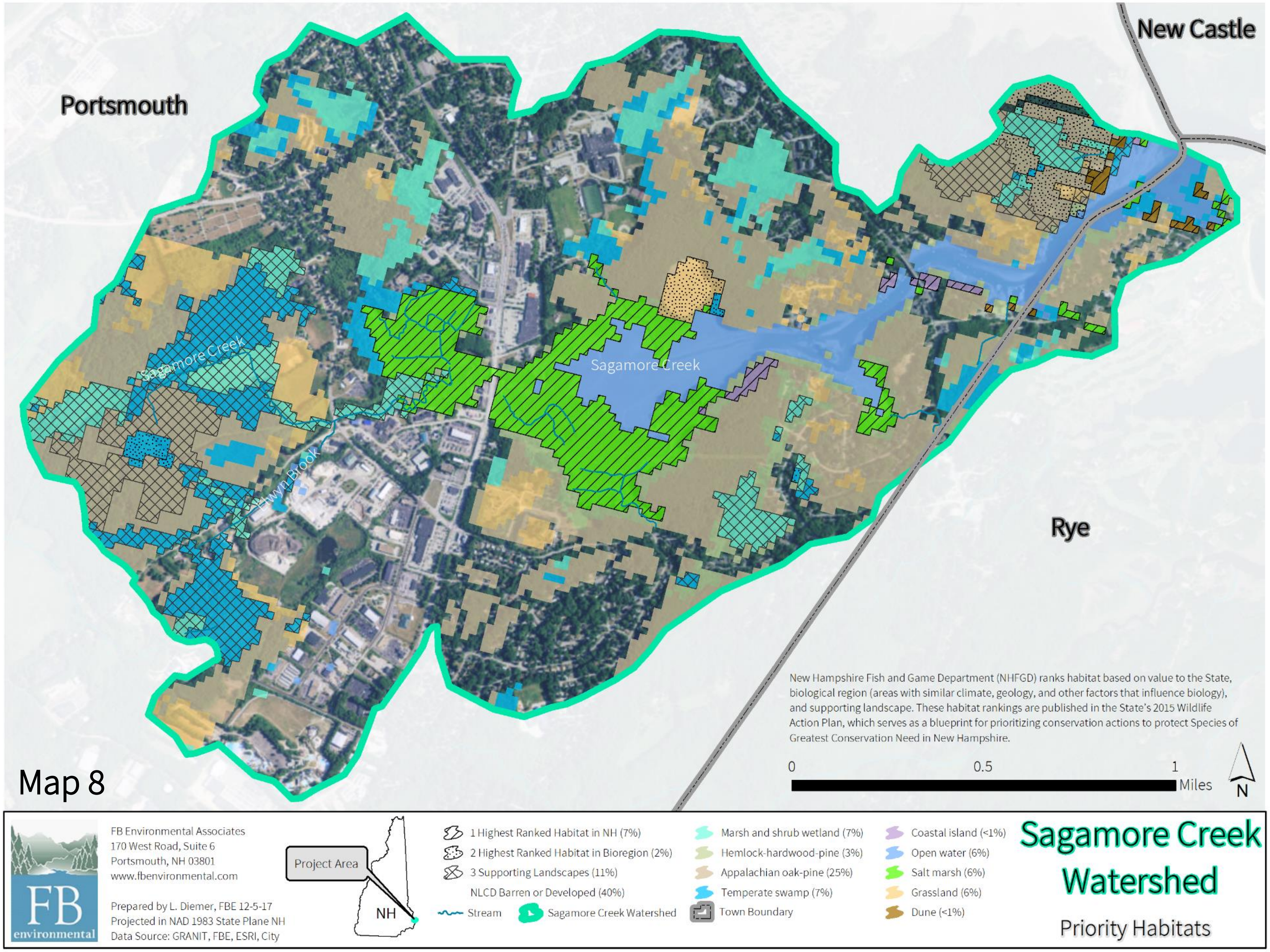

Map 3
Portsmouth
New Castle
Rye
Greenleaf Woods (Easement)
Sagamore Creek Land
Jones Ave Conservation Land
Creek Farm & Wentworth Coolidge Historic Site
Great Bog WMA
Hett (Easement)
Sagamore Creek
Elwyn Brook
Mark H. Wentworth Homeland (Portsmouth) & Brown (Rye)
Sagamore Creek Headlands
Urban Forestry Center
33
1
1A
1B
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 03-29-2018
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Town Boundary
Conservation Easement (1%)
Conserved Land (18%)
Public Land (12%)
Stream
Sagamore Creek Watershed
Sagamore Creek Watershed
Conservation & Public Land

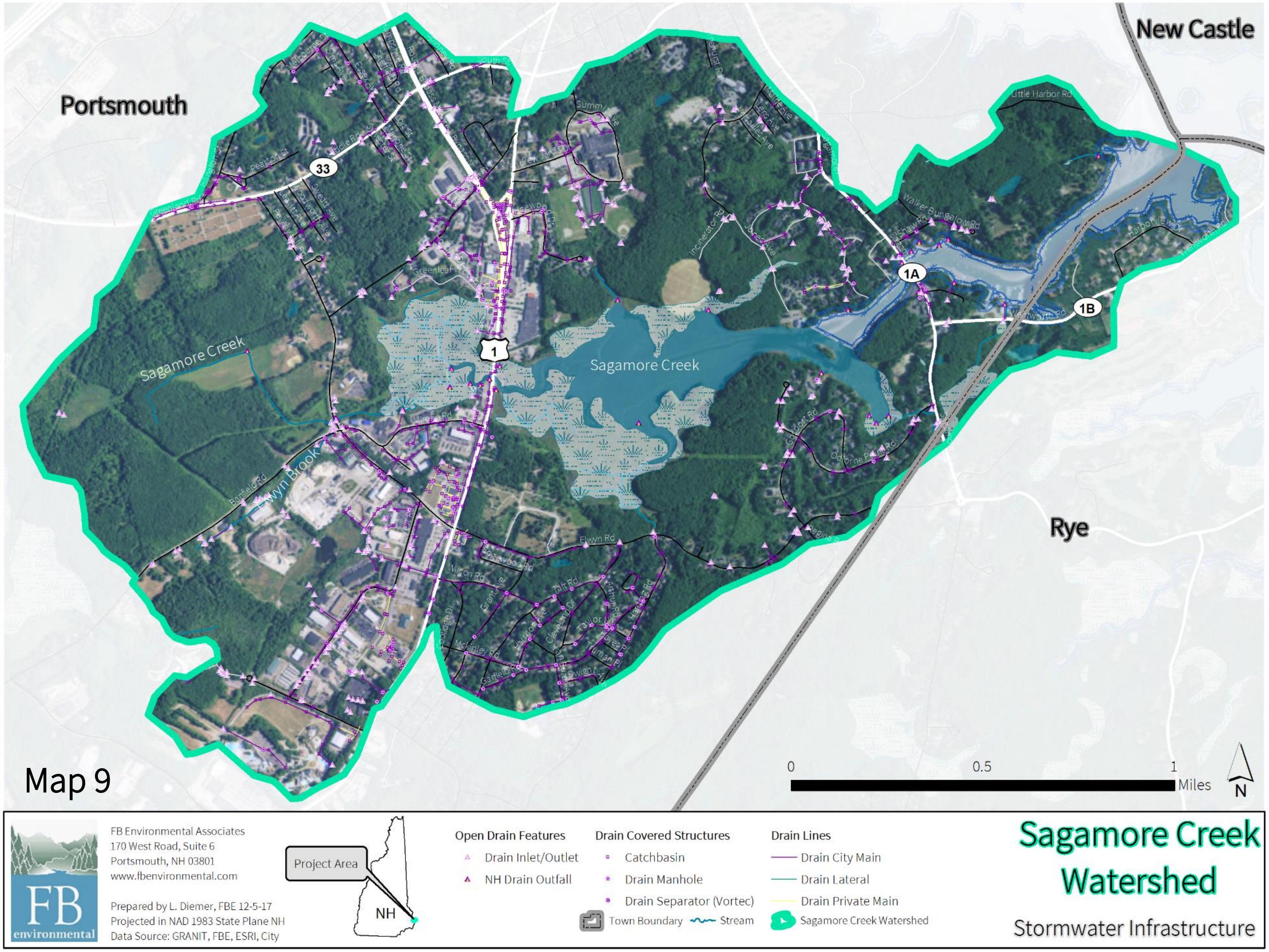

New Castle
Portsmouth
Rye
33
1
1A
1B
Sagamore Creek
Sagamore Creek
Map 4
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 11-25-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Elevation (ft)
0-10
12-20
22-30
32-40
42-50
52-60
62-70
72-80
82-90
Town Boundary
Stream
Sagamore Creek Watershed
Sagamore Creek Watershed
Topography

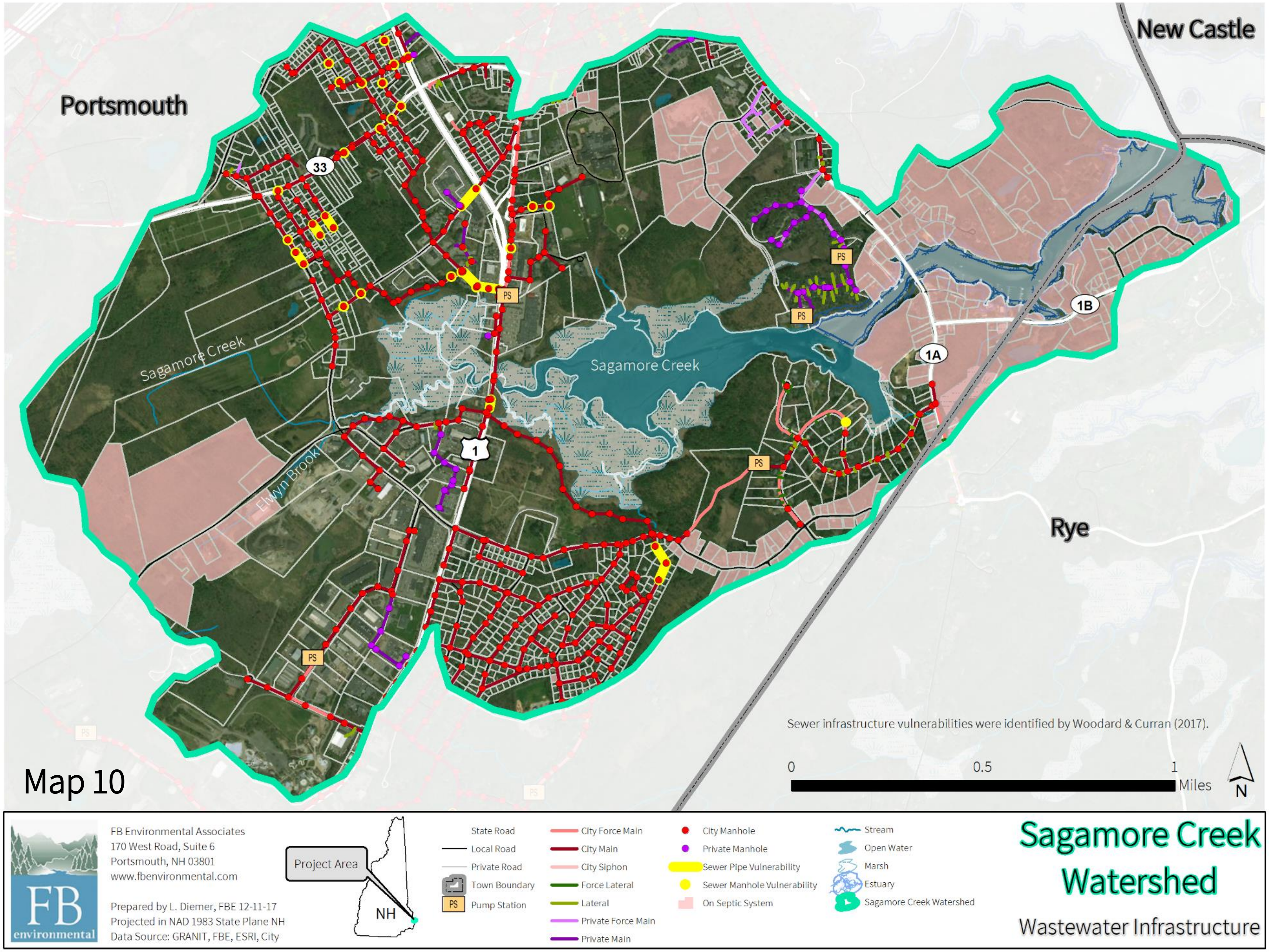

New Castle
Portsmouth
Sagamore Creek
Sagamore Creek
Rye
Map 5
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 11-25-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Stream
Sagamore Creek Watershed
Mixed sand and gravel
Sand, minor silt
Undifferenciated sand, silt, clay
Water (7%)
Bedrock (<1%)
Artificial Fill (1%)
Till (21%)
Town Boundary
Salt Marsh Deposits (7%)
Presumpscot Formation (38%)
Freshwater Wetlands Deposits (<1%)
Wave-Modified Marine Delta Deposits (26%)
Sagamore Creek Watershed
Surficial Geology & Texture


New Castle
Portsmouth
Sagamore Creek
Sagamore Creek
Elwyn Brook
Rye
Generally, blacks, grays, and gray-blues are poorly-drained, wetland areas; reds and pinks are disturbed urban areas; and greens, browns, yellows, and oranges are other well-drained soil types. Refer to soil series table in Appendix 2 for key and description of soil classes.
0
0.5
1
Miles
N
Map 6
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-5-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
134
140B
140C
140D
26A
26C
295
298
299
313A
314A
33A
38A
38B
397
447B
460C
495
510A
510B
510C
538A
547B
597
699
799
97
W
Stream
Town Boundary
Sagamore Creek Watershed
Sagamore Creek Watershed
Soils

