APPENDIX A. TOPICAL WHITE PAPERS

At the outset of this project, the project team worked to understand and describe the existing conditions within the watershed in order to provide a basis of collective understanding from which to develop the plan. These documents evolved into topical white papers, which were used to record notes, understanding and information among the project team during the watershed planning project. These topical white papers are not intended to be entirely complete and exhaustive reviews of key elements of the watershed, but rather as working documents that can be updated and augmented in the future as conditions change and actions are undertaken. They are provided here to help readers understand the watershed in more detail.

The topics covered in the white papers are as follows:

Flooding and Flood Management
Drinking Water Supply
Water Quality
Ecology
Land Development
Public Stewardship and Culture of Watershed Protection
Recreational Access

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

FLOODING AND FLOOD MANAGEMENT

CURRENT CONDITIONS IN THE WATERSHED

Overview: Flooding Concerns and Mapped Flood Risk

The Assawompset Ponds Complex (APC) and Nemasket River Watershed has several characteristics—natural and anthropogenic—that make it prone to flooding. Natural factors include topography, depth to groundwater, soils, and natural climatic variability (Figure 1 and Figure 2). Anthropogenic factors include development patterns, infrastructure locations, installed barriers to hydrologic connectivity, and climate change. In general, flooding becomes a problem when it has negative impacts on human uses of land, structures, and infrastructure; otherwise, it is simply a natural periodic inundation of the land. Temporary increases in water levels following storms or particularly wet years are not a concern in undeveloped areas. Historically, APC flooding has resulted from a variety of events and conditions including hurricanes, snow melt on top of spring rains, and thunderstorms in the summer (Federal Emergency Management Agency [FEMA], 2020). In general, stakeholders around the APC have focused flooding concerns on Long Pond and other developed areas that have experienced historic flooding (see Historic and Recent Floods section below), as well as areas that have mapped or perceived flood risks.

In terms of natural features, the watershed's topography is relatively flat. The Nemasket River drops only 39 feet over its 11.2-mile course from the Assawompset Dam to the Taunton River junction (The Pilgrim Resource Conservation and Development Area, 1980). This topography, exacerbated by excessive aquatic vegetation and hydrological disjuncture from dams and other infrastructure, makes the watershed slow to drain, which can cause a build-up of water during and after precipitation events and lead to flooding. U.S. Geological Survey surficial geologic mapping (Figure 1) indicates that the area surrounding the APC is approximately 75% coarse glacial deposits of relatively high permeability. This indicates that flooding concerns in the area are less likely to be exacerbated by slow infiltration of rain than they are by flat topography, shallow depth to groundwater (Figure 2), and the various human factors discussed below. The area immediately surrounding Long Pond is characterized by a lower percentage of coarse glacial deposits than the APC area as a whole. The area around Long Pond is mapped as approximately 50-60% low permeability till deposits or bedrock. The geologic setting around Long Pond is, therefore, characterized by slower infiltration of precipitation to the subsurface and is more prone to generate runoff during storm events (U.S. Geological Survey [USGS], 2018a, 2018b).

Human alterations in the watershed have impacted flood risk as well, particularly related to dams, infrastructure, and sedimentation. The Nemasket River originates at the outlet from Assawompset Pond, which was dammed for water supply purposes in the late 19th century. Approximately three miles downstream, another dam restricts Nemasket River flows at Wareham Street[1] in Middleborough. Additional dams downstream of the Wareham Street Dam include the Oliver Mill Pond Dam on the Nemasket River at Nemasket Street in Middleborough and the two dams on the Pratt Farm Property on an unnamed Nemasket River tributary near Route 105 in Middleborough, one of which was considered a Significant Hazard by Pare's 2020 Emergency Action Plan (FEMA, 2016; Pare Corporation [Pare], 2020b, 2020a) (Figure 3).

[1] This dam is also referred to as the Bascule Dam or the Nemasket Park Dam.

Information on the Wareham Street Dam and Assawompset Dam is included below from available dam inspection reports. At the time of writing, equivalent information is not available to the authors about the other dams in the watershed.

The Assawompset Dam is owned by the City of Taunton and under the care of the Department of Public Works Water Division. It was constructed in 1894 for water supply purposes, with a concrete fish ladder added in 1968. It has earthen embankments on either side of a spillway and is approximately 900' long on the west side and 1,900' long on the east side. The embankment's design height averages 5'. The Assawompset Dam is classified as "Large" size. Its drainage area (i.e., extent of land where water that collects eventually reaches the dam through runoff, streams, ponds, and other features) is approximately 38.1 square miles, with 19.4 square miles draining to Long Pond, 10.6 square miles draining into Great Quittacas Pond (not including Little Quittacas Pond), and 8.1 square miles draining directly into Assawompset Pond. The normal pool storage volume is 50,000 acre-feet, and the maximum storage volume is 70,000 acre-feet. The dam's spillway design flood (SDF) is the 500-year precipitation event. The dam's spillway capacity is 510 cubic feet per second (cfs), with part of the embankment serving as an auxiliary spillway with an additional capacity of 97 cfs. A 2004 study recommended that with upgrades to the embankment, the total peak discharge through the dam would be 440 cfs with 0.8' of freeboard at the lowest point and 1' of freeboard for most of the dam (CDM, 2006). A Supervisory Control and Data Acquisition (commonly referred to as SCADA) system at the Taunton Water Treatment Plan monitors elevations through a computer interface and stacked wooden board stoplogs are manually utilized to adjust elevations as needed (CDM, 2006). There is no automation for the dam at this time.

A 2006 inspection report conducted by CDM noted that the dam was in "fair" condition at that time. The report had two major recommendations (2006):

- Develop and implement an Operations and Maintenance Plan for the dam.
- Develop an Emergency Action Plan that includes an Emergency Early Warning System or rehabilitate the auxiliary spillway on the Middleborough side of the structure.

Dam Safety Regulations categorize this structure as Large in size due to its height and storage capacity. The dam was previously categorized as a Class II or Significant hazard dam, meaning the dam is "located where failure may cause loss of life and damage to home(s), industrial or commercial facilities, secondary highway(s) or railroad(s) or cause interruption of use or service of relatively important facilities" (Massachusetts Department of Conservation and Recreation, 2017, p. 10). For Significant Hazard Potential (Class II)" dams, an Emergency Action Plan (EAP) is required under state regulations. In April 2012, the Massachusetts Department of Conservation and Recreation (DCR) Office of Dam Safety (ODS) approved an application to Change Hazard Classification of this Dam submitted by CDM-Smith in a request dated March 20, 2012. As a result, the Hazard Classification was changed from Significant to Low Hazard. According to the ODS letter, the 2012 report presented a dam failure assessment including downstream conditions and CDM's conclusion that a failure of the dam would not result in any appreciable increase in downstream flooding (Town of Middleborough, 2015).

The Wareham Street Dam is owned by the Town of Middleborough. Originally constructed as a hydroelectric power source, it was reconstructed in 1964 and currently serves flood control purposes. It is approximately 340' long, 23' high, and has a hydraulic height of 15'(Pare, 2020b). Because of its size,

location, and potential hazard, it is classified as “Intermediate” size and “Significant Hazard Potential (Class II)” under state standards. The dam’s drainage area is approximately 62.3 square miles, and it has a maximum storage capacity of 400 acre-feet. The dam’s SDF is the 100-year precipitation event, with an associated peak flow of 1,215 cfs and 2.4’ of freeboard at peak water surface elevation (Pare, 2020b).

A 2020 draft inspection report for the dam indicated that it was in “fair” and “satisfactory” condition. The report recommended additional studies, maintenance, and minor repairs, noting that there is no formalized operations and maintenance plan for the dam, although the Town of Middleborough Department of Public Works conducts routine maintenance (Pare, 2020b). There is a detailed Emergency Action Plan (EAP) for the dam, developed in 2020. The EAP reviewed which areas downstream of the dam, including roads and structures, would be subject to flooding during 100-year storm events; the EAP also reviews which additional areas would be impacted in the event of a dam failure (Pare, 2020a; FEMA, 2016).

In addition to these dams, there are also gatehouses between Little Quittacas Pond and Great Quittacas Pond and between Pocksha Pond and Great Quittacas Pond that are used to control water levels, mostly for water supply purposes. The pump house between Pocksha and Great Quittacas has a pipe and meter on it to determine how many gallons New Bedford is taking from Pocksha into Great Quittacas (APC Management Plan Steering Committee discussion, 2022). The gatehouses between Little Quittacas and Great Quittacas also serve flood control purposes (FEMA, 2016).

As described in the Drinking Water Supply white paper, the dam at Assawompset Pond was not designed for flood protection. Instead, the role of Assawompset Pond as a water supply reservoir means that the Assawompset Dam is operated primarily to maintain water storage within the APC. That operational priority causes concerns among some watershed stakeholders that maintaining such water levels—with infrastructure that cannot be readily adjusted to drain excess water from the ponds during periods of high water—exacerbates flooding risk. Recently, a lack of information and communication may also be contributing to perceived flood risk in pondside neighborhoods. In previous time periods, Taunton has recorded pond water levels and reported these findings to Lakeville, Freetown, and Middleborough for posting on their municipal websites. This practice has recently become less consistent, leading to confusion about where residents can go for this information and creating an additional unknown that can raise anxiety. Currently, there is no automated water level reader that could populate a database or website independently of manual data entry and export. Each additional step in this data reporting process represents a point at which it is vulnerable to breakdown.

Undersized culverts and other aging infrastructure restrict flows and further complicate flooding risks (Figure 3). In addition, increased sedimentation—largely driven by development and impoundment of river levels by dams and undersized road crossings—and excessive aquatic vegetation have been documented to exacerbate flooding risks in the APC and Nemasket River Watershed by reducing the flood storage and flow capacity of waterbodies, especially the Nemasket River (Truesdale, 2011). These issues have been documented as particularly problematic in the area immediately downstream of the Assawompset Dam and Vaughan Street, with additional critical areas of sedimentation identified around major developed areas and roads, such as Interstate 495 (Truesdale, 2011). Because of these flow conveyance issues and restrictions, previous studies have concluded that “the Nemasket River cannot be relied upon for a rapid decrease in pond elevation” (Assawompset Pond Level and Dam Committee, 2011). An on-going study is currently examining the extent to which dam and bridge infrastructure in the

Nemasket River contribute to constricting water flow and elevating water levels upstream at the APC dam.

More broadly, the APC and Nemasket Watershed has been highly altered by human development activities over centuries. Additional impervious cover in the form of buildings, pavement and other compacted lands increases the quantity and velocity of floodwaters and reduces flood storage capacity, as described further in the Land Development white paper. In many areas, development has encroached upon areas of flood risk. FEMA Flood Insurance Rate Maps (FIRMs) are one tool that document such risk, and the watershed's FIRMs show many areas with development in 100- and 500-year floodplains (Figure 4). In addition, roads and other infrastructure cross the regulated floodways depicted on FEMA FIRMs for the watershed, causing further constrictions. These FEMA maps likely underestimate flood risk in the APC and Nemasket Watershed, as evidenced by recent experience, such as the 2010 floods, during which areas not mapped for flood risk also experienced flooding (Figure 5). Designed for insurance purposes, FEMA maps are generally based on historic conditions and modeling, with limited field studies of local conditions or future projections, such as those related to climate change. Even though FIRMs for areas within the APC and Nemasket Watershed were updated in 2012, 2015, or 2021, many of these limitations persist. Therefore, the absolute values of published FEMA mapping, flood elevations, and flow rates should be considered within the context of these limitations during planning endeavors like this one.

More specifically, FEMA's Assawompset Pond hydrologic and hydraulic analyses are based on regression equations and modeling Assawompset Pond, Long Pond, and the Nemasket River as a "continuous system" (FEMA, 2016). Further, Great Quittacas Pond's elevations were based on Pocksha Pond and not modeled directly. FEMA states (2016):

> "Flood elevations shown on the FIRM are primarily intended for flood insurance rating purposes. For construction and/or floodplain management purposes, users are cautioned to use the flood elevation data presented in this [Flood Insurance Study (FIS)] Report in conjunction with the data shown on the FIRM. The hydraulic analyses for this FIS were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail." (p. 68)

Summaries of FEMA Flood Insurance Study (FIS) Modeled Nemasket River Discharges and Modeled Stillwater elevations are included in Table 1 and Table 2, respectively.

Historic and Recent Floods

Historic and recent flood events have borne out this flood risk. FEMA flood studies note that, historically, the Town of Lakeville has experienced little flood damage due to the large storage capacity available in the APC and associated ponds and wetlands, with a few key exceptions in areas adjacent to the ponds. On Long Pond, Buena Vista Shores has experienced flooding; less severe recurring flooding has also occurred at Huckleberry Shores, Nelson Shore, Churchill Shores, and other developed areas along the heavily populated shores of the pond. Areas along Assawompset Pond and in Staples Shore, Pine Bluffs, and Indian Shore have also been affected by flooding (FEMA, 2016).

In particular, a series of heavy rains during periods of early spring snowmelt led to substantial flood events in 1968 and 2010.

1968 Floods

In Middleborough, two storms in March of 1968 caused extensive flooding damage, with monthly rainfall totals as high as 7-12 inches across southeastern Massachusetts and Rhode Island. On top of the rainfall, snowmelt runoff and the timing before the beginning of the growing season exacerbated the flooding. As a result of these storms, many 24-hour precipitation records were established in the region. The Wading and Taunton Rivers reached peak flows exceeding the 50-year recurrence intervals (FEMA 2016, 2020; Rostvedt, 1972). The Wading River in nearby Norton reached a flood stage of 11.5 feet, making the 1968 flood the flood of record at the time (National Weather Service, n.d.).

In Middleborough, most of the 1968 flooding damage was along the Taunton and Nemasket Rivers, with low-lying areas inundated. The Nemasket River overtopped Plymouth Street, causing minor damage; a small unnamed Nemasket tributary washed out Precinct Street and caused minor damage to Summer Street; and the Purchade Brook tributary to the Nemasket River caved in a stone culvert at Cross Street.

2010 Floods

In 2010, from mid-February through the end of March, three primary storms dropped 17-23 inches of rain in the APC area (FEMA, 2020). The rainfall was exacerbated by seasonal low evaporation leading to record water depths in the Taunton River and upstream waterbodies, including the Nemasket River and APC (FEMA, 2016).

Across the whole Nemasket River, 23 high-water marks across 10 locations were established during these floods (USGS, 2011). APC pond elevations reached a peak of 57.3’ (NGVD 88), more than two feet above the base flood elevation of 55’ and nearly reaching the 500-year flood mark in Table 2 above (USGS, 2011; FEMA 2020; SRPEDD, 2011).

The majority of homes and other structures damaged or otherwise impacted by the 2010 floods were those immediately surrounding the APC or its upstream tributaries. Nemasket River flooding in 2010 did affect some homes and structures but especially impacted roads in Lakeville and Middleborough, which become impassable. In Lakeville, homes on the shore of the APC along Staples Shore Road and Clark Shores neighborhoods were particularly affected by flooding, and Route 18 was closed for several weeks along Assawompset Pond. On the border of Lakeville and Middleborough, the I-495/Route 105 highway ramps were inundated due to flooding of the Nemasket River (FEMA, 2016; Gazette Staff, 2016; Littlefield, 2010; MapGeo, n.d.). In Middleborough, the Nemasket River overtopped Plymouth Street and a sink hole developed at Murdock Street. Nemasket River tributary, Fall Brook, overtopped Wood Street, and the Beaver Dam Brook tributary washed out the Summer Street culvert. Purchade Brook in Woloski Park and Poquoy Brook at Vernon Street, tributaries to the Taunton River, were overtopped. An unnamed tributary to Assawompset Pond also overtopped Walnut Street, and the Pratt Farm Dam was breached. In Freetown, APC flooding impacted homes in the Lafayette Park, Heaven Heights, and Hemlock Point neighborhoods. Flooding of Fall Brook, a tributary to Long Pond[2], resulted in Route 140 flooding near Chace Road.

[2] Note that there are two Fall Brooks in the watershed area–a Fall Brook that is a tributary to Long Pond, and a Fall Brook that is a tributary to the Nemasket River (the latter is referenced extensively in the Ecology white paper).

Figures 5 & 6 show flood impact areas and road closures associated with the 2010 floods. The map was created based on interviews with Freetown and Middleborough staff and is therefore only a partial representation of the total flooding impacts. Table 3 lists flood-prone areas by town.

Local Flood Planning and Studies

Following the 2010 flooding, the towns in the APC undertook additional planning efforts related to flood risk.

Middleborough conducted hazard mitigation planning that included an assessment of areas vulnerable to flooding and completed its Hazard Mitigation Plan in 2015. Middleborough expects to begin an update to this Plan in August 2022. In the 2015 plan, however, several primary areas of local flood risk were identified within the APC and Nemasket Watershed (Town of Middleborough [Middleborough], 2015):

- Downstream of Wareham Street and the Wareham Street Dam, particularly homes on Montello Street, the East Main Street wastewater pumping station, Oliver Mill Park, the East Grove Street Well and Treatment Plant, and the Middleborough Wastewater Treatment Plant off of Everett Street.
- Downstream of the Pratt Farm Dams, particularly East Main Street (Route 105) and homes along East Main Street, Montello Street, and Sachem Street.
- Downstream of the Marion Road Cranberry Reservoir Dam, particularly Marion Road and nearby New Bedford Water Supply property.

At the time of writing, Lakeville is in the process of drafting its first town-specific hazard mitigation plan (Town of Lakeville [Lakeville], 2021), as an update to the 2004 Regional Hazard Mitigation Plan that covered the Southeastern Regional Planning & Economic District's (SRPEDD) region in southeastern Massachusetts (SRPEDD, 2004). Freetown does not have a hazard mitigation plan, although the town does include 2013 and 2014 Assawompset Pond levels data on its emergency management webpage (Town of Freetown [Freetown], n.d. a). Rochester's 2005 hazard mitigation plan expired in 2010 (Massachusetts Emergency Management Agency, 2021).

In 2019, all four municipalities completed Municipal Vulnerability Preparedness (MVP) workshops, further identifying local flooding and drainage issues. In all four municipalities, MVP workshops and associated reports identified flooding as a top priority and highlighted areas vulnerable to flooding (in addition to the aforementioned locations):

- Middleborough: The MVP workshop and report emphasized groundwater and undersized infrastructure that exacerbate flooding. In particular, the MVP efforts mentioned threats to Middleborough's wastewater infrastructure from Nemasket River flooding. Flooding concerns were highlighted in the context of increasing development and loss of wetlands in town. A series of priority recommendations covered studying culverts, wastewater treatment facilities, and town center drainage issues, as well as broader APC planning. The Wareham Street Dam, Thomas Street Culvert, and Woods Pond Dam were all identified as potential sources of flooding, along with transportation infrastructure flood risks and flood risks to town properties (e.g., library, Pratt Farm, Oliver Mill Park, Oliver House) (Middleborough, 2019).
- Lakeville: Flooding was highlighted as "a primary concern" during the MVP process, especially in the context of shorefront property damage, road closures, and water quality concerns. The

workshop and associated report highlighted the 2010 Nemasket River flooding and APC residential development in the recent decades. Top priorities included planning around the Nemasket River and APC (e.g., Integrated Water Resources Management), culvert assessment, and flood-related property acquisitions. Several culverts were identified, including along Route 105/Snake River, Taunton Street (Poquoy Brook), Cross Street, Pickens Street, Route 18, Pierce Avenue (at Bittersweet Road), and Country Road by the Eagles Building. Highland Road, Bedford Street, Taunton Street, and Cross Street were identified as frequently inundated roadways. Additionally, Captain's Way, Freetown Street, Country Road, Riverside Drive, and Old Powder House were noted as having issues related to drainage (Lakeville, 2019).

- Freetown: The MVP workshop and report described "increased stress due to increased flooding," highlighting "the need for improved management of Long Pond/Assawompset Pond Complex for flood control and water quality." More specifically, the report called for improved management and regional approach(es) across towns, and additional education and monitoring. The Chipaway Road culvert on Fall Brook was identified as causing frequent localized flooding (Freetown, 2019).
- Rochester: Flooding was highlighted as a resilience concern, especially in the context of control of water resources by external parties (i.e., Town of Marion and City of New Bedford water suppliers). Vulnerable infrastructure—including dams, roads, and culverts—were also identified, although specific examples from the report are all located outside the APC and Nemasket Watershed (Rochester, 2019).

Regional efforts have also sought to address flooding issues. In 2011, a cooperative agreement was proposed among watershed stakeholders that would balance watershed needs (e.g., water supply, recreation) with flooding risk and established desired pond elevations to accommodate precipitation events, while preventing or minimizing flood damage (Assawompset Pond Level and Dam Committee, 2011). That proposed agreement included the following desired pond elevations in the APC:

- December to approximately mid-March: 53.0'
- Mid-March to early June: increase from 53.0' to 54.0'
- Early June through September: gradual drop from 54.0' to 53.5'
- October and November: decrease from 53.5' to 53.0'

In 2014, these target levels were adjusted by the City of Taunton on the basis of work performed by the Federal Emergency Management Agency and the U.S. Geological Survey in a flood hazard map update that also provided local towns and water departments with reference elevations in one consistent vertical datum from which water levels could be measured (Schwartz, 2013). Prior to this time, Taunton had measured levels based on the National Geodetic Vertical Datum 1929. This study enabled a shift to the North American Vertical Datum 1988 (NAVD 88). As of this writing, the water suppliers use the following target elevations (NAVD 88):

- January and February to March 1: 51.32'
- April 1: 51.82'
- May 1: 52.82'
- June 1 and July 1: 51.82'
- September, October, November and December: 51.32'

SRPEDD's subsequent 2018 Floodplain Management Program Project convened the APC Management Team and stakeholders to review and synthesize previous APC floodwater recommendations, going back to 1980 (SRPEDD, n.d. a). That project also suggested additional or alternative mitigation measures, integrating nature-based solutions, green infrastructure solutions, and improved inter-jurisdictional coordination

In total, the group recorded 140 recommendations, with 48 specific to floodwater management, and 26 of those 48 identified as high priority. From that list, the project's Steering Committee determined six top priority actions and provided further details on implementation. The six priority action items are as follows:

- Hydrological and Hydraulic Study
- APC and Nemasket Watershed Management Plan
- Snake River Culvert Replacement
- Study and Plan to address Sedimentation Issue
- Upgrade/Replace Assawompset Pond Dam
- Prioritize Wetland Restoration Areas

Municipal Flood Regulations

The Towns of Lakeville, Rochester, and Middleborough all include floodplain district regulations within their Zoning Bylaws; the Town of Freetown does not regulate floodplain development through zoning but does require developments within the 100-year floodplain to acquire permits through their Conservation Department (Lakeville, 2021; Rochester, 2020; Middleborough, 2015). Lakeville, Rochester, and Middleborough permit the following activities within the 100-year floodplain: agriculture; forestry and nursery; conservation of water, plants, and wildlife; outdoor recreation uses; wildlife management and trails; temporary non-residential structures; and buildings built prior to the introduction of zoning regulations (Lakeville, 2021; Rochester, 2020; Middleborough, 2015). Middleborough also allows residential uses such as lawns, gardens, parking areas, and storage structures (Middleborough, 2015). In Rochester, special permits may be granted for other types of buildings and structures to be built within the floodplain so long as there is no loss of flood storage area (Rochester, 2020; MapGeo, n.d.; Freetown, n.d. b).

SUMMARY OF THREATS A CHALLENGES TO A HEALTHY, FUNCTIONING SYSTEM

- Existing and increasing flood risk due to climate change and increased impervious cover from development threatens infrastructure and other human development, especially adjacent to the APC and Nemasket River. Transportation, wastewater treatment and water supply infrastructure, and residential development are particularly at risk.
- Water supply interests and coordination gaps pose additional concerns about flood risk and contribute to ecosystem stressors, particularly when mechanisms for reporting pond levels to the public are interrupted.
- Aging and restrictive infrastructure such as dams and undersized culverts exacerbate flood risks and contribute to ecosystem stressors.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes.

The implications of these anticipated changes are considered below.

More frequent and intense storm events:

- Events like the 1968 and 2010 floods will likely become more common. Ongoing consideration is being given to whether the current definition of the storm with a one-in-one-hundred-year probability (the 100-year storm) is in fact, underreporting the likelihood of events with this magnitude (i.e., the 100-year storm may actually be the 50-year storm as climate change occurs). Such events pose increased risk for the aging and, in some cases, undersized infrastructure described earlier (e.g., culverts and dams). Undersized culverts and dam overtopping—or even failure—are of particular concern in this context.
- The continued shift towards heavy precipitation events will increase the threat of flooding, especially flash flooding. This problem will likely worsen as urbanization continues and impervious surface area in the watershed increases.

Increasing total precipitation:

- Increasing total annual precipitation will change the water budget in the watershed and result in the need to revisit assumptions about water storage capacity of the ponds and flood hazard.
- As with increases in heavy precipitation events, increased total precipitation may make events like the 1968 and 2010 floods more common because the intensity of those events was driven in part by extreme precipitation occurring on top of large amounts of total springtime precipitation. Additional study and modeling of groundwater flows in the watershed can help to evaluate this hypothesis.
- Changes in precipitation quantity and timing will also likely require broader redesigns and sizing of existing and new infrastructure, as design standards based on historic conditions become obsolete. As with increased heavy precipitation, undersized culverts, and dam overtopping—or even failure—are of particular concern in this context of increasing total precipitation.

More intense flood and drought cycles:

- More intense floods will increase flood risk.
- Changing and intensifying flood and drought cycles will complicate water level management, as previous experience loses applicability to management decisions.
- These changes may complicate water level management decisions, as managers increasingly have to incorporate more intense extremes (i.e., droughts and floods) into their management decisions.

Extreme temperatures:

- Over time, this trend will result in a higher percentage of precipitation occurring as rain rather than snow, which could exacerbate existing and projected flooding trends, such as those described above, especially in the spring. This trend could make events like the 1968 and 2010 floods more common, as those events were driven by early spring rains on top of snowmelt. Additional study and modeling could evaluate this hypothesis.
- The combination of a longer growing season, higher evaporation rates, and increasing evapotranspiration rates will result in reduced soil moisture and reduced stream and pond levels during dry periods.

DATA GAP DOCUMENTATION

As described above, there are concerns that management to maintain water supply levels increases flood risk. A technical evaluation of this concern would be valuable. In addition, equivalent and updated technical information and inspection reports are needed for the dams other than the Wareham Street Dam and Assawompset Dam. It would also be valuable to have additional details about impacts, conditions, and causes of other historic floods (in addition to the 1968 and 2010 events) to inform future-decision making and climate change implications. Above all, comprehensive modeling of the APC-Nemasket River system would be very useful to confirm existing condition and associated assumptions, such as the influence of dams on water levels. These additional information sources and analyses would aid in evaluating and comparing experienced flooding, models, and projected conditions to inform management strategies.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Flood control and…

- Drinking Water Supply Levels: Trade-Off. The need to maintain water storage for drinking water supply in both the APC Ponds as well as in the Nemasket River near Murdock Street and East Main Street creates concerns that such management limits the extent to which the storage capacity of the pond can be used to buffer flood events.

- Stormwater Management: Co-Benefit. Stormwater management is a key component of flood control. Maintaining and expanding opportunities for onsite infiltration of stormwater could reduce flooding in short duration, high-intensity rain events. Longer term precipitation events that result in saturated soils could overwhelm onsite infiltration features. Opportunities to rapidly move stormwater out of the watershed are limited due to the flat topography.

- Ecology, Unique Habitats and Natural Resources: Co-Benefit and Trade-Off. Wetland restoration, invasive species management, and sediment controls have the potential to both increase floodwater water storage capacity and improve and expand associated habitat. Conversely, flood protection efforts have the potential to impact or destroy habitat areas and/or cause other adverse impacts to natural resources., especially if utilizing large engineered (i.e., “gray”) infrastructure, such as dams.

- Water Quality: Co-Benefit. Flooding can inundate septic systems and other potential sources of pollution, causing adverse water quality impacts. Improving floodwater management could therefore improve septic system management, preventing some water quality impacts.
- Increased Land Development: Trade-Off. Future development and associated increase in impervious surface will likely exacerbate flooding unless an effective mix of nature-based and engineered stormwater management features are included. The placement of new development outside of flood hazard areas and/or gradual removal of development from high hazard areas will also be required to minimize future flood impacts.
- Increased Inter-Agency Cooperation: Co-Benefit. Improved coordination between stakeholders in the watershed, including water suppliers, could help with water management and flood control. On-going communication around pond levels, until such time as these readings can be automated, is helpful to the public and pondside municipalities. Additional cooperation between local and state operators on roadway drainage systems could help reduce flood impacts.
- Recreational Access: Co-Benefit. Some nature-based stormwater management features could include public access for passive recreation. Additional conservation land and waterway buffers for flood protection could also provide recreational opportunities.
- Increased public stewardship: Land conservation could result in protecting flood hazard areas from development and maintaining and increasing flood storage capacity on protected open space.

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FIGURES

Figure 1. U.S. Geological Survey Surficial Geology

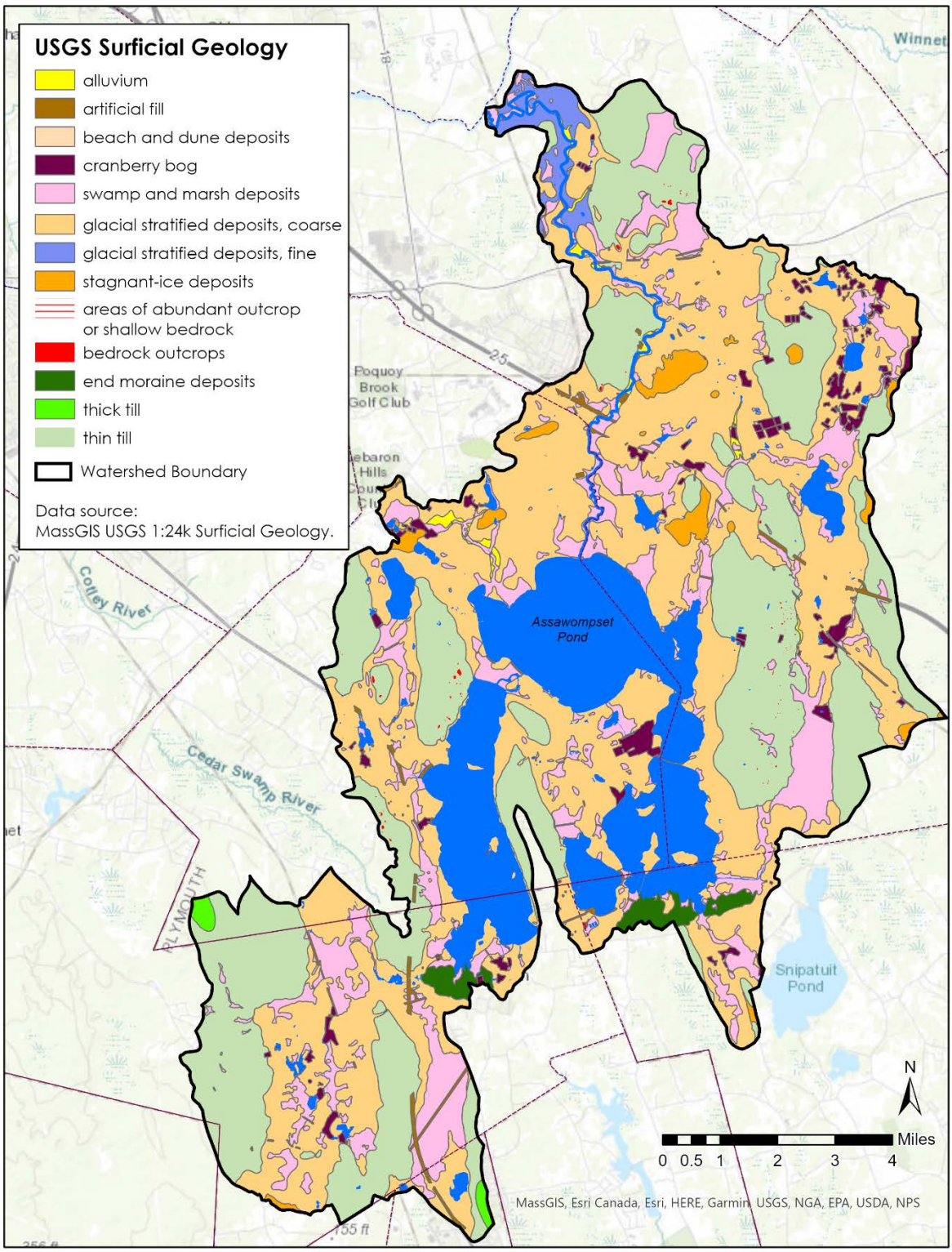


Figure 2. Hydrologic Soil Groups

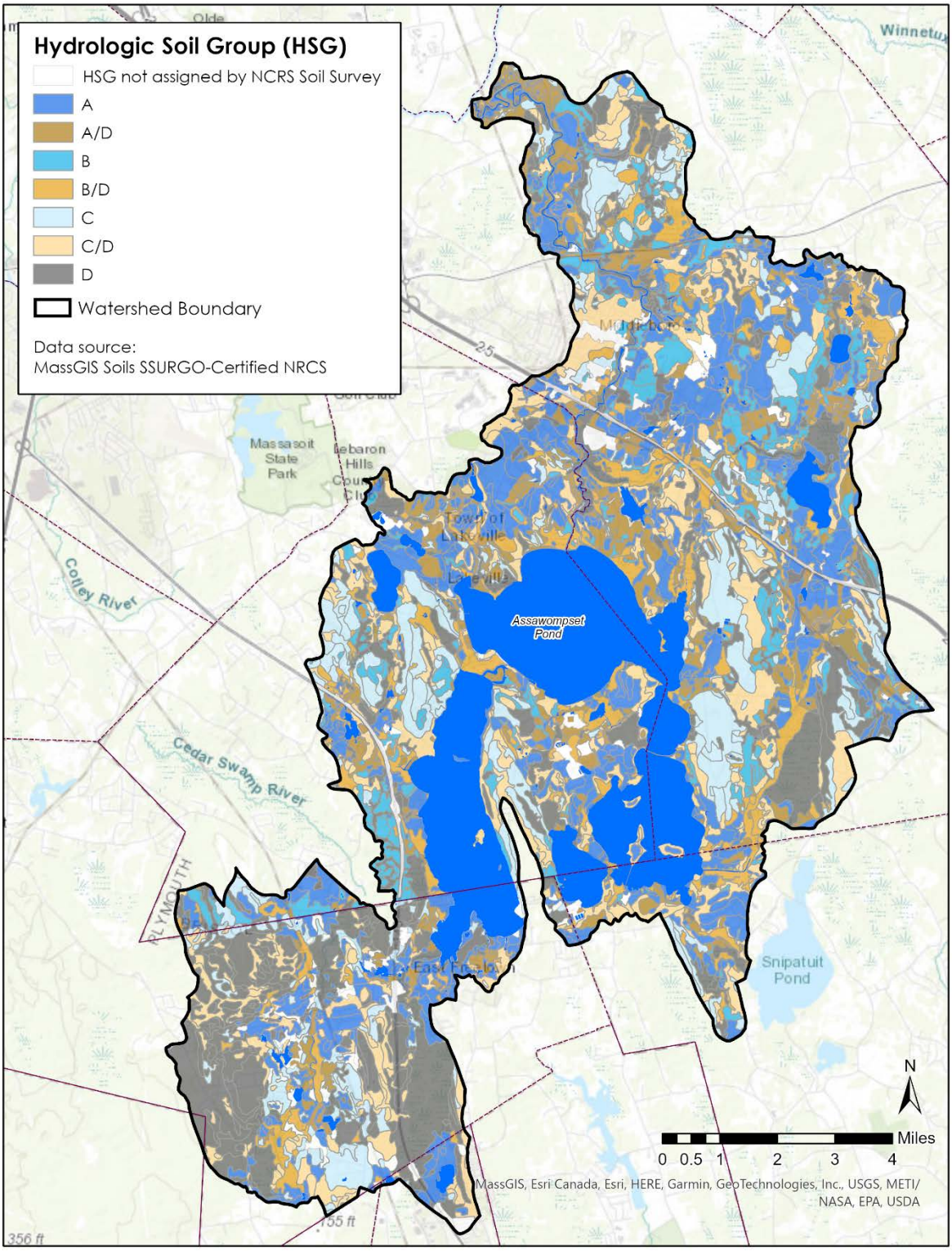


Figure 3. Flood Infrastructure

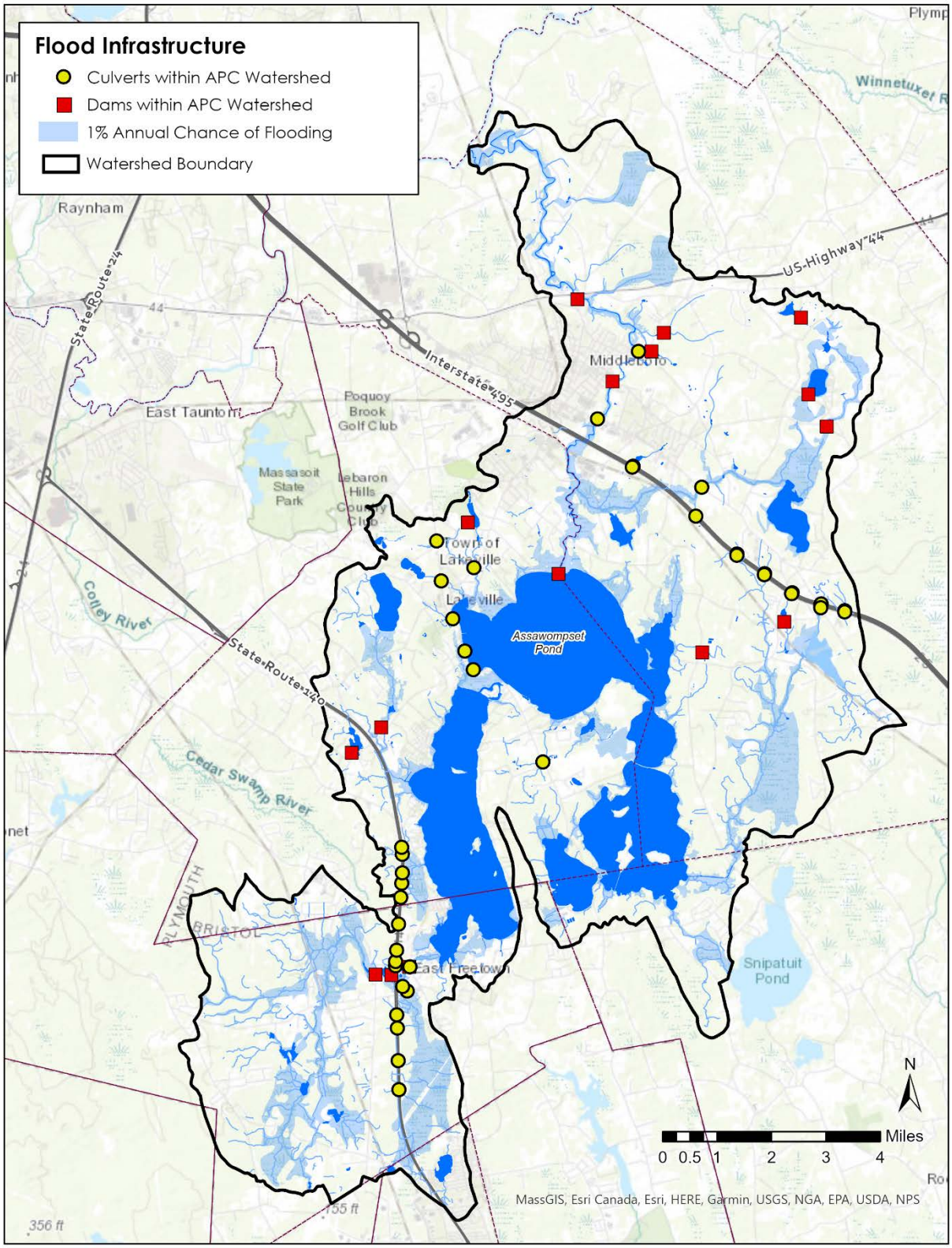
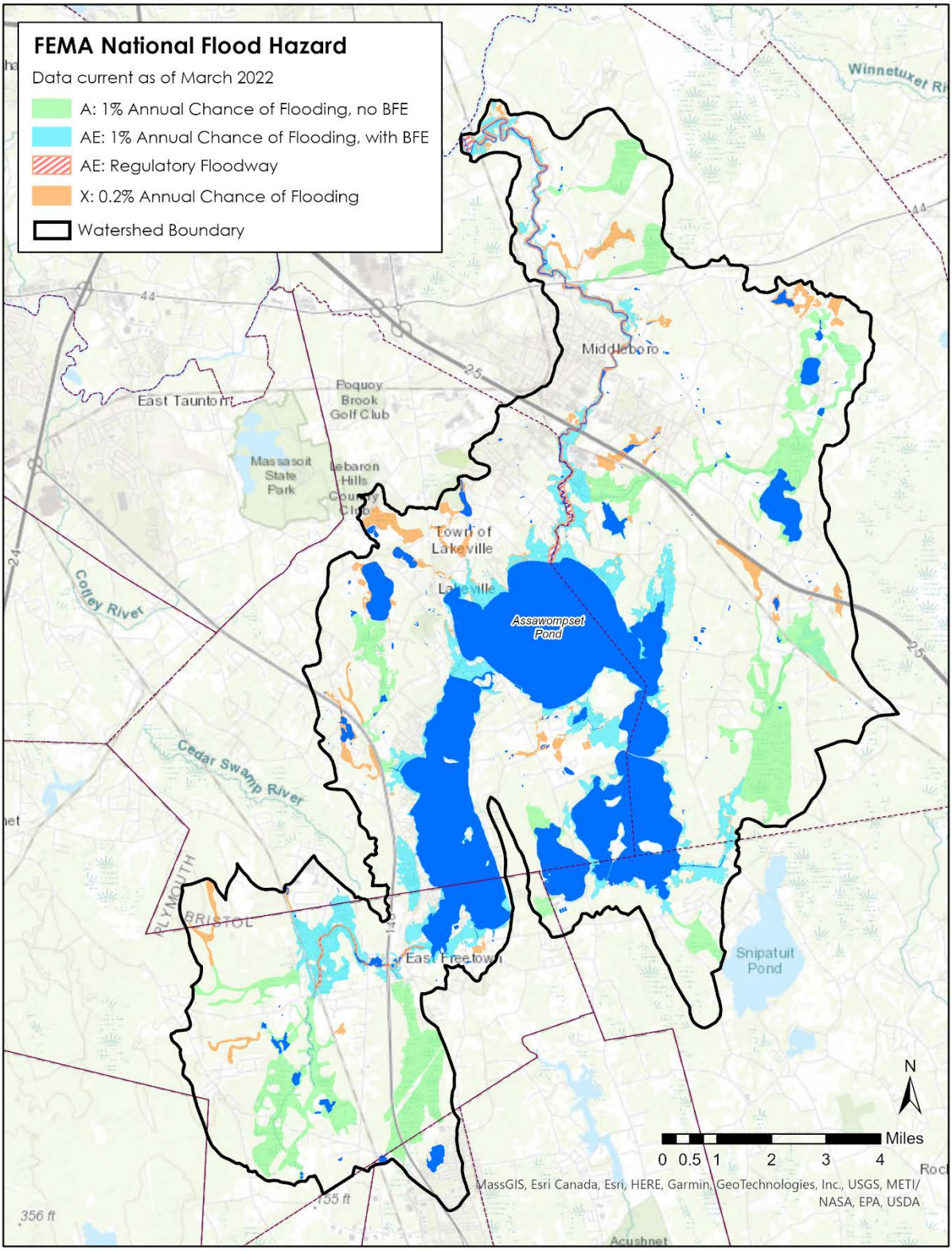
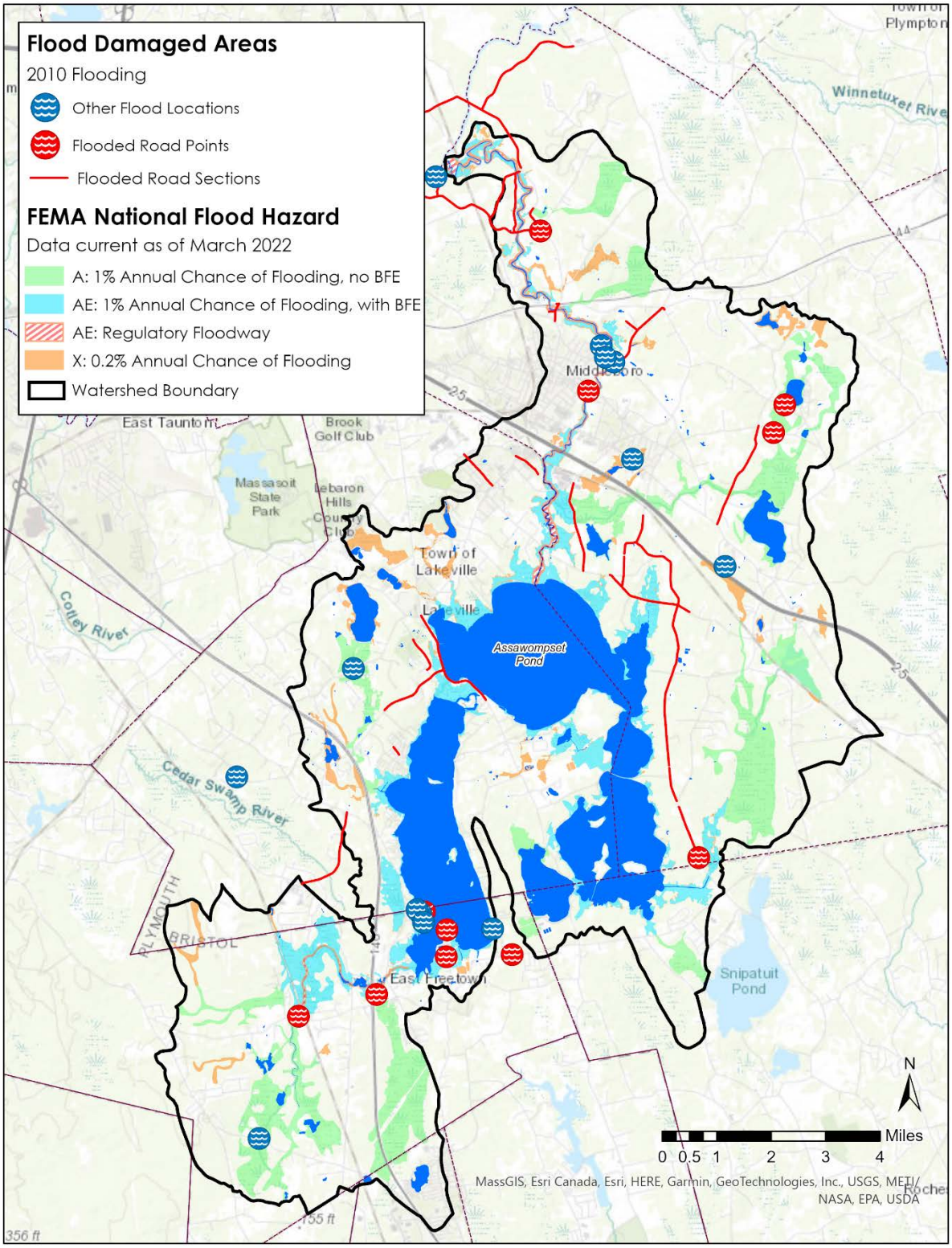

Flood Infrastructure
Culverts within APC Watershed
Dams within APC Watershed
1% Annual Chance of Flooding
Watershed Boundary
Raynham
State Route 24
US Highway 44
Interstate 495
East Taunton
Poquoy Brook Golf Club
Massasoit State Park
Lebaron Hills Country Club
Middleboro
Town of Lakeville
Lakeville
Assawompset Pond
Colley River
State Route 140
Cedar Swamp River
PLYMOUTH
BRISTOL
East Freetown
Snipatuit Pond
N
Miles
0 0.5 1 2 3 4
MassGIS, Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
356 ft
155 ft

Figure 4. FEMA National Flood Hazard Areas



Notes. FEMA data compiled from MassGIS, current as of March 2022.

