Building a Municipal Resilience Portfolio: Assessment of Critical Land in the Winnetuxet River Corridor In Plympton

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This report is written to serve as a companion piece to the public presentations, power point and pdf presentations, and video recordings of the workshops that were at the of this project. These pieces, as well as additional resources gathered by the project team, can be found on the Winnetuxet Watershed Project Page at: https://srpedd.org/comprehensive-planning/environment/climate-resilience-planning/municipal-vulnerability-preparedness-mvp-planning/winnetuxet-watershed-resilience-portfolio/

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Background

The focus of this project was to identify, assess and protect natural systems and open space in the Winnetuxet River corridor that provide local and regional climate resilience benefits, and co-benefits, to Plympton as well as to its Winnetuxet River watershed neighbors in Carver and Middleboro. The ultimate goal of this project is to recognize the value, and encourage the protection and use of our natural green infrastructure to help address the potential impacts of climate change. This approach is guided by priorities identified in both the Plympton Open Space Plan and MVP Plan, including protecting water quality, insuring adequate drinking water supply, minimizing flood threat, provision of public open space, and protection of wildlife habitat.

This first phase of the project (9/30/2020 – 6/30/2021) is an assessment of the resiliency capacity of land in the target watershed, with the goal of preserving the resiliency built into the natural green infrastructure found there, in order to help manage the anticipated impacts of climate change (per the state climate change data projected for this watershed and locale). Once completed, the Town will use the results of this assessment during a planned second phase of the project (2021 and beyond) to prioritize specific property/properties for acquisition in order to promote, as is appropriate, ecological restoration and habitat management, in order to increase resiliency, and nature-based solutions to reduce vulnerability to other climate change impacts.

What is This Project All About?

Plympton has a significant need for understanding how to best protect and manage our substantial natural resources. Over 2/3 of the Town is ranked in the top BioMap 2 categories for landscape richness and species at risk. Protection of its natural resources was identified during the MVP Planning Process as a top priority. Plympton is also a small town (population of 2,985), and all of its residents currently rely on private well water and septic systems. There are no designated community wells in reserve. The western part of Town, located in the Taunton Watershed, particularly the area adjacent to the Winnetuxet River, is rated by BioMap 2 as part of one of the three most ecologically important areas in southeastern MA, and in the top 20% in the Commonwealth. Conversely, Plympton also ranks almost last in the Commonwealth in terms of protected land, and in the top 50 towns for current rate of development (Mass Audubon, Losing Ground, 2020).

Plympton has no professional planning staff and limited resources to put toward an assessment of this vulnerable land in an effort to address its ecological significance and potential resiliency value. This assessment, made possible through grant funding from the MA MVP Program and Taunton River Stewardship Council, was conducted by an experienced land use, forestry, climate change and resilience technical team. The results of the assessment will help the Town identify, manage, and prioritize the next steps for maintaining critical components of its ecological systems, while helping to preserve its nature based resilience.

Project Team and Elements

In addition to the Town's MVP Core Team, the project technical team consists of the Southeastern Regional Planning and Economic Development District (SRPEDD), Manomet, Mass Audubon (MAS), and The Nature Conservancy (TNC). The team brings decades of experience working with stakeholders throughout the Taunton River Watershed, and its numerous sub-watersheds, on issues related to water quality, flooding, and climate change resilience, and an action- oriented focus on achieving Nature Based Solutions (NBS).

As the project technical team lead, **SRPEDD** has a long history of engagement with the communities of Plympton, Carver, and Middleboro around watershed management issues, including studies, plans and workshops on the issues of: natural resource management plans; groundwater and surface water protection plans; stormwater infrastructure assessment; stream continuity; open space and master plans; resilience planning; serving as MVP planning grant providers; and hazard mitigation planning. In this project, SRPEDD provided grant administration services, helped to develop agendas for monthly project team meetings, established an appropriate public engagement strategy and schedule, served as the main point of contact between the project team and the Town, provided land use planning and GIS support, led project task scheduling, and led the process of project action item prioritization with the Town.

SRPEDD also engaged staff from the MA Division of Ecological Restoration's (DER) Cranberry Bog Restoration Program, and State Healthy Soils Action Plan team, in order to more completely assess bog restoration potential and retention of carbon critical soils as resilience strategies within the project study area.

TNC led the task of Prioritizing Nature Based Solutions in the project study area. TNC explained and demonstrated, in a public workshop, its new tool developed to help users site nature-based solutions (NBS) for climate resilience outcomes. This tool can help guide the implementation of NBS by looking at how such climate related threats as inland flood, coastal flood, and drought hazards overlap with opportunities for nature-based solutions. TNC explored a few examples of local potential priority areas, then walked workshop participants through the use of the tool, and helped to develop a plan of work for moving forward with feasibility planning and implementation.

Manomet, Inc., led the task of Identification and Analysis of Critical Green Infrastructure (GI)/forested lands in the project area. Emphasis was placed on identification and prioritization of land conservation opportunities that address protection of water quality, insuring adequate drinking water supply, minimizing flood threat, provision of public open space, and protection of wildlife habitat. Manomet achieved this through a mix of GIS analysis and field work (including field trips with members of the Steering Committee) to support site selection for potential acquisition, environmental stewardship, and restoration efforts, both in the headwater forests of the Winnetuxet, and at the intersection of green infrastructure network with other natural and man-made features of note, within the broader watershed boundaries.

MAS drew upon their extensive experience in local land use, habitat protection, and bylaw review, through the Shaping the Future of Your Community program. MAS protects 38,000 acres of land for people and wildlife in the Commonwealth of Massachusetts. The Shaping program, established in 2009, has reached over 9,500 people in 300 workshops and trainings on sustainable development. In this project, MAS worked with the public to identify the top barriers to integrating LID best practices into local regulations and, provided, in coordination with the Steering Committee and Town Bylaw Review Committee, one training in LID and the use of the MAS Bylaw Review Tool. This also included an exercise for local staff to conduct a guided evaluation of identified problematic bylaws in their community, compare results as a group, and brainstorm improvements to enhance environmental protection, GI and NBS opportunities, and greater regional consistency.

What Have We Said in Our Planning Documents?

During Plympton's previous MVP planning meetings and subsequent public listening session, land in the Winnetuxet River corridor came up as an important resilience related priority, as did concerns over the town's lack of public wells, areas of vulnerability to flooding, and the high percentage of land in cranberry ownership. At the conclusion of the MVP planning session meetings, when asked to list the top five high priorities, the consensus was that listing "implement the Open Space Plan" was the best way to make sure that all of the above listed concerns were acknowledged, since they are all covered in both the Open Space and MVP Plans. This approach was reinforced during the MVP Plan's subsequent public listening session, where the #1 concern raised was acquisition of land to support the Plan's resiliency goals, bringing focus back on the critical open space in the Winnetuxet corridor.

Specific sections of the Open Space Plan identifying resource protection needs include:
Section 7.1

- *Protection of significant parcels within the BioMap 2 Critical Landscape and Core Habitat designations to help protect Plympton's extensive wetlands, forests and riparian corridors and the natural services they provide.*
- *About 2/3 of Plympton falls within one of these two categories, so protecting strategically located large blocks will have the greatest impact.*
- *Only 4% (as of 2020) of Plympton's land is permanently protected*
- *Protection of prime farmlands and related uplands especially around cranberry bogs, which comprise about 1/3 of the Town, including planning for possible abandonment of cranberry bogs and development of related uplands as industry changes*
- *Protection of areas used for cranberry growing, especially recently abandoned upland bogs, which could return to forest or be developed, and related lands that have suitable water resources (a pond or reservoir) and nearby sources of sand.*

Section 8, Goal 2: Protect and preserve Plympton's natural resources, including water and unique wildlife habitats, for the benefit of present and future generations.

<u>*Objective 2A*</u>*: In the Taunton River Watershed area of Town, especially near the Winnetuxet River, evaluate the natural infrastructure services provided by Critical Natural Landscape #465, one of the largest in the state, as well as by the Core Habitat #798, in order to develop a land protection and management plan for this area*

<u>*Objective 2B*</u>*: Identify and protect high priority lands through acquisition, easements and restrictions to preserve natural resources, healthy ecosystems and biodiversity and to maintain functioning ecological connections*

<u>*Objective 2D*</u>*: Evaluate and update as needed Plympton's current Watershed Protection Districts for their contributions to maintaining the groundwater table, protecting against floods and contamination, preserving streams and conserving watershed areas*

Objective 2C: Based on BioMap 2, protect unique habitats and natural communities to support state listed Animal and Plant species
Objective 2E: Promote the adoption of updated planning and zoning bylaws to ensure that future residential and commercial development in Plympton effectively integrates growth with natural resource preservation.

Many of these lands are currently privately-owned, and are also amongst the largest parcels in the Winnetuxet corridor, exclusive of the cranberry bog acreage on the Middleboro side of the Winnetuxet River. When considering these areas in the context of the community MVP Plan, we were more concerned with the broader implications of the state climate data projections:

- increase in intense storms, yielding 2.56 more inches of rain annually by 2050;
- temperature increase resulting in 9 more days over 90 degrees by 2050;
- 2 more days of extreme weather annually by 2090, and;
- flood-draught cycle impacts; with 1.25 more consecutive dry days by 2090; (resilientma.org)

We believe that focusing on the Winnetuxet River corridor is the best strategy, both for the reasons stated above, as well as the fact that the Winnetuxet is recognized as a Tributary Focus Area in the federally designated Wild & Scenic Taunton River Stewardship Plan (2005). The Taunton River Stewardship Council (TRSC) supports efforts in the Taunton River Watershed that address Ecology and Biological Diversity, specifically those that:

- Increase Public Awareness of the biological diversity and intact ecology of the Taunton River Ecosystem;
- Protect Water Quality and Natural Flow regimes critical to health and long-term viability of aquatic biodiversity, and;
- Prevent Fragmentation of riparian systems, floodplains, and contiguous upland habitat blocks; retain our intact natural "green infrastructure."

This assessment project is the first phase of a resiliency building strategy that looks at the function of the subject land, and its potential to help retain or enhance resilience, as well as aesthetics and recreational potential. This will be the new standard for prioritizing open space for acquisition in Plympton, and a first step in **building a resilience portfolio for the Town.**

For more information on the project, please visit the Plympton Open Space Committee page on the Town of Plympton website, and click on **Winnetuxet Watershed Resilience Project**.

This project was made possible by a grant from the **Taunton River Stewardship Council** (Wild & Scenic Taunton River), and a **Massachusetts Executive Office of Energy and Environmental Affairs, Municipal Vulnerability Preparedness (MVP) Program Action Grant.**

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Definitions

Climate Adaptation is a relatively new field, and uses terms that are used by other fields like hazard mitigation, environmental restoration, and urban planning. Because of this, some of the terms below have different meanings in other contexts. For this report, the following definitions apply.

Adaptation – In relation to climate change impacts, adaptation refers to actions to reduce vulnerability and increase resilience to climate impacts.

Conservation – long term preservation, through purchase, zoning, or easements of existing undeveloped, unprotected open spaces and/or ecosystems

Green Infrastructure - An interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife.

Management – Nature-based solutions that rely on management strategies that incorporate elements of ecosystems or mimic natural processes in developed and altered areas, including agricultural areas. Management processes can be incorporated into new projects, or implemented as retrofits. Management also includes active practices for managing existing ecosystems and areas (these management actions are not included in the mapping product described herein).

Nature-Based Solutions (NBS) - NBS are projects that protect, restore, and/or manage an existing ecological system, and/or mimic natural processes, to safeguard public health and clean water, increase natural hazard resilience, and/or sequester carbon. Nature-based Solutions are inclusive of Green Infrastructure.

Resilience – The capacity for a system or entity to respond and recover quickly after a natural hazard or disaster.

Restoration – a suite of practices to renew and/or restore a degraded or developed ecosystem to some state of pre-disturbance function through some or all of the following practices: re-vegetation, hydrology restoration, stormwater management design, and soil remediation. Stormwater management (aka: green stormwater infrastructure, Best Management Practices (BMPs), and Low Impact Development (LID) projects are a subset of the restoration opportunities identified in this project.

Introduction

Plympton, MA has an extensive portfolio of natural areas, including wetlands, forests and riparian corridors that are still relatively intact and therefore provide a rich set of ecosystem services to residents of both the Town and the surrounding region. Planning for both conservation and management of priority resource areas will help to maximize the benefits associated with land protection and make wise use of limited fiscal resources. This chapter is intended to provide a framework for planning and decision making as Plympton considers conservation and management alternatives.

While the emphasis in this report is clearly on Plympton, the regional context merits consideration in prioritizing local decisions. Plympton is located at the dividing line between the Atlantic Coastal Pine Barrens ecoregion to the east and the Northeastern Coastal Zone ecoregion to the west. Plympton's location at this boundary enhances the ecological diversity of the Town and conservation decisions in Plympton have the potential to contribute to the integrity of both of these ecoregions.

Local Conservation Priorities

During the course of this project several local conservation priorities have been identified by Town representatives, including the following:

- Securing a public water supply for Plympton: Development of a public water supply well is a high priority for the town. The Plymouth-Carver aquifer extends into eastern Plympton and previous analytic work by a consultant hired by Plympton identified this portion of the town as a priority search area. Identification of a multiple benefits site that serves as a water supply and meets other conservation priorities may be possible, but the specifics of the decision-making process associated with obtaining a water supply are beyond the scope of this report.
- Cranberry industry in transition: Several economic factors are making cranberry agriculture challenging in Massachusetts, including stiff competition from other regions, fluctuating prices,

and conversion of the land surrounding bogs to residential and other uses. This transition presents a mix of conservation challenges and opportunities for Plympton. Some bogs that cease production may present opportunities for hybrid conservation/restoration projects. These opportunities are discussed in the chapter of this report on nature-based solutions.

- Winnetuxet River corridor conservation: Conservation of the Winnetuxet River corridor was identified during the scoping for this project as a top local priority. The southwestern quadrant of Plympton, where the Winnetuxet River is located, is highly ranked for several ecosystem services including support of biodiversity and flood control. The *Green Infrastructure and Forest Resources* section of this report is an exploration of conservation opportunities in the Winnetuxet corridor both within the Town boundaries and as part of a larger regional conservation initiative.

The following two sections of the report, *Nature-Based Solutions* and *Green Infrastructure and Forest Resources* take an iterative look at these priorities using two approaches. The Nature-Based Solutions section looks broadly at potential future hazards and nature-based solutions, then the Green Infrastructure and Forest Resources digs into a more detailed local analysis and conservation recommendations for Plympton.

Nature-Based Solutions (NBS)

To assess the role for nature and NBS to protect people from the current and unavoidable impacts of climate change, The Nature Conservancy (TNC) partnered with Massachusetts Executive Office of Energy and Environmental Affairs to create a screening tool to identify how opportunities for NBS overlap with potential future hazards[1]. These maps were reviewed with Plympton to investigate local priorities as outlined in the *Green Infrastructure and Forest Resources in Plympton: Conservation and Management Strategy* section of this report.

Hazards are presented by combining existing maps and models of both current regulatory hazards (like the FEMA mapped 100-year floodplains and areas of current wetlands), maps and models of more extreme hazard events that are not currently regulatory (like the FEMA 500 year floodplains, and NOAA's SLOSH inundation zones for categories 1&2 hurricanes). Climate change intensifies existing natural hazard experiences; this combination approximates potential future hazard scenarios. This approach allows for future planning efforts to increase resilience. In the case of drought, the likelihood of drought is based on impervious cover (which prevents groundwater recharge) and widely available indicators of public groundwater usage.

Conservation is inclusive of projects that preserve land into perpetuity through conservation easements or purchase, projects that review ordinances and bylaws to develop conservation overlay districts, or priority conservation assets in conservation subdivision planning. In areas where conservation opportunities pop-up in current residential areas, this information could be used in developing future development and build-out scenarios to evaluate the feasibility of redevelopment, or increasing density in an area.

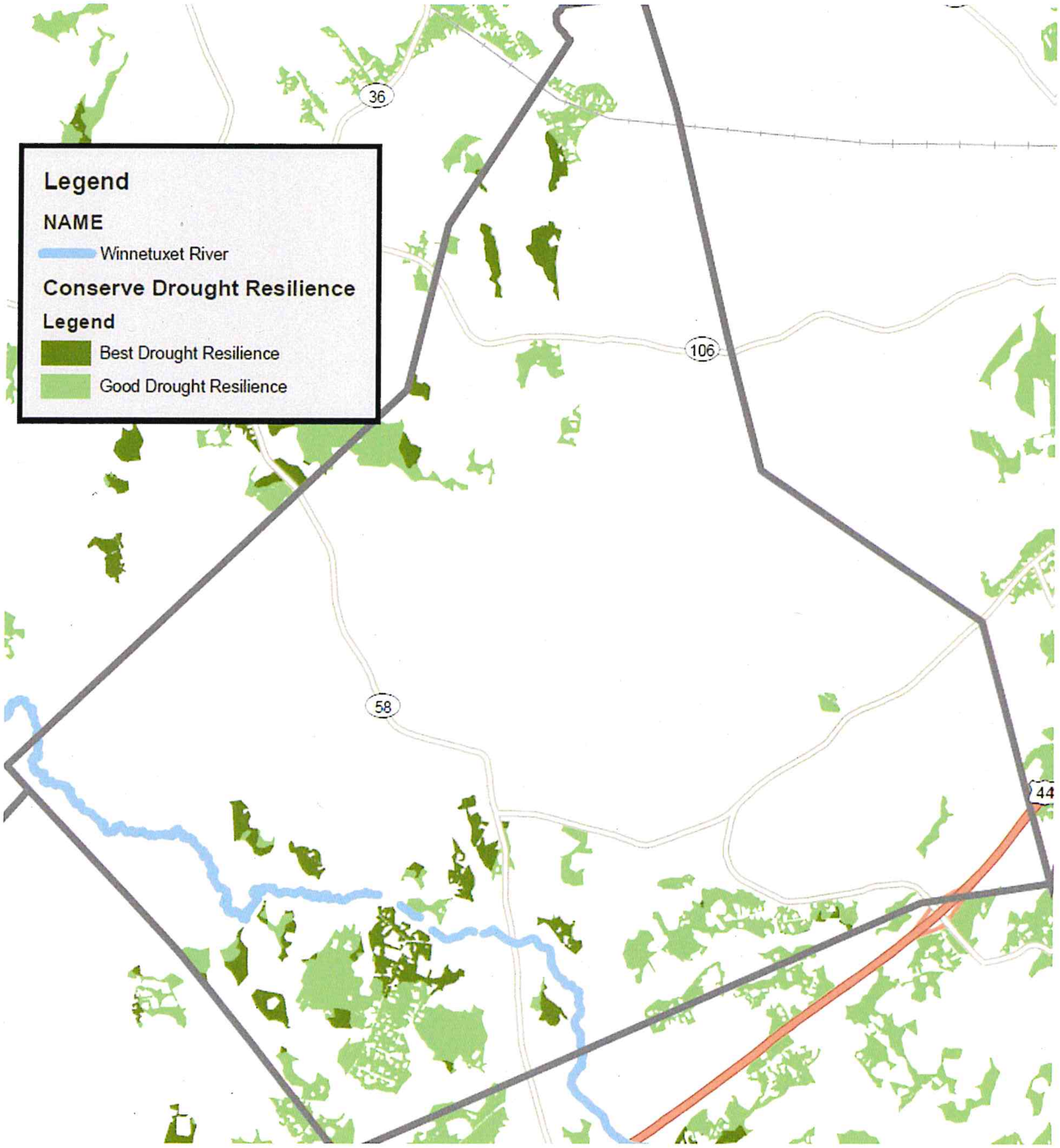
Restoration is inclusive of opportunities to restore developed or degraded habitats. In some cases, the development may still consist of active use. In these cases, the potential resilience benefits could be

[1] https://maps.coastalresilience.org/massachusetts/

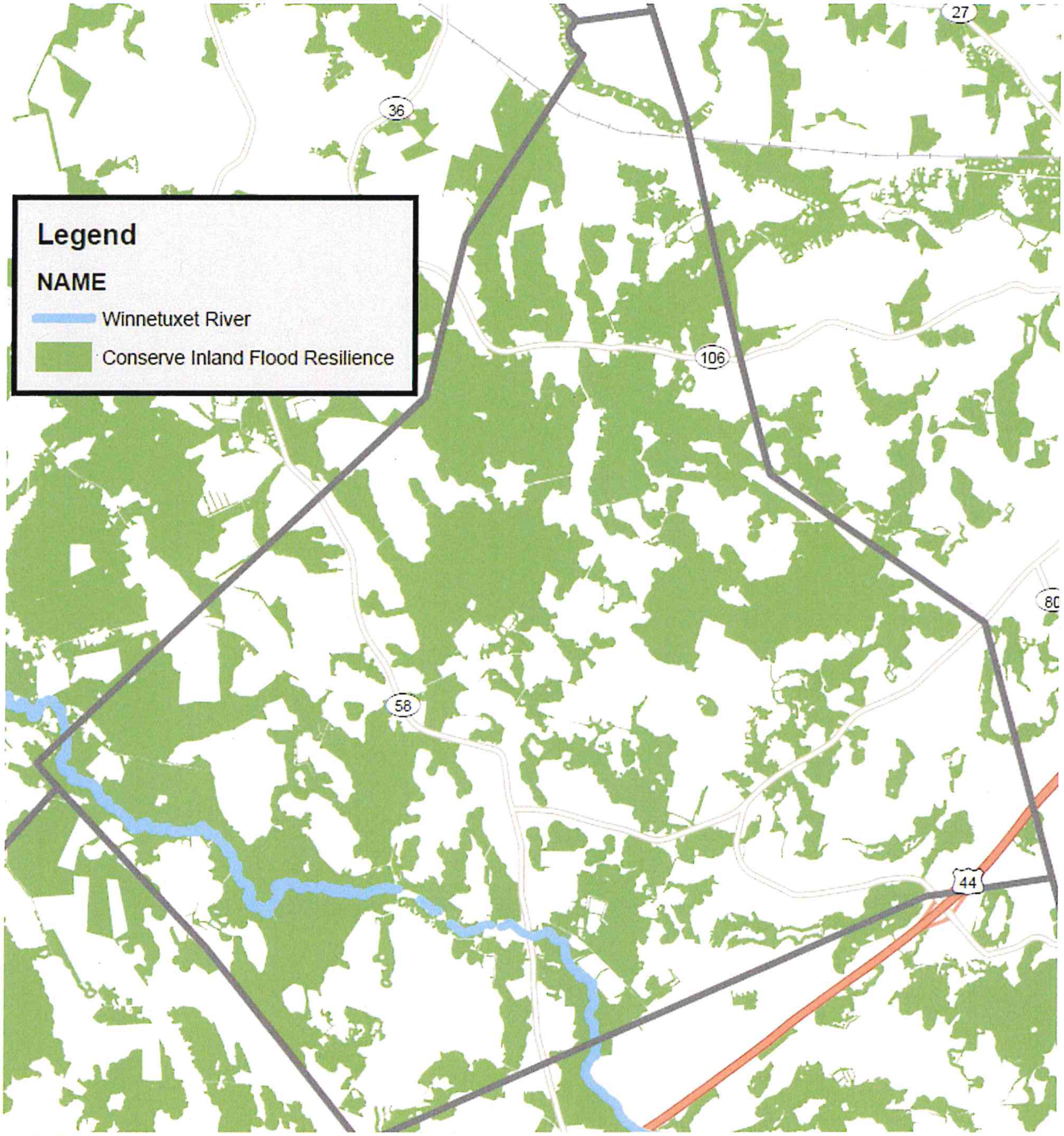
considered in scenario planning, consideration of redevelopment, and/or retrofitting existing developed areas to be more resilient.