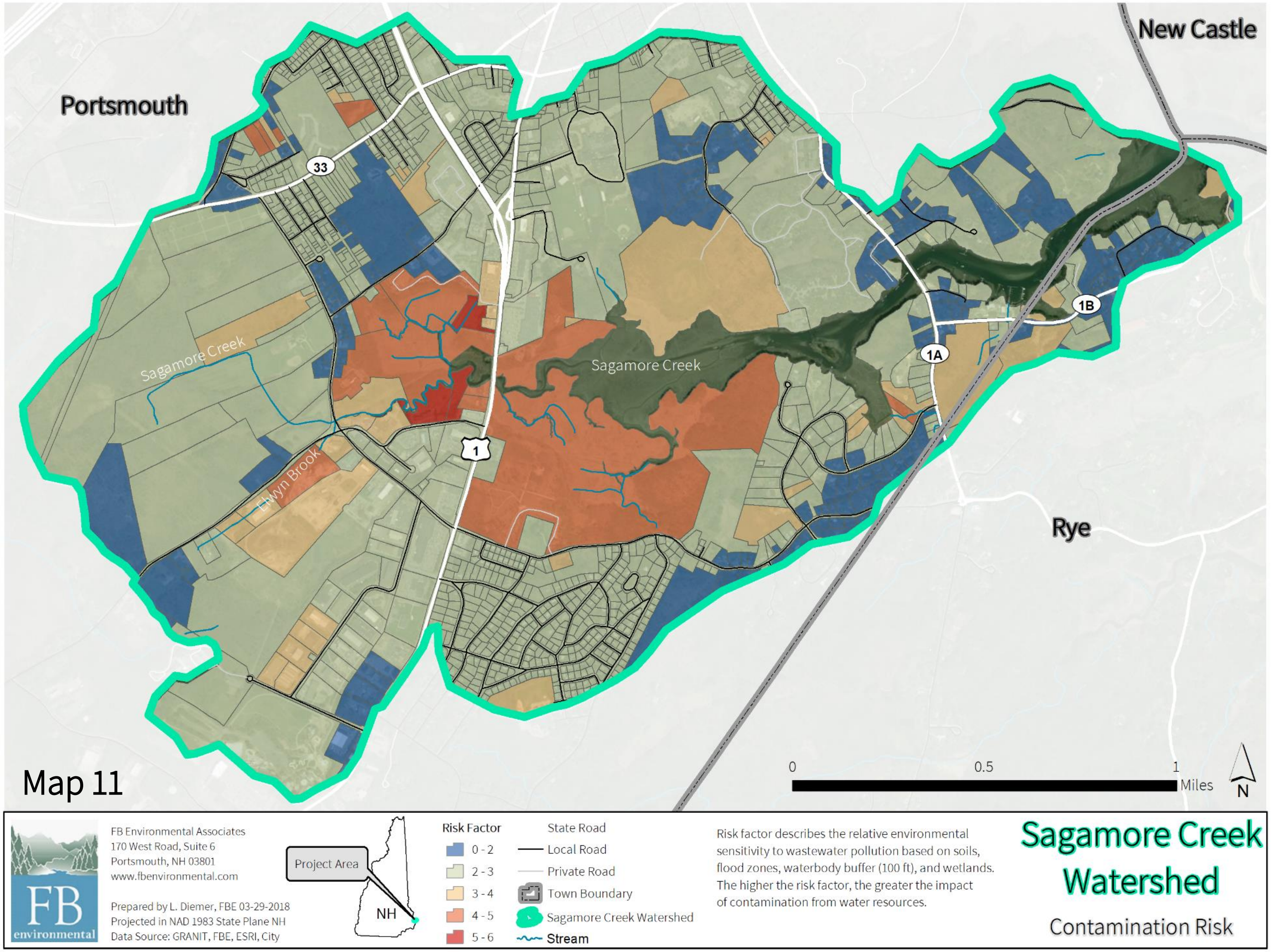

New Castle
Portsmouth
Sagamore Creek
Sagamore Creek
Elwyn Brook
Rye
The soil erosion potential for the Sagamore Creek watershed was determined from the associated whole soil erosion factor Kw2 used in the Universal Soil Loss Equation (USLE). The USLE predicts the rate of soil loss by sheet or rill erosion in units of tons per acre per year.
0
0.5
1
Miles
N
Map 7
FB environmental
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-5-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City, WSS
Project Area
NH
Unclassified (81%)
Low (0.02-0.24) (8%)
Moderate (0.25-0.40) (11%)
High (0.41-0.69) (0%)
Stream
Sagamore Creek Watershed
Town Boundary
Sagamore Creek Watershed
Soil Erosion Potential


New Castle
Portsmouth
Sagamore Creek
Sagamore Creek
Lawn Brook
Rye
New Hampshire Fish and Game Department (NHFGD) ranks habitat based on value to the State, biological region (areas with similar climate, geology, and other factors that influence biology), and supporting landscape. These habitat rankings are published in the State's 2015 Wildlife Action Plan, which serves as a blueprint for prioritizing conservation actions to protect Species of Greatest Conservation Need in New Hampshire.
0
0.5
1
Miles
N
Map 8
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-5-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
Project Area
NH
1 Highest Ranked Habitat in NH (7%)
2 Highest Ranked Habitat in Bioregion (2%)
3 Supporting Landscapes (11%)
NLCD Barren or Developed (40%)
Stream
Sagamore Creek Watershed
Marsh and shrub wetland (7%)
Hemlock-hardwood-pine (3%)
Appalachian oak-pine (25%)
Temperate swamp (7%)
Town Boundary
Coastal island (<1%)
Open water (6%)
Salt marsh (6%)
Grassland (6%)
Dune (<1%)
Sagamore Creek Watershed
Priority Habitats

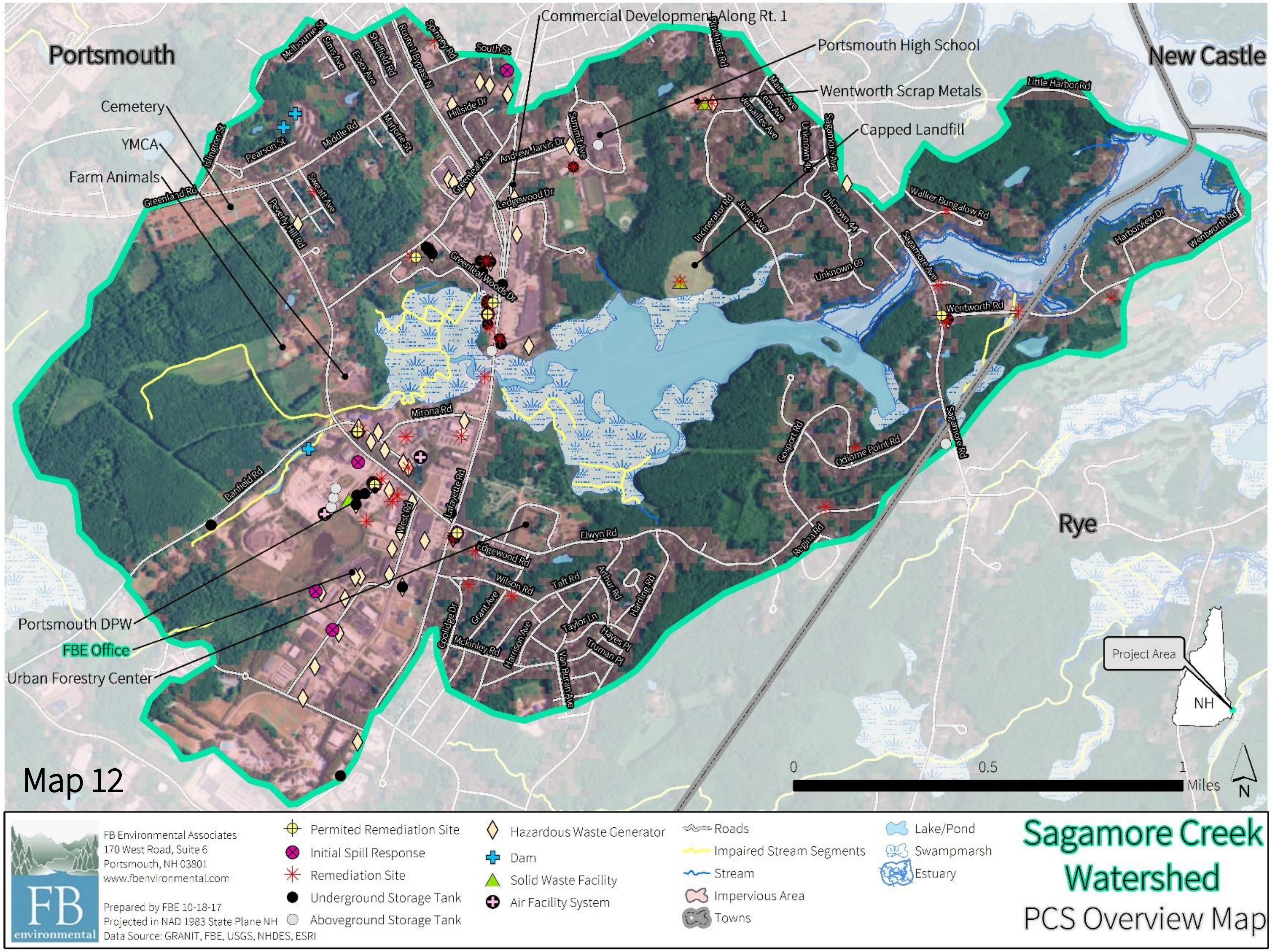

New Castle
Portsmouth
Rye
Sagamore Creek
Sagamore Creek
Elwyn Brook
33
1
1A
1B
Map 9
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-5-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
Project Area
NH
Open Drain Features
Drain Inlet/Outlet
NH Drain Outfall
Drain Covered Structures
Catchbasin
Drain Manhole
Drain Separator (Vortec)
Town Boundary
Stream
Drain Lines
Drain City Main
Drain Lateral
Drain Private Main
Sagamore Creek Watershed
Sagamore Creek Watershed
Stormwater Infrastructure