Figure 5. Flood Damaged Areas



Notes. Adapted from FEMA FIRMs current as of March 2022 (accessed via MassGIS) and personal communications with Fire Chief Lance Benjamino, Town of Middleborough (5/4/2021) and Fire Chief Gary Silva, Town of Freetown (5/21/2021).

Figure 6. Flooding experienced in the Woloski Park neighborhood during 2010 floods

Credit: Photo source: Tricia Cassady

TABLES

Table 1. Summary of FEMA FIS Modeled Discharges for Nemasket River

Nemasket River Location	Drainage Area (Square Miles)	Peak Discharge (cfs)			
		10% Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
At MBTA Commuter Railroad Bridge	70.1	694	1,063	1,256	1,628
At Murdock Street	69.9	684	1,048	1,239	1,605
At Plymouth Street	67.7	659	1,009	1,193	1,544
At Nemasket Street	66	631	966	1,142	1,476
At Wareham Street	62.1	579	886	1,048	1,353
At Bridge Street	60.3	555	848	1,003	1,293
At Vaughan Street	49.7	434	662	784	1,006
At Assawompset Pond Dam	49.2	427	652	772	990
At culvert at Route 105 and outlet of Long Pond into Assawompset Pond	23.4	224	348	414	533

Notes. Modified from Table 9 in FEMA (2020).

Table 2. Summary of FEMA FIS Modeled Stillwater Elevations

Flooding Source	Location	Elevations (feet NAVD88)			
		10 % Annual Chance	2% Annual Chance	1% Annual Chance	0.2% Annual Chance
Assawompset Pond	Entire shoreline in Towns of Lakeville and Middleborough	54.9	56.1	56.8	57.8
Great Quittacas Pond	Entire shoreline in Towns of Lakeville and Middleborough	54.9	56.1	56.8	57.8
Long Pond	Entire shoreline in Town of Lakeville	55.6	56.9	57.2	57.8
Pocksha Pond	Entire shoreline in Towns of Lakeville and Middleborough	54.9	56.1	56.8	57.8

Notes. Summarized from Table 10 in FEMA (2016, 2020).

Table 3. Flood-prone Areas

Town	*Historically Flood-prone Neighborhoods*	*Historically Flood-prone Roads*	*Potentially Problematic Infrastructure*
Freetown	• *Ashley Heights* • *Heaven Heights* • *Hemlock Point*	• *Beech Bluff Road* • *Charbonneau Ave* • *Chase Road* • *Chipaway Road* • *Estelle Ave* • *Lafayette Park* • *Lucie Ave* • *Middleborough Road* • *Morton Road* • *Point of Pines Road* • *Route 140 ramp (near Chace Road)*	• *Chipaway Road Culvert* • *Morton Road Culvert*
Lakeville	• *Clark Shores* • *Staples Shore*	• *Captain's Way* • *Country Road* • *Cross Street* • *Freetown Street* • *Highland Road* • *Old Powder House Road* • *Riverside Drive* • *Taunton Street* • *Route 18/Bedford Street* • *Route 105 highway ramps* • *I-495 highway ramps*	• *Snake River Culvert* • *Taunton Street (Poquoy Brook)* • *Cross Street Culvert* • *Pickens Street Culvert* • *Pierce Avenue Culvert (Bittersweet Road)* • *County Road Culvert (by Eagles building)*
Middleborough	• *Woloski Park*	• *Ashley Lane* • *Cherry Street* • *East Grove Street* • *East Main Street* • *France Street* • *Marion Road* • *Montello Street* • *Murdock Street* • *Plymouth Street* • *Precinct Street* • *River Street* • *River's Edge Drive* • *Sachem Street* • *Summer Street* • *Taylor Way* • *Vernon Street* • *Walnut Street* • *Woloski Park* • *Wood Street*	• *Cross Street Culvert (Purchade Brook)* • *Pratt Farm Dam* • *East Main Street wastewater pump* • *East Grove Street well and treatment plant* • *Middleborough wastewater treatment plant* • *Wareham Street Dam* • *Thomas Street Culvert* • *Woods Pond Dam*

Notes. Adapted from FEMA (2016, 2020) and SRPEDD (2011); personal communications with Fire Chief Lance Benjamino, Town of Middleborough (5/4/2021) and Fire Chief Gary Silva, Town of Freetown (5/21/21); and APC Management Plan Steering Committee's meeting discussion (1/12/22).

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

DRINKING WATER SUPPLY

CURRENT CONDITIONS IN THE WATERSHED

Geographic and Water Suppliers Overview

The Assawompset Ponds Complex (APC) is a critical drinking water source, providing drinking water for approximately 250,000 people in southeastern Massachusetts (Southeastern Regional Planning and Economic Development District [SRPEDD], 2020). The ponds are the primary drinking water source for the City of Taunton and City of New Bedford. Taunton also supplies water to the Village of North Dighton and the Bridgewater Correctional Complex, and Taunton's system also services parts of Berkley, Lakeville, Middleboro, Norton, and Raynham (City of Taunton Department of Public Works Water Division [Taunton Water Division], 2020). New Bedford also serves parts of Freetown and Acushnet, seasonally serves Dartmouth, and serves Fairhaven in emergencies (City of New Bedford Department of Public Infrastructure [New Bedford DPI], 2019). These other municipalities generally have their own water departments or divisions that purchase water from New Bedford; in some cases, they have additional supplies outside the APC Watershed (Acushnet Water Department, 2020; Dartmouth Water Division, 2020; Freetown Water Commission, 2020; Town of Acushnet, n.d.; Town of Dartmouth, n.d.; Town of Fairhaven, n.d.; Town of Freetown, n.d.).

In addition to the public water suppliers described above, the communities of Lakeville and Middleborough obtain public water supplies via groundwater wells located in the APC watershed. In addition, individual homes and businesses in pondside communities are supplied by individual private groundwater wells. While these groundwater wells do not physically withdraw water from any of the individual ponds in the APC, the water they withdraw is part of and interdependent on the same groundwater/surface water system that forms the APC itself.

Beginning with the farthest upstream (and southernmost) waterbody in the APC, Little Quittacas Pond is the second smallest pond in the APC and the site of New Bedford's drinking water treatment plant (Figure 1). Little Quittacas Pond exchanges water with Great Quittacas Pond. Great Quittacas Pond receives flow from Snipatuit Brook and Black Brook and is located east and extends north of Little Quittacas Pond. These ponds are connected by a culvert underneath Route 105 (Braley Hill Road/Bedford Street). Great Quittacas outlets to the north via a culvert under Long Point Road to Pocksha Pond, which is the smallest pond in the APC. Flow is uninhibited from Pocksha Pond west to Assawompset Pond, the largest pond in the APC. Assawompset Pond also receives flow from a number of smaller tributaries, as well as from Long Pond. Long Pond is the second largest pond in the APC and flows into Assawompset Pond via the Snake River (also known as the Long Pond River) through a culvert under Bedford Street (Route 105/Route 18). While technically not part of the APC, but located within the APC and Nemasket River Watershed, Elders Pond is the site of Taunton's drinking water treatment plant and is located just east of Assawompset Pond.

Taunton's drinking water is managed by the city's Department of Public Works' Water Division. Its drinking water originates from the five ponds of the APC and Elders Pond, in addition to two wells in the city that are outside the APC Watershed. The city pumps raw water from Assawompset Pond underground to Elders Pond before treating the water at the Charles J. Rocheleau Water Filtration Plant on the north side of Elders Pond in Lakeville (Figure 1). The intake is near residential development in a relatively shallow area. With a treatment capacity of 14 million gallons per day (MGD) for meeting peak summer demand, the plant removes color and turbidity through filtration and bacteria through ultraviolet disinfection and the addition of chloramines. In fact, Taunton was the first system in New

England to use ultraviolet disinfection, starting in 2004 (Kempe, 2006). Acidity is also reduced to control pipe corrosion, and fluoride is added to the water for oral health. Following these processes, water is distributed to customers and the city's five storage facilities, which together provide over 25 million gallons (MG) of storage capacity: the Prospect Hill Reservoir, which is the principle storage facility (22.5 MG); East Taunton Elevated Storage Tank (1 MG); the Westville Elevated Storage Tank (0.3 MG); the Oakland Elevated Storage Tank (0.75 MG); and the Myles Standish Industrial Park Elevated Storage Tank (1 MG) (Taunton Water Division, 2020, 2016a; Massachusetts Department of Environmental Protection [MassDEP], 2003). There is an additional storage facility in Lakeville (Taunton Water Division, 2016a). In total, Taunton's system consists of 371 miles of pipes and serves 60,000 customers (Taunton Water Division, 2016a).

New Bedford's drinking water is managed by the city's Department of Public Infrastructure's Water Division under the Department of Public Infrastructure. The Department of Public Infrastructure was established in 2003 to manage all underground utilities in the city, reorganized from the Department of Public Works, which included the Water Department, Highways Department, and Wastewater Division (City of New Bedford [New Bedford], n.d.). New Bedford draws its water from the five ponds of the APC, treating water from its intake in Little Quittacas Pond at the Quittacas Water Treatment Plant on the southern end of the pond (Figure 1). The plant has a treatment capacity of 45 MGD and provides conventional filtration, disinfection, corrosion control, and fluoridation for oral health (New Bedford, 2019). In dry conditions when water levels are low, at the discretion of the Water Division, New Bedford can pump from Great Quittacas Pond into Little Quittacas Pond. New Bedford had to do so during the Phase 3 drought that occurred in the summer and fall of 2020 for the first time in many years. After leaving the treatment plant, drinking water is distributed to over 283 miles of pipes and two storage facilities: the High Hill Reservoir (67 MG) and the Hathaway Road elevated tank (0.3 MG) (City of New Bedford, n.d.). In total, New Bedford serves its 95,000 residents and additional commercial/industrial customers, plus customers in the other municipalities it serves (City of New Bedford, 2019).

Treated Drinking Water Quality

New Bedford's and Taunton's treated drinking water quality both met all EPA standards for regulated substances based on each city's 2020 Annual Water Quality Report. While Taunton had a single highest turbidity result of 0.36 NTU, its typical turbidity levels are equal to or less than 0.05 NTU in nearly all samples, well below the regulatory threshold of 95% of monthly measurements below 0.30 NTU. However, Taunton's sodium levels (42 ppm) exceeded MassDEP's guideline level of 20 ppm (City of New Bedford, 2019; City of Taunton, 2020; Jodi Raposa, personal communication, 2022)).

Historical Context

Taunton and New Bedford's public water supplies date to the late 19th century after a series of Massachusetts Legislative Acts granted the cities rights to water sources, including those of the APC.

Taunton's water system originated in 1876 as the city began withdrawing water from the Taunton River at the Harris Street Pumping Station primarily for fire protection as well as for sanitary purposes, following several large fires in the city. By the 1890s, this source was deemed inadequate. After applying to and receiving permission from the Massachusetts Legislature via a special act in 1875, Taunton began construction on a 30-inch gravity water main to withdraw water from the APC in 1892. The 1875 act granted Taunton the rights to construct a dam at the outlet of the Nemasket River on Assawompset Pond, which was constructed in 1894 (Figure 2) (Maddigan, 2014; Emery, 1893; Secretary of the

Commonwealth, 1924; City of Taunton, 1892). Water was pumped from Assawompset Pond to Elders Pond via a coal-powered pump house on Bedford Street/Route 18 that today houses the Lakeville town offices. It was replaced by electric pumps in 1952 (Taunton Water Division, 2016a; Maddigan, 2011; Fire and Water Engineering, 1906; Emery, 1893).

New Bedford's water system dates from the 1860s, when the city initiated several studies related to supplying water, largely in response to fires, as well as interests in supplying power for industry and concerns about the quality of existing drinking water sources. Many in New Bedford had previously argued that waterpower serving industrial uses was key to the city's future prosperity, as the whaling industry had begun to decline following the discovery of petroleum in Pennsylvania and the Civil War. Spearheaded by the Board of Water Commissioners' Chairman, William Wallace "Waterworks" Crapo, the city's efforts culminated in 1869 when New Bedford began utilizing the Acushnet River for water supply. By 1886, the water levels in New Bedford's Acushnet River reservoir fell to the point that vegetation was exposed to sunlight, negatively affecting the taste of the water. As a temporary fix, New Bedford also began sourcing water from Little Quittacas Pond, using a channel cut between the pond and the Acushnet reservoir. While some argued for upgrading the Acushnet reservoir, its supplies were eventually deemed inadequate. Water demand continued to grow as the arguments about utilizing waterpower for industry were validated by new industrial and population growth in New Bedford during the late 19th century (and subsequently, into the early 20th century). By 1899, New Bedford had developed a new waterworks system that used a coal-powered pump station, with Little Quittacas as the sole source of New Bedford's supply. This new system was based on plans from 1896. In 1924, the Massachusetts Legislature granted New Bedford rights to also withdraw water from Assawompset, Pocksha, and Long Ponds. Diesel-powered engines replaced the steam pumps in 1949, and a secondary treatment plant was completed in 1977. In the 1950s-1970s, a series of droughts led to studies and calls for additional sources of water (Motta, 2014; Maddigan, 2014; Secretary of the Commonwealth, 1924).

Taunton and New Bedford's water withdrawals impacted water levels and downstream conditions almost immediately. The reduced water volume in the Nemasket River hindered the migration of juvenile herring and the operations of Middleborough's Municipal Light Plant, leading to a 1903 lawsuit by Middleborough against Taunton and New Bedford, which Middleborough won in 1909. Nevertheless, Taunton and New Bedford's water rights were maintained. By 1920, water systems were blamed for reducing water levels and trapping alewives in Little Quittacas Pond, to the point that the fish clogged drinking water intakes. An account from 1916 noted, "one day a year or so ago employees of the New Bedford water works removed over 50 barrels of the young fish that had died" (Maddigan, 2014). In order to remedy this situation, a screen was constructed between Pocksha and Great Quittacas Pond in 1916 to prevent fish from impacting drinking water operations, thereby blocking their access to spawning grounds (Maddigan, 2014).

Again, in the mid-1990s, juvenile herring became trapped in Great Quittacas Pond. Middleborough's Town Manager and several volunteers transferred the fish from Great Quittacas to Pocksha Pond by hand net, and even that led to the development of the current Middleborough-Lakeville Herring Fishery Commission (APC Management Plan Steering Committee Communication, 2022). Today, this group coordinates with the water suppliers to manage flows from the Ponds to the Nemasket River during key times for the annual herring migration. While the water suppliers consult with the Middleborough-Lakeville Herring Fishery Commission to reduce impacts to herring, maintaining the water supply is still the primary concern for management of the water level in the Ponds and the Assawompset Pond Dam,

and there are no legal requirements for protecting fisheries and wildlife (APC Management Plan Steering Committee communication, 2022).

Current Water Withdrawals

Currently, water withdrawals are dictated by Massachusetts Department of Environmental Protection (MassDEP) water withdrawal permits under the 1986 Water Management Act and subsequent revisions. Figure 1 shows the location of water withdrawals in the APC Watershed. For the APC, these permits have been largely based on a 1988 study of the ponds. Water withdrawal permits for Taunton and New Bedford reference the following waterbodies and source identification numbers: Little Quittacas Pond (4293000-06S), Great Quittacas Pond (4293000-05S), Pocksha Pond (4293000-04S), Assawompset Pond (4293000-01S), Long Pond (4293000-03S), and Elders Pond (4293000-02S).

Under the 2012 Massachusetts Sustainable Water Management Initiative (SWMI) and its subsequent 2014 incorporation into the Water Management Act, safe yield is defined as "the maximum amount of water withdrawal that can be allowed at a major basin scale during drought conditions, and incorporates environmental protection factors and hydrologic factors" (Massachusetts Department of Environmental Protection, n.d.; Massachusetts Executive Office of Energy and Environmental Affairs, 2012). Prior to these revisions, in Water Management Act Permits, the term "safe yield" tended to refer to the capacity of a reservoir, and therefore did not incorporate broader environmental and hydrologic considerations as in the SWMI and Water Management Act definition. That concept is frequently referred to as "firm yield" today. Currently, under the Water Management Act, firm yield "is the basis for permitting maximum annual withdrawals from reservoirs" and defined as "a simulated estimate of the water volume available in a reservoir or reservoir system, as approved by the Department" (MassDEP, 2021b; Fennessey, 1996). Both New Bedford and Taunton's 2021 draft Water Management Act Permits note that the safe yield (as defined by SWMI) of the Taunton River Basin is 134.4 MGD with a total registered and permitted withdrawal amount of 93.86 MGD, as of February 14, 2020 ((MassDEP, 2021a, 2021b). A 2014 study indicated, "When attempting to calculate a 'Safe Yield' for the Assawompset Complex under the Sustainable Water Management Imitative (SWMI), the Executive Office of Energy and Environmental Affairs found that that reservoir storage capacity is less than the drought year inflow plus annual use, therefore a Safe Yield could not be achieved" (Edward J. Collins, Jr. Center, 2014, p. 30). Follow-up assessments of these statements are needed (see Data Gap Documentation section below).

Under its previous MassDEP Water Withdrawal Permit, originally effective in 1991 and modified in 2003, New Bedford is permitted to withdraw a total 2.52 MGD, or 919.8 million gallons per year (MGY) from the ponds. Combined with a previously registered withdrawal of 18.27 MGD, New Bedford's authorized withdrawal limit is 20.79 MGD from the ponds. The permit was active from June 1, 1991 to February 28, 2010. Based on a 1988 study from the engineering firm Camp, Dresser, and McKee (CDM), the permit also noted that the firm[1] yield of the five APC ponds is 27.5, with 6.71 MGD allocated to Taunton and the remaining 20.79 MGD allocated to New Bedford (MassDEP, 2003).

New Bedford's draft 2021 permit from MassDEP maintained the previously registered volume up to 20.79 MGD from the previous permits (18.27 plus 2.52 MGD), although it notes that New Bedford's

[1] Note: The permit and 1988 study use the term "safe" yield, but to avoid confusion with today's terminology, the authors here have used the term "firm" yield for this value.

average daily withdrawal was 12.19 MGD in 2018. The permit asserts, "If water needs are expected to exceed the 20.79 MGD potentially available through a permit amendment and New Bedford is meeting all of its permit conditions, New Bedford may apply for additional volume at any time by submitting a new Water Management Permit application BRPWM03. However, any withdrawals requested above New Bedford's baseline of 18.27 MGD will require the mitigation of that volume" (MassDEP, 2021a, p. 3). The draft 2021 permit also confirmed the firm[2] yield values from the previous permit. The draft permit cites anticipated population growth, including potential impacts from the proposed South Coast Rail project, as rationale for supporting New Bedford's water withdrawal needs.

The draft 2021 permit demonstrates that New Bedford has met the water per capita water use standard known as "residential gallons per capita day (RGPCD)" of 65 (Table 1), required of all public water suppliers, and the "unaccounted for water" standard of 10%. Unaccounted for water (UAW) is a term that refers to a utility's water supplied to its distribution system that is not captured in customer billing, sometimes also referred to as "non-revenue water," although it has different meanings and calculation methodologies in different contexts. UAW accounts for leaks and other losses in the system (American Water Works Association, 2012). Of note, New Bedford's UAW value from a five-year compliance review in 2000 cited in the 2003 permit was 22% and therefore has gone down substantially since that time (Table 2).

Through its 2011 MassDEP Water Withdrawal Permit, Taunton was permitted to withdraw 6.29 MGD (2,295.85 MGY) from June 1, 1991 through February 28, 1995; 6.72 MGD (2,452.80 MGY) from March 1, 1995 to February 29, 2000; 7.29 MGD (2,660.85 MGY) from March 1, 2000 to February 28, 2005 and from March 1 2005 to May 24 2011; and 7.486 MGD (2,732.35 MGY) from May 24, 2011 through February 28, 2013). The permit also noted that the firm yield for Elders Pond was 0.58 MGD (211.7 MGY), and that the Taunton Reservoir System's firm yield was 7.29 MGD (2,660.85 MGY), indicating "Taunton's combined withdrawal from Elders Pond and the Assawompset Pond Complex shall not exceed 2660.85 MGY on an annual average basis" (MassDEP, 2011, p. 4). This and associated permits also allocated 0.196 MGD (71.50 MGY) to Taunton through two wells at the Dever School.

Taunton's draft 2021 permit reiterated the 7.49 MGD (2,660.85 MGY) total authorized combined volume for Taunton for the APC and Dever School wells and the Elders Pond and APC firm yield values from the previous permit (7.29 MGD). However, because of Taunton's recent water use, the draft permit (MassDEP, 2021b) also sets a baseline volume of 6.44 MGD, requiring the city to "limit its withdrawal volume to its baseline volume of 6.44 MGD, 2350.60 MGY, unless and until:

1. The City submits to MassDEP an application for a permit amendment requesting authorization to withdraw more than the baseline volume of 6.44 MGD up to a total authorized volume of 7.49 MGD, and a plan to mitigate the amount by which the total requested authorized withdrawal volume exceeds the baseline volume of 6.44 MGD, as adjusted for any wastewater returned to groundwater in the basin;
2. MassDEP issues a permit amendment in response to that application; and

[2] Note: This 2021 draft permit uses both "firm" and "safe" yield to refer to the 27.5 MGD value. The authors suspect that use of "safe" yield for this value (in the draft 2021 permit) is an inaccurate terminology carryover from the previous permits and pre-SWMI definitions. Additional discussion of this point is in the Data Gap Documentation section.

3. The City, in accordance with the amended permit, implements the mitigation plan prior to withdrawing more than the baseline volume of 6.44 MGD." (p. 9, 15)

Taunton's recent water use from all sources, including those within the APC, is shown in Table 3.

The draft 2021 permit also noted that Taunton has met the RGPCD standard of 65 (Table 4), required of all public water suppliers, but has not met the UAW standard of 10%; this necessitated additional conditions imposed on Taunton in its Water Withdrawal Permit (Table 5).

There are additional requirements for water conservation measures in both cities' draft 2021 permits, as well as commitments for APC management. These are included in Figure 3 for Taunton and Figure 4 for New Bedford, with virtually identical content for each municipality.

Aside from New Bedford and Taunton's municipal systems, additional public water withdrawals account for an estimated total 6,465.02 MGY in the APC and Nemasket River Watershed; private well withdrawals within the Assawompset Pond watershed total 447.03 MGY (MassDEP, n.d.). Middleborough, for example, sources its drinking water from eleven groundwater wells, with an authorized total volume of 2.25 MGD from June 1, 1991, through February 29, 1995; 2.42 MGD from March 1, 1995, through February 29, 2000; 2.73 MGD from March 1, 2000, through February 29, 2005; and 2.25 MGD from March 1, 2005, through 2010. Of these wells, seven are in the Nemasket River Watershed (MassDEP, 2006, 2016).

Inflow and infiltration to the Nemasket River Watershed represent an additional 44.80 MGY of watershed loss. Inputs into the watersheds include 423.40 MGY from wastewater treatment plant effluent and 572.11 MGY from septic system effluent.

Based on MassDEP's SMWI tool (2010), within the Assawompset Pond Watershed, septic systems account for 1.184 MGD (432 MGY) of input. Public and commercial wells account for 2.830 MGD (1033 MGY) of uptake, and private wells account for 1.357 MGD (495 MGY) of uptake. In the Nemasket River Watershed, septic systems account for 1.532 MGD (559 MGY) of input. Public and commercial wells are responsible for 2.653 MGD (968 MGY) of uptake, while private wells account for an additional 1.613 MGD (559 MGY) of uptake.

Watershed Protection

MassDEP has designated water supply originating from the APC as "high susceptibility" to potential contamination due to surrounding land uses, including cranberry bogs, horse farms, roads and highways, septic systems and cesspools, a utility right of way, and residential land uses. Both New Bedford and Taunton engage in source water protection activities to protect the APC. Public access for passive recreation is allowed at some source water protection lands, but swimming and boating are only allowed in Long Pond (Dupere, 2019). Additional information on these topics is in the Recreational Access white paper.

New Bedford owns approximately 12,352 total acres in the APC watershed (Figure 5). These acres include the entire shoreline around Little and Great Quittacas Ponds. This land is kept undeveloped, and a state-certified forester has provided forest management through a contract with New Bedford since 2004. Public access is allowed, and the property features miles of trails for walking, biking, skiing, and

snowshoeing. In 2003, New Bedford purchased additional land near Betty's Neck for $600,000 for additional source water protection. Walking and fishing is permitted on that property.

Taunton owns 486 acres of conservation land around Assawompset Pond (Figure 5). The Taunton Water Division participates in the APC Management Committee, including patrolling the APC, and reviews and comments on all proposed permit requests within 400 feet of the system's source waters (Taunton Water Division, 2020). Additional information on these topics is in the Stewardship and Culture and Recreational Access white papers.

Other APC watershed municipalities and conservation groups protect land, providing additional source water protection (Dupere, 2019) (Figure 6). Additional information is in the Recreational Access and Stewardship and Culture white papers.

Current Management

Currently, New Bedford and Taunton manage their water supplies based on their respective water withdrawal permits and historical legislative acts granting them authority. These authorizations include Taunton's rights to build and manage the Assawompset Dam at the outlet of the Nemasket River. New Bedford is also involved in managing the dam (CDM, 2006). According to New Bedford, the Assawompset Dam is generally kept open during flood seasons. Water is held back only in anticipation of having enough water in the system during drought conditions to maintain water supply (Nemasket River Enhancement Steering Committee, 2020). The dam was constructed for water supply purposes—not necessarily flood protection—and never designed to control or manage the entire APC system. Recent technical studies have noted that the dam is "highly porous and minimally effective at controlling the pond level" (SRPEDD, 2020, 2011). Two such studies during recent floods found that removing the bascule gate at the Wareham Street Dam also did not affect APC levels, indicating that these two dams are not the primary drivers of APC water levels (SRPEDD, 2011; Fennessey, 2013). As of writing in 2022, there is ongoing research and modeling of these dams and flooding levels. The dam lacks automation; is in somewhat poor condition; and adding or removing the wooden boards to control flow during high water is dangerous, making operation of the dam a liability (Nemasket River Enhancement Steering Committee, 2020; SRPEDD, 2020).

While these conditions limit operational flexibility, New Bedford does have more flexibility than Taunton because it can pump from Great Quittacas Pond into Little Quittacas Pond when water levels are low, and its intake is lower than Taunton's (New Bedford, n.d.).

New Bedford ordinances do allow for the implementation of local water restrictions when deemed necessary (Pers. Comm. Ymane Galotti, New Bedford Water Superintendent, APC Steering Committee, April 2022). In addition, the New Bedford website is being updated with public-facing strategies and practices for water conservation. This model can serve as a best practice example for other communities once it is final. However, few if any of the communities in the watershed have bylaws that facilitate water conservation restrictions on those using private wells.

Stakeholders' Drinking Water Supply Management Concerns

As described above, Taunton and New Bedford are drinking water supply stakeholders, responsible for supplying drinking water from the APC to hundreds of thousands of customers in the area. Associated drinking water quality and quantity priorities include ensuring adequate supplies, protecting source water, providing necessary treatment for finished water, and maintaining infrastructure.

Other stakeholders in the APC and surrounding areas have voiced concerns about current management of the APC for drinking water supply.

In Rochester, the majority of town residents get their water from individual wells; municipal wells owned by the Town of Marion receive their water from Rochester; and Taunton and New Bedford water suppliers draw from the APC. As a result, there are concerns that when drought hits, the local water table may be drawn down to supply other communities, leaving Rochester residents without sufficient supply (Town of Rochester, 2019).

Members of the Mattapoiset River Valley Water District Commission, which includes Fairhaven, Marion, Mattapoisett, and Rochester, have discussed New Bedford and Taunton's draft 2021 withdrawal permits and raised concerns about allowed volumes (Colageo, 2021, Town of Mattapoisett, n.d.). Some have argued that the cities do not need as much water as the draft permits would allow, especially given recent water use levels and industrial decline (Colageo, 2021; Sparling, 2015). In addition, others have raised questions about the draft water withdrawal volumes' justification based on South Coast Rail projections (MassDEP, 2021a) and questioned whether New Bedford's volumes are motivated by revenue generation considerations for the city (Colageo, 2021; Sparling, 2015), though recent state mandates for additional multi-family zones in all MBTA communities may lessen the validity of this critique. Some stakeholders have noted that for Rochester in particular, while parts of the APC are in the town, Rochester has no access to APC water because all has been allocated to New Bedford and Taunton (Colageo, 2021; Town of Rochester, 2019).

Another stakeholder concern is potential flooding caused or exacerbated by maintaining water levels for water supply (Figure 7 and Figure 8). There is no single entity which local pondside residents can turn to for information about whether dam boards are in place. That condition aggravates this concern further by adding a layer of anxiety around this issue that could be averted with a single updated information source on dam status.

More broadly, there are critiques about the lack of consistent coordination between Taunton and New Bedford in managing the shared water resources of the APC. As described above, both cities' water withdrawals are governed by MassDEP permits, but the cities operate their water systems independently of one another.

Alternative Management Approaches

Various alternative management approaches have been proposed, dating back to the aforementioned legislative acts that established and modified New Bedford and Taunton's water supplies. In 1920-21, for example, the Massachusetts State Department of Health proposed an APC "water supply district" for Fall River, New Bedford, and Taunton, as well as other municipalities in the areas of the APC (Fire and Water Engineering, 1922). New Bedford objected, as it did not want to give up its existing control of the water supplies. While the 1924 legislative act that granted New Bedford water rights to Assawompset, Pocksha, and Long Ponds also included Taunton and Fall River, an arrangement between the three cities never came pass. Today, Fall River sources its drinking water from North Watuppa Pond and the Copicut Reservoir, outside the APC Watershed (City of Fall River, 2017; Fire and Water Engineering, 1922). Despite having historic legislative rights to Long Pond, Fall River no longer has access to the resource as a water supply source. Because Fall River had no withdrawals from there during the five-year Water Management Act registration period ending in 1987, those water right ceased to exist.

Decades later, in 1957, severe droughts throughout New England led to calls for new water supplies (Motta, 2014). By 1963, a report to New Bedford recommended that the city seek legislative reapportionment of the APC's water rights and additional rights to divert Fall Brook in Middleboro in order to increase the capacity[3] of the APC from 35 MGD to roughly 50 MGD, which would be made available to New Bedford and Taunton. This recommendation was based on a projected 2005 water demand of 30 MGD for New Bedford, which has not come to pass (U.S. Area Redevelopment Administration, 1963).

Drought conditions again in 1966 led Mayor Harrington of New Bedford to call for a 14-municipality water district, and in 1970, New Bedford hired engineering firm CDM to study additional sources of water (Motta, 2014).

In 2011, following review of APC levels and operations, a cooperative agreement was proposed between New Bedford, Taunton, Middleborough, Freetown, Lakeville, and Rochester. Under this agreement, the cities would share data related to weather, dam adjustments, and the ponds with each other and other stakeholders. The stakeholders would meet at least four times annually and review the prior three months of operations. Following these reviews and discussions, the target levels would be adjusted. The development of interim pond levels considered six factors (SRPEDD, 2011):

- "Seasonal needs of the water suppliers and communities
- Adequate groundwater to supply Middleborough's well
- Adequate flow and storage to provide for anadromous fish passages up and down the Nemasket seasonally
- Adequate storage capacity to prevent or minimize damage from precipitation events
- Minimize winter ice damage to personal property
- Adequate capacity for recreational uses"

This management paradigm continues to this day in the form of the APC Management Team, which meets quarterly.

In 2011-2012, Massachusetts House Bill 2669 An Act to Preserve Public Water Supply in Assawompset Ponds Complex Communities was proposed but never enacted (An Act to Preserve Public Water Supply, 2021).

SUMMARY OF THREATS AND CHALLENGES TO A HEALTHY, FUNCTIONING SYSTEM

- The perception that there is limited coordination among water suppliers causes concerns among stakeholders about management challenges, including flooding risks associated with maintaining pond levels for water supply interests.
- There is a complex network of stakeholders and water withdrawals with limited coordination between them.

[3] This reference uses "safe yield."

- Management decisions are not necessarily made in coordination with other topics, such as flood risk or ecosystem health.
- Old studies (e.g., 1988) drive water withdrawal permits and may be based on conditions that are no longer applicable to the APC, especially in the context of climate change.
- Water supply infrastructure is old, and management is based on historic conditions. Climate change exacerbates these challenges.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes, consequently the estimated Taunton and New Bedford APC firm yields will probably fall in conflict with both rising municipal demand and the instream/ecological flow water requirements of the Nemasket River. It is likely that CDM did not include ecological flow releases and leakage/seepage from the APC earthen dam in those original safe yield studies.

The implications of these anticipated changes are considered below.

More frequent and intense storm events:

- Intense storm events will increase flooding risks, adding additional urgency to the need to address regional concerns about flooding and its relevance to water supply levels.
- Flooding associated with intense precipitation could damage or make inoperable critical water supply infrastructure and/or block personnel access to water infrastructure for operations.
- Increased extreme precipitation events will increase erosion, requiring additional treatment and causing new challenges for water treatment.
- Intense storm events would be associated with changes in precipitation levels, potentially invalidating existing and historic baselines for management decisions. Some of these baselines date back to the late 19th and early 20th centuries, and more recent decisions are based on a study from 1988.

More intense flood and drought cycles:

- Extended dry periods will strain the existing trade-offs between water supply levels and habitat.
- Extended dry periods will create additional needs to store more surplus water, potentially exacerbating trade-offs.

- Drought conditions are of particular concern in the APC because the water supply (via New Bedford treatment and distribution) is the seasonal and emergency backup for the Town of Dartmouth's public water supply. The APC is, therefore, called upon for additional withdrawals during times of regional water scarcity, compounding water supply management challenges.

Extreme temperatures:

- Increasing water temperatures can cause water quality issues, such as increased cyanobacteria blooms and nitrogen loading, further requiring additional treatment.
- Extreme temperatures can harm existing water treatment infrastructure.
- In the absence of water conservation measures, higher temperatures also tend to be associated with additional public water supply demand and withdrawals.

DATA GAP DOCUMENTATION

Additional details on existing water supply management (including the role of the APC Management Team and coordination between suppliers) and operations (including dam operations) would be helpful to confirm how management decisions are made in practice and their legal ramifications, including relevance to historic Legislative acts, if any. Sources to compare could include historic and current legal agreements, the 1970 and 1988 CDM studies, MassDEP public water supply Annual Statistical Reports (ASRs), operating procedures documents from water suppliers, and interviews with water suppliers. More generally, it would be helpful to confirm each water supplier's system size, geographic extent, and other details. In addition, follow-up research on previously proposed water management strategies, such as the 1967 water district proposal and 2011-2012 Massachusetts House Bill, could inform future management strategies ideas. Confirmation is also needed on the status and next steps of current and draft water withdrawal permits.

In relation to water withdrawal permits, the terminology "safe yield" and "firm yield" can introduce confusion, especially with differing and evolving definitions over time (see Current Water Withdrawals section above). In particular, New Bedford's draft 2021 draft permit has the following statements:

> "Based upon the most recent information available to the Department, Investigations of Surplus Safe Yield Available to New Bedford by Camp Dresser and McKee, June 1988, the firm yield of Long Pond, Asswompsett Pond, Pocksha Pond, Great Quitticas Pond and Little Quitticas Pond has been determined to be 27.5 MGD. The Department notes that this firm yield also supplies a significant portion of the volumes withdrawn by the City of Taunton."
>
> "Based on the most recent information available to the Department, Investigations of Surplus Safe Yield Available to New Bedford by Camp Dresser and McKee, June 1988, the safe yield of Long Pond, Asswompsett Pond, Pocksha Pond, Great Quitticas Pond and Little Quitticas Pond has been determined to be 27.5 million gallons per day (MGD)." (2021a, p. 8, 12)

These two statements seem to indicate that both the firm yield and safe yield of the APC is 27.5 MGD. There appears to be confusion between previous uses of the term "safe yield" prior to SWMI; previous permit text using this term before SWMI may have simply been copied over into the 2021 draft permit. Clarification is needed on these parameters and uses of the terminology, with regard to particular values for the APC and Nemasket River. While Water Management Act and SWMI documentation include a

safe yield for the entire Taunton River basin, a 2014 study indicated that a safe yield for the APC "could not be achieved" (Edward J. Collins, Jr. Center, 2014, p. 30) (see Current Water Withdrawals section above). Follow-up assessment of this statement with regard to current conditions is needed.

Some additional clarification from Dr. Neil Fennessey on this issue is summarized as follows: DEP WMP staff refer to Firm Yield as that average daily withdrawal rate which can be sustained from active storage during a period of extensive drought as used by modern Water Supply systems analysis (Fennessey, 1996) and Safe Yield when referring to the SWMI defined watershed, not reservoir, safe yield. When the WPA was written in 1985, textbooks at that time discussed the safe yield of watersheds. Unfortunately, from a hydrological point of view, there is no such thing. The regulatory definition developed by MA DEP and approved by the Mass. Water Resources Commission (WRC) in 1992 became obsolete when DCR ceased to provide river basin "minimum streamflow" recommendations to the WRC. Because that number was required by the MA DEP WMP regulations basin safe yield formula, issuing permits ground to a halt by 1994. Following a 20-year hiatus, the SWMI developed a new regulatory definition of river basin safe yield which allowed the issuing of WMP withdrawal permits once again. This was critical because all existing WMP registrations once approved had to be reviewed after 20 years to be renewed.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Water supply and…

- Flooding: Trade-off. Water suppliers need to maintain APC pond levels for adequate water supply, including in emergency conditions. During periods of prolonged high water (wet springs and winters, especially) those levels have the potential to create or exacerbate concerns about flooding risks.
- Habitat: Trade-offs. Stakeholders with interests around habitat and ecological health have argued that low water levels, as experienced during droughts, contribute to weed growth and degraded ecological habitat. Maintaining adequate levels for ecological health may be at odds with water suppliers' management desires to maintain high pond levels for adequate supplies. Water levels needed for ecological restoration activities could also complicate water suppliers' management operations.
- Nemasket River Flow Management and Dam Operations: Co-Benefits and Trade-offs. Despite the potential conflicts above, all stakeholders would likely benefit from more flexible and reliable dam operations in order to be able to prepare management strategies accordingly and improve transparency. Regular flows could help with habitat, sedimentation, and weed control issues. However, as described above, the actual management of the dam and water levels could lead to trade-offs or conflicts.
- Upstream and Downstream Flow Restrictions: Co-Benefits and Trade-offs. Reducing downstream and upstream flow restrictions, such as sedimentation, weeds, dams like the Wareham Street Dam, and the Snake River culvert, could create co-benefits by increasing flows, reducing flood risks, and restoring habitat and access to spawning grounds for herring. However, there could also be trade-offs from these changes, especially related to changes in flows and water levels, and in the potential migration of invasive species.

- Water Conservation Efforts: Co-Benefits. Reducing water use from the APC sources through conservation measures, reducing leaks and other UAW (i.e., non-revenue water), and/or including additional supplies could reduce the strain on APC sources, thereby providing additional flexibility for flows for habitat and flooding benefits. These strategies would effectively "create" more water.
- Land Conservation: Co-Benefits. Land conservation areas can provide areas for habitat and source water protection. These efforts can improve water quality and quantity, ecological health, and provide recreational opportunities–depending on permitted access. In terms of recreation, co-benefits may be provided for users who are permitted to access the conservation areas. However, trade-offs may exist for users who were previously able to access areas but have access and/or activities restricted (e.g., hunting, motorized vehicle use) once the area is protected.
- Stormwater Management: Co-Benefits and Trade-Offs. Infiltrative stormwater practices could help to restore or augment water supply volumes, especially groundwater. In some contexts, however, water suppliers have raised concerns that such practices in proximity to water supplies can pose risks to water quality; however, stormwater practices can be designed, installed, and maintained appropriately for the site conditions.

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Figures

Figure 1. Water Withdrawal Locations

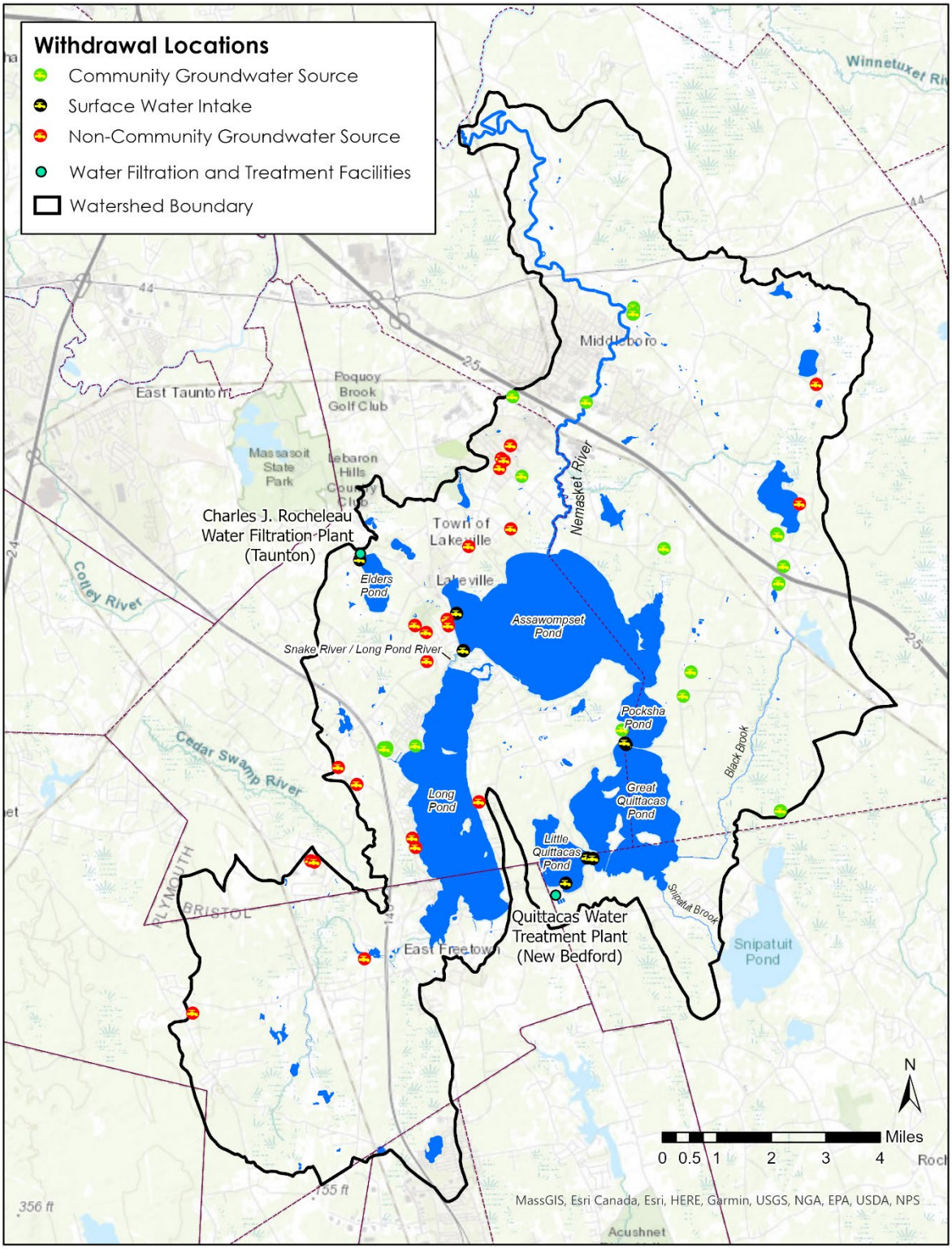
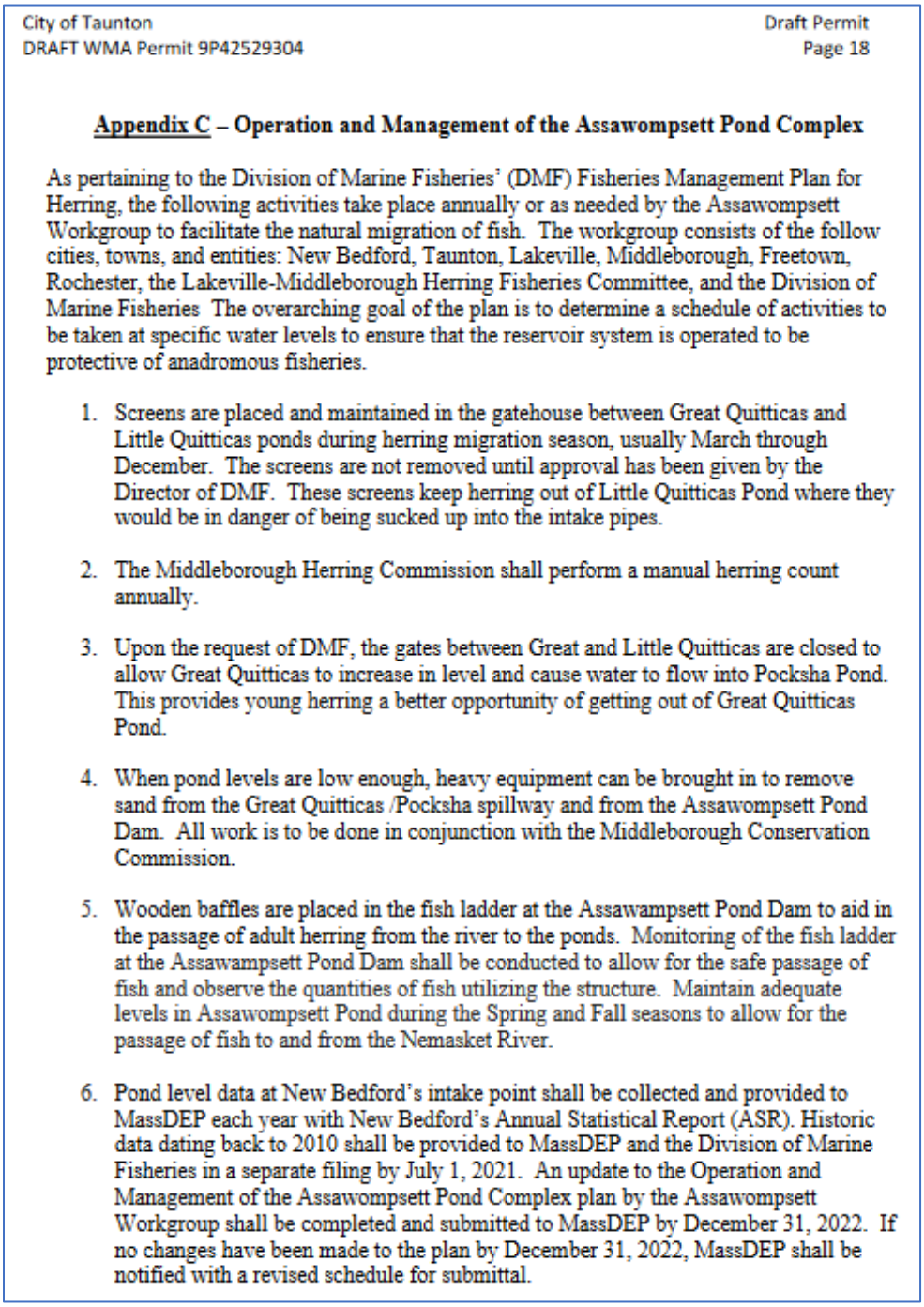


Figure 2. Assawompset Dam, circa 1920

Note. Photo Source: Maddigan, Michael J. 2014. Nemasket River Herring: A History. Natural History Press. Charleston, SC.