Plympton NBS Opportunities

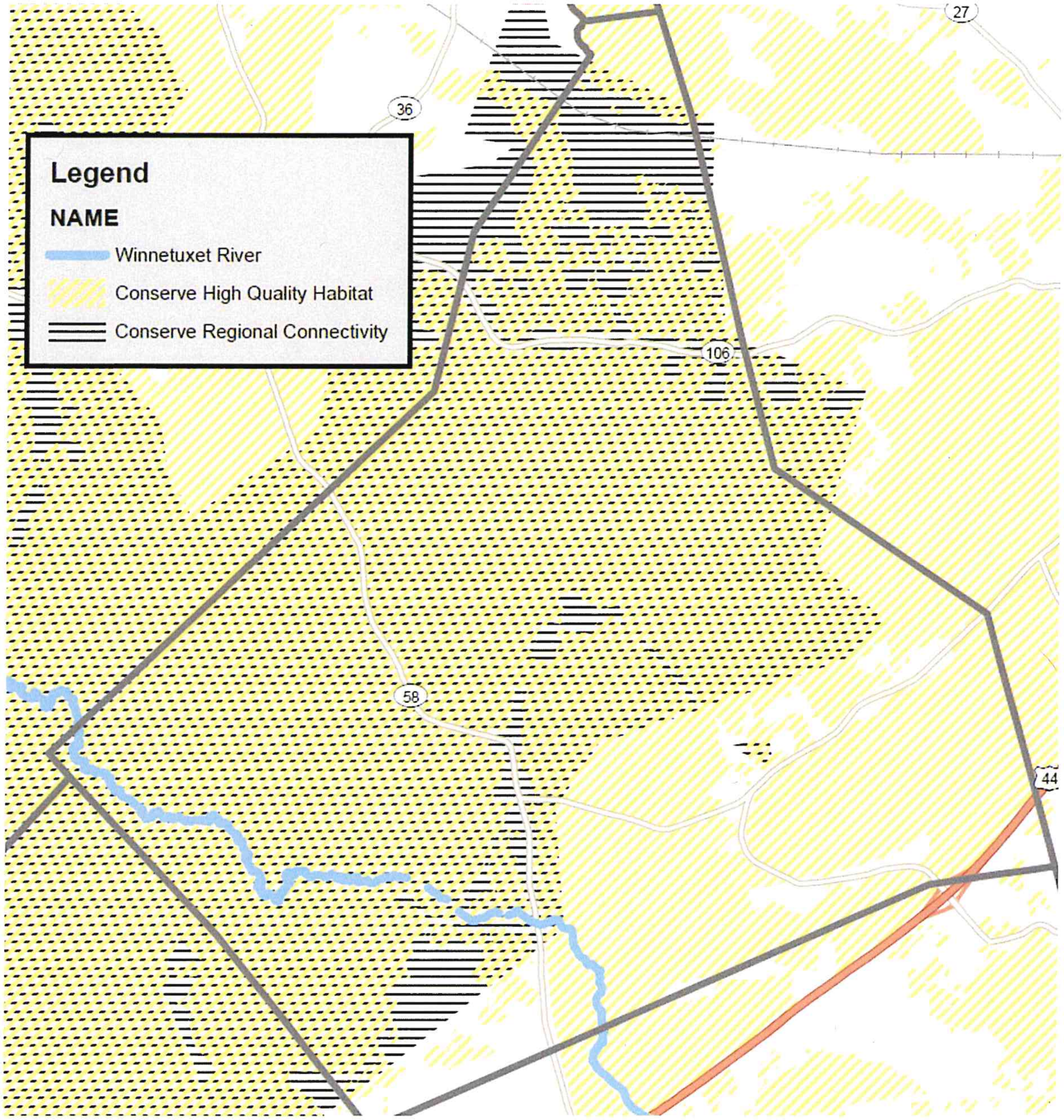
Based on Plympton's priorities to develop a climate resilience portfolio, the entire town was screened for the following NBS opportunities: Conserve for Drought Resilience (NBS Map 1), Conserve for Inland Flood Resilience (NBS Map 2), and High Quality and Connected Habitat (NBS Map 3). These maps were then combined with Mass DEP's wetland layers to look for current cranberry bog areas that abut conservation opportunities, the resulting maps identify areas where cranberry bog restoration and conservation could both conserve and restore flood and drought resilience in Plympton. (NBS Map 4).



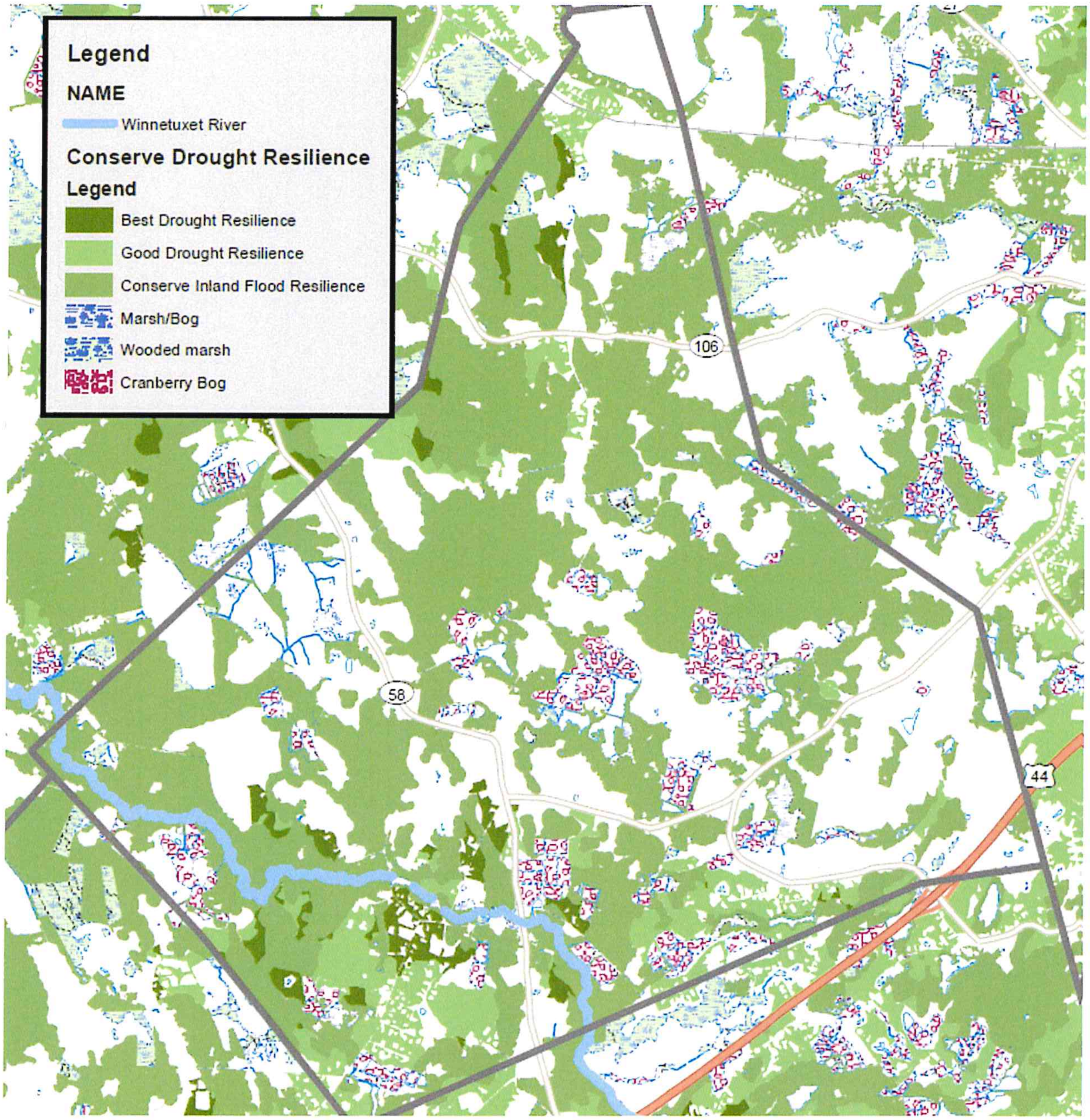
NBS Map 1. Areas where Drought Hazard (as indicated by percent impervious cover and/or depleted groundwater overlaps with <u>public</u> water supply areas) overlap with either 1) Good Opportunities for Drought Resilience (areas which if developed would reduce drought resilience, and which contribute some recharge opportunity to the aquifer: undeveloped, unprotected open spaces that are greater than 100 feet from surface water, and have hydrologic soil groups that provide some recharge potential (A&B)) or 2) Best Opportunities for Drought Resilience (unprotected and undeveloped areas that contribute outsized recharge opportunities based on their distance from surface water and hydrologic soil group (C group).



NBS Map 2. Areas where the inland flood hazard (indicated by FEMA 100 and 500 year floodplains, Active River Areas, current and former wetlands, and modeled 500 year floodplains) overlap with undeveloped, unprotected open space.



NBS Map 3. Areas with High Quality and/or Connected Habitat. Biodiversity is represented by critical habitat for rare and native species (BioMap2), above average resilience for biodiversity (TNC Resilient and connected Landscapes, 2016), Areas of potential salt marsh migration (Resilient Coastal Sites for Conservation, TNC 2017), areas important for terrestrial habitat connectivity (Regional Flows, TNC Resilient and Connected Landscapes), and wetlands with high ecological integrity (UMass CAPS). The high-quality habitat and areas for connectivity are inclusive of developed areas, and open water areas.



NBS Map 4. Mass DEP wetlands (including cranberry bogs), Conserve for Drought Resilience and Conserve for Inland Flood Resilience Opportunities.

Map Discussion and Plympton Priorities

As previously identified, this effort focused on exploring 3 conservation priorities for Plympton: 1) Securing a public water supply for the Town, 2) stewarding cranberry bog transition, and 3) Conserving the Winnetuxet River corridor. As above, the first priority of securing a public water supply is out of scope for the project, but we can retain the drought resilience lens as we investigate other potential projects. The second priority, stewarding cranberry bog transition involves active retirement of cranberry bogs to restore natural wetlands. Cranberry bog restoration enhances flood resilience, has the capacity to enhance drought resilience, and improves habitat values. Every cranberry bog in NBS Map 4 would benefit Plympton through a restoration project. Each bog would increase continuous wetland area, and each bog is also adjacent to opportunities to conserve existing flood and/or drought resilience. As evidenced in NBS Map 3, all but the most southern bog overlap with high quality or connected habitat. Based on this screen, it would be reasonable for the Town to prioritize potential bogs for restoration based on price, owner willingness to sell, proximity to other Town priorities, and expert guidance from the Division of Ecological Restoration Cranberry Restoration Program. The third priority to conserve the Winnetuxet River corridor presents an almost continuous conserve inland flood resilience opportunity (NBS Map 2) and presents some Good and Best Conserve Drought Resilience opportunities (NBS Map 1). NBS Map 4 illustrates extensive opportunities for conserving inland flood and drought, and the existing cranberry bogs along the Winnetuxet. It is worth noting that a significant portion of these conservation opportunities are existing wetlands. During conversation about these areas, the existing conservation commission was lauded for its enforcement of the Wetland Protection Act. However, through discussion, it was determined that additional conservation efforts would be worthwhile to secure these areas into perpetuity, especially into the future where the membership of the commission will certainly change. Based on this screen, the NBS maps support the recommended conservation approach outlined in the Green Infrastructure and Forest Resources section of the report.

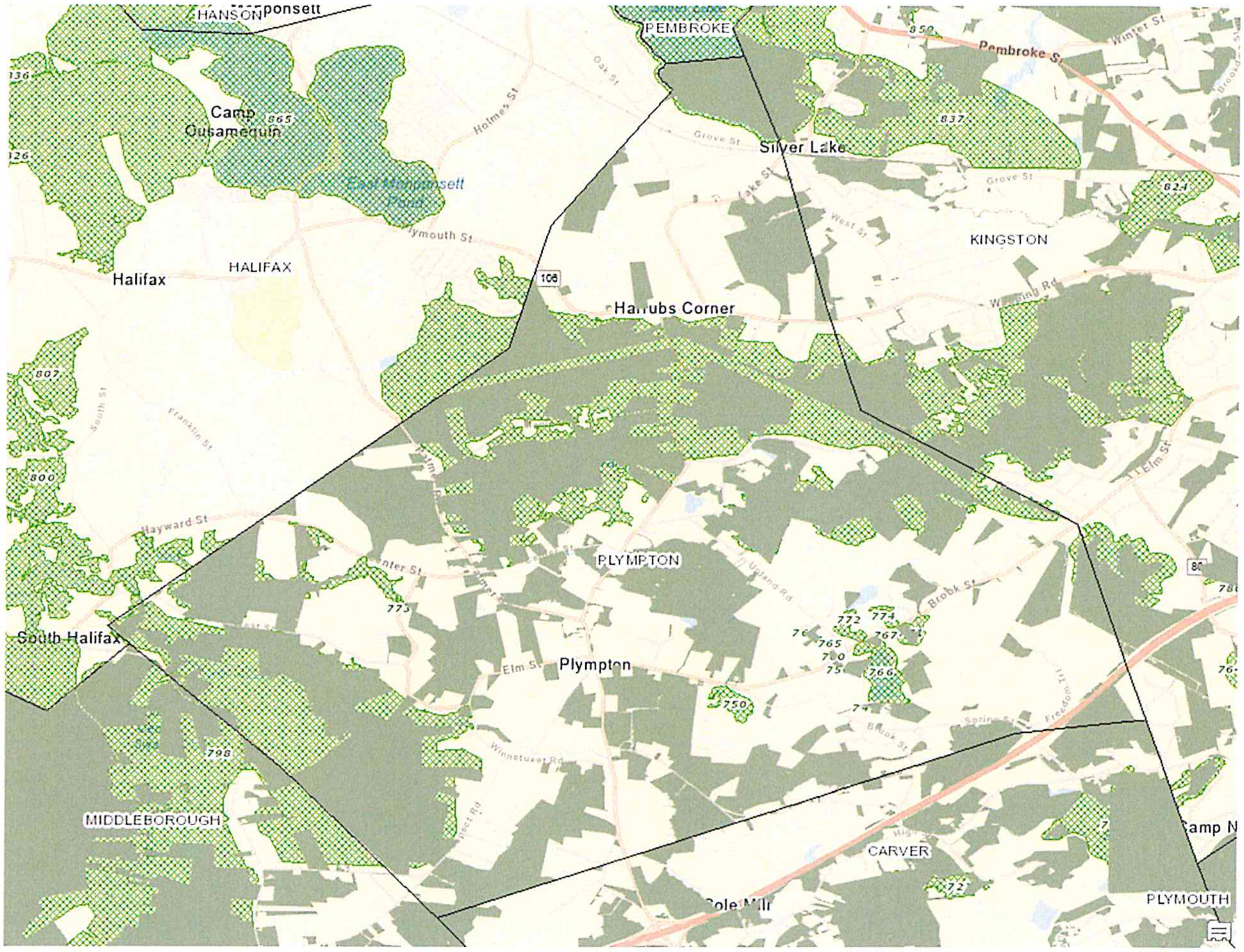
Green Infrastructure and Forest Resources in Plympton: Conservation and Management Strategy

Green Infrastructure as Framework for Conservation Planning

Green Infrastructure, in the context of this report, can be defined as follows:

> "An interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife."[i]

A recently completed green infrastructure analysis for Plympton and the surrounding region includes consideration of existing biological integrity, projected biodiversity support under climate change, and several climate change resilience factors that impact both natural and human communities. Once priority conservation areas were identified in the analysis, developed and protected lands were clipped out to yield the undeveloped/unprotected component. These are lands of high ecological value that are vulnerable to development and therefore should be prioritized in conservation planning. Map 1 shows the undeveloped/unprotected component of the green infrastructure analysis for Plympton and the surrounding region (shown in solid green) overlayed on the Biomap2 habitat core 798 (shown in green crosshatch). It is evident from the analysis that Plympton and the surrounding region are home to a remarkable set of natural resource areas with many opportunities for impactful conservation planning.



Map 1: Undeveloped/Unprotected Green Infrastructure over BioMap2 Habitat Cores

Winnetuxet Conservation: Local Opportunities and Regional Context

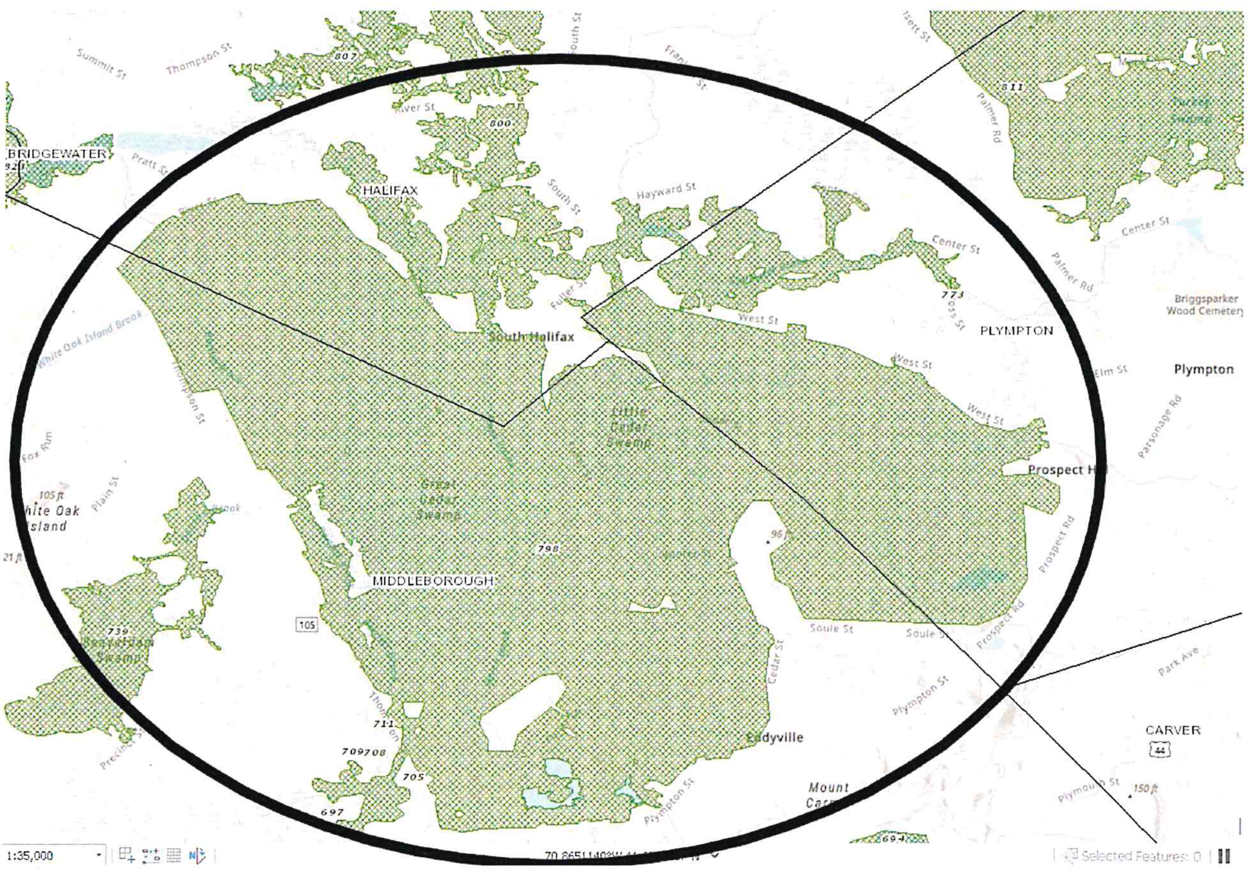
The Winnetuxet River corridor in southwest Plympton is a prime conservation target for multiple reasons. This area ranks highly in the regional green infrastructure analysis as depicted in map 1. The Winnetuxet corridor is part of one of the largest and most diverse habitat cores in eastern Massachusetts, habitat core 798 as identified by the Biomap2 analysis. Figure 1 below, from the Biomap2 town report for Plympton[ii], list the range if resources present in this habitat core that overlaps southwest Plympton, south Halifax, and northeast Middleborough.

Core 798

Forest Core
Wetland Core
Aquatic Core
Species of Conservation Concern

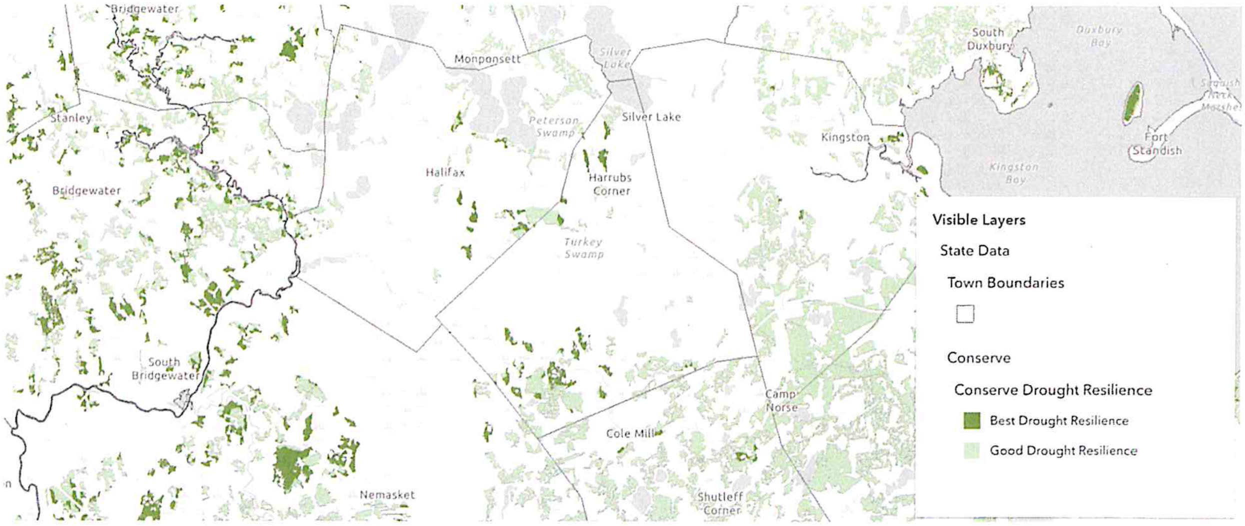
Water-willow Stem Borer	*Papaipema sulphurata*	T
Four-toed Salamander	*Hemidactylium scutatum*	Non-listed SWAP
Eastern Box Turtle	*Terrapene carolina*	SC
Eastern Hognose Snake	*Heterodon platirhinos*	Non-listed SWAP
Bridle Shiner	*Notropis bifrenatus*	SC
American Bittern	*Botaurus lentiginosus*	E
Common Moorhen	*Gallinula chloropus*	SC
King Rail	*Rallus elegans*	T
Pied-billed Grebe	*Podilymbus podiceps*	E
Sora	*Porzana carolina*	Non-listed SWAP
Upland Sandpiper	*Bartramia longicauda*	E
Vesper Sparrow	*Pooecetes gramineus*	T

Figure 1: Components of BioMap2 Habitat Core 798



Map 2: BioMap2 Habitat Core 798 encircled in black

As described in the NBS section of the report, the TNC resilience tool[iii] ranks this area highly for both drought resilience and conservation of inland flood resilience. Map 3 depicts drought resilience rankings for the Winnetuxet corridor and map 4 shows the rankings for inland flood resilience.



Map 3: Areas of High Drought Resilience

Map 4: Conservation of Inland Flood Resilience

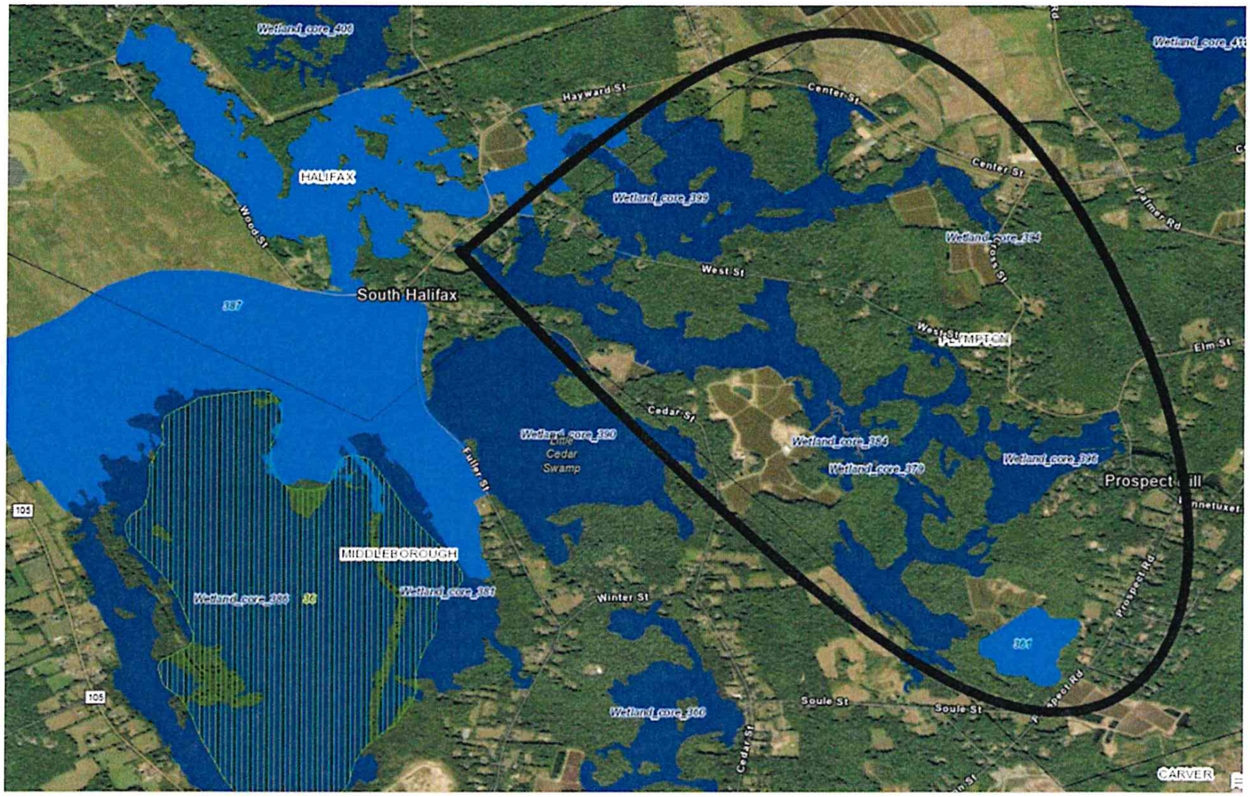
Recommended Conservation Approach

The recommended conservation approach for the Winnetuxet corridor includes both a set of local actions and coordination of a regional conservation initiative involving Plympton, Middleborough, and Halifax.