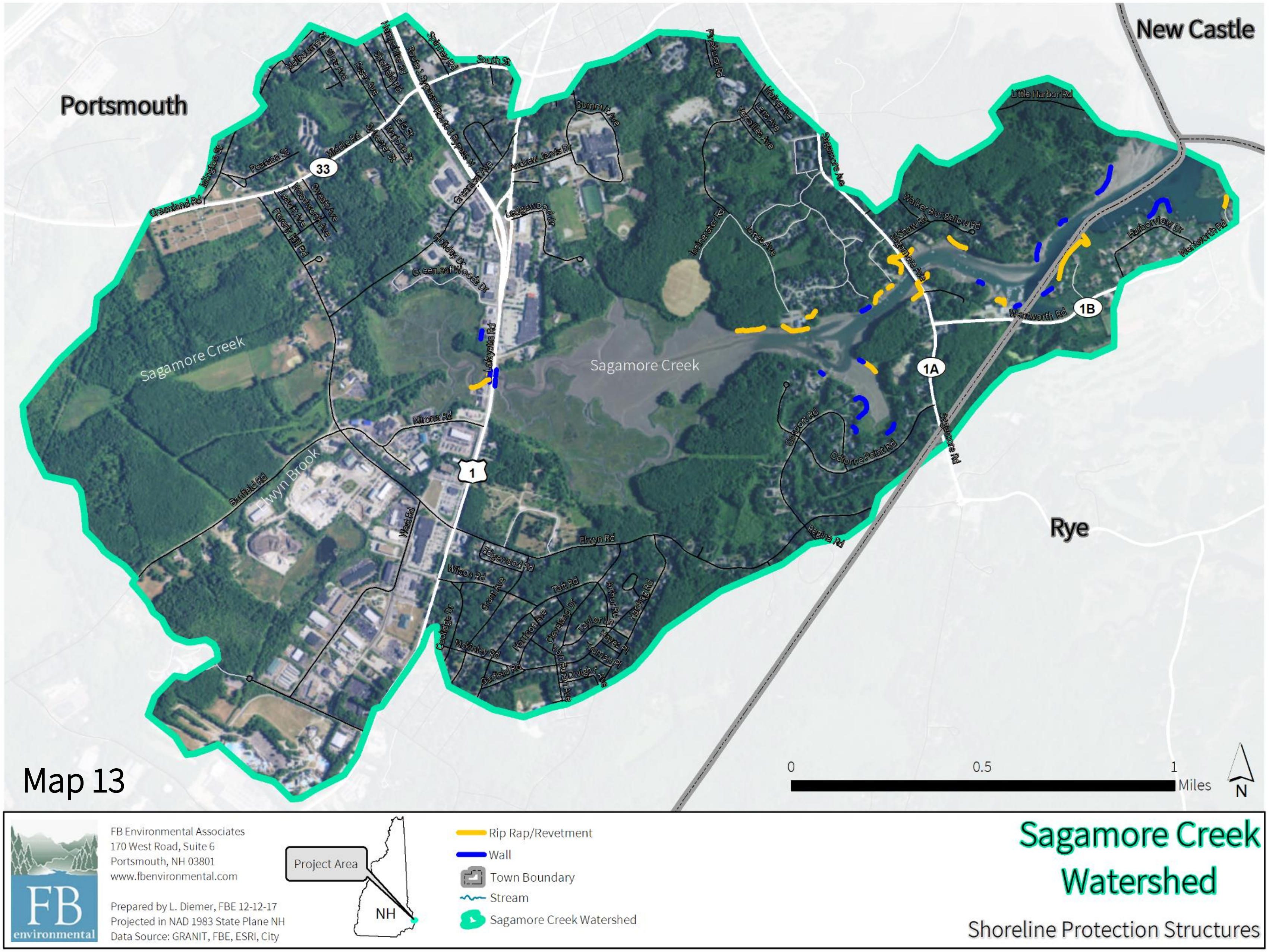


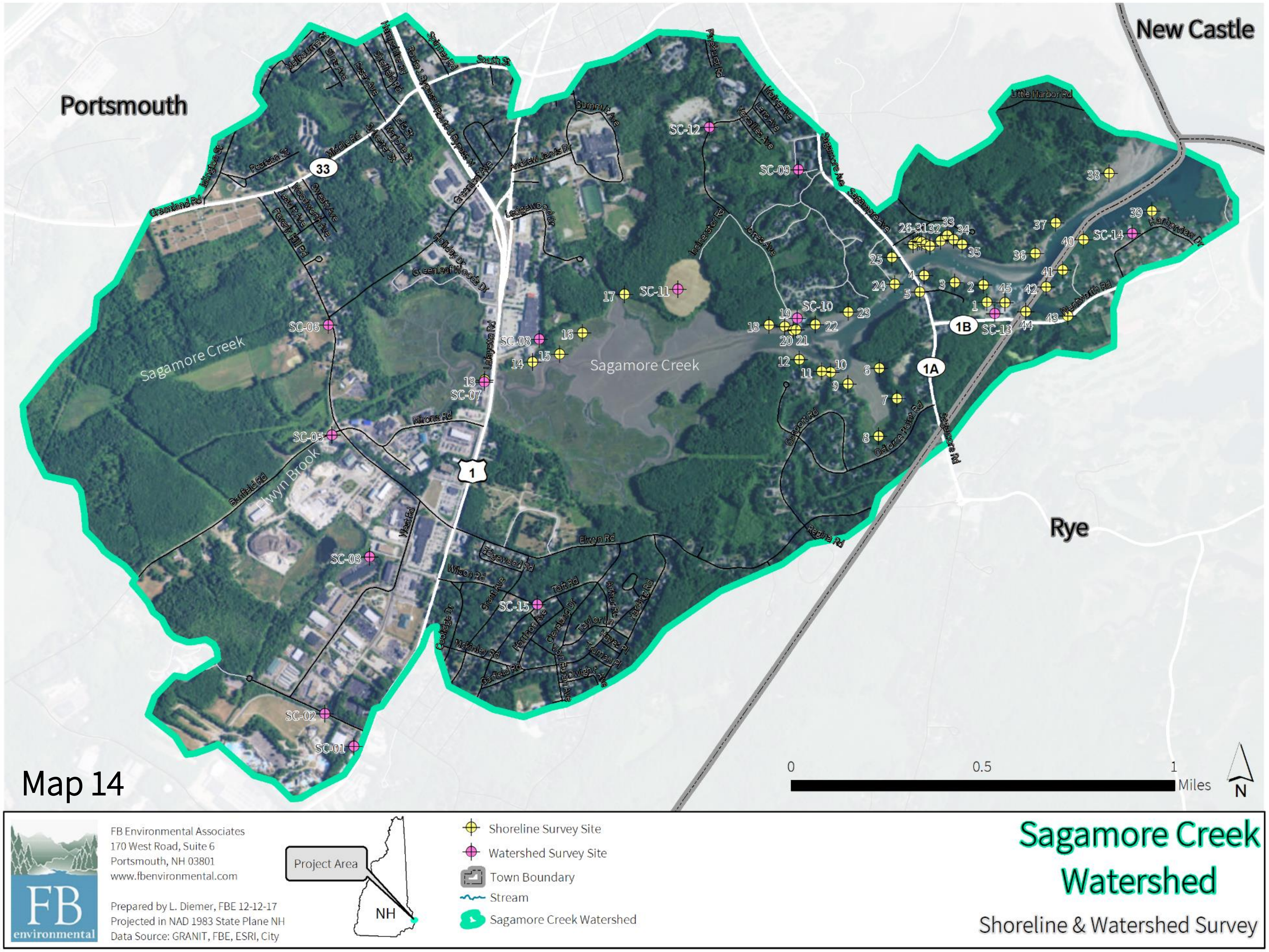
New Castle
Portsmouth
Rye
Sagamore Creek
Elwyn Brook
33
1
1A
1B
PS
Sewer infrastructure vulnerabilities were identified by Woodard & Curran (2017).
0
0.5
1
Miles
N
Map 10
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-11-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
Project Area
NH
State Road
Local Road
Private Road
Town Boundary
Pump Station
City Force Main
City Main
City Siphon
Force Lateral
Lateral
Private Force Main
Private Main
City Manhole
Private Manhole
Sewer Pipe Vulnerability
Sewer Manhole Vulnerability
On Septic System
Stream
Open Water
Marsh
Estuary
Sagamore Creek Watershed
Sagamore Creek Watershed
Wastewater Infrastructure



New Castle
Portsmouth
33
Sagamore Creek
Sagamore Creek
Elwyn Brook
1
1A
1B
Rye
Map 11
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 03-29-2018
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
Project Area
NH
Risk Factor
0 - 2
2 - 3
3 - 4
4 - 5
5 - 6
State Road
Local Road
Private Road
Town Boundary
Sagamore Creek Watershed
Stream
Risk factor describes the relative environmental sensitivity to wastewater pollution based on soils, flood zones, waterbody buffer (100 ft), and wetlands. The higher the risk factor, the greater the impact of contamination from water resources.
Sagamore Creek Watershed
Contamination Risk


Portsmouth
New Castle
Rye
Commercial Development Along Rt. 1
Portsmouth High School
Wentworth Scrap Metals
Capped Landfill
Cemetery
YMCA
Farm Animals
Portsmouth DPW
FBE Office
Urban Forestry Center
Project Area
NH
Map 12
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by FBE 10-18-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, USGS, NHDES, ESRI
Permited Remediation Site
Initial Spill Response
Remediation Site
Underground Storage Tank
Aboveground Storage Tank
Hazardous Waste Generator
Dam
Solid Waste Facility
Air Facility System
Roads
Impaired Stream Segments
Stream
Impervious Area
Towns
Lake/Pond
Swampmarsh
Estuary
Sagamore Creek Watershed
PCS Overview Map


New Castle
Portsmouth
Rye
Sagamore Creek
Sagamore Creek
Elwyn Brook
Map 13
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-12-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Rip Rap/Revetment
Wall
Town Boundary
Stream
Sagamore Creek Watershed
Sagamore Creek Watershed
Shoreline Protection Structures


New Castle
Portsmouth
Rye
Sagamore Creek
Sagamore Creek
Elwyn Brook
SC-01
SC-02
SC-03
SC-05
SC-06
SC-07
SC-08
SC-09
SC-10
SC-11
SC-12
SC-13
SC-14
SC-15
Map 14
0
0.5
1
Miles
N
FB Environmental Associates
170 West Road, Suite 6
Portsmouth, NH 03801
www.fbenvironmental.com
Prepared by L. Diemer, FBE 12-12-17
Projected in NAD 1983 State Plane NH
Data Source: GRANIT, FBE, ESRI, City
FB environmental
Project Area
NH
Shoreline Survey Site
Watershed Survey Site
Town Boundary
Stream
Sagamore Creek Watershed
Sagamore Creek Watershed
Shoreline & Watershed Survey

# A3: Soil Series

| Code (MUSYM) | Soil Series Description | Drain Class | Parent Material | Acres | % |
|---|---|---|---|---|---|
| 140B | Chatfield-Hollis-Canton complex, 3 to 8 percent slopes, very stony | Well drained | till | 520 | 22% |
| 799 | Urban land-Canton complex, 3 to 15 percent slopes | | | 411 | 18% |
| 140C | Chatfield-Hollis-Canton complex, 8 to 15 percent slopes, very stony | Well drained | till | 226 | 10% |
| 299 | Udorthents, smoothed | Excessively drained | | 171 | 7% |
| W | Water | | | 156 | 7% |
| 33A | Scitico silt loam, 0 to 5 percent slopes | Poorly drained | | 106 | 5% |
| 699 | Urban land | | | 89 | 4% |
| 510B | Hoosic gravelly fine sandy loam, 3 to 8 percent slopes | Somewhat excessively drained | outwash | 80 | 3% |
| 397 | Ipswich mucky peat | Very poorly drained | | 75 | 3% |
| 134 | Maybid silt loam | Very poorly drained | silty and clayey marine deposits | 65 | 3% |
| 538A | Squamscott fine sandy loam, 0 to 5 percent slopes | Poorly drained | | 63 | 3% |
| 298 | Pits, sand and gravel | | | 62 | 3% |
| 597 | Westbrook mucky peat | Very poorly drained | | 60 | 3% |
| 495 | Ossipee mucky peat | Very poorly drained | organic material over till | 30 | 1% |
| 26A | Windsor loamy sand, 0 to 3 percent slopes | Excessively drained | | 26 | 1% |
| 38A | Eldridge fine sandy loam, 0 to 3 percent slopes | Moderately well drained | outwash over glaciolacustrine | 26 | 1% |
| 510A | Hoosic gravelly fine sandy loam, 0 to 3 percent slopes | Somewhat excessively drained | outwash | 23 | 1% |
| 140D | Chatfield-Hollis-Canton complex, 15 to 35 percent slopes, very stony | Well drained | till | 23 | 1% |
| 460C | Pennichuck channery very fine sandy loam, 8 to 15 percent slopes | Well drained | till | 21 | 1% |
| 38B | Eldridge fine sandy loam, 3 to 8 percent slopes | Moderately well drained | outwash over glaciolacustrine | 14 | 1% |
| 510C | Hoosic gravelly fine sandy loam, 8 to 15 percent slopes | Somewhat excessively drained | outwash | 14 | 1% |
| 447B | Scituate-Newfields complex, 3 to 8 percent slopes, very stony | Moderately well drained | | 14 | 1% |
| 97 | Greenwood and Ossipee soils, ponded | Very poorly drained | organics | 12 | 0% |
| 295 | Greenwood mucky peat | Very poorly drained | organics | 8 | 0% |
| 547B | Walpole very fine sandy loam, 3 to 8 percent slopes, very stony | Poorly drained | | 7 | 0% |
| 313A | Deerfield fine sandy loam, 0 to 3 percent slopes | Moderately well drained | sandy outwash derived mainly from granite, gneiss and schist | 6 | 0% |
| 26C | Windsor loamy sand, 8 to 15 percent slopes | Excessively drained | | 4 | 0% |
| 314A | Pipestone sand, 0 to 5 percent slopes | Poorly drained | | 2 | 0% |

# A4: Water Quality Sampling Program Plan

The following sampling plan narrative (and accompanying Quality Assurance Project Plan or QAPP) serves to identify the rationale and approach for site selection, sampling method, and data management and analysis for the Sagamore Creek Water Quality Sampling Program. The sampling plan addresses identified data gaps and details protocols for consistent, reliable data collection that can be used in statistical analysis and modeling to better understand the water quality of Sagamore Creek.

The Water Quality Sampling Program seeks to achieve the following objectives with new data collection:

1) Perform statistical analysis and modeling for overall water quality understanding,
2) Apply state and federal water quality criteria for status determination,
3) Quantify of the type, amount, and location of pollutant sources to the Creek for follow-up investigation and remediation, and
4) Assess water quality following watershed improvements.

The Water Quality Sampling Program was divided into several major components that strategically build on the achievements of each successive year (Table A4-1). We will build a robust baseline dataset in the first two years to better inform the development of a watershed management plan for Sagamore Creek. Later investigative water quality sampling will target polluted sites identified during the baseline monitoring. Following development and approval of a watershed management plan, the City will then become eligible for federal grant funds to help cover implementation costs for remediation of identified polluted sites. The Water Quality Sampling Program was designed with the intent to provide a long-term management strategy for Sagamore Creek, beyond the scope of funded work generated by the Consent Decree.

Table A4-1. Timeline of major components of the Sagamore Creek Water Quality Sampling Program.

| WQSP Component | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Baseline Water Quality Sampling | ■ | ■ | | |
| Sediment Study | | ■ | | |
| Database Management | ■ | ■ | ■ | ■ |
| Watershed Management Plan Development | | ■ | ■ | |
| Investigative Water Quality Sampling | | | ■ | ■ |

## Baseline Water Quality Sampling

The baseline water quality sampling component builds upon existing datasets at sites that have multiple years of data, adds new sites that provide better spatial coverage of the watershed, expands the type of parameters measured, and extends the temporal coverage of collected data to account for intra- and inter-annual variation because of seasons and variable weather patterns.

## Continuous Data Collection

Continuous data provide valuable baseline information that can capture nuanced changes in water chemistry because of precipitation events, seasonal or daily fluctuations, tidal inundation, etc. Continuous data can also inform interpretation of discrete grab sampling results.

Two sites (05-SAG and 04-SAG or 02-SAG) will be monitored continuously at 15-minute intervals in April, August, and September for dissolved oxygen, conductance, water level, temperature, pH, and turbidity using YSI multiparameter data sondes rented from US Environmental (Table A4-2, Figure A4-1). Water level will be relative and serve only to assign tidal position to any given point. Data sondes will be secured to weighted crates so that the sondes sit in place above bottom sediments, and the crates will be tethered to a solid land-based object (e.g., tree). Data sondes will be maintained at least monthly by swapping out deployed data sondes with freshly-calibrated data sondes and by taking in-field readings with calibrated field meters. Maintenance may be performed more frequently depending on observed site conditions and the discretion of the project manager. Data will be QA/QC'd by FB Environmental Associates (FBE) and summarized in an end-of-field-season report.

Table A4-2. Sampling sites in the Sagamore Creek watershed that will include continuous monitoring equipment, with site descriptions and justification for selection.

| SITE NAME | DESCRIPTION | JUSTIFICATION |
|---|---|---|
| 05-SAG | Below Peverly Hill Road culvert, below confluence of 01-ELW and SAGCK01. | This established site has been sampled since 2001. It is currently considered a freshwater sampling site, however, high mean chloride (250 ppm, 13 samples) compared to its upstream sampling sites (01-ELW and SAGCK01) indicates possible tidal influence. Continuous monitoring for specific conductivity and stage height will provide valuable insight to its hydrologic connectivity with the tidal system. |
| 04-SAG | At Route 1 crossing. | Captures water chemistry and hydrological dynamics in the upper portion of the estuary. This site was chosen for ease of access and equipment installation at the Route 1 bridge. |
| 02-SAG (Alternate) | At Route 1A crossing. | Captures water chemistry and hydrological dynamics in the lower portion of the estuary. This site is located below most residential and commercial development in the watershed. This site is also chosen for ease of access and equipment installation at the Route 1A bridge. Runoff from the non-sewered portion of Route 1B would not be captured by this continuous monitoring site (except possibly on the diluted incoming tide). |

## Synoptic Grab Sampling

Synoptic grab sampling will maximize both temporal and spatial coverage of key inputs to Sagamore Creek to establish a baseline of water quality and pollutant loading. Up to 10 sites will be sampled for 8 total sample events from April to November at both high and low tide to capture spring snowmelt[7] and baseflow[8] conditions. Freshwater sites will only be sampled at low tide. Antecedent precipitation will be

[7] Spring melt can be a period of high contaminant flux from the watershed, particularly for chloride from winter road salt application. Snow accumulations can also have a concentrating effect on atmospherically-derived pollutants like nitrate, leading to a flush of nitrate during snowmelt.

[8] Baseflow is the dry-weather period when streamflow is largely supplied by groundwater, wetlands, impoundments, or other forms of stored water within the watershed. During baseflow, waterborne pollutants may become concentrated by evaporation and transpiration, and contaminated groundwater or impounded water may become more pronounced in the absence of diluting precipitation.

tracked for each event to ensure that at least 25% of sample events are stormflow[9] (>0.5" rain with 24 hours). Tidal position will also be recorded for each sample event; this will help distinguish the movement and transport of pollutants from within or outside the watershed. Characterizing variability across a range of antecedent conditions is important to understanding what controls ambient water quality and for accurate model parameterization. Sample parameters will include nitrate and nitrite, ammonium, total dissolved nitrogen, soluble reactive phosphorus, dissolved organic carbon, total carbon and nitrogen, chloride (freshwater sites only), Enterococci (estuarine sites only), *E.* coli (freshwater sites only), total suspended solids, chlorophyll-a, and YSI field meter readings for temperature, salinity, conductivity, pH, and dissolved oxygen. Samples will be analyzed at the University of New Hampshire Water Quality Analysis Laboratory in Durham, NH, Jackson Estuarine Laboratory in Durham, NH, Nelson Analytical Laboratory in Kennebunkport, ME, and the City of Portsmouth Water Division Laboratory in Madbury, NH.