Figure 3. City of Taunton, Operation and Management of the APC



City of Taunton
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Appendix C – Operation and Management of the Assawompsett Pond Complex

As pertaining to the Division of Marine Fisheries' (DMF) Fisheries Management Plan for Herring, the following activities take place annually or as needed by the Assawompsett Workgroup to facilitate the natural migration of fish. The workgroup consists of the follow cities, towns, and entities: New Bedford, Taunton, Lakeville, Middleborough, Freetown, Rochester, the Lakeville-Middleborough Herring Fisheries Committee, and the Division of Marine Fisheries The overarching goal of the plan is to determine a schedule of activities to be taken at specific water levels to ensure that the reservoir system is operated to be protective of anadromous fisheries.

1. Screens are placed and maintained in the gatehouse between Great Quitticas and Little Quitticas ponds during herring migration season, usually March through December. The screens are not removed until approval has been given by the Director of DMF. These screens keep herring out of Little Quitticas Pond where they would be in danger of being sucked up into the intake pipes.

2. The Middleborough Herring Commission shall perform a manual herring count annually.

3. Upon the request of DMF, the gates between Great and Little Quitticas are closed to allow Great Quitticas to increase in level and cause water to flow into Pocksha Pond. This provides young herring a better opportunity of getting out of Great Quitticas Pond.

4. When pond levels are low enough, heavy equipment can be brought in to remove sand from the Great Quitticas /Pocksha spillway and from the Assawompsett Pond Dam. All work is to be done in conjunction with the Middleborough Conservation Commission.

5. Wooden baffles are placed in the fish ladder at the Assawampsett Pond Dam to aid in the passage of adult herring from the river to the ponds. Monitoring of the fish ladder at the Assawampsett Pond Dam shall be conducted to allow for the safe passage of fish and observe the quantities of fish utilizing the structure. Maintain adequate levels in Assawompsett Pond during the Spring and Fall seasons to allow for the passage of fish to and from the Nemasket River.

6. Pond level data at New Bedford's intake point shall be collected and provided to MassDEP each year with New Bedford's Annual Statistical Report (ASR). Historic data dating back to 2010 shall be provided to MassDEP and the Division of Marine Fisheries in a separate filing by July 1, 2021. An update to the Operation and Management of the Assawompsett Pond Complex plan by the Assawompsett Workgroup shall be completed and submitted to MassDEP by December 31, 2022. If no changes have been made to the plan by December 31, 2022, MassDEP shall be notified with a revised schedule for submittal.

Note. Adapted from Massachusetts Department of Environmental Protection, Taunton Water Management Act Permit # 9P-4-25-293.04 (2021b).

Figure 4. City of New Bedford, Operation and Management of the APC

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Note. Adapted from Massachusetts Department of Environmental Protection, New Bedford Water Management Act Permit #9P-4-25-201.01 (2021a).

Figure 5. New Bedford- and Taunton-owned Open Spaces

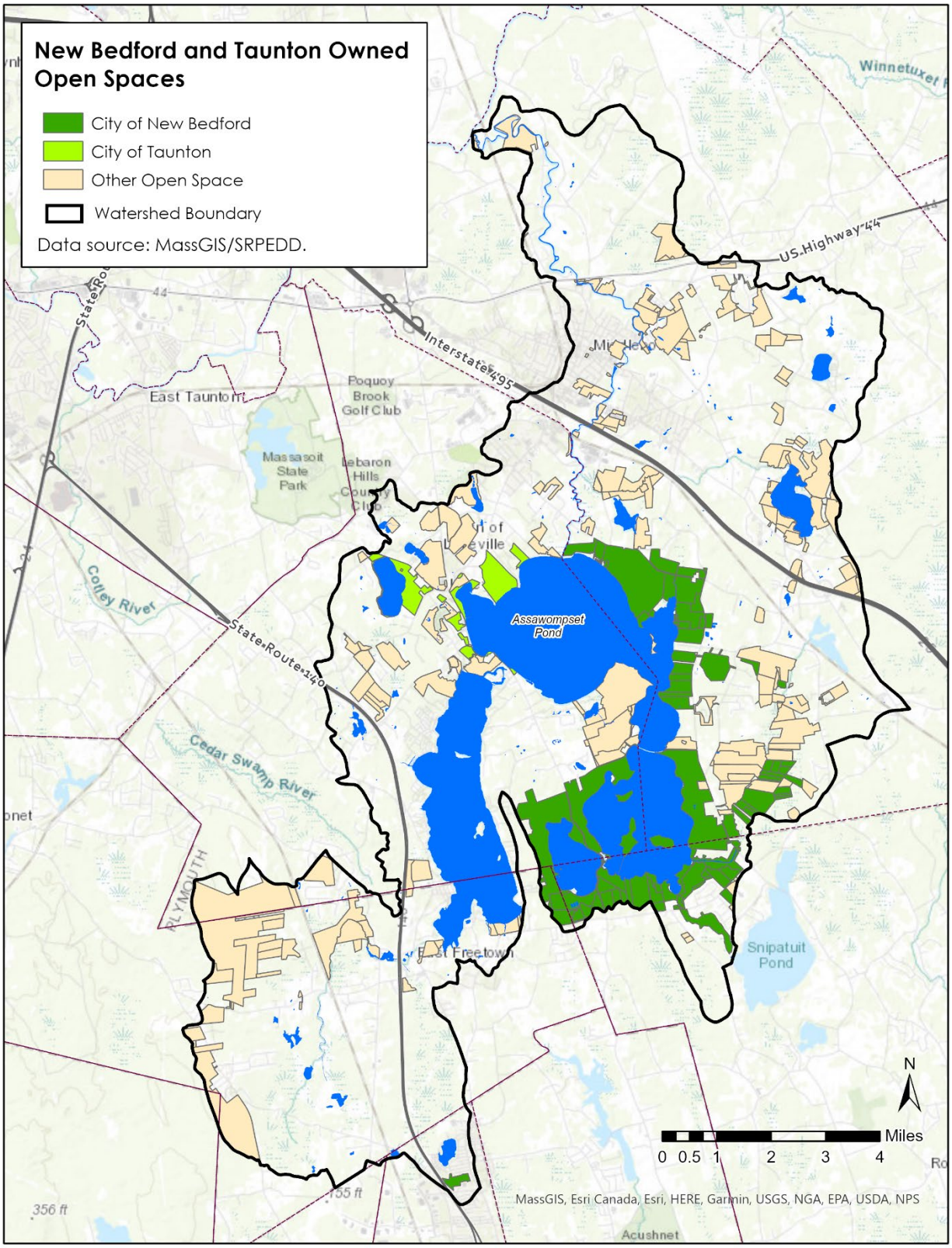

Figure 6. Open Space by Owner

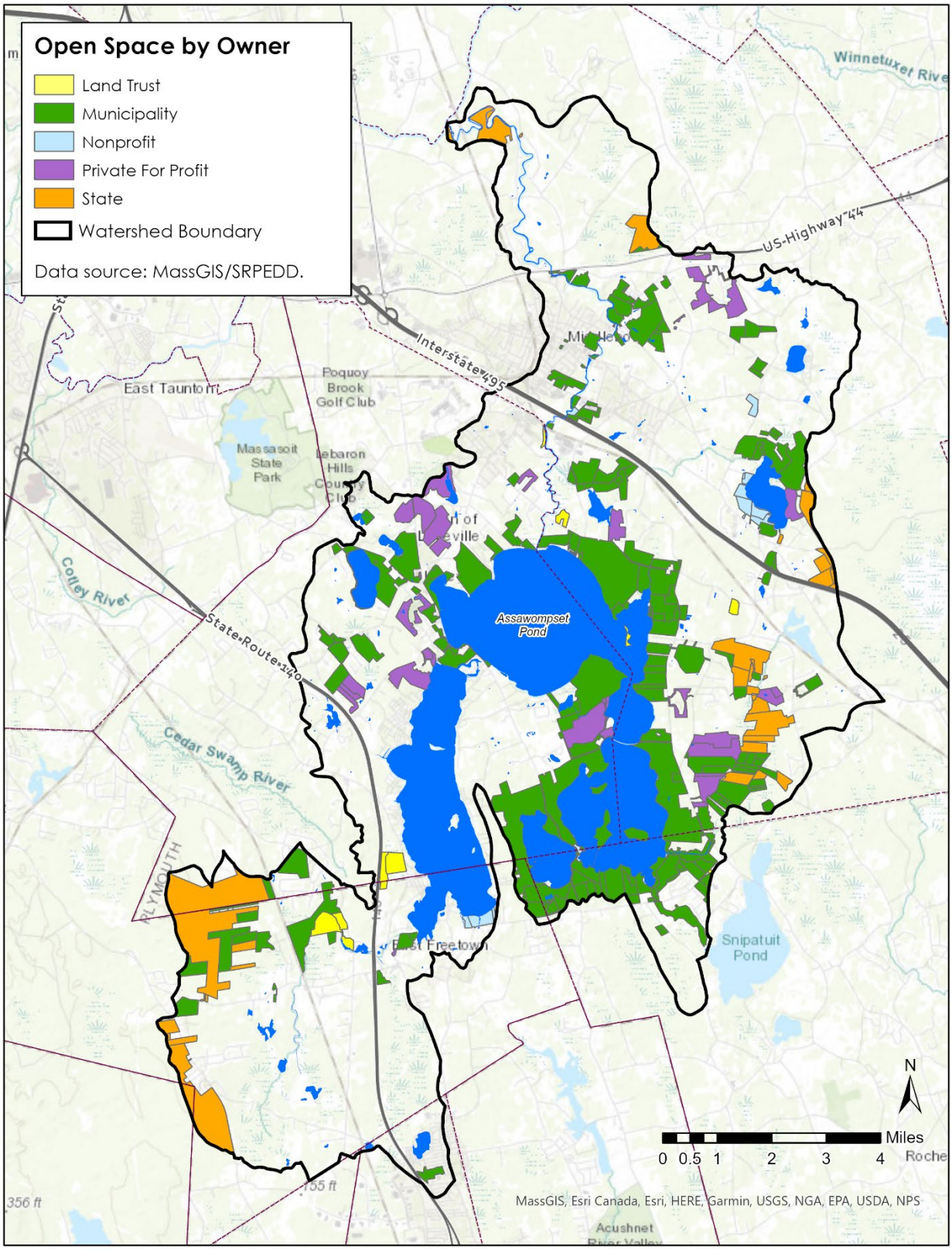

Figure 7. Assawompset Dam During Drought Conditions, 2020

Note. Photo courtesy of Southeastern Regional Planning & Economic Development District (2020).

Figure 8. Assawompset Dam During High Water Conditions, 2021

Note. Photo courtesy of Southeastern Regional Planning & Economic Development District (2021).

TABLES

Table 1. Residential Gallons Per Capita Per Day Water (RGPCD) Use – City of New Bedford

Year	2014	2015	2016	2017	2018
RGPCD	52	52	59	60	50

Note. Adapted from Massachusetts Department of Environmental Protection, New Bedford Water Management Act Permit #9P-4-25-201.01 (2021a).

Table 2.Unaccounted for Water (UAW) – City of New Bedford

Year	2014	2015	2016	2017	2018
UAW	8%	8%	8%	6%	9%

Note. Adapted from Massachusetts Department of Environmental Protection, New Bedford Water Management Act Permit #9P-4-25-201.01 (2021a).

Table 3. Average Water Withdrawals (MGD) – City of Taunton

Year	2014	2015	2016	2017	2018
Average Actual Withdrawals (MGD)	5.60	5.98	6.28	5.81	5.68

Note. Adapted from Massachusetts Department of Environmental Protection, Taunton Water Management Act Permit #9P-4-25-293.04 (2021b).

Table 4. Residential Gallons Per Capita Day Water (RGPCD) Use – City of Taunton

Year	2014	2015	2016	2017	2018
RGPCD	53	59	56	53	53

Note. Adapted from Massachusetts Department of Environmental Protection, Taunton Water Management Act Permit #9P-4-25-293.04 (2021b).

Table 5. Unaccounted for Water (UAW) – City of Taunton

Year	2014	2015	2016	2017	2018
UAW	17.6%	16.8%	19.7%	19.5%	13.7%

Note. Adapted from Massachusetts Department of Environmental Protection, Taunton Water Management Act Permit #9P-4-25-293.04 (2021b).

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

WATER QUALITY

CURRENT CONDITIONS IN THE WATERSHED

Overview

The Assawompset Ponds Complex (APC) in the Taunton River Watershed is the largest natural freshwater reservoir in Massachusetts. The APC drains north via the Nemasket River to its confluence with the federally designated Wild and Scenic Taunton River, which then flows southwest to Mount Hope Bay on the Rhode Island border. The major water bodies in the APC and Nemasket River Watershed include Assawompset Pond, Long Pond, Pocksha Pond, Great Quittacas Pond, Little Quittacas Pond and the Nemasket River, as well as their associated streams and wetland systems (Table 1).

Assawompset, Pocksha, Great Quittacas, Little Quittacas Ponds are the primary water supply source for over 250,000 people in the Cities of New Bedford and Taunton, as well as portions of adjacent communities. Unlike most communities within the Taunton Watershed that rely almost entirely on groundwater resources for their water supply, New Bedford and Taunton depend primarily on the APC surface waters, and thus their surrounding uplands have been largely protected to help maintain suitable water quality. Additional information on this topic is in the Drinking Water Supply white paper. Good water quality is also vital for the fish and rare aquatic species that live within the APC and Nemasket River, as well as for the wide range of species that that rely on it for habitat needs, such as feeding Eagles, migrating waterfowl, and foraging otters.

The Long Pond shoreline, however, is heavily developed and public access is allowed. The larger APC and Nemasket River Watershed also faces increasing development, and portions of Freetown, Rochester, and Lakeville have some of the highest development rates in Massachusetts (Massachusetts Audubon Society, 2020). Problematically sited current and new development has the potential to fragment and degrade intact functioning ecosystems, while increasing impervious surfaces, pollution sources, and stormwater runoff and heightening the demand for drinking water. All these factors contribute to diminished water quality for both people and nature. Increased drought, rising temperatures, and intense storms expected with climate change are anticipated to exacerbate these stressors. Additional details on development are in the Land Development white paper.

Current Conditions

In fulfillment of reporting requirements under the federal Clean Water Act (Sections 305(b), 314, and 303(d)), the Massachusetts Department of Environmental Protection (MassDEP) evaluates waters with respect to their attainment of designated uses in the state's Surface Water Quality Standards Regulations (314 CMR 4.00) including suitable habitat for Fish, other Aquatic Life and Wildlife (Aquatic Life), Fish Consumption, Public Water Supply, Shellfish Harvesting, Primary (e.g., swimming) and Secondary (e.g., boating) Contact Recreation, Aesthetics, Agricultural, and Industrial uses (Massachusetts Department of Environmental Protection [MassDEP], 2021).

MassDEP's Final Massachusetts Integrated List of Waters for the Clean Water Act 2018/2020 Reporting Cycle notes the following (also see Figure 1) (MassDEP, 2021):

- **Long Pond**: Assessed as Impaired for not supporting the Aquatic Life Use based on the presence of the non-native aquatic macrophyte *Cabomba caroliniana* and *Myriophyllum heterophyllum* (TMDL not required because impairment not caused by a pollutant).
- **All other APC ponds**: Uses have not been assessed.

- **Upper Nemasket River**: The reach from the Assawompset Dam to the Middleborough Wastewater Treatment Plant (WWTP) is listed on the 303(d) list—those waters requiring a Total Maximum Daily Load (TMDL)—for not supporting the Aquatic Life Use due to low dissolved oxygen, high temperatures, and aquatic toxicity (ambient bioassays).
- **Lower Nemasket River**: The reach from the Middleborough WWTP to the Taunton River is assessed as fully supporting the Aquatic Life Use based primarily on fish community data and the typically excellent effluent quality of the Middleboro WWTP in terms of whole effluent toxicity. However, this use is identified with an Alert Status due to the presence of the non-native aquatic Asian Clam (*Corbicula fluminea)* at the mouth of the river.
- **Fall Brook**: This major tributary to the Nemasket River and coldwater fishery habitat is assessed as Impaired for not supporting the Aquatic Life Use due to the presence of diadromous Fish Passage Barriers (for river herring and American eel) at the Happy Hollow and Route 28 Dams.

MassDEP's Source Water Assessment and Protection Program Reports (SWAP) for the southeast region, produced in 2002 and 2003, are still used today as water supply protection guides. Four major potential water supply pollution sources were identified leading to the SWAP's 'High Susceptibility' rankings for the New Bedford and Taunton Water Supplies: active cranberry bogs and small horse farms, local roads and highways, septic systems and cesspools, and residential land uses (MassDEP 2002, 2003; City of New Bedford, 2020). Both cities have been proactive in water quality protection efforts, including New Bedford's acquisition of over 3,000 acres around the APC, forestry management, ranger patrols, participation in the APC Management Committee, and reviews of permitted activities within 400 feet of source waters (Rojko et al., 2001). Additional information on these topics, including source water protection and treated drinking water quality, is in the Drinking Water Supply white paper. Further details about the APC Rangers Program are in the Recreational Access white paper.

On a watershed scale, the APC and Nemasket River drain to the Taunton River, which then drains to Mount Hope Bay at the Rhode Island border. Both the Taunton River and Mount Hope Bay are on the 303(d) list and require pathogen TMDL reports (MassDEP et al., 2011; MassDEP, 2010) due to fecal coliform, E. coli, and enteroccoci bacterial impairments. While these TMDLs are specific to the water bodies, MassDEP recommends the TMDLs guide management activities for all waters throughout the watershed to help reduce bacteria and maintain and protect existing water quality. This approach is recommended because bacteria concentrations in upstream waterbodies have cumulative effect on downstream waters.

Previous studies demonstrate that high algae and depressed dissolved oxygen in the Taunton River Estuary and Mount Hope Bay are attributable to high nitrogen loads (Howes and Samimy, 2007). According to the Taunton River Watershed Alliance's water quality monitoring results (2022) Taunton River Watershed nitrogen sources include "wastewater treatment plants (66% of load) and other sources including stormwater runoff, excess lawn/turf/crop fertilization (and sloppy application of fertilizer i.e. on sidewalks, roads and driveways), pet wastes, stream bank erosion, stream buffer loss, and poor manure management from farming areas(34% of load)" Figure 2). These sources, in combination with pinch points in the upper Nemasket River—from dams, bridge crossings, undersized culverts, sand bars, and aquatic vegetation — reduce flows and impound water, further degrading water quality due to increased water temperatures, decreased dissolved oxygen, and excessive turbidity.

In compliance with the Environmental Protection Agency's new, more stringent nitrogen and phosphorus reduction requirements, Middleborough completed upgrades to its wastewater treatment plant in 2017. The Environmental Protection Agency (EPA) previously established that reaching allowable Total Nitrogen loads for the Taunton River Estuary (both ocean and watershed loads) would require a 51% watershed reduction; however, since much of that is allocated to wastewater, the EPA considers a 20% nonpoint source reduction a good target to restore estuary water quality. Now that the Middleborough Wastewater Treatment Plant is upgraded, other important nutrient sources also need attention and remediation in the watershed, including stormwater runoff, residential and commercial fertilizer use, improperly maintained septic systems, and agriculture including cranberry bogs and manure management from farming areas (MA DEP 2003; 2021). See Figure 3, Table 2, and Table 3 for a breakdown of nitrogen source loads in the APC-Nemasket Watershed.

SUMMARY OF THREATS AND CHALLENGES TO A HEALTHY, FUNCTIONING SYSTEM

- Current and future development increases impervious surfaces, pollution sources, stormwater runoff, and the demand for drinking water, all of which can create water quality stressors.
- Residential and commercial fertilizer use, improperly maintained septic systems, and agriculture (including cranberry bogs and manure sites) all contribute contaminants to waterbodies.
- Poor stormwater management contributes excess nutrients and other contaminants to waterbodies.
- The lack of both rapid response and long-term management plans to address invasive species.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes.

The implications of these anticipated changes are considered below.

More frequent intense storm events:

- The increased frequency of storms will lead to more water entering the APC and Nemasket River during concentrated periods of time, bringing increased sediment, nutrients, disease pathogens, and invasive species, degrading water quality and aquatic habitats. As this pollutant load travels downstream to estuaries and the ocean, it can lead to blooms of harmful algae and bacteria.
- Increased storm magnitude and intensity will increase flooding and stormwater flooding, thereby decreasing infiltration.

More intense flood and drought cycles:

- Increased frequency and intensity of drought will reduce infiltration and base flows, which in turn exacerbates impacts of temperature and nutrients. In combination, these and other factors will likely exacerbate environmental and community impacts associated with both wet and dry periods across seasons. Planning both for more impactful drought periods and increased water volume during wet periods will be required to protect water quality.

Increasing Total Annual Precipitation:

- Increased total annual precipitation will change the water budget in the watershed, resulting in the need to revisit assumptions about water nutrient loading.

Extreme temperatures:

- Warmer waters hold less dissolved oxygen and can lead to eutrophication and excess algal growth, which will reduce drinking water quality and degrade habitat for fish and other aquatic species, altering food webs.
- Higher surface water temperatures may make attaining water quality standards or temperature criteria more and lead to greater outbreaks of harmful algal blooms. Thus, efforts to reduce the temperature of treated wastewater discharges may be needed to help maintain water quality.
- Increased surface water temperatures will lead to less dissolved oxygen and diminished water quality habitat for aquatic species. With increased surface water temperatures, eutrophic conditions, triggered by high nutrient concentrations, may be triggered by nutrients at lower concentrations than under current conditions.

DATA GAP DOCUMENTATION

Additional water quality monitoring sites and data would be useful. In particular, a longer time scale and wider geographic range of water quality data would help identify trends. Additional coordination on water quality sampling with water suppliers would also be valuable.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Improved Water Quality and…

- Ecology, Unique Habitats and Natural Resources: Co-Benefit. Strategic land conservation and wetland restoration efforts have the potential to filter and reduce pollutants and enhance water quality; riparian restoration has been shown to be most cost-effective phosphorus control (WMOST). Removing invasive species and restoring trees might improve phosphorous, sediment, and temperature. Conversely, development of priority green infrastructure could worsen water quality in the watershed.
- Floodwater Management: Co-Benefit. Flooding over built areas has the potential to move and migrate pollutants and debris into the water system; reducing these floodwater extents will minimize this effect.
- Stormwater Management: Co-Benefit. Increased stormwater infiltration decreases runoff that carries pollutant loads into the water system, improving water quality. Stormwater flooding, potentially as frequently as the two- year flood event can cause bed moving events, destabilizing

sediments and banks, and re-circulating pollutants, especially phosphorous. This further exacerbates water quality impairment.

- Inter-Agency Cooperation: Co-Benefit. Improved coordination between local and state operators on roadway drainage systems could reduce runoff and help improve water quality. Additional agency coordination could also identify and highlight additional benefits of water quality protections, such as habitat restoration, recreational access, and stormwater management.
- Land Development: Trade-Off to Co-Benefit. Increasing land development can contribute to water quality stressors, especially through increased impervious cover. Conversely, siting new development outside of riparian areas and adjacent uplands, as well as using low impact development techniques (LID), can enhance green infrastructure and improve water quality.
- Recreational Access: Co-benefit and Trade-Off. Increased recreation can encourage users to become stewards of the areas they frequent, potentially building support for water quality improvement measures; however, watercrafts that move between watersheds could transport invasives that can harm water quality.
- Drinking Water Supply Levels: Trade-off to Co-Benefit. Lower water levels may negatively affect water quality; drought, high temperatures, and excess nutrients (nitrogen and phosphorous) can also contribute to declining water quality. Maintaining high water levels for water supply in the APC could negatively affect downstream waters such as the Nemasket but enhance conditions in the APC waterbodies.

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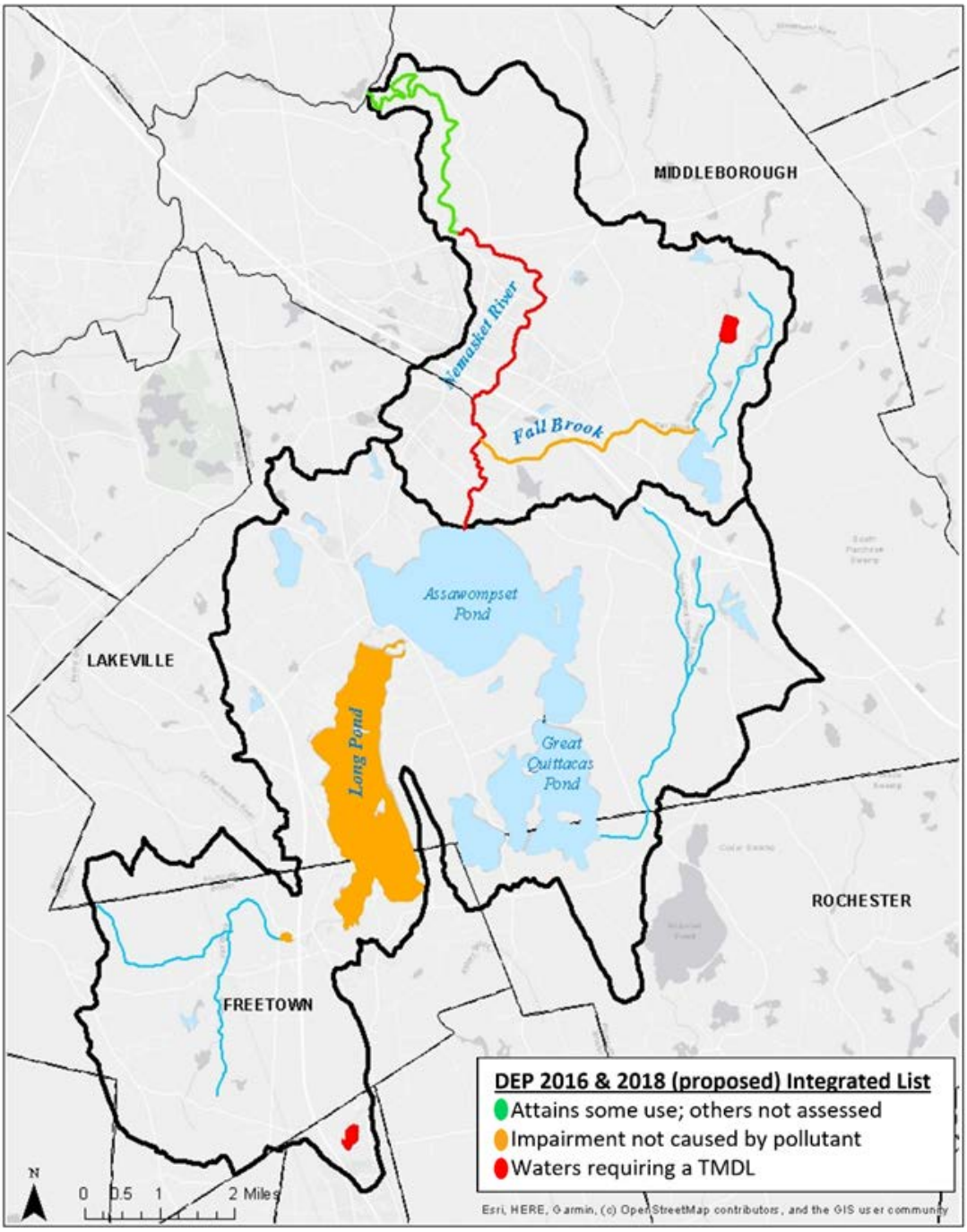
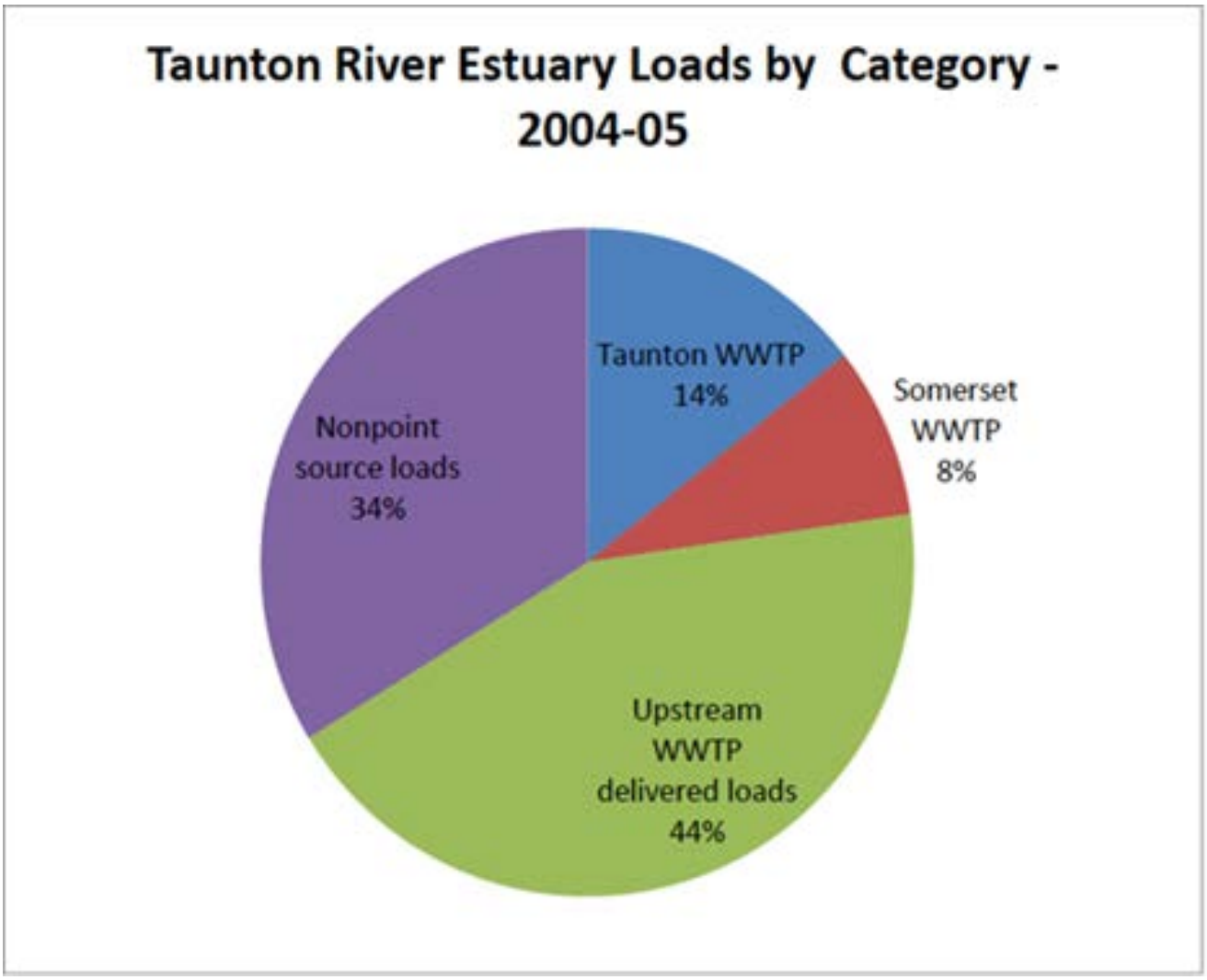
FIGURES

Figure 1. APC-Nemasket Massachusetts Department of Environmental Protection Impaired Waters.



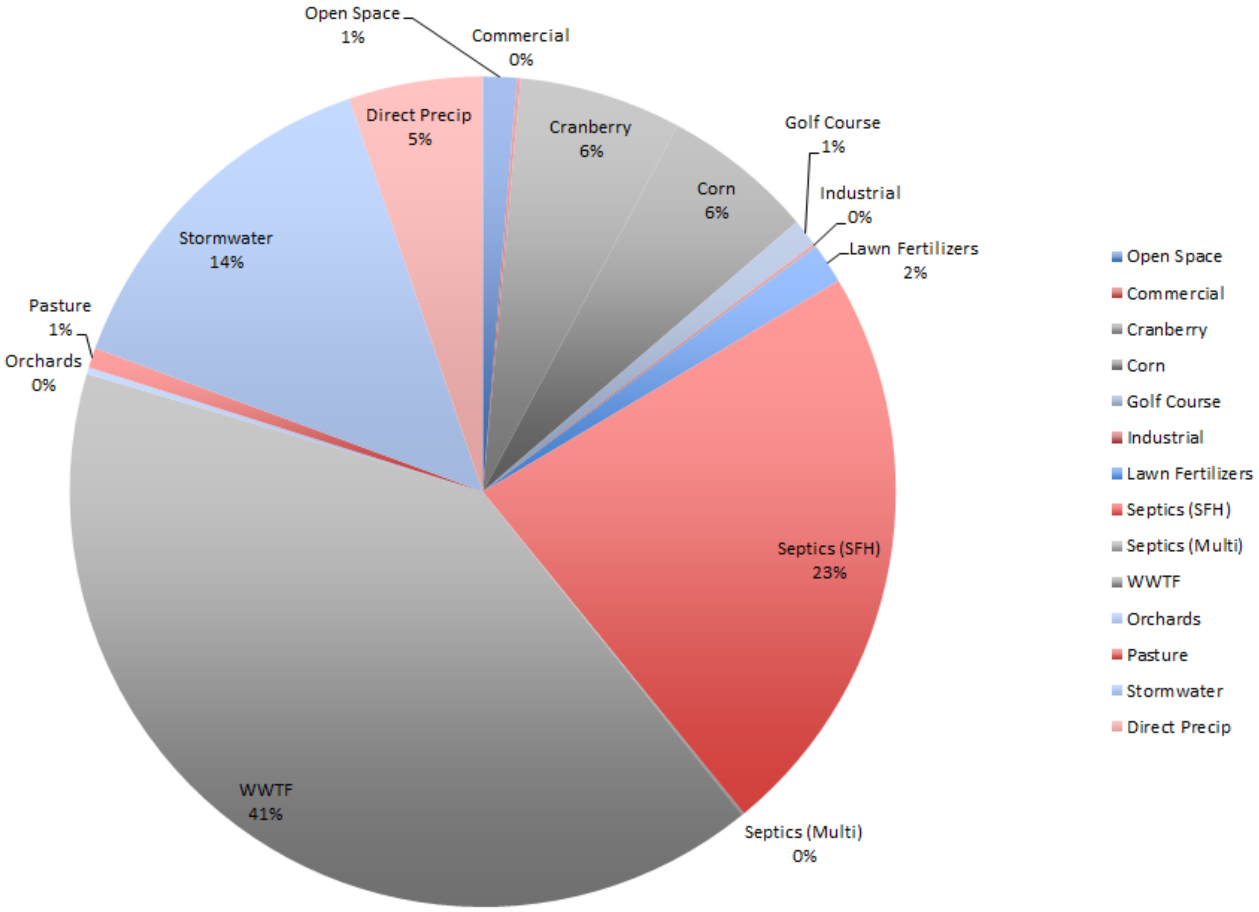
Source: MassGIS MassMapper (2022).

Figure 2. Sources of Nitrogen Loads for the Taunton River Estuary.



Notes. Adapted from Town of Middleborough (2015) Data from EPA Draft Permit Middleboro, 2015.

Figure 3. Sources of Nitrogen Loads for the Combined APC-Nemasket River HUC 12 Watersheds.



Notes. Nutrient Loading Assessment Using Method adapted from Cape Cod Section 208 Area-Wide Water Quality Management Plan. Scott Horsley and TNC. 2017.

TABLES

Table 1. APC-Nemasket Major Water Bodies

Water Body	Classification/Qualifier	Size (acres)	Avg Depth (ft)	Length (miles)
Assawompset Pond	A: PWS/ORW	2034	7-9	
Long Pond	A: PWS/ORW	1728	14	
Long Pond River	A: PWS, ORW (Tributary)			0.4
Pocksha Pond	A: PWS/ORW	592	20	
Great Quittacas Pond	A: PWS/ORW	1125	20	
Little Quittacas Pond	A: PWS/ORW	295	10-15	
Nemasket River (Assawompset Pond outlet to Middleborough WWTP discharge)	B			6.2
Nemasket River (Middleborough WWTP discharge to confluence with Taunton River)	B: WWF			5.1
Fall Brook (Nemasket tributary)	B			3.8
Black Brook				
Bates Brook				

Notes. PWS=Public Water Supply; ORW=Outstanding Resource Water; WWF=Warm Water Fishery. Adapted from Massachusetts Department of Environmental Protection (2021).

Table 2. APC-Nemasket Major Water Quality Issues

CONTRIBUTING SOURCES	MAJOR STRESSORS							
	High Nutrient Loads (N & P)	Bacteria: Fecal coliform	Low Dissolved Oxygen	Increased Water Temps.	Invasive Species	Altered Flow / Water Levels	Erosion / Sedimentation	Hazardous Materials (e.g., PFAS, oil)
Failing Septic Systems / Cesspools	X	X	X		X			
Residential / Commercial Fertilizer Use	X		X		X			
Cranberry Bogs	X		X		X	X		
Farms / Livestock / Animals	X	X	X		X	X	X	
Stormwater / Impervious Surfaces	X	X	X	X	X	X	X	X
Bridges & Culverts (river fragmentation / impoundment)			X	X		X	X	
WWTP	See Note							X
Water Withdrawals			X	X		X		
Improperly Sited Development / Loss Vegetated Buffers / Wetlands	X	X	X	X	X	X	X	X

Notes. Water quality sampling results show low nitrate levels reflecting the upgrade of the Middleborough wastewater treatment system; N = nitrogen; P = phosphorus. Adapted from MassDEP (2002, 2003, 2021); City of New Bedford (2020);)].

Table 3. Summary of Water Quality Sampling Results in the APC and Nemasket River Watershed

EXCESSIVE NITROGEN AND PHOSPHORUS	
Water Supply standard: nitrate 10 mg/L; TRWA target of concern >0.4 mg/l (slightly lower than EPA TN estuary target value of 0.45 mg/L for the Taunton River because of transport concerns to estuary); TRWA TP target of concern >0.100 mg/L	
BSC WQ Sampling 2000-2001	*Nov. high spike in Total P in Long Pond River and Snipituit Brk; Snipituit Brk has lowest discharge of 0.91 cfs but highest Total P concentration of 0.63 mg/LP.*
DEP Sampling 2013	*Nemasket 1500' DS from 495: indicative of good conditions, avg/max TP concentrations 0.032/0.045 mg/L and very low ammonia nitrogen concentrations—max 0.03 mg/L (DRAFT MA ILW for CWA 2018/20 Reporting Cycle)*
BACTERIA: FECAL COLIFORM	
TMDL for Taunton Watershed; TRWA target of concern: Enterococci >61 colonies/100 ml; also must meet primary/secondary contact standards—MA Surface Water Quality Standards/DPH: for enterococci, no single sample during bathing season shall >61 colonies/100ml	
TRWA Sampling	*Nemasket at Murdock St exceeded 2019 (4 months) and 2021*
BSC WQ Sampling 2000-2001	*Exceeded at Snipituit and Bates Brks Oct rain event and Fall Brk in early Aug; only Bates Brk samples during fall regularly approached limit (200 CFU)*
LOW DISSOLVED OXYGEN	
TRWA target of concern <5.0 mg/L (or high values during blooms); Massachusetts Class B Water Quality Standards for warm water freshwater fisheries; not be less than 6.0 mg/l in cold water fisheries	
TRWA Sampling	*Nemasket at Murdock St: DO low 7/2019*
DEP Sampling 2013	*Nemasket 1500' DS from 495: DO quite low, ranged 0.2-7.7 mg/L and was <4 mg/L for total of 276.9 of 354.5 hrs of probe deployment; Fish, other Aquatic Life and Wildlife Use: Not Supporting (Alert) (DRAFT MA ILW for CWA 2018/20 Reporting Cycle; DO Impairment Added)*
DEP Sampling 2013	*Nemasket 1500' DS from 495: although not added as impairment, sample dominated by naid worm so identified with an 'Alert' (DRAFT MA ILW for CWA 2018/20 Reporting Cycle)*
BSC WQ Sampling 2000-2001	*20 of 49 samples <5.0 mg/l, most during fall at Nemasket at Vaughn St., Bates Brk, Long Pond River inflow to AP, Black Brk, and Snipituit Brk (low flow fall 2000 contributed to these at Bates, Black, Snipituit Brks, all except Bates <5.0 mg/l Aug-Oct, below MA Warm Water Fish Criteria Minimum of 5.0 mg/l. Snipituit Brk barely reached 4.0 mg/l by end of fall and began showing low DO again in April 2001.*
INCREASED AIR / WATER TEMPERATURES	
DEP Sampling 2013	*Nemasket 1500' DS from 495: max water temp 30.4° C and exceeded acute max 24-hr avg of 28.3° C on 2 days in July while chronic 7-DADM of 27.7° C was exceeded 11 times; further DS near Oliver Mill Pond Dam (2004-2017), ~7-day exposure survival Pimephales promelas was not good, ranged <75% (13-100%); and all tests with P. promelas survival <50% were in May (DRAFT MA ILW for CWA 2018/20 Reporting Cycle; Temperature Impairment Added)*
BSC WQ Sampling 2000-2001	*49 pH measurements at 7 sites 8/2000-4/2001, only 3 had >6.5; inlet waters typically had pH <6.0; the lowest of 4.61 & 4.67 occurred at Black & Fall Brks during March after major snowfall*
DEP Sampling 2013	*Nemasket 1500' DS from 495: pH quite low 5.8SU (n=3); Low pH and alkalinity are considered naturally occurring so they are no longer being identified as 'Alert' issues (as in 2001 report)*

Notes: Adapted by TNC for this White Paper from Taunton River Watershed Alliance (2021); Massachusetts Department of Environmental Quality (2021); and Southeast Regional Planning and Economic Development District (2002)

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

ECOLOGY, UNIQUE HABITATS, AND NATURAL RESOURCES

CURRENT CONDITIONS IN THE WATERSHED

Overview

The Assawompset Ponds Complex (APC)—including Assawompset Pond, Pocksha Pond, Great Quittacas Pond, Little Quittacas Pond, and Long Pond—is the largest natural body of fresh water in Massachusetts. The APC, within the Taunton River watershed, drains north via the Nemasket River to its confluence with the federally designated Wild and Scenic Taunton River, which then flows southwest to Mount Hope Bay on the Rhode Island border. The APC and Nemasket River Watershed is well-known as critical habitat for the largest herring run in the state, and the basin's variety of wetland and upland habitats provide a wide range of environments rich in biodiversity.

In fact, nearly 23,500 acres, or 52% of the 45,000-acre APC-Nemasket basin, are designated as Natural Heritage BioMap2 (BM2) Core Habitat and/or Critical Natural Landscape (Figure 1)—those areas defined as most critical to ensuring long-term persistence of rare and native species and their habitats, exemplary natural communities, and a diversity of intact, functioning ecosystems (BioMap2, 2010). Sixteen state-listed rare species and a high number of globally imperiled species are present in the basin—including the northern red-bellied cooter (*Pseudemys rubriventris)*, Plymouth gentian (*Sabatia kennedyana*), water-willow borer moth (*Papaipema sulphurata*), and bridle shiner (*Notropis bifrenatus*) (BioMap2, 2010; Massachusetts Division of Fisheries and Wildlife, Natural Heritage and Endangered Species Program [MA DFW-NHESP], 2021)—as well as numerous uncommon wildlife and plant species, such as environmentally sensitive river otters and freshwater mussels.

The APC waterbodies and Nemasket River are further designated as BM2 Aquatic Core Habitat—intact river systems where important physical and ecological processes function for fish and aquatic species of special concern (BioMap2, 2010). These same ecosystem functions provide crucial services for people as well. Assawompset Pond, Pocksha Pond, Great Quittacas Pond, and Little Quittacas Pond are the water supply for over 250,000 people, and thus their surrounding uplands have been largely protected to help maintain suitable water quality. The Long Pond shoreline, however, is heavily developed and allows public access. The larger APC and Nemasket River Watershed also faces increasing development, and portions of the watershed are among the most rapidly developing areas in the state (Massachusetts Audubon Society, 2020). This trend has the potential to fragment and degrade functioning intact ecosystems while simultaneously increasing water supply needs and impervious surfaces, exacerbating droughts and flooding, and reducing ecosystem services for both nature and people. Additional information on these trends and topics are in the Drinking Water Supply, Land Development, and Water Quality white papers.