Local Efforts

Recommended actions at the local level include protection of a riparian buffer system fronting the Winnetuxet River through a mix of fee simple purchase and negotiation of conservation easements. If implemented, this approach will provide multiple benefits including protection of water quality by minimizing nonpoint source pollution, limiting flood risk to new development, protection of biodiversity and protection of carbon rich soils.

Map 5 outlines the recommended riparian corridor conservation area, with the focus area encircled in black and the recommended land protection area shown in dark blue. Note that the wetlands core shown in dark blue includes Colchester Brook, located to the north of the Winnetuxet River. Protection of the Colchester Brook has the potential to provide many of the same benefits as protection of the Winnetuxet.



Map 5: Recommended Winnetuxet River conservation area encircled in black with recommended conservation lands shown in dark blue

Much of the prioritization and detailed planning for land acquisition and easement within the Winnetuxet corridor will have to be worked out at the local level in Plympton. With thoughtful planning it will likely be possible to meet several local goals through this process including provision or public open space and access to the river in addition to the above mentioned environmental and climate change resiliency benefits. Time is of the essence in securing land in the Winnetuxet corridor as once the system is substantially fragmented by development it will be difficult compensate for that damage through conservation efforts.

Given that many factors, including evolving local priorities, location of willing sellers and available funding will influence what is possible in the way of land protection in the Winnetuxet corridor, the following suggestions are offered with the realization that it may not be possible to simply do what is best from a scientific perspective.

Recommended best practices in selecting land for protection:

- To the extent possible, protect a continuous riparian buffer fronting both shores of the Winnetuxet River. A seamless, 200-foot-wide vegetated buffer on each side of the river will provide multiple benefits including water quality protection and protection of high value habitat. 200 feet is a recommended minimum buffer width. Where possible, protect the entire footprint of the wetlands core shown in blue on map 5. Protecting a wider buffer and including adjacent uplands will increase the functional value of the buffer system.
- Inclusion of one or more contiguous upland nodes with the buffer system will also increase the ecological value of the system. Protection of larger, more ecologically diverse nodes will increase climate change resilience by providing increased opportunity for species assemblages to shift and reorganize as temperature, precipitation and flood frequency change. In addition, inclusion of upland nodes will increase opportunities for public access to protected lands.
- In keeping with the idea of ecological diversity enhancing resiliency in a dynamic climate, protection of a diverse, heterogeneous portfolio of conservation lands to complement the riparian buffer system is recommended. In particular, Plympton is home to several rare wetland forest areas including a small area of white cedar swamp in the southwestern portion of town. The Little Cedar Swamp and Great Cedar Swamp are just across the town line in Middleborough, creating an opportunity for win/win conservation collaboration between Plympton and Middleborough.

Appendix A is a synopsis of the ecology of the North Atlantic Coastal Plain Basin Peat Swamp, which is the ecosystem type associated with the white cedar stands in and adjacent to southwestern Plympton. Appendix B is a synopsis of Laurentian-Acadian Freshwater Marsh, the ecosystem type associated with the Winnetuxet corridor. Finally, Appendix C is a synopsis of North-Central Appalachian Acidic Swamp, the ecosystem type associated with additional wet forests located in southwestern Plympton.

Regional Conservation Efforts

In parallel with this local strategy, Plympton, working in conjunction with the Resilient Taunton Watershed Network, should initiate conversations with Middleborough and Halifax to determine interest and feasibility of a regional initiative to protect elements of habitat core 791 to complement the ongoing Winnetuxet conservation efforts in Plympton. The recommend geographic focus for this effort is encircled in black on Map 2. A successful regional conservation initiative will increase the value and resiliency of the protection efforts in the Winnetuxet corridor.

The logic for prioritizing lands for protection in the regional initiative will likely include the points covered in the preceding discussion of the Winnetuxet corridor. In addition, the broader and more varied landscape will introduce new factors in the decision-making process. In particular, the forest core, aquatic core, and the enumerated species of conservation concern associated with habitat core 798 should be considered.

Plympton Forests: Climate Change Impacts and Management Response

As discussed previously, Plympton is located at the juncture of the two ecoregions, the Atlantic Coastal Pine Barrens ecoregion to the east and the Northeastern Coastal Zone ecoregion to the west. This location influences forest composition, forest response to climate change, and should help to inform forest conservation and management decisions.

Forest type groups[iv], as defined by the Forest Inventory and Analysis system, that overlap Plympton include the following:

Oak-pine: Forests in which hardwoods (usually upland oaks) comprise a plurality of the stocking, but in which pine or eastern redcedar comprises 25-50 percent of the stocking. Common associates include gum, hickory, and yellow-poplar. Note that in extreme southeastern Massachusetts this forest type is dominated by pitch pine and scrub oak.

Oak-hickory: Forests in which upland oaks or hickory, singly or in combination, comprise a plurality of the stocking except where pines comprise 25-50 percent, in which case the stand is classified as oak-pine. Common associates include yellow-poplar, elm, maple, and black walnut.

Elm-ash-cottonwood: Forests in which elm, ash, or cottonwood, singly or in combination, comprise a plurality of the stocking. Common associates include willow, sycamore, beech, and maple.

Appendix D provides detail on the ecology and species associated with pine-oak forest in New England.

Projected Climate Change Impacts on Forest Composition

While it is impossible to know exactly how forests in Plympton will respond to climate change, modeled projections of the changing climate envelope and analysis of resiliency characteristics of pertinent tree species provide insight on potential shifts in the relative importance of tree species currently present in the region. In addition, these modeled projections rank the likelihood of new tree species moving into the region as conditions change. The Climate Change Tree Atlas[v] takes both of these factors into account in developing projections of species increase and decline for the eastern U.S. Appendix E shows the projected change in forest composition for two different future climate scenarios for a 1 degree by 1 degree grid cell that includes Plympton and the surrounding region. The tree species that are currently present in the region are listed starting with the most common trees at the top of the table based on their importance value. (Importance value is the sum of relative frequency, relative density, and relative basal area. Each value is expressed as a percent, ranging from 0 to 100. Importance values range from 0 to 300.) The species with the highest importance values in the Plympton region are red maple, eastern white pine, black oak scarlet oak, northern red oak, white oak, pitch pine, black cherry, and white ash. Significant changes are projected for several of these species, a brief synopsis follows:

- Red maple: small to large decrease depending on emission scenario, high adaptability
- Eastern white pine: large decrease and low adaptability
- Black oak: no change and medium adaptability
- Scarlet oak: no change to small decrease depending on emission scenario, medium adaptability
- Northern red oak: no change to small decrease depending on emission scenario, high adaptability
- White oak: small increase, high adaptability
- Pitch pine: small to large decrease depending on emission scenario, medium adaptability
- Black cherry: large increase, low adaptability

- White ash: small increase, low adaptability

Additional detail on these and the remainder of the tree species present in the region are in the table in Appendix E. In addition, the table includes information on currently present species that are projected to infill and species that are not currently present in the region but have the potential to move into the region as climate conditions change. Some notable projections in this category include:

- Projected infill species include:
  - American beech, eastern red cedar, sugar maple, green ash, and sassafras
- Species projected to migrate into the area include:
  - Shortleaf, loblolly, and Virginia pine, sweetgum, and southern red oak.

These projected long-term changes will be punctuated by short-term changes driven by other stressors including pest and disease impacts and land use change driven by development. In particular, tree species with low adaptability are vulnerable to these compound stressors.

Forest Health: Pest and Disease Concerns

The Massachusetts State Forest Action Plan[vi] (2020) documents the dominant damage causing agents for Massachusetts forests. Table 1.6 below provides a synopsis for the period 2009-2018.

Year	Total Acres	1st Damage Causing Agent	Acres	2nd Damage Causing Agent	Acres	3rd Damage Causing Agent	Acres
2009	39,333	Winter Moth	18,936	Snow-Ice	9,705	Gypsy Moth	4,304
2010	139,135	Winter Moth	67,737	Frost	40,292	Gypsy Moth	5,879
2011	102,984	Winter Moth	89,006	Wind-Tornado/ Hurricane	11,424	Unknown	546
2012	23,563	Winter Moth	10,213	Black Oak Gall Wasp	3,815	Wind-Tornado/ Hurricane	3,444
2013	52,216	Winter Moth	16,250	Black Oak Gall Wasp	14,576	Hail	10,379
2014	50,823	Winter Moth	36,505	Red Pine Scale	4,955	Black Oak Gall Wasp	2,712
2015	112,108	Winter Moth	61,924	Gypsy Moth	38,175	Black Oak Gall Wasp	4,571
2016	363,595	Gypsy Moth	349,866	Black Oak Gall Wasp	6,503	White Pine Needle Damage	3,623
2017	939,051	Gypsy Moth	923,186	White Pine Needle Damage	8,638	Fire Damage	1,950
2018	194,000	Gypsy Moth	159,705	Oak Mortality	23,602	Red Pine Scale	2,476

Table 1.6. Annual canopy damage from top three agents in Massachusetts by acreage for 2009-2018.

Oak Decline

Several overlapping stressors have contributed to oak decline in eastern Massachusetts over the last several years. These stressors include the gypsy moth outbreak between 2015 and 2019 and defoliation by winter moth. In addition, a significant drought in 2016, boring insects, root fungus, fall webworm and cankerworm, and a series of intense coastal winter storms have all compounded the damage inflicted by the gypsy and winter moth outbreaks[vii]. In combination these factors have resulted in a significant increase in oak mortality in Massachusetts with over 23,000 impacted acres recorded in a 2018 aerial survey.

Emerald Ash Borer

Emerald Ash Borer (EAB) is spreading in Massachusetts but thus far has not been documented in Plympton. Figure 1.15 from the Massachusetts State Forest Action Plan 2020 shows EAB detections through 2020.

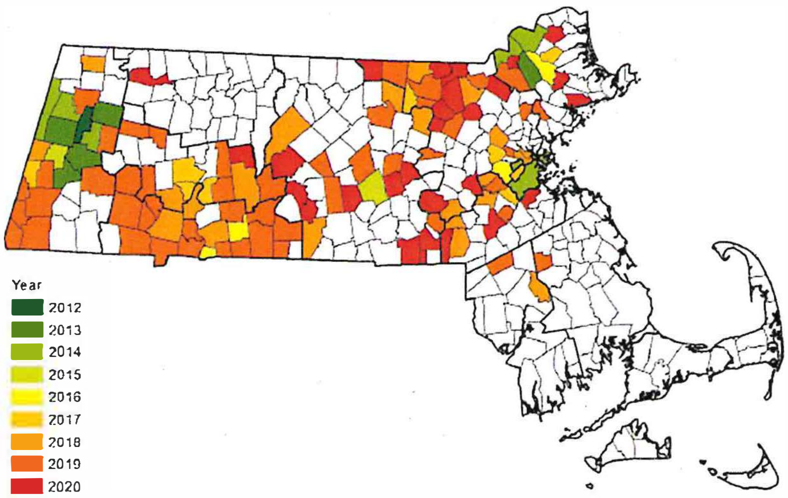


Figure 1.15. New Emerald ash borer detections in Massachusetts, by year (N. Keleher 7/27/2020).

Southern Pine Beetle

Southern pine beetle is expanding northward into Massachusetts and has been detected in traps on Cape Cod and Martha's Vineyard. Thus far the impacts have not been extensive but as average annual temperatures continue to warm southern pine beetle is likely to become a more significant threat in Massachusetts.

Oak Wilt

Oak wilt is a fungus that limits the flow of water nutrients from roots to crown, causing leaves to wilt and fall off. Oak wilt often kills the majority of oaks in a stand once it becomes established. While not currently known to be present in Massachusetts, oak wilt has progressed to near the western New York/Massachusetts border.[viii] Oak wilt spreads between trees through root system contact and bark beetle activity. Treatment options are limited with removal and disposal of infected trees required to limit the spread.

Forest Management Strategies for Plympton

Maintaining health productive forests in Plympton will require observant, nimble forest management. Climate change-related impacts are coupling with other forest stressors to change the composition and vigor of forests in and around Plympton. Tracking changing climate and forest conditions and adapting forest management strategies will be necessary to stay abreast of new developments. A comprehensive

Climate Change and Forestry Handbook[ix] and associated videos is available through Manomet's Climate Smart Land Network website at http://climatesmartnetwork.org/climate-resources/handbook.

A common framing for climate smart forest management involves thinking in terms of three categories of response: resistance, resilience and transition. Resistance in this context is attempting to sustain current forest composition despite the warming climate. Resilience relies on minimizing stressors to maintain forest health as a gradual climate-related transition occurs. Transition involves facilitating the shift to a new forest composition when maintain the existing state is no longer feasible.

Figure 2 below, from *Forest Adaptation Resources*[x], provides a high-level synopsis of how several categories of forest management relate to resistance, resilience and transition. Note that many of these approaches align with the conservation recommendations for the Winnetuxet corridor. In particular, maintaining refugia, structural diversity and genetic diversity are all supported by the recommended conservation measures. In addition, focusing land conservation efforts along the river corridor will promote connectivity among contiguous conservation nodes. Finally, linking the Winnetuxet conservation effort to a multijurisdictional conservation effort organized around habitat core 798 will promote landscape-level connectivity.

Beyond the conservation work in the Winnetuxet corridor, the following practices will provide forest health benefits across the entire town:

- Conserve connected blocks and examples of the diverse forest types present in the region,
- Monitor and manage for stressors including pest and disease impacts, changing weather and climate conditions, and encroachment of development,
- Select management approaches based on forest health and change:
    - Resistance to climate-driven change for unique forest types that appear to be viable in new conditions,
    - Transition to emphasize new tree species combinations in those areas where stressors are taking a toll, and
    - Experimentation with varied management techniques as conditions change.

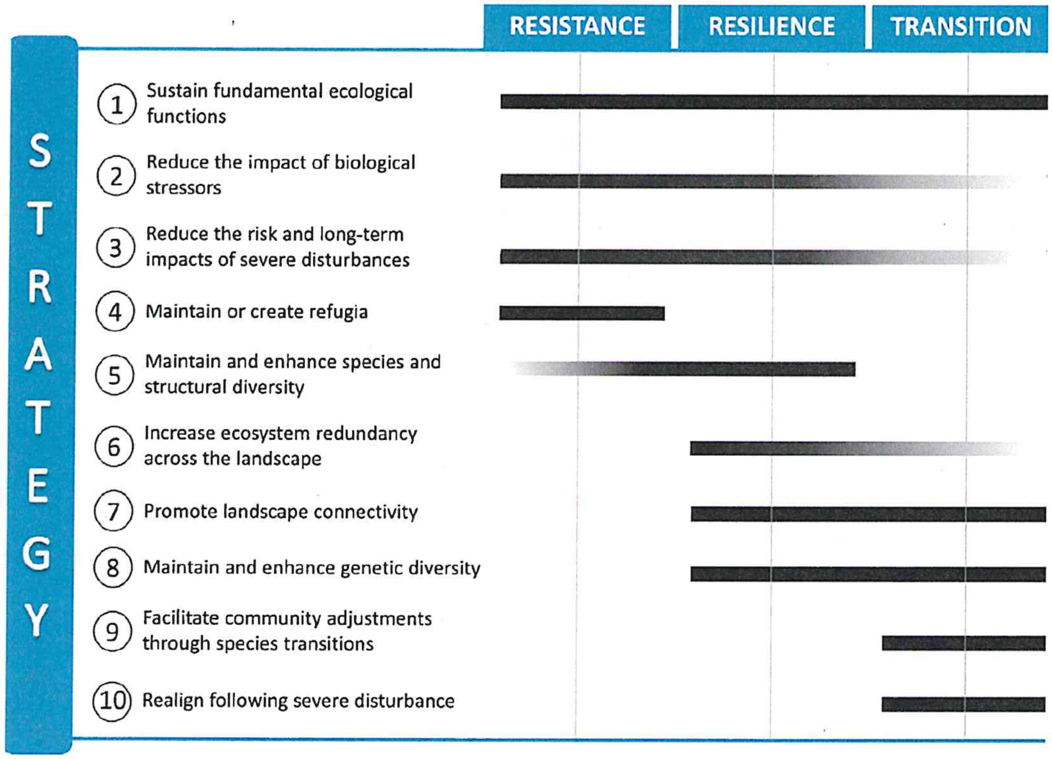


Figure 2: Climate Smart Forest Management Approaches.

Managing for specific pests and diseases

Gypsy Moth

For areas behind the invasion front suppression of gypsy moth outbreaks is typically through aerial application of microbial pesticides and insect growth regulators[xi].

Winter Moth

Similar to gypsy moth, microbial pesticides such as Spinosad and bacillus thuringiensis are used to treat free feeding caterpillars[xii].

Southern Pine Beetle

Thus far southern pine beetle has not been a significant problem in Massachusetts. If beetle infestations become more problematic measures such as cutting and salvaging infested areas or thinning uninfested stands ahead of an advancing infestation may be warranted[xiii].

Emerald Ash Borer

The Massachusetts forest health program is currently working to establish host specific parasitic wasp populations from the emerald ash borer's native range to limit the borer's impact[xiv]. While not yet necessary in Massachusetts, states with more established and problematic EAB populations have implemented complex strategies to reduce the percentage of ash in impacted stands while retaining sizable enough populations to maintain long-term ash viability.

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[i] Mark Benedict and Edward McMahon, *Green Infrastructure: Linking Landscapes and Communities,* (Island Press, 2006). 1

[ii] *BioMap2 Plympton Town Report,* http://maps.massgis.state.ma.us/dfg/biomap/pdf/town_core/Plympton.pdf, 2012.

[iii] Coastal Resilience – Massachusetts Online Mapping Tool, The Nature Conservancy, https://maps.coastalresilience.org/massachusetts/

[iv] National Forest Type Dataset, USDA Forest Service, https://data.fs.usda.gov/geodata/rastergateway/forest_type/

[v] Climate Change Tree Atlas, version 4, USDA Forest Service Northern Research Station, 1 X 1 Degree Summaries, https://www.fs.fed.us/nrs/atlas/combined/resources/summaries/grid/

[vi] Massachusetts Department of Conservation and Recreation, *Massachusetts State Forest Action Plan 2020, https://www.mass.gov/doc/massachusetts-forest-action-plan/download*

[vii] Nicole Keleher, *Massachusetts Oak Decline and Mortality,* https://www.youtube.com/watch?v=4eK4wdtuHPQ, 2021

[viii] Massachusetts Department of Conservation and Recreation, *Massachusetts State Forest Action Plan 2020, https://www.mass.gov/doc/massachusetts-forest-action-plan/download*

[ix] Jennifer Hushaw, Eric Walberg and Si Balch, *Climate Change and Forestry Handbook,* Climate Smart Land Network, Manomet, Inc., 2018

[x] Swanston, et. al., *Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers, 2nd edition*, USDA Forest Service, Northern Research Station, 2016

[xi] Gypsy Moth Control and Management, USDA Forest Service, https://www.nrs.fs.fed.us/disturbance/invasive_species/gm/control_management/

[xii] Winter Moth Identification and Management, UMass Extension Program, https://ag.umass.edu/landscape/fact-sheets/winter-moth-identification-management

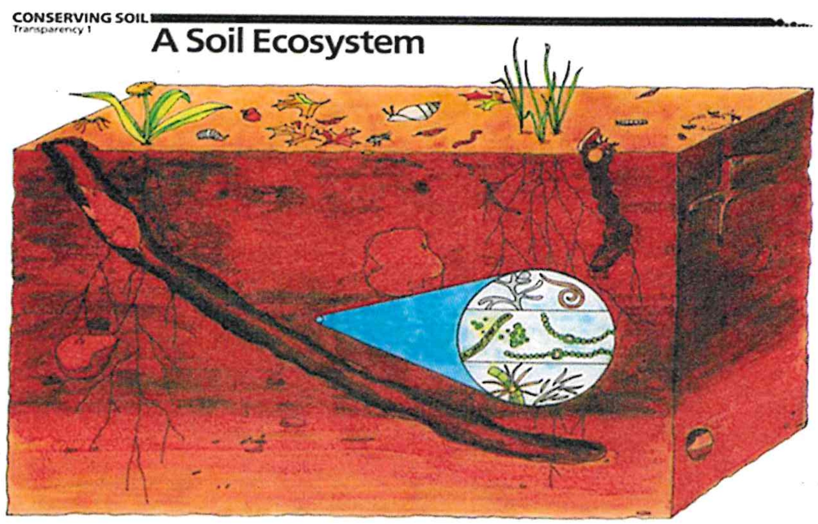
[xiii] Southern Pine Beetle, UMass Extension Program, https://ag.umass.edu/landscape/fact-sheets/southern-pine-beetle

[xiv] Emerald Ash Borer in Massachusetts, Massachusetts Department of Conservation and Recreation, https://www.mass.gov/guides/emerald-ash-borer-in-massachusetts

Investing in Our Soils

Our Soils Assets

Soil, Earth, Dirt . . . no matter what we call it, it's the material that we build on, grow crops in, and mine resources from. While they appear to be part of an unchanging carpet in our everyday world, soils are dynamic ecosystems that provide numerous nature based services that are critical to our long-term resilience.

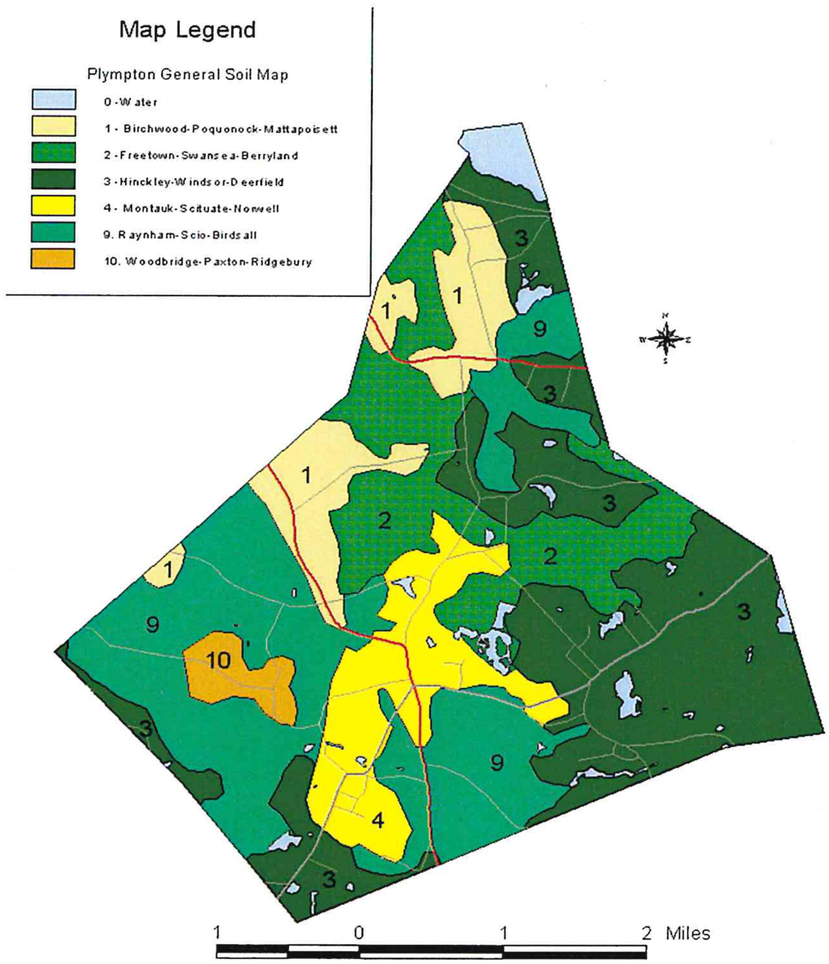


Soil Health is defined by the **UDSA Natural Resource Conservation Service (NRCS)** as the continued capacity of soil to function as a vital **living ecosystem** that sustains plants, animals, and humans. Farming, especially cranberry growing, is one of the most important aspects of Plympton's culture, history, and economy. This has been the case for generations and it is the town's hope that agriculture will continue to thrive in the future. Retention of healthy productive soil is key to a resilient agricultural community. **Four general management principles that support soil health have been identified by the NRCS: Minimize soil disturbance; Maximize soil cover; Maximize biodiversity, and; Maximize presence of living roots**

What Types of Soils Do We Have to Work with in the Winnetuxet River Watershed and Plympton in General?