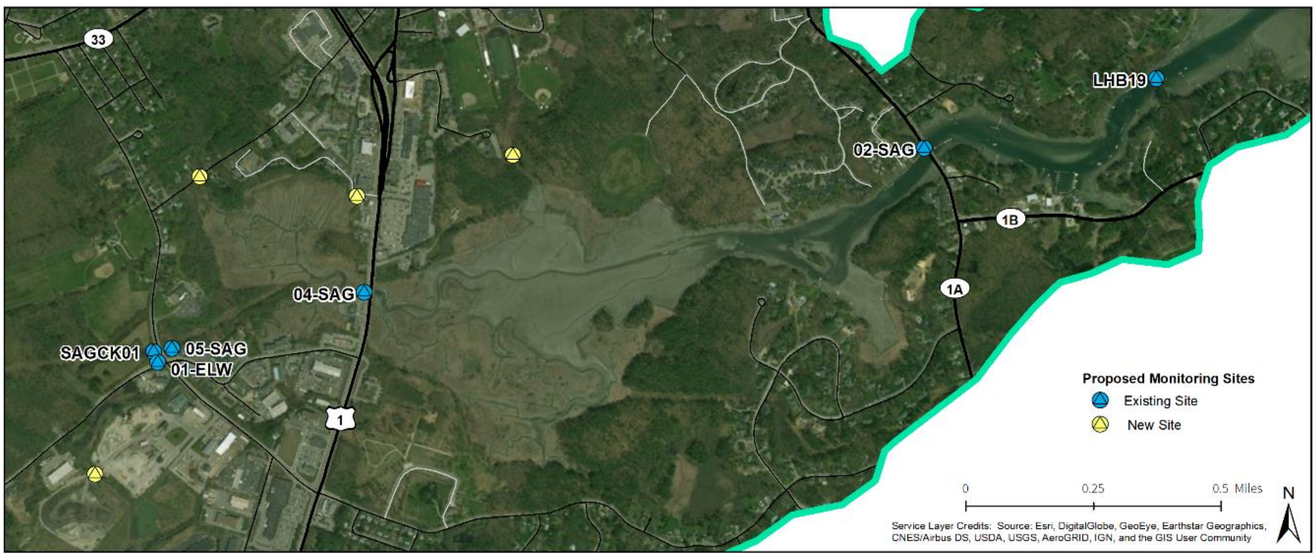



Figure A4-1. Proposed existing and new sampling sites in the Sagamore Creek watershed to be included in the synoptic sampling.

## 24-Hour Grab Sampling

Collecting samples over a lunar day (just over 24 hours) that captures two full tidal cycles can highlight changes in water quality because of both tide and daily fluctuations that would otherwise be missed during regular daylight sampling. Following protocols set forth in the Great Bay Estuary Water Quality Monitoring Program QAPP 2018 and the National Estuarine Research Reserves System Wide Monitoring Program (SWMP), automated ISCOs will be deployed at 2 sites (recommend 05-SAG and 04-SAG or 02-SAG). The ISCOs will be set to collect 12 one-liter samples every 2 hours, 4 minutes over the course of two full tidal cycles. This will be conducted once in August-September under dry or wet-weather, baseflow

[9] Stormflow is the period of increased streamflow during and after a precipitation event, when a watershed wets up, soil and other pervious surfaces saturate, impervious surfaces runoff, and water moves quickly through the various surface and groundwater flowpaths. During stormflow, pollutants that would otherwise be relatively stationary on the landscape or in groundwater can be transported quickly to surface waters.

conditions to observe diel fluctuations during peak growing season and/or storm event response. Sample parameters will include nitrate and nitrite, ammonium, total dissolved nitrogen, soluble reactive phosphorus, dissolved organic carbon, total carbon and nitrogen, chloride (freshwater sites only), Enterococci (estuarine sites only), *E.* coli (freshwater sites only), total suspended solids, chlorophyll-a, and YSI field meter readings for temperature, salinity, conductivity, pH, and dissolved oxygen. Samples will be analyzed at the University of New Hampshire Water Quality Analysis Laboratory in Durham, NH, Jackson Estuarine Laboratory in Durham, NH, Nelson Analytical Laboratory in Kennebunkport, ME, and the City of Portsmouth Water Division Laboratory in Madbury, NH.

### Sediment Study

Sagamore Creek was originally listed as impaired for aquatic life use due to elevated levels of various contaminants in sediment. Sediment samples were collected from the upper estuary in 2000, 2004, and 2006 at three different sites. Resampling sediment over a great spatial area is recommended. Sediment samples should be analyzed for all contaminants that were part of the original impairment listing, including heavy metals, PAHs, PCBs, and VOCs, plus additional legacy or emerging contaminants as recommended by Dr. Stephen Jones of the Jackson Estuarine Laboratory, who has access to a dataset that would help identify contaminant parameters applicable to the region.

Using explicit protocols as part of the National Coastal Condition Assessment Program, Dr. Jones will assist with sediment sample collection and analysis at up to three sites (two in the upper estuary near original testing site locations and one just south of the Sagamore Creek island in a small cove influenced by medium-density residential development along Odiorne Point Rd and Gosport Road). Dr. Jones was part of the original National Coastal Condition Assessment Program conducted through NHDES along the New Hampshire Seacoast and will provide consistency of data collection for comparisons between the two assessments.

### Database Management

Many data currently exist for Sagamore Creek but have yet to be compiled and synthesized for use in assessing monitoring results. Examples include biological parameters (e.g., submerged aquatic vegetation) and hydrology (e.g., hydrodynamic model results and water level data to determine tidal range, estuary bathymetry, and tidal current patterns in the Creek). Volunteers may also collect additional data for the Creek (e.g., bird, plant, and fish or macroinvertebrate surveys). FBE will compile, analyze, and interpret existing data to better inform new monitoring data and maintain an ongoing database for the Creek. Any analysis will be incorporated to the annual report for Sagamore Creek. The database will be housed and maintained by FBE and will be made available upon request by the City.

### Watershed Management Plan Development

Development of a watershed management plan that lays out a specific series of actions to achieve a set water quality goal is a critical step to ensuring the long-term protection of a waterbody. Since some of the components of a watershed management plan have already been completed with this initial process, the following list outlines the remaining components to be completed:

- Establish a steering committee with key stakeholders and host a kick-off meeting to engage citizen support and involvement in the process.
- Compile, analyze, and incorporate new data gathered during the two-year baseline monitoring and compare to state criteria for assessment listing status.
- Run a pollutant load model for Sagamore Creek that estimates pollutant contribution and biological response at the watershed scale, as calibrated to measured data.
- Reassess the watershed for point or nonpoint source pollution sites in identified “hotspot” drainages and estimate the possible pollutant load reduction with implementation of recommended BMPs.
- Consider running a build-out analysis that simulates future population growth and development in the watershed. This information can be used to simulate future water quality conditions and help guide the establishment of a water quality goal.
- Set a water quality goal for the Creek based on the pollutant load analysis, identified impairments, and stakeholder feedback.
- Hold a public forum to solicit feedback from the community on specific actions or recommendations that can be done to achieve the water quality goal. The action plan will identify responsible parties, potential funding sources, timeframes, and estimated costs. Interim or benchmark milestones will also be listed to check progress on the action plan.
- Develop a draft and final watershed management plan and present the final plan to the community.

### Investigative Water Quality Sampling

Based on results from the two-year baseline monitoring, several sites will be prioritized for more intensive investigative water quality sampling. The goal of this investigative water quality sampling will be to conduct a combination of upstream bracket sampling and land use investigations to pinpoint possible sources of pollutant contamination. Sampling will be conducted during either dry weather or wet weather or both and either low tide or high tide or both depending on when pollutants were elevated during the two-year baseline monitoring and whether a site is considered freshwater or estuarine. The bracket sampling will target not only flowing surface waters, but also stormwater through outfalls, connected catchbasins, and any discovered potential illicit discharges. Samples will be tested for the elevated pollutants of interest, along with standard YSI field meter readings for temperature, salinity, conductivity, pH, and dissolved oxygen. For any samples collected from stormwater outfalls, samples will also be tested for *E. coli* or Enterococci, ammonia, chlorine, and surfactants, along with any “pollutants of concern” to satisfy the 2017 New Hampshire Small MS4 General Permit requirements. This approach will help minimize duplicative efforts across other regulatory sampling required of the City, all of which have similar goals of tracking and remediating sources of pollution to surface waters. Samples will be analyzed at the University of New Hampshire Water Quality Analysis Laboratory in Durham, NH and/or Nelson Analytical Laboratory in Kennebunkport, ME. Specific recommendations for remediation and follow-up actions will be provided to the City.

### Data Analysis

Data will be summarized and analyzed in various ways to help inform the objectives of the Water Quality Sampling Program. Possible data analysis methods include the following:

- **General quantitation that summarizes the distribution and central tendency of data by site, assessment unit, season, discharge, month, and year.** Data summarized according to procedures detailed in the NHDES Consolidated Assessment & Listing Methodology (CALM) will be compared to applicable criteria to determine the frequency of occurrence for criteria exceedances.
- **Multi-year and historic comparisons for sites or assessment units with sufficient data.** This may include Mann-Kendall trend tests (for sites or assessment units with more than 10 years of data) or analysis of variance (ANOVA), especially for determining statistically-significant differences between pre- and post-improvements in the watershed.
- **Statistical correlation or relational groupings among measured variables for general understanding of water quality.** This may include linear discriminant analysis, multiple regression analysis, or principal components analysis.
- **Analyze variable versus discharge relationships** at various time scales (yearly, single storm event) to characterize baselines and determine response to improvement efforts in the watershed.
- **Frequency-domain distributions or time series analysis of continuous data that extracts daily, seasonal, or tidal signals and identifies noise or trends in the data.**

# A5: Quality Assurance Project Plan (QAPP)

## 1.0 Project Management

### 1.1 Title and Approval Page

**Quality Assurance Project Plan for the Sagamore Creek Water Quality Sampling Program**

DRAFT July 3, 2018

*Prepared by* FB Environmental Associates & City of Portsmouth, NH
170 West Rd, Suite 6 | 680 Peverly Hill Rd
Portsmouth, NH 03801 | Portsmouth, NH 03801

*Prepared for* EPA Region 1
5 Post Office Square, Suite 100
Boston, MA 02109

Approval Signatures:

______________________________________________ Date: ___________________
Terry Desmarais, City of Portsmouth, Program Manager

______________________________________________ Date: ___________________
Forrest Bell, FB Environmental Associates, Principal Manager

______________________________________________ Date: ___________________
Laura Diemer, FB Environmental Associates, Project Manager

______________________________________________ Date: ___________________
Vincent Perelli, NHDES QA Manager

______________________________________________ Date: ___________________
TBD, EPA QA Manager

## 1.2 Table of Contents

## 1.3 Distribution List

Table A5-1 lists people who will receive copies of the approved Quality Assurance Project Plan (QAPP) for the Sagamore Creek Water Quality Sampling Program.

**Table A5-1.** QAPP distribution list. City = City of Portsmouth. FBE = FB Environmental Associates. WQAL= UNH Water Quality Analysis Laboratory. Nelson = Nelson Analytical Laboratory. UNH = University of New Hampshire. Jackson Lab = Jackson Estuarine Laboratory. CLF = Conservation Law Foundation. PREP = Piscataqua Region Estuaries Partnership. NHDES = New Hampshire Department of Environmental Services. Individuals highlighted in grey will not have a direct role in the sampling effort but will be made aware of the Sagamore Creek sampling effort to help coordinate existing sampling efforts throughout the Great Bay Estuary.

| Name | Title/Project Role | Organization | Phone/E-mail |
|---|---|---|---|
| Terry Desmarais | City Engineer/Program Manager | City | 603-766-1421<br>tldesmarais@cityofportsmouth.com |
| Forrest Bell | Principal Manager | FBE | 207-221-6699<br>info@fbenvironmental.com |
| Laura Diemer | Project Manager/QA Officer | FBE | 603-828-1456<br>laurad@fbenvironmental.com |
| Margaret Burns | Hydrologist/Field Staff | FBE | 603-534-0600<br>margaretb@fbenvironmental.com |
| Rich Brereton | Project Scientist/Field Staff | FBE | 617-519-7993<br>richb@fbenvironmental.com |
| Christine Bunyon | Project Scientist/Field Staff | FBE | 516-417-7778<br>christineb@fbenvironmental.com |
| William McDowell | Lab Director | WQAL | 603-862-2249<br>bill.mcdowell@unh.edu |
| Jody Potter | Lab Manager | WQAL | 603-862-2341<br>jody.potter@unh.edu |
| Lorri Maling | Lab Manager | Nelson | 207-467-3478<br>lorri@nelsonanalytical.com |
| Jessica Pearce | Water Quality & Resource Protection Specialist | City | 603-516-7338<br>jpearce@cityofportsmouth.com |
| Stephen Jones | Associate Director & Professor | Jackson Lab | 603-862-5124<br>stephen.jones@unh.edu |
| Thomas Gregory | Research Scientist | Jackson Lab | 603-862-5136<br>tomgregory.unh@gmail.com |
| Melissa Paly | Great Bay WaterKeeper/VRAP Coordinator | CLF | 603-225-3060<br>mpaly@clf.org |
| Kalle Matso | Coastal Science Program Manager | PREP | 603-781-6591<br>kalle.matso@unh.edu |
| Chris Nash | Shellfish Program Manager | NHDES | 603-559-1509<br>chris.nash@des.nh.gov |
| Matthew Wood | Water Quality Assessment Program Coordinator | NHDES | 603-271-8868<br>matthew.wood@des.nh.gov |
| Vincent Perelli | QA Manager | NHDES | 603-271-8989<br>vincent.perelli@des.nh.gov |
| TBD | QA Manager | EPA Region 1 | TBD<br>TBD |

## 1.4 Project Organization

The Water Quality Sampling Program will be funded by the City of Portsmouth, per the Consent Decree. An approved QAPP was not required (as no federal funds will be used for the program) but was determined as important for validation of field methods and possibly qualifying future monitoring work for federal funding.

The Water Quality Sampling Program will be carried out by a qualified environmental consulting firm, FB Environmental Associates (FBE), under a contract with the City of Portsmouth (Program Manager, Terry Desmarais). The Project Manager (Laura Diemer, FBE) will be responsible for coordinating all program activities, managing all field and laboratory staff, making "stop/go" decisions for daily sampling runs, notifying lab managers of sample deliveries, and resolving any problems with field and laboratory staff. Field staff (Margaret Burns, Richard Brereton, and Christine Bunyon, FBE & Dr. Stephen Jones, UNH per sub-contractual agreement) will be responsible for completing specific tasks as assigned by the Project Manager, carrying out all field work, and reporting any problems to the Project Manager.

Laboratory staff will be responsible for assigning appropriate personnel to perform the analyses according to Standard Operating Procedures (SOPs) specified in the QAPP, identifying any non-conformities or analytical problems, and reporting any problems to the Project Manager. Samples will be delivered to Nelson Analytical Laboratory (Lab Manager, Lorri Maling), the UNH Water Quality Analysis Laboratory (Director, Dr. William McDowell & Lab Manager, Jody Potter), the Jackson Estuarine Laboratory (Associate Director, Dr. Stephen Jones & Research Scientist, Thomas Gregory), and the City of Portsmouth Water Division Laboratory (Water Quality & Resource Protection Specialist, Jessica Pearce).

Throughout and at the end of each field season, the Project QA Officer (Laura Diemer, FBE) will perform QA/QC of field collection methods, field and laboratory duplicates, and laboratory results to verify that the procedures of the QAPP were followed. The Project QA Officer (Laura Diemer, FBE) will be responsible for a memorandum summarizing any deviations from the procedures in the QAPP, results of the QA/QC tests, and confirmation that reported data meet the data quality objectives.