The following sub-sections cover information about the ecology and habitat of the APC and Nemasket River Watershed. Information is organized by ecological community type, with information about species and habitat, stressors, and anticipated climate change impacts.

Anadromous Fisheries

Species and Habitat

The Taunton and Nemasket Rivers host the largest herring runs in southern New England, as fish migrate upstream 46 miles to reach 5,000 acres of spawning and nursery habitat in the APC—the largest such habitat in the state. This run was almost decimated in the 1940s when sewage discharge, industrial pollution, and depleted dissolved oxygen in the Taunton River led to a massive die-off, abruptly halting

the spring run (Maddigan, 2014). Under management of the Middleboro-Lakeville Herring Fishery Commission, the Nemasket River has supported the largest herring run in Massachusetts for the last 20 years among the over 40 runs with count data (with the exception of the Mystic River (Medford) and Herring River (Harwich)). Nemasket counts from 2020 to 2021 declined only modestly compared to other runs, decreasing from 811,000 to 739,000 fish, respectively (Chase, 2021). A barrier prevents fish from entering Little Quittacas Pond in order to prevent them from being drawn into and harmed by the New Bedford water supply intake.

Stressors

Despite being flat and slow, current conditions in the Nemasket River allow the upstream herring migration in the spring. The fish navigate beyond three dams and numerous culvert, road, and railroad crossings—structures which can present challenges to upstream passage. Emergent aquatic vegetation in the impoundment above the Wareham Street Dam[1] and other slow-moving sections of the river cause problems for migrating fish (Reback et al., 2004; T. Barron, personal communication, 2021). These same low gradient conditions—and a combination of water supply withdrawals, reduced pond levels and river flows, sediment aggradation, and invasive aquatic vegetation—present challenges to the fall downstream herring emigration. As a result, juveniles can become stranded or trapped behind the Assawompset Dam (T. Barron, personal communication, 2021).

Downstream flows can become further reduced during periods of drought, when pond levels need to be maintained for water supply purposes. Currently, the Assawompset Dam spillway boards are manually manipulated to manage flow and allow emigration during low flow periods. Aside from very low water years, there does not appear to be limitation of spawning or nursery habitat for adults (MA Division of Marine Fisheries, 2016). Although herring are transient inhabitants of the APC and Nemasket River Watershed, poor water quality can affect all age classes, including eggs.

Fall Brook, a major tributary to the Nemasket River, is listed on the Massachusetts Department of Environmental Protection's (MassDEP) Massachusetts List of Impaired Waterbodies as not supporting the Aquatic Life Use because of the presence of diadromous fish passage barriers (for river herring and American eel) at the Happy Hollow and Route 28 Dams.

Anticipated Climate Change Impacts

Warmer ocean temperatures can shift fish species distributions further north toward cooler waters and trigger earlier spring herring migrations. Research shows that several New England streams have reached suitable spawning temperatures almost two weeks earlier than 40 years ago, indicating herring runs are occurring earlier (Ellis & Vokoun, 2009). Earlier spawning, in combination with expected changes in amount and timing of water, will need to be accounted for in dam management and fishway operations. Additionally, increased drought, low flows, and dewatering may further exacerbate pinch points (e.g., bridge crossings) along the Nemasket River, limiting and/or restricting upstream migrations.

The 2016 drought is believed to have caused substantial declines in many 2020 Massachusetts herring runs, as degradation of spawning habitat, water quality, and reduced downstream emigration led to poor recruitment that year, resulting in lower numbers of returning four-year-old individuals in 2020

[1] This dam is also referred to as the Bascule Dam or Nemasket Park Dam. Additional relevant information is in the Floodwaters Management white paper.

(Chase, 2021). The Nemasket River was spared this loss, with a count of over 800,000 herring in 2020, but the effects of the more recent 2020 drought are yet to be seen. Future increases in temperatures, drought, and water withdrawals have experts concerned over this trend (Chase, 2021). In the future, the Nemasket River herring run may not be spared from impacts like the 2016 drought.

Although the APC ponds are naturally shallow and prone to temperature changes, except for years of very low water, there has not been observed degradation of spawning or nursery habitat (MA Division of Marine Fisheries, 2016). However, the combination of future increased temperatures, increased storms with excessive runoff and pollution, and water withdrawals could degrade these habitats. For example, many lakes and ponds in southeastern Massachusetts have experienced an increase in seasonal algal blooms, including toxic cyanobacteria, and low levels of dissolved oxygen, leading to fish kills.

Warmwater Fisheries

Species and Habitat

The APC supports a diverse warmwater fishery, including largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), yellow perch (*Perca flavescens* and white perch (*Morone americana*), bluegill (*Lepomis macrochirus*), pumpkinseed (*Lepomis gibbosus*), chain pickerel (*Esox niger*), white sucker (*Catostomus commersonii*), brown bullhead (*Ameiurus nebulosus*), sessellated darter (*Etheostoma olmstedi*), golden shiner (*Notemigonus crysoleucas*), and lake chubsucker *(Erimyzon sucetta*). Long Pond is a major site for largemouth bass fishing tournaments. The APC is also believed to support a limited remnant walleye (*Sander vitreus)* population. The Nemasket River has one of the most diverse and productive warmwater fish communities in southeastern Massachusetts, known for largemouth bass, yellow perch, and sunfish. Based on available habitat and years of fish surveys conducted by Kevin Curry of Bridgewater State, any species found in the Taunton River watershed can be expected to occur in the Nemasket River (S. Hurley, personal communication, 2021).

Long Pond supports the bridle shiner, a minnow state-listed as Special Concern (MA DFW-NHESP, 2021). Important habitat for this species includes moderate amounts of submerged aquatic vegetation mixed with open areas of clear water for schooling and feeding, as they are visual feeders and weak swimmers (Massachusetts Division of Fisheries and Wildlife, Natural Heritage and Endangered Species Program [MA DFW-NHESP], 2015b).

Stressors

Long Pond is heavily developed and the only pond in the APC with public access. Associated impacts to water quality from runoff and excessive use of personal watercraft could lead to increases in turbidity and aquatic vegetation, decreasing water clarity and feeding efficiency for bridle shiners (MA DFW-NHESP, 2015b). Long Pond is designated on MassDEP's Massachusetts List of Impaired Waterbodies as not supporting the Aquatic Life Use due to non-native aquatic macrophytes variable milfoil (*Myriophyllum heterophyllum*) and fanwort (*Cabomba caroliniana)* (Massachusetts Department of Environmental Protection [MassDEP], 2021). Substantial concentrations of milfoil can displace native submergent vegetation used as cover and spawning habitat for the bridle shiner, and predation by largemouth bass can further stress populations. Bridle shiner populations have decreased dramatically from their historic range; healthy populations are critical for persistence of this species (MA DFW-NHESP, 2015b).

Anticipated Climate Change Impacts

Although it may seem counterintuitive, warmwater fish also face threats from predicted climate change. Naturally occurring fish kills in late spring-early summer, due to low dissolved oxygen levels and occasional spawning stress or fish disease, may increase with warming temperatures (Environmental Emergency Response Program, n.d.). Warmer water cannot hold as much oxygen as cooler waters, and oxygen can be further reduced in ponds with dense aquatic vegetation when plants increase overnight oxygen consumption. This stress can be further compounded in late spring-early summer when most warmwater fish congregate to spawn in shallow, near shore areas (Environmental Emergency Response Program, n.d.). Warmer waters also create a breeding ground for bacterial infections and parasites (Climate Central, 2018). During this crowded spawning period, fish may become more vulnerable to disease (Environmental Emergency Response Program, n.d.).

Milder winters, however, may reduce natural fish kills for some species as reduced ice cover and increased light helps maintain adequate dissolved oxygen levels (Shuter et al., 2012; Environmental Emergency Response Program, n.d.). Although many warmwater fish are fine above 70°F, warmer temperatures, droughts, and limited water, could push some species towards thermal tolerance limits, forcing them to seek new habitats and expand their range if freshwater systems remain connected and fish are able to navigate obstructions (Yoder, 2012; Climate Central, 2018). Warmer temperatures could also trigger earlier spawning and impact peak season for recreational bass fishing in Long Pond (Massachusetts Climate Adaptation Partnership, 2015e; Climate Central, 2018).

Coldwater Fisheries

Species and Habitat

In addition to the APC ponds supporting a warmwater fishery, some tributaries to Little Quittacas Pond, Long Pond (Mullein Hill Brook), and the Nemasket River (Stony Brook, Fall Brook, and Fords Brook) with cold, highly oxygenated water host wild brook trout (S. Hurley, personal communication, 2021; Hartel et al., 2002; MassGIS, 2021). Brook trout would also be expected to occur in some of the predominantly warmwater habitats of the APC when temperature conditions allow, such as cooler months in winter and early spring (S. Hurley, personal communication, 2021).

Stressors

Coldwater streams are very sensitive to land use changes, and very few remain in eastern Massachusetts. Wild Brook Trout require clean, cold oxygenated water—not tolerating temperatures above 68° for extended periods—and have experienced extensive reductions in distribution and abundance due to habitat degradation (Massachusetts Climate Adaptation Partnership, 2015; Massachusetts Division of Fisheries and Wildlife, 2015; Hartel et. al., 2002). The healthiest populations occur in western Massachusetts and those in eastern Massachusetts, including those around the APC, have been greatly reduced and primarily inhabit headwater streams (Trout Unlimited, 2006).

Anticipated Climate Change Impacts

Coldwater streams are highly vulnerable to climate change (Massachusetts Climate Adaptation Partnership, 2015c). Increased air temperatures, droughts, erratic precipitation events, and altered flows are predicted to affect many coldwater streams, inducing earlier upstream trout migration and spawning and reducing survival (Massachusetts Climate Adaptation Partnership, 2015; Chague, G. 2020; Ebersole et al., 2020). Ultimately, these habitats may likely become too warm to support brook trout

during summer months and transform instead to habitats that support more tolerant species, leading to changes in species composition and a reduction in native species (Chague, G. 2020).

The identification and conservation of lakes and streams likely to support coldwater fisheries—which would serve as climate change refugia—will be critical to maintaining these populations. Management strategies include the protection of flow to small spring-fed headwater streams, conservation of forested riparian buffers along small tributary streams to provide shading and temperature control, and selective removal of unnecessary dams and other obstructions and warm water impoundments to enhance cold-water habitats and connectivity with habitats for different life stages (Massachusetts Climate Adaptation Partnership, 2015, 2015d; Ebersole et al., 2020; Albright et al., 2021; Willliams, et al., 2015). As described above, Fall Brook, a major tributary to the Nemasket and some coldwater fisheries habitat, is listed on MassDEP's Massachusetts List of Impaired Waterbodies as not supporting the Aquatic Life Use due to the presence of diadromous fish passage barriers (for river herring and American eel) at the Happy Hollow and Route 28 Dams.

Freshwater Mussels

Species and Habitat

Along with portions of the Nemasket River, the sandy substrates, good water quality, and limited pond shore development in the APC supports six of the twelve mussel species in Massachusetts, two of which—the tidewater mucket (*Leptodea ochrarcea*) and eastern pondmussel *(Ligumia nasuta*)—are state-listed as Special Concern. The APC (and several coastal ponds in southeastern Massachusetts) support some of the healthiest populations of these two species along the Atlantic slope, demonstrating the importance of these habitats and associated fish populations. Mussel life history is uniquely tied to healthy fish populations; in Massachusetts, most mussels spawn in summer, brood fertilized eggs in female gills over the winter, and release glochidia (larvae) the following spring-summer to attach to the gills and fins of host fish(es). After several weeks, juveniles drop from their host to the pond or river bottom where they remain burrowed for several years until emerging as adults. Host attachment is the primary dispersal mode for mussels, so if habitat conditions are good, mussels may spend the next 10, 20, or over 100 years of their life (species dependent) in these habitats. Although all host fish are not confirmed, it is speculated that ponds with strong spring alewife runs may provide the best habitat for the tidewater mucket (MA DFW-NHESP, 2015e). Mussels are good for the APC's water quality too: one adult mussel can filter up to 15 gallons of water per day and with abundant populations 'cleaning' the water, they collectively filter out tons of particulates per year.

Stressors

In general, healthy populations of freshwater mussels need clean water, adequate water quantity, suitable substrates free of heavy silt loads, and healthy host fish populations. Essentially sedentary filter feeders, mussels are unable to flee from degraded environments and are the second most imperiled animal group in North America (recently displaced by snails).

Loss of stream connectivity in the upper Nemasket River—from dams, bridge crossings, undersized culverts, low flows, sedimentation, and aquatic vegetation—can limit host fish passage, reduce mussel dispersal, limit upstream colonization, and lead to habitat and population fragmentation compounded by potential genetic isolation. The aforementioned Fall Brook diadromous fish passage barriers exemplify this type of connectivity loss and may reduce fish passage to Tispaquin Pond, which supports one known Special Concern mussel species.

Heavy precipitation and intense storm events, combined with increased development and impervious surfaces, can lead to excessive run-off, pollution (especially phosphorus and nitrogen), and sedimentation. Sediment obliterates suitable substrate and can bury and suffocate mussels. Associated degradation in water quality—particularly reduced dissolved oxygen levels, increased water temperatures, and turbidity—interferes with mussel filter feeding and reproduction and potential loss of less tolerant species. MassDEP has added the upper Nemasket River, from the Assawompset Dam to the Middleborough Wastewater Treatment Plant, to the 303(d) list—those waters requiring a Total Maximum Daily Load report (TMDL)—for not supporting the Aquatic Life Use due to low dissolved oxygen, high temperatures, and aquatic toxicity (ambient bioassays) (MassDEP, 2021). Additional details are in the Water Quality white paper.

Combined with low flows and warmer summer temperatures, these conditions can lead to increased aquatic vegetation (e.g., invasives) and algal blooms, further reducing dissolved oxygen and increasing the potential for toxicity and possible fish and mussel die-offs. In 2018, a Cyanobacteria bloom in Woods Pond in Middleborough lead to a Board of Health Advisory and closure of the bathing beach (C. Hassett, personal communication, 2022).

In addition to development along Long Pond, other potential sources of contamination include polluted (e.g., nutrients, sediments) stormwater runoff from road drainage (Routes 18 and 105), septic system leachate, and sediments from sand and gravel processing on Assawompset Neck, which is a specific threat to groundwater quality (Massachusetts Audubon Society, n.d.);

Sandy, nearshore areas in the APC are believed to be important nursery habitat for juvenile mussels. Current water level fluctuations and rapid or prolonged dewatering of these areas for water supply, flood control, or maintenance activities can strand mussels leading to massive die-offs of adults and juveniles with loss of recruitment. Minimizing recreation in these areas in Long Pond is important, as these activities often lead to shell crushing/mortality due to trampling or boat use.

The invasive aquatic plants, variable milfoil and fanwort are present in the APC and Nemasket River Watershed. Lake populations occupy the photic zone, or same shallow nearshore areas as mussels, and dense concentrations can limit or obliterate available substrate for mussels. Long Pond is listed on MassDEP's Massachusetts List of Impaired Waterbodies as not supporting the 'Aquatic Life Use' due to these two non-native aquatic macrophytes; uses of the other APC ponds have not been assessed. Invasive vegetation in the Nemasket River aggregates sediment, limiting suitable substrates for mussels; when combined with low flows, these conditions can block host fish movements. Treatments for invasive plants in ponds includes the use of herbicides, which may pose a threat to mussels. Manual removal in the Nemasket with an EcoHarvester was recently conducted.

A large population of invasive Asian clam (*Corbicula sp*.) occurs in Long Pond, and further research is needed to assess populations in other APC ponds. Dense populations—with their ability for rapid reproduction, growth, and high filtering capacity—can alter aquatic ecosystem processes, most notably when high levels of nitrogen are released during excretion, further stimulating algal and plant growth (Lauritsen and Mozley, 1989; Sousa et al., 2008). Decomposition after massive clam die-offs can degrade water quality (New York Invasive Species Information, 2019; McDowell et al., 2014). More research is needed to determine whether dense populations could displace native mussels and if their high filtering capacity reduces mussel food resources. Additionally, if present in Little Quittacas Pond, juveniles carried by water currents could potentially pass-through filter screens and colonize the intake pump at

the New Bedford Water Treatment Plant, possibly obstructing flows and becoming a costly management problem (Prokopovich & Herbet, 1965; Isom et al., 1986; Devick, 1991). Accumulating clam shells at Long Pond beaches can interfere with recreational use. Anglers should take care to empty live wells and remove aquatic plants from boats and trailers before leaving the pond (Massachusetts Division of Fisheries and Wildlife [MA DFW], 2019). The lower Nemasket River (i.e., from the Middleborough Wastewater Treatment Plant to the Taunton River) is listed on MassDEP's Massachusetts List of Impaired Waterbodies as fully supporting the Aquatic Life Use based primarily on fish community data and the typically excellent effluent quality of the Middleboro WWTP in terms of whole effluent toxicity (the WWTP was recently upgraded to meet current EPA standards); however, this reach is identified with an Alert Status due to the presence of the Asian clam at the mouth of the river (upstream extent unknown). Additional details are in the Water Quality white paper.

Anticipated Climate Change Impacts

The APC ponds are naturally shallow and prone to temperature changes. The combination of increased temperatures, drought, and excessive drawdowns will likely prolong periods of low water, reduced flows, and expand dewatered areas, leading to mussel die-offs which may be particularly problematic for sensitive juveniles burrowed in nearshore substrates.

Additionally, these conditions could cause seasonal algal blooms, including toxic cyanobacteria, and low dissolved oxygen, leading to mussel die-offs. Such an event occurred over multiple years in two lakes in Barnstable, leading to the loss of hundreds of thousands of mussels and significant mussel filtering and water cleaning capacity. The potential for more eutrophic conditions can lead to changes in mussel food resources, fish populations, and reduced viability of rare mussel populations with shifts towards species more tolerant of degraded conditions.

Warmer water temperatures could induce earlier seasonal mussel spawning, and warmer ocean and stream temperatures can trigger earlier anadromous fish species migration and spawning, possibly leading to a misalignment of host fish presence and spring glochidial release. Earlier snowmelt and runoff are expected to lower spring peak stream flows by the second half of the century, possibly limiting fish migration and further limiting successful mussel host fish attachment.

Invasive Asian clams are sensitive to high temperatures, reduced dissolved oxygen, and exposure to air (McMahon & Bogan, 2001). While warmer winters may favor healthier populations, warmer summers with degraded water quality and dewatering could lead to die-offs.

These conditions can further reduce stream connectivity, precluding mussels from reaching cooler upstream refugia in response to thermal intolerances in degraded downstream conditions.

Increased storms and heavy precipitation, in combination with increased development and impervious surfaces, will lead to flash flooding that can dislodge mussels and wash them downstream to unsuitable habitats or strand them in dewatered areas once flood waters recede. During the summer, such floods could interfere with spawning success and egg fertilization.

Waterfowl and Birds

Species and Habitat

The APC and Nemasket River Watershed is designated by Massachusetts Audubon as a state Important Bird Area (IBA) containing assemblages of species characteristic of a representative, rare, threatened, or

unique habitat and supports significant concentrations of a flocking species. The watershed's oak-conifer forests, lakes and ponds, and limited inland wooded swamps have been known to support bald eagle (*Haliaeetus leucocephalus*), northern parula (*Setophaga americana*), king rail (*Rallus elegans*), and American bittern (*Botaurus stellaris*).

The APC—with extensive waterbodies, good water quality, large fish, and intact forested shorelines—is one of only four sites in Massachusetts that bald eagles (state-listed as Special Concern) use for both nesting and overwintering (MA DFW-NHESP, 2019a). The APC also hosts the first naturally returning pair of eagles and one of the most productive nest sites in Massachusetts (Massachusetts Audubon Society, n.d.). The protected, intact forested shoreline provides the critical buffer from human disturbance that eagles require, and its tall trees are vital for nesting, roosting, and providing unimpeded water views when perching. The APC was also the first inland site to be colonized (Massachusetts Audubon Society, n.d.) by osprey when populations began to recover after near extinction in Massachusetts. The freshwater marshes that fringe the APC are known to support the secretive least bittern (*Ixobrychus exilis*), state-listed as Endangered (MA DFW-NHESP, 2015d). Recently, as a result of a multi-year common loon (*Gavia imm*er) restoration project, loon chicks that were translocated to the APC from out of state, successfully fledged. They then returned to the region years later to breed, resulting in the first chick to hatch in southeastern Massachusetts in over a century (MA DFW-NHESP, 2020a).

The APC is a waterfowl hotspot during both fall migration and the winter season (J. Sweeney, personal communication, 2021), with some of the highest numbers of migrating birds in the state (Massachusetts Audubon Society, n.d.). While many birds utilize the ponds briefly before moving south, good numbers of a diversity of species remain for the winter. Recently, it is not unusual to have 200 ring-necked ducks (*Aythya collaris*) at Little Quittacas Pond during peak migration. Both greater scaup *(Aythya marila*) and lesser scaup (*Aythya affinis*) can be found during the winter at Assawompset, Pocksha, and Great Quittacas Ponds, including mixed species scaup rafts of up to 150 birds. This abundance and diversity of waterfowl demonstrates that the APC is an important feeding area during migration and throughout the winter (J. Sweeney, personal communication, 2021).

Large concentrations of wintering gulls can be found at Assawompset Pond, Elders Pond, and occasionally other APC ponds during the winter. Recent mixed species flocks have exceeded 2,000 birds. The most common species are herring gulls (*Larus smithsonianus)*, ring-billed gulls (*L. delawarensis)*, and great black-backed gulls (*L. marinus*); however, Iceland gulls (*L. glaucoides*) and lesser black-backed gulls (*L. fuscus)* have been observed recently at Assawompset and Elders Ponds. Other species observed at various times of year include Bonaparte's, laughing, and glaucous gulls (J. Sweeney, personal communication, 2021).

While the APC and Nemasket River Watershed has hosted small numbers of migrant shorebirds over the years, there has been an apparent increase in species taking advantage of available food on exposed shorelines during recent droughts. Semipalmated sandpipers (*Calidris pusilla*) and white-rumped sandpipers (*C. Fuscicollis)* have been observed foraging at Great Quittacas Pond and, although it is unclear, may be feeding on exposed mollusks and attendant insects (J. Sweeney, personal communication 2021). In the early 1990s, a single least tern (*Sternula antillarum*) (state listed as Special Concern) was observed foraging at Pocksha Pond, much further from its coastal breeding habitat than is typical for post-breeding foraging. The APC and Nemasket River area does not get much coverage by birders in mid-late summer, and it is possible least terns may occasionally use some of the APC as

ancillary foraging in areas not publicly accessible, thus going unnoticed (J. Sweeney, personal communication, 2021).

The upland habitats in the APC and Nemasket River Watershed also support uncommon breeding birds. The eastern whip-poor-will (*Antrostomus vociferus*) (state listed as Special Concern), now absent from much of its historical range in the state, relies on Massachusetts for important breeding grounds (National Audubon Society, n.d. b). This nocturnal ground-nester occurs in the APC and Nemasket Watershed and requires habitats that experience regular disturbance, such as fire, and generally nests in dry, open woodlands near meadows and shrublands for foraging (MA DFW-NHESP, 2019c). There are currently several purple martin (*Progne subis*) colonies within the watershed. Although this aerial insectivore is an uncommon and local breeder in Massachusetts, the APC has historically been a breeding hotspot for this species. In recent years, the fields at Betty's Neck have supported nesting bobolinks (*Dolichonyx oryzivorus*) (J. Sweeney, personal communication, 2021), a species that has declined due to loss of grassland habitat. The intact, forested riparian corridor along the Nemasket River is important for nesting forest interior species, including several state-listed species such as the sharp-shinned hawk (*Accipiter striatus*), coopers hawk (*Accipiter cooperii*), and northern parula warbler.

Stressors

Protection and enhancement of potentially suitable wetland and forest habitats and maintenance of known breeding, roosting, and wintering areas will be critical to long-term conservation of bald eagles in Massachusetts. The increased population of bald eagles in Massachusetts has also brought competition from other eagles and raptors for nesting sites (MA DFW-NHESP, 2019a).

Recent declines to least bittern populations are likely due to marsh destruction and chemical and sediment runoff. Invasions of purple loosestrife and phragmites plants are also major threats to habitat. Wakes from boats in Long Pond could inundate nests (MA DFW-NHESP, 2015d).

The decline of whip-poor-will populations over the past few decades is due to a variety of reasons, including habitat loss and reduction in insect populations (Purves, 2015). In Massachusetts, the primary threat appears to be habitat loss due to development or the lack of natural disturbance, such as fire exclusion (MA DFW-NHESP, 2019c). As ground nesters, they are very vulnerable to dogs, cats, and unnaturally high predator populations, such as raccoons and skunks, often associated with residential development close to their habitat (MA DFW-NHESP, 2019c).

Bobolinks are in decline throughout Massachusetts due to loss of extensive grassland habitat that is not mowed before the young have fledged (MA DFW-NHESP, 2015a).

Anticipated Climate Change Impacts

The National Audubon Society's climate model estimates that only 26% of bald eagles' current summer range in North America will be remaining by 2080. Although 73% of the summer range could potentially be recovered in new areas opened up by a shifting climate, establishment of these areas is not certain unless suitable food and nesting habitat is secured. It is anticipated that breeding habitats will be sought further north into Canada and Alaska (National Audubon Society, n.d. a). Warmer temperatures, droughts, and low flows may reduce water quality and threaten abundance of fish populations and food resources for eagles. Extreme weather with high winds can impacts eagle nests and chicks.

Increased precipitation can lead to flooding of marsh and nesting habitat and increased temperatures, development, and associated runoff can lead to changes in water quality affecting food resources for least bitterns, as well as increase potential impacts from the nematode parasite Eustrongilides, known to reduce wading bird populations (MA DFW-NHESP, 2015d). The National Audubon climate change model also predicts by 2080, least bittern summer range will be reduced by 69%, and winter range is expected to shift further north. Although its summer range could increase 73% in new habitats, there is no guarantee how these birds will adapt to new habitats (National Audubon Society, n.d. c). Warmer spring temperatures and heat waves can endanger whip-poor-will chicks in nests, and heavy rains can flood nests and interfere with feeding. The National Audubon Society climate change model predicts that 78% of its breeding range and 55% of the non-breeding range will be lost by 2080.

More frequent and extended periods of precipitation with associated cool temperatures in the spring could make it more difficult for purple martins to find enough insects to feed their young during the breeding season (J. Sweeney, personal communication, 2021).

With potential increase in prolonged dry periods, the APC shoreline habitat may become more attractive to migrating shorebirds**,** as many of these species are long distance migrants (e.g., white-rumped sandpiper migrates from the Canadian high arctic to Tierra Del Fuego) requiring reliable and accessible feeding sites for successful migrations. Any expansion of shoreline habitat is likely to yield increased human and pet traffic, especially in places accessible to the public. Places marked no trespassing may also see increases in human and pet traffic. These trends are likely to disturb shorebirds (and other avian species) using this area for feeding during critical migration stops (J. Sweeney, personal communication, 2021).

Turtles

Species and Habitat

Two state-listed turtles are known from the APC and Nemasket River area. The eastern box turtle (*Terrapene carolina*), state-listed as Special Concern, occurs in low densities in Massachusetts where it is at the northeastern edge of its range. Populations are more heavily concentrated in southeastern Massachusetts where this small terrestrial turtle uses a mix of habitats, including varied forested and open uplands and shallow wetlands near portions of the APC and Nemasket River (MA DFW-NHESP, 2015c). The northern red-bellied cooter, federally and state listed as Endangered, is at the far northern edge of its range in Massachusetts and only occurs in portions of Plymouth and Bristol Counties, separated by over 200 miles from the nearest population in New Jersey. The abundant aquatic vegetation and warm, sunny basking sites in the APC and Nemasket River Watershed provide critical year-round habitat for this species (MA DFW-NHESP, 2016; M. Jones, personal communication, 2021). Anecdotally, two other state Special Concern species, the wood turtle (*Glyptemys insculpta*), and Blanding's turtle (*Emydoidea blandingii*), as well as the uncommon spotted turtle (*Clemmys guttata*) are also known from the vicinity and appropriate habitat for these species occurs within the APC-Nemasket basin. Other common species that appear abundant are the snapping turtle (*Chelyddra serpentina*) and painted turtle (*Chrysemys picta*).

Stressors

Box turtle populations in southeastern Massachusetts overlap with the portion of the state facing the heaviest development pressures. Combined with their use of upland habitats, this overlap poses significant threats from habitat destruction from residential and commercial development, road

mortality, field mowing, predation, and nesting disturbance from all-terrain vehicles (MA DFW-NHESP, 2015c). Conservation of viable populations will depend on protecting large, unfragmented habitats, maintaining access to nesting sites, and installing wildlife corridor structures for bridge and culvert upgrades and roadway projects. Best management practices for landowners, particularly around forestry, agriculture, and restricted motorized vehicle use, are also necessary for successful conservation (MA DFW-NHESP, 2015c). Thousands of acres in the vicinity of the APC and Nemasket River Watershed have been identified as some of the best remaining box turtle habitat in the state where conservation is important to secure populations and allow for long-term persistence throughout the species current range (Massachusetts Division of Fisheries and Wildlife [MA DFW], 2012).

Given the small population and geographic isolation of the northern red-bellied cooter, it is particularly vulnerable to habitat threats from residential and agricultural development, especially to exposed sand and gravel nesting areas close to the APC and Nemasket River (M. Jones, personal communication, 2021). Additionally, the lack of open-canopy, sunny habitats critical for nesting and egg incubation are limited due to the suppression of natural fires (MA DFW-NHESP, 2016), and encroaching vegetation makes movement to and from nesting areas difficult (US Fish & Wildlife Service, 2017). Increased development, impervious surfaces, runoff and pollution and resultant changes to water quality can alter food resources and increase turtle's chemical exposure.

Anticipated Climate Change Impacts

It is possible that box turtles in Massachusetts could benefit from some aspects of climate change. Warmer temperatures with milder winters could reduce overwintering mortality, and extended duration of warm seasons could increase nesting success. However, warmer yearly temperatures could also lead to a higher prevalence of disease. Increased precipitation storm events in the spring and summer could cause delayed nesting and substantial increases in hatchling and nest mortality (MA DFW, 2012).

Impacts to wetland habitats are a major concern for the northern red-bellied cooter (Osland et al., 2016). Increased flooding along the APC and Nemasket River and water level fluctuations may reduce and limit available basking sites and objects (Swarth, 2004).

Mammals and Other Wildlife

Species and Habitat

North American River otter (*Lontra canadensis*), American mink (*Neovison vis*on), gray fox (*Urocyon cinereoargenteus)*, and white-tailed deer (*Odocoileus virginianus)* are all active along the Nemasket River corridor. River otters are relatively large and secretive animals, and their presence is an indicator of the extent and quality of riparian habitats. Beaver *(Castor canadensis*), previously absent from southeastern Massachusetts, have returned to this region. Beaver activity has been observed in the APC Nemasket River Watershed for several years, including in Pocksha Pond (N. Yeats, personal communication, 2021) and are suspected along Purchade Brook (P. Cassady, personal communication, 2021), a Taunton River tributary just outside the APC-Nemasket basin. Far downstream, harbor seals are often seen in the Taunton River and its tributary streams, following herring and other prey species upriver.

As noted earlier, nearly 52% of APC-Nemasket basin is designated as BioMap2 Core Habitat and/or Critical Natural Landscape (CNL) (Figure 2). The primary component of CNLs is Landscape Blocks—large, intact areas with natural vegetation and contiguous forests, wetlands, rivers, lakes, ponds—most likely to maintain dynamic ecological processes such as buffering, connectivity, natural disturbance, and

hydrological regimes. These attributes not only support wide-ranging wildlife and many other species, but also provide other ecosystem services, such as clean drinking water, flood mitigation, and carbon absorption from the atmosphere. Roughly one third, or 11,900 acres, of one of the largest Landscape Blocks in the state occurs in the eastern portion of the APC and Nemasket River Watershed, with a rich mosaic of important habitats that include extensive upland forest and relatively high percentage of forested and open wetlands, lakes, and ponds and provide invaluable wildlife habitat. Only about 4,300 acres of this block are currently protected open space. Additionally, 1,100 acres of this Landscape Block have been further designated as BioMap 2 Forest Core. Forest Cores are one of the best examples of large, intact forests less impacted by roads and development that are especially important habitat for interior forest bird species (BioMap2, 2010).

Anticipated Climate Change Impacts

Increased beaver in southeastern Massachusetts, while part of a natural, healthy ecosystem, have the potential to enhance flooding and drought conditions anticipated with climate change. To date, there do not appear to be any reports of beaver-induced flow or flooding concerns in the APC and Nemasket River. However, beavers are beginning to create some public health and safety concerns for some homeowners and municipal officials in nearby areas. Beaver dam construction in the Mattapoisett River, especially during drought, have raised concerns from cranberry growers about reduced surface water availability for bog irrigation (S. Wright, personal communication, 2021). Another concern is the potential disruption of herring runs. In addition to the state-regulated trapping season, mitigation of beaver-related public health and safety issues can be managed through local-level permitting—local Boards of Health have authority to issue permitting for landowners to trap or hire Problem Animal Control Agents to remove problem beavers under certain conditions, and local Conservation Commissions can issue permitting to breach beaver dams causing public health and safety issues.

Rare Plants and Priority Natural Communities

Species and Habitat

Little Quittacas Pond's naturally fluctuating water levels support an excellent example of a coastal plain pondshore community (CPP), considered 'vulnerable' in Massachusetts (Swain, 2016, 2020; MassGIS, 2021). In late summer, during low water years, this globally rare herbaceous community grows along its exposed, nutrient poor-acidic sandy shoreline. Its persistence, however, requires other years of high water to help keep upland shrubs and invasive plants from inhabiting this shoreline (Swain, 2016, 2020). Plymouth gentian, state endangered as Special Concern, is one plant of CPPs and is also known from Assawompset, Great Quittacas, and Long Ponds, in addition to Little Quittacas Pond. Some of the few remaining records of the state-Endangered round-fruited seedbox (*Ludwigia polycarpa*) in Massachusetts are within the APC, where it is at the northern edge of its range. Although habitat requirements are not well understood in Massachusetts for this species, it requires fluctuating water levels and has been found in nutrient rich sites elsewhere within its range (MA DFW-NHESP, 2019e). The state-Threatened dwarf bulrush (*Licoparpha micrantha*), another CPP plant, is found in Assawompset Pond (MA DFW-NHESP, data request, 2021).

Alluvial red maple swamps**,** designated as 'vulnerable' in Massachusetts, are a type of red maple swamp that occurs in low areas along rivers and streams where regular flooding enriches the soil with nutrients, resulting in an unusual set of associated trees and plants. An excellent example of this community is found along Black Brook, which flows into Great Quittacas Pond (Swain, 2016, 2020; MassGIS, 2021). A

good example of a small kettlehole level bog is also found along Black Brook. These dwarf shrub peatlands form in circle depressions left by melting glacial ice blocks; have little water input or outflow; and are designated 'imperiled' in Massachusetts (Swain, 2016, 2020).

There are also three rare plants found in uplands around the APC and Nemasket River Watershed: the state-endangered taperleaf water-horehound (*Lycopus rubellus*), which is represented by only six occurrences in the state along small streams in red maple swamps in southeastern Massachusetts (MA DFW-NHESP, 2019f); Philadelphia panic-grass (*Panicum philadelphicum*), state-listed as Special Concern, which grows in open, sunny seasonally flooded sandy areas bordering acidic streams, lakes, and wetlands and is found along roadsides in Massachusetts (MA DFW-NHESP, 2020); and the Canadian sanicle (*Sanicula odorata*), state-listed as Threatened, which is found in openings in moist woodlands (MA DFW-NHESP, 2019b).

Stressors

Threats to CPP communities and their distinct flora include artificially maintained high water levels for consecutive years, trampling, off-road vehicles, soil disturbance from recreational use, and beach development, which can restrict or even eliminate plant growth (Swain, 2016, 2020). Purple loosestrife is already well established in the emergent marsh bordering Sampsons Cove in Assawompset Pond (D. Turner, personal communication, 2021) and along Pocksha Pond (Epsilon Associates, 2002). Excessive drawdowns for water supply purposes reduce natural water fluctuations and can allow woody species to establish along the shores. Nutrient enrichment can lead to eutrophication, increase in algal growth, and expansion of non-native aquatic vegetation, reducing available habitat for this community (Swain, 2016, 2020).

Activities that alter hydrological regimes could threaten Philadelphia panic-grass, as well as overgrowth and shading by other plants (MA DFW-NHESP, 2020).

Given its habitat of open woodlands, populations of Canadian sanicle also co-occur and can be threatened by non-native invasive plants (MA DFW-NHESP, 2019b).

To avoid inadvertent harm to rare plants, all active management for rare plant populations, including invasive species, removal should be planned in consultation with the Massachusetts Natural Heritage and Endangered Species Program.

Threats to kettlehole level bogs include hydrologic alteration and nutrient enrichment from road and lawn runoff and trampling from humans, affecting peat mat integrity (Swain, 2016).

While the alluvial red maple swamp near Black Brook is in excellent condition, threats to this community type in general include invasion of non-native plant species, including moneywort (*Lysimachia nummularia*) and glossy buckthorn (*Frangula alnus*) (Swain, 2016, 2020) and negative impacts from recreational use (BioMap2, 2010).

Anticipated Climate Change Impacts

Increased temperatures and warmer pond water will enhance evaporation; when combined with increased precipitation, these conditions will impact the naturally fluctuating water levels these CPP communities require. This stressor can be further compounded by drought and increased water withdrawals. Warmer temperatures may also reduce ice scour, important for CPP communities

Increased precipitation can also cause groundwater levels to rise, further altering pond water levels. Such conditions are more hospitable to invasive plants, such as milfoil and purple loosestrife in the APC and may displace native species (MA DFW, 2015).

Additionally, intensified runoff and transport of sediments, nutrients, and other pollutants to the ponds would alter the biology and chemistry of pond habitats (Massachusetts Climate Adaptation Partnership, 2015a), potentially enhancing eutrophication and increasing algal growth and non-native aquatic vegetation (Swain, 2016, 2020). Some treatments for variable milfoil and fanwort include the use of herbicides, although this may pose a threat to nontarget plants (and fauna) (Massachusetts Audubon Society, n.d.).

Dominant Forest Types

North Atlantic coastal plain hardwoods, dominated by various species of oak — including white (*Quercus alba*), black (*Q. velutina*), northern red (*Q. rubra*) and scarlet oak (*Q. coccinea*) — are found throughout the APC Watershed, particularly on drier sites (LANDFIRE, 2016). Important mid-seral associates in these oak-dominated forests include Eastern white pine (*Pinus strobus*) on sites with sandy soils and better drainage, and red maple (*Acer rubrum*) and eastern hemlock (*Tsuga canadensis*) on wetter sites. Red maple is also a dominant species in the swamp forests that occupy the wettest sites in the APC watershed. These swamp forests, which may also include blackgum (*Nyssa sylvatica*) and black and green ash (*Fraxinus nigra, F. pennsylvanica, respectively*) are widely distributed in small patches throughout the APC, with the largest contiguous tracts found in the southeast of the watershed. These swamp forests intergrade with a maple-ash-dominated riparian forest type and also with the Coastal Atlantic White Cedar Swamp, a relatively rare plant community in which Atlantic white-cedar (*Chamaecyparis thyoides*) is a notable overstory component (Swain, 2020).

Anticipated Climate Change Impacts

Several approaches to projecting future forest conditions are utilized by scientists working in this topic area. One approach, as utilized in the United State Forest Service (USFS) Climate Change Tree Atlas (Peters et al., 2020), considers the impact of projected future climate conditions on individual tree species. Assessment includes both the geographic shift in climate conditions and the adaptability of individual species to a variety of stressors. A second approach is to consider existing forest types and to assess projected change to the entire system. These differing approaches can sometimes result in somewhat different projections in future conditions. A common theme in both of these approaches is that multiple stressors will impact forests as the climate warms and precipitation patterns change. Differences in projections are often the result of uncertainty on the extent and impact of particular stressors.

The USFS Climate Change Tree Atlas makes several projections for the area that surrounds the APC, including:

- large decreases in eastern white pine in all future climate scenarios and low adaptability;
- small to large increases in northern red oak depending on emissions scenario and high adaptability;
- small increase to no change in white oak depending on emissions scenario and high adaptability;
- small increases in black oak in all emissions scenarios and medium adaptability; no projected change in eastern hemlock and low adaptability; and

- significant increases in black cherry (*Prunus serotina*), eastern redcedar (*Juniperus virginiana*), and American beech (*Fagus grandifolia*).

American beech, eastern red cedar, sugar maple (*Acer saccharum*), green ash, and sassafras (*Sassafras albidum*) are projected as infill species. Shortleaf (*Pinus echinata*), loblolly (*P. taeda*), and Virginia pine (*P. virginiana*), sweetgum (*Liquidambar styraciflua*), chestnut oak (*Q. prinus*), and southern red oak (*Q. falcata*) are projected to migrate to the area. The USFS notes that due to these projected changes, along with pests and disease, there is likely to be a restructuring of the dominant forest types in the APC and Nemasket River Watershed, including reduction of white pine, increase in those oak species that can resist stressors, and increase in black cherry, eastern redcedar, and beech. Those species with low adaptability are the most vulnerable.

Disturbances and coupled climate-disturbance effects

Although climate change will alter the competitiveness of existing species and those migrating into southern New England, species turnover and forest structural change in the APC and Nemasket River Watershed over the immediate decades are most likely to result from interactions between climate change and disturbances (Janowiak et al., 2018).

With the exception of extreme weather events, such as ice storms, changes in climate are rarely the sole cause of adult tree mortality in northeastern North America. Mature trees with established root systems are relatively resistant to gradual changes in climate, resulting in a lagged response of mature trees to environmental change (Gustafson et al., 2020). Instead, changes in climate, particularly higher temperatures and reductions in moisture availability, contribute to the death of mature trees via interactions with disturbance phenomena, including pests and fungal pathogens, and fire (Millar and Stephenson, 2015). As an example, periods of high temperature and low precipitation may reduce the ability of trees to produce the defensive compounds required to repel insects and fungal pathogens (e.g., Park Williams, 2013).

Potentially the most significant climate-disturbance pressure to forests of the APC and Nemasket River Watershed is that posed by defoliating insects and low soil moisture, collectively part of a broader stress complex known as Oak Decline (e.g. Oak et al., 2016). Oak-dominated forests across southern New England, including the APC watershed, experienced successive gypsy moth (*Lymantria dispar*) outbreaks over recent decades (Earth Observatory, USDA FS FORWARN-II). Defoliation caused by this pest weakens trees and successive defoliation events may eventually lead to mortality, and this risk is exacerbated by conditions that further induce “stress” – such as drought episodes and high temperatures (Janowiak et al., 2018). Changes in climate are therefore likely to increase oak vulnerability to gypsy moth effects, and this is occurring as part of a broader suite of environmental stressors that are contributing to reduced vigor and mortality of oaks across eastern North America. An associated concern for forests in the APC and Nemasket River Watershed is that mortality of adult oaks will reduce seed availability for future oak regeneration, amplifying an existing background trend of poor oak recruitment in eastern North American forests (Lorimer, 1993).

Other species at risk of disturbance-induced decline in the APC and Nemasket River Watershed are Eastern hemlock and black and green ash. Hemlock woolly adelgid (*Adelges tsugae*) and emerald ash borer (*Agrilus planipennis*), both native to Asia but introduced to North America, have greatly reduced eastern hemlock and ash populations across the eastern U.S. (Potter and Conkling, 2020). These pest

species are present in Massachusetts forests and are likely to cause significant host species mortality under any future climate change scenario (MASS.gov). Within the APC watershed, the effects of these pests are likely to be greatest in riparian forests and the mesic to wet sites on which hemlock and ash are most common. Hemlock and ash mortality on these sites may facilitate changes in species composition, potentially favoring non-host species, such as red maple, that have high climate adaptability (Peters et al., 2020).

Land-use change and associated forest degradation caused by house-building and urban expansion are an important anthropogenic disturbance to southern New England forests and represent a potential driver of forest change over the 21st Century (Duveneck and Thompson, 2016). In addition to the direct removal of vegetation, forest fragmentation caused by splintering and expansion of the wildland urban interface alters the balance between forest edge and interior conditions and interrupts key ecological processes involving the transfer of energy and matter, including seed dispersal. The APC and Nemasket River Watershed already contains substantial ruderal forest and further urban expansion and house-building within the forest will favor fast-growing ruderal and edge species able to tolerate degraded site conditions.

Continuity of ecosystem services

Diversity is a key tenet of forest climate change adaptation. The principal is that forests composed of a wide range of tree species, ages and size classes have a higher probability of one or more species/age classes being able to tolerate or thrive in changing conditions than does a forest with low compositional and structural diversity (Swanston et al., 2016). Forests of the APC and Nemasket River Watershed, and surrounding areas, exhibit relatively high species diversity. This provides a good foundation for adaptation. Forest species and age classes may change, but in general, continuity of some species should enable continuity of key ecosystem functions, including carbon storage, flood water attenuation and runoff filtration.

Wetlands and Vernal Pools

In addition to the uncommon and important natural communities mentioned above, abundant and diverse wetland habitats in the basin make this an important area for wildlife and plants. Most notably, BioMap2 Wetland Cores—those that are the least disturbed within undeveloped landscapes—fringe the APC (excluding Long Pond) and Black Brook. These shrub/forested swamps and deep marshes with vegetated buffers and limited fragmentation—like Owl Swamp and Nelsons Grove in Assawompset Pon—are most likely to maintain critical wetland functions into the future (BioMap2, 2010). Numerous vernal pools, or small seasonal wetlands, are like stepping-stones across the landscape and provide important wildlife habitat, especially for 'obligate vernal pool species' like spotted salamanders and wood frogs that require these areas for breeding.