The soils in the Winnetuxet River Watershed, and throughout much of Plympton, are characteristic of the Hinckley-Merrimac-Muck association, which consist of broad, low ridges; nearly level plains and terraces; and knobby, irregular ridges. Intermingled with these are extensive low, flat, wet areas. These low areas consist mainly of organic soils known as muck. Other very poorly-drained soils in Plympton are Scarboro, Carver, and Peat . . . Plympton has a lot of Peat, the value of which will be discussed in subsequent text in this Section (NRCS, Plymouth County Soil Survey Update, 2010).

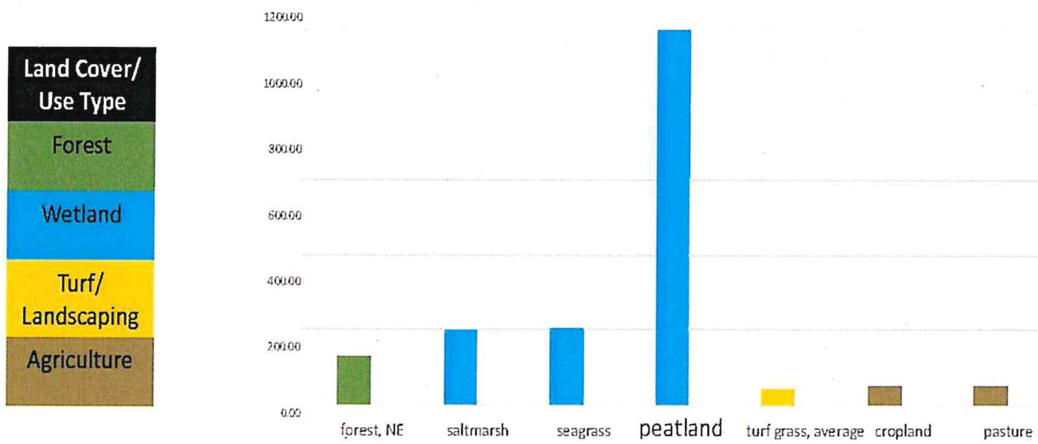
The terrain and soil composition of Plympton makes much of it ideal for the production of cranberries, but limited for residential and commercial development. Plympton's soils pose some development challenges, and most of Plympton has moderate to severe limitations for the installation of successful, properly functioning septic systems. Therefore, careful planning and on-site testing is necessary to overcome soil conditions and to avoid potential water/groundwater contamination issues. Since many areas with slight soil limitations have already been developed, much of Plympton's future development will likely be proposed in more marginal areas, emphasizing the need for conscientious, creative, and sustainable land use management practices. (Soils map below courtesy of NRCS, Plymouth County Soli Survey Update, 2010, and www.nesoil.com).



Carbon content is one of the few universally agreed-upon indicators of soil health. Various natural and human-driven processes (agriculture, development, conservation, etc.) create increases and decreases in the amount of carbon held in soils. Soil Organic Carbon (SOC) varies widely across soil types and drainage classifications. In general, more poorly drained soils generally have more SOC than more well drained soils . . . hence, the significance of Plympton's wetland and bog peatlands. The graphic below illustrates the SOC capacity of peatland in comparison to other types of land cover and land uses. (graphic courtesy of Jim Newman, Linean Solutions)

Soil Carbon Stocks tons/hectare

Excluding carbon in biomass



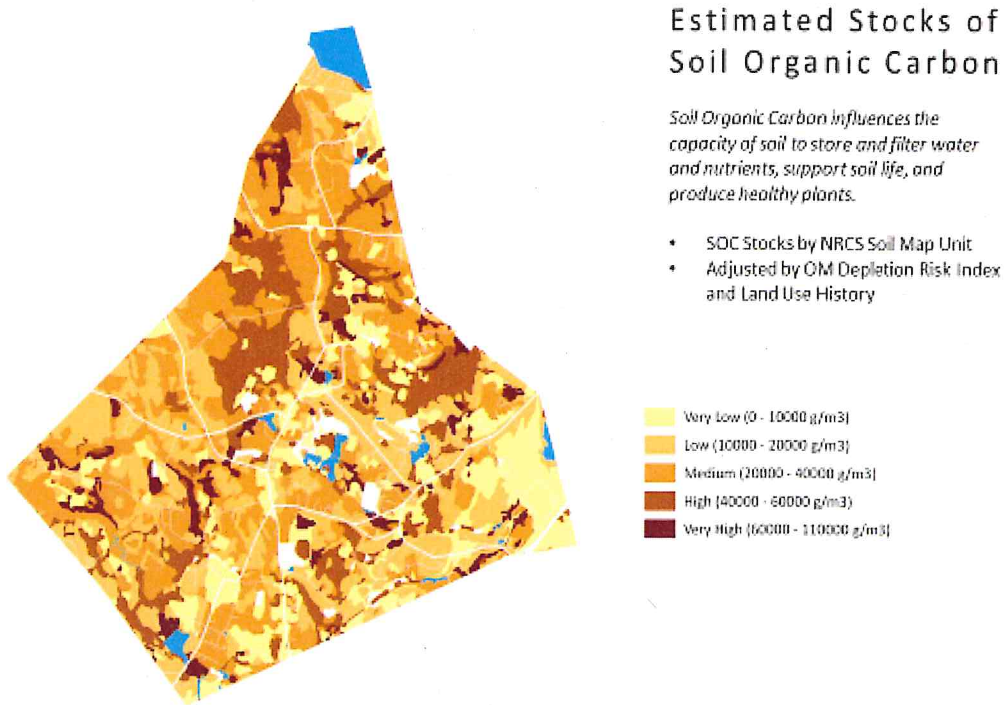
Soil Vulnerabilities: Land Use Decisions and Climate Change

Unpredictable seasonal weather patterns including, periods of very heavy precipitation, more frequent heatwaves, changes in time and length of the growing season, and an emerging flood-drought cycle, will challenge the **viability of plant communities** that feed and protect soils. A gradual shift to toward hotter summers and warmer winters may increase the intensity and duration of consumers and decomposers in the soil and lead to an **increase the rate of loss of soil carbon stocks and a suppression of sequestration**.

More extreme storm events increase the risk of flooding and catastrophic erosion. This in turn leads to loss of topsoil, destabilization, and soil and nutrient transport to local and regional receiving waters.

Healthy soils play an important role infiltrating, storing, and filtering water. Healthy soils work like a sponge to slow stormwater, recharge groundwater, and clean polluted surface flows. As climate change brings more and heavier storms to our region, this vital soil function becomes even more essential. The changing climate has brought into sharp focus another function of soil - carbon sequestration and storage. Second to the world's oceans, soil is the largest carbon store on earth. "At the global level, 19 percent of the carbon in the earth's biosphere is stored in plants, and 81 percent in the soil" (IPCC, 2000). Disturbance of soil through poor land management and unchecked development patterns and practices all release carbon into the atmosphere, and disrupt a landscape's ability to sequester carbon through photosynthesis. Improving soil health for agriculture has the co-benefit of improving the soil's capacity to support ecosystem services, such as carbon sequestration.

(Plympton graphic below courtesy of Jim Newman, Linnean Solutions).



Plympton Soil Organic Carbon

We can see that conserving the ecosystem services and carbon storage of wetlands and riparian areas are critically important. Healthy soil provides a foundation for the production quality food crops, both in and above the ground, and a filter for the quality of the water needed to sustain the community, below. The responsible practice of agriculture helps to retain the health and productivity of those soils best suited to agricultural production. Knowing the location, significance and uniqueness of important farmland soils is essential to preserving these areas for future food production and supply as part of the statewide Food Security Plan. This will also help to inform land use practices and direct growth to appropriate areas.

Investing in Healthy Soils: Recommendations

While wetlands are valued and protected in Massachusetts, the dynamics and complexities of the ecosystem services they provide and their role in climate change mitigation and adaptation aren't fully accounted for in existing legislation, policy, replication practices, and regulation. The key physical processes that sustain rivers, floodplains, and wetlands are the movement and storage of water on the landscape. The recommendations below are intended to increase awareness and action at all levels to minimize disturbance of wetland and agricultural soils and the hydrology that supports the function of these important ecosystems and the values they provide.

- No Net Loss of wetlands
- Actively manage land for climate adaptation (understand the landscape, its function, and the services that it provides)
- Manage soils for accelerated carbon drawdown
- Restore degraded wetland, forests, and farmland where practical and feasible

- Work with local, regional, state, and federal partners to Increase monitoring and research on impacts of climate change on forested and farmed soils
- Incentivize integration of tree crops and other perennials on flood prone farmland

Cranberry bogs and bog restoration

"Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (Society for Ecological Restoration (SER) Primer (2004).

How can cranberry bog restoration, wetlands preservation, riparian ecosystem restoration, and development work together to carbon stores and other ecosystem services? The Town and Agricultural Commission should plan now to work with DER restoration and USDA/NRCS soils scientists on the conversion of abandoned bogs to wetland rather than agricultural "dead zones" (get projects lined-up).

Cranberry farming has been part of the southeastern Massachusetts landscape for over 100 years. Culturally iconic and economically important, the industry now faces declining prices, out-of-state competition, and other challenges. The result is a new wave of retirements, farmland abandonment, and significant development pressure. Meanwhile, abandoned cranberry farms lose wetland characteristics as a result of legacy agricultural practices (e.g. fill, ditches, and dams). These factors represent a 'perfect storm' in terms of opportunity for wetland restoration, but also risks associated with alternative land-use outcomes and permanent wetland losses. While the soils that make-up of the former bogs present challenges, the successful conversion to wetlands will help to support greater biodiversity and resilience in the community (before and after photos of a DER bog restoration project below, courtesy of Alex Hackman, DER).

Practical 'Process-Based' Restoration Framework (Developed by MA DER for cranberry bog projects, but it has much broader potential use)

- Understand the site
- Focus on key ecological processes (the engine)
- Identify 'stressors' or limiting factors
- Plan responses that relieve stress

- Mother Nature and Father Time, (DER's Alex Hackman's words to the wise . . . it takes time, study, and patience to affect a well done restoration project)

Investing in the Town's Two Brooks Area

While this beautiful bog, reservoir, wetland, and forest complex area was initially thought to be ready for some type of restoration project, a deeper look and a field visit and assessment, led by Alex Hackman of DER, showed the Open Space/MVP Steering Committee how much more there is to know before we decide what our long term goal/investment strategy is.

We all agreed that we are not ready to put in a full project proposal because the first need is to understand the geological structure/ecological potential of the Two Brooks area. Alex was emphatic about this knowledge gap and the importance of filling it. Once we have that information, we can better choose among many options for the landscape's future.

Alex, as a first course of action in investing resources into this property, recommended the Town submit an application/letter of interest to DER in an effort to become a DER Provisional Project. This would enable Alex and other experts to spend some time next year in the field, collecting soil profiles and other data, delving in to the biology, hydrology, soils and peat of the area. This would also afford us (Town Committee members) the opportunity of working with and learning form Alex and his team along the way, so that we better understand how each future scenario would work.

The results of those studies would then enable us to look at the Two Brooks options in terms of more efficient and practical future investment of time and resources. These fall into three categories:

- **Restoration of Streams** and related wetlands,
- **Habitat Restoration** including elements of stream restoration, and
- **Maintenance** of the current system as is. Alex and team are most inclined to do the full restoration projects, but also may participate/support Habitat restoration that incorporates some stream/wetland areas. The DER program cannot help us with the "system as-is option."

The Takeaways

The retention/restoration of the physical processes that sustain rivers, forests, floodplains, soils, and wetlands, the movement and storage of water on the landscape, is key to a healthy ecosystem.

The loss of soil, or the loss of soil health, is a loss of land asset value to the community.

Tools and Resources to help us make our investment decisions:

- The Massachusetts **Healthy Soils Action Plan** is currently in final review at the Executive Office of Energy and Environmental Affairs (EEA), and should be released soon.

  "The purpose of the Massachusetts Healthy Soils Action Plan is to provide evidence-based recommendations that help people better manage soils of five major land types including: Forests, Wetlands, Agriculture, Turf and Ornamental Landscapes (developed open space), and Impervious and Urbanized Lands. Through targeted conservation, soil-smart development, and better soil management, the recommendations of the HSAP will propose a coordinated approach to protecting the productivity of our working lands and diverse wild lands, assisting cities and towns to improve resilience and reduce their vulnerability to natural hazards and climate change."

- **The Massachusetts Division of Ecological Restoration (DER) Cranberry Bog Restoration Program.** DER's mission is: *"To restore and protect the health and integrity of the Commonwealth's rivers, wetlands, and watersheds for the benefit of people, fish, and wildlife."*

  Go to www.mass.gov/cranberry-bog-program to learn more about the process and opportunity to connect with DER staff.

- NOFA/Mass Carbon Resources: http://nofamass.org/carbon

- The Plymouth County Soil Survey, Updated 2010, USDA NRCS, and www.nesoil.com

- The Nature Conservancy. "rethink Soil: A Roadmap for U.S. Soil Health." (2016). http://bit.ly/rethinksoil , The Nature Conservancy www.tnc.org

- Cape Cod Cranberry Growers Association, www.cranberries.org

- USDA Natural Resource Conservation Service (NRCS) www.ma.nrcs.usda.gov

- USDA/NRCS. Soil Health Awareness - Unlock the Secrets in the Soil. http://bit.ly/UnlockSoil

- MA Department of Agricultural Resources www.mass.gov/agr

- US EPA www.epa.gov

- Jackson, Dana L., and Jackson, Laura L., eds., The Farm as Natural Habitat: Reconnecting Food Systems with Ecosystems. Island Press, Washington, D.C., 2002.

Do Our Bylaws, Rules, and Regulations Let Us Properly Address Our Open Space Investment Goals? Using the Mass Audubon Bylaw Review Tool

Local Planning for Resilience

Once the town establishes a portfolio of potential conservation projects, implementation of those land protection priorities will be determined largely by the land use regulations that are in place in the town of Plympton. Where and how development takes place depends on local zoning and regulations, and Plympton will need to take steps to ensure these bylaws are not encouraging unsustainable development practices on priority conservation land. To ensure success in taking steps to achieve Plympton's resilience goals, Mass Audubon led the steering committee through an analysis of Plympton's land use regulations over two workshops.

Resilient Bylaw Reform Workshop Series

The first bylaw workshop Mass Audubon conducted with the steering committee on April 22 examined recent development trends in Plympton and the surrounding region, obtained from Mass Audubon's Losing Ground report and associated land use data analysis, and how traditional development patterns impair natural resources, harming community well-being and resilience. We then offered an alternative path of growth, via low impact development. We shared examples of how low impact development practices work with nature to protect the natural resources that improve air and water quality, reduce flooding damages, mitigate climate change impacts, and improve community quality through proactive land use planning and proper stormwater management. The steering committee was introduced to Mass Audubon's Low Impact Development Bylaw Review Tool, and learned how to use the tool to review their local regulations and identify opportunities where sustainable and climate-smart development practices can be encouraged during future development projects.

The participants were then sent home from workshop one with the assignment to review one of their existing bylaws using the tool. The steering committee decided to look at their Rules and Regulations Governing the Subdivision of Land, given the significance this set of regulations has over guiding development practices. The steering committee and Mass Audubon reviewed these subdivision regulations before reconvening for the second workshop on May 27, which focused on discussing the analysis and next steps for making updates to the regulations to encourage low impact development that protects land and natural resources.

Opportunities for LID in local regulations

Traditional development trends can often promote sprawling development that alters and fragments natural areas, and may impact community character and resources if unprepared to manage increasing development pressures. Building over natural areas with pavement and buildings, impervious surfaces, also prevents rainfall from soaking into the ground, resulting in increased stormwater runoff which must be managed to prevent flooding and water quality impairments.

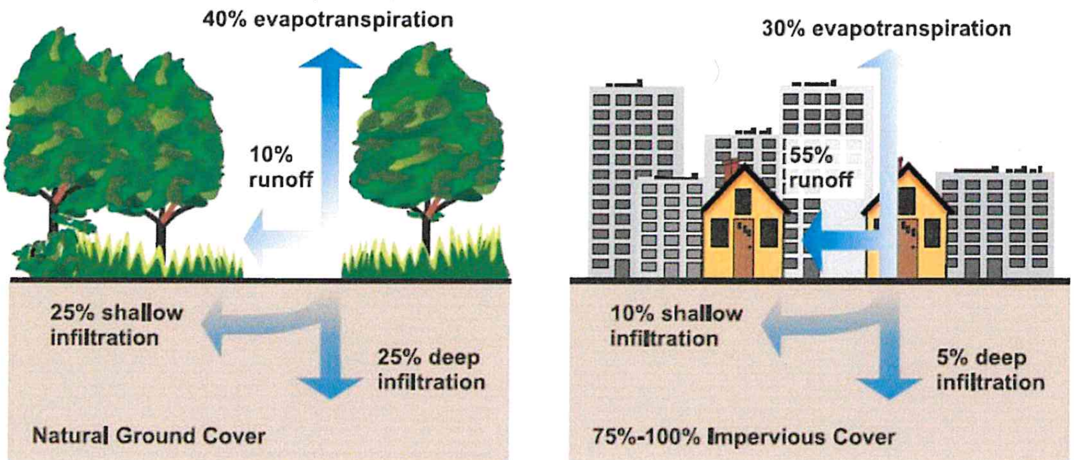


Fig: conversion of natural areas to impervious cover results in reduced rates of infiltration and increases in stormwater runoff (source: EPA).

Low impact development (LID) largely focuses on working with nature to avoid land disturbance in environmentally sensitive areas (i.e. valuable areas that provide resilience benefits to the community, such as the Green Infrastructure Network), as well as reducing impervious surfaces and managing stormwater as close to the source as possible to protect water quality and save money on stormwater infrastructure costs. Best practices minimize the alteration of natural green infrastructure such as forests; minimize creation of impervious surfaces; support retention of substantial naturally vegetated buffers along wetlands and waterways; minimize grading and alterations to natural flow patterns; and support the use of LID techniques as the preferred, most easily permitted methods for managing stormwater.

Why low impact development?

ACTION	RESULT
Reduce sprawling development	• Open space protection and access • Limit environmental impacts
Decrease impervious area	• Mitigate flooding • Alleviate heat impacts
Infiltrate stormwater	• Improve water quality • Recharge groundwater supply
Utilize green infrastructure	• Longer lasting, less costly maintenance • Mitigate climate change • Community co-benefits (aesthetics, health)
Rainfall utilized as a resource	• Reduced water costs • Protect water supply

Plympton's subdivision regulations are already encouraging low impact development stormwater practices by stating LID as the preferred drainage approach and requiring a waiver for traditional systems. The bylaw review tool revealed additional opportunities to incorporate LID into site designs by requiring that land disturbance on sites avoid priority natural areas, as identified in the Town's Open Space and Recreation Plan (OSRP), and only allowing development of these areas where no other alternatives reasonably exist. The design standards could further specify which LID practices are preferred, and require measures to protect water quality, particularly in priority groundwater protection areas. Allowing more flexibility in road, sidewalk, and lot dimensions and layouts to accommodate natural areas and large trees could also support more natural resource protection. Additional steps identified to reduce impervious cover include allowing more permeable pavement options on sidewalks, driveways, and low-volume roads, as well as encouraging shared access ways. A detailed analysis of Plympton's existing subdivision rules and regulations follows.

Bylaw Analysis and Recommendations

The following analysis was prepared by Mass Audubon using their Low Impact Development Bylaw Review Tool and evaluates selected land use regulations in relation to models and examples from the Commonwealth of Massachusetts' Smart Growth/Smart Energy Toolkit and other sources in relation to the use of LID and Green Infrastructure (GI) techniques in development. The focus is primarily on residential development. The tool analyzes the existing regulations through five key goal areas. Outlined below is the analysis of Plympton's subdivision regulations, as well as some provisions of the zoning bylaw where noted, and recommended improvements for each goal. The completed analysis tool with recommended best practices and recommended changes, along with resources to assist the town in identifying best practices to include in the updates, were shared with the town following the workshop, and are included in the Appendix of this report.

Goal 1: Protect natural resources and open space

- Plympton's regulations are better than most when it comes to allowing LID strategies that protect natural resources and open space: encouraged reuse of topsoil on site and preservation of existing large trees are great aspects of the regulations.
- Further prohibiting or limiting land disturbance outside of built areas as well as prohibiting removal of soil from site are potential next steps to further reduce impacts to the land.
- Requiring development avoid sensitive natural areas, such as the Green Infrastructure Network, larger connected landscapes, and other forested or wetland areas and their buffers, unless there is no reasonable alternative, would have significant positive impacts on protecting natural areas and the services they provide to our built communities. Referencing the town's Open Space and Recreation Plan for identifying areas that development should avoid may be a streamlined way for the town to communicate its most recent protection goals to developers to account for in site designs.
- Any required plantings should specify the use of native, low maintenance plants for the greatest wildlife and habitat benefit, and the least impact on water resources.

Goal 2: Promote efficient, compact development patterns and infill

- Plympton's existing regulations are mostly in line with conventional practices when it comes to efficient development that reduces sprawl.
- Adding language that encourages the use of common drives, where appropriate, in the site design standards could help to reduce unnecessary impervious cover that contributed to stormwater runoff and water quality impairments.
- Plympton's existing zoning bylaw has strict requirements for lot sizes and dimensions; allowing more flexibility, as well as allowing shared driveways in more situations, could further help developers adopt low impact development practices that reduce impacts on the land.

Goal 3: Smart designs that reduce overall imperviousness

- Plympton has done an excellent job encouraging low impact development stormwater practices in site design, but the regulations could be strengthened further.
- Allowing more flexibility in subdivision street layouts and requiring the layout conform to existing natural features to the extent feasible and safe would help minimize excessive regrading and land disturbance.
- Adopting a tier system for road width requirements, and reducing requirements for sidewalks would reduce impervious area in new developments.
- Further clarification in the design standards and updated design plates in the appendix could include preferred best practices for low impact development stormwater management, and additional standards that protect water quality are preferred.

Goal 4: Adopt green infrastructure stormwater management provisions

- Plympton's subdivision regulations are better than most, particularly when it comes to encouraging sustainable stormwater management practices.
- Low impact development practices are specified and traditional systems require a waiver – this is a great step, but further specifications for the types of stormwater systems that are preferred would help streamline review and permitting.
- Rooftop runoff is not currently addressed in the regulations, but should be prohibited from being directed into roadways, and only into roadside swales where the system is designed to handle it.
- Allowing permeable pavement options for driveways, sidewalks, and low volume roads is a great option for reducing runoff.
- Operation and Maintenance Plans including clear expectations of who will maintain drainage systems and stronger standards for erosion and sedimentation plans will help to ensure the success of drainage systems and reduce impacts during construction.

Goal 5: Encourage efficient parking

- Parking is not addressed in the subdivision regulations, but it should be.
- Encouraging shared parking areas and driveways where practical could help to limit impervious cover.
- Requiring landscaped bioretention systems in parking lots to capture runoff is a potential option for reducing strormwater impacts.

Making any of the above recommended updates to the subdivision rules and regulations has the benefit of not having to be approved by town meeting, as bylaw changes do. It is recommended that the town consult their legal counsel as well as review any potential changes in the context of the existing bylaws to ensure the updates will not be in conflict with other standing regulations, before proposing updates.

Additional Considerations

Stormwater Calculations: Ensure your regulations reference the most updated data on storm intensities from the Northeast Climate Center or the NOAA 2014 Atlas

Landscaping and Recommended Trees: Ensure your local landscaping regulations require native, pollinator friendly species

Funding and Maintenance:

- Ensure sufficient funding for DPW to perform maintenance of stormwater management facilities, whether conventional or LID (i.e. establish a Stormwater Enterprise Fund that charges landowners for the amount of stormwater they produce).
- Consider reduced costs of paving, plowing, salt when comparing LID maintenance costs with conventional designs
- Create mechanisms for enforcement of maintenance agreements; establish regulations/fines for property owners who fail to maintain stormwater facilities.

Training and Public Education:

- Provide opportunities for and encourage municipal staff and committee/board members to participate in LID workshops or conferences.
- Implement LID demonstration programs at city or town hall, schools, DPW, etc.

Nonpotable uses of clean stormwater: Local plumbing codes should allow the use of clean (e.g. rooftop) rainwater for landscape irrigation and interior non-potable uses such as toilet flushing.