Matthew Wood (Water Quality Assessment Program Coordinator, NHDES) will be responsible for submitting the QAPP to the QA Manager (Vincent Perelli) for review before submittal to the EPA Region 1 QA Manager for final review and approval. The Project Manager (Laura Diemer, FBE) will be responsible for any revisions during the review process.

The principal user of the data will be the City of Portsmouth. The Project Manager (Laura Diemer, FBE) will prepare an annual report for the City of Portsmouth (Program Manager, Terry Desmarais), summarizing field methods and results that will help inform the development of a watershed management plan for Sagamore Creek. The City of Portsmouth (Program Manager, Terry Desmarais) will be responsible for further dissemination of the annual report to appropriate stakeholders, which may include individuals listed in Table A5-1. A hierarchy of project organization is shown in Figure A5-1.

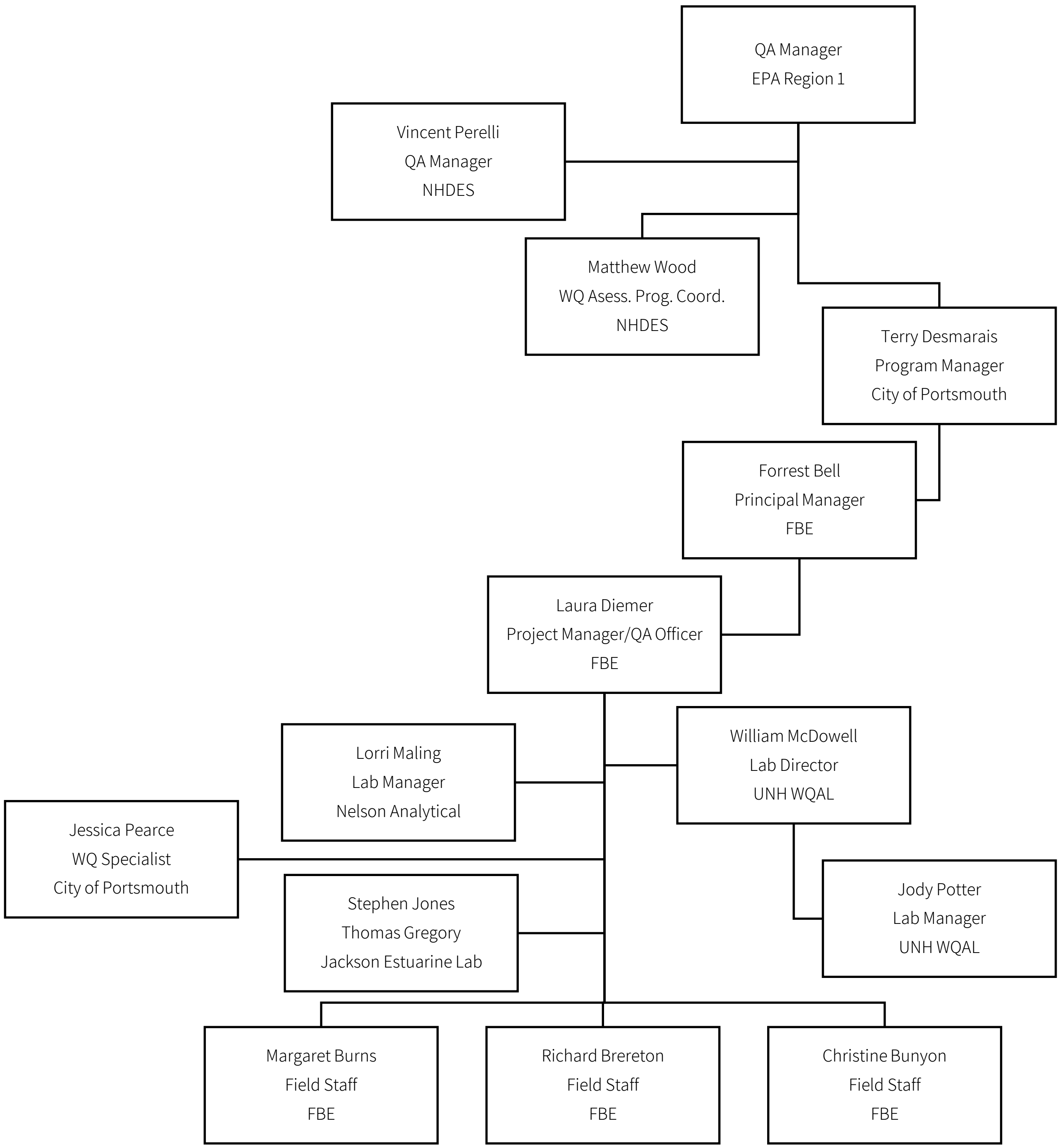



**Figure A5-1.** Organization Chart. FBE = FB Environmental Associates. WQAL= Water Quality Analysis Laboratory. Nelson Analytical = Nelson Analytical Laboratory. UNH = University of New Hampshire. NHDES = New Hampshire Department of Environmental Services.

## 1.5 Problem Definition/Background

The genesis for this work arose from the City's obligations under the Consent Decree, Second Modified, in *United States et. al. v. City of Portsmouth*, No. 09-cv-283-PB (Consent Decree). The Consent Decree requires mitigation for the delayed implementation of secondary treatment at the Peirce Island wastewater treatment facility. The City will provide $100,000 annually for a period of five years to support water quality and ecosystem health efforts related to the Great Bay estuary. A portion of that annual financial commitment is being used to support the Sagamore Creek Water Quality Sampling Program. Sagamore Creek was selected partly because the City will be undertaking sewer system improvements and stormwater projects in the Sagamore Creek watershed over the next three to six years, as part of the same Consent Decree. The City and other stakeholders have a unique opportunity to measure changes in water quality because of these infrastructure improvements.

Sagamore Creek was also partly selected because the freshwater and estuarine portions of the Creek are considered impaired waters in the State of New Hampshire. Sagamore Creek does not meet state criteria for the designated uses of aquatic life, fish consumption, and shellfishing due to elevated levels of various contaminants and/or poor estuarine bioassessments. These contaminants are likely coming from the residential, commercial, and industrial developed areas or from legacy human activities in the watershed. However, significant data gaps for contaminants in surface waters and sediments prevent a thorough analysis of the source, magnitude, and variability of contaminants in Sagamore Creek – an issue that will be addressed in the sampling plan set forth here. Further information on watershed characteristics, water quality analysis, pollutant source inputs, and data gaps can be found in the main report.

## 1.6 Project Description and Schedule

The Sagamore Creek Water Quality Sampling Program seeks to achieve the following objectives with new data collection:

1) Perform statistical analysis and modeling for overall water quality understanding,
2) Apply state and federal water quality criteria for status determination,
3) Quantify of the type, amount, and location of pollutant sources to the Creek for follow-up investigation and remediation, and
4) Assess water quality following watershed improvements.

The Water Quality Sampling Program was divided into several major components that strategically build on the achievements of each successive year (Table A5-2). We will build a robust baseline dataset in the first two years to better inform the development of a watershed management plan for Sagamore Creek. Later investigative water quality sampling will target polluted sites identified during the baseline monitoring. Following development and approval of a watershed management plan, the City will then become eligible for federal grant funds to help cover implementation costs for remediation of identified polluted sites. The Water Quality Sampling Program was designed with the intent to provide a long-term management strategy for Sagamore Creek, beyond the scope of funded work generated by the Consent Decree.

**Table A5-2.** Timeline of major components of the Sagamore Creek Water Quality Sampling Program.

| WQSP Component | 2018 | 2019 | 2020 | 2021 |
|---|---|---|---|---|
| Baseline Water Quality Sampling | ■ | ■ | | |
| Sediment Study | | ■ | | |
| Database Management | ■ | ■ | ■ | ■ |
| Watershed Management Plan Development | | ■ | ■ | |
| Investigative Water Quality Sampling | | | ■ | ■ |

The sampling plan and accompanying QAPP identifies the rationale and approach for site selection, sampling method, and data management and analysis for the Sagamore Creek Water Quality Sampling Program. The QAPP covers the field sampling components: Baseline Water Quality Sampling, Sediment Study, and Investigative Water Quality Sampling. Discussion of the approach for Database Management and Watershed Management Plan Development is provided in the narrative sampling plan (Appendix 4) of the Water Quality Sampling Program. Wherever applicable, existing QAPPs and SOPs detailing similar protocols are referenced, including the 2018 Great Bay Estuary Water Quality Monitoring Program QAPP, which also follows the National Estuarine Research Reserves System Wide Monitoring Program sampling design.

After each field season, data will undergo QA/QC before being input to the database and submitted to the NHDES Environmental Monitoring Database (EMD) for final QA/QC and validation. Data will be summarized in an annual report, along with a description of any deviations from the procedures set forth in the QAPP. Data will be accessible to the public through the NHDES EMD or by request of the database manager (the Project Manager).

## 1.7 Quality Objectives and Criteria for Measurement Data

Measurement performance criteria for sample parameters that will be collected for this project will follow EPA-approved QAPPs for established projects to ensure comparability of data. Details on each data quality objective (precision, accuracy, comparability, sensitivity, and data completeness) are provided in the 2018 Great Bay Estuary Monitoring Program QAPP. Table A5-3 contains a list of water quality analytes, methods, and reference limits for this project to be analyzed by the following:

- UNH Water Quality Analysis Laboratory (WQAL) for nitrate+nitrite, ammonium, orthophosphate, dissolved organic carbon, total dissolved nitrogen, total suspended solids, and particulate organic matter (total carbon and nitrogen) - refer to the 2018 Great Bay Estuary Water Quality Monitoring Program QAPP, Appendix A, B, C, and E for the UNH WQAL QAPP and associated SOPs for nutrient analyses.
- Jackson Estuarine Laboratory (JEL) for chlorophyll-a – refer to the 2018 Great Bay Estuary Water Quality Monitoring Program QAPP, Appendix I for Ocean Optics Protocols.

- ∅ **Nelson Analytical Laboratory** for Enterococci - refer to Standard Methods 9020 B-8 (APHA, 1998) and Lab Manager Lorri Maling for a copy of the Quality System Procedures for Enterococci and Bacterial Analysis SOP.
- ∅ **City of Portsmouth Water Division Laboratory** for chloride using HACH Chloride QuanTab test strips (refer to bottle instructions) and *E. coli* - refer to Colilert Testing Procedures using IDEXX 24-hr Colilert with Quanti-Tray/2000 method online IDEXX manual instructions.
  - Internal split-sample testing by the City of Portsmouth showed that results from chloride test strips were consistently lower than laboratory analyses, ranging from 8% from 0-200 mg/L (n=15) to 11% for 300+ mg/L (n=3). This suggests that chloride test strip results of 205-229 mg/L could signify an exceedance of state criteria and should be flagged.

Table A5-3. Water quality analytes, methods, and reference limits. Adapted from 2018 Great Bay Estuary Water Quality Monitoring QAPP. Project reporting limits for each parameter meet project action levels and sensitivity needs.

| Analyte | Analytical method (See Appendices in Great Bay QAPP for SOP details) | Project Action Level | Project Reporting Limit |
|---|---|---|---|
| $NO_2^-/NO_3^-$ | USEPA 353.2 Revision 2.0, August 1993 | NA | 0.005 mg/L |
| $NH_4^+$ | USEPA method 350.1, 1971, modified March 1983 | NA | 0.005 mg/L |
| TDN | High temperature catalytic oxidation | NA | 0.1 mg/L |
| TSS | APHA Method 2540-D | NA | 1 mg/L |
| Chlorophyll-a | Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 5, Volume V: Biogeochemical and Bio-Optical Measurements and Data Analysis Protocols | NA | 0.12 µg/L |
| Pheophytin-a | Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 5, Volume V: Biogeochemical and Bio-Optical Measurements and Data Analysis Protocols | NA | 0.12 µg/L |
| DOC | USEPA 415.3, Revision 1.1, February 2005 | NA | 0.05 mg/L |
| $PO_4^{3-}$ | USEPA 365.3, 1978 | NA | 0.001 mg/L |
| POC | USEPA 440.0, Revision 1.4, September 1997 | NA | 4 µg/L |
| PON | USEPA 440.0, Revision 1.4, September 1997 | NA | 3 µg/L |
| *Escherichia coli* | IDEXX 24-hr Colilert with Quanti-Tray/2000 method | 406 mpn/100 mL single sample; 126 mpn/100 mL for multiple samples | 1 mpn/100 mL |
| Enterococci | APHA Method 9020 B-8 (APHA, 1998) using Enterolert | 104 mpn/100 mL single sample; 35 mpn/100 mL for multiple samples | 10 mpn/100 mL |
| Chloride | HACH Chloride QuanTab test strips | 230 mg/L state criteria; 205 mg/L to account for error in test strips | 30-600 mg/L in 10-20 mg/L increments |

Table A5-4 lists water quality parameters, SOP reference, equipment accuracy, resolution, and range, and calibration criteria for continuous data collection using YSI or similar datasondes and discrete instantaneous data collection using YSI or similar field meters (for performing quality control checks on the datasondes and collecting additional data during synoptic sampling). Data from the field meter may be collected up to the sample frequency from the time of the last datasonde reading (15 minutes in this project), and therefore a wider divergence between meter and sonde readings is allowed than if data were collected simultaneously. Data outside of the acceptable ranges will be flagged or unvalidated for use in analyses.