Invasive Species

Long Pond was designated by the MassDEP as Impaired(2019) for aquatic life due to non-native aquatic plants and has significant problems with variable milfoil and fanwort, which are also now found in Assawompset and Pocksha ponds. Milfoil is also present throughout the Nemasket (Massachusetts Audubon Society, n.d.). Purple Loosestrife (*Lythrum salicaria)* is well established in the emergent marsh bordering Sampsons Cove in Assawompset Pond (D. Turner, personal communication, 2021) and along

Pocksha Pond (Epsilon Associates, 2002). Reed canary grass (*Phalaris arundinacea)* is abundant on banks of the upper Nemasket River and adjacent to Assawompset Pond (Massachusetts Audubon Society, n.d.). In the uplands, Oriental bittersweet (*Celastrus orbiculatus)* was documented on Betty's Neck as well as the fire road north of Great Quittacas Pond (Epsilon Associates, 2002). A large population of invasive Asian clams has been found in Long Pond (MA DFW, 2019) and is likely present in other waterbodies within the basin. These invasive species can create ecological stressors, as described in the following sub-section.

Stressors

Variable milfoil can outcompete and displace native species, reduce biodiversity, and decrease water quality. Its dense, extensive mats on the water surface reduce sunlight penetration; its decomposition increases sediment deposition; and overall, it can alter biological and chemical processes and deplete dissolved oxygen levels (Massachusetts Division of Conservation Services [MA DCS], 2002). Dense growth and the resulting sediment accumulation in the Nemasket River limits kayak and canoe use and can inhibit aquatic species movements. This dense growth also exacerbates flooding concerns, as described further in the Floodwater Management white paper.

There are several methods for milfoil management. Mechanical removal can greatly reduce plants, but fragmentation can increase reproduction in situ and further downstream. Drawdowns are effective at removal but may impact fish, mussels, and other aquatic organisms and downstream conditions (MA DCR, 2002), and may a problematic solution in areas where maintaining water levels is important for water supply. Herbicides may pose a threat to nontarget plants and fauna (Massachusetts Audubon Society, n.d.), and also require careful consideration within an ecological community that doubles as a public water supply environment.

For details on stressors caused by Asian clams, see the freshwater mussel section above.

In addition, the potential for large populations Canada geese and some gull species, have the potential to degrade water quality (Epsilon Associates, 2002).

Anticipated Climate Change Impacts

Warming climate and water temperatures, shortening of annual ice cover duration, and longer growing seasons likely benefit aquatic macrophytes (Fernandez, I. and Marvinney, R., 2020) and there is some evidence that warmer temperatures differentially benefit invasive aquatic flora, and warmer pond temperatures favor growth of milfoil species (Patrick et al., 2012).

Increased precipitation, intense storms, and flooding could increase presence of phragmites (*Phragmites australis)* in wetlands.

Resilience to Climate Change

The Nature Conservancy's Resilient Land Mapping Tool assigns Resilience Scores to terrestrial land areas—ranging from Far Below to Far above Average—which estimate its capacity to maintain species diversity and ecological function as the climate changes. Sites that are considered resilient are those areas where high microclimatic diversity and low levels of human modification provide species with connected, diverse climatic conditions they will need to persist and adapt to changing regional climates.

Of the approximately 45,000-acre APC and Nemasket River Watershed, 39% of the area (excluding waterbodies) scores Slightly Above, Above, or Far Above Average for Terrestrial Resilience (Resilient

Land Mapping Tool, 2022). However, of the 23,500 acres of the APC and Nemasket River Watershed that are designated as BioMap2 Core Habitat and/or Critical Natural Landscape, 60% score Slightly Above, Above, or Far Above Average for Terrestrial Resilience, or those areas expected to be most resilient to climate change (Figure 2). This score means the effects of climate change here are buffered by the natural properties of these complex and connected landscapes with low levels of human modification, thereby providing species with connected, diverse climatic conditions needed to persist and adapt to changing regional climates. It also means they have an above average to far above average estimated capacity to maintain species diversity and ecological function as the climate changes.

SUMMARY OF THREATS AND CHALLENGES TO A HEALTHY, FUNCTIONING SYSTEM

- Development threatens habitat and ecological processes, especially through habitat fragmentation.
- Degraded environmental conditions, especially water quality, adversely impacts habitat and ecological processes.
- Invasive species challenge native species and adversely alter ecological conditions.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes.

The implications of these anticipated changes are considered below and in Table 1.

More frequent intense storm events:

- The increased frequency of storms will lead to more water entering the APC and Nemasket during concentrated periods of time—bringing increased sediment, nutrients, disease pathogens, and invasive species— degrading water quality and aquatic habitats. As this pollutant load travels downstream, to estuaries and the ocean, it can lead to blooms of harmful algae and bacteria.

More intense flood and drought cycles:

- These changes could reduce habitats and ecological process that are critical for species.
- More impactful droughts affect forest health, increasing likelihoods of falling trees and fire hazards, altering habitats/ecological processes as well as threating public health and property.
- Can lead to changes distributions and abundances of invasive species which can impact forest health, and vulnerability to falling trees and fires, threating public health and property.

Extreme temperatures:

- Warmer waters hold less dissolved oxygen and can lead to eutrophication and excess algal growth, which will degrade water quality and habitat for fish and other aquatic species (e.g., fish kills) and alter food webs. These conditions are predicted to alter many coldwater streams, likely becoming too warm in summer to support eastern brook trout. Even some warmwater fish species could be pushed towards thermal tolerance limits, forcing them to seek new cooler habitats if hydrologic connectivity is intact.
- Shortening of annual ice cover duration and longer growing seasons will likely benefit aquatic invasive plants (Fernandez, 2020) and there is evidence warmer lake temperatures favor growth of milfoil species (Patrick et al., 2012).
- The warming climate will limit the ranges of some species, such as eagles (see above).
- In combination, these and other factors not only exacerbate ecological impacts, but associated environmental and community impacts. Planning to maintain ecosystem function and intact landscapes will help maintain ecosystem services for nature and people.

DATA GAP DOCUMENTATION

Field verification of species composition in the APC and Nemasket River Watershed is needed. In addition, it would be useful to obtain additional details on mortality regeneration, and encroachment of certain species in the field. In general, ongoing modeling and field verification of projections and impacts is necessary for ongoing adaptive management. Assessment of forest condition relative to deadfall in areas around the APC is needed, as excessive tinder is observable from trails and during periods of drought and high winds could be fire hazard. Removal methods need to be further investigated (New Bedford does contract work out) and potential management plan developed.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Improved Ecology, Unique Habitats and Natural Resources and…

- Floodwater Management: Co-Benefit. Flooding over built areas has the potential to move and migrate pollutants and debris into the water system. Minimizing these floodwater extents will minimize this effect and associated adverse impacts on habitats.
- Stormwater Management: Co-Benefit. Increased stormwater infiltration decreases runoff that carries pollutant loads into the water system, improving water quality and habitat.
- Ecology, Unique Habitats and Natural Resources: Co-Benefit. Strategic land conservation and wetland restoration efforts have the potential to both filter and reduce pollutants and enhance water quality; riparian restoration has been shown to be most cost-effective phosphorus control (WMOST). Removing invasive species and restoring trees might improve phosphorous, sediment, and temperature. These improvements all have the potential to improve habitat and ecology. Conversely, development of priority green infrastructure could worsen water quality in the watershed.
- Inter-Agency Cooperation: Co-Benefit. Improved coordination between local and state operators on roadway drainage systems could help with implementation of wildlife corridor structures and implementation of green infrastructure and nature-based solutions to help improve habitat and water quality. Additional agency coordination could also identify and

highlight additional benefits of these protections, such as water quality improvements, recreational access, and stormwater management.

- Land Development: Trade-Off to Co-benefit. Increasing land development can contribute to habitat and ecological stressors, especially through fragmentation. Conversely, siting new development outside of riparian areas and adjacent uplands, as well as using low impact development techniques (LID), can also enhance riparian habitat connectivity, maintain movement and migration corridors, and an enhance water quality.
- Recreational Access: Co-Benefit and Trade-Off. Increased recreation can encourage users to become champions of the flora and fauna they encounter and stewards of their habitats, potentially building support for land conservation and habitat management recommendations; watercrafts that move between watersheds could transport invasives that can create adverse ecological impacts. Over-use of recreation areas can also create adverse ecological impacts.
- Drinking Water Supply Levels: Trade-Off to Co-Benefit. Lower water levels risk negative impacts on water quality, with drought, high temperatures, and excess nutrients (nitrogen and phosphorous) all exacerbating these issues. Maintaining high water levels for water supply in the APC could negatively impact downstream waters such as the Nemasket River while simultaneously enhancing conditions in the APC waterbodies.

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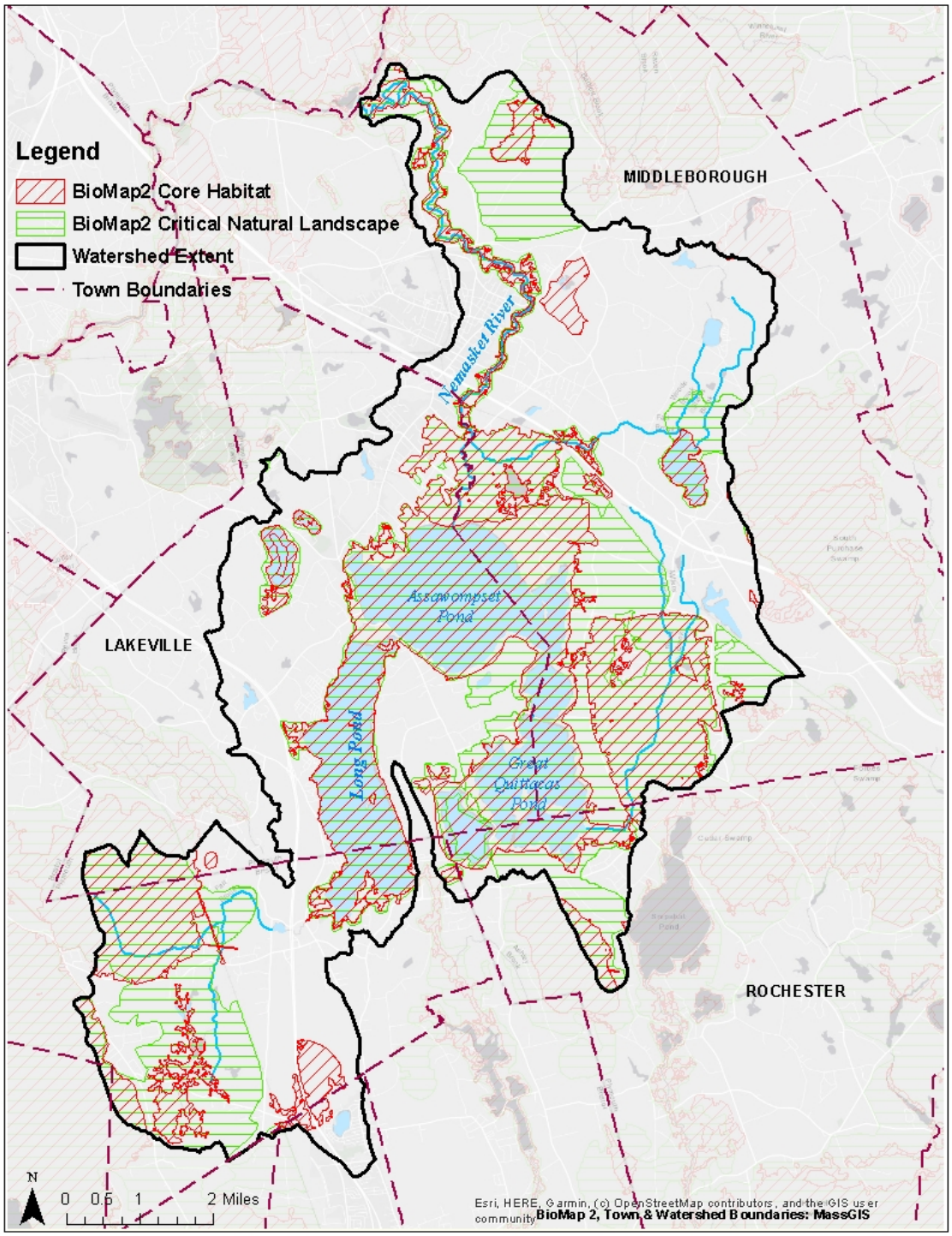
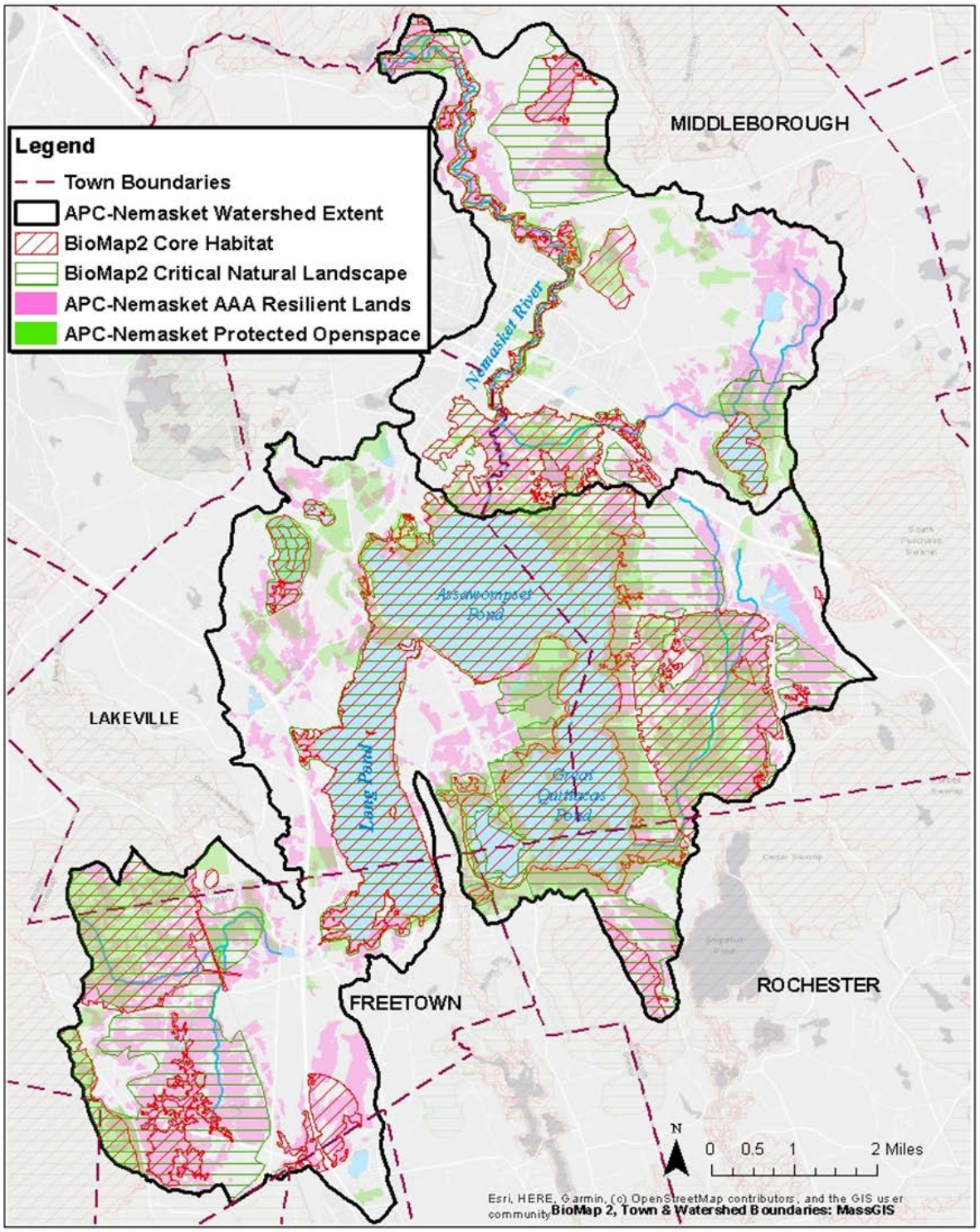
FIGURES

Figure 1. MA NHESP BioMap 2 Core Habitat and Critical Natural Landscape



Note. Created by TNC, 2022.

Figure 2. APC-Nemasket NHESP BioMap 2 Core Habitat and Critical Natural Landscapes and TNC's Resilience and Connected Lands



Note. Created by TNC, 2022.

TABLES

Table 1. Summary of Potential Ecological Implications of Climate Change in the APC-Nemasket Watershed

ANTICIPATED CLIMATE CHANGE IMPACTS	POTENTIAL ECOLOGICAL IMPLICATIONS
WATER QUALITY DEGRADATION	
Warmer Temperatures, Increased Precipitation/Stormwater	Can degrade water quality and limit **herring** spawning/nursery habitats
	Can impact available food resources for **wading birds (Least Bittern (E))**, abundance of fish for **Bald Eagles (SC)**, plankton for **Freshwater Mussels**, and increase potential harm from parasites, including the nematode Eustrongilides known to reduce wading bird populations
	Can enhance eutrophication, with increased growth of non-native aquatic vegetation and algal blooms, further reducing DO, increasing potential for toxicity, and possible **fish and mussel die-offs**, with significant loss of mussel filtering/water cleaning capacity
	Could increase naturally occurring **fish** kills in late spring/early summer due to low DO, spawning stress, fish disease (e.g., bacterial infections, parasites)
	Can increase toxic algal blooms/low DO w/ fish and mussel die-offs; loss of significant mussel filtering/water cleaning capacity
AQUATIC CONNECTIVITY LOSS	
Warmer Temperatures, Drought, Low Flows	Can further constrict downstream **herring** emigration (DMF about concerned drought/reduced juvenile recruitment trends)
	Can further limit/restrict aquatic species (**fish, mussels**) from reaching cooler upstream refugia in response to thermal intolerances in degraded downstream conditions
	Prolonged low water periods will increase the extent of dewatered areas leading to habitat degradation and stranding/die-offs of aquatic species (**fish, mussels**)
SPECIES PHYSIOLIGICAL RESPONSE	
Warmer Ocean/Stream Temperatures	Could induce earlier spring **herring** migration and mismatch with available flows and dam/fishway operation
	Predicted to alter many coldwater streams, inducing earlier upstream migration, spawning, and reduction in survival as habitats likely become too warm to support **Eastern Brook Trout** in summer
	Impact seasonal **mussel** spawning, possibly leading to misalignment of **mussel host fish** presence and spring glochidial release
	Push some aquatic species towards thermal tolerance limits forcing them to seek new habitats if hydrologic connectivity intact
	Could trigger earlier spawning and impact peak season for recreational **Bass** fishing in Long Pond
Drought, Low Flows	Could threaten abundance of large-sized fish populations, an important food sources for **Eagles**
Earlier Snowmelt, Lower Spring Peak Streamflows	Lead to changes in amount/timing of water, disrupting **anadramous fish** spring migrations and lead to mismatch with dam/fishway operations
Warmer Temperatures, Extreme Storms, Prolonged Dry Periods	Could lead to higher prevalence of disease in **Box Turtles** (SC) and increased spring/summer storms could cause delayed nesting and substantial increases in hatchling/nest mortality
HYDROLOGIC ALTERATION	
Warmer Temperatures/Enhanced Evaporation, Increased	Alter the naturally fluctuating groundwater and surface water levels required for the APC **Coastal Plain Pondshore** communities - this is further impacted by incrased development, impervious surfaces, and water withdrawals
Increased Periods of Inundation & Drought	Can alter wetland plant communities (loss of diverse plant and animals habitats) and alter wetland function
	Flooding and degradation/loss of **Least Bittern** (E) marsh and nesting habitat
Sea Level Rise & Coastal/Wetland Habitat Impacts	A major concern for the **Endangered turtle species** as increased flooding along the Nemasket and water level fluctuations in APC may reduce/limit available basking sites/objects
HABITAT FRAGMENTATION	
Warmer Temperatures, Prolonged Dry Periods, Heat Waves	Estimated to lead to 3/4 of current **Eagle** summer range becoming unsuitable by 2080, and although 73% of that summer range could be expanded to new areas, success is contingent upon securing suitable food/nesting habitat; breeding habitats will be sought further N in
	Estimated that by 2080 the **Least Bittern** summer range will be reduced by 69% and the winter range to shift further N; although its summer range could increase 73% in new habitats, there's no guarantee these birds will adapt to these habitats
	Warmer spring temperatures can endanger ground nesting **Whip-poor-will** chicks and heavy rains can flood nests and interfere with feeding; it is predicted that 78% of Whip-poor-will breeding range and 55% of non-breeding range will be lost by 2080 (NAS)
Extreme Weather/Increased High Winds	Can impact tree and nesting habitat for **Eagles**/chicks
INVASIVE SPECIES	
Warmer Temperatures, Reduced Ice Cover, Longer Growing Seasons	Likely benefit aquatic macrophytes (McPhedran, 1/2020) and there is some evidence that warmer tempratures differentially benefit **invasive aquatic flora** and warmer lake temperatures favors growth of **milfoil** species (Patrick et al. 2012)
Warmer Temperatures, Drought, Low Flows	More hospitable to invasive plants, such as **milfoil** and **purple loosestrife** in the APC, which may further displace native species
	Asian clams are sensitive to high temperatures, reduced dissolved oxygen, and exposure to air (McMahon and Bogan 2001) and while warmer winters may favor healthier populations, warmer summers with degraded water quality and dewatering could lead to die-offs, decomposition, and further reduced dissolved oxygen

Note. This table is a summary prepared by TNC for this report, 2022, from information contained in this white paper.

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

LAND DEVELOPMENT

CURRENT CONDITIONS IN THE WATERSHED

Watershed Development Overview

The Assawompset Ponds Complex (APC) watershed is dominantly rural in character with extensive areas of medium and low-density residential development, forests, wetlands, and agricultural areas. The watershed includes several areas of protected open space including the APC and Betty's Neck Wildlife Conservation Easements, the Black Brook Wildlife Management Area, and eastern portions of the Southeastern Massachusetts Bioreserve.

Why Land Development Matters in the Watershed

Levels of development vary across the ponds. Great and Little Quittacas Ponds' shores are completely protected from development, and Pocksha and Assawompset Ponds' shores are largely protected, mainly for water supply protection. In contrast, Long Pond is unprotected and heavily developed (Mass Audubon, n.d.). The dense residential development along Long Pond is problematic for a number of reasons. Existing and expanded impervious surfaces such as pavement and new buildings, artificial turf, and intensive fertilizer applications are all corollary features of residential development that threaten water quality. Private septic systems around the pond, some of which pre-date Title V septic standards, are also a source of nutrient contamination in Long Pond that contribute to the entrenchment of invasive species (Mass Audubon, n.d.). Watershed stakeholders have raised concerns that regulatory flexibility and lack of strict buffer requirements exacerbates these conditions, in particular by, allowing residential development close to the water's edge (APC Management Plan Steering Committee, meeting discussion, 2022).

Threats to water quality and wildlife in the ponds include the following:

- Nutrients and pesticides from shoreline development
- Polluted (e.g., nutrient-, sediment-laden) stormwater runoff, especially from Routes 18 and 105
- Fallout from the Southeastern Massachusetts (SEMASS) Resource Recovery Facility (an incinerator) in West Wareham
- Sediments from sand and gravel processing on Assawompset Neck (groundwater quality)
- Invasive species transport from recreational watercraft use on Long Pond (Town of Lakeville [Lakeville], 2020; Mass Audubon, 2020).

Lakeville

Overview

Lakeville is located in the northeast portion of the watershed and contains large portions of each of the ponds in the APC and the western bank of the Upper Nemasket River. It is the most intensively developed of the four towns bordering the ponds. One measure of development, land cover, categorizes land without regard for property boundaries and ownership. According to the land cover measure, 19% of Lakeville's land is categorized as developed, meaning it is occupied by a building or other kind of impervious cover (Mass Audubon, 2020). Between 1970 and 2000, Lakeville's population increased by 124%, a greater rate than that of Plymouth County (90%), the Southeast Regional Planning and Economic Development District's region (25%), and the state (12%) during the same period (Town of Lakeville, 2020). Land development accompanied this population growth: over 400 acres were subsequently developed between 1999 and 2005 (Mass Audubon, 2020). The rate of development has

since slowed; between 2012 to 2017, 90 acres of land were developed, a development rate of 2.5 acres per square mile over that time (Mass Audubon, 2020). New residents have been drawn to Lakeville following the construction of the MBTA Middleborough/Lakeville Commuter Rail station in.

Lakeville boasts abundant environmental resources, including the Assawompset Ponds, woodlands, farms, fields and cranberry bogs, all of which provide important services like flood control and drinking water protection (Town of Lakeville, 2019). As of 2017, only 15% of land in Lakeville was permanently protected, leaving many of these natural areas vulnerable to development (Mass Audubon, 2020). Residents old and new must stay familiar with proper well and septic maintenance to minimize residential site impacts on water quality.

Land Use and Zoning

According to assessment records, which categorize land use by parcel, residential uses occupy 39% of Lakeville's land area, institutional uses (including some categories of public open space) occupy 35%, vacant land 11%, open space and recreational uses 6%, industrial 2%, and agriculture 2% (Figure 1). (MassGIS, 2019)

In considering potential future development scenarios, Lakeville's APC and Nemasket River Watershed area is zoned largely for residential use (single family, with accessory dwelling permitted), with some areas zoned for business and industrial use. A small portion of the watershed falls within the Mixed Use Development and Smart Growth Overlay Districts in northeast Lakeville that allow for more intensive residential and mixed development with multiple uses per lot (Lakeville, 2021).

As of writing, there is a new state law, Section 3A of MGL ch.40A, included in a January 2021 economic development bill which would require Lakeville to put zoning in place for an additional 750 units of housing at a minimum density of 15 units per acre (Executive Office of Housing and Economic Development, 2022). This multi-family zoning requirement prioritizes placement of this zone within a half-mile of the Middleborough/Lakeville MBTA commuter rail station located at the Lakeville-Middleborough town border. This zone would be located entirely within the APC and Nemasket River Watershed and would include a portion of the Nemasket River and its floodplain. Lakeville's current Smart Growth Overlay District is located in this half-mile radius and allows densities in compliance with the new state requirements; however, the existing district may not be sufficient to reach the 750-unit requirements (Lakeville, 2021). At the time of writing, it is unclear whether existing zoning could be used to comply with the new requirement.

Much of the land that appears available for future development would result in a conversion of land from mixed-use residential/agriculture, mixed-use residential/open space areas, agricultural areas, and open space and recreation land use categories. In combination, these categories occupy approximately 27% of Lakeville's total land area. There is no public sewer available in town, meaning future development would require additional septic systems. Municipal water lines do run through the northern section of town along Route 79 with several offshoots and could accommodate additional development, particularly in Lakeville's Mixed Use and Smart Growth Overlay Districts (Lakeville, 2020).

There are two large commercial development proposals of concern in Lakeville within the watershed, as of 2022. One 400,000 sq. ft. development is under regulatory review and a second development has been proposed on land hydrologically connected to Assawompset Pond (APC Management Plan Steering Committee, member communication, 2022).

Population

As of the 2010 U.S. Census, the population of Lakeville was 10,602 and projected to reach 12,175 by 2040 (U.S. Census Bureau, 2010; UMass Donahue Institute, n.d.). As of the 2020 U.S. Census, the population of Lakeville is 11,523 (U.S. Census Bureau, 2021).

Middleborough

Overview

Middleborough encompasses the northeast portion of the watershed and contains the lower Nemasket River and eastern banks of Assawompset, Pocksha, and Great Quittacas Ponds. These APC waterbodies are the drinking water source for the Cities of New Bedford and Taunton, as described further in the Drinking Water Supply white paper. At over 70 square miles, Middleborough is the largest town by area in the watershed and the second largest in the state (Town of Middleborough, 2019). Historically an agricultural community, Middleborough is characterized by a low-density development pattern. However, agriculture has become less common, and development rates have increased in recent years (Town of Middleborough [Middleborough], 2019). Though less developed than Lakeville and Freetown, with 16% of the town's area developed, Middleborough had the highest rate of development—6.8 acres per square mile— of the four towns in the watershed from 2012 to 2017 (Mass Audubon, 2020). These development patterns are threatening the town's rural landscape and valued open spaces. Population growth is also contributing to a growing income gap and lack of affordable housing for low-income and elderly residents (Town of Middleborough, 2002).

Permeable soils in Middleborough make for excellent groundwater recharge capability but also make groundwater supplies more vulnerable to pollution. Municipal water supply lines are available throughout a large portion of the town, but sewer infrastructure is limited to the more developed cores of town between the intersections of Routes 28, 44 and 105 (Horsley Witten Group, 2008). The town has established wellhead protection zones to preserve drinking water supplies; however, these areas are in need of review to ensure adequate protection under future climate scenarios (Middleborough, 2019). Current development regulations do not adequately protect important resource areas like wetlands and their buffers (Middleborough, 2019).

Land Use and Zoning

The area of the watershed within Middleborough is largely zoned Residence Rural (single family only, accessory apartments by special permit). There are also General Use (multi-family by special permit and mixed business-residential use), Residence A, Residence B[1], and Business zones clustered around Middleborough Center and along Interstate 495 and the MBTA commuter rail line. Water Resource Protection Overlay districts lie in several areas within the watershed and provide protection measures for the town's established wellhead protection zones. (Middleborough, 2015) (Figure 2).

Middleborough is also subject to the state's new MBTA Multi-Family Zoning Requirement. Future multi-family housing may be targeted within a half-mile radius of the Middleborough/Lakeville MBTA commuter rail station located on the Lakeville-Middleborough town border (again, this is co-located with portions of the Nemasket River and its floodplain) (Executive Office of Housing and Economic Development, 2022).

[1] There are no obvious differences between the three residential zones, except open space residential preservation development allowed by special permit in Residence Rural and Residence A, but not at all in Residence B.

Development projections indicate the potential for additional future development in Middleborough. In particular, the I-495 corridor through Middleborough appears to have significant buildable land that is currently undeveloped (Middleborough, 2008) (Figure 3).

As of 2022, the proposed development of a large commercial distribution center, over 1 million sq. ft., adjacent to Fall Brook, a tributary of the Nemasket, is being followed for potential impacts to the watershed (APC Management Plan Steering Committee, member communication, 2022).

Population

As of the 2010 U.S. Census, the population of Middleborough was 23,116 and projected to reach 34,964 by 2040 (U.S. Census Bureau, 2010; UMass Donahue Institute, n.d.). As of the 2020 U.S. Census, the population of Middleborough is 24,245 (U.S. Census Bureau, 2021).

Freetown

Overview

Freetown is a town in southeastern Bristol County. The south and eastern portions of Freetown are in the APC Watershed. The town has limited public water service available along Braley Road and Chace Road in East Freetown, a village of Freetown, and no public sewer infrastructure available within the watershed area (Horsley Witten Group, 2008; CAI Technologies, 2013). This dependance on private well and septic systems has favored large minimum lot sizes and fostered a landscape dominated by large lot, single family homes (Town of Freetown [Freetown], 2019a).

A recurring theme in the Freetown's MVP process was the need for improved management of Long Pond and the APC for flood control and water quality (2019a). The Heaven Heights and Hemlock Point neighborhoods in eastern Freetown and the APC Watershed were both identified as vulnerable areas. Heaven Heights is flagged in both the infrastructure and environmental risk matrices of the MVP documentation due to problems with septic systems (2019a). Hemlock Point is included in the infrastructure risk matrix as being vulnerable due to flooding issues that impair the road network (2019a). Additional information on these topics is in the Floodwater Management white paper.

Land Use and Zoning

Freetown has significant unbuilt land area in the southwest quadrant of the ACP Watershed. Much of this unbuilt area may be constrained by wetlands (Figure 4). The portion of the watershed that lies in Freetown is largely zoned as Residential (single family or duplex, and multi-family by special permit) and General (mixed use residential/business). There are some areas zoned as Open Space,[2] Industrial, and a concentrated area of Business, Village Business, and Village Residential uses in the East Freetown downtown area (Freetown, 2019b) (Figure 5).

Freetown is subject to the state's new MBTA Multi-Family Zoning Requirement as a commuter rail adjacent community, and it is unclear at this point how future multi-family housing development may impact the portion of Freetown within the watershed. This condition is further complicated by the fact that Freetown is targeted for a future South Coast rail station located on the west side of town, which would fall outside of the watershed (Executive Office of Housing and Economic Development, 2022).

[2] Only uses permitted are agriculture; religious, educational, or municipal use by town; cemeteries; and recreational facilities.

Population

As of the 2010 U.S. Census, the population of Freetown was 8,870 and projected to reach 9,313 by 2040 (U.S. Census Bureau, 2010; UMass Donahue Institute, n.d.). As of the 2020 U.S. Census, the population of Freetown is 9,206 (U.S. Census Bureau, 2021).

Rochester

Overview

Rochester's landscape is dominated by forests and waterways, with many surrounding towns benefitting from Rochester's abundant water resources. In fact, Rochester's aquifers provide drinking water for over 25,000 people, including its own residents and those of neighboring towns, including Marion, Mattapoisett, and Fairhaven (Town of Rochester [Rochester], 2019). In addition, the APC, which acts as the drinking water source for the Cities of New Bedford and Taunton, is partially located within Rochester's borders. Rochester's high water table, dependence on private wells and septic systems (there is limited municipal water service in southeastern Rochester, but no public water or sewer infrastructure within the watershed area of Rochester) (Tata & Howard, 2012), and role as a local hub for drinking water supply make water resources protection a central issue in town. Future development must contend with both water supply concerns during times of drought and basement flooding concerns during wetter periods (Town of Rochester [Rochester], 2019). Further details are in the Drinking Water Supply white paper.

Participants in Rochester's MVP Planning process highlighted flood/drought cycles, pest (vectors, invasive species), storms/high winds, and forestry health as their top four concerns (Rochester, 2019). Top management recommendations for climate resilience included proactive forestry management related to protecting development:

- Develop a Forest Management Plan to address tree death from invasive species and resulting hazards; include utility resilience planning for private and public property.
- Couple Forest Management Plan with a utility infrastructure vulnerability study, prioritizing tree assessments along power corridors. Recommend power line undergrounding where feasible (Rochester, 2019).

Solar Development Pressure

Solar development pressure was a unique topic discussed in Rochester, as MVP workshop participants expressed extreme concern about the increase in solar development in Rochester. While acknowledging the need for clean energy, participants lamented the clearcutting of forest for solar development, a practice that has been increasing in town. Participants were also concerned that the town's many cranberry bogs will be the next targets for solar development, further straining Rochester's ability to retain its rural and agricultural character and associated environmental benefits. Participants eagerly and recurringly suggested a review of the town's solar bylaw to include responsible siting and sizing guidelines (Rochester, 2019).

Land Use and Zoning

A relatively small portion of the southern watershed lies within the northwest portion of the town of Rochester. This section of the town is zoned for Agricultural-Residential use (allowing single family and agricultural uses, one multi-family dwelling up to four units per lot, and additional units by special permit); it is also partially within the Mattapoisett River Valley Watershed overlay district (uses not in

zoning bylaw) (Figure 6) (Rochester, 2020). The land directly bordering Great and Little Quittacas Ponds is predominantly protected forested habitat (MassGIS, 2019). Single family residential development is scattered along and south of North Avenue within the watershed. Rochester is subject to the state's new MBTA Multi-Family Zoning Requirement as a commuter rail adjacent community, and it is unclear at this point how future multi-family housing development may impact the portion of Freetown within the watershed (Executive Office of Housing and Economic Development, 2022).

Population

As of the 2010 U.S. Census, the population of Rochester was 5,232 and projected to reach 6,404 by 2040 (U.S. Census Bureau, 2010; UMass Donahue Institute, n.d.). As of the 2020 U.S. Census, the population of Rochester is 5,717 (U.S. Census Bureau, 2021).

New Bedford

Overview

A relatively small portion of the southern extent of the watershed lies in New Bedford, a coastal city. New Bedford is the most developed community in the watershed, with 59% of land area developed and 33% natural (Mass Audubon, 2020). The portion of the city that lies within the watershed is the developed area around Sassaquin Pond, a 34-acre warm water kettle pond, and Route 140. This area is zoned for residential (single family, and two-family in Residential B zone only) or mixed business uses (single or multi-family, agriculture, business) (Figure 7) (New Bedford, 2021). Sassaquin Pond is heavily utilized for recreational fishing. Dense residential development, including cottages built on its shores, contribute to Sassaquin Pond's impaired water quality, and swimming is not allowed due to bacterial contamination (New Bedford, 2014). As of its 2014 Open Space Plan, New Bedford proposed a watershed overlay district restricting development in the area surrounding Sassaquin Pond with an increased minimum lot size (2014). The city also encouraged best management practices to reduce stormwater pollution, including education and outreach in the surrounding neighborhoods (New Bedford, 2014).

As described in the Drinking Water Supply white paper, development patterns in New Bedford have historically shaped development of water supplies and ongoing demands.

Watershed Summary

An overview of APC and Nemasket River Watershed land cover is included in Figure 8 and Table 1 below. The largest land cover type is evergreen forest at 24%. Approximately 6% of the watershed is impervious cover, and land cover associated with agriculture (cultivated and pasture/hay) makes up approximately 4% of the watershed. Forest land cover types (deciduous, evergreen, and palustrine forested wetland) occupy approximately 61% of the watershed (MassGIS, 2019).

An overview of APC and Nemasket River Watershed land use is included in Figure 9 and Table 2 below. Approximately half (49.7%) of the watershed is residential land uses of three units or fewer. The next largest land use type is publicly owned lands at 19%—including large areas on the shores of Assawompset, Pocksha, and Great Quittacas Ponds—followed by forest/open space/agricultural/woodlot at 10%, and mixed use at 7%. All other land uses in the watershed occupy 5% or less of the area, including developable land (5%) and undevelopable land (4%) (MassGIS, 2019).

A summary of each town's zoning regulations within the watershed boundary is included in Table 3 below. All towns allow residential single family uses and some form of multi-family housing, but differences exist between the towns. Other land uses are variously restricted in the towns' zoning regulations. Table 4 compares land use regulations in these towns.

Recent Development Trends

The APC and Nemasket River Watershed is mostly situated in Plymouth County with the southeast portion of the watershed located within Bristol County. Plymouth County is the seventh most developed county in the state at 26% developed; Bristol County is the sixth most developed county in the state at 29% developed (Mass Audubon, 2020). Between 2012-2017, Plymouth County was the most rapidly developing county in the state at a rate of 6.1 acres per square mile, and Bristol County was the fifth most rapidly developing county in the state at 3.9 acres per square mile (Mass Audubon, 2020). A summary of these trends is included in Figure 10 and Table 5 below.

SUMMARY OF THREATS AND CHALLENGES TO A HEALTHY FUNCTIONING SYSTEM

- Continued development increases impervious area and exacerbates stormwater flooding issues and increasing temperature trends.
- Imperviousness associated with development prevents infiltration of rainfall and decreases groundwater supplies.
- Increasing development, and associated water supply demands, strain water resources and complicates water supply management.
- Dense residential development, excessive pavement, and fertilizer use—particularly along Long Pond— negatively affects water quality in the ponds.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes.

The implications of these anticipated changes are considered below.

More frequent intense storm events:

- The size and extent of flood hazard areas will likely increase due to the combination of increasing total precipitation and biasing of precipitation towards high intensity events. This progression will reduce the inventory of developable land outside of flood zones in the watershed and increase threats to existing development

- More frequent and intense rainfall events will exacerbate stormwater flooding and associated damages to development and aging public infrastructure, including culverts, dams, bridges, roads, and rail infrastructure. If impacted by too much stormwater, these features would be at risk of failure.
- The likelihood of flood damage to shorefront properties will increase.
- The potential exists for increasing intensity of coastal storms due to rising sea surface temperatures. Associated high wind events have the potential to cause more extensive and frequent damages to property and falling trees, creating further damage.
- Flooding and falling trees would impact road access and threaten above ground power infrastructure and other development.
- Power outages and flooding would impact private well pumps and sewer systems used for drinking water and wastewater management, including those used by Lakeville and Middleborough residents
- Flooding and rising water tables can compromise sewer and septic systems, resulting in pollutant discharges.
- Improper stormwater management, and improperly managed retired cranberry bogs throughout the region, can support mosquito populations, impacting public health. More frequent intense storm events could exacerbate these issues by creating more and larger areas of standing water, further supporting mosquito populations.

More intense flood and drought cycles:

- More impactful droughts affect forest health, increasing likelihoods of falling trees and fire hazards, threating public health and property.
- Changing distributions and abundances of invasive species impact forest health, and vulnerability to falling trees and fires, threating public health and property.
- Fluctuating water table levels will impact environmental health and threaten drinking water supplies (private and public wells as well as supplies in the ponds), especially as population growth increases demand for potable water.

Extreme temperatures:

- There will be public health impacts related to both extreme heat and extreme cold. Vulnerable residents and those living in highly developed areas are particularly at risk.
- Forest fire hazards will be exacerbated, threating public health and property.

DATA GAP DOCUMENTATION

Overall development trends for land within the watershed would be useful (Losing Ground statistics are by town only). CommunityViz buildout analyses may be able to provide some of that data, as well as predict future projections for the watershed area. In addition, each municipality's available information (i.e. development trends and tracking) is not always equivalent to the information of the other municipalities, in terms of extent, availability, and specificity.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Future Land Development and…

- Water Quality: Trade-Off. Development of natural areas often results in water quality impairments due to losses of important buffer habitats to wetlands and streams. Larger stormwater volumes traveling over impervious surfaces carry pollutants from built areas. Without vegetated buffers, this contaminated stormwater often flows directly into waterways, resulting in pollution and stream bank erosion.

- Drinking Water Supply Levels: Trade-Off. Development increases demand for drinking water and also impacts its supply. Built areas allow less groundwater infiltration to recharge wells, and water quality impairments can affect drinking water supply. Managing development in well water recharge areas and managing stormwater with low impact development practices can reduce these impacts.

- Floodwater Management and Water Quality: Trade-Off. Impervious surfaces from development prevent infiltration of rainfall into the ground. Flooding over built areas has the potential to move and migrate pollutants and debris into the water system. Floodwater management and development controls would reduce this effect.

- Stormwater Management: Trade-Off to Co-Benefit. Increased development can increase stormwater runoff and associated treatment needs. Increased stormwater infiltration decreases runoff that carries pollutant loads into the water system. Low impact development practices can improve stormwater management with fewer associated negative environmental impacts and put less stress on municipal systems and budgets.

- Ecology, Unique Habitats and Natural Resources: Trade-Off. Conversion of natural areas for development fragments wildlife habitat and impairs natural resources. Low impact development that adapts to the land and preserves natural resources can minimize these impacts.

- Increased Inter-Agency Cooperation: Co-Benefit. Cooperative planning, regulatory updates, and enforcement of land use regulations can help manage development and its negative impacts. Additional cooperation can also highlight cross-disciplinary impacts of development and associated innovative approaches to address such impacts.

- Recreational Access: Trade-Off, traditionally, with some opportunities for Co-Benefits. Conversion of natural areas for development can impair passive recreation opportunities in nature. Traditional development has often prevented public access to waterfront areas and barring watersport recreation. Thoughtful development and redevelopment of abandoned waterfront industrial sites can enhance public recreation opportunities.

- Increased public stewardship: Potential Co-Benefit. Low impact development that works with the land can result in reduced environmental impacts and enhanced developed landscapes, which, alongside public education and awareness, can enhance stewardship of local natural areas. Low impact development and green infrastructure techniques can create design and quality of life improvements (e.g., streetscape enhancements, more greenspace), thereby increasing stakeholder buy-in for environmental stewardship.