For **additional information** on best practices, model bylaws and regulations, case studies, and other related resources see the following websites:

- Massachusetts Smart Growth/Smart Energy Toolkit, including case studies and model bylaws: www.mass.gov/envir/smart_growth_toolkit/
    - Models are available for Open Space Design and Transfer of Development Rights bylaws, both of which could further assist Plympton in financing land protection to achieve its resilience goals.
- Metropolitan Area Planning Council's (MAPC) LID Toolkit https://www.mapc.org/resource-library/low-impact-development-toolkit/
- MA-APA *Neighborhood Road Design Guidebook* https://www.apa-ma.org/wp-content/uploads/2018/12/NRB_Guidebook_2011.pdf
- EPA's Water Quality Scorecard, which was reviewed and incorporated into this analysis framework in July 2017, including using the 5 goals listed: http://www.epa.gov/smartgrowth/water-quality-scorecard
- Mass Audubon's resources on Low Impact Development, including fact sheets on Cost-Effective LID: www.massaudubon.org/LIDCost

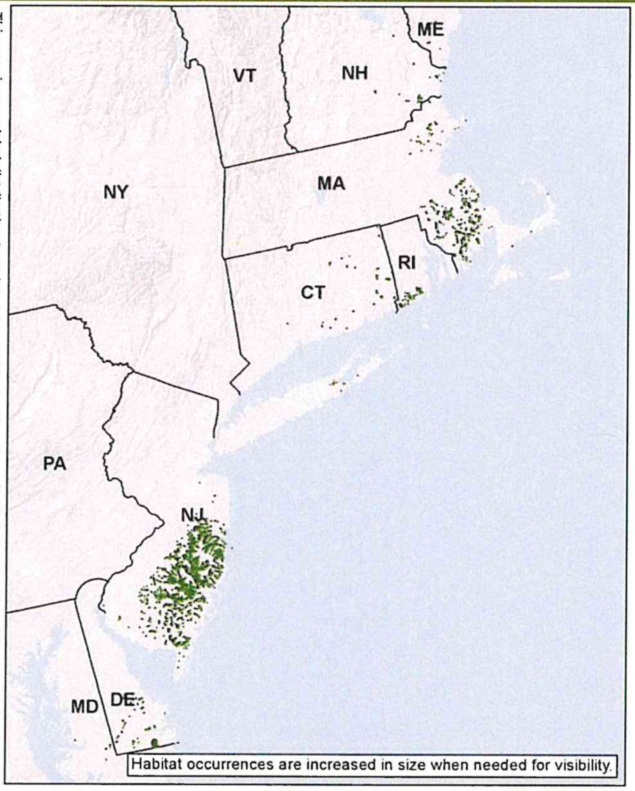
- Mass Audubon's *Value of Nature* fact sheets: www.massaudubon.org/valueofnature
- SNEP Network grant funding inventory: http://snepnetwork.org/grant-funding-inventory/
- EPA GI Funding resources: https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities
- Georgetown Finance Center GI Toolkit: https://www.georgetownclimate.org/adaptation/toolkits/green-infrastructure-toolkit/how-to-pay-for-green-infrastructure-funding-and-financing.html
- EPA stormwater financing webinars: https://www.epa.gov/waterfinancecenter/leading-edge-stormwater-financing-webinars

APPENDIX A-E

Forests

North Atlantic Coastal Plain Basin Peat Swamp

Macrogroup: Coastal Plain Swamp



This map is a modeled distribution based on current data and is not a substitute for field based inventory. Contact your State Natural Heritage Ecologist for more information about this habitat.

© Keith Love

Description:

A forested swamp of peat-accumulating basins in the coastal plain from southern Maine down to the Delmarva Peninsula. Atlantic white cedar is characteristic and often dominant; red maple may also be an important species, especially after logging. Black spruce is occasional in examples in the northern part of the region. Herbaceous species are typically more abundant than dwarf shrubs in the understory, which includes alder, great laurel, high-bush blueberry, winterberry, swamp azalea, and sphagnum moss. The saturated hydrology is evidenced by sphagnum-based hummock-and-hollow microtopography.

State Distribution: CT, DE, MA, MD, ME, NH, NJ, NY, RI

Total Habitat Acreage: 58,301

Percent Conserved: 53.5%

State	State Habitat %	State Acreage	GAP 1&2 (acres)	GAP 3 (acres)	Unsecured (acres)
NJ	61%	35,366	9,187	10,781	15,398
MA	20%	11,830	1,820	3,750	6,259
DE	8%	4,845	127	3,191	1,527
CT	4%	2,480	221	596	1,663
RI	3%	1,750	156	444	1,150
NH	2%	1,158	259	434	464
ME	1%	654	0	106	548
MD	0%	121	15	52	54
NY	0%	97	50	14	33

Ecological Setting and Natural Processes:

Basins are often configured along streams and rivers of the coastal plain. Relatively shallow water-saturated peat overlies mineral sediments in these swamps. Standing water generally occurs for half of the growing season or longer. The acidic soils are poor in nitrogen and phosphorus and often have a high iron content.

Similar Habitat Types:

May be similar compositionally to other acidic swamps in shallow basins in the region (like North-Central Appalachian Acidic Swamp), except for the prominence of Atlantic white cedar. The peat layer is deeper, and the canopy trees shorter and less dense, in the more northerly Boreal-Laurentian-Acadian Acidic Basin Fen.

Crosswalk to State Name Examples:

Acidic Atlantic White Cedar Basin Swamp (CT), Coastal Plain Atlantic White Cedar-Red Maple Swamp (DE), Coastal Atlantic White Cedar Swamp (MA), Atlantic White Cedar Swamp (MD), Atlantic White Cedar Swamp (ME), Atlantic white cedar-yellow birc -pepperbush swamp (NH), Forested Wetlands - White Cedar Swamps (NJ), Coastal Plain Atlantic White Cedar Swamp (NY), Atlantic White Cedar Swamp (RI)

Crosswalk to State Wildlife Action Plans:

Forested Inland Wetland - Atlantic White Cedar Swamps (CT), Atlantic White Cedar Non-tidal Wetlands (DE), Forested Swamps (MA), Forested wetlands - white cedar swamps (NJ), Atlantic White Cedar Swamp (NY), Forested Wetlands - Forested Coniferous Wetland White Cedar (RI)

Places to Visit this Habitat:

Pachaug State Forest | CT
James Branch Nature Preserve | DE
Freetown-Fall River State Forest | MA
Brendan T. Byrne State Forest | NJ
Wharton State Forest | NJ

Associated Species: *Appendix lists scientific names*

BIRDS: northern waterthrush, veery, wood duck

INSECTS: ebony boghaunter, elfin skimmer, great purple hairstreak, owlet moth, pennsylvania firefly, spatterdock darner, sphagnum sprite

PLANTS: bayonet rush (Juncus militaris), bushy bluestem (Andropogon glomeratus), coast sedge (Carex exilis), fibrous bladderwort (Utricularia fibrosa), heartleaf twayblade (Listera cordata), seaside alder (Alnus maritima), smooth winterberry holly (Ilex laevigata), southern bladderwort (Utricularia juncea), ten-angle pipewort (Eriocaulon decangulare), tickseed sunflower (Bidens coronata), white beakrush (Rhynchospora alba)

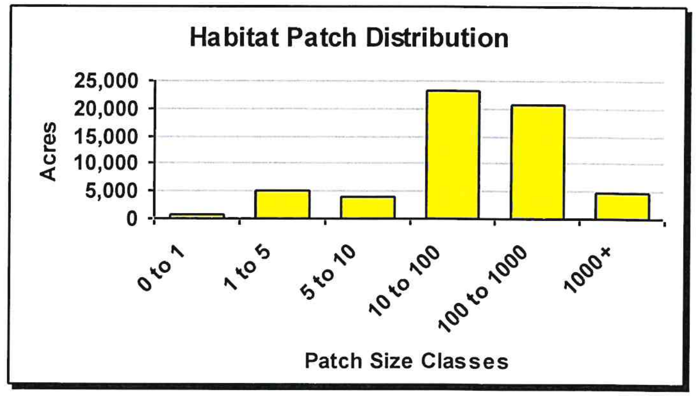
Species of Concern (G1-G4): *Appendix lists scientific names*

HERPTILES: blue-spotted salamander, carpenter frog, four-toed salamander, spotted turtle

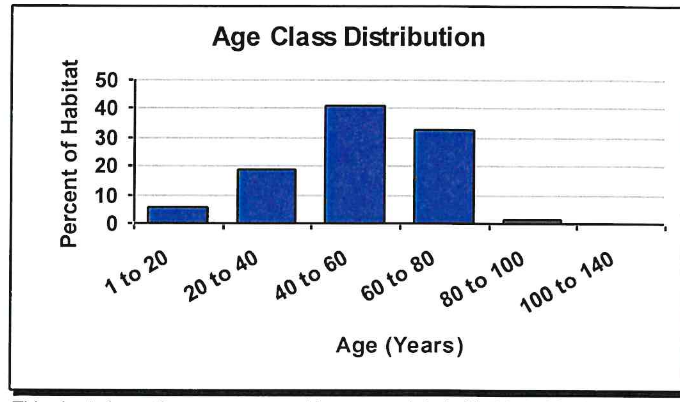
INSECTS: coastal swamp metarranthis moth, Hessel's hairstreak, pitcher plant borer moth, plant hopper, spatterdock darner, sphagnum sprite, a firefly (photuris tremulans), a moth (Exyra fax)

PLANTS: swamp-pink (Arethusa bulbosa), yellow nodding ladies'-tresses (Spiranthes ochroleuca)

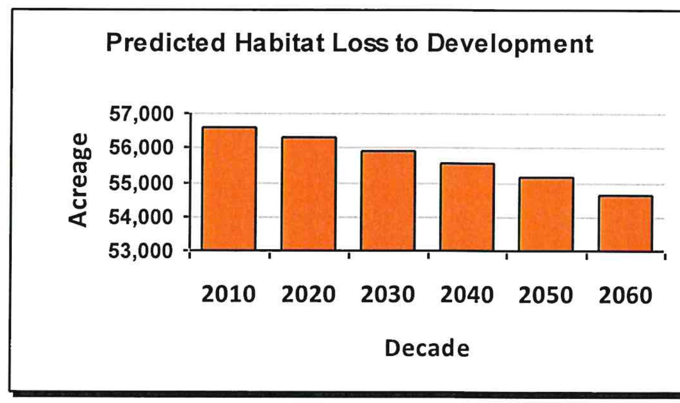
© Robert Coxe (Delaware Species Conservation & Research Program)



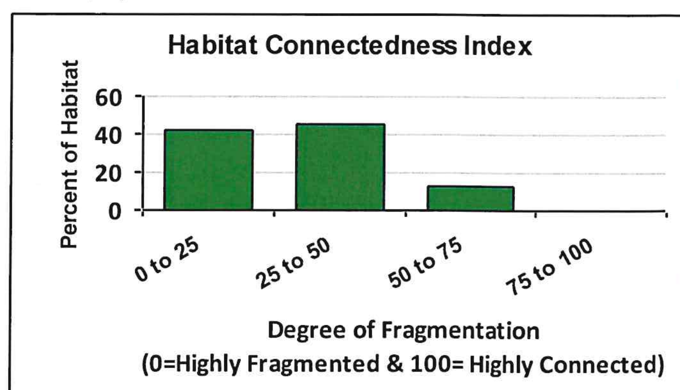
The average patch size for this habitat is 10 acres and the largest single patch is 1,791 acres. This chart shows the proportion of the habitat that is in each patch-size class.



This chart shows the average age of trees associated with this habitat based on forest Inventory data. For non-forested systems or small habitats the average age is influenced by the surroundings.



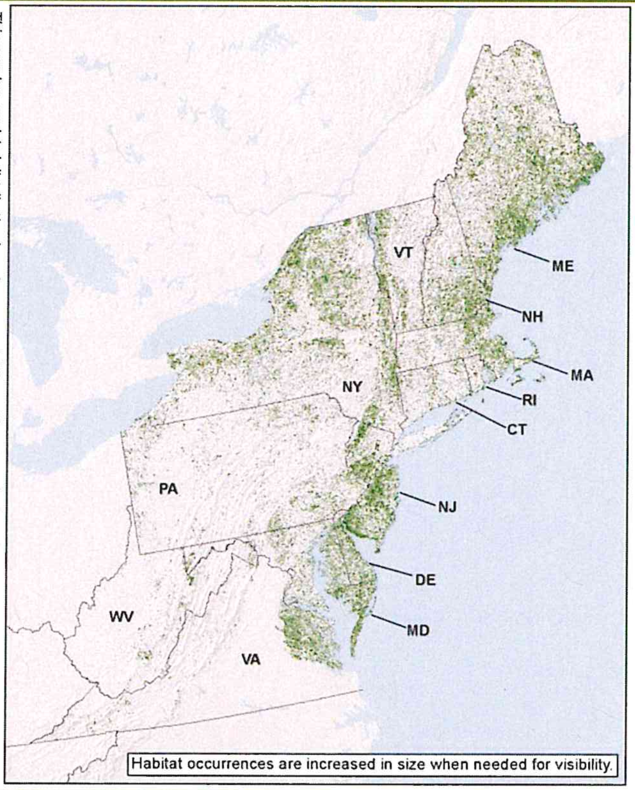
This chart shows the predicted loss of habitat over the next five decades (1,960 acres) if loss continues at the same rate as 1990-2000. The average rate of loss is 39 acres per year.



This metric measures how connected or fragmented the land directly surrounding (18 square miles) the habitat is, this the chart shows the proportion of the habitat in each connectedness class.

Laurentian-Acadian Freshwater Marsh

Macrogroup: Emergent Marsh



This map is a modeled distribution based on current data and is not a substitute for field based inventory. Contact your State Natural Heritage Ecologist for more information about this habitat.

© Maine Natural Areas Program

State Distribution: CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VA, VT, WV

Total Habitat Acreage: 906,723

Percent Conserved: 21.6%

State	State Habitat %	State Acreage	GAP 1&2 (acres)	GAP 3 (acres)	Unsecured (acres)
ME	25%	225,999	13,432	26,406	186,161
NY	25%	224,007	25,309	27,887	170,811
NJ	11%	98,802	17,497	9,039	72,265
VA	7%	61,229	1,285	3,949	55,995
MA	6%	57,011	4,217	12,825	39,969
MD	6%	52,867	2,802	10,177	39,888
PA	5%	48,783	3,585	4,395	40,802
NH	5%	48,642	2,373	10,747	35,523
VT	4%	39,373	2,385	5,542	31,445
DE	2%	21,773	1,518	3,960	16,294
CT	2%	16,321	1,506	2,964	11,851
WV	1%	6,766	156	244	6,366
RI	1%	5,089	413	1,010	3,666
DC	0%	61	0	0	61

Crosswalk to State Name Examples:

Herbaceous Inland Wetland - Freshwater Marshes (CT), Bulrush Deepwater Marsh (DE), Deep Emergent Marsh (MA), Cattail Marsh (ME), Emergent Marsh (NH), Robust Emergent Marsh (NJ), Deep Emergent Marsh/Backwater Slough (NY), Cat-Tail Marsh (PA), Emergent Marsh (RI), American Lotus Aquatic Bed (VA), Cattail Marsh (VT), Emergent Marsh (MD)

Description:

A freshwater emergent or submergent marsh dominated by herbaceous vegetation and associated with isolated basins, edges of streamways, and seepage slopes. Typical plants include cattails, marsh fern, touch-me-not, pondweeds, water lilies, pickerelweed, and tall rushes, species that tolerate sustained inundations and do not persist through the winter. Scattered shrubs are often present and usually total less than 25% cover. Trees are generally absent and, if present, are scattered. Zonation within a marsh is associated with water depth and length of inundation. This is a very broadly defined system, with many variants distributed widely in the Northeast.

Ecological Setting and Natural Processes:

Freshwater marshes are associated with lakes, ponds, headwater basins and slow-moving streams, impoundments, ditches, or any low lying basin that collects water. Such basins are often flat-bottomed and shallow, or marsh vegetation forms a ring around the edge of deeper basins. They typically occur on muck over mineral soil, and as part of a larger wetland complex that may include forested or shrubby swamps, peatlands, and/or open water.

Similar Habitat Types:

Very often occurs with Laurentian-Acadian Wet Meadow-Shrub Swamp, acidic or circumneutral forested swamps, peatlands, and floodplain vegetation in large, diverse complexes.

Crosswalk to State Wildlife Action Plans:

Herbaceous Inland Wetland - Freshwater Marshes (CT), Marshes and Wet Meadows - Deep Emergent Marsh (MA), Emergent Marsh and Wet Meadows (ME), Marsh and Shrub Wetlands (NH), Freshwater Marsh (NY), Wetlands - Emergent Freshwater (PA), Emergent Wetlands - Freshwater Wetland Unspecified (RI), Marshes and Sedge Meadows - Cattail Marsh (VT)

Places to Visit this Habitat:

Moosehorn National Wildlife Refuge | ME
Wharton State Forest | NJ
Five Ponds Wilderness Area | NY
Green Mountain National Forest | VT
Canaan Valley National Wildlife Refuge | WV

Associated Species: *Appendix lists scientific names*

BIRDS: american bittern, american black duck, blue-winged teal, common gallinule, great blue heron, least bittern, marsh wren, pied-billed grebe, sora, swamp sparrow, virginia rail, wood duck

MAMMALS: eastern cottontail, meadow jumping mouse, mink, moose, muskrat, raccoon, southern bog lemming, virginia possum, water shrew

HERPTILES: blue-spotted salamander, northern leopard frog, northern spring peeper, red-spotted newt, spotted turtle

INSECTS: bar-winged Skimmer, ringed emerald, spatterdock darner

PLANTS: autumnal water-starwort (Callitriche hermaphroditica), floating pennywort (Hydrocotyle ranunculoides), hardstem bulrush (Schoenoplectus acutus), marsh felwort (Lomatogonium rotatum), marsh hedge-nettle (Stachys pilosa),whorled pennywort (Hydrocotyle verticillata)

Species of Concern (G1-G4): *Appendix lists scientific names*

BIRDS: black tern, king rail, northern harrier

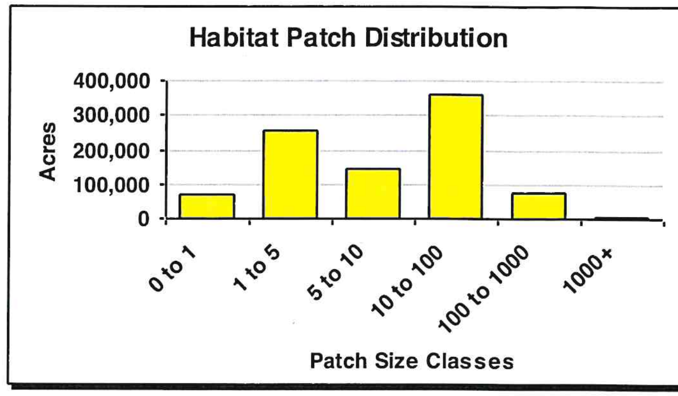
MAMMALS: water shrew

HERPTILES: wood turtle, blanding's turtle

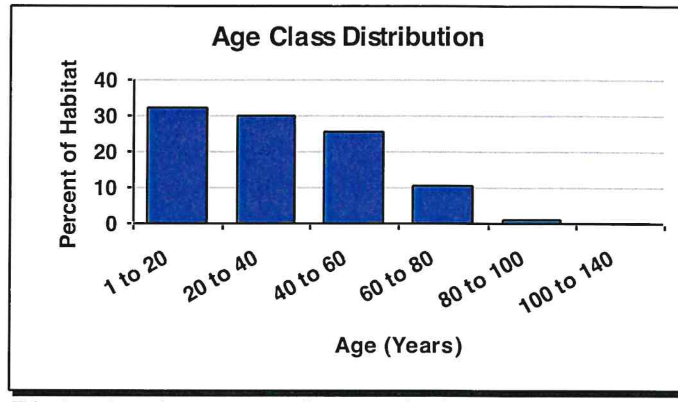
INSECTS: bogbean buckmoth, broadtailed shadowdragon, eyed brown, granitosa fern moth, little bluet, Martha's pennant, scarlet bluet, spatterdock darner, two-spotted skipper

PLANTS: blue maiden-cane (Amphicarpum purshii), fly-poison (Amianthium muscitoxicum), northeastern bladderwort (Utricularia resupinata), ohio goldenrod (Oligoneuron ohioense), Robbins' spikerush (Eleocharis robbinsii), sago pondweed (Potamogeton pectinatus), Sartwell's sedge (Carex sartwellii), slender arrowhead (Sagittaria teres), Walter's sedge (Carex striata), watermeal (Wolffia papulifera)

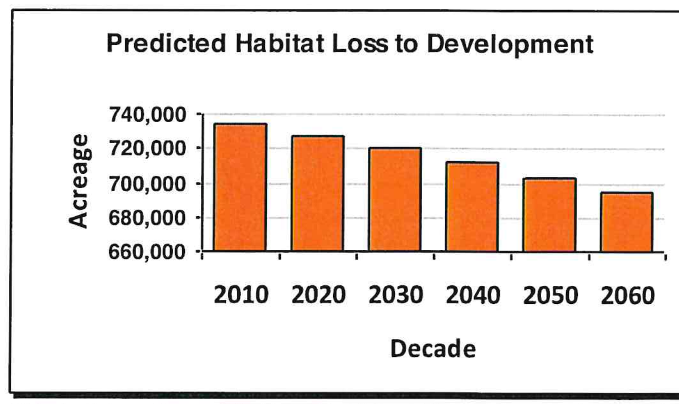
© Maine Natural Areas Program



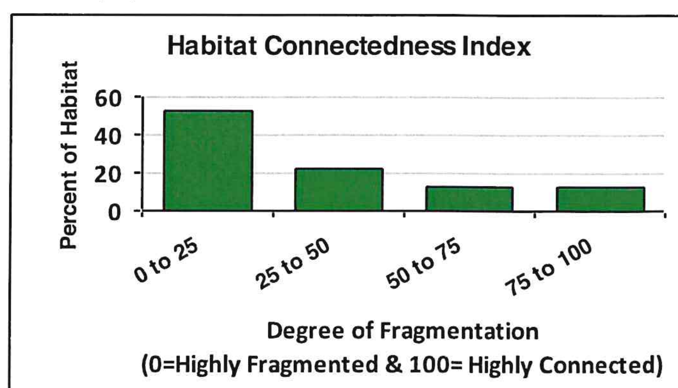
The average patch size for this habitat is 3 acres and the largest single patch is 1,258 acres. This chart shows the proportion of the habitat that is in each patch-size class.



This chart shows the average age of trees associated with this habitat based on forest Inventory data. For non-forested systems or small habitats the average age is influenced by the surroundings.



This chart shows the predicted loss of habitat over the next five decades (39,208 acres) if loss continues at the same rate as 1990-2000. The average rate of loss is 784 acres per year.

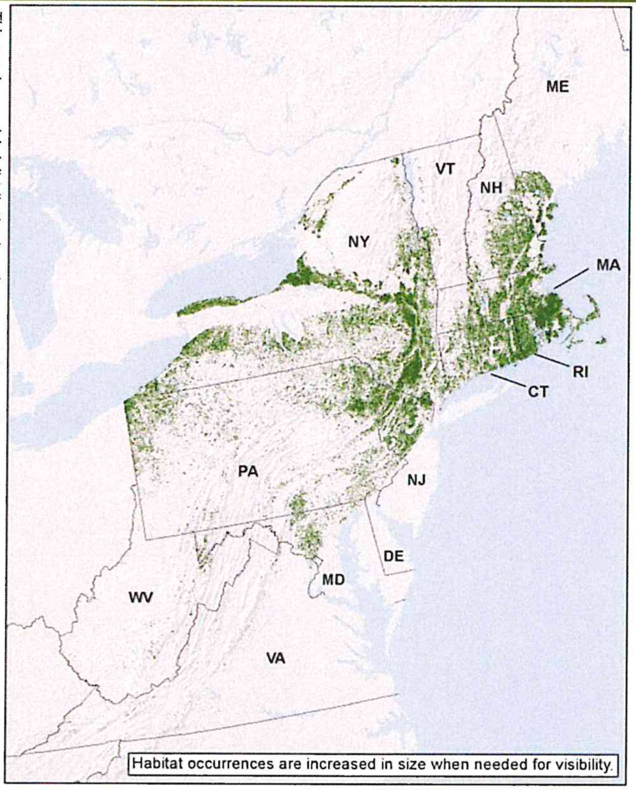


This metric measures how connected or fragmented the land directly surrounding (18 square miles) the habitat is, this the chart shows the proportion of the habitat in each connectedness class.