Table A5-4. Data limitations of methods proposed for instantaneous water quality parameters.

| Parameter (units) | SOP Reference | Equipment Accuracy | Resolution | Range | Calibration Criteria |
|---|---|---|---|---|---|
| Temperature (°C) | YSI or similar 6-series datasonde manual | ± 0.15 °C | 0.01 °C | -5 to 50°C | ± 0.2°C vs. field meter |
| Dissolved oxygen (% and mg/L) | | 0-200% ± 1% of reading or 1% air saturation, 200-500% ± 15% of reading; 0-20 m/L ± 0.1 mg/L or 1% of reading, 20-50 mg/L ± 15% of reading | 0.1% air saturation; 0.01 mg/L | 0-500%; 0-50 mg/L | ±0.3 ppm vs. field meter |
| Conductivity (mS/cm) | | ±0.5% of reading or 0.001 mS/cm | 0.001 to 0.1 mS/cm (range dependent) | 0-100 mS/cm | ± 0.005 mS/cm or ±3% vs. field meter |
| pH | | ± 0.1 pH units within ± 10°C of calibration temp or ± 0.2 pH units for entire temp range | 0.01 units | 0-14 units | ± 0.2 pH units vs. field meter |
| Water Depth (m) | | ± 0.12 m | 0.001 m | 0-61 m | 0.001 m vs. field measurement |
| Turbidity (NTU) | | ± 2% of reading or 0.3 NTU | 0.1 NTU | 0-1000 NTU | ± 0.5 NTU or ± 5% vs. field meter |
| Temperature (°C) | YSI or similar field meter manual | ± 0.2°C | 0.1°C | -5 to 70°C | ±0.2°C vs. a NIST-certified thermometer |
| Dissolved oxygen (% and mg/L) | | 0-200% ± 2% of reading or 2% air saturation, 200-500% ± 6% of reading; 0-20 mg/L; 0-20 m/L ± 0.2 mg/L or 2% of reading, 20-50 mg/L ± 6% of reading | 0.1% air saturation; 0.01 mg/L | 0-500%; 0-50 mg/L | ±2% vs water-saturated air calibration and ±0.3 mg/L vs. atmospheric pressure check |
| Conductivity (mS/cm) | | ±0.5% of reading or 0.001 mS/cm | 0.001 to 0.1 mS/cm (range dependent) | 0-200 mS/cm | ± 0.005 mS/cm or ±3% vs. standard |
| Salinity (ppt) | | ± 1% of reading or 0.1 ppt | 0.01 ppt | 0-70 ppt | 0.1 ppt |
| pH | | ± 0.2 units | 0.01 units | 0-14 units | ± 0.2 pH units vs. standards |

Sediment samples will be analyzed for all contaminants that were part of the original impairment listing (for comparability), including heavy metals, PAHs, PCBs, and VOCs, plus additional legacy or emerging contaminants as recommended by Dr. Stephen Jones of the UNH Jackson Estuarine Laboratory, who has access to a dataset that would help identify contaminant parameters applicable to the region. A qualified laboratory (e.g., Battelle national laboratories or SGS AXYS Analytical Services) will perform sediment sample analyses to ensure the highest-quality precision, accuracy, and sensitivity of results. The selected laboratory will meet sensitivity needs (e.g., reporting limits less than applicable criteria).

## 1.8 Special Training Requirements/Certification

Internal annual review and training with field staff with the Project Manager, covering SOPs for maintenance of field instruments, deploying datasondes, and collecting field data, will be performed before each sampling season to ensure consistent and quality data collection that meet the data quality objectives. The Project Manager is fully trained in all water quality sampling procedures. Training in sediment sample collection will be provided by Dr. Stephen Jones, UNH. No other special training or certification requirements are necessary.

### 1.9 Documents and Records

QAPP Distribution: The Project Manager will be responsible for maintaining the approved QAPP and for distributing the latest version to all parties on the distribution list in Section 1.3. The Project Manager will keep a copy of the approved QAPP on file.

Field Documentation and Records: Field data forms will be completed using the Fulcrum application on tablets and will include entries for date, sampler name, sample ID, time, field measurements, and notes. Field staff will fill in a new field data form for each sampling event and return the form to the Project Manager upon completion. Calibration and deployment records for datasondes will be completed as physical hardcopies (Attachment A). The information will be exported or transcribed to a Microsoft Excel file. The Project Manager will keep the original electronic or physical field sheets on file.

Laboratory Documentation and Records: The Laboratory Manager will transmit electronic laboratory data sheets to the Project Manager containing the results of analyses and the results of QC tests. Chain of Custody forms for each applicable laboratory will be completed by field and lab staff and will be included as a copy in the electronic results.

Reports to Management: The Project Manager will submit to the Program Manager a yearly monitoring report summarizing findings, as well as the database (upon request) that contains quality controlled and quality assured results. The Project QA Officer will also include a description of any deviations from QAPP protocols. The annual report will be completed in February following each field season. The Program Manager will be responsible for distribution and/or public posting of the annual report.

Archiving: The QAPP, annual reports, and original field and laboratory data sheets will be kept on file by the Project Manager for a minimum of 10 years after the publication date of each annual report.

## 2.0 Data Generation and Acquisition

### 2.1 Sampling Design

Refer to Appendix A4 for more details on rationale of sampling design.

Baseline Water Quality Sampling

*Continuous Data Collection*

Two sites (05-SAG and 04-SAG or 02-SAG) will be monitored continuously at 15-minute intervals in April, August, and September for dissolved oxygen, conductance, water level, temperature, pH, and turbidity using YSI multiparameter data sondes rented from US Environmental (Table A5-5, Figure A5-2). Water level will be relative and serve only to assign tidal position to any given point. Data sondes will be secured to weighted crates so that the sondes sit in place above bottom sediments, and the crates will be tethered to a solid land-based object (e.g., tree). Data sondes will be maintained at least monthly by swapping out deployed data sondes with freshly-calibrated data sondes and by taking in-field readings with calibrated field meters. Maintenance may be performed more frequently depending on observed site conditions and the discretion of the Project Manager. Data will be quality controlled and quality assured by the Project QA Officer and summarized in an end-of-field-season report.

Table A5-5. Sampling sites in the Sagamore Creek watershed that will include continuous monitoring equipment, with site descriptions and justification for selection.

| SITE NAME | DESCRIPTION | JUSTIFICATION |
|---|---|---|
| 05-SAG | Below Peverly Hill Road culvert, below confluence of 01-ELW and SAGCK01. | This established site has been sampled since 2001. It is currently considered a freshwater sampling site, however, high mean chloride (250 ppm, 13 samples) compared to its upstream sampling sites (01-ELW and SAGCK01) indicates possible tidal influence. Continuous monitoring for specific conductivity and stage height will provide valuable insight to its hydrologic connectivity with the tidal system. |
| 04-SAG | At Route 1 crossing. | Captures water chemistry and hydrological dynamics in the upper portion of the estuary. This site was chosen for ease of access and equipment installation at the Route 1 bridge. |
| 02-SAG (Alternate) | At Route 1A crossing. | Captures water chemistry and hydrological dynamics in the lower portion of the estuary. This site is located below most residential and commercial development in the watershed. This site is also chosen for ease of access and equipment installation at the Route 1A bridge. Runoff from the non-sewered portion of Route 1B would not be captured by this continuous monitoring site (except possibly on the diluted incoming tide). |

### *Synoptic Grab Sampling*

Up to 10 sites will be sampled for 8 total sample events from April to November at both high and low tide to capture spring snowmelt and baseflow conditions (Figure A5-2). Freshwater sites will only be sampled at low tide. Antecedent precipitation will be tracked for each event to ensure that at least 25% of sample events are stormflow (>0.5" rain with 24 hours). Tidal position will also be recorded for each sample event. Sample parameters will include nitrate and nitrite, ammonium, total dissolved nitrogen, soluble reactive phosphorus, dissolved organic carbon, total carbon and nitrogen, chloride (freshwater sites only), Enterococci (estuarine sites only), *E.* coli (freshwater sites only), total suspended solids, chlorophyll-a, and YSI field meter readings for temperature, salinity, conductivity, pH, and dissolved oxygen. Samples will be analyzed at the University of New Hampshire Water Quality Analysis Laboratory in Durham, NH, Jackson Estuarine Laboratory in Durham, NH, Nelson Analytical Laboratory in Kennebunkport, ME, and the City of Portsmouth Water Division Laboratory in Madbury, NH.

### *24-Hour Grab Sampling*

Automated ISCOs will be deployed at 2 sites (recommend 05-SAG and 04-SAG or 02-SAG). The ISCOs will be set to collect 12 one-liter samples every 2 hours, 4 minutes over the course of two full tidal cycles. This will be conducted once in August-September under dry or wet-weather, baseflow conditions to observe diel fluctuations during peak growing season and/or storm event response. Sample parameters will include nitrate and nitrite, ammonium, total dissolved nitrogen, soluble reactive phosphorus, dissolved organic carbon, total carbon and nitrogen, chloride (freshwater sites only), Enterococci (estuarine sites only), *E.* coli (freshwater sites only), total suspended solids, chlorophyll-a, and YSI field meter readings for temperature, salinity, conductivity, pH, and dissolved oxygen. Samples will be analyzed at the University of New Hampshire Water Quality Analysis Laboratory in Durham, NH, Jackson Estuarine Laboratory in Durham, NH, Nelson Analytical Laboratory in Kennebunkport, ME, and the City of Portsmouth Water Division Laboratory in Madbury, NH.


Figure A5-2. Proposed existing and new sampling sites in the Sagamore Creek watershed to be included in the synoptic sampling.

Sediment Study

Dr. Stephen Jones will assist with sediment sample collection and analysis at up to three sites (two in the upper estuary near original testing site locations and one just south of the Sagamore Creek island in a small cove influenced by medium-density residential development along Odiorne Point Rd and Gosport Road). Sediment samples will be analyzed for all contaminants that were part of the original impairment listing, including heavy metals, PAHs, PCBs, and VOCs, plus additional legacy or emerging contaminants as recommended by Dr. Stephen Jones of the Jackson Estuarine Laboratory, who has access to a dataset that would help identify contaminant parameters applicable to the region.

Investigative Water Quality Sampling

Based on results from the two-year baseline monitoring, several sites will be prioritized for more intensive investigative water quality sampling. The goal of this investigative water quality sampling will be to conduct a combination of upstream bracket sampling and land use investigations to pinpoint possible sources of pollutant contamination. Sampling will be conducted during either dry weather or wet weather or both and either low tide or high tide or both depending on when pollutants were elevated during the two-year baseline monitoring and whether a site is considered freshwater or estuarine. The bracket sampling will target not only flowing surface waters, but also stormwater through outfalls, connected catchbasins, and any discovered potential illicit discharges. Samples will be tested for the elevated pollutants of interest, along with standard YSI field meter readings for temperature, salinity, conductivity, pH, and dissolved oxygen. For any samples collected from stormwater outfalls, samples will also be tested for *E. coli* or Enterococci, ammonia, chlorine, and surfactants, along with any "pollutants of concern" to satisfy the 2017 New Hampshire Small MS4 General Permit requirements. Samples will be analyzed at the University of New Hampshire Water Quality Analysis Laboratory in Durham, NH, Jackson

Estuarine Laboratory in Durham, NH, Nelson Analytical Laboratory in Kennebunkport, ME, and the City of Portsmouth Water Division Laboratory in Madbury, NH. Specific recommendations for remediation and follow-up actions will be provided to the City.

### 2.2 Sampling Methods

Sampling methods and protocols will adhere to the following documents:

- 2018 Great Bay Estuary Water Quality Monitoring Program QAPP (on file with the Project Manager and PREP) – includes description of sample bottle preparation, decontamination, water sampling field procedures, and lab filtration and processing, along with a table that identifies sample volume, container size and type, preservation requirements, and maximum holding time for analytical parameters.
- National Estuarine Research Reserves System Wide Monitoring Program (on file with the Project Manager and PREP) – includes procedures on 24-hour automated sampling.
- FBE Internal SOPs for grab sampling (Attachment A) and datasondes (Attachment B)
- User manuals for field equipment (on file with the Project Manager and available online)
- USGS guidelines for datasonde maintenance, deployment, and QA/QC (http://pubs.usgs.gov/tm/2006/tm1D3/)
- National Coastal Condition Assessment protocols for sediment sample collection (on file with the Project Manager)

Samples will be collected during daylight hours only. The safety of the samplers will be taken into consideration as they may be at risk during severe weather conditions, including but not limited to lightning, high winds, and hurricanes. No sampling will occur if a severe weather alert is issued for the area. The Project Manager will monitor the National Weather Service for issuance of severe weather alerts.

Duplicate field measurements for all laboratory samples will be collected randomly on 10% of field samples, equating to about 12 duplicate samples or 1-2 duplicate samples per sampling event.

### 2.3 Sample Handling and Custody

Sample handling and custody procedures for field staff are described in the 2018 Great Bay Estuary Water Quality Monitoring Program QAPP and FBE internal protocols for bacteria sampling (Attachment A). Field staff, along with the Project Manager, will be responsible for having the samples delivered on ice in coolers to the laboratory within 6-24 hours of collection (depending on parameter) and within laboratory operating hours so that samples can be immediately processed and frozen by laboratory staff. Sediment samples will be collected in accordance with National Coastal Condition Assessment Program protocols, packaged on ice, and mailed overnight to the selected laboratory. All chain of custody (COC) forms provided by each laboratory will be filled out completely by field and laboratory staff. The UNH WQAL provides an electronic COC form; all other laboratories provide paper copies. Copies will be retained by the Project Manager.

Sampling handling and custody procedures for laboratory staff will follow SOPs identified for each laboratory in Section 1.7.

## 2.4 Analytical Methods

Analytical methods for each parameter are described in Table A5-3 and the SOPs identified for each laboratory in Section 1.7. Analytical methods for sediment samples are described in the National Coastal Condition Assessment Program QAPP, Appendix C, Section 5.5, p.86, and summarized in Table 25 therein.

Field analyses methods will include temperature, dissolved oxygen, conductivity, salinity, pH, turbidity, and/or water level measured by a YSI or similar field meter and/or datasonde that meet the data quality objectives identified in Table A5-4. Field meters and datasondes will be calibrated and maintained according to manual instructions (available online) and FBE internal SOP for datasondes (Attachment B).

## 2.5 Quality Control Requirements

The Project Manager will verify that field staff are following the protocols correctly during a field sampling audit. This will occur during the first sampling event at the beginning of each season. The Project Manager will observe the field scientist complete the sampling and verify that all protocols are being followed. Field forms will be thoroughly checked in the field for completeness by field staff. Field staff will enter data to Excel data files and submit data and COC forms to the Project QA Officer, who will check for adequate holding times, proper sampling handling, and completeness of data forms. Database entries will be checked for transcription errors and bad data using two methods. First, the entire data set will be checked against the entries in each field or laboratory data sheet by the Project QA Officer. Second, the Project QA Officer will construct box-plots and other graphical tools (such as residual plots) to determine if there are outliers in the data set. The Project QA Officer/Project Manager will determine whether any data that do not meet the data quality objectives should remain in the dataset or be discarded. Field duplicates will be collected to represent 10% of the samples and checked that they are meeting data quality objectives identified in Section 1.7.

Quality control for laboratory analyses will follow SOPs identified for each laboratory in Section 1.7. Laboratory managers will report any deviations in data quality objectives and quality control measures to the Project Manager.

## 2.6 Instrument/Equipment Testing, Inspection, and Maintenance

Laboratory instruments and equipment are inspected, maintained, and calibrated by the laboratory. The schedules and protocols for inspection and calibration of laboratory instruments will follow SOPs identified for each laboratory in Section 1.7.

Field measurement instruments (field meters and datasondes) will be calibrated, maintained, and inspected according to the manufacturer's specifications and FBE internal datasonde protocols (Attachment B). Datasondes will be maintained in the field every 2 to 4 weeks, depending on the rate of biofouling; this will consist of replacing the datasondes with freshly-calibrated sondes monthly with cleanings and calibrated field meter reference readings bi-weekly (or more frequently depending on environmental conditions and the discretion of the Project Manager).

## 2.7 Instrument/Equipment Calibration and Frequency

Laboratory instruments and equipment are inspected, maintained, and calibrated by the laboratory. The schedules and protocols for inspection and calibration of laboratory instruments will follow SOPs identified for each laboratory in Section 1.7.