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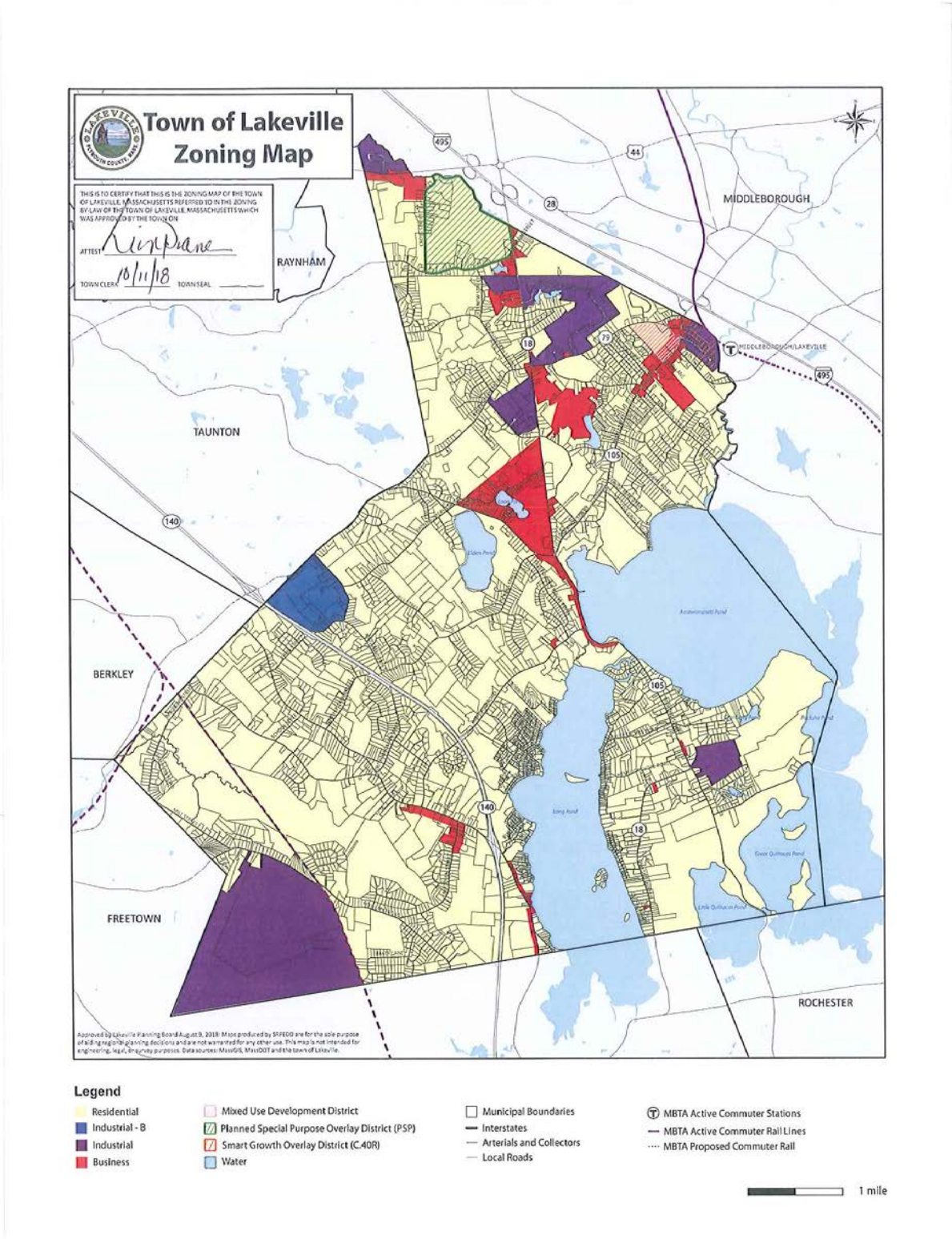
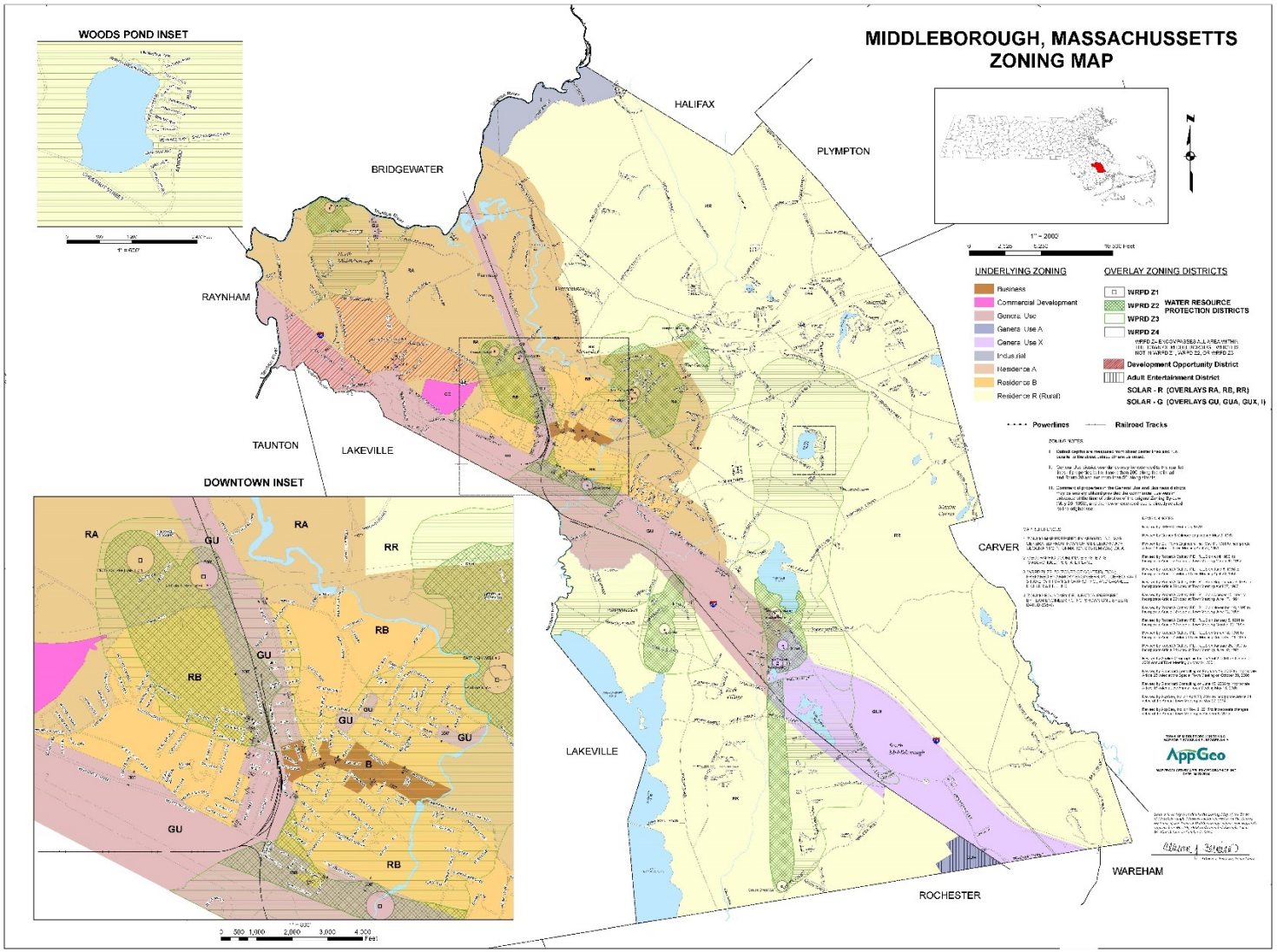
FIGURES

Figure 1. Lakeville Zoning Map



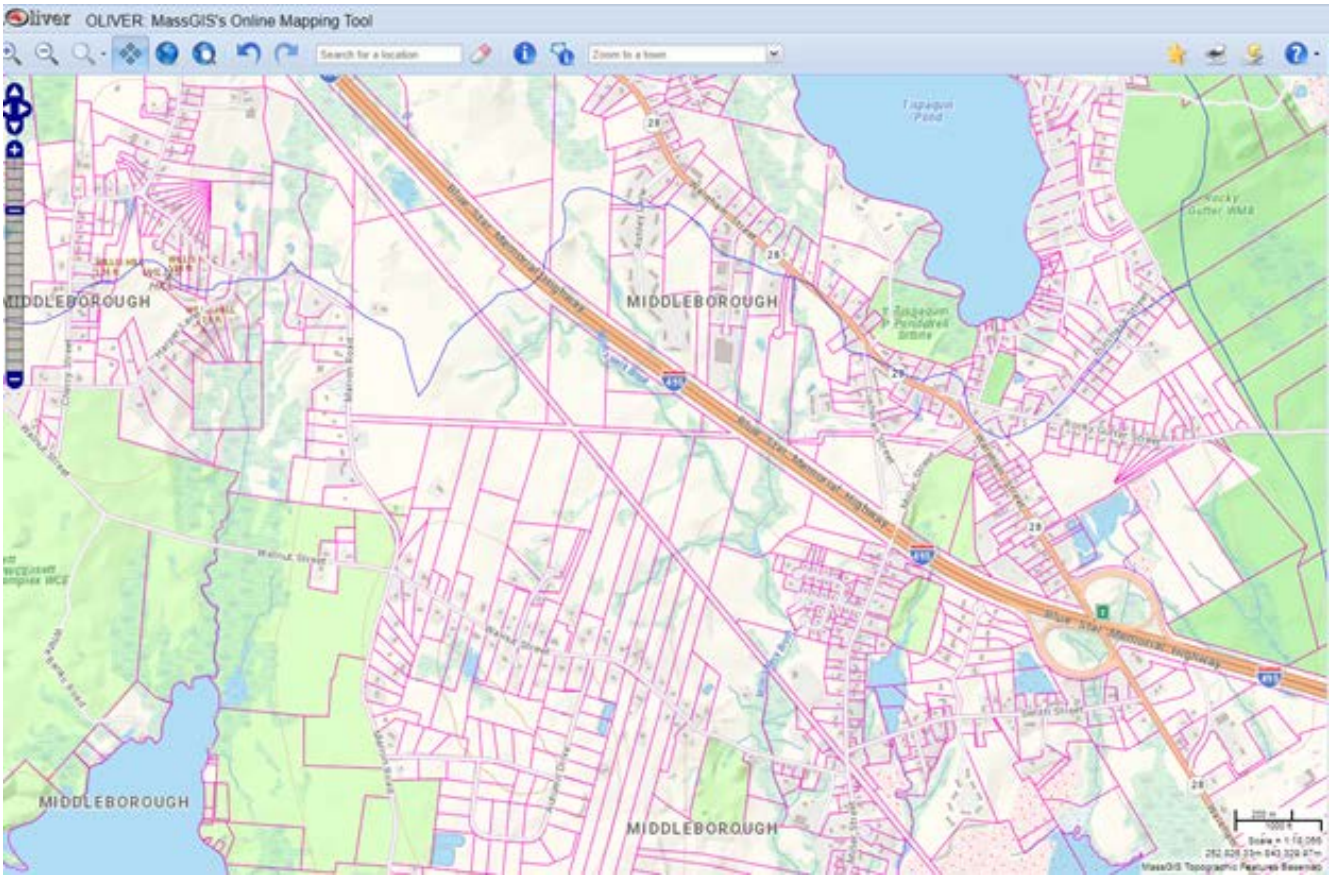
Source: Town of Lakeville (2018)

Figure 2. Middleborough Zoning Map



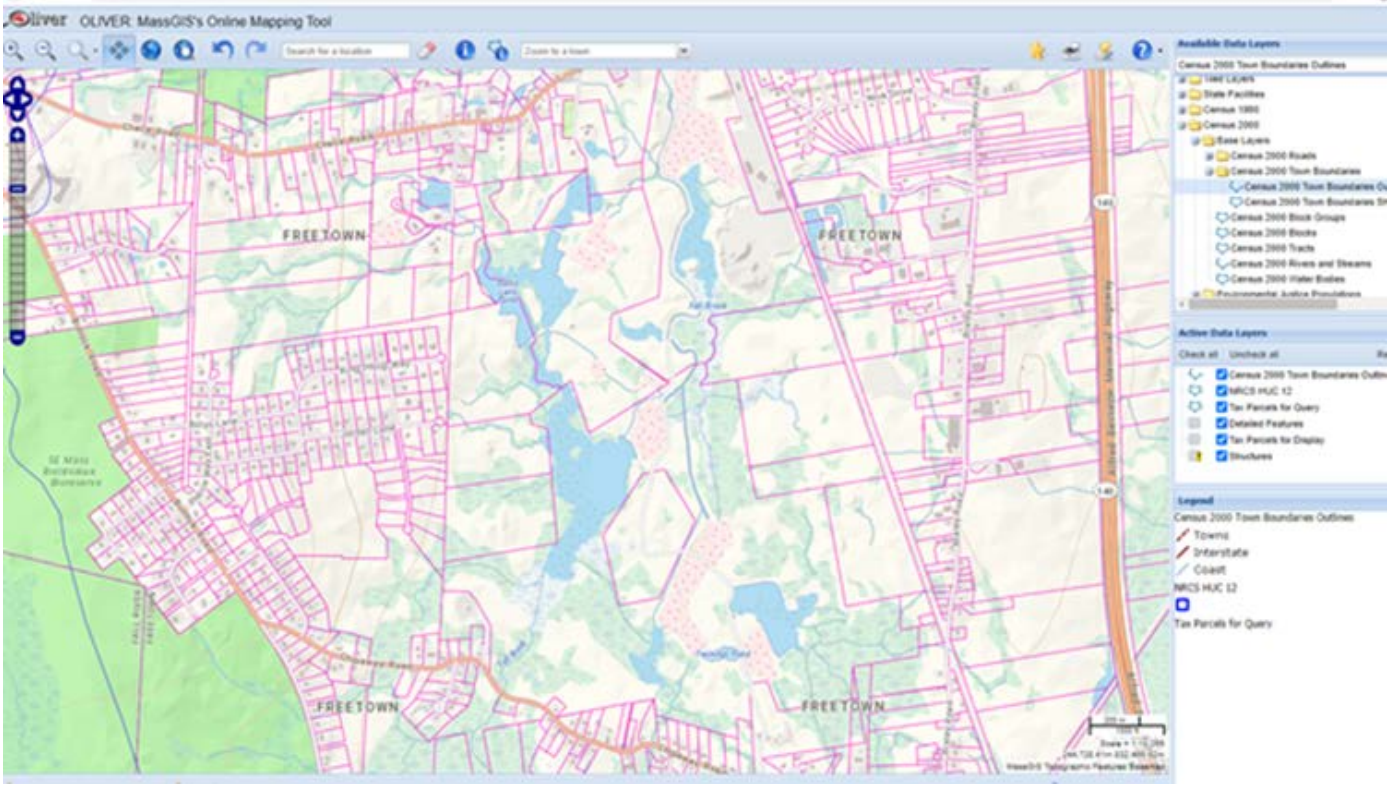
Source: Town of Middleborough (2015a)

Figure 3. MassGIS Parcel Map for Middleborough I-495 Corridor



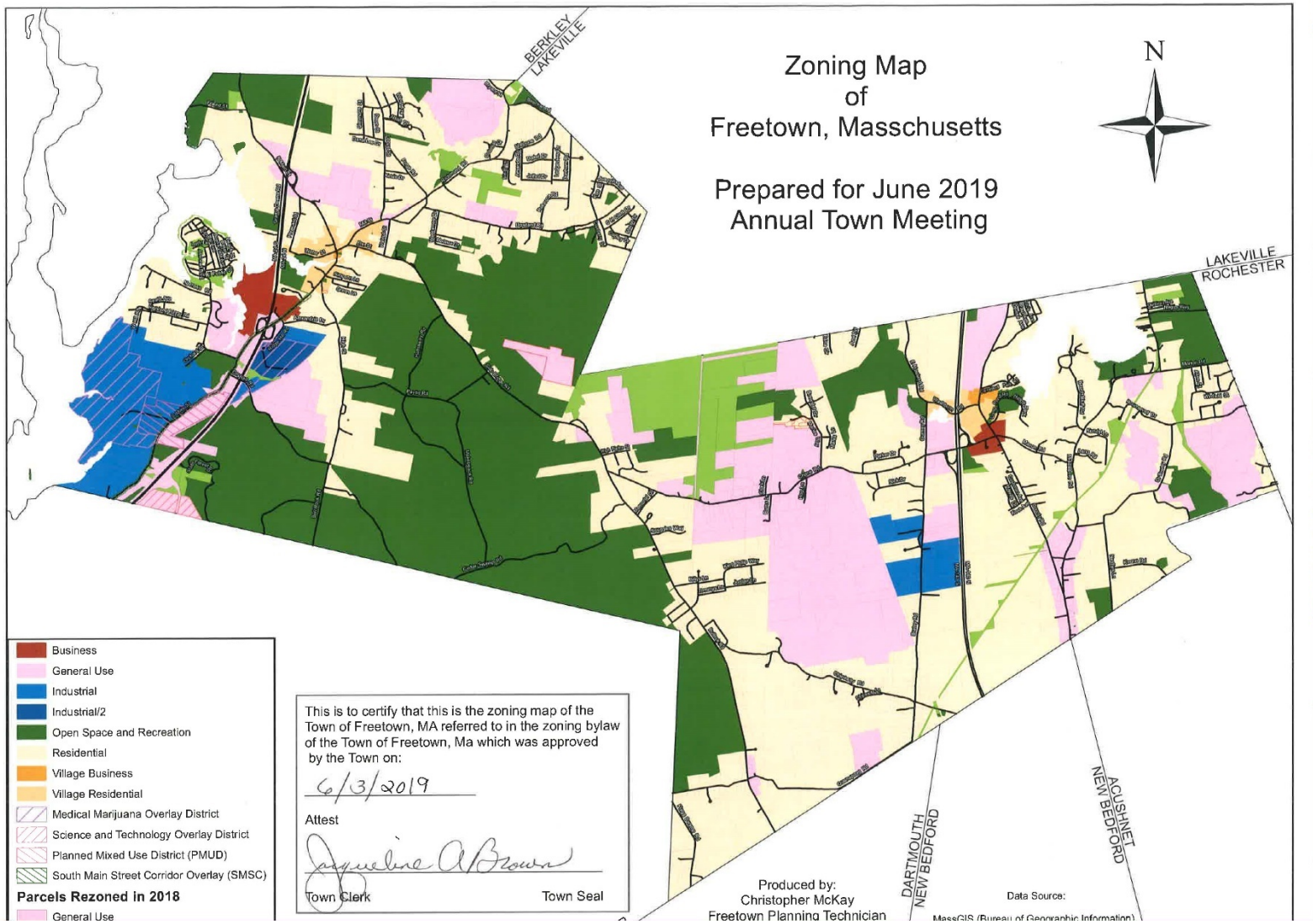
Source: MassGIS OLIVER online mapping tool

Figure 4. MassGIS Parcel Map for Western Freetown



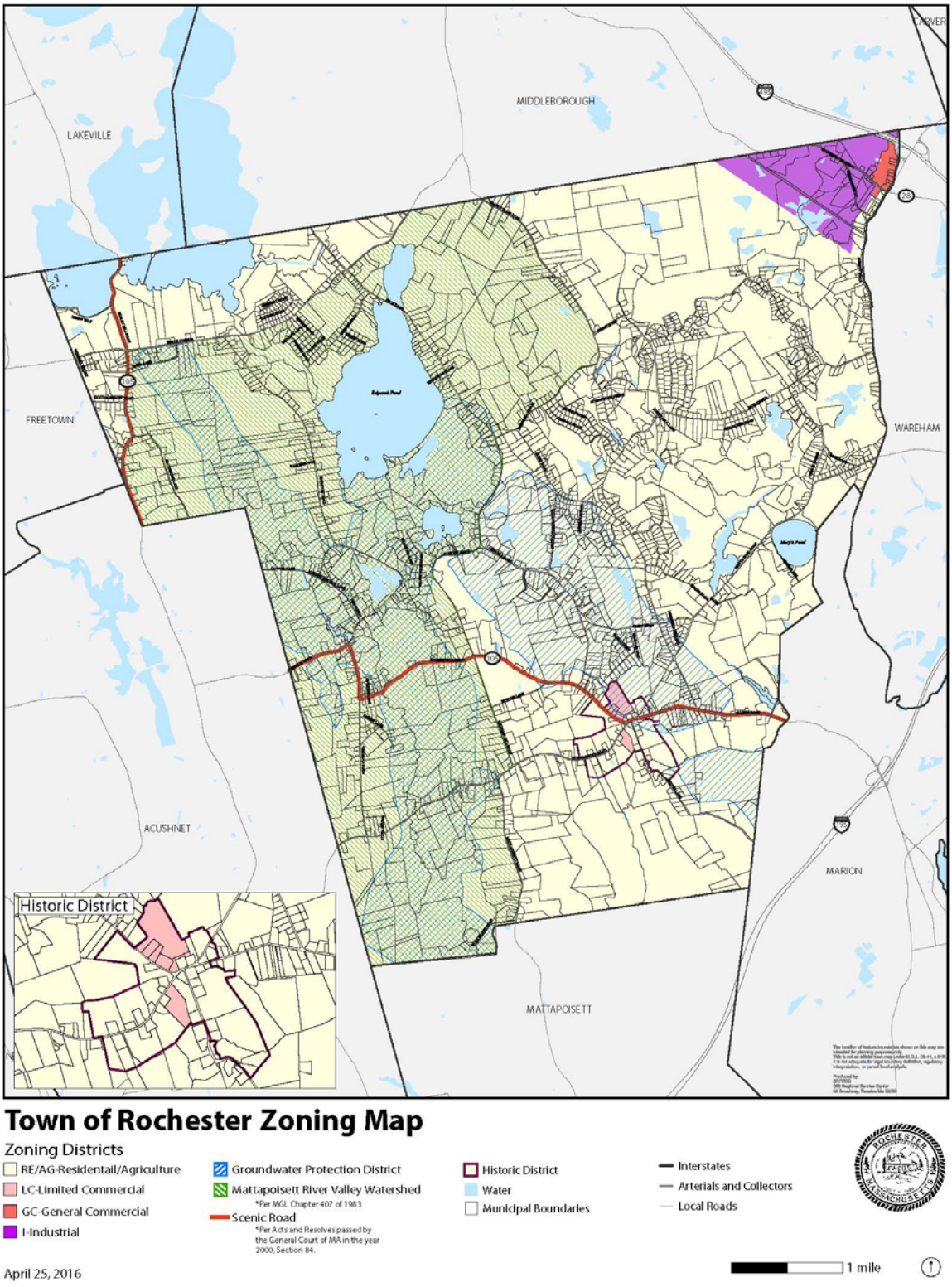
Source: MassGIS OLIVER online mapping tool

Figure 5. Freetown Zoning Map



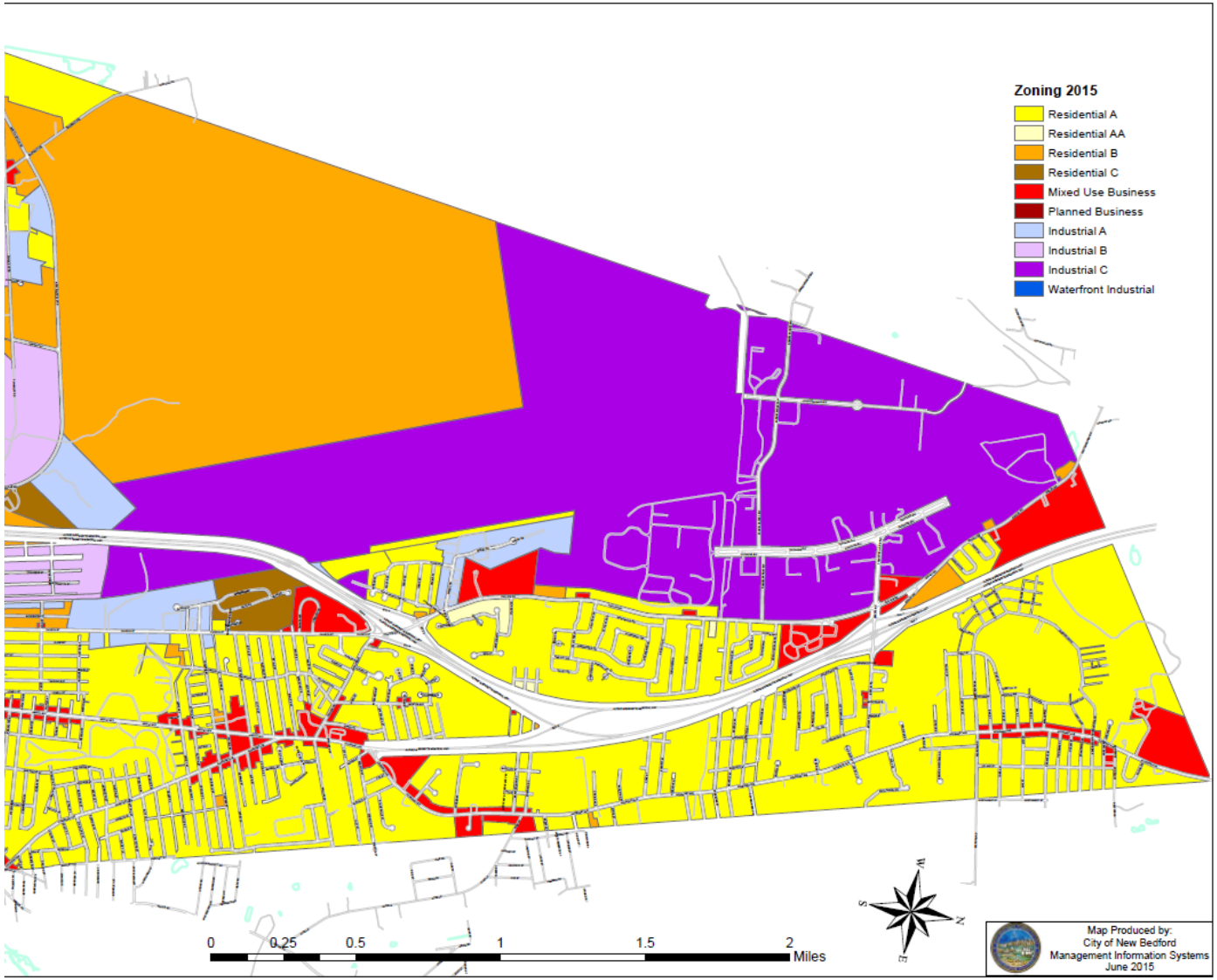
Source: Town of Freetown (2019b)

Figure 6. Rochester Zoning Map



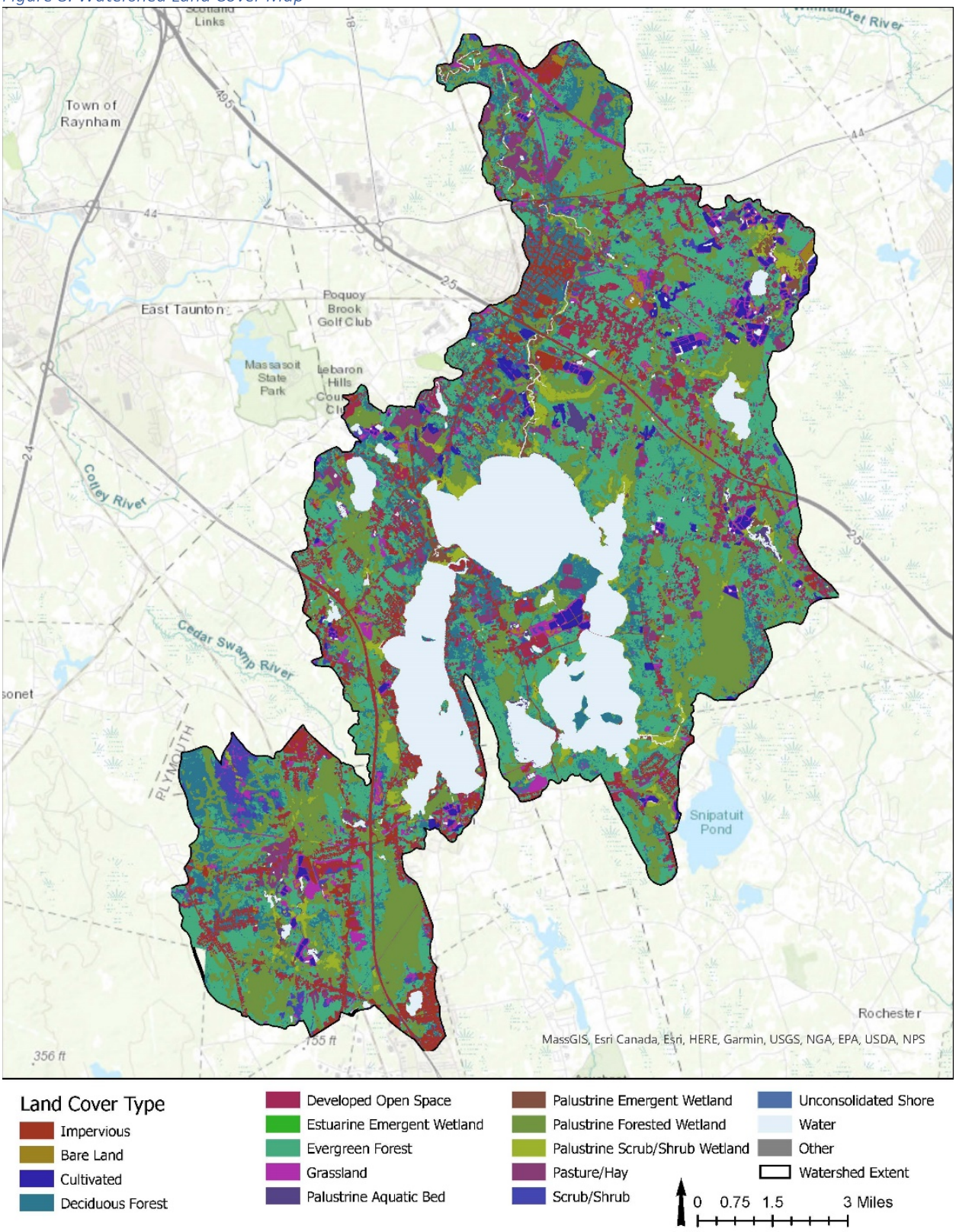
Source: Town of Rochester (2016)

Figure 7. New Bedford Zoning Map (Cropped to Watershed Area in Northern Extent of City)



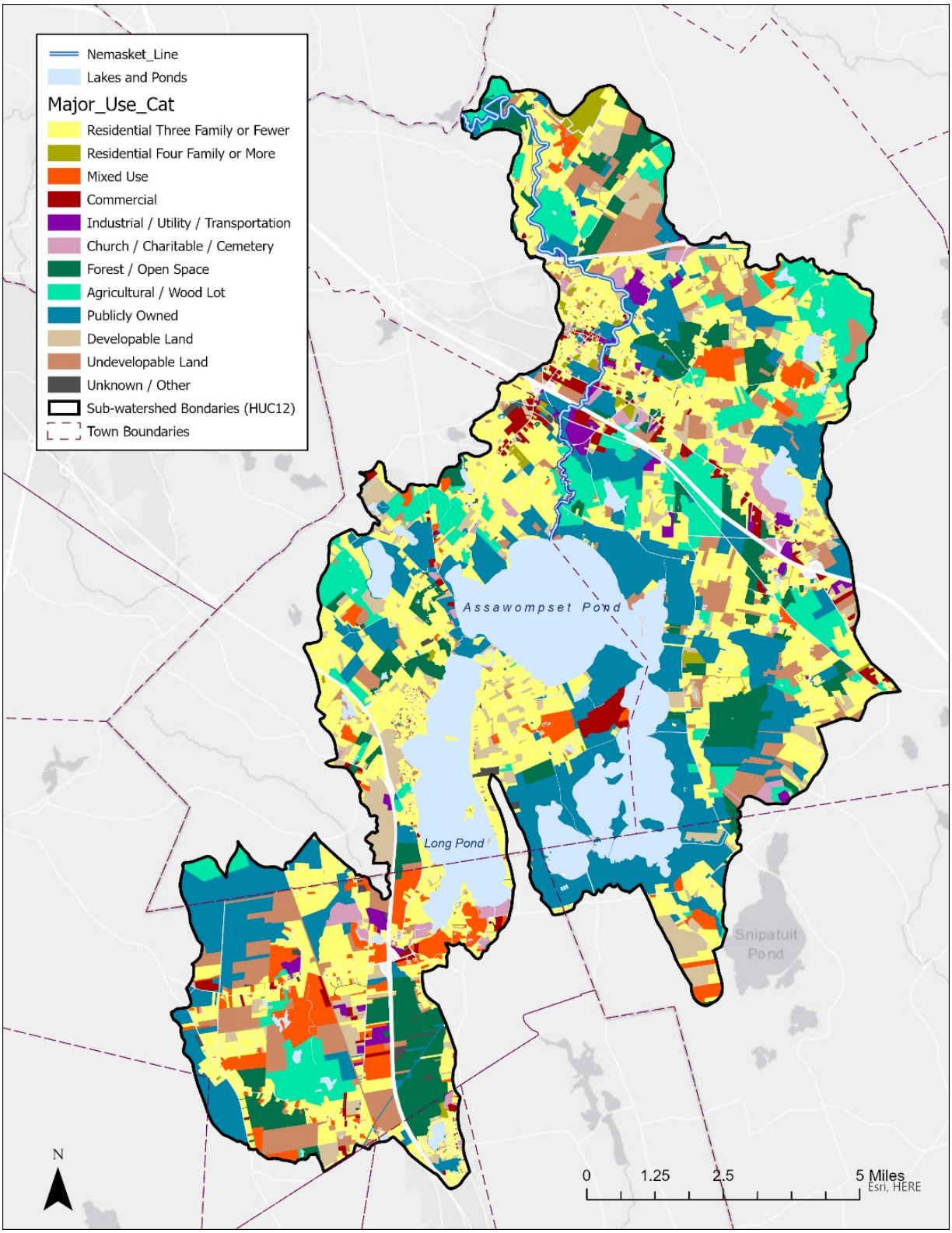
Source: City of New Bedford (2015)

Figure 8. Watershed Land Cover Map



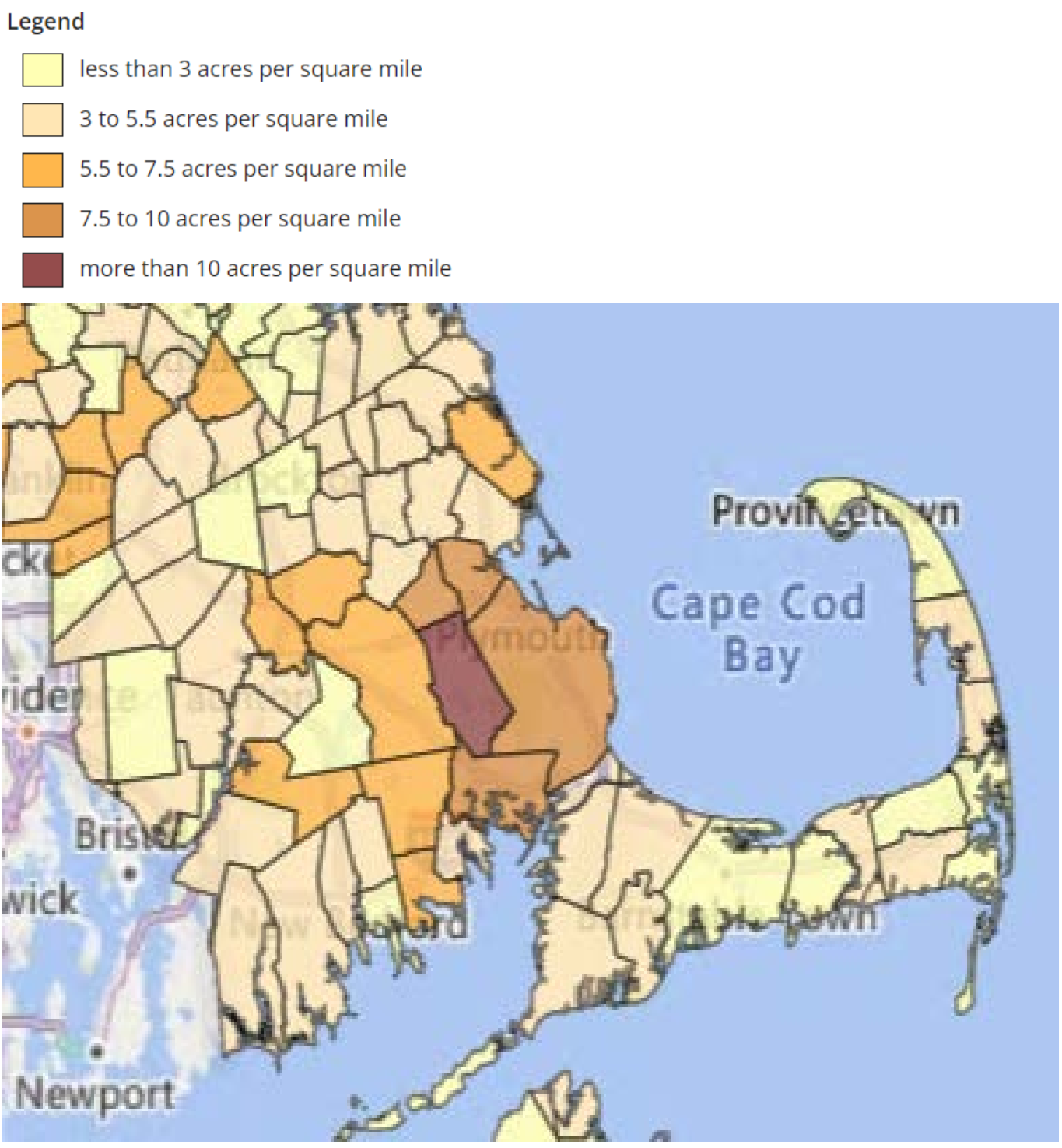
Source: MassGIS (2019)

Figure 9. Watershed Land Use Map



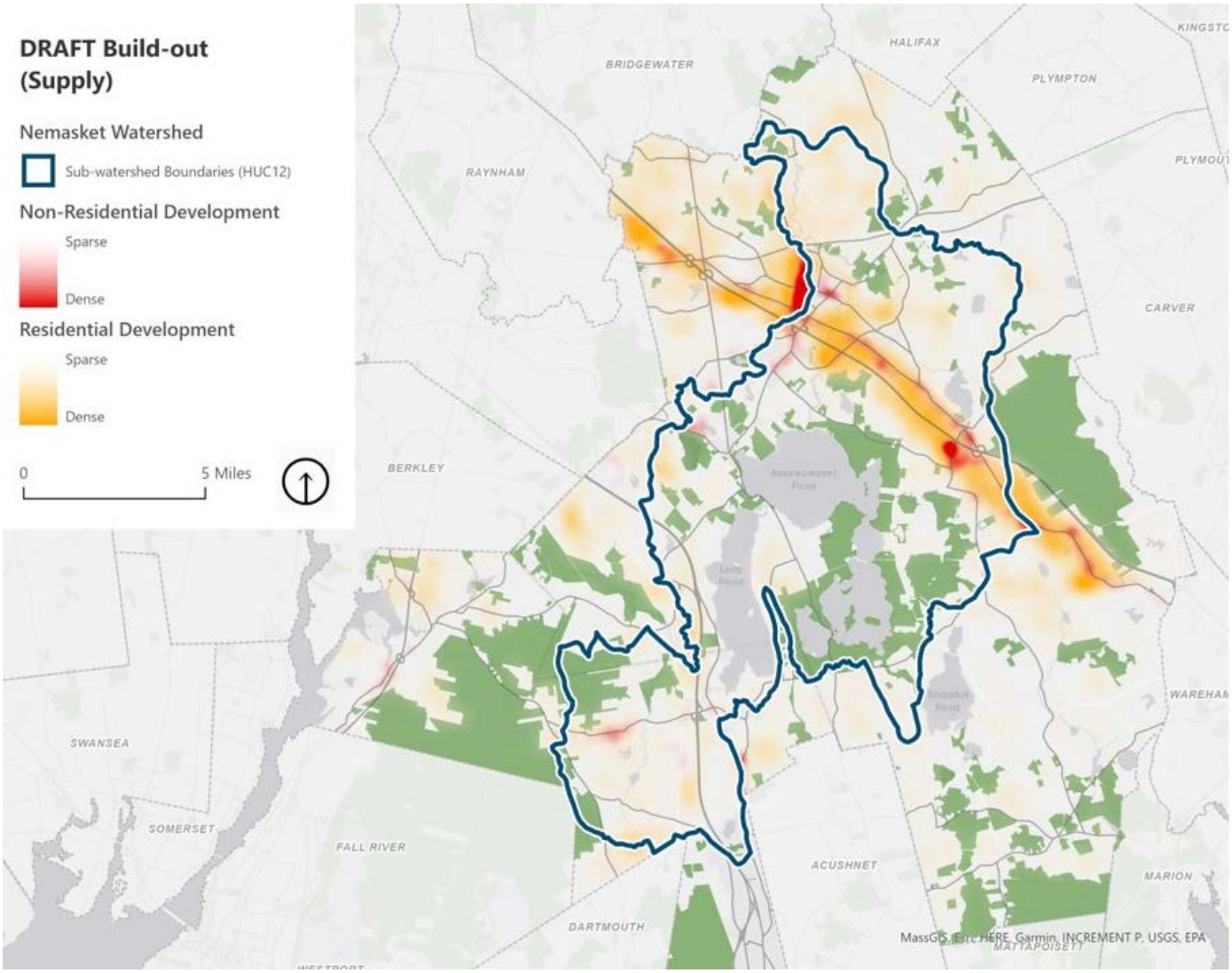
Source: MassGIS (2015, 2018a, 2018b, 2019a, 2019b, 2020a, and 2020b)

Figure 10. Development Rates by Town in Southeastern Massachusetts



Source: Mass Audubon (2020)

Figure 11. Identified Areas with Large Potential Supply of Developable Land



Source: Built-Out Analysis Using Community Viz. SRPEDD, 2021.

TABLES

Table 1. Watershed Land Cover Type

Type	Acres	Percentage of Watershed
Bare Land	458	1.0%
Cultivated	951	2.1%
Deciduous Forest	8,047	17.9%
Developed Open Space	3,268	7.3%
Evergreen Forest	10,771	24.0%
Grassland	1,059	2.4%
Impervious	2,555	5.7%
Palustrine Aquatic Bed	282	0.6%
Palustrine Emergent Wetland	563	1.3%
Palustrine Forested Wetland	8,373	18.7%
Palustrine Scrub/Shrub/Wetland	769	1.7%
Pasture/Hay	792	1.8%
Scrub/Shrub	419	0.9%
Water	6,560	14.6%

Source: MassGIS, 2019

Table 2. Watershed Land Use

Type	Acres	Percentage of Watershed
Residential 3 Units or Fewer	22,649	49.7%
Residential 4 Units or More	322	0.7%
Mixed Use	3,250	7.1%
Commercial	757	1.7%
Industrial/Utility/Transportation	605	1.3%
Church/Charitable/Cemetery	697	1.5%
Forest/Open Space/Agricultural/Woodlot	4,399	9.7%
Publicly Owned	8,672	19.0%
Developable Land	2,195	4.8%
Undevelopable Land	1,849	4.1%
Unknown/Other	161	0.4%

Source: MassGIS (2015, 2018a, 2018b, 2019a, 2019b, 2020a, and 2020b)

Table 3. Watershed Zoning Summary

Use	Lakeville	Middleborough	Freetown	Rochester	New Bedford
Residential – single family	Yes	Yes	Yes	Yes	Yes
Residential – two family	Not addressed	Special permit only within General Use	Yes	Yes	Yes
Residential – three or more family	Yes, in Smart Growth Overlay District	Special Permit only; up to 3 units	Special Permit	Yes (up to 4 units, or up to 8 in Limited Commercial District; Special Permit for more)	Yes, in MUB only
Agriculture	Yes	Yes	Yes	Yes	Yes
Mixed Use	Special permit for residential uses in business district	Yes – general use district	Yes – general use; village-residential & business districts	Yes, in Limited Commercial District	Yes – Mixed Use Business District
Business & Commercial	Yes	Yes	Yes	No	Yes
Industrial	Yes	No, but some uses allowed in general use district	Yes	No	No
Open Space	No designated use	No designated use	Yes	No designated use	No designated use

Notes. Adapted from Lakeville (2021), Middleborough (2015), Freetown (2019), Rochester (2020), and New Bedford (2021).

Table 4. Land Use Regulations

	Lakeville	Middleborough	Freetown	Rochester	New Bedford
Wetland Bylaw	No	No, 25ft vegetated buffer required within Water Resource Protection Overlay Districts	Yes, 100ft wetland buffer; 200ft river/ stream/ lake buffer	Yes, 100ft buffer	Yes, 100ft buffer; 25 ft setback from all resources areas preferred but not required
Stormwater Bylaw	No, illicit discharges addressed in general bylaws	Yes	No, illicit discharges addressed in general bylaws	No, but stormwater management design guidelines provided in Subdivision Rules and Regulations	Yes
Soil/ Earth Removal bylaw	Yes	Yes	Yes	Yes	No
Conservation Subdivision / Open Space Residential Design	No (OSD Bylaw being voted on in Spring 2022 town meeting)	Yes – special permit in residential and general use districts	No (but Planned Mixed Use Development overlay district requires open space protection)	No, but Flexible Development SP option allows higher density and permanent protection of open space (no required min), and density bonuses	35% green space required all residential lots; 20% industrial
Cluster Development	Density bonuses in business/ industrial districts; mixed use and smart growth overlay districts	No	No	Special Residential Development and Flexible Development special permits	Mixed Use Business, Planned Business districts, "KHTOD"?
43D	Yes	Yes	Yes	No	Yes
Master Plan	2020	2002	No	No	2010
Open Space Plan	2012	In process	In process	2019	2014
MVP-Certified	2019	2020	2019	2019	2018
Community Preservation Act (CPA)	Yes (adopted 2022) – 1% surcharge	Yes (adopted 2010) - 1% surcharge	No (failed vote 2012)	No (failed vote 2006)	Yes (adopted 2014) - 1.5% surcharge

Source: Adapted from Lakeville (2021), Middleborough (2015), Freetown (2019), Rochester (2020), and New Bedford (2021).

Table 5. Development Trends by Town

	Lakeville	Middleborough	Freetown	Rochester	New Bedford
Town area	23,117 ac	46,198 ac	22,652 ac	23,057 ac	12,906 ac
% Developed	19%	16%	17%	12%	59%
% Natural land	73%	71%	75%	72%	33%
% Open land	8%	12%	7%	16%	6%
New development 2012-2017	90 ac 2.5 ac / sq mi	490 ac 6.8 ac / sq mi	222 ac 6.3 ac / sq mi	245 ac 6.8 ac / sq mi	76 ac 3.8 ac / sq mi
Rank in state (ac developed per sq mi)	196	16	24	17	114
Development 2005-13	117 ac 3.2 ac / sq mi	373 ac 5.2 ac / sq mi	167 ac 4.7 ac / sq mi	122 ac 3.4 ac / sq mi	103 ac 5.1 ac / sq mi
Permanently conserved land (in 2019)	3,475 ac	8,211 ac	6,003 ac	5,005 ac	2,220 ac
% Permanently conserved	15%	18%	27%	22%	17%
Rank in state (% permanently conserved)	247	224	137	178	230

Notes. Adapted from Mass Audubon (2020): "Natural land consists of forest, wetland, and water; open land consists of agricultural areas, bare soil, beaches, barrens, or low vegetation; development includes low density residential and commercial/industrial/high density residential development. Percentage calculations are based on the state's total land area, excluding major waterbodies."

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

PUBLIC STEWARDSHIP AND CULTURE OF WATERSHED PROTECTION

CURRENT CONDITIONS IN THE WATERSHED

Definitions

Environmental stewardship is frequently defined as "the responsible use and protection of the natural environment through conservation and sustainable practices to enhance ecosystem resilience and human well-being" (National Oceanic and Atmospheric Administration, 2021). In less academic parlance, environmental stewardship in this paper's usage is the practice of consciously acting (or not acting) in ways that respect humans' interdependence with nature and protect essential natural resources. The National Oceanic and Atmospheric Administration points to five dimensions of stewardship action, which provides a succinct and helpful framework (2021):

1. **Restoration and Protection:** "Actions that assist in the recovery or preservation of an ecosystem... and allow that ecosystem to evolve with minimal human influence" (e.g., litter cleanups, habitat restoration, invasive plant removal, rain gardens).
2. **Everyday Choices:** "Actions that reduce resource inputs and emissions... through technological change and consumer purchasing, use and disposal behaviors" (e.g., recycling, composting, energy efficient products).
3. **Community Awareness: "**Actions that inform others in an effort to convince them to take action to address community-level environmental issues" (e.g., organizing community events, providing information on community platforms).
4. **Civic Action:** "Actions that inform public or organizational policy decisions that can improve environmental outcomes for many people or organizations at once" (e.g., speaking or presenting at town meetings, meeting with elected officials).
5. **Stewardship Science:** "Actions that collect and report monitoring data in an ecosystem that inform management of the natural resource."