North-Central Appalachian Acidic Swamp

Macrogroup: Northern Swamp

This map is a modeled distribution based on current data and is not a substitute for field based inventory. Contact your State Natural Heritage Ecologist for more information about this habitat.



© Shane Gebauer (New York Natural Heritage Program)

Description:

A conifer or mixed conifer-hardwood swamp of poorly drained acidic substrates throughout central New England and the Central Appalachians, encompassing a broad range of basin, seepage, and stream-associated wetland communities. Hemlock is usually present and may be dominant. It is often mixed with deciduous wetland trees such as red maple or black gum. Spruce is rarely present. Basin swamps tend to be more nutrient-poor than seepage swamps; in some settings, the two occur adjacent to each other with the basin swamp vegetation surrounded by seepage swamp vegetation on its upland periphery.

State Distribution: CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VA, VT, WV

Total Habitat Acreage: 1,505,822

Percent Conserved: 19.1%

State	State Habitat %	State Acreage	GAP 1&2 (acres)	GAP 3 (acres)	Unsecured (acres)
NY	38%	573,190	12,114	41,979	519,097
MA	18%	272,643	13,012	62,775	196,856
PA	14%	213,320	15,593	42,685	155,042
CT	7%	112,088	6,555	17,448	88,085
NJ	6%	86,025	18,977	6,977	60,071
NH	6%	85,981	3,020	15,884	67,078
RI	4%	67,734	6,254	13,470	48,010
ME	4%	61,849	1,027	4,633	56,189
MD	1%	15,080	424	2,666	11,991
VT	1%	10,235	149	544	9,542
VA	0%	4,111	113	498	3,500
WV	0%	3,060	22	180	2,857
DE	0%	358	6	137	215
DC	0%	147	0	0	147

Crosswalk to State Name Examples:

Acidic Red Maple-Ericaceous Basin Swamp (CT), Red Maple/Tussock Sedge Wooded Marsh (DE), Hemlock/Inland Atlantic White Cedar Swamp (MA), Montane - Piedmont Acidic Seepage Swamp (MD), Red Maple - Skunk Cabbage Swamp (NH), Inland Red Maple Swamp (NJ), Red Maple-Hardwood Swamp (NY), Red Maple - Mixed Shrub Palustrine Woodland (PA), Hemlock/Hardwood Swamp (RI), Central Appalachian Low-Elevation Acidic Seepage Swamp (VA), Red Maple-White Pine-Huckleberry Swamp (VT)

Ecological Setting and Natural Processes:

Occurs at low to mid elevations (generally <2000 feet) in poorly drained depressions that may be in proximity to a stream. The acidic substrate is mineral soil, often with a component of organic muck; if peat is present, it usually forms a thin layer over the mineral soil rather than a true peat substrate.

Similar Habitat Types:

Similar to the Northern Appalachian-Acadian Conifer-Hardwood Acidic Swamp system, but with vegetation characteristic of a warmer climate. North-Central Interior and Appalachian Rich Swamps occur in the same region, but in more enriched hydrologic settings. Small patch poor fens may be embedded within larger wetland complexes of this type.

Crosswalk to State Wildlife Action Plans:

Forested Inland Wetland - Red/Black Spruce Swamps (CT), Forested Swamps (MA), Upland Depression Swamps (MD), Forested wetlands - hardwood swamps (NJ), Mixed Hardwood Swamp (NY), Wetlands - Forested Wetlands and Bogs (PA), Forested Wetlands - Forested Deciduous Wetland Unspecified (RI), Wetland Habitat - Forested (VA), Softwood Swamps - Hemlock Swamp (VT)

Places to Visit this Habitat:

Pachaug State Forest | CT
Douglas State Forest | MA
Great Swamp National Wildlife Refuge | NJ
Stewart State Forest | NY
Delaware State Forest | PA

Associated Species: *Appendix lists scientific names*

BIRDS: blue-headed vireo, great-crested flycatcher, green heron, green-winged teal, northern waterthrush, veery, wood duck, yellow-bellied flycatcher

MAMMALS: black bear, golden mouse, northern flying squirrel, snowshoe hare

HERPTILES: spotted turtle

INSECTS: arctic skipper, belted whiteface, boreal bluet, common sanddragon, emerald spreadwing, great blue skimmer, harlequin darner

PLANTS: bog rosemary (Andromeda polifolia), boreal bog sedge (Carex magellanica), bushy cinquefoil (Potentilla paradoxa), canada lily (Lilium canadense), common labrador tea (Ledum groenlandicum), creeping snowberry (Gaultheria hispidula), hairy hedge-nettle (Stachys pilosa), smooth gooseberry (Ribes hirtellum), swamp dock (Rumex verticillatus), sweet bayberry (Myrica gale)

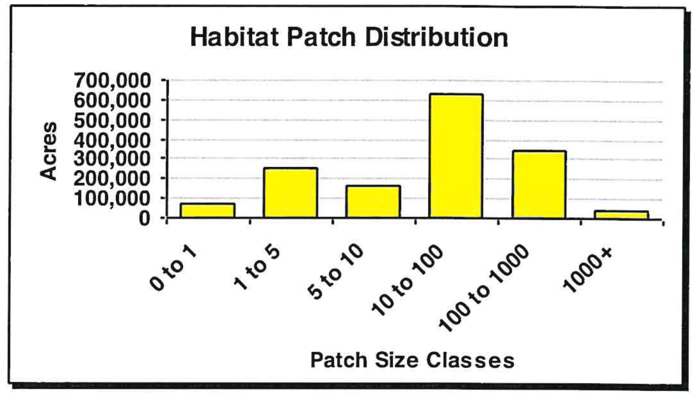
Species of Concern (G1-G4): *Appendix lists scientific names*

BIRDS: loggerhead shrike, olive-sided flycatcher

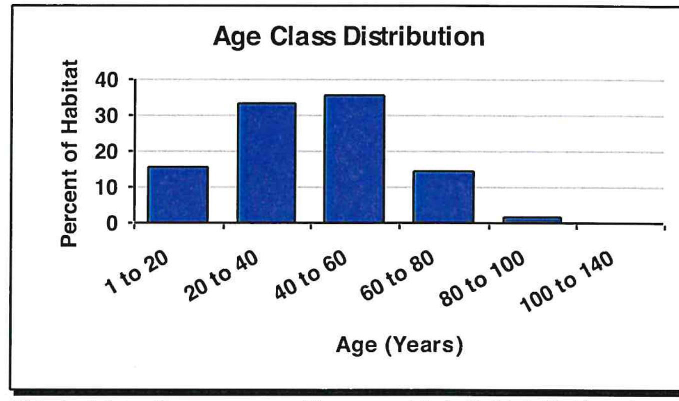
INSECTS: Amber-winged spreadwing, attenuated bluet, bog elfin, bog oligia, broad-lined catopyrrha, chain fern corer moth, macrochilo louisiana, northern brocade moth, white corporal

PLANTS: Collins' sedge (Carex collinsii), dwarf azalea (Rhododendron atlanticum), golden puccoon (Lithospermum caroliniense), incurved umbrella-sedge (Cyperus aristatus), many-fruit false-loosestrife (Ludwigia polycarpa), mitchell's sedge (Carex mitchelliana), tall beakrush (Rhynchospora macrostachya), tall bentgrass (Agrostis altissima)

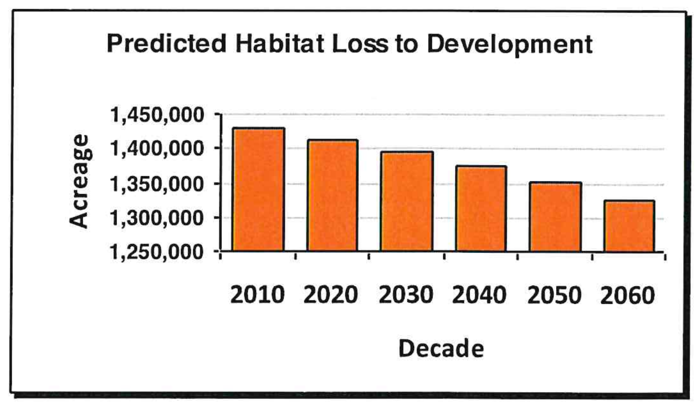
© Hal Malde



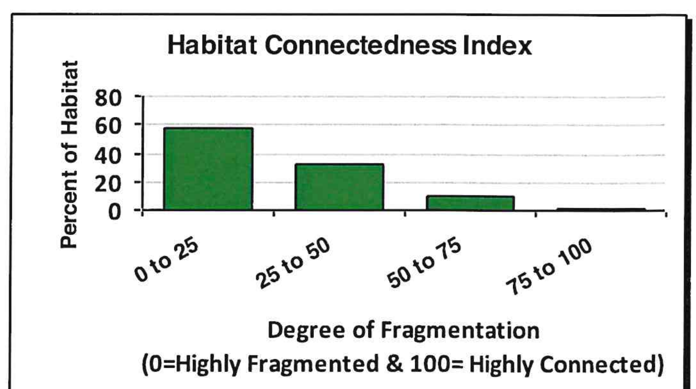
The average patch size for this habitat is 4 acres and the largest single patch is 2,811 acres. This chart shows the proportion of the habitat that is in each patch-size class.



This chart shows the average age of trees associated with this habitat based on forest Inventory data. For non-forested systems or small habitats the average age is influenced by the surroundings.



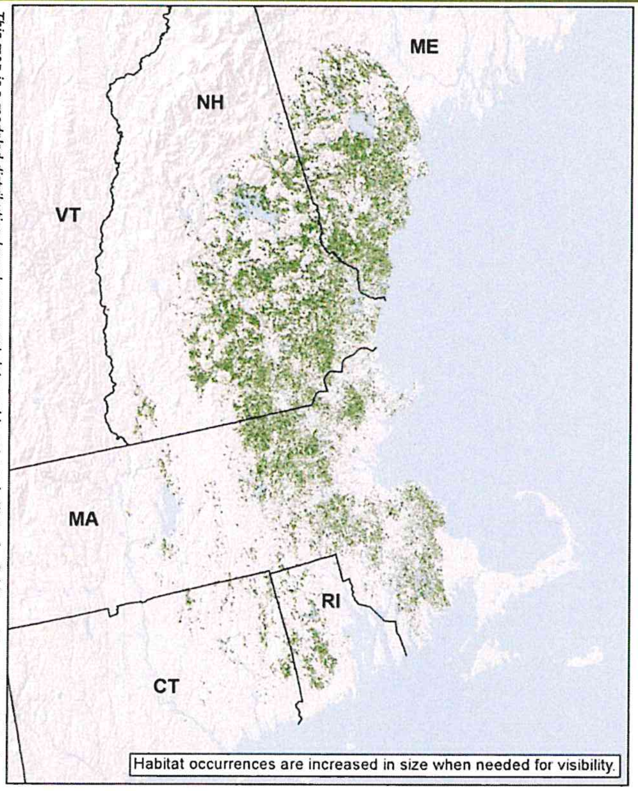
This chart shows the predicted loss of habitat over the next five decades (104,239 acres) if loss continues at the same rate as 1990-2000. The average rate of loss is 2,085 acres per year.



This metric measures how connected or fragmented the land directly surrounding (18 square miles) the habitat is, this the chart shows the proportion of the habitat in each connectedness class.

Northeastern Coastal and Interior Pine-Oak Forest

Macrogroup: Northern Hardwood & Conifer



This map is a modeled distribution based on current data and is not a substitute for field based inventory. Contact your State Natural Heritage Ecologist for more information about this habitat.

© Maine Natural Areas Program

Description:

A mixed forest dominated by white pine, red oak, and hemlock in varying proportions. Red maple and white and black oak are common associates, and northern hardwoods like white ash and American beech can appear as minor components. This forest of low to moderate moisture is usually closed canopy and can be heavily coniferous, with some nearly pure stands of white pine and red maple; hemlock is often more abundant in moister settings. This system type occurs over broad areas, but most of it is in early to mid-successional stages and heavily fragmented. It may well be that it is more widespread and abundant as a result of human occupation of and changes to the New England landscape.

State Distribution: CT, MA, ME, NH, RI

Total Habitat Acreage: 1,538,080

Percent Conserved: 15.8%

State	State Habitat %	State Acreage	GAP 1&2 (acres)	GAP 3 (acres)	Unsecured (acres)
NH	43%	654,780	12,748	89,778	552,254
MA	26%	403,139	9,054	81,076	313,009
ME	25%	391,637	5,423	19,649	366,566
RI	3%	50,081	2,770	15,070	32,241
CT	2%	38,443	835	7,136	30,471

Ecological Setting and Natural Processes:

Usually occurs on flat to rolling glacial landscapes on nutrient-poor, sandy substrates, and is often found near water or wetlands. Upper elevation limit is about 1000' to 1200' (305-365m) in central Massachusetts and southern New Hampshire, but it is usually considerably lower.

Similar Habitat Types:

Often grades upslope to Appalachian (Hemlock-)Northern Hardwood, which has a stronger hardwood component. To the north, grades into Laurentian-Acadian Pine-Hemlock-Hardwood Forest, but it is not a Laurentian-Acadian system (from which white and black oak are essentially absent). Laurentian-Acadian Northern (Pine-)Oak Forests are cooler and drier, and feature red pine.

Crosswalk to State Name Examples:

White Pine-Oak Forest (MA), Oak-Hickory Forest (ME), Mixed Oak/White Pine Forest (RI)

Crosswalk to State Wildlife Action Plans:

Places to Visit this Habitat:

Pachaug State Forest | CT
Harold Parker State Forest | MA
Sebago Lake State Park | ME
Great Bay National Wildlife Refuge | NH
Arcadia Management Area | RI

Associated Species: *Appendix lists scientific names*

BIRDS: black-and-white warbler, blue-headed vireo, brown creeper, eastern wood-pewee, hermit thrush, ovenbird, pine warbler, scarlet tanager, veery, wood thrush

MAMMALS: black bear, gray fox, gray squirrel, northern flying squirrel, southern flying squirrel, white-footed mouse

HERPTILES: jefferson salamander, marbled salamander, black rat snake, eastern hognose snake, eastern worm snake, northern black racer, northern coppperhead, northern redbelly snake

PLANTS: Sundial Lupine (Lupinus perennis), Large Whorled Pogonia (Isotria verticillata), Northern Blazingstar (Liatris scariosa var. novae-angliae), Philadelphia Panicgrass (Panicum philadelphicum), Sassafras (Sassafras albidum), Swamp Saxifrage (Saxifraga pensylvanica), Sand Violet (Viola adunca), Pale Green Orchid (Platanthera flava var. herbiola), Redtop Panicgrass (Panicum rigidulum var. pubescens)

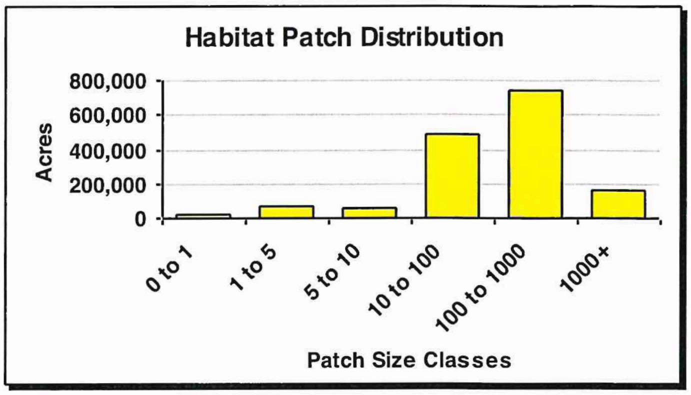
Species of Concern (G1-G4): *Appendix lists scientific names*

BIRDS: eastern whip-poor-will

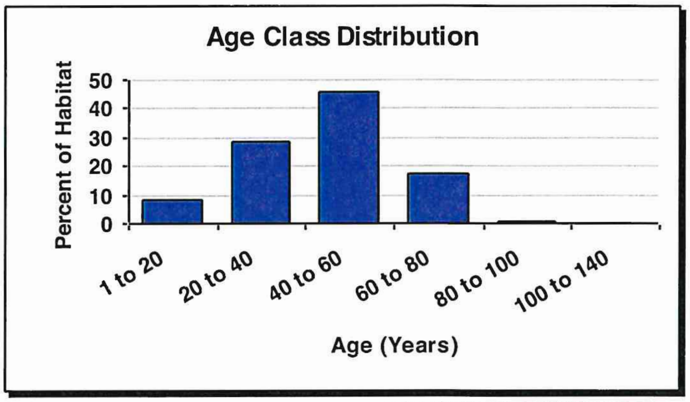
INSECTS: red-winged sallow, ringed boghaunter

PLANTS: small whorled pogonia (Isotria medeoloides), climbing fern (Lygodium palmatum), plymouth gentian (Sabatia kennedyana)

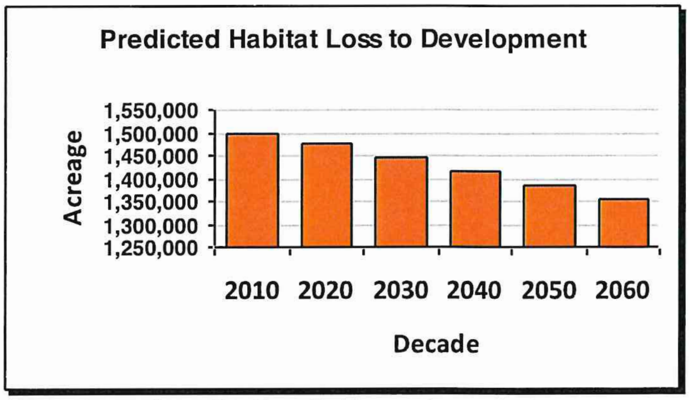
© Patricia Swain (Massachusetts Division of Fisheries & Wildlife/Natural Heritage & Endangered Species Program)



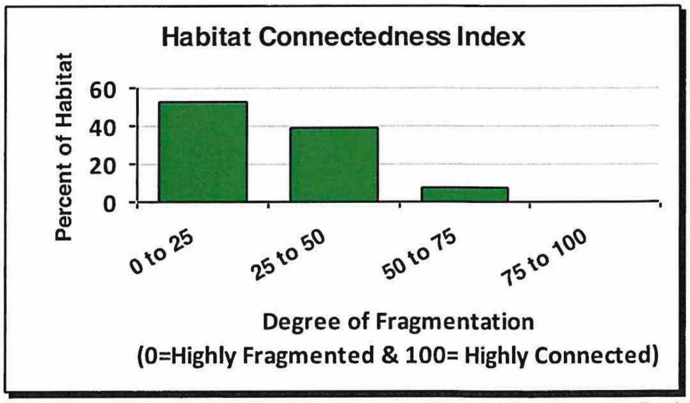
The average patch size for this habitat is 10 acres and the largest single patch is 2,638 acres. This chart shows the proportion of the habitat that is in each patch-size class.



This chart shows the average age of trees associated with this habitat based on forest Inventory data. For non-forested systems or small habitats the average age is influenced by the surroundings.



This chart shows the predicted loss of habitat over the next five decades (146,436 acres) if loss continues at the same rate as 1990-2000. The average rate of loss is 2,929 acres per year.



This metric measures how connected or fragmented the land directly surrounding (18 square miles) the habitat is, this the chart shows the proportion of the habitat in each connectedness class.

S41 E70

One x One Degree

Climate Change Atlas Tree Species

Current and Potential Future Habitat, Capability, and Migration

Landscape Change Research Group
Iverson, Peters, Prasad, Matthews
USFS Northern Research Station
Delaware, OH

Common Name	Scientific Name	Range	MR	%Cell	FIAsum	FIAiv	ChngCl45	ChngCl85	Adap	Abund	Capabil45	Capabil85	SHIFT45	SHIFT85	SSO	N
eastern white pine	Pinus strobus	WDH	High	66.1	1950.37	17.63	Lg. dec.	Lg. dec.	Low	Abundant	Poor	Poor			0	1
red maple	Acer rubrum	WDH	High	74.4	1764.37	13.7	Sm. dec.	Sm. dec.	High	Abundant	Good	Good			1	2
pitch pine	Pinus rigida	NSH	High	77.9	1582.47	14.86	Sm. dec.	Lg. dec.	Medium	Abundant	Fair	Fair			0	3
scarlet oak	Quercus coccinea	WDL	Medium	83.7	750.27	7.09	No change	Sm. dec.	Medium	Abundant	Good	Fair			1	4
white oak	Quercus alba	WDH	Medium	77.4	506.17	4.75	Sm. inc.	No change	High	Abundant	Very Good	Very Good			1	5
black oak	Quercus velutina	WDH	High	69.5	438.94	5.21	Sm. inc.	Sm. inc.	Medium	Common	Good	Good			1	6
black cherry	Prunus serotina	WDL	Medium	35.5	144.98	3.46	Lg. inc.	Lg. inc.	Low	Common	Good	Good			1	7
blackgum	Nyssa sylvatica	WDL	Medium	23.5	139.76	1.8	Sm. inc.	Sm. inc.	High	Common	Very Good	Very Good			1	8
yellow birch	Betula alleghaniensis	NDL	High	12.2	65.75	2.73	No change	No change	Medium	Common	Fair	Fair			1	9
eastern redcedar	Juniperus virginiana	WDH	Medium	25.7	62.59	1.13	Lg. inc.	Lg. inc.	Medium	Common	Very Good	Very Good	Infill ++	Infill ++	1	10
bear oak; scrub oak	Quercus ilicifolia	NSLX	FIA	16.9	59.73	2.9	Unknown	Unknown	Medium	Common	FIA Only	FIA Only			0	11
eastern hemlock	Tsuga canadensis	NSH	High	9	58.93	4.33	No change	No change	Low	Common	Poor	Poor	Infill +	Infill +	0	12
American beech	Fagus grandifolia	WDH	High	11.5	41.14	1.66	Lg. inc.	Lg. inc.	Medium	Rare	Good	Good	Infill ++	Infill ++	2	13
sweet birch	Betula lenta	NDH	High	7.6	37.03	4.82	No change	No change	Low	Rare	Very Poor	Very Poor			0	14
honeylocust	Gleditsia triacanthos	NSH	Low	0.3	33.71	0.57	Sm. dec.	Sm. dec.	High	Rare	Poor	Poor			0	15
northern red oak	Quercus rubra	WDH	Medium	9.5	31.31	0.79	Sm. inc.	Lg. inc.	High	Rare	Good	Good			1	16
post oak	Quercus stellata	WDH	High	9.6	30.44	4.75	No change	Sm. inc.	High	Rare	Fair	Good	Infill +		2	17
Atlantic white-cedar	Chamaecyparis thyoides	NSH	Low	6.2	25.06	0.81	No change	No change	Low	Rare	Very Poor	Very Poor			0	18
black locust	Robinia pseudoacacia	NDH	Low	11.9	19.08	1.96	Sm. inc.	Lg. inc.	Medium	Rare	Fair	Good	Infill +	Infill ++	2	19
sassafras	Sassafras albidum	WSL	Low	13.7	14.09	0.64	Lg. inc.	Lg. inc.	Medium	Rare	Good	Good			1	20
black willow	Salix nigra	NSH	Low	9.5	12.68	8.14	Sm. dec.	Sm. dec.	Low	Rare	Very Poor	Very Poor			0	21
white ash	Fraxinus americana	WDL	Medium	7.7	11.62	1.52	Sm. inc.	Lg. inc.	Low	Rare	Poor	Fair	Infill +	Infill +	1	22
American holly	Ilex opaca	NSL	Medium	5.2	10.4	1.15	Lg. inc.	Lg. inc.	Medium	Rare	Good	Good		Infill ++	2	23
tamarack (native)	Larix laricina	NSH	High	1.9	10.28	1.29	Very Lg. dec.	Very Lg. dec.	Low	Rare	Lost	Lost			0	24
shagbark hickory	Carya ovata	WSL	Medium	10.5	10.17	0.98	Sm. dec.	Sm. dec.	Medium	Rare	Very Poor	Very Poor			2	25
American elm	Ulmus americana	WDH	Medium	4.2	9.14	0.67	Sm. dec.	No change	Medium	Rare	Very Poor	Poor		Infill +	2	26
Norway spruce	Picea abies	NSH	FIA	5.7	8.91	0.73	Unknown	Unknown	NA	Rare	NNIS	NNIS			0	27
gray birch	Betula populifolia	NSL	Low	8.5	8.38	0.47	No change	Sm. inc.	Medium	Rare	Poor	Fair			1	28
sugar maple	Acer saccharum	WDH	High	3.6	6.67	1.64	No change	No change	High	Rare	Fair	Fair		Infill +	2	29
chokecherry	Prunus virginiana	NSLX	FIA	1.2	5.33	0.43	Unknown	Unknown	Medium	Rare	FIA Only	FIA Only			0	30
pignut hickory	Carya glabra	WDL	Medium	3.9	4.38	1.15	Sm. inc.	Lg. inc.	Medium	Rare	Fair	Good	Infill +	Infill ++	2	31
bigtooth aspen	Populus grandidentata	NSL	Medium	0.9	4	0.25	No change	No change	Medium	Rare	Poor	Poor	Infill +		2	32
red pine	Pinus resinosa	NSH	Medium	5.2	3.47	1.22	Lg. dec.	Lg. dec.	Low	Rare	Very Poor	Very Poor			0	33
American hornbeam; muscle	Carpinus caroliniana	WSL	Low	1.9	2.4	0.31	No change	Lg. inc.	Medium	Rare	Poor	Good		Infill ++	2	34
pin cherry	Prunus pensylvanica	NSL	Low	0.8	1.94	0.1	Lg. dec.	Very Lg. dec.	Medium	Rare	Very Poor	Lost			0	35
green ash	Fraxinus pennsylvanica	WSH	Low	1.9	1.03	0.13	Lg. inc.	Lg. inc.	Medium	Rare	Good	Good			2	36
shortleaf pine	Pinus echinata	WDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3	37
longleaf pine	Pinus palustris	NSH	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			0	38
loblolly pine	Pinus taeda	WDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3	39
Virginia pine	Pinus virginiana	NDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3	40
striped maple	Acer pensylvanicum	NSL	Medium	0	0	0	Unknown	Unknown	Medium	Absent	Unknown	Unknown			0	41
cittamwood/gum bumelia	Sideroxylon lanuginosum ssp	NSL	Low	0	0	0	Unknown	New Habitat	High	Absent	Unknown	New Habitat			0	42
black hickory	Carya texana	NDL	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			0	43
mockernut hickory	Carya alba	WDL	Medium	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate +	3	44
flowering dogwood	Cornus florida	WDL	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat		Migrate +	3	45
sweetgum	Liquidambar styraciflua	WDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat	Migrate +	Migrate ++	3	46
yellow-poplar	Liriodendron tulipifera	WDH	High	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate +	3	47
Osage-orange	Maclura pomifera	NDH	Medium	0	0	0	Unknown	Unknown	High	Modeled	Unknown	Unknown			0	48
red mulberry	Morus rubra	NSL	Low	0	0	0	Unknown	Unknown	Medium	Modeled	Unknown	Unknown			0	49
southern red oak	Quercus falcata	WDL	Medium	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate +	3	50
blackjack oak	Quercus marilandica	NSL	Medium	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat			3	51
water oak	Quercus nigra	WDH	High	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3	52
willow oak	Quercus phellos	NSL	Low	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			3	53