Field measurement instruments (field meters and datasondes) will be calibrated, maintained, and inspected according to the manufacturer's specifications and FBE internal datasonde protocols (Attachment B). Datasondes will be maintained in the field every 2 to 4 weeks, depending on the rate of biofouling; this will consist of replacing the datasondes with freshly-calibrated sondes monthly with cleanings and calibrated field meter reference readings bi-weekly (or more frequently depending on environmental conditions and the discretion of the Project Manager).

## 2.8 Inspection/Acceptance Requirements for Supplies and Consumables

Inspection schedules for consumables for laboratories follow SOPs identified for each laboratory in Section 1.7.

In-situ monitoring supplies and consumables will be handled by the Project Manager and field staff. Consumables may include items such as membranes, cleaning fluids, standards, etc., and will only be accepted if they come from intact packages within the "use-by" date. Grab sampling materials, such as whirl-pak bags or bottles, will be inspected by field staff, and will only be accepted if they are intact. An inventory by the Project Manager of existing and needed supplies will be conducted prior to each field season, and ongoing inspection of supplies will be performed by field staff in preparation for each sampling event.

## 2.9 Data Acquisition Requirements (Non-Direct Measurements)

This project will use publicly-available local weather and tide forecasts to determine sample timing. No other non-direct measures are required.

Weather will be tracked using local weather stations. The Haymarket Square (KNHPORTS16) hourly weather history as provided by Weather Underground ([www.weatherunderground.com](http://www.weatherunderground.com)) will be considered representative for the sample area due to its proximity to sampling locations and real-time availability online (for determining sample timing). Land-based quality controlled weather data (for use in data analysis and reporting) will be obtained from NOAA NCDC Greenland, NH (GHCND:USC00273626) or Portsmouth 1.6 NE, NH (GHCND:US1NHRC0059).

Tides will be tracked using US Harbors for Portsmouth Harbor (https://nh.usharbors.com/monthly-tides/New%20Hampshire/Portsmouth%20Harbor).

### 2.10 Data Management

Field data will be recorded on standard field forms and transferred to Excel data files. Laboratory data will be transferred from laboratory data sheets to Excel spreadsheets. Protocols for detecting and correcting errors and preventing loss of data are described in Sections 1.7 and 2.5-2.8. All data will be stored electronically in Excel spreadsheets which will be provided to the Program Manager as part of the final report. NHDES will be responsible for uploading EMD-compatible data (submitted by the Project Manager) to the NHDES EMD. Management of hardcopy and electronic data and documents is described further in Section 1.9.

## 3.0 Assessment and Oversight

### 3.1 Assessments/Oversight and Response Actions

To confirm that field sampling, field analysis, and laboratory activities are occurring as planned, the Project Manager shall confer with field staff and lab managers at the beginning of each field season. Review of all field and data collection activities on the actual sampling day (or soon thereafter) will be the responsibility of field staff and the Project QA Officer. If adequate quality measures are not attained during a sampling event, then appropriate response actions, such as re-scheduling a sample day, will be taken. Protocols for detecting and correcting errors and preventing loss of data are described in Sections 1.7-1.8 and 2.5-2.8.

### 3.2 Reports to Management

The Project Manager will produce an annual report to the City of Portsmouth (Program Manager). The final work product will be a database containing quality assured laboratory and field results for each site on each date and an annual report summarizing data and describing any deviations from the protocols established in the QAPP. Data from the annual reports will be added to the NHDES EMD. Refer to Sections 1.9 and 2.10 for more information.

## 4.0 Data Review and Usability

### 4.1 Data Review, Verification, and Validation Requirements

The Project QA Officer will be responsible for a memorandum summarizing any deviations from the procedures in the QAPP and results of the QA/QC tests. The Project QA Officer will review all field data sheets and final computer data files for completeness and quality based on the criteria described in Section 1.7. The Project Manager will also *affirmatively* verify that the methods used for the study followed the procedures outlined in this QAPP. If questionable entries or data are encountered during the review process (see Quality Control methods in Section 2.5), the Project Manager will contact the appropriate personnel to determine their validity.

### 4.2 Verification and Validation Methods

The Project Manager will determine if deviations from the QAPP constitute data removal. Final decisions made regarding the usability of the data will be left to the Project Manager.

### 4.3 Reconciliation with User Requirements

The Project Manager will be responsible for reconciling the results from this project with the ultimate use of the data. Results that are qualified by the Project QA Officer/Project Manager may still be used if the limitations of the data are clearly reported to decision-makers in the yearly reports.

## 5.0 References

American Public Health Association (APHA). 1998. Standard Methods for the Examination of Water and Wastewater (20th Ed), 922B.6.c

Nelson Analytical Laboratory. Bacterial Analysis Standard Procedures – Quality Manual. October 8, 2013.

Nelson Analytical Laboratory. Quality System Procedure for Enterococci and *E. coli*.

## Attachment A: FBE Grab Sampling SOP

The following provides a standard sampling protocol for our water quality monitoring projects.

<u>For every project:</u>

- Field duplicates of bacteria samples should be taken every 10 samples or 10% of the entire sample set per year.

<u>Prior to sampling:</u>

- Check refractometer or YSI 85 calibration using distilled water.
- Check YSI ProODO percent DO saturation calibration (this can also be done in the field).

<u>Sample collection:</u>

- Label each whirlpak sample with the site ID, date, and time.
- Record information on a standard field data sheet and COC form.
- Samples should be collected along beaches or rivers where the water is about 3 feet deep and should be taken 6-8 inches below the surface in a single motion. For smaller streams, samples should be collected near the deepest part of the channel or mid-channel, if the deepest part is not obvious. If necessary, wade into the water carefully and slowly to minimize sediment suspension into the water column and collect the sample upstream of where you walked in from. The water must be deep enough to submerge the opening of the whirlpak or sample bottle below the surface of the water so as not to collect any surface particulates that may contain an excessive and unrepresentative number of bacteria.

  - If bottom particulate suspension is a concern, then it is acceptable to take a sample from the bank without wading into the water. This is typical for most sites that we encounter.
  - For areas with very low flow, a "fresh" syringe should be used to collect water and fill the whirlpak bag. The syringe should be rinsed three times and should not touch the whirlpak bag at all.
    - A "fresh" syringe is a new syringe that has been rinsed three times with distilled water prior to field work (unless the syringe was purchased with sterile certification), then rinsed three times again with sample water in the field. If the syringe has been used, it should be thoroughly rinsed with distilled water and dropped off to Nelson Analytical for sterilization in an autoclave. Nelson can take 5-6 syringes at a time.

- Using fresh gloves, fill the whirlpak or bottle to at least two-thirds full, being careful not to touch the opening of the container. Spin whirlpak bag away from you several times and secure yellow tabs. Secure cap on bottle. <u>The use of gloves is to protect the sampler from potentially-high bacteria counts and to prevent cross-contamination between samples.</u>
- Store samples upright in a cooler, being sure the samples do not touch the ice directly. One way of doing this is to line the bottom of a large cooler with plastic cups and fill the spaces around the cups with loose ice (depending on the amount of space). This will keep the samples within the required 0-10 °C. Taping the cups together would make it much easier. Ice must be loose around the cups to cool the samples quicker.
- Take field meter readings.
- Before taking a refractometer reading (if using), rinse the refractometer window three times with sample water using the pipette and wipe the window with a Kim wipe between each reading.
- Bacteria samples must be delivered to the laboratory within 6 hours of the first sample.
- Check for field data sheet completion and obtain a signed copy of the COC form from the laboratory.

<u>Post Sampling Procedures:</u>

- Upon return from the office either that day or the very next day, log all data from the field data sheet into an Excel spreadsheet or database for the project. Recheck that everything was completed fully and note any missing information.
- Field data sheets and COC forms should be scanned into the computer and loaded onto the FTP or other backup device and saved in the appropriate project folder. Hard copies of field data sheets and COC forms should be kept in the office in a properly labeled project folder. If an

electronic field form on a tablet was used, the extracted csv file should be stored in a raw data folder. Photos should be uploaded and labeled with site name and date.

Laboratory Results Analysis:

- Nelson Analytical provides lab duplicates for each sample set. Their QAPP specifies that low level duplicates (< 20 MPN/100mL) must be within a relative percent difference (RPD; see equation below) of ±25% and high-level duplicates (> 20 MPN/100mL) must be within ±10%. A similar method is typically also employed for field duplicates, which must be within ±20%.
  - This is generally not a practical measure of precision for biological samples. Lab or field duplicates will likely have a much greater range of difference due to the variability of biological communities, which are very different from more stable, chemical constituents. Nelson Analytical focuses their QA/QC efforts on annual checks between technicians for counting colonies within the same sample and being within 10% error of each other.
  - Lab duplicates should be used only to check the reasonable accuracy of the laboratory technique and variability of biota. Differences can be quite large (up to 200% or more) especially with lower values (<200 MPN/100mL). Higher values should be within 100% of each other or less. There is no set guideline for this. Use of professional judgment is recommended. The lab duplicate value should not be used in the actual data set for clients.
  - Field duplicates (to assess environmental and sampler variability) should be taken by the same sampler to reduce variability related to sample collection. If the same sampler was used, field duplicates can be averaged for a single day and serve as a single value for that site on that sample day.

$$\text{RPD} = \frac{\text{Sample Result} - \text{Duplicate Result}}{(\text{Sample Result} + \text{Duplicate Result})/2} \times 100$$

- The method detection limit (MDL) for Enterococci at Nelson Analytical is 1 col/100mL. The MDL for *E. coli* at Nelson Analytical is 1 col/100mL.

Annual Review

- Before the beginning of each field season, the methods outlined in this memo should be re-evaluated for relevancy and an updated version should be sent to all samplers for review. It may be beneficial to have a brief (15min) in-person review with all staff to ensure everyone understands their responsibilities.

## Attachment B: FBE Datasonde SOP and Data sheets

Supplies

- YSI 6-series sonde, plus probes.
- Data cable.
- Eco-watch software and a personal computer.
  - Alternative: field connection possible using a YSI 650 handheld and field cable.
  - Windows 7 users: "Ecowatch Lite" (request from YSI) can be made to work.
  - "Serial to USB" adapter cable if computer does not have a serial port (Gigaware cable by RadioShack is known to work).
- Calibration standards:
  - pH 7
  - pH 4 (substitute with pH 10 if stream is above this range of pH.)
  - SPC (1413 μS/cm for freshwater or 10 mS/cm for brackish)
- Calibration cup.
- Smaller calibration tube for conductivity probe. A centrifuge tube works well and cutting a notch out of the top will help it fit better over the probe.
- Two small sponges (approx. 1cm in diameter) to maintain humidity in calibration cup)
- Alkaline batteries (chose a high-quality brand; do not use rechargeables)
- Lint-free tissues (e.g., Kim-wipes®)
- Two squirt bottles for focused rinsing
- Small bottle brush for reaching inside conductivity probe (supplied by YSI)
- Mild, phosphate-free detergent
- YSI-approved grease for O-rings
- DEP-approved "hand-held" dissolved oxygen, temperature, and conductivity meter/probes (see MDEP 2010) for gathering additional, instantaneous field data when retrieving datasondes
- *Old-style DO membrane only: deionized or distilled water*
- *Turbidity probe only: Parafilm*

Required Reference Material

6-Series Multiparameter Water Quality Sondes User Manual. YSI, 2009 (or as revised)

http://www.ysi.com/media/pdfs/069300-YSI-6-Series-Manual-RevF.pdf

Calibration, Maintenance & Troubleshooting Tips for YSI 6-Series Sondes & Sensors. YSI, 2010 (or as revised).

http://www.ysi.com/media/pdfs/YSI-Calibration-Maintenance-Troubleshooting-Tips-6-Series-Sondes-2-8-10.pdf

Definitions

**Bail**: Wire loop at top of sonde.

Bulkhead: Data port at top of sonde. Covered by a waterproof cap when deployed.

Cal cup: Calibration cup, transparent plastic cup that screws onto sonde, used to protect the probes and immerse them in various solutions when calibrating.

DI water: Deionized water (distilled water also acceptable).

Eco-watch®: YSI software used to communicate with, calibrate, and download data from the sonde.

Probe: Small, interchangeable sensor attached to the bottom of the instrument. Probes are available for temperature/conductivity, pH, DO (membrane), DO (optical), and other parameters.

Probe guard: Opaque plastic cup with wide slots used to allow water to flow over the probes, while still protecting them, during field deployment. This guard is sometimes weighted, and sometimes fine mesh is attached to it for additional protection.

Sonde: The main body of the instrument, or the entire instrument. AKA, datasonde.

Notes on Deployment Locations and Systems

Sondes have important deployment needs, including:

1. Place the sonde in a location representative of stream conditions. Typically, this means the center half of the stream, where flow is greatest, about six inches from bottom of stream (will vary based on stream depth and practical installation constraints).
2. Protect the instrument from debris. If space allows, a PVC tube mounted vertically, affixed to a pole or pylon is a good option. A bolt through the lower portion of the tube keeps the sonde from falling through. Large holes at the level of the sonde guard are needed so water flows through the tube and over probes.
3. A fixed installation method allows for consistent depth readings, and more comparable data overall. Installation considerations:
    a. A metal signpost can be driven into soft substrate.
    b. Ledge or rocky bottoms may not allow a truly fixed location. A good alternative is a deployment cage (e.g., a weighted, low plastic crate) or PVC tube attached to a heavy block (cement with embedded re-bar and/or steel straps).
    c. In shallow streams one can put the sonde in a perforated PVC pipe for protection and lay it on the bottom tethered to a tree on shore with a good chain and brass lock.
    d. In deeper water, one can use a milk crate filled with rock ballast, especially when cement is too heavy to transport to the field site.
4. Protect from curiosity and/or vandalism. Choosing remote location, away from trails and traffic is usually the best approach. Sonde cables may be camouflaged by leaves, branches, etc. A

small tag attached to a cable can prevent tampering by those who are merely curious. Padlocks, locking wells, etc., may be necessary in high traffic areas.

5. Protected from loss during high flow. Whatever deployment system is used, it is wise to have a security cable or zinc-coated chain (with a lock) running to a tree or land-based anchor so the sonde will not wash away under storm conditions.

<u>Step by Step Guide to Using YSI 6-Series Sondes</u>

*NOTE: This SOP cannot take the place of the manufacturer's user manual. Users of YSI datasondes must take the time to read the manual before working independently and unsupervised with them.*

*NOTE: If using a membrane-style DO probe, you must start <u>the day before</u> (or up to three days before) deployment to allow for DO membrane burn-in. See YSI 6-Series User Manual for details.*

*NOTE: <u>SPC</u> and <u>temperature</u> are measured by a single combined probe. These two measurements <u>are used by many other probes as input coefficients</u>. If the temp/cond probe breaks, or SPC is calibrated wrong, it means all other parameters for that deployment will have to be deleted. Pay special attention to calibration of specific conductivity.*

<u>Calibration</u> (adapted from Section 2 of YSI 6-Series Manual, and NOAA National Estuarine Research Reserve System Wide Monitoring Program methods.)