It is important to note that everyone plays a role in stewardship, and there are opportunities for municipal managers, residents, recreational users and other stakeholders to take actions across all five dimensions of this framework that would advance the protection and quality of the Assawompset Ponds Complex (APC) and Nemasket River watershed. But perhaps the most crucial antecedent step to seeing the widespread adoption of stewardship behavior is to create the feeling of connection between the watershed's people and its landscape. Fostering this connection, through communication channels such as public information, civic processes, stewardship events, and public art, takes thoughtful partnerships and resources.

Municipalities Overview

The communities surrounding the APC and Nemasket River (Lakeville, Middleborough, Freetown, Rochester), as well as those that get their drinking water from the ponds (New Bedford and Taunton), play a role in watershed stewardship. Representatives from each municipality participate in the Assawompset Ponds Complex (APC) Management Team, an inter-municipal and inter-agency committee that meets regularly to discuss challenges and collaborate on management actions related to the ponds.

Each municipality plays a significant role in managing the watershed lands within its jurisdiction, protecting water quality, and promoting environmental stewardship in its daily operations. These

communities prioritize stewardship of natural resources in many of their local planning documents, including Master Plans, Open Space and Recreation Plans (OSRPs), and Municipal Vulnerability and Preparedness (MVP) Plans, and in their bylaws governing aspects of the use of private property.

Lakeville's and Middleborough's OSRPs identify the APC and Nemasket River as significant shared resources, with associated management and stewardship responsibilities. In Lakeville's 2012 OSRP, the town identified protecting the watershed areas and water resources of the town and conserving unprotected lands bordering the APC as high priorities. Additional priorities included promoting responsible use of open space in the town and expanding outreach to promote appreciation for and protection of open space (Town of Lakeville, 2012). Middleborough's 2015 OSRP identified protecting water resources, protecting lands along the Nemasket River corridor, promoting recreational use, improving the Nemasket River ecosystem and educating the community about the values of open space protection as priorities (Town of Middleborough, 2015). Rochester's 2008 OSRP identified the APC as an important regional water resource and expressed responsibility for guarding this regional water supply (Town of Rochester, 2008). Freetown is currently updating its OSRP. While New Bedford's OSRP does not have any action items or goals specific to the APC, there is a section devoted to it as the City's water supply (City of New Bedford, 2014). Taunton's OSRP also addresses the APC as the city's main drinking water source and discusses land acquisition efforts surrounding the ponds by the Cities of Taunton and New Bedford to protect water supply, though it does not include any related action items or goals (City of Taunton, 2015). Additional details on these topics are in the Water Supply white paper.

Local community members, as landowners and users, also have watershed stewardship opportunities, especially related to sustainable use of natural resources. It is important for these local stakeholders to understand that stewardship requires a balance between the right to enjoy local natural resources and the responsibility to do so mindfully. Municipal leaders and local community organizations can play a major role in fostering a culture of stewardship within the community through ongoing communication. They can help encourage the local community to take an active role in stewarding their local parks and other natural resources.

Community Preservation Act (CPA)

State programs like the Community Preservation Act (CPA) give community members the option to prioritize natural resource protection locally. Middleborough and New Bedford adopted CPA in 2010 and 2014, respectively, meaning their residents opted in to paying a surcharge on their taxes that goes into a local Community Preservation Fund for open space protection, historic preservation, affordable housing, and outdoor recreation (MassGIS, 2021). Lakeville residents voted to adopt CPA in the spring election ballot on April 4, 2022 (Town of Lakeville, 2022). Freetown considered CPA in 2021, but the measure did not pass town meeting (Leombruno, 2021). Rochester chose not to adopt CPA when it was proposed in 2013 (Deciccio, 2013).

Public Education and Recreational Access

Watershed stakeholders have expressed a need for more public education to encourage public stewardship. In particular, there is a desire to increase awareness of the Nemasket River as a public resource and to encourage its responsible use (APC Management Plan Steering Committee, meeting discussion, 2022). There seems to be a lack of widespread understanding of where and how the public can use the Nemasket River and APC. Better online information and clear signage showing the locations that are and are not publicly accessible are proposed as approaches to increase stewardship (APC

Management Plan Steering Committee, meeting discussion, 2022). More specifically, some have suggested information and signage about why some areas are not open to the public (e.g., drinking water source protection) in order to build awareness and stewardship, especially around water supply protection (APC Management Plan Steering Committee, meeting discussion, 2022). Greater assurance that use restrictions are not arbitrary, that they, in fact, serve an essential function, may help to achieve greater compliance.

Building a public connection to the watershed through high quality access to respectful recreational activities that have a minimal impact on environmental resources (i.e. nature walks and canoe/kayak access) can also improve public stewardship. More education around proper behaviors and practices when recreating outdoors can help existing issues with public use, such as excessive litter, particularly discarded fishing line, along the river. Educational kiosks in public parks throughout the watershed are a favored action to highlight the ecology and history of the watershed and how the public can appropriately engage with these natural resources (APC Management Plan Steering Committee, meeting discussion, 2022). Empowering community members to to be better stewards requires awareness of what type of behavior is appropriate where. More details about which recreational uses are allowed throughout the watershed can be found in the Recreational Access paper.

Signage can go a long way in encouraging responsible and respectful use of the watershed's open spaces. However, some of the watershed's natural areas are already overburdened by excessive use, especially as outdoor activities are becoming increasingly popular (APC Management Plan Public Meeting, 04/13/2022). Furthermore, organized outdoor group activities sometimes take place without coordinating with the town and acquiring the required permits, which can result in unnecessary stress on natural resources and conflicts with other users (APC Management Plan Steering Committee, meeting discussion, 2022). When it comes to encouraging more widespread use of open spaces across the watershed, advertisements and outreach should focus on increasing public awareness of allowed recreational uses and permitting requirements, and direct groups and new recreational users to appropriate areas that can accommodate the use, such as Betty's Neck in Lakeville and Pratt Farm in Middleborough (APC Management Plan Steering Committee, meeting discussion, 2022).

Land Management

Existing land uses and the specific choices that landowners make when developing their land have a large impact on environmental resources and watershed health. With the majority of the watershed area privately owned (Figure 1) and a large portion of that privately-owned land in residential use, individual landowners tend to have the largest stewardship responsibility. This challenge can be addressed through strong local land use regulations and enforcement as well as public education that encourages sustainable land development and property management practices, such as proper septic system maintenance, restraint in installing new impervious cover, and responsible fertilizer usage. Additional information on such practices is included in the Land Development white paper. There is interest among the APC Management Plan Steering Committee in implementing a communication strategy with property owners who live on Long Pond and Assawompset Pond that stresses the local responsibility and importance of stewardship, and offers information both about what local residents can do and what the municipalities are doing so that property owners know they are not alone (APC Management Plan Steering Committee, meeting discussion, 2022).

As shown in Figure 1 and in the Land Development white paper, much of the land adjacent to the APC—especially around Assawompset, Great Quittacas, Little Quitacas, and Pocksha Ponds—is publicly owned and/or has conservation restrictions on it, particularly for water supply protection. This condition reflects important stewardship of APC lands, but there are additional unrealized protection opportunities that do arise, such as the recent closure of Camp Cathedral, a large parcel along Long Pond (Walsh, 2021). Additional information on these opportunities is in the Recreational Access white paper. As part of the APC and Nemasket River Watershed Management Plan, a sub-committee of municipal staff are meeting to identify current possibilities and priorities for additional land preservation (APC Management Plan Steering Committee, meeting discussion, 2022).

The protection of lands adjacent to APC waterbodies and associated restricted public access may be counterproductive towards encouraging public stewardship if the public feels disconnected from or even unaware of the waterbodies because of the restrictions. That potential disconnect furthers the importance of public engagement and education as well enhancing public access where appropriate to do so. This makes a case for developing and maintaining a select number of very high quality, publicly accessible recreation opportunities around APC and Nemasket River where it is possible to do so without compromising drinking water supply quality. This might include passive and/or low impact recreational activities, such as nature walks at sites with facilities that are capable of accommodating a large number of people, like Pratt Farm in Middleborough or Betty's Neck in Lakeville, and kayak access on the Nemasket River with clear signage explaining that Assasompet Pond is off-limits and why (APC Management Plan Steering Committee, meeting discussion, 2022).

Municipalities and state agencies are the largest owners of open space and recreation lands and associated natural resources in the watershed. Together, these entities own approximately 83% of the watershed's open space and recreation lands (Figure 2) (MassGIS, 2020). The Cities of New Bedford and Taunton own more than a third (37%) of the watershed's open space and recreation lands, managing large parcels of protected land surrounding the APC (in Lakeville and Rochester) for drinking water supply protection (MassGIS, 2020).

Each watershed municipality's Conservation Commission is responsible for managing municipally owned lands. Maintenance and upkeep of these lands, particularly those in recreational use, is critical, both for watershed health and public benefit. Well-kept recreational lands are more likely to provide high value recreational opportunities, whereas visibly unkept areas may discourage a public stewardship ethic (APC Management Plan Steering Committee, meeting discussion, 2022). Municipal land managers and the public must work together to steward the watershed's open spaces; however, the majority of responsibility falls on very limited municipal budgets for land management. Each of the four watershed municipalities have only a handful of town staff between their local Conservation Commissions and Parks and Recreation Departments, and rely on volunteer members for their local Park Commissions (APC Management Plan Steering Committee, meeting discussion, 2022). Middleborough has a special volunteer stewardship group that helps to oversee town conservation lands and implement management projects (Town of Middleborough [Middleborough], n.d. b). Freetown's Conservation Commission appoints a three-member Town Forest Committee to help steward town conservation land (Town of Freetown [Freetown], n.d.).

Municipal and private landowners can access assistance to develop forest management plans for their property from the Natural Resources Conservation Service (Natural Resources Conservation Service,

n.d.) of the United States Department of Agriculture (USDA) and from the Massachusetts Department of Conservation and Recreation (DCR) (Massachusetts Department of Conservation & Recreation [DCR], n.d.).

There are several existing stewardship and land management plans in the watershed, including the following:

- Stewardship Plan Proposal for Vigers Conservation Area, Pickens Street (Lakeville Conservation Commission, 2013).
- Forest Management Plan for Vigers Conservation Area (Lakeville Conservation Commission, approved by DCR, 2013).
- Pratt Farm Conservation Area Management Plan (Middleborough Conservation Commission, 1987).
- Pratt Farm Forestry Plan (Middleborough Conservation Commission, approved by DCR, 2011).

Community Engagement

Community groups, including (but not limited to) environmental stewardship organizations, play a significant role in improving public awareness and knowledge around environmental issues. Community events and programming can go a long way in influencing local behaviors and promoting responsible recreational use, that does not cause adverse impacts, throughout the watershed.

Local and regional environmental stewardship organizations and efforts active in the watershed include the following:

- **APC Management Team**: Local management team for the APC Ponds Complex, composed of representatives from each of the pondside communities, as well as the water suppliers from New Bedford and Taunton and other local and regional stakeholders. The Team meets quarterly to discuss management concerns across the watershed and review and comment on proposed permit requests that may impact the system. The regulatory arm of the Team includes the APC Rangers, headed by the APC Environmental Manager, who patrol the ponds, enforce use regulations, and provide public education. The Rangers are funded jointly by New Bedford and Taunton's Water Suppliers.
- **Middleborough High School**: Students participate in community service projects, including helping to maintain a community garden, and an active environmental club participates in volunteer projects.
- **MassDEP Volunteer Water Quality Monitoring Program:** The Massachusetts Department of Environmental Protection (MassDEP), Southeast Regional Office oversees a statewide water quality monitoring program, including volunteer programs. There are active volunteers in the APC and Nemasket River. The Taunton River Watershed Alliance manages the water quality sampling and submits the data to MassDEP (see below).
- **Middleborough-Lakeville Herring Fishery Commission**: With the mission to "actively work to improve the River Herring fishery of Middleborough and Lakeville through sound management practices and public education" (Town of Lakeville [Lakeville], n.d.), the commission monitors

the Nemasket River herring run, including the navigability of fish ladders at the Wareham Street Dam[1], Oliver Mill Park, and Assawompset Dam for migrating herring, working with municipalities and water suppliers when water levels are low in the fish ladders. Water quality and invasive species are also key concerns for the Commission, as these effect the ability of herring to migrate up- and down-stream. The Commission recently piloted the removal of invasive species from a segment of the Nemasket River between Vaughan Street and Bridge Street with an ecoharvester and is monitoring the area for the long-term impacts of this effort. The Commission collaborates with the state Division of Marine Fisheries to prepare and update the *Nemasket Fishery Plan for River Herring*, with the objective to one day reopen the Nemakset River herring run to recreational harvest (Massachusetts Division of Marine Fisheries and the Middleborough-Lakeville Herring Fishery Commission, 2016).

- **Mass Audubon**: The organization owns Little Cedar Swamp in Lakeville and Freetown, but this property is not open to the public. Mass Audubon has partnered with a library and local high schools on youth programming.
- **Taunton River Stewardship Council**: The council (TRSC) implements the Taunton River Stewardship Plan and provides a forum for all parties responsible for managing the Taunton River and its tributaries to discuss river interests and make recommendations. The TRSC also provides grants for local stewardship projects, from funding portions of large-scale studies to paying for materials that enable scout projects that promote stewardship of the Taunton River and its mainstem branches. In the past, they have funded informational kiosks and access projects at several sites along the Nemasket River, as well as helped to advance land acquisition and dam removal planning projects and public education in the Nemasket River Watershed.
- **Taunton River Watershed Alliance**: The organization manages a volunteer water quality monitoring program in the Taunton Watershed in coordination with MassDEP (see above), with one monitoring site on the lower Nemasket River at Murdock Street in Middleborough.
- **Wildlands Trust**: This conservation organization works throughout southeastern Massachusetts to protect and conserve significant natural areas; it manages properties in Rochester that are outside of the watershed.
- **Sustainable Middleborough**: This community organization works on clean energy and other sustainable policies in Middleborough and the state; it has partnered on climate outreach events, such as a climate café with Mass Audubon and other partners.
- **Rochester Land Trust**: While this organization works on conserving land, it has no properties within the watershed.
- **Citizens Environmental Health Impact Committee**: This volunteer committee of the Town of Middleborough is not currently active, though in the past they worked to address health and environmental concerns throughout town, with a particular focus on pollutants and contamination.
- **Green Team**: This volunteer group from New Bedford cares for lands in New Bedford and looks after watershed lands during the off-season (winter).

[1] This dam is also referred to as the Bascule Dam or Nemasket Park Dam. Additional relevant information is in the Floodwaters Management white paper.

- **Trail Running and Equestrian Groups**: Several groups in the watershed care for trails, though issues have arisen when these groups have organized events without local permissions and tagged trees for running routes without local buy-in.
- **Long Pond Association**: This homeowners association on Long Pond in Freetown and Lakeville organized volunteer aquatic plant management program in the past but has been less active in recent years. As of February 2022, the group has reformed and achieved 501(c)3 status.

There is also regular stewardship programming and popular events in the watershed, including the following:

- The Middleborough Tourism Board offers five annual events that attract visitors to the watershed:
    - Herring Festival (Oliver Mill Park each spring)
    - CrantoberFest
    - Town Hall Ghost Tours
    - Town Hall Christmas Tree Lighting
    - Festival of Lights
- Middleborough on the Move hosts regular community events, including their annual Krazy Days outdoor festival
- Middleborough Parks Department hosts an annual canoe and kayak race and fishing programs.
- Taunton River Stewardship Council holds archeological and historic tours.
- Samuel Fuller School in Middleborough organizes an annual trail race at Pratt Farm.
- Cranberry Trifest (an athletic event) is held annually in Lakeville.
- Ongoing invasive species removal volunteer events have been held by the Lakeville-Middleborough Herring Fishery Commission (particularly on the Nemasket River) and the Long Pond Assocation (particularly on Long Pond). Past events have also been coordinated by Bridgewater State Professor Donald Padgett.

In addition, groups have expressed interest in more future events about history and Native American relationships with river (e.g., visitor days planned around Native American Heritage month in November). There are opportunities for the communities to coordinate with local historical and archaeological groups, such as those listed in the following section, to offer these types of events. There is also an aspirational plan for a Downtown Middleborough River Walk that would extend from Route 28 to 105 (East Main Street), which would be a powerful means of connecting more Middleborough and regional residents to the Nemasket River.

Historical and Cultural Resources

We cannot plan for the future of the Watershed without first reflecting on its past. And we cannot expect to be good stewards of its resources without recognizing and learning from the stewards who have lived on its land for millennia. The Watershed is situated on the ancestral unceded lands of the Massa-adchu-es-et (Massachusett), Wôpanâak (Wampanoag) and Pauquunaukit (Pokanoket) (Native Land Digital, 2021; The Massachusett Tribe at Ponkapoag, 2022; Speck, 1928; Sowams Heritage Area, 2017). Honor and respect are due to the Watershed for the bountiful natural, recreational, and cultural

resources it provides us with today, as well as to the indigenous peoples who discovered, cultivated, and cared for these resources. [2]

There is a long history of human involvement in the watershed and wider region dating back at least 10,000 years, with the APC and Nemasket River identified as playing a significant role in the lives of the Indigenous groups in the area for thousands of years up to the present day. These groups in particular include Algonquin-speaking peoples, such as the Wampanoag, from whose Wôpanâak language Assawompset is said to get its name meaning "the place of the white rock" (Sweeney, 2011). In 1675, Assawompset Pond was the site of the murder of John Sassamon and subsequent hanging of the three Wampanoag people believed to have killed him, which elevated tensions between the Wampanoag leader known as King Philip and the Plymouth Colony and led to King Philip's War (1675-1676) (Sweeney, 2011). More than 40% of the Wampanoag people died in that war, and many of the remaining men were enslaved (Mashpee Wampanoag Tribe, n.d.).

In *A Nemasket River Story* (LakeCAM Original Production, Eric Anderson), anthropologist Dr. Curtis Hoffman discusses the seasonal population centers of Indigenous peoples that lived along the Nemasket River and APC in the pre-colonial era, with herring providing a reliable resource to these communities (Lakeville Community Access Media, Inc., 2019). Indigenous communities also used the river for hunting and gathering along its banks. The word "Nemasket" refers to a particular place on the river, around the present-day Route 105 crossing, and means "the fishing place" or "place of fish" in the Wôpanâak language (Massachusetts Division of Marine Fisheries et al., 2016).

Henry David Thoreau wrote about the beauty of the ponds in his journals in the 1850s. His journals reveal much information about what flora and fauna existed at that time and how much has changed, since then. The ponds today are best known for bald eagles (resident since 1993), Plymouth gentian (plant), northern red-bellied cooters (turtle), eastern pondmussels (aquatic invertebrate), and locally uncommon saffron-winged meadowhawk (dragonfly). The area draws many birders to see a variety of species throughout the seasons (Sweeney, 2011).

The Nemasket River's spring herring migration is still one of the most significant in the region, with around hundreds of thousands of[3] fish traveling to the Assawompset Ponds annually to spawn, and attracts visitors from near and far. In a prime example of stewardship, community members perform an integral role in monitoring herring activity, counting fish that pass through the Wareham Street dam in ten-minute intervals that serve as the basis for extrapolating total run sizes. Herring are present

[2] SRPEDD and other project team members are in the initial phases of learning how to respectfully and responsibly acknowledge indigenous history and present-day culture in our planning work and documents. We understand that we must take on the task of formulating the description of this history without also burdening indigenous communities further by asking them to explain it to us or for us without compensation for that educational work. If anything in this section offends any reader, SRPEDD is very open to hearing from you. We acknowledge up front that in all likelihood, we will not get it right on the first try, despite our best efforts. Please contact enviro@srpedd.org with any comments, questions, or feedback on this section, and we will listen with open hearts and ears, and work to do better.

[3]Nemasket counts from 2020 to 2021 declined only modestly compared to other runs, decreasing from 811,000 to 739,000 fish, respectively (Chase, 2021).

throughout April and into May. Traditionally the upstream migration peaks in April and fades during the second or third week of May, although in times of abundance the run can continue into June (Massachusetts Division of Marine Fisheries et al., 2016). The Commonwealth of Massachusetts recognizes the aboriginal practice of the Wampanoag tribe to harvest river herring in Massachusetts. An agreement has been signed between the parties with the tribe agreeing to harvest only for sustenance purposes and to report their harvest by river to the Massachusetts Division of Marine Fisheries (Massachusetts Division of Marine Fisheries et al., 2016).

The Nemasket River is also a part of the Wampanoag Canoe Passage, a water trail that Indigenous groups used to travel from Massachusetts Bay to Narraganset Bay. The water trail is still used recreationally today. In the 1870's, a steamboat carried passengers up the Nemasket River and into Assawompset Pond, offering private parties and tours, until the City of Taunton began using Assawompset Pond for water supply and built a gatehouse across the mouth of it in 1875 (Taunton Wild & Scenic River Study Committee, 2005). Additional details on water supply infrastructure and history are included in the Water Supply white paper.

The arrival of European Traders in the 16th and 17th centuries introduced new diseases to the region, and a devastating plague killed nearly 80% of indigenous people across New England in 1616 (The Massachusett Tribe at Ponkapoag, 2022). Shortly thereafter, English settlers established Plymouth Colony on Wampanoag land, in 1620, and years of systemic oppression followed (Mashpee Wampanoag Tribe, n.d.). The indigenous populations of the region were forced off their lands and resettled in reservations, overseen by white guardians or overseers, limiting indigenous freedom (Mashpee Wampanoag Tribe, n.d.). Around the start of the 20th century, surviving indigenous children were sent to assimilation boarding schools, where they were forced to change their names, abandon their languages and traditions, and adopt white Christian culture (Mashpee Wampanoag Tribe, n.d.; The Carlisle Indian School Project, n.d.).

Despite this long history of trauma, indigenous groups have persevered and continue to inhabit their homelands. Today, three Wampanoag tribes remain in the area: the federally-recognized Mashpee Wampanoag Tribe (Mashpee and Taunton area), the Pocasset Wampanoag Tribe of the Pokanoket Nation (Fall River area), and the Assawompsett-Nemasket Band of Wampanoags (Lakeville and Middleborough area) (Department of the Interior, Bureau of Indian Affairs, 2021; Mashpee Wampanoag Tribe, n.d.; Pocasset Wampanoag Tribe, n.d.; Assawompsett-Nemasket Band of Wampanoags, n.d.). There are several areas of spiritual importance to Indigenous groups, particularly along the Nemasket River and a burial site on Long Pond (APC Management Plan Steering Committee, meeting discussion, 2022).

It is important that those who live, work and play in the Watershed today acknowledge this complicated history as we all continue to understand the devastating legacies of colonialism that have contributed to life as we each know it today. Expanding land protections in these areas of interest, enhancing access for all, and providing more opportunities to learn about the history of the region have been identified as priorities by the APC Steering Committee. With time, this will enable increased public awareness of indigenous history and the burdens placed upon indigenous peoples by our ancestors, and we can begin down a path of healing to repair relationships between non-indigenous and indigenous co-inhabitants of the Watershed.

Local Cultural & Historical Stewardship Groups

There are several local groups who work to steward historical and cultural resources, some of which may already offer educational programming. Municipal and other community groups can work with these organizations to expand desired programming. The following are known groups that play a role in the watershed:

- **Freetown Historical Commission**: local preservation advocates in Freetown, ensuring preservation concerns are incorporated into local planning and development decisions (Freetown, n.d. a).
- **Lakeville Historical Commission**: stewards the historical resources in the Town of Lakeville and offers scholarships to community members or groups to complete projects related to local and/or regional history and historic preservation (Lakeville, n.d. a).
- **Massachusetts Historical Commission** (MHC or Mass Historic): as part of the office of the Secretary of the Commonwealth, oversees state and federal preservation programs to preserve the Commonwealth's heritage. MHC offers Preservation Planning services, grants and technical support to communities (Secretary of the Commonwealth of Massachusetts, n.d.). MHC also approves permits for any archaeological investigations proposed on lands encumbered by a Conservation Restriction through MassWildlife (APC Management Plan Steering Committee, meeting discussion, 2022). MHC also maintains a database and online information system (MACRIS) with locations and information about historically significant places across the Commonwealth, containing hundreds of records relevant to the Watershed (Secretary of the Commonwealth of Massachusetts, n.d. a).
- **Middleborough Historical Commission**: stewards the historical and archeological assets of the Town of Middleborough; works with the Town Building Inspector to protect and preserve historically significant structures; and manages several historic sites throughout the watershed, outlined in a historic preservation strategy adopted in 1989 (Middleborough, 2008; Middleborough, n.d. c).
- **Rochester Historic District Commission**: works to preserve historical buildings and places, specifically within the Rochester's historic district (Rochester, n.d.).

Areas of Cultural Significance[4]

Particular sites of historical significance identified by The Pilgrim Resource Conservation and Development Area (PRCDA, 1980) include:

- Titicut Village, downstream from the junction of the Taunton and Nemasket Rivers
- Northern shore of Assawompset Pond near the head of the Nemasket River
- Fall Brook sawmill and gristmill at Wareham Street
- Fall Brook Iron Furnace at East Grove Street; Chesemuttock Indian Village and burial ground
- Oliver Mill and Foundry
- Benjamin Warren's shovel-shop and hammershop near Plymouth Street bridge
- John Warren's sawmill, gristmill, and shinglemill near Murdock Street bridge

[4] Areas of historical, cultural and/or stewardship significance; see Recreational Access paper for a full list of recreational sites in the Watershed.

- "Wading Place" at East Main Street bridge
- Site of the Old Fort behind the Memorial Early Childhood Center
- Royal Wompanoag Cemetery near Little Quittacas Pond
- Former sites of Fort Hill, Sentinal or Table Rock, and a historic fishing weir near Pratt's Bridge between Plymouth and Vernon Streets
- Peter Pierce Store on Main Street
- Tuspaquin Village on the southerly shore of Assawompsett Pond at Betty's Neck

Other recreational lands with local cultural significance include:

- **Oliver Mill Park**: Located at Muttock Hill, where Indigenous communities once settled, this park is the site of a burial ground and a former fish weir that Indigenous communities used to catch fish. A dam was constructed in place of the fish weir for a slitting mill (Oliver's Mill), which provided provisions for fish to travel past the dam to protect the fish run. Today, Oliver Mill Park is a public space where people can access the river, learn about the local history, and observe the spring herring migration (Taunton Wild & Scenic River Study Committee, 2005).
- **Pratt Farm**: This property, located on East Maine Street (Route 105) and along two tributaries to the Nemasket River, is the historical Pratt Farm site and currently a Town of Middleborough Conservation and Recreation Area (Osborne, 2020). The site has a series of public hiking trails and historical structures. The Taunton River Stewardship Plan recommended the site for environmental education with school groups (Taunton Wild & Scenic River Study Committee, 2005).
- **Wapanucket site**: This historical site is located along Assawompset Pond near Vaughan and Walnut Streets in Middleborough. Artifacts found on site show evidence of human settlement as long as 10,000 years ago. This site was prioritized for protection from development pressures in Middleborough's 1989 Historic Preservation Plan due to its historical significance and watershed protection value.

SUMMARY OF THREATS A CHALLENGES TO STEWARDSHIP

- Limited and disjointed access to waterways and lack of clarity around which portions of ponds are publicly accessible can hinder connection to and stewardship of the APC and Nemasket River.
- Lack of awareness could result in historical and cultural sites unintentionally being developed or otherwise lost.
- Spiritual and historic sites along the Nemasket River and the APC shores are vulnerable to flooding and erosion.
- It is difficult to reach private landowners (who own the majority of lands in the watershed) to reiterate best property management practices for protecting the watershed.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes.

Climate change impacts that threaten environmental health can also impact the public's ability to access environmental resources. Additional details on these potential impacts are in the Ecology, Recreational Access, and Land Development white papers. Climate change can impair the important values that the communities get from their natural resources, including flood storage and temperature regulation. These threats make environmental stewardship even more important in the watershed. Public education that equips communities with the knowledge and tools to steward their environment with climate change in mind is imperative for protecting the watershed and its resources.

DATA GAP DOCUMENTATION

Additional information is needed about public and private stewardship and land management plans and local programs that promote environmental stewardship.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Increased Public Stewardship and…

- Water Quality: Co-Benefit. High quality waters will enhance opportunities for the public to connect with and enjoy watershed resources. Water quality improvements can also demonstrate the values and benefits of public involvement and action around environmental restoration.

- Drinking Water Supply Levels: Co-Benefit. Adequate and reliable drinking water supply levels can demonstrate the importance of stewardship and protection of critical natural resources the watershed.

- Floodwater Management: Co-Benefit. Floodwaters threaten cultural and historic resources and uses of the watershed, as presented above. Effective floodwater management can help protect these resources.

- Stormwater Management: Co-Benefit. Polluted stormwater runoff can threaten the quality and uses of the APC and Nemasket River. Effective stormwater management can help protect these resources.

- Ecology, Unique Habitats and Natural Resources: Co-Benefit. These natural resources have important cultural and historic connections to the people of the watershed. Protecting such

natural resources safeguards their ongoing presence and relevance to current and future generations.

- Increased Land Development: Trade-Off, typically, but potential Co-Benefits. Land development typically threatens natural resources and cultural and historic sites, posing unique stewardship challenges. However, there can be opportunities to develop with stewardship in mind through low impact development and green infrastructure techniques, as well as historic preservation.
- Increased Inter-Agency Cooperation: Co-Benefit. Inter-agency cooperation can help identify and highlight multiple benefits of stewardship efforts, including relevance to natural resources, history, and culture. Additional coordination and stewardship can help promote adequate protections.
- Recreational Access: Co-Benefit and Trade-Off. Increased recreation can encourage users to become stewards of the sites they love to frequent, potentially building support for environmental protections and restorations, such as water quality improvement measures. Watercrafts that move between watersheds and systems can bring invasives with them that would harm water quality.

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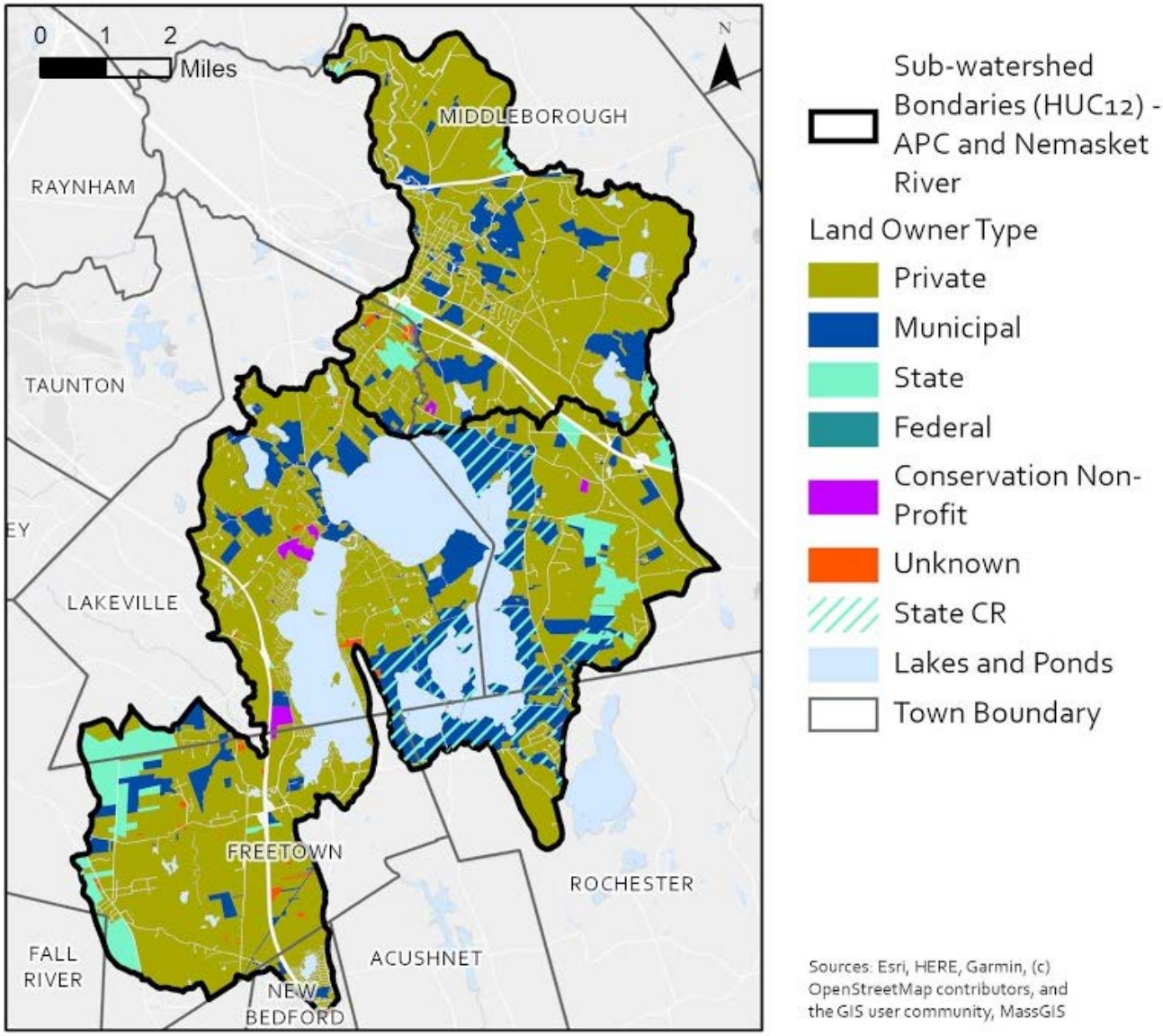
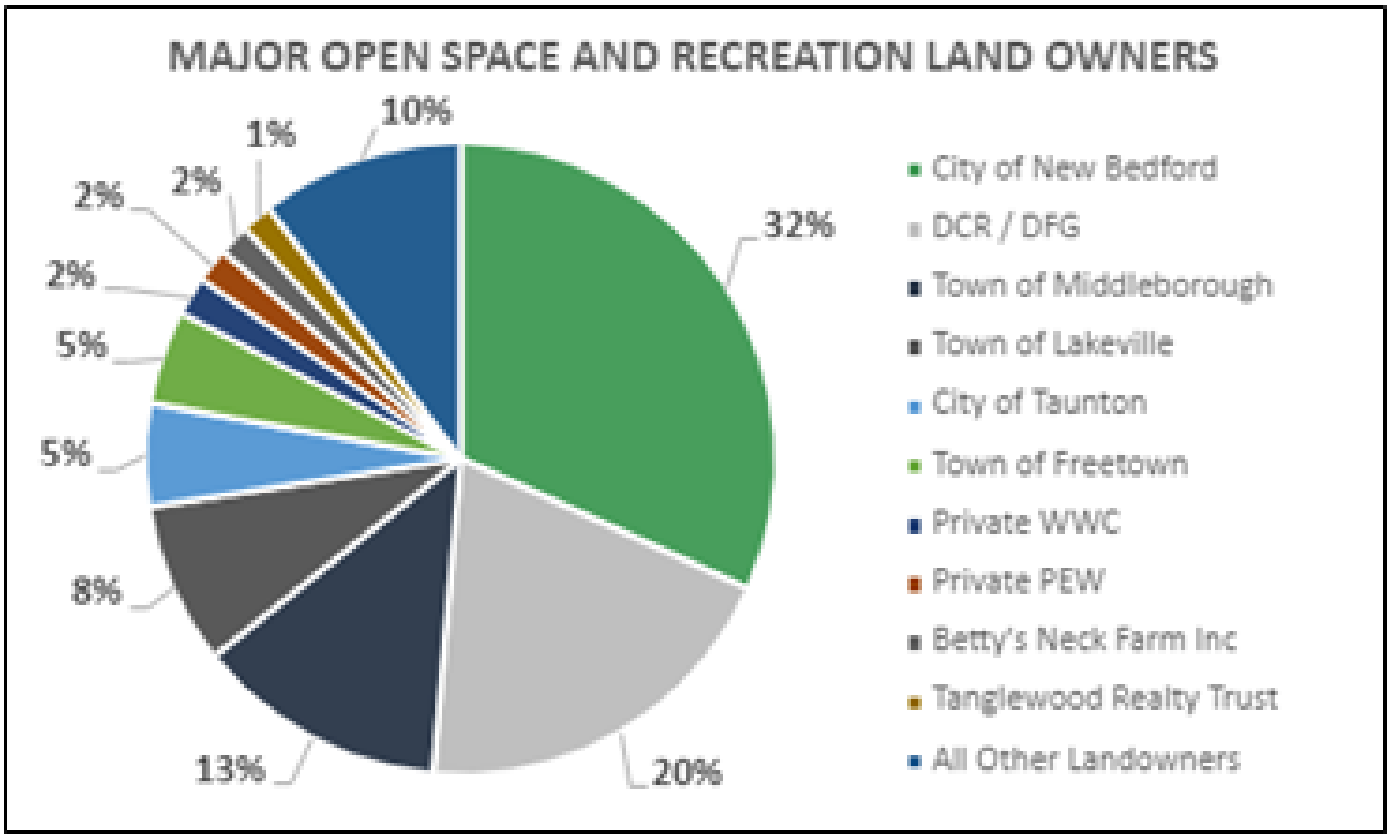
FIGURES

Figure 1. Watershed Land Ownership



Notes. MassGIS Level 3 Parcel Data for Middleborough, Lakeville, Rochester, Freetown, and New Bedford, 2020.

Figure 2. Major Open Space and Recreation Land Owners



Notes. MassGIS Protected and Recreational Open Space data layer (vintage 12/15/2020 with minor updates based on local knowledge from the APC Management Team January 2022).

WHITE PAPER to the APC & Nemasket Watershed Management and Climate Action Plan

RECREATIONAL ACCESS

CURRENT CONDITIONS IN THE WATERSHED

Open Space and Recreation Lands Overview

Open Space and Recreation areas represent a significant portion of the Assawompset Ponds Complex (APC) and Nemasket River Watershed's total land area. As represented in Figure 1, 21% (9,345 acres) of the watershed's approximately 44,900 acres are open space and recreation tracts (MassGIS, 2020).

Further, the APC and Nemasket River waterbodies serve as a hub for open space and recreation lands in the immediate region. Forty-three percent (4,016 acres) of the 9,345 acres of open space and recreation lands throughout the watershed are situated in tracts that are adjacent to the APC or Nemasket River. Of these 4,016 acres of water-adjacent open space lands, 80% (3,218 acres) are categorized as publicly accessible. Figures 2 & 4 show open space and recreation areas by their primary purpose and public accessibility, respectively.

Within the APC and Nemasket River Watershed, other key clusters of open space and recreation land are found around Tispaquin Pond in Middleborough, along Black Brook and Fall Brook in Middleborough, along Snipatuit Brook in Rochester, in the area around Loon Pond in Lakeville, and within the Freetown-Fall River State Forest/Southeastern Massachusetts Bioreserve in Freetown.

Much of the open space and recreation land in the watershed area is owned by specific public entities. The ten largest individual open space and recreation landowners are shown in Figure 3. As described further in the Stewardship and Culture white paper, approximately 83% of the watershed's open space and recreation lands are owned by municipalities and state agencies. Among these, the City of New Bedford is by far the largest landowner of open space and recreation lands by total acreage holdings, especially because the city is the owner of 2,942 acres of water supply protection lands around Assawompset, Poksha, Great Quittacas and Little Quittacas Ponds. Additional details on this topic are in the Water Supply white paper.

Recreational Opportunities

Within the watershed, recreational opportunities can be grouped into four main geographies: Long Pond, the other APC ponds, the Nemasket River, and upland parks. Generally, these areas have different landscapes and types of restrictions on permitted recreational activities.

Long Pond is the hub of water-based recreation in the APC. Most kinds of water-based recreational activities are permitted, including swimming and motorized and non-motorized boating. Long Pond has a different operational framework from the rest of the APC ponds, with an independent permitting system for boat access. Because Long Pond's shorefront is a densely settled residential community, most access points are part of privately-owned residences. This creates enforcement challenges when users access Long Pond from private docks without the required permits for motorized boats and jet skis (APC Management Plan Steering Committee, meeting discussion, 2022).

There are three public recreation areas on Long Pond:

- Long Pond Town Beach in Freetown is a 5.6-acre town-owned property with limited public access (users must pre-purchase a parking pass).

- Long Pond Boat Ramp in Freetown is a Division of Fisheries and Wildlife parcel with a concrete boat ramp and 47 trailer spaces. Any member of the public is able to use the boat ramp. There is currently no attendant on site (MassWildlife, n.d. f).
- Tamarack Park and Long Pond Conservation Area in Lakeville is a combined 54-acre property with a parking area, meadow, trail to the water, and small paddle-craft put-in with Full Public Access (Buzzards Bay Coalition, n.d. e). Upland recreational access is limited to 5 acres. There is video about the park's history available online (LakeCAM, 2014).

The Cathedral Camp is an additional privately-owned waterfront access and recreation site, owned by the Roman Catholic Archdiocese of Boston and located in the southeast corner of Long Pond. As of April 15, 2021, information was posted publicly that the summer camp and retreat center are closing (Walsh, 2021). The potential for this site to become a public recreation access point is unknown at this time.

Given its role in drinking water supply, no water-based recreation, except for shoreline fishing, is permitted in the APC outside of Long Pond, with limited exceptions. Boating is allowed only for shorefront residents on Assawompset and Pocksha Ponds, and two boats are allowed per residence. All boats used on Assawompset and Pocksha Ponds must have a special permit ($25 per boat per year in 2020) (N. Yeatts, personal communication, 2021; APC Management Plan Steering Committee, meeting discussion, 2022). Boats that receive permits from Taunton are inspected and issued stickers to display on the boat. Permitting practices are not consistent from community to community, however, and the requirements are not always clear to residents, and therefore not always followed. Unpermitted boats are also known to access the ponds. Taunton, New Bedford, and the APC Rangers are working together to address these issues and to make permitting more consistent, streamlined, and enforceable (APC Management Plan Steering Committee, meeting discussion, 2022).

There is, however, an extensive area of publicly-accessible recreation land around the APC for passive recreation activities without water contact, such as walking, hiking, and nature study. There are sites with parking areas, trails, and picnicking and fishing amenities, including the following:

- New Bedford Waterworks in Rochester is an area along the southern edge of Great Quittacas Pond with a trails network for hiking, biking, snowshoeing, skiing and waterfront views (Buzzards Bay Coalition, n.d. c).
- Betty's Neck in Lakeville is a large town-owned property with parking and three miles of trails through meadow, forest, and to a shorefront fishing area (Buzzards Bay Coalition, n.d. b). Access to the property is provided by a private access road that can be difficult to access (APC Management Plan Steering Committee, meeting discussion, 2022).
- Stuart F. Morgan Conservation Area is a town-owned property in Middleborough on Great Quittacas Pond that offers walking and equestrian trail from Long Point Road, leading to views of the Pond (Buzzards Bay Coalition, n.d. f).

The Nemasket River and its surrounding corridor offer a number of land- and water-based recreation opportunities. Popular recreational areas include the Nemasket River Village/Ja Mar Turkey Farm Property and Oliver Estate Property & Conservation Land, both in Middleborough. There are locations for canoe and kayak put-ins adjacent to managed recreational parklands, such as Oliver Mill Park and the Nemasket Herring Run Park at Wareham Street in Middleborough. Others have improved parking areas only, such as the Old Bridge Street site in Lakeville. Kayaking from Oliver Mill Park to Vaughn

Street is approximately 5.15 miles of paddling with portages. Low water levels and extensive plant growth limit the reach of canoers and kayakers in the river, with paddling best in early spring.

Farther afield from the ponds and river, several regionally significant nature-based recreation areas are located in the APC and Nemasket River Watershed uplands. These include the following sites:

- Wildlife Management Areas (WMAs), including portions of the Taunton River WMA, Meetinghouse Swamp WMA, Rocky Gutter WMA and Black Brook WMA, with hunting, fishing, trapping, and wildlife viewing possibilities (MassWildlife n.d. e, n.d. b, n.d. c, n.d. a).
- Pratt Farm in Middleborough
- Tispaquin Pond Access in Middleborough
- Fall Brook-Washburn Conservation Area in Middleborough
- Forest preserves, including Middleborough Town Forest, Talcott White Edminster Memorial Forest in Freetown, Fredrick Weston Memorial Forest in Middleborough
- Freetown-Fall River State Forest and Southeastern Massachusetts Bioreserve
- Pulaski Park in New Bedford

Allowed Recreational Uses

Passive recreational uses, such as walking, hiking and sightseeing, are generally allowed on all publicly-accessible sites in the Watershed. See Figure 4 for a map of publicly accessible sites around the ponds. Additional activities, like hunting, fishing, and mountain biking, are allowed in designated areas only. The following is a list of all allowed uses within the APC and surrounding recreational areas (APC Management Team, n.d.; MassWildlife, n.d. g):

- Walking, running, hiking
- Nature study & observation, sightseeing
- Photography, artistic work
- Picnicking (no fires; carry in/carry out policy)
- Dog walking (dogs required to be leashed; pick up/carry out pet waste)
- Cross country skiing, Snowshoeing (on designated trails only)
- Mountain biking (on designated trails only)
- Horseback riding (on designated trails only)
- Hunting, trapping (in accordance with state regulations; deer hunting on Betty's Neck is by special permit and subject to lottery)
- Shoreline fishing (in accordance with state regulations; not allowed on western shores of Assawompset or Little Quittacas Ponds)
- Boat-based fishing (in accordance with state regulations; on Long Pond only)
- Organized group activities by special permit only

Recreational Programming, Culture, and Values

Spiritual practices and values inherent to the APC and Nemasket River Watershed are another important aspect of public recreation and land conservation in the area, albeit frequently less appreciated and studied. In the watershed, a degree of spirituality around the unique natural features of the APC—

including feelings of perspective, wholeness in nature, and taking joy in variety and beauty—is relatively universally accessible.

Local Indigenous communities have particularly significant spiritual ties to the APC, Nemasket River, and surrounding lands. Many places that are important to Indigenous traditions and spiritual practices are not overtly advertised so that they can remain intact. An exception, the Royal Wampanoag Cemetery, is located on the ponds between Great and Little Quittacas Ponds. In addition, several land and water trails that were historically used by Indigenous communities are recreational resources today. Additional details on this topic are included in the Stewardship and Culture white paper.

The APC and Nemasket River are also tied into local town recreational programming and cultural events. The Middleborough Tourism Board hosts the annual Herring Festival at Oliver Mill Park to mark the herring run as a unique, celebratory annual event that ties into local history. There is a local annual canoe and kayak race on the Nemasket River organized by the Middleborough Parks Department. The Taunton River Stewardship Council water-access sub-committee is also heavily involved in designing paddling programs in the Nemasket. Additional public events are described in the Stewardship and Culture white paper.