S41 E70

One x One Degree

Climate Change Atlas Tree Species

Current and Potential Future Habitat, Capability, and Migration

Landscape Change Research Group
Iverson, Peters, Prasad, Matthews
USFS Northern Research Station
Delaware, OH

Common Name	Scientific Name	Range	MR	%Cell	FIAsum	FIAiv	ChngCl45	ChngCl85	Adap	Abund	Capabil45	Capabil85	SHIFT45	SHIFT85	SSO	N
chestnut oak	Quercus prinus	NDH	High	0	0	0	New Habitat	New Habitat	High	Absent	New Habitat	New Habitat	Migrate +	Migrate +	3	54
bluejack oak	Quercus incana	NSL	Low	0	0	0	Unknown	New Habitat	Medium	Absent	Unknown	New Habitat			0	55
American mountain-ash	Sorbus americana	NSL	Low	0	0	0	Unknown	Unknown	Low	Absent	Unknown	Unknown			0	56
winged elm	Ulmus alata	WDL	Medium	0	0	0	New Habitat	New Habitat	Medium	Absent	New Habitat	New Habitat			0	57

APPENDIX F-G

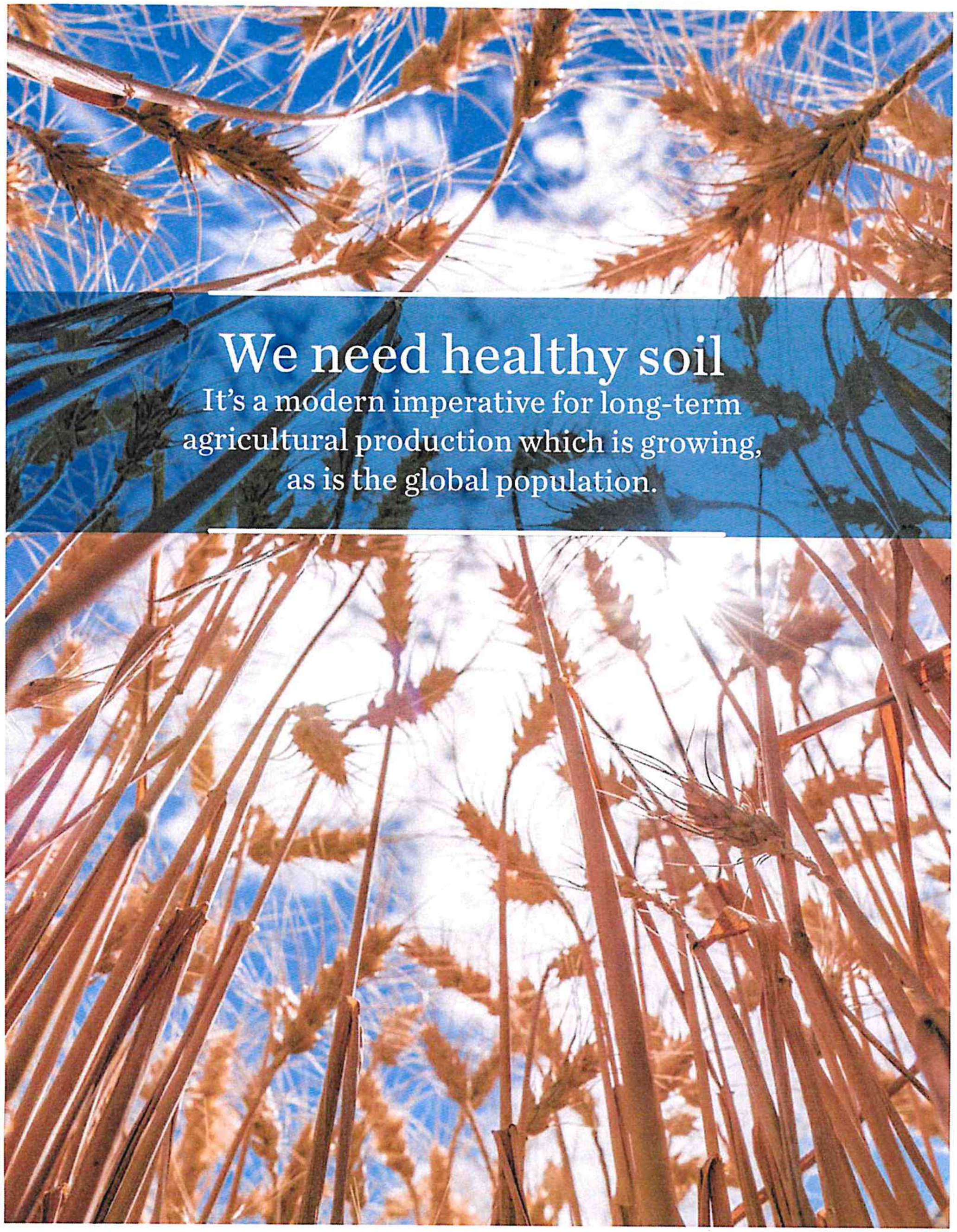
Soils

reThink Soil

A Roadmap to U.S. Soil Health

A roadmap for collective action to secure the conservation and economic benefits of healthy soils

The Nature Conservancy



reThink Soil: A Roadmap for U.S. Soil Health

Soil health is inextricably linked to broader conservation goals

Improving soil health on U.S. agricultural land holds the potential for achieving meaningful conservation and economic benefits, as well as mitigating the growing threat of climate change. Healthy soil is the cornerstone of life on earth, facilitating ecosystem biodiversity, ample food production, effective water filtration and storage, and carbon sequestration.

Advancements in agricultural technology throughout the past century have allowed farmers to feed a population that has grown from less than 2 billion people to more than 7 billion today. Over the same time period, however, soil managed for agricultural purposes in the U.S. has degraded, losing as much as 60% of its original organic carbon content.[1] The degradation of soils has undermined the productivity of farmers and the resilience of croplands while leading to significant direct and indirect environmental impacts annually on a national level:

- 346 million metric tons of greenhouse gas emissions[2]
- 4.4 billion pounds of nutrient loss to the environment[3]
- 996 million metric tons of soil erosion[4]
- 48.4 million acre-feet of water used for irrigation[5]

Drawing upon respected analyses in soil health literature, The Nature Conservancy estimates the annual societal and environmental costs of the status quo are up to $85.1 billion annually through unintended effects on human health, property, energy, endangered species, loss of biodiversity, eutrophication, contamination, agricultural productivity, and resilience. As global food demand grows, U.S. agriculture needs to be competitively positioned to increase production to meet both domestic and international food requirements. Managing for soil health serves as a nexus for achieving increased production while reducing the societal and environmental impacts of the current U.S. row crop production system.

Improving soil health can yield significant benefits

The U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service (NRCS) defines soil health as "the continued capacity of the soil to function as a vital living ecosystem that sustains plants, animals, and humans." The concept of adaptive management is inherent in this well-accepted definition. Adaptive management for soil health means minimizing soil disturbance while optimizing plant diversity, allowing more continuous plant and residue covers to create vital, living ecosystems in the soil. In turn, the soil nurtures a complex web of microbes with the healthiest soils often being those with the greatest diversity and abundance of life. Healthy soil more efficiently stores and recycles carbon, water, and nutrients such as nitrogen and phosphorous.

The full version of this abridged paper (available at nature.org/soil) presents The Nature Conservancy's vision for soil health in the U.S., with the goal of a majority of farms managed for soil health by 2025, and a proposed roadmap for collective action amongst key stakeholders. The full version includes a situation analysis, estimation of economic and conservation benefits of soil health, citations to literature used in writing the paper, and additional soil health resources.

Soil health as a scalable conservation opportunity

The mission of The Nature Conservancy is to conserve the land and water upon which all life depends. Over the past 65 years, the Conservancy has protected millions of threatened lands, waters, and species. Yet the vision of the organization is a world where people and nature thrive together. To achieve this vision, we must attend to the major global challenges facing humanity and support the solutions that can be found in nature.

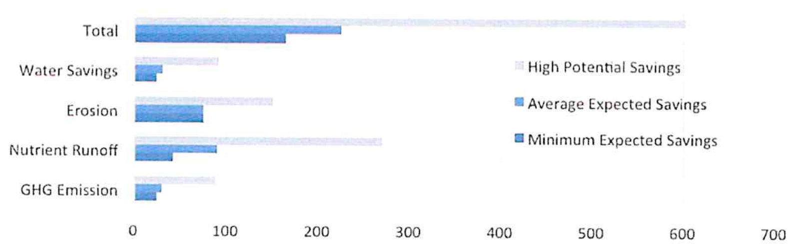
For this purpose, The Nature Conservancy examined the opportunity to deliver scalable conservation gains in the U.S. by focusing on the adoption of soil health management systems across row crop agricultural landscapes. The Conservancy assembled a multidisciplinary team of internal experts, interviewed internal and external stakeholders, developed an analytical approach to estimate the technical benefits, and developed a strategic theory of change consistent with our Conservation by Design 2.0 methodology.

While the conservation opportunity is sufficiently large, the barriers to widespread adoption of soil health systems are multiple and persistent. Therefore, more collaborative efforts across capable and committed partners, coupled with greater levels of sustained investment, will be required to make meaningful progress. The Conservancy recommends taking collective action across a "roadmap" of highly coordinated set of strategic inventions toward realizing benefits which accumulate among farmers, communities, and future generations. In doing so, we can "reThink" our opportunities with soil.

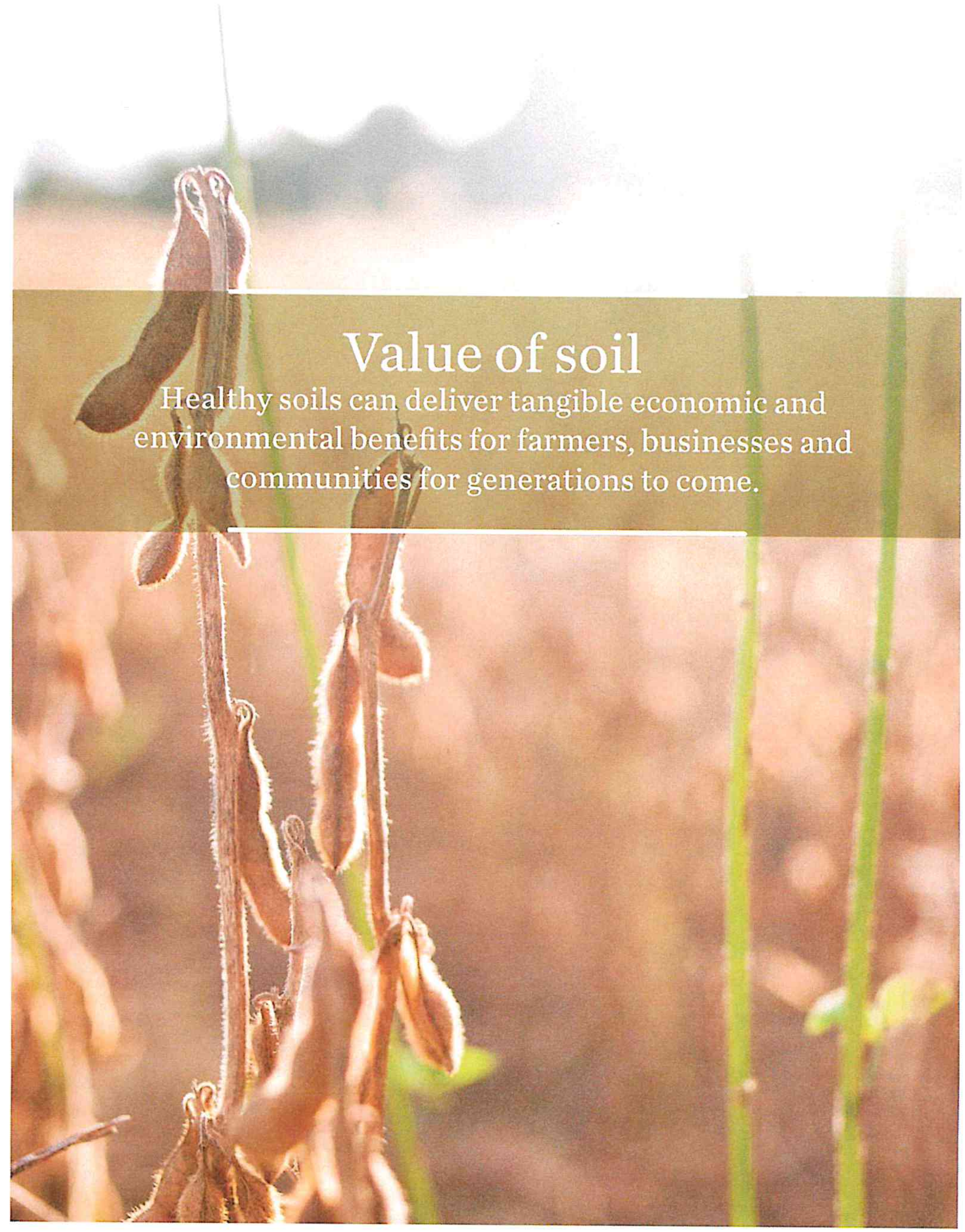
At the farm level, the benefits of improved soil health include higher rates of productivity and profitability over the long term, as well as reputational value for farmers who put conservation at the center of their management approach. At the societal level, the benefits of boosting soil health are even more profound, including improved water quality, filtration, and storage; richer biodiversity; and reduced greenhouse gas emissions, mitigating the impacts of climate change.

In order to estimate the scale of benefits attributable to changes in soil health, the Conservancy chose three management practices—reduced tillage, cover cropping, and crop rotations—to serve as proxies for the adaptive soil health systems, which will vary geographically. Reduced tillage decreases disturbance of the soil, thereby improving the soil's ability to retain nutrients and sequester carbon dioxide from the atmosphere. Cover cropping between cash crop seasons is a heritage practice that maximizes the time each year that living roots are building soil nutrients and keeping the surface protected. Diverse crop rotations help build nutrients, limit erosion, and foster soil carbon sequestration. While these three practices do not represent the full spectrum of soil health solutions available, they serve as valuable measurement proxies because of the extensive, validated research on the conservation and economic benefits of each.

Economic benefits ($M) of increased adoption by 1% of U.S. corn-soy-wheat acres



Estimated benefits based on minimum, average, and maximum potential impacts of cover crops, conservation tillage, and increased rotation practices



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reThink Soil

A Roadmap to U.S. Soil Health

SCIENCE AND RESEARCH

Overcome the science and research gap to support expansion of soil health management

1. Create cost-effective soil health measurement standards and tools
Create accurate, accessible, and standardized methods for rapid measurement of key soil health indicators at a scale that impacts management choices by farmers and landowners
LEAD ACTORS: Research institutions, private sector, Soil Health Institute, grower organizations

2. Develop operational management strategies for adaptively integrating soil health practices and systems
Build evidence and understanding among farmers regarding operational strategies locally tailored for integrating multiple soil health practices on a farm, including optimal cover crop programs
LEAD ACTORS: Research institutions, extension, conservation districts, NRCS, grower organizations, agricultural retailers, private sector

3. Advance the science of soil health benefits
Further quantify the economic costs, benefits and environmental impacts of different management practices on soil health, including organic systems, with consideration for different regions, soil types, and cropping systems
LEAD ACTORS: Research institutions, Soil Health Institute

ECONOMIC

Overcome economic obstacles by providing the market systems to secure soil health

4. Align incentives between landowners and farmers
Cultivate understanding among absentee landowners of soil health benefits for society and land value, encouraging new lease arrangements integrating soil health systems and practices
LEAD ACTORS: Landowners, farm management companies, lenders, etc.

5. Leverage technological innovation to overcome operational hurdles
Leverage technological innovations, such as sensors, drones, cover crop seeding equipment, precision agriculture software and hardware to advance adoption and continued implementation of soil health systems and practices
LEAD ACTORS: Public and private research institutions, agricultural retailers

6. Provide broader access to products and services supporting soil health
Develop new business models with agricultural retailers providing broader access to new products and services in order to accelerate the adoption of soil health systems and practices
LEAD ACTORS: Agricultural retailers

7. Create market signals in sustainability programs for soil health
Develop improved indicators rewarding soil health management outcomes in sustainability assessment programs, aligning the incentives of farmers and society
LEAD ACTORS: Field to Market, food companies, agribusinesses, leading sustainability programs and farmers

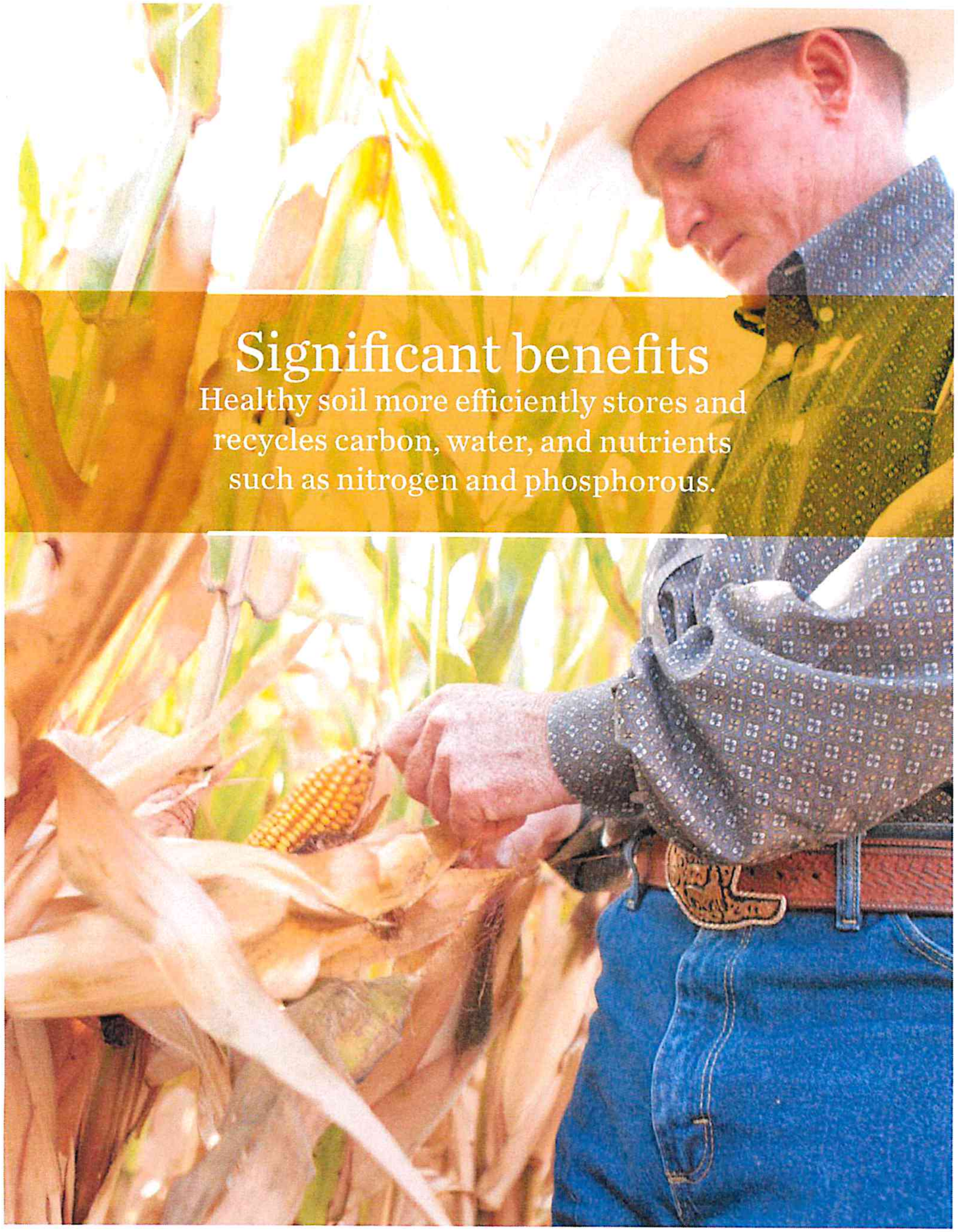
POLICY

Improve the policy environment to advance soil health

8. Reward farmers who optimize long-term soil health with lower crop insurance premiums
Advocate for federally subsidized crop insurance programs to value the benefits generated from improved soil health profiles through lower insurance premiums
LEAD ACTORS: Commodity organizations, agri-food sector, conservation organizations seeking to expand constituency, federal and state governments

9. Support policies that enable greater investment in soil health
Support state and federal policy improvements focusing on reducing barriers to soil health practice adoption, targeting priority areas for implementation, and comprehensively assess impacts for societal value
LEAD ACTORS: State and federal governments, conservation organizations seeking to expand constituency

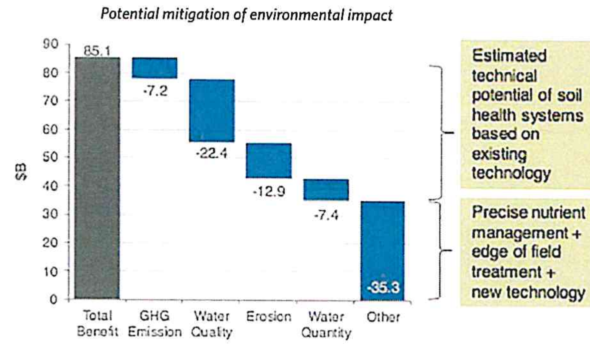
10. Build a more diverse constituency for soil health policy
Build a strong and diverse network of supporters for soil health policy, including farmers, landowners, the agri-food sector, community leaders, and societal interest groups
LEAD ACTORS: Farmers, landowners, agri-food sector, community leaders, societal interest groups



Significant benefits

Healthy soil more efficiently stores and recycles carbon, water, and nutrients such as nitrogen and phosphorous.

At the high end estimates, the combined potential impact of increased soil health practices could mitigate environmental impacts by almost $50B annually



Restoring soil health can create net economic benefits for farmers while removing environmental and societal costs associated with intensified agricultural production that will otherwise amass into an unfunded liability to be passed along to future generations.

The Nature Conservancy estimates that the benefits or "size of the prize" for adopting adaptive soil health management systems in the U.S. are significant. Our base case scenario for estimating benefits suggests that for each 1% of cropland[6] adopting an adaptive soil health system, annual economic benefits translate into $226 million of societal value through increased water capacity, reduced erosion and nutrient loss to the environment, and reduced greenhouse gas emission, as well as $37 million of on-farm value through greater productivity. In the most optimistic case, the team estimated soil health solutions could address up to $50 billion in social and environmental impacts annually across the U.S.