1. Verify that sonde has been washed and stored properly. Verify that you are using a **non-brush wiper** for calibration. Do not use an Extended Deployment System combination brush + wiper during calibration because it interferes with readings.

2. Start personal computer and connect sonde. Open Ecowatch. Hit logger icon button in Ecowatch (resembles a firecracker) to connect to sonde. You should see a "#" prompt. Type "menu," then "2" for calibration menu
   *NOTE: the YSI 650 interface (with a high amount of memory) can be used instead of Ecowatch and personal computer. Refer to the YSI 6-series manual, most recent revision, for more detail.*

3. Calibration:
   *NOTE: Calibrate <u>conductivity first</u>, as it is the easiest to contaminate with other solutions. Also, do not try to calibrate in the field (another huge source of contamination.*
   *NOTE: if a new probe has been added to the logger, follow directions in the YSI 6-Series User Manual to ensure it is properly recognized by the sonde.*

   a. **Specific conductance:**

      i. Dry the probe off with a Kim-Wipe.

      ii. Rinse with conductivity solution 3 times (either dunk in fluid or use a squirt bottle). Fill calibration tube with fresh SpCond standard, submerge probe so that holes on probe are completely submerged. Tap tube gently to remove any trapped air bubbles.

*iii.* In Ecowatch, chose conductivity, and enter the value of the conductivity solution. (E.g., “1.413” mS/cm, which equals 1413 µS/cm). Wait 2-3 minutes until conductivity and temperature stabilize.
*NOTE: Do not re-use conductivity standard. You can save it for the post-deployment rinses if you want. SPC must be as accurate as possible, because salinity, pH, DO (mg/L) are calculated from this probe. Depth also depends on the temp/cond probe functioning.*

iv. Press enter to calibrate. Record pre and post calibration number. Rinse probe with tap water.

b. pH: Escape to main menu. Report/turn on “pH mV”. Do a two-point calibration. Start with pH 7. For freshwater deployment, follow with pH 4. (For brackish, saltwater, or alkaline freshwaters, substitute pH 10 instead). Record pre and post calibration pH, and post-calibration pH mV, and check that they are within the range shown on calibration sheet (below). After both calibrations, check that the difference between the mV at the two pH calibrations is in correct range of 165 - 180. When the sensor drops below 160 pH mV slope, it should be taken out of service.
Equation: *Slope = ph4mV − ph7mV*; OR Slope *= ph7mV − pH10mV*
NOTE: Step away from the probe when you calibrate. Some glass probes are jumpy if you are standing close to it, or if there are electric fields nearby.
NOTE: If you get the message “warning, out of range. Do you accept?” enter NO. To troubleshoot this, try:

i. typing in “uncal” when prompted for pH value, then recalibrating.

ii. follow the “pH Troubleshooting” section of YSI *Calibration, Maintenance, Troubleshooting Tips for 6-Series Sondes*.

iii. replace the probe.

c. Dissolved Oxygen (DO) optical probe (aka ROX probe):

i. See that the DO probe wiper is parked 180° from the optical window (dark circle) on the probe. If not, see manual and troubleshooting document. DO NOT rotate the wiper by hand, it is a delicate mechanism that breaks easily.

ii. Check that the wiper makes gentle contact with the probe. Adjust vertically with tiny allen wrench if necessary.

iii. **6600 sonde:** Make sure there is a little water (0.5 cm approx) in the bottom of the calibration cup. Thread the cup on the sonde as loosely as possible, just enough so it does not fall off. There must be air exchange between inside and outside the cal cup.

iv. **600OMS sonde:** There is no calibration cup, so either wrap a wet towel around the guard, or turn on the aerator in a bucket of tap water at least an hour before calibrating to ensure water at 100% saturation. Note that the little metal nub is the thermometer, and also needs to be submerged, therefore you need a tall narrow bucket.

v. Determine current barometric pressure using a weather website or barometer. (You will probably have to convert from inches to mm.) Should be somewhere around 750 – 785.

vi. Enter calibration menu, chose DO, chose 1-point % option, enter barometric pressure, and wait for DO and temperature readings to stabilize. Record pre- and post-cal DO figures. Note that post-calibration DO may be +/- 1% from 100%. This is normal.

4. **Calibrate Depth**: Chose calibrate/pressure: enter 0.0 m for depth (*note the units, the sonde might be feet*). Record pre- & post- cal numbers. Post-calibration number must be 0 ± 0.02 m, or data may be rejected.

5. Main menu/8-Advanced/1-Calibration constants.
   Write down the following values and make sure they are in correct range, as shown on calibration sheet (below). If data are not within correct range, data for that parameter may be rejected. DO NOT DEPLOY if Temp/SpCond probe does not meet all requirements.

   a. **Cond** (this is conductivity cell constant)

   b. **DO gain** (for DO optical and old-style)

6. Change wiper from normal wiper to EDS brush + wiper combination, if available.

7. Turn on the data loggers. Main menu/6-Report: make sure these parameters are selected:
   1-date
   2-time
   3-temp C
   4-specific conductivity mS/cm
   9-DO sat %
   A-DO mg/L
   B-DO chg [DO membrane probe only]
   D-depth meters

E-pH – *if attached*
H-battery volts

Turn off:
pH mV – if pH attached

8. Main menu/5-system
    a. Check DATE/TIME, time should be DAYLIGHT SAVING TIME.
    b. Page length = 0
9. Main menu/run/unattended sample
    a. Interval = 00:15:00 (or other, as appropriate)
    b. Start date = today's date, or known deployment date
    c. Start time = add one minute!, ex. 11:01:00, this prevents inconsistent formatting of midnight between Excel and YSI (00:00 vs 24:00).
    d. Duration = 365
    e. File name of eight characters = code + date (MMDDYY). For example: EM071510
    f. Check that free memory is sufficient (usually aim for 100+ days). If insufficient, you must delete all data from the sonde using main menu/file/… (no option to delete individual files).
10. Ensure battery volts sufficient: (>11.0 for 6600 series, fresh batteries for small sondes such as 600OMS).
11. Start logging
12. Cap the sonde hand-tight, grease the bulkhead cap very slightly on the o-ring. Avoid greasing the metal terminals. Periodically inspect o-ring for cracks. Replace as needed.
13. Transport the sonde in a secure manner to the sample site. Do not allow the probes to dry out, be exposed to direct sun, or experience temperature extremes. Recommended transportation method is to wrap the sonde guard in a light-colored, wet towel, then carry entire sonde in a bucket or cooler.

Post-Deployment Procedure

1. Retrieve sonde from field, transporting it carefully back to the lab. Avoid temperature extremes, probes drying out, etc. Use a cal cup or damp towel and bucket to protect the probes.
2. Cal cup: put two small sponges with a bit of water in a cal cup.

3. Rinse the probes in tap water. Wipe down with a lint-free tissue (e.g. Kimwipe®). Do not touch the sensor-end of the probes. (Thorough cleaning is performed later.)
4. For any probes that have an Extended Deployment System (EDS), take off the brush/wiper combination, and replace it with a regular wiper (no brush).
5. Put sonde in cal cup from step (1).
6. Record date/time/weather/other notes on calibration sheet.
7. If possible, retrieve instantaneous DO value of stream using a hand-held dissolved oxygen, temperature, and conductivity meter/probes:
8. Plug in datasonde to computer.
9. Open *EcoWatch*®, type in *menu*.
10. Run/unattended sample/(see that it's logging) stop logging/esc to main menu
11. Download files from the logger:
    a. File/upload/(chose the data file)/proceed/PC6000
12. View graph of data:
    a. From top menu: file/open. Navigate to the data file you just downloaded.
    b. Go to settings / parameters, and make sure all needed parameters are visible on graph.
    c. Conduct initial inspection for consistent, plausible data. Large discontinuities, or implausible trends in data (ex. DO which gradually drops to zero and never rebounds), should be noted. If a likely cause has been observed (ex. sonde was buried in sediment when retrieved; DO membrane punctured; etc.), note that, too.
    d. Close graph. Note on calibration sheet whether you think there were any errors.
13. Go to file/export and export the datafile into CDF file.
14. To convert to Excel:
    a. Open excel.
    b. Got to file/open (or hit ctrl+O). Set file type as "all files." Navigate to CDF file.
    c. When import wizard opens, check "comma" as delimiter, and click through.
15. Immediately save the data file to a backup location (e.g., FTP)
16. Main menu/system/page length/25/esc to main menu.

17. Run/discreet mode/start sampling. All values should be within the sum of manufacturer's sensor accuracy and calibration standard accuracy (See YSI *6-Series User Manual*, Appendix O). Discrepancies should be noted and require the data to be flagged.
    b. Write down battery charge.
    c. Check that cal cup is loose and contains calibration sponges and a few millimeters of water on bottom. DO optical probe: Look at DO% once readings have stabilized.
    d. Depth: use empty cup, should read close to zero (will vary depending on changes to barometric pressure since deployment).
    e. Conductivity: wipe off the probe with tissue to remove the bulk of algae, rinse once with used conductivity solution, then immerse in conductivity solution. In Ecowatch, chose conductivity, and enter the value of the conductivity solution. (E.g., "1.413" mS/cm, which equals 1413 μS/cm). Wait 2-3 minutes until conductivity and temperature stabilize. Press enter to calibrate. Record pre and post calibration number. Rinse probe with tap water.
    f. pH: use 7.0 soln only, wait a couple of minutes before taking reading.
18. Wash sonde, probe tubes and sensors with mild phosphate-free soap and water. Don't touch sensors directly with brush. Clean temp and SPC holes with brush (insert and remove three times, on third time turn brush fully). Take off wiper and clean with a lint-free tissue. Store sonde with two sponges and a few millimeters of water in bottom of cal cup. Screw on cal cup all the way, but do not make it tight (they are very hard to get off!).

To change or add a probe, refer to the YSI 6-Series Manual, section 2.

To troubleshoot calibration and other issues, see YSI 6-Series Manual, section 6.

<u>Data Validation and Management</u>

Data validation requires inspection of the data. Do this soon after you collect your data, so you can fix any problems before future deployments.

1. Compare your deployment and retrieval data from the VRMP-approved "hand-held" meter/ probes to your first and last datasonde readings. Are they close? Especially important are temperature and conductivity, because many other parameters are calculated from these. These readings should be within 10% of each other. Differences may be attributable to difference in time between handheld and sonde readings, sensor drift, allowable variation within each instruments' rated accuracies. The handheld readings are to be used as helpful tool to assess sonde functionality at retrieval, and not to set strict quantitative limits that trigger data rejection.

2. Inspect the data for obvious discontinuities, missing data periods, outliers (data outside of the expected range). Inspect the sonde for possible causes. For example, if the DO rapidly declines to zero with the datasonde, while the handheld meter shows higher DO at retrieval, this could indicate a punctured DO membrane. Low battery voltage can also cause missing or erratic readings.
3. Once you have data from multiple deployments, check for continuity between deployments. Variability which falls within the rated accuracy of the probes is acceptable. Variability outside of this range should be flagged.

References

Maine Department of Environmental Protection (MDEP or DEP). 2010. Quality Assurance Project Plan Framework for Water Resource Professionals Monitoring Impaired Streams in Maine (2010-2015) (a.k.a. Framework for Impaired Stream QAPPs [FISQ]). Prepared by Jeff Varricchione, MDEP, Portland, Maine. http://www.maine.gov/dep/blwq/docstream/vrmp/qapp/index.htm

# Water Quality Monitoring Calibration Log

File Name: ______________________

## Maintenance

Date of Calibration ______________ Technician(s) __________________

| | | | | | |
|---|---|---|---|---|---|
| Turbidity Wiper Replaced? | Y N | Wiper parks 180° from optics? | Y N | | |
| Chlorophyll Wiper Replaced? | Y N | Wiper parks 180° from optics? | Y N | | |
| Replace Batteries? | Y N | Replace DO membrane? | Y N | | |
| | | Membrane Integrity Test | ________ initial | | |

Sonde Number:

Comments:

## Pre / Post –Deployment Calibration: (turn on pH mV and DO Chrg in Report menu)

| | Pre-Deployment | | | | | Post-Deployment |
|---|---|---|---|---|---|---|
| | Pre-Calib | At Calib | Error | Sensor Diagnostics | | |
| %DO @ 100% sat | % | % | Y or N | DO Chrg (range 25-75) | | % |
| Baro Press (mm) | mm | | | DO Gain (0.8-1.7) | Adv menu | DO chg |
| | | | | DO Warm Up Test (Hi/Low) | P or F | |
| Depth (m) | m | M | Y or N | | | m |
| Sp Cond (mS/cm) | mS/cm | mS/cm | Y or N | Cell Const (4.6-5.45) | Adv menu | mS/cm |
| pH @ Buffer 7____ | | | Y or N | pH 7 (0 ± 50 mV) | | pH |
| pH @ Buffer 10___ | | | Y or N | pH 10 (-180 ± 50 mV) | | |
| pH @ Buffer 4____ | | | Y or N | pH 4 (+180 ± 50 mV) | | |
| Calculate pH Slope | → | | | pH slope (165-180) | | |
| Turb @ _____NTU | NTU | NTU | Y or N | | | NTU |
| Turb @ ____ NTU | NTU | NTU | Y or N | | | |
| Chl @ ____ µg/L | µg/L | µg/L | Y or N | | | µg/L |
| Battery Voltage remove ext. power -650, 6038 | V | | | | | V |

## Programming:

| | | | | | |
|---|---|---|---|---|---|
| Interval | 30 min | Set Clock (Status) | Y N | Start Time | ________ |
| Duration | 365 days | Start Date | ________ | Free Mem | days |
| Deleted data from sonde? | Y N | Parameters | Date, Time, T°C, SpCon, Sal, DO%, mg/L, Depth, pH Turb, Chl, Batt | | |

Water Quality Monitoring Calibration Log

**File Name:** ____________________________

## Deployment Information:

Date Deployed ______________ Time ____________ Std Time White towel? Y or N

### Field Data

$H_2O$ Temp ____________ °C DO % ____________ %

Salinity ____________ ppt DO mg/L ____________ mg/L

Comments

## Infield Maintenance: note any changes to site during deployment, sonde (e.g., sonde tube cleaning, etc.)

Date ________ Duration ________ Maintenance ____________________

Comments

## Retrieval Information:

Date Retrieved ______________ Time ____________ Std Time White towel Y or N

### Field Data

$H_2O$ Temp ____________ °C DO % ____________ %

Salinity ____________ ppt DO mg/L ____________ mg/L

## Fouling Presence: (record type of fouling and amount — e.g., A, B, E / H)

Type: A=algae, B=barnacles, C=crabs, E=eggs, F=fish, O=other, N=none / Amount: H=heavy, M=moderate, L=light, N=none

Sonde/Guard ____________ External Screen ____________ Temp/Cond ____________

DO probe ____________ pH probe ____________ Turbidity ____________

Chlorophyll ____________

Comments

## File Retrieval:

EcoWatch filename ____________ .csv, .dat View Graph? Y or N Any Probe Malfunction? Y or N