Information on Recreational Opportunities and Regulations

Varied watershed stakeholders, including towns and environmentally oriented non-profits, have developed substantial materials explaining the range and location of permitted recreational activities in the watershed. A key current question is the extent to which these informational materials are reaching their intended audiences. It is unclear if these resources are posted and available where potential users would look for information on recreational opportunities, rules, and regulations.

Non-Profit Organizations and Associations

The Buzzards Bay Coalition (BBC)

BBC tends to be the organization that posts the most information about recreation in the APC, with a *dedicated webpage* describing ways to visit the APC and locations to do so . The webpage specifically highlights recreation access at Tamarack Park, Betty's Neck, New Bedford Waterworks (cautioning that trails are not marked), the Long Pond Boat Ramp (noting good fishing for largemouth bass, white, and yellow perch, as well as the fact that there are no restrictions on speed or boat size in the pond), and the Stuart F. Morgan Conservation Area (horse riding permitted). The BBC webpage has a *1:40 minute video* that showcases how to access each of these areas. The website *hikingproject.com* also has a *map of the trails* at Betty's Neck and the New Bedford Waterworks recreation areas.

TEAMS

An organization called TEAMS (no longer active) created *an informational map of the APC* (with the exception of Long Pond) with permitted usage regulations enumerated. This document, included as a basemap in Figure 4 is hosted on the Buzzards Bay Coalition website and appears in a Google Search for "Assawompset Pond Complex." However, it is not linked to the BBC webpage "How to explore the Assawompset Pond Complex" page, nor is it posted on any town websites. Paper versions are available for a small fee at the Lakeville and Middleborough town halls. Some information on public access in the flyer conflicts with state open space data.

The Long Pond Association

The Long Pond Association has a *website* with information on recreation, which lists boating (no boat size or speed restrictions), swimming, water skiing, fishing, ice-fishing, skating, camping, and aesthetic view appreciation as pond recreational uses. The website does not appear to have been updated since the late 2000s. Long Pond Association is currently focused on forming a non-profit entity.

The Taunton River Watershed Alliance

The council (TRSC) implements the Taunton River Stewardship Plan and provides a forum for all parties responsible for managing the Taunton River and its tributaries to discuss river interests and make recommendations. The TRSC also provides grants for local stewardship projects, including informational kiosks and access projects at several sites along the Nemasket River, and has helped to advance land acquisition and dam removal planning projects and public education in the Nemasket River Watershed.

The Taunton River Stewardship Council

The Taunton River Watershed Alliance, in partnership with the Rhode Island Blueways and Greenways program, has a *mapping resource* and printed materials with descriptions of kayak put-ins on the Nemasket River. Five sites are identified between Vaughn Street Bridge and Oliver Mill Park, as shown in Figure 5.

Municipalities

Freetown

Freetown does not have a Parks Department, although the town does have a publicly available document establishing a Parks and Recreation Committee on July 13, 2020. The current status of the committee is not known at this time. The website does have a prominent GIS portal, where various community attributes can be explored. The Open Space layer falls under the general category “MassGIS Data,” making it difficult to access intuitively, especially for a non-GIS data user. The Conservation Commission has some links to recreational opportunities like the Southeastern Massachusetts Bioreserve, but nothing about the APC, despite the Long Pond Town Beach and Long Pond Boat Ramp being located in Freetown.

Lakeville

Lakeville has a Parks Commission that oversees certain properties. Its webpage focuses on describing the process to rent facilities. Similar to Middleborough, specific information about parks, park regulations, and programs are not listed on the site. There is a dedicated page for the APC listed under Boards and Committees, but it presents as “Under Construction” (Town of Lakeville [Lakeville], n.d. a). The Select Board page leads to some information about pond levels and a link to a page on Betty’s Neck that is also listed as “Under Construction” (Lakeville, n.d. b). The only water-related recreational bylaw that appears to be on the books in Lakeville is a prohibition against motorized boats on Loon Pond, just northwest of Assawompset Pond.

Middleborough

Middleborough has a Parks and Recreation Department and a Parks Commission, but information about specific parks, park regulations, and programs are not listed on their website. The Nemasket River and APC are mentioned on the website, but in the context of community history (Thayer, n.d.). It does not seem like any ponds use regulations are present in Middleborough’s community bylaws.

Rochester

Rochester has a wealth of information on its website. Management of public lands is generally overseen by the Parks Commission, an entity within the Conservation Commission and Town Forest Committee. Their statement of purpose is to be "responsible for protecting Rochester's natural resources, managing the Town Forest & Conservation lands, environmental and open space planning, and administering state and local wetlands statutes" (Town of Rochester [Rochester], n.d. b). The town has a dedicated website (Rochester, n.d. a) with detailed trail maps for 15 recreational properties, including the New Bedford Waterworks site (Rochester Conservation Commission & Town Forest Commission [RCC], n.d.), though these maps do not mention details on permitted activities. The town's GIS database has a clearly labeled Open Space layer (MapGeo, n.d.). Rochester also has a herring inspector, though position duties are not listed on the town webpage.

New Bedford

New Bedford has a robust Department of Parks, Recreation and Beaches. Despite owning a tremendous amount of publicly accessible land around the ponds for water supply protection (outside of New Bedford), the department's listing of open space and parks excludes parcels not within New Bedford itself. Detailed information and trail maps are available on the website for facilities in New Bedford. The City's Park Board of Commissioners develops rules governing park facilities.

Taunton

According to the 2002 Assawompset Ponds Complex Management Plan (Epsilon Associates, 2002), most of Taunton's 486 acres of land within the APC is open to public access, with certain prohibitions including public access within 85 feet of the shoreline of Elders' Pond and fishing in Elders' Pond and Sampson Cove. The Town has information about its parks and recreation facilities in the city of Taunton on the Parks and Recreation, Cemeteries, and Public Ground webpage, but this does not include information about the APC lands in particular. Posting information about recreational opportunities on lands in the APC that *do* permit public access could encourage residents of Taunton to visit the area and be more connected to their water supply source.

State and Regional Entities

MassWildlife

MassWidlife is a division of the State Department of Fish and Game that is responsible for the conservation of freshwater fish and wildlife in the Commonwealth (Commonwealth of Massachusetts, 2022). They restore, protect and manage land, including several properties in the Watershed. MassWildlife owns several upland properties, managed as Wildlife Management Areas (WMAs), where full public access is allowed for wildlife-related activities, including hunting, fishing, trapping, nature observation, boating and hiking (i.e. Black Brook, Purchade Brook and Meetinghouse Swamp WMAs). MassWildlife also holds Wildlife Conservation Easements on several properties surrounding Assawompset, Pocksha, Great Quittacas, and Little Quittacas Ponds, with limited public access allowed (MassWildlife, n.d. g).

The Natural Heritage and Endangered Species Program (NHESP) of MassWildlife is responsible for reviewing projects that may impact rare species habitat for compliance with the Massachusetts Endangered Species Act (Commonwealth of Massachusetts, 2022a). There are several areas of protected habitat throughout the watershed (see Ecology, Unique Habitats and Natural Resources white paper for

more details), for which certain activities proposed within would require coordination with NHESP to prevent adverse impacts to rare and endangered wildlife.

Department of Conservation & Recreation (DCR)

The state Department of Conservation and Recreation (DCR) manages the Commonwealth's state parks and other conservation lands, with the goal to protect, promote, and enhance the state's natural, cultural and recreational resources (Commonwealth of Massachusetts, 2022a). There are no DCR Park properties within the watershed.

Division of Marine Fisheries (DMF)

The Division of Marine Fisheries (DMF) is a part of the State's Department of Fish and Game and manages the Commonwealth's commercial and recreational saltwater fisheries (Commonwealth of Massachusetts, 2022b). Being a migratory fish, river herring are a saltwater fishery, and therefore under the jurisdiction of DMF, who coordinates with the Middleborough-Lakeville Herring Fishery Commission to manage the Nemasket herring run.

Other Websites with Information on Recreation in the APC and Nemasket

- *Discover Middleborough* has an *Assawompset Pond Complex page* under "Outdoor Recreation."
- *Paddling.com* has an *account* of paddling the Nemasket.
- *Rhode Island Land Trust Council* has a *"Explore Rhode Island's Blueways and Greenways" website*, which includes the Nemasket Corridor.
- *Nemasket Kayak Center* out of Wareham offers *guided kayak tours of the Nemasket*.
- *New England Mountain Bike Association* (NEMBA) includes Pratt Farm and Rocky Gutter in Middleborough on its Massachusetts trail map

Recreational Rules Enforcement and Challenges

In such an environmentally sensitive and important water supply area, any recreational program has to balance multiple competing needs. Recreational use is important to the health of the whole system because it creates advocates and stewards, but overuse and misuse can be destructive. For the purpose of watershed and climate resilience planning, a balanced recreation program is one which provides a quality outdoor recreation experience for people within a range of recreational activities that have a low impact on ecology and water quality in the APC and Nemasket River (see more details addressing the balance between recreation and stewardship in the Stewardship and Culture paper). Accordingly, recreational uses in the APC and Nemasket River Watershed are governed by federal, state, and local regulations. Rule violations, knowingly or unknowingly perpetrated, are an on-going threat to a balanced recreational program in and the ecology of the APC and Nemasket River Watershed.

The main enforcement arm of water access and public lands regulations around the APC is the team of APC Rangers. The APC Rangers were created in 2002 and 2003 as part of the Assawompset Ponds Complex Management Plan for Betty's Neck, with the express purpose of on-site environmental management. The rangers are hired, based on their abilities to perform critical environmental monitoring and safety tasks, such as safety and hazard reporting and groundskeeping. Rangers have to have a bachelor's degree or one year of professional experience in natural resources management, ecosystem restoration, wetland mitigation, fish/aquatic resources management, or wildlife management. More than just stewards of the land, the APC Rangers are also responsible for developing

and disseminating information about the APC's resources and areas, performing administrative duties for the APC Management Team, and coordinating with relevant Massachusetts state agencies (i.e., Department of Environmental Protection, Department of Fisheries and Wildlife). The Rangers were originally hired for 10-month terms and would conduct their activities five days of the week, including during the weekends and major holidays, such as Memorial Day and Independence Day. In recent years, the Rangers have enabled access to the ponds for special wildlife and habitat restoration projects and studies, such as the loon project, which has re-established a loon population on the ponds.

The APC Ranger Program is jointly funded by the City of New Bedford Water Supply, the City of Taunton Water Supply, and the Town of Lakeville. Lakeville pays all expenses for the Ranger Program up front and then bills New Bedford and Taunton for their contributions at the end of the season (each entity pays $6,000 for a total budget of $18,000 per year). In 2020, for the first time, the Rangers were funded in part by the sale of annual boat permits to pond-front property owners issued by Taunton Water Supply ($25 a year). This arrangement may have been a one-time occurrence and is not built into the Ranger Program financing structure in a formal and regular ongoing way. In 2022, the City of New Bedford and Taunton upped their contribution to $9,000 per year.

The Ranger team fluctuates between two and four part-time staff members depending on the time of year. The head of the Ranger team—the APC Environmental Manager—is active all year. The Ranger team patrols all lands around the APC ponds but puts special emphasis on maintaining a presence in high-use areas. Ranger patrol hours vary based on weather conditions and are kept variable to maintain random checks on a very limited budget. Attracting and retaining staff is difficult, in part due to the limited funding available for salary. The Environmental Manager and Rangers are paid as 1099 contract employees. Rangers are paid minimum wage. The Environmental Manager has a slightly higher hourly rate. As minimum wage increases while the overall budget for the ranger program remains relatively fixed year on year, the ultimate effect is to restrict the number of hours that the Rangers can work.

The Rangers are the APC's first line of defense against rule violations. Hot spots of rule violations occur at several areas throughout the complex, including White Banks, Great Island, the Causeway, the Assawompset Dam and Betty's Neck. Typical rule violations include alcohol usage, parties that extend past recreational area closing hours at dusk, illegal fires, littering, and dogs off leash. During the 2020 season, this latter rule violation resulted in two children being bitten by dogs. Another consistent rule violation is canoeists and kayakers attempting to access and paddle the restricted water supply portion of the ponds. In Summer 2020, the Rangers counted over 100 people in a single day trying to portage over the Assawompset Dam at the end of the Nemasket River and into Assawompset Pond (APC Management Plan Steering Committee, meeting discussion, 2022).

When an APC Ranger confronts a group of rule violators, their procedure is to hand out a copy of system regulations, or to leave a copy of the regulations on cars if individuals cannot be located. Tickets and fines are a last resort. In previous years, there has been hesitancy to call local police, even in extreme situations of rule breaking and in instances of hostility toward the APC Rangers. The Rangers are rethinking this approach as call volumes could better show an accurate picture of the level of enforcement confrontations, substantiating requests for additional staffing and funding. The State Environmental Police are another enforcement resource, though there are so few environmental police shared by the entire state of Massachusetts that any calls placed by the Rangers have hours-long response times before environmental police officers can be on site.

Future Goals for Recreation

In recognition of their unique opportunities for recreation, several towns have explicitly adopted policies and future goals and recommendations for protecting and enhancing the APC and Nemasket River as part of their municipal Open Space and Recreation Plans (OSRPs).

On the whole, the recommendations in local OSRPs take a systems-level, comprehensive approach and put forth recommendations for supporting the improved management of the APC and Nemasket River on a corridor or watershed wide basis. The documents identify cooperation as a key tool for keeping the region and its natural areas healthy, productive, and useful to recreators. In particular "cooperative regional programs for shoreline protection," is one intervention that was advanced as being a potential starting point for enhancing the Nemasket River's health (Lakeville, 2013, p. 37). Shoreline protection covers topics such as increasing access to the Nemasket River through the use and maintenance of hiking and walking trails, better flood controls, and improvements to leaching septic systems. Shoreline trails would not only serve as recreational amenities in their own right, but also would connect protected areas to each other for potential wildlife passage. Cooperation was also mentioned in the domains of water level management – particularly in reference to water withdrawal permits - and wildlife protection (Lakeville, 2013, p. 116).

The OSRPs also highlight water management as a primary concern, first in the context of climate change (Middleborough – Recommendation Number 5, Lakeville – Recommendation Number 1) and then in the context of water management to ensure aquatic flora and fauna health and sustainability for human uses (Lakeville - Recommendation Numbers 5 and 6). As climate change has a multitude of effects on the region's open and natural spaces, runaway impacts to the system's water levels may require programmatic or infrastructural changes (Table 1). Additional information on this topic is in the Water Supply white paper and the Implications of Anticipated Climate Change Impacts section below.

Future Recreational Opportunities and Priorities Under Discussion

While OSRP planning processes attempt to anticipate recreational needs, there are always unanticipated specific opportunities that emerge that advance the spirit and general policies of the plan. Several such opportunities have recently presented themselves around the APC and Nemasket River. Other issues and opportunities have also emerged in recent discussions. Specific examples are included below:

- The Middleborough Department of Public Works (DPW) has vacated its previous headquarters on Wareham Street, directly adjacent to the Nemasket River above the Wareham Street Dam[1]. The DPW site is already integrated into recreational river access and unique species conservation: the DPW readily allowed the site to be used as a kayak put-in, and it is the location where volunteers perform fish counts as herring migrate through the river. With this site vacant, the town is exploring options for this property and has executed a public survey surrounding its use as a park and the specific elements that the public would like to see included. Responses emphasized expanding water access.

[1] This dam is also referred to as the Bascule Dam or Nemasket Park Dam. Additional relevant information is in the Floodwaters Management white paper.

- Additional public education is required around Indigenous rights and uses of the river. In future years, events and speakers could be organized for November, which is Native American Heritage Month. Additional information on this topic is in the Stewardship and Culture white paper.
- There is a need to balance recreational and habitat needs when it comes to tree falls in the Nemasket River. While naturally-occurring tree falls into the river are very valuable for habitat and are essential to some ecological processes, they also conflict with recreational enjoyment and safety of paddling on the river. The management plan provides an opportunity for guidance on this issue, potentially working with the Massachusetts Department of Fisheries and Wildlife to advise on downed tree management.
- The Wareham Street area is a particularly difficult portage, as it involves having to cross Wareham Street. An improved crossing is a priority.
- There is interest in expanding town-run recreational programming opportunities in the ponds and river.
- There is information that the Picone-Sunnyside Farm in Middleborough may be sold in upcoming years. This property abuts Oliver Mill Park and Estate and encompasses the east riverbank of the Nemasket River, almost the entire distance from Route 44 to Plymouth Street. The Town of Middleborough is actively trying to protect this property as open space and for farming (APC Management Plan Steering Committee, meeting discussion, 2022).
- There is a conceptual Downtown Middleborough River Walk in development on public properties from Route 28 to Route 105/East Main Street near the Nemasket River. There are some private properties interrupting the proposed pathway at present, but many properties are already public that could be used for a walkway and/or bike path. Funding through the Community Preservation Committee to conduct a feasibility study will be discussed for a vote at Middleborough's April 2022 Annual Town Meeting.
- The acquisition of Cathedral Camp in Freetown for public recreational use and/or water supply protection should be given some consideration, after its recent closure (see above).

SUMMARY OF THREATS A CHALLENGES TO A HEALTHY FUNCTIONING SYSTEM

- Disparate and unclear information on public access can be challenging for members of the public to access and understand.
- Competing interests and recreational uses pose conflicts between users and threaten ecological health of the watershed.
- Violations of recreational use regulations adversely impact users' experiences and threaten the ecological health of the watershed.
- Limited resources make enforcement of regulations challenging.
- Aspirational open space and recreational opportunities remain unrealized.

IMPLICATIONS OF ANTICIPATED CLIMATE CHANGE IMPACTS

Climate projections for the Taunton River Drainage Basin (Northeast Climate Science Center, 2018) and broader climate assessments (Kossin et al., 2017; Easterling et al., 2017) indicate the following anticipated changes with regard to precipitation and temperature:

- The frequency and intensity of larger, more intense storm events will continue to increase.
- The total annual precipitation will continue to increase, and most of the increase is likely to occur in the winter and spring.
- The frequency and extent of consecutive dry days will continue to increase.
- The combination of hotter and drier periods will increase the likelihood of drought episodes.

The implications of these anticipated changes are considered below.

More frequent intense storm events:

- More intense storm events could inundate or otherwise damage recreational amenities.
- Flood events can mobilize pollutants, threatening water quality and ecological health in recreational areas enjoyed by users.
- More frequent tree blow-downs, particularly on recreational trails, create hazards to recreational users in forested open spaces.

More intense flood and drought cycles:

- Many recreational access points are by nature close to the water's edge and, therefore, more susceptible to flooding. Recreational amenities within flood-prone areas along the Nemasket River and APC will need to have improvements that can be flooded without causing substantial damage (i.e., “floodable”), floodproofed by virtue of their height and specific location, easily mobile and movable from floodplains before a storm event, and/or designed without much infrastructure at all so that investments in recreational amenities are not consistently inundated and damaged.
- Flood damage could have the capacity to damage the archeological and/or sacred sites with significance to local Indigenous communities, depending on their nature. More research on this topic is needed.
- More intense droughts would affect stream levels, further limiting the times of year when the Nemasket River is navigable in canoe or kayak.

Extreme temperatures:

- The correlation between increased temperatures, especially in the summer, and recreational demand is not certain. On the one hand, water-based recreation may increase in areas like Long Pond where there is existing recreational infrastructure and where an expanded array of water-based uses like swimming and boating, which can have a cooling effect, are possible. On the other hand, specific increases in summer temperatures may cause high use periods to shift from the summer months into the cooler spring, fall, and even winter months for more strenuous uses with less of a cooling effect, such as river paddling. Planning for both scenarios should be pursed, especially in scheduling the peak need for Ranger monitoring.

- Increased temperatures are having the spillover effect of increasing susceptibility to vector-borne diseases. Mosquitos and ticks carrying specific diseases like West Nile virus or Rocky Mountain spotted fever are expanding their range as winters become more temperate with lessened instances or periods of hard freeze. Eastern equine encephalitis ("Triple E") has become a regular threat from year to year in the watershed, varying in lesser or greater extent with weather and breeding patterns, prompting sprays. Increased spraying could negatively impact water quality and associated recreational uses. As people recreate outdoors and near the water, it will become more and more imperative to continually remind recreators of the risks and of the steps that can be taken to mitigate (but not eliminate) these public health risks.

Invasive species:

- One of the major recreational interests around the ponds is passive enjoyment of views, nature study, and photography. These activities can be diminished by the presence of invasive species that overtake natural landscapes. To the extent that climate change forces the migration of certain species or stresses native species, the system may face increased vulnerability to domination by invasive plant and animal species.
- Excessive growth of invasive aquatic weeds, like fanwort and milfoil, impede paddling on the Nemasket River and pose swimming hazards in Long Pond. Climate change-fueled water quality impacts may favor the growth of these weeds over many native species.
- Proactive invasive species management will become even more vital to preserving aspects of passive and active recreation, and in assisting in limiting the spread of invasives through best management practices like boat washing, ecoharvesting and nutrient management.

DATA GAP DOCUMENTATION

The following additional data sets do not currently exist that would assist in better recreational access management:

- A mechanism for keeping systematic track of Ranger interactions with parties that violate recreational usage regulations would be helpful in identifying the worst problem areas, most common types of violations, and for making the case for additional enforcement resources where necessary. Tracking these data in coordination with other enforcement entities (e.g., State Environmental Police) would provide the most comprehensive information.
- Information on the process for re-evaluating the budget of the Ranger program would be useful. For example, it would be helpful in planning processes to understand the state-lead minimum wage increase threshold that would trigger a reevaluation of the existing $18,000 budget, especially with minimum wage increases in 2022 and scheduled for 2023. A deeper understanding of municipal budgets tied to recreation would also be valuable.
- A central system of annual reporting on number of boating permits issued and other more readily tracked elements indicating recreational usage on the ponds would be helpful to track over time.

- Lastly, a signage inventory around the APC and Nemasket River, with regular inspections, can help to identify where additional signage or different types of signage are needed to explain water access regulations and track vandalism and identify needs for sign replacements.

Existing data that could benefit from further refinement and clarification include public access areas and site boundaries. A more thorough review of open space properties across the watershed, including surveying to demarcate boundaries and clarify where public access is allowed, and dissemination of this information to the public via an online map, or some other publication, would improve public awareness and help streamline enforcement.

TRADE-OFFS AND CO-BENEFITS WITH OTHER INTERESTS

Improved Recreational Access and…

- Drinking Water Supply Levels: Neutral and Trade-offs. Recreational activity does not have a direct bearing on water supply levels. However, maintaining water supply levels in APC waterbodies where public access is not permitted could limit water levels in other waterbodies, such as the Nemasket River, where public access is permitted.
- Water Quality: Co-Benefit and Trade-Off. Maintaining and improving water quality would benefit recreational users. On the other hand, recreational activities involving equipment can spread contaminants in the water that are particularly of concern for drinking water supply and effects on aquatic and riverine species.
- Floodwater Management: Co-Benefit. Improved floodwater management would reduce the vulnerability of any improved site access amenities that towns or other groups invest, especially those that are vulnerable to floodwater damages. Undeveloped greenspace and recreational areas along waterbodies and in upland areas can also provide floodwater management benefits through holding back floodwaters and buffering adjacent areas.
- Stormwater Management: Potential Trade-Off and Co-Benefit. Improved recreational site access amenities, such as paved parking lots, if not engineered with proper infiltration and stormwater management features, can increase stormwater runoff. Undeveloped greenspace and recreational areas along waterbodies and in upland areas can also provide stormwater management benefits through infiltration.
- Ecology, Unique Habitats and Natural Resources: Potential Trade-Off and Co-Benefit. If not properly maintained and washed, watercrafts and other recreational equipment like boots and waders that are used across watersheds and water bodies can introduce invasive species into the system that spread and threaten existing unique habitats. Over-use of recreational areas can also threaten ecology, habitats, and natural resources. Increased recreational use can also increase awareness and stewardship of these lands, thereby improving public support for protections.
- Land Development: Neutral, Trade-Off, and Co-Benefit. While better recreational access can be a local amenity, it is unlikely the main driver of where new land development occurs within the watershed. Increases in development, however, can put a strain on local recreational systems if

demand increases beyond the system's capacity to absorb additional users without being degraded. Land development can also threaten unprotected and informal recreational areas with restricted access, alteration, or even elimination. Conversely, land development can open up new areas for formalized recreational opportunities if provided as a public benefit.

- Increased Inter-Agency Cooperation: Potential Co-Benefit. More cooperation between local town departments on organizing recreational programming is positive in decreasing duplicative events and providing a wider range of water-based recreational programming activities. Increases in recreational usage numbers can also assist in making the case and lobbying for the state to offer additional services tied to recreation, such as environmental police presence or the improvement of state-owned water access sites like the Long Pond Boat Ramp. Inter-agency cooperation can also further highlight co-benefits of recreation lands, such as habitat value, environmental services, non-motorized transportation, and historic preservation. Such cooperation can open up additional support and funding for recreational efforts.
- Increased public stewardship: Co-Benefit. Increased recreation can encourage users to become stewards of the sites they love to frequent, potentially building support for water quality improvement measures.

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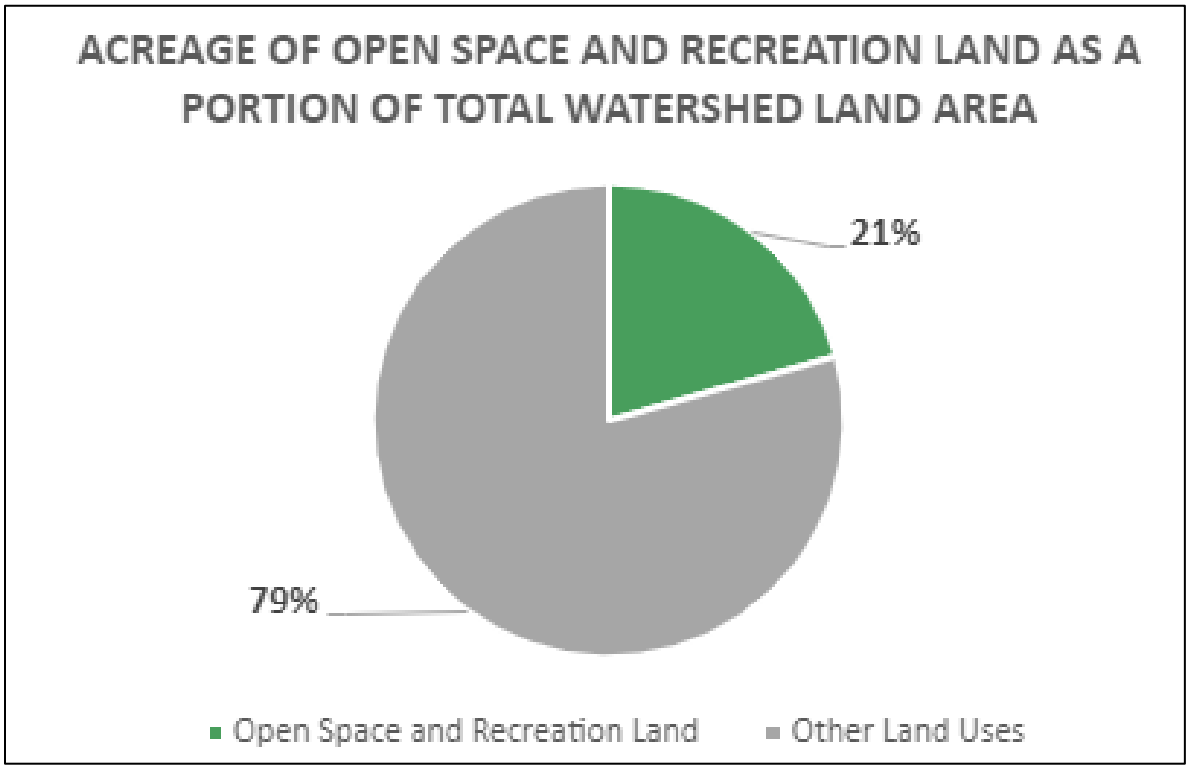
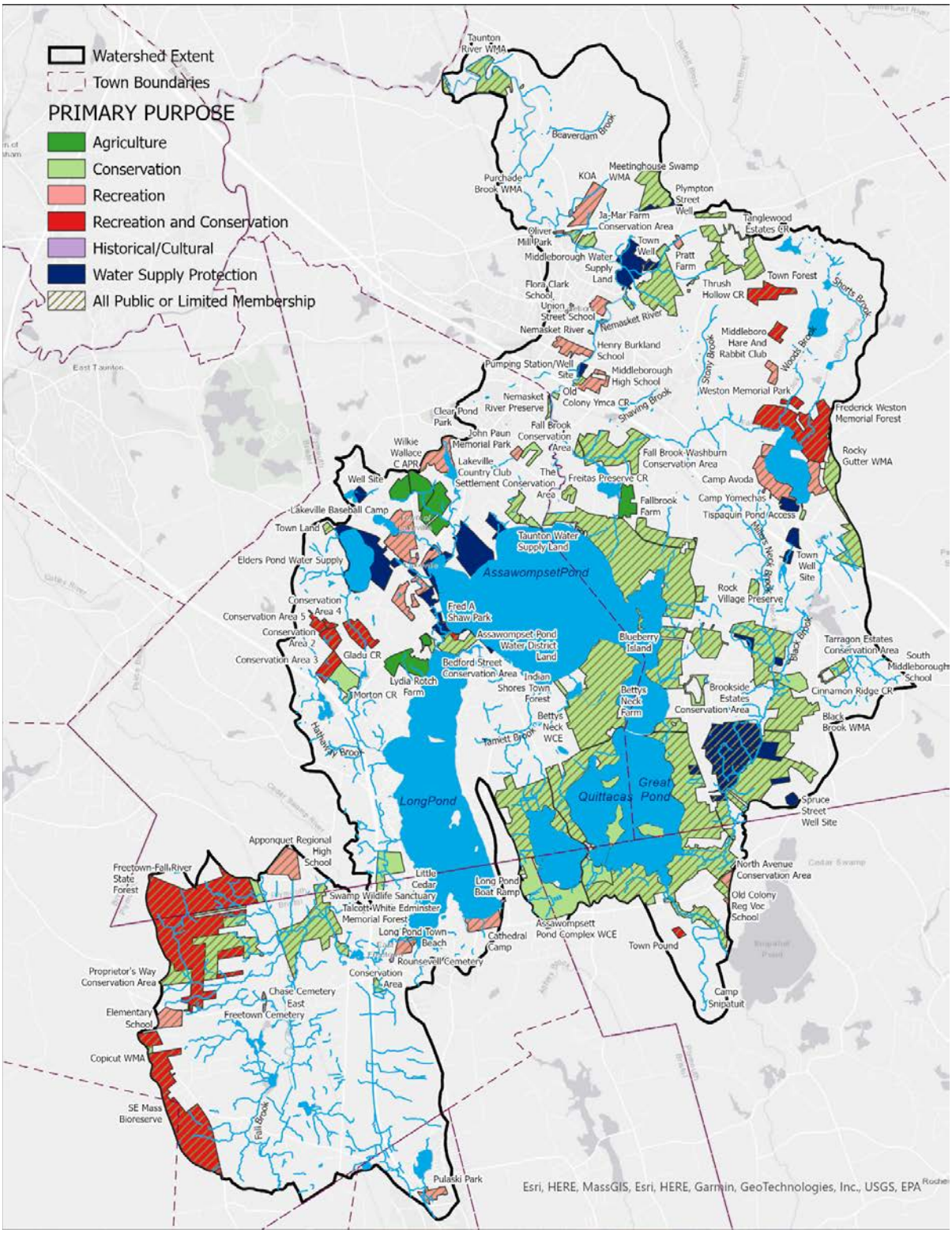
FIGURES

Figure 1. Acreage of Open Space and Recreation Land as a Portion of Total Watershed Land Area



Notes. From SRPEDD analysis based on MassGIS Protected and Recreational Open Space data layer (vintage 12/15/2020 with minor updates based on local knowledge from the APC Management Team January 2022).

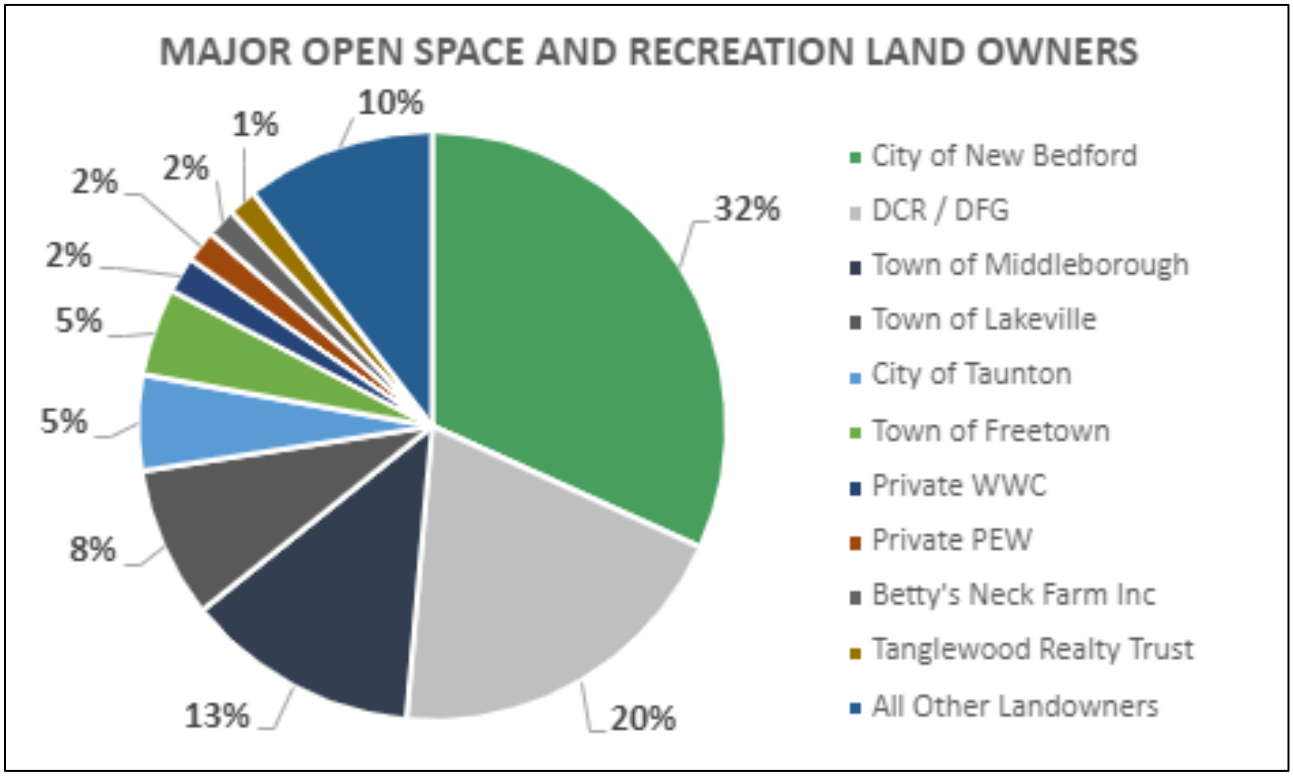
Figure 2. Open Space and Recreation Lands by Purpose



Notes. We note that the Map above is an imperfect and incomplete resource. It was compiled from the MassGIS Protected and Recreational Open Space data layer, vintage 12/15/2020, with minor updates based on local knowledge from the APC Management Team January 2022. One of the clear outcomes of this research process is

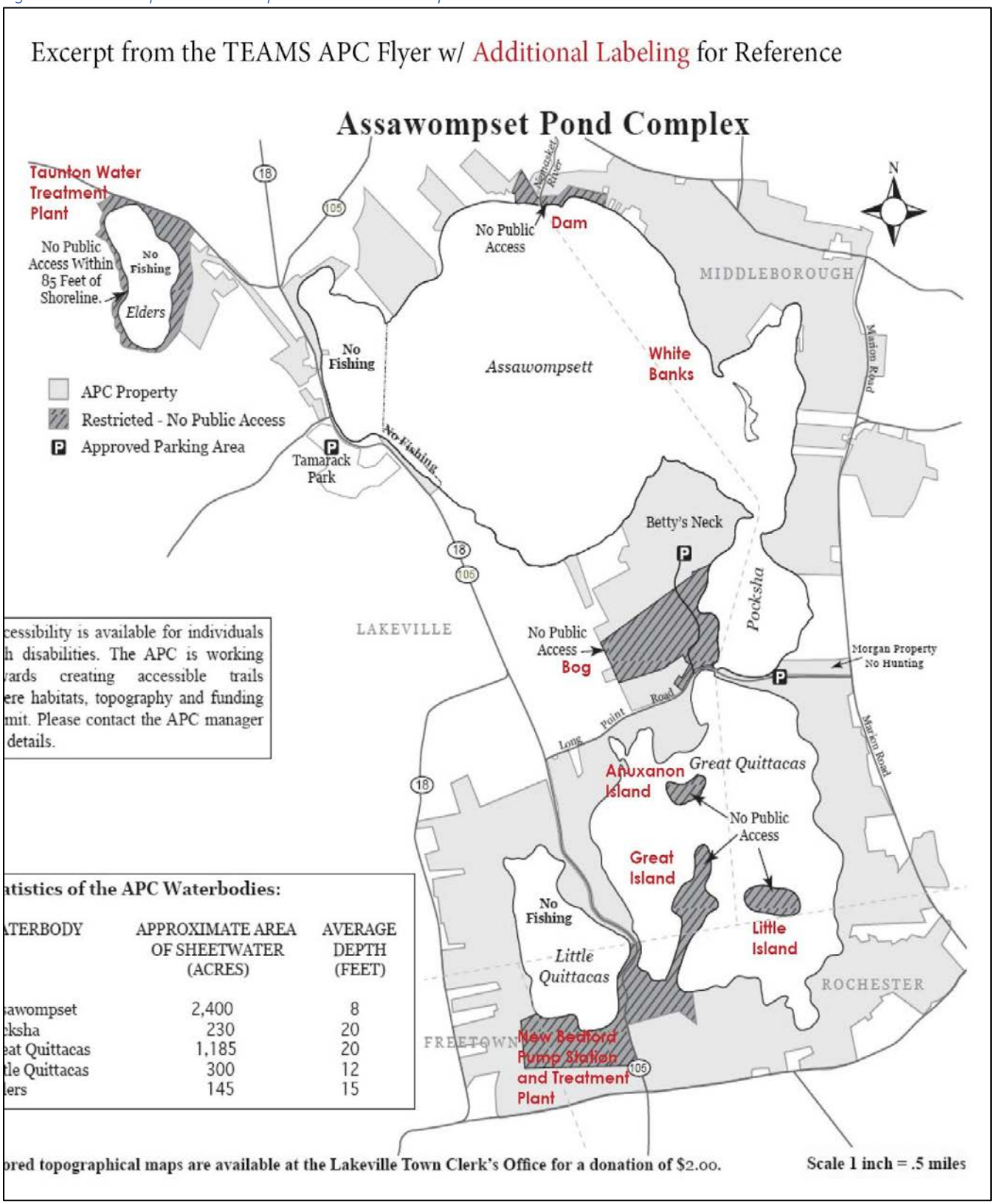
that a comprehensive, up-to-date map of open space and recreation resources does not exist for the watershed. In future, the development of such a map could be a priority action item, particularly in the context of a regional Open Space and Recreation Plan, or a Water-Access Master Plan.

Figure 3. Major Open Space and Recreation Land Owners



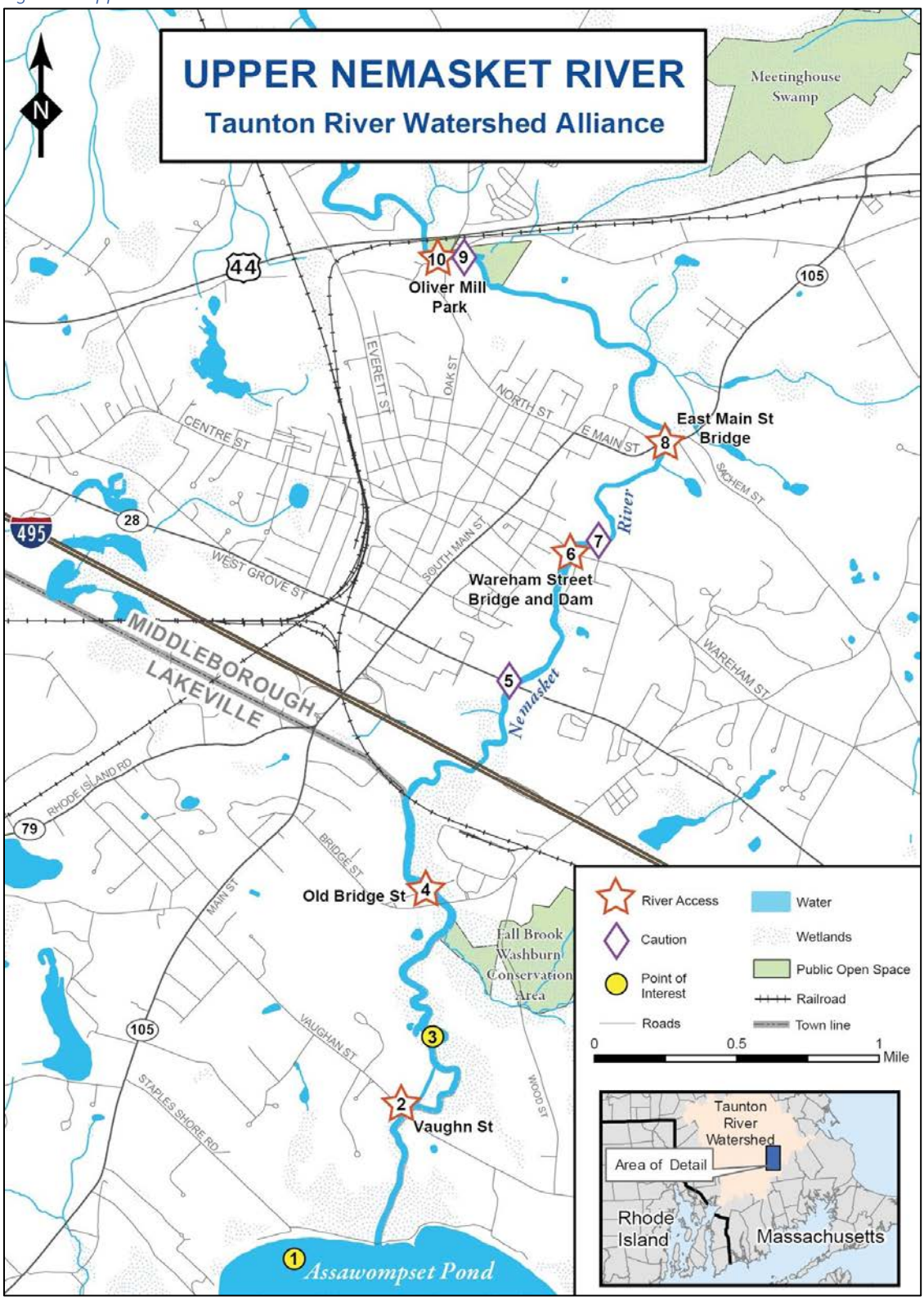
Notes. From SRPEDD analysis based on MassGIS Protected and Recreational Open Space data layer (vintage 12/15/2020 with minor updates based on local knowledge from the APC Management Team January 2022).

Figure 4. Assawompset Pond Complex Public Access Map



Notes. Adapted from Buzzards Bay Coalition (n.d. a); includes additional labeling by SRPEDD in red.

Figure 5. Upper Nemasket River



Notes. From Rhode Island Blueways Alliance and Rhode Island Land Trust Council (n.d.).

TABLES

Table 1. Open Space and Recreation Plan Recommendations related to the Nemasket River and/or the Assawompset Ponds Complex

Middleborough	
1	Wading Place: Connect foot-trails along the Nemasket River for a continuous foot-trail system. Provide parking, signage, and improve access. A to-scale site map should be developed that depicts walking trails, forest stand types, unique features and public amenities provided, if any.
2	Improve access (including handicap access) to the Wareham Street Herring Run at Thomas Memorial Park.
3	Andreattola Property: This property has passive recreational potential as part of the Nemasket River corridor. It is in close proximity to the Pratt Farm site and the historic Wading Place and should be opened to the public for limited use. It was acquired after the 2008-2013 OSRP.
4	New Bedford Water Works Property: Negotiate limited access for the purposes of passive recreation in this wooded land along Assawomponset and Pocksha Pond.
5	Consider the APC as a potential future water supply for Middleborough as additional development occurs.
6	Manage and improve the Nemasket River ecosystem to encourage recreational use of land and on the river while at the same time, improve the anadromous fish run by various conservation and restoration means
7	Explore the possibilities of creating a Nemasket / Taunton River Corridor designation similar to the Natural Heritage Corridor (Blackstone Valley), State Heritage Corridor, or Greenways State Park (Connecticut River Valley). Support efforts of involved communities in nominating this corridor for distinction.
Lakeville	
1	Post flooding of 2010, investigate how better septic systems will protect the Nemasket River and our communities from flooding related to wastewater or leaching.
2	"It will be, therefore, extremely important for Lakeville to develop cooperative regional programs with [neighboring towns] to gain complete shoreline protection [for the Nemasket]. Further, the over water views are so extensive that for truly complete protection, vigilance must extend well beyond the Pond's immediate shorelines [particularly viewsheds]" (Lakeville, 2013, p. 37).
3	The health of the Nemasket River should be taken into consideration as potential impacts of water mining can contribute to negative "impacts [on] the plant communities of coastal plain ponds, such as our Great Ponds," as shown by DEP (Lakeville, 2013, p. 50).
4	"The Nemasket River is regionally renowned for excellent flatwater paddling. The development of parking at Vaughan Street has augmented that at Old Bridge Street, providing easy access to the river. Public awareness of the scenic and ecological value of the Nemasket would increase support for improved protection of river shoreline areas and upland buffers. Use of motor boats on the Nemasket River, however, is disruptive to wildlife and paddlers" (Lakeville, 2013, p. 121)
5	Advocate for sustainability of new water withdrawal permits from APC to assure healthy flow level of the Nemasket River.
6	Promote efforts of new regional committees to study APC dam management and water level.
7	Create and implement forest plan for town forest areas, including Betty's Neck [APC shorefront], James Jasper Vigers Jr. Conservation Area [upland within the APC watershed], and the night soil repository area.

Notes. Adapted from Middleborough's 2008 and 2015 OSRPs and Lakeville's 2012 OSRP (updated in 2013).