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Figure 01. Removal of the Bartlett Rod Shop Company dam on Amethyst Brook in Pelham, Massachusetts (WAMC.org).

Figure 02. A timber dam on Amethyst Brook dating to 1730 was removed in 2016 (MassLive.com).

Introduction

The Bartlett Rod Shop Company Dam on Amethyst Brook, a tributary to the Fort River in Pelham, Massachusetts, was built in 1820 to power a fly-fishing rod factory. The 172-foot long and 22-foot high stone dam was in operation until 1931. In 2012, it was removed (**Fig. 01**) to restore nine miles of upstream habitat for aquatic wildlife as the first project of three aimed at restoring natural resources in the Connecticut River watershed damaged by hazardous substances released from the Holyoke Coal Tar Site in Holyoke, Massachusetts. Upon its removal, the changing flow of Amethyst Brook revealed a timber dam dating to 1730 just four hundred feet upstream from the Bartlett Rod Company dam, which was subsequently removed in 2016 (**Fig. 02**). Dams such as these dot streams and rivers throughout New England and point to the long history of the region's waterways sustaining the livelihoods of its inhabitants. However, many of these dams are now vestiges of an industrial past with more than one thousand obsolete dams obstructing tributaries to the Connecticut River.

The 58-acre Fort River watershed which drains to the Connecticut River, is located in western Massachusetts, encompasses the towns of Amherst, Belchertown, Hadley, Pelham, and Shutesbury. Headwater streams located in the towns of Belchertown, Pelham, and Shutesbury converge in Amherst, forming the Fort River, which meanders in a serpentine fashion, southwesterly through Hadley where it releases into the Connecticut River. At seventeen miles long, the Fort River is ecologically significant as the longest, undammed tributary in Massachusetts to the Connecticut River. Undammed rivers and streams not only allow aquatic wildlife such as migratory fish and mussels access to critical habitat to reproduce but also allow for natural fluvial processes to occur that provide ecosystem services such as the attenuation of floods and increasing ecosystem resilience by supporting greater amounts of biodiversity. If there is any doubt of the ecological value of free flowing streams and rivers, it became demonstrably evident when only six months after the removal of the Bartlett Rod Company dam along Amethyst Brook, sea lamprey (*Petromyzon marinus*) returned to spawn (**Fig. 03**). Despite the great success of such efforts to restore ecosystem function to the watershed's streams, both Amethyst Brook and the Fort River have been identified as having water quality that does not meet the standards of the Clean Water Act due to the presence of elevated levels of phosphorous and *E. coli*.

In 2019, a small group of volunteer citizens that included scientists, conservationists, town planners, educators, and activists saw an opportunity to improve the water quality of their home watershed when the Hickory Ridge Golf Club in Amherst, Massachusetts, went up for sale. Approximately two miles of the Fort River bisect the golf club and members of this newly formed group recognized it as a potential site for another restoration project. The group formed the Fort River Watershed Association to petition the Town of Amherst to purchase and restore this property for conservation purposes and to advocate for the protection of the Fort River and its watershed. The association quickly set its sight on a broader goal to investigate strategies for managing and improving water quality on a watershed scale. Shortly thereafter, the association partnered with the Connecticut River Conservancy whose "source to sea" mission aims to "prevent pollution, improve habitat, and promote enjoyment of [the Connecticut River] and its tributaries" (CRC), the Conway School, and key stakeholders within the watershed to investigate such strategies. This report is the result of that collaboration, providing an ecological assessment of the watershed and recommending strategies for improving water quality.

"Our goal is to restore and protect the ecology of the Fort River, its tributaries, and watershed lands for the benefit of present and future generates. Through advocacy, research, and education, our aim is to ensure that people from all walks of life can access, enjoy, and value the beauty and importance of this waterway."

-Fort River Watershed Association (fortriver.org)

Figure 03. Sea lamprey (*Petromyzon marinus*) returning to spawn in Amethyst Brook only six months after the 2012 removal of the Bartlett Rod Company dam (Chelminsky 8).