Off-farm economic benefits (corn, soy & wheat acres) [gross]

U.S. Potential Societal Benefits (in $ millions / year)	Effect of increased adoption by 1% of U.S. acres of corn-soy-wheat	Effect of adoption on 50% of U.S. acres of corn-soy-wheat	Effect of adoption on 100% of U.S. acres of corn-soy-wheat
GHG emission	$29.7	$903	$2,387
Nutrient loss	$90.1	$2,951	$7,457
Erosion	$75.8	$2,657	$6,447
Water benefits	$30.6	$923	$2,453
Total	$226	$7,435	$18,744

On-farm economic benefits (corn acres only) [net]

	Effect of increased adoption by 1% of U.S. acres of corn	Effect of adoption on 50% of U.S. acres of corn	Effect of adoption on 100% of U.S. acres of corn
On-farm profit potential; corn only (in $ millions / year)	$36.7	$1,156	$2,991

Estimates of GROSS societal off-farm economic benefits and NET on-farm economic benefits accruing to farmers attributable to adoption of the adaptive soil health system. Benefits are listed with the mean estimated value of economic benefits.

Restoring soil health can create net economic benefits for farmers while removing environmental and societal costs associated with intensified agricultural production that will otherwise amass into an unfunded liability to be passed along to future generations. The Nature Conservancy has a rich history achieving conservation goals for the most important landscapes in the world, and this must include the agricultural landscapes that meet society's critical need for food, fiber, and energy, as well as the people whose livelihoods depend on those lands. The Conservancy views soil health restoration as the primary way to bring economic value to farmers while achieving conservation goals. Yet, this strategy is part of an emerging conservation solution set—which also includes targeted edge-of-field and in-stream solutions for water quality and more precise nutrient management timed to plant needs.

Barriers to achieving soil health are multifaceted

A small yet influential segment of farmers, including organic farmers, have catalyzed a movement toward a new array of both innovative and heritage soil health practices that protect and build soils. Despite these efforts, widespread adoption of soil health systems appears unlikely unless the multiple barriers to adoption are systemically identified and addressed. These barriers, which are undeniably complex, cluster around three key areas: science, economics, and policy.

First, the science of soil health is still evolving. Accurate, standardized, and cost-effective on-field soil health measurement tools have yet to be developed and widely implemented. As a result, soil health is not easily measured, thus limiting the ability for timely management responses by farmers, or the development of useful policy and economic signals in the marketplace. Likewise farmers contemplating this change need more evidence and demonstration of operational strategies locally tailored for integrating specific soil health practices on their farms.

> The Nature Conservancy seeks a transformation of the U.S. cropland paradigm, with soil health becoming the leading indicator of economic and environmental outcomes on the majority (>50%) of farms by 2025.

Second, current business models between landowners, farmers, and agricultural retailers do not adequately encourage soil health management. Conservation systems and practices to restore soil health introduce potential operational complexities and may require farmers to make higher capital or variable cost outlays in the short term. Recouping these investments requires a longer planning horizon. Yet the majority of farmers in the U.S. lease the land they manage. While lease terms vary, most incent short-term planning and do not allow the farmer to recover costs or plan for a longer horizon. Large segments of landowners have not been brought into the broader conversation about the value of soil health improvements for society and land value. Therefore, lease arrangements do not adequately factor in soil health improvements. Likewise, agricultural retailers are often trusted advisors to farmers, and opportunities exist for engaging retailers in providing agronomic knowledge about the transition to soil health systems as well as selling products and services designed to improve soil health.

Finally, public policy has not been fully developed and implemented to encourage landowners and farmers to reduce production risk and support soil health investments requiring longer planning horizons. Given the value creation potential to address important social and environmental challenges, broadening the coalition of interested stakeholders who advocate for these improvements in state and federal policies is essential.

A roadmap to transform the agricultural management paradigm

A notable change is underway, and momentum is gathering around the opportunity presented by soil health systems. The Nature Conservancy is not alone in recognizing the potential of soil health to be the catalyst for delivering conservation and productivity benefits at a meaningful scale.

Innovative initiatives by government agencies such as USDA, NRCS, and the U.S. Department of Energy (DOE), as well as newer public-private entities such as the Soil Health Partnership and the Soil Health Institute, are already making important progress. The Conservancy is partnering with these efforts and other public and private sector organizations to help further a paradigm shift, but greater coordination, innovation, and investment is still needed.

Rather than a constellation of well-intended efforts, the Conservancy calls for a coordinated and aligned approach toward the goal of transforming the U.S. cropland management paradigm, with soil health becoming the leading indicator of economic and environmental outcomes on the majority (>50%) of farms by 2025. In doing so, we can significantly improve the pace and certainty of reversing the negative trends on water quality over the next decade while establishing one of the most cost effective natural climate solutions. Specific and measureable benefits of attaining the proposal goal in the U.S. are summarized on an annual basis:

- **Mitigating 25 million metric tons of greenhouse gas emissions,**
- **Reducing 344 million pounds of nutrient loss to the environment,**
- **Eliminating 116 million metric tons of soil erosion,**
- **Creating 3.6 million acre-feet of available water capacity in cropland soils.**

Taken together, these improvements will create a diverse basket of environmental and social benefits valued at $7.4 billion annually. Through higher rates of productivity resulting from higher yields or lower production costs, farmers stand to gain modest, albeit meaningful net economic benefits of $37 million for each one percent of cropland transformed, or $1.2 billion annually across the U.S. corn belt.

The Conservancy proposes a roadmap for collective action to secure the conservation and economic benefits of healthy soils. Coordinated and collective actions across ten priorities spanning science, economic, and policy outcomes will overcome the multiple barriers to widespread adoption. The roadmap is offered as a starting point for greater collaboration. In time, it will conform to the combined knowledge and capacity of committed partners, as well as the evolving state of the science, economics, and public policy environment regarding soil health.

Conclusions and invitation

Managing U.S. croplands for soil health offers an exciting value proposition to farmers and society. The Nature Conservancy is compelled—by both our mission and the size of the benefits for people and nature—to lend our support to this important cause. In doing so, we intend to bring about a more concerted and coordinated effort, accelerating the adoption of soil health systems and achieving economic and environmental outcomes at a scale that addresses our most pressing global challenges.

The Conservancy is committed to expanding our capacity to seize this important and timely opportunity. The science agenda for soil health will require significant, long-term investments and collaborations. The Conservancy is expanding scientific capacity through the addition of a new lead scientist role for soils. As such, the Conservancy will be a more capable partner with organizations charting the future of soil health research.

It is clear new business models will be necessary to align the economic interests of farmers, landowners and agricultural retailers on soil health benefits. The Conservancy seeks to be a collaborative and positive force for the advancement of new value creation opportunities. Expanding on the successful model of the Soil Health Partnership will be a priority given the importance of farmer-to-farmer knowledge transfer with adaptive and locally tailored soil health solutions.

The Conservancy has actively engaged in discussions about the current and future opportunities for improved public policies in support of soil health at the state and federal level. These efforts include targeting existing conservation programs for the highest impact as well as policy planning efforts on the future of crop insurance. The Conservancy's network of state chapters and trustees can serve as effective advocates for public policies in support of the soil health movement.

The Nature Conservancy invites interested organizations and individuals to share feedback and expressions of interest in the ideas articulated in this paper by emailing soil@tnc.org.

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[1] Lal, R. (2004) Soil Carbon Sequestration Impacts on Global Climate Change and Food Security. Science. Vol 304 pp 1623-1627 Special Section: Soils-The Final Frontier.

[2] As estimated using USDA ERS data of fossil fuel combustion, crop residue burning, and soil management (http://www.ers.usda.gov/media/434512/tb1909_1_.pdf)

[3] As estimated using average nitrogen application reported by USDA ERS and typical leaching as reported by a USDA NRCS study (http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx, Tables 10, 22, 28 and http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/crops/?cid=nrcs143_014202)

[4] As estimated using USDA NRCS figures for wind and water erosion (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/technical/nra/nri/results/?cid=stelprdb1041678)

[5] As estimated using figures from a USDA ERS report (http://www.ers.usda.gov/media/884158/eib99.pdf)

[6] While there are more than 400 million acres of cropland in the U.S., our estimates include the three largest commodity crops: corn, soybeans, and wheat. One percent of these acres is equivalent to 2.3 million acres.

Section 319
NONPOINT SOURCE PROGRAM SUCCESS STORY

Massachusetts

Restoring Historical Cranberry Bogs Improves Aquatic Life in the Eel River

Waterbody Improved

Historical cranberry farming activities in Massachusetts' Eel River resulted in aquatic life impairments caused by fish barriers and non-native aquatic plants. As a result, in 2001 the state of Massachusetts listed Eel River as Category 4c in the state's Integrated Report, for non-attainment of the state's water quality standard for aquatic life. Project partners performed a series of restoration activities that simplified channel and floodplain structure and addressed barriers to fish and wildlife passage as well as Eel River's altered hydrology and degraded wetland soils. Aquatic life improved after completion of the restoration project.

Problem

The Eel River (Figure 1) is a small spring-fed system that flows east of Long Pond Road in the town of Plymouth, flows through Russell Mill Pond, and discharges into Plymouth Harbor in southeastern Massachusetts. Current land use estimates for the South Shore Coastal watershed (an approximately 15-square-mile subwatershed within the Cape Cod watershed) are forest (70 percent), open land (11 percent), and residential (8 percent). Historically, this area was a wetland known as Finney's Meadow.

The river's flow was uninterrupted and supported a wide variety of wildlife until a series of mills and dams were constructed in the early 1800s. In the late 1800s, cranberry farming began and continued until 2002. Cranberry farmers removed trees, modified the stream channel, and built upland berms and water control structures. In addition, the Sawmill Pond dam was a barrier to fish migration, and the impoundment affected habitat, water quality, and natural riverine processes.

The Massachusetts Department of Fish and Wildlife surveyed the fish population on the Eel River in 2001. With the exception of American eel, the overall number of fish was low. This was attributed to the lack of quality fish habitat, including available fish cover which was noted as poor. It was also noted that two small impoundments of this segment of the Eel River were both heavily infested with the non-native aquatic plant *Cambomba caroliniana* (fanwort). In order for the Eel River to meet the aquatic life designated use, the fish population

Photo by USDA NRCS

Figure 1. The Eel River meanders through a restored wetland area that was once a commercial cranberry bog.

should contain multiple age classes (indicative of reproducing populations) of any cold water fish and there should be no non-native aquatic species. As a result, in 2001 the Massachusetts Department of Environmental Protection listed the 3.9-mile Eel River (Segment MA94-23) as impaired (Category 4c) in the state's Integrated Report because it was not meeting its designated use for fish, other aquatic life, and wildlife.

Project Highlights

Beginning in 2004, project partners worked to improve water quality and reduce the impacts of hydromodification on fish and wildlife in the Eel River. Project partners naturalized over 40 acres of retired cranberry bogs (Figure 2) to mitigate the effects of historical hydromodification and removed

Photo by USDA NRCS

Figure 2. Land around the Eel River was converted for cranberry farming as early as the late 1800s.

Photo by Brian Graber

Figure 3. The Sawmill Pond Dam, built downstream of one of the bogs, altered the river's hydrology and blocked fish passage.

Photo by Alex Hackman

Figure 4. Wetlands have been restored in a portion of the river that was once a commercial cranberry bog.

Photo by Alex Hackman

Figure 5. Removing an impoundment has restored the hydrology of the Eel River and improved fish passage.

Sawmill Pond Dam, a large stone dam located downstream of the bogs (Figure 3). Restoration techniques included stream channel and floodplain reconstruction, fill removal, extensive wetland plantings, rare-species habitat creation and enhancement, dam removals, and culvert replacements (Figures 4 and 5). The project took approximately 5 years to complete from feasibility through construction.

Results

In 2006 the town of Plymouth's Community Preservation Committee purchased the cranberry bogs and upland areas. Through the Eel River Headwaters Restoration Project, the town and project partners transformed over 40 acres of former commercial cranberry farm into self-sustaining freshwater wetlands. In addition to improving over 40 acres of habitat, the project addressed the flow of 1.7 miles of headwater stream that had been extensively altered and degraded by human use. This project has made dramatic improvements to wetland and riverine habitat that resulted in new and more abundant fish and wildlife, helped the local ecology become more resilient to climate change, and enhanced public use of the conservation land.

Rare wetland plant communities have also been reestablished. Over 24,000 plants, including more than 17,000 Atlantic white cedar trees, have been planted, representing the first large-scale restoration of this rare wetland type in Massachusetts. Now known as the Eel River Preserve, the area is managed by the town of Plymouth for public use and benefit. The Eel River project won the 2011 Coastal America Partnership Award, and provides valuable guidance for other wetland restoration projects.

Partners and Funding

Partners included the town of Plymouth, the Massachusetts Division of Ecological Restoration, the Massachusetts Department of Environmental Protection, the U.S. Fish and Wildlife Service, the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS), American Rivers, The Nature Conservancy, the Massachusetts Corporate Wetlands Restoration Partnership, and the Horsley Witten Group. The project was funded through several sources with major contributions provided by the U.S. Fish and Wildlife Service ($1 million), the Massachusetts Department of Environmental Protection ($400,000 in Clean Water Act section 319 funds), and NRCS ($350,000).

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APPENDIX H

Mass Audubon Bylaw Review Summary

Factors	Conventional	Better	Best	Community's Zoning	Community's Subdivision Rules & Regulations	Community's Site Plan Review	Community's Stormwater/LID Bylaw/Regulations
GOAL 1: PROTECT NATURAL RESOURCES AND OPEN SPACE							
Soils managed for revegetation	Not addressed	Limitations on removal from site, and/or requirements for stabilization and revegetation	Prohibit removal of topsoil from site. Require rototilling and other prep of soils compacted during construction	*(Not applicable)*	loam suitable for reuse should not be removed from site (sect. 5. A. 1) topsoil only removed from disturbed areas (roadways, driveways, building sites, cut/fill areas only); 6" loam placed on all distured areas, protected from erosion and seeded, planted areas guaranteed for at least 2yrs (Sect. 5.F)		
Limit clearing, lawn size, require retention or planting of native vegetation/naturalized areas	Not addressed or general qualitative statement not tied to other design standards	Encourage minimization of clearing/ grubbing	Require minimization of clearing/grubbing with specific standards		natural areas, fill/removal areas/volumes, trees >12" with full EIA required with definitive plans suitable street trees should be maintained; all 16" trees should be maintained within subdivision (Sect. 5.H), no specific limitations on clearing		
Require native vegetation and trees	Require or recommend invasives	Not addressed, or mixture of required plantings of native and nonnative	Require at least 75% native plantings		ROW/planted areas seeded with perennial lawn grass or other approved ground cover (does not require native, Sect. 5.F) street trees every 30', species approved by tree warden (native not specified) (Sect. 5.H)		
GOAL 2: PROMOTE EFFICIENT, COMPACT DEVELOPMENT PATTERNS AND INFILL							
Lot size	Required minimum lot sizes	OSRD/NRPZ preferred. Special permit with incentives to utilize	Flexible with OSRD/NRPZ by right, preferred option	1.4 ac all districts, 2.3 ac for multi-family, 2.8 ac for retreat lots	*(Not applicable)*	*(Not applicable)*	*(Not applicable)*
Setbacks	Required minimum front, side, and rear setbacks	Minimize, allow flexibility	Clear standards that minimize and in some instances eliminate setbacks	Front: 40' Side/rear: 20' AR, 30' B/LM, 40' I/multi-family retreat lots: 100' all	*(Not applicable)*	*(Not applicable)*	*(Not applicable)*
Frontage	Required minimum frontage for each lot/unit	Minimize especially on curved streets and cul-de-sacs	No minimums in some instances, tied into other standards like OSRD design and shared driveways.	200' / retreat lots 40'	*(Not applicable)*	*(Not applicable)*	*(Not applicable)*
Common driveways	Often not allowed, or strict limitations	Allow for 2-3 residential units	Allow for up to 4 residential units, preferrably constructed with permeable pavers or pavement	retreat lots cannot share driveways (did not look elsewhere)	not addressed		*(Not applicable)*

Limit impervious area – Rural Districts In high density areas, require post-development infiltration to = or > predevelopment	Not usually addressed in zoning and subdivision regs for rural/suburban residential	<15%	<10%	max 30% building cover / 60% impervious cover	not addressed, but no increase in runoff allowed		
GOAL 3: SMART DESIGNS THAT REDUCE OVERALL IMPERVIOUSNESS							
Street location	Numeric and geometric standards based primarily on vehicular travel and safety, with basic pedestrian requirements e.g. sidewalks	Flexibility in applying standards, to reduce area of impact, grading, avoid key natural features	OSRD design preferred by-right. Require locating streets to minimize grading and road length, avoid important natural features	*(Not applicable)*	intersections >75deg, as close to right angles as possible, no flexibility to reduce grading and env impacts (except preserving stone walls, large trees Ided in plans)	*(Not applicable)*	*(Not applicable)*
Road width	Major and minor categories, 24-30'	Wide, medium, narrow categories. 22-24' max, plus 2' shoulders	Wide, medium, narrow, and alley categories. 20-24' widest for 2 travel lanes, 18-20' low traffic residential neighborhood, plus 2' shoulders. Allow alleys and other low traffic or secondary emergency access and all shoulders to use alternative, permeable materials.	*(Not applicable)*	24' min all minor/major secondary streets, at least 4' shoulder sloped down to edge of rd	*(Not applicable)*	*(Not applicable)*
Road ROW width	50-75', fully cleared and graded	40-50', some flexibility in extent of clearing	20-50'depending on road type		50ft min or 25ft min where sidewalks and bikeways adj to street (Sect. 5.C.1) completely cleared, 4 ft buffer excavated/graded, only areas in path of pavement/ sidewalks/ curbs to be excavated (contradictory? - sect. 5. A. 1) construction standards (plates 4 and 4A0 show 40' - **contradictions**		
Access Options	No common drives allowed, dead end allowed with limit on length and # of units	Allow dead end with limit on length and # of units. Allow common drives up to 2-3 units	Allow one way loop streets. Allow common drives up to 4 units, and alleys and rear-loading garages where suitable.	*(Not applicable)*	dead ends allowed for up to 8 dwellings, common drives not addressed	*(Not applicable)*	*(Not applicable)*
Dead Ends/Cul-de-sacs	120 ft or more minimum turnaround	Minimize end radii – 35 ft	Allow hammerhead turnaround	*(Not applicable)*	cul-de-sac paved turnaround same width as servicing road, outer roadway diameter at least 120', center natural/landscaped	*(Not applicable)*	*(Not applicable)*

Cul-de-sacs	Full pavement standard	Encourage center landscaping with bioretention	Require center landscaping with bioretention	*(Not applicable)*	center natural/landscaped, bioretention not addressed	*(Not applicable)*	*(Not applicable)*
Curbing	Curbing required full length both sides of road	Allow curb breaks or curb flush with pavement to enable water to flow to vegetated LID features	Open drainage with roadside swales and no curbs preferred	*(Not applicable)*	not required where roadside swales; required where traditional drainage to contain runoff (Sect. 5.D.1)		
Roadside Swales	Allowed as an option	Preferred over closed drainage	Preferred, with criteria for proper design. Adoption of technical specifications and design templates for green infrastructure recommended	*(Not applicable)*	LID / country drainage preferred; traditional drainage allowed by waiver only (sect. 5.B.2, design standard cross section 4B), recommended types of drainage, but design criteria not specified		
Utilities	Off sets required contributing to wide road ROWs	Not specified, flexible	Allow under road, sidewalks or immediately adjacent to roads to enable placement of roadside swales.	*(Not applicable)*	underground required (sect. 5. A.3) Placed under road/sidwalks (construction standards, plate 4)		*(Not applicable)*
Sidewalks	Concrete or bituminous	Some flexibility in material and design	Prefer permeable pavement or permeable pavers	*(Not applicable)*	4' width / 15' ROW width required, bituminous concrete 25' ROW if bikeway and sidewalk adj)		*(Not applicable)*
Sidewalk location	Required both sides of road	Allow on only 1 side of road especially in low density neighborhoods	Prefer siting with land contours and for best pedestrian utility (e.g. connect with common areas and shared open spaces) – not necessarily immediately parallel to road.	*(Not applicable)*	required on both sides of all roadways (Sect. 5.C.1) must provide convenient access to certain areas; typical roadway section (plate 4) includes on both sides, country drainage (plate 4B) does not include sidewalks		*(Not applicable)*
Sidewalk drainage	Drains to road closed drainage system	Not addressed	Disconnect drainage from road system – e.g.adjacent green strips or within vegetated areas that can absorb sheet flow	*(Not applicable)*	drainage not addressed; side slopes at grade with adjacent lot, except where required to facilitate country drainage - should be more specific about where/how sidewalks drain		*(Not applicable)*
GOAL 4: ADOPT GREEN INFRASTRUCTURE STORMWATER MANAGEMENT PROVISIONS							
Rooftop runoff	Prohibit directing clean roof runoff into closed municipal drainage systems.	Allow clean roof runoff to be directed to landscaped or naturally vegetated areas capable of absorbing without erosion, or infiltration	Require directing clean roof runoff to landscaped or naturally vegetated areas capable of absorbing, or infiltration	*(Not applicable)*	not addressed		
Overall stormwater design; piping and surficial retention vs. LID	Conventional stormwater system design standards		LID design standard. Allow surficial ponding of retained runoff for up to 72 hours and credit for green roofs towards stormwater requirements	*(Not applicable)*	LID preferred with examples given, traditional drainage by waiver only (sect. 5.B.2)		

Site Plan Requirements	LID may not be addressed	Encourage use of LID features in site design	Count bioretention and other vegetated LID features toward site landscaping/open space requirements.	*(Not applicable)*	*(Not applicable)*		
Allow easy siting of LID features (bioretention, swales, etc.)	Often not addressed, may require waivers from subdivision standards	Encouraged along road ROW	Allowed on lots, common open space, or road ROW, easement recorded. For commercial development, allow an increase in floor area ratio or other developmental incentives for green roofs		country drainage preferred on all roadways; credits for runoff reduction from Center for Watershed Protection's runoff reduction method (Sect. 5.B.2) LID on lots not addressed		*(Not applicable)*
Permeable paving	Often not addressed, may require waivers from subdivision standards	Allowed on private residential lots for parking, patios, etc.	Allowed for residential drives, parking stalls, spillover parking spaces, emergency access ways (with proper engineering support for emergency vehicles) Two track design allowed for driveways and secondary emergency access ways (where required).	*(Not applicable)*	all roadways require bituminous concrete (Sect. 5. A. 3), as do sidewalks (Sect. 5.C.1) Porous concrete/pavers allowed in country drainage construction standards plate 4B		
Stormwater management O&M plan	Typically only addressed if municipality has a stormwater or LID bylaw, or for areas subject to wetlands permitting	Required	Required, surficial bioretention and swales preferred. Closed/underground systems requiring specialized inspection and clean out discouraged.	*(Not applicable)*	Stormwater management plan, meeting DEP standards required with definitive plans SW Management Required with drainage plan, no increase in runoff from subdivision, traditional systems discouraged (Sect. 5.B.2) No O&M Plan		
Construction Erosion and Sedimentation Plan required	Basic general requirements	Required, contents specified	Goes beyond minimum NPDES requirements, requires minimization of site disturbance	*(Not applicable)*	Erosion and sedimentation plan required both during and post construction (required in definitive plan with EIA), contents/requirements not specified		
GOAL 5: ENCOURAGE EFFICIENT PARKING							
Parking	Specific minimums set based on projected maximum use times	Encourage minimum # needed to serve routine use (e.g. 2/residential unit with any additional/visitors parking behind in driveway or on street.	Establish Maximum Parking spaces allowed. Do not require more than 2/residence. Allow tenants separate, optional lease agreements for parking.		*(Not applicable)*		*(Not applicable)*

Commercial Parking	Specific minimums set based on projected maximum use times adding all on-site uses together.	Some flexibility to reduce minimums based on street or other available nearby parking or transit.	Allowed shared parking for uses with different peak demand times. Provide model agreements/deed restrictions. Reduce parking requirements near transit. Limit parking stall size (9ftx18ft max), with up to 30% smaller for compact cars		*(Not applicable)*		*(Not applicable)*
LID in Parking Areas	Often not addressed, may require waivers e.g. for planting islands to drain down rather than built up surrounded by curbs	Allow LID/bioretention within parking areas.	Require landscaping within parking areas, as LID/bioretention, at a minimum of 10% of the interior area landscaped and a minimum of 25 square feet for island planting areas.	*(Not applicable)*	not addressed for parking areas		