Project Goals

Primary goal: Identify strategies for protecting and improving water quality within the Fort River watershed

- Conduct a broad scale ecological assessment of the Fort River watershed
- Map and identify areas of vulnerability within the watershed
- Investigate the impact of land use on water quality
- Identify current conservation efforts and areas for future conservation that:
    - Increase ecological connectivity
    - Support wildlife habitat
    - Provide recreational access where appropriate
    - Protect and improve water quality of both ground and surface waters

Watershed Study Partners & Stakeholders

Fort River Watershed Association

This volunteer community group formed in 2019 with a mission to protect and improve the ecology of the Fort River, its tributaries, and watershed lands for the benefit of present and future generations. In winter 2020, the Association contracted graduate students at the Conway School to produce this report.

Connecticut River Conservancy

The Connecticut River Conservancy "is the voice of the Connecticut River Watershed, from source to sea" (www.ctriver.org). In partnership with the Connecticut River Conservancy, the central mission of the Fort River Watershed Association is to improve and protect the water quality of the Fort River, a tributary of the Connecticut River.

Additional Stakeholders

Additional stakeholders for this project include residents and employees within the towns of Amherst, Belchertown, Hadley, Pelham, and Shutesbury, such as town planners, farmers, researchers and scientists, conservationists, activists, and those who participate in outdoor recreation within the watershed.

Process

This broad scale assessment of the Fort River watershed was conducted using geospatial data including GIS data, satellite and other aerial imagery, and datasets provided by towns within the watershed. Analyses of these data aim to show how different landscape features and land use may be impacting water quality and where to focus recommended interventions for improving water quality.

Additionally, two community meetings were held to identify directly observed vulnerabilities within the watershed, such as specific land management practices, that may not otherwise appear in geospatial data sets, and to gather feedback on proposed recommendations. The first meeting was held on February 10, 2020 with members of the Fort River Watershed Association, and the second meeting on March 9, 2020, which was open to the community at large.

Figure 04. Amethyst Brook in Amherst, Massachusetts.

Water Quality Parameters

Key terms used to describe and assess water quality

Conductivity: A measure of water's capability to pass electric flow, determined by the concentration of ionic nutrients and minerals present, which provides a measure of what is dissolved in water. Changes in conductivity can indicate that pollution has entered a waterbody. A higher conductivity value indicates that there are more nutrients and minerals dissolved in the water.

Dissolved Oxygen: A measure of how much oxygen is dissolved in water—the amount of oxygen available to living, aquatic organisms which depend on it for survival.

Eutrophication: Eutrophication occurs when a body of water receives an excessive nutrient load, particularly phosphorus and nitrogen, which often results in an overgrowth of algae. As the algae die and decompose, dissolved oxygen is depleted from the water, and this lack of oxygen in the water causes the death of aquatic life.

Nutrients: Naturally occurring nutrients such as nitrogen and phosphorus are necessary to support plant and animal life in streams. An overabundance of nutrients could lead to eutrophication.

pH: Describes the acidity or alkalinity of water; acidic solutions have a pH lower than seven, alkaline solutions a pH higher than seven, and solutions with a pH of seven are neutral. Some fish and other aquatic organisms have a specific, narrow pH tolerance range and their ability to survive may be threatened by changes in pH outside of this range.

Temperature: Water bodies are classified as cool or warm water fisheries because most fish and other aquatic organisms have a preferred temperature range for survival. Raising water temperature can decrease levels of dissolved oxygen and increase conductivity which can create stressful conditions for aquatic species.

Pathogens: Disease producing organisms like bacteria and viruses. These organisms often result from fecal contamination of water. The presence of Escherichia coli (E. coli) bacteria in water is used as an indicator of pathogenic organisms and a source of water quality impairment for drinking or swimming.

Total Maximum Daily Load (TMDL): The maximum amount of a pollutant allowed to enter a waterbody so that the waterbody will meet and continue to meet water quality standards for that particular pollutant.

Turbidity: A measurement of suspended particulate matter in water that reduces the transmission of light, typically measured as total suspended solids (TSS). Increases in turbidity can contribute to a range of water quality problems (e.g., increases in nutrient levels and decreases in dissolved oxygen) and can be a source of physical agitation for fish, making them more prone to disease-causing pathogens.

Existing Fort River Watershed Water Quality Data

Water Quality

Water quality is measured by several factors including pH, dissolved oxygen, Escherichia coli (*E. coli*), temperature, and turbidity. Too much or too little of one parameter can adversely affect the use of the water for people and the state of the aquatic ecosystem. Water is considered polluted or impaired when the presence of pathogens, nutrients, chemicals, or sediments is too great for its intended use or purpose. Pathogens like *E. coli* indicate possible fecal contamination that may cause illness in people and make water unsafe to drink or swim in. High amounts of nutrients like phosphorus and nitrogen in water can promote the growth of undesirable algae and aquatic weeds that both lead to reduced levels of oxygen, which in turn causes a die-off of aquatic life. Sediment, which can be transported during times of increased flow, can smother stream beds, fish eggs, and benthic organisms, which are those that live on the bottoms of stream beds. Thermal pollution is also a threat to water quality and can result from heated runoff from dark surfaces like parking lots.

Maintaining good water quality that supports anthropogenic uses like drinking water, swimming, and fishing, as well as natural aquatic ecosystems is important to the Fort River Watershed Association. Monitoring water quality can provide quantitative evidence that can be used to make decisions on how to manage land uses for their effect on water quality.

Fort River Water Quality: Historical Data

In September 2019, water quality testing was conducted in the Fort River watershed as part of the Samplepalooza effort throughout the Connecticut River watershed. These test results indicated that the total nitrogen was 0.54mg-N/L and the total phosphorus was 53ug-P/L, both nutrients exceeding Massachusetts' surface water quality standards of 0.1mg-N/L and 5ug-P/L respectively (**Table 01**). These high levels have the potential to increase algae and aquatic vegetation and could lead to low levels of dissolved oxygen levels in the Fort River. Additionally, the nutrient concentrations could adversely affect downstream waterways like the Connecticut River and, ultimately, Long Island Sound.

During Samplepalooza 2019, the Fort River had the highest levels of phosphorus when compared to other streams tested in Massachusetts (**Fig. 05**). Further assessment is needed to determine the sources of phosphorus in the watershed.

In 2008, water quality analytical data was collected at five locations in the Fort River watershed as part of a national effort to test streams and rivers. The testing locations included the Amethyst Brook, Hop Brook (another tributary of the Fort River), and two locations on the Fort River. These results (APPENDIX B) indicate the high levels of *E. coli* at all sample sites. Specifically, the Fort River at the Route 47 Hadley test location had the highest concentration of *E.coli* of 1,500 CFU/100mL.The Massachusetts' Consolidated Assessment and Listing Methodology (CALM) Guidance Manual for the 2018 Reporting Cycle lists the acceptable level of E. coli as 126 colony forming units (CFU) per 100/mL in Class B water (waters suitable for swimming but not drinking) (CALM 2018).

The 2008 sampling data also indicate high levels of Total Nitrogen (N) and Total Phosphorus (P) in Hop Brook and the Fort River, ranging from 0.25mg-N/L to 4.5mg-N/L and 0.014mg-P/L to 0.07mg-P/L. In Massachusetts, the limit for Total Nitrogen is 0.1mg-N/L and Total Phosphorus is 0.005 mg-P/L (Samplepalooza 2019). The high levels of nitrogen in streams of the Fort River watershed may be a result of non-point sources like the use of fertilizer, improper manure management, combustion of fossil fuels, and/or natural chemical processes. The high levels of phosphorus in streams of the Fort River watershed may also be due to non-point sources like decomposing organic matter, such as leaf litter or grass clippings, leachate from private septic systems, and/or the use of fertilizers. High levels of nitrogen and phosphorus can impair streams when eutrophication occurs, suffocating fish and other aquatic life.

Date & Time	Analyte	Result	Recommended Limit
9/12/2019 7:00	Nitrogen Nox	0.298mg-N/L	0.05mg/N/L
9/12/2019 7:00	Total Nitrogen	0.54mg-N/L	0.1mg/N-L
9/12/2019 7:00	Total Phosphorous	53ug-P/L	5ug/P-L

Table 1. Fort River water quality data. Source: Samplepalooza September 2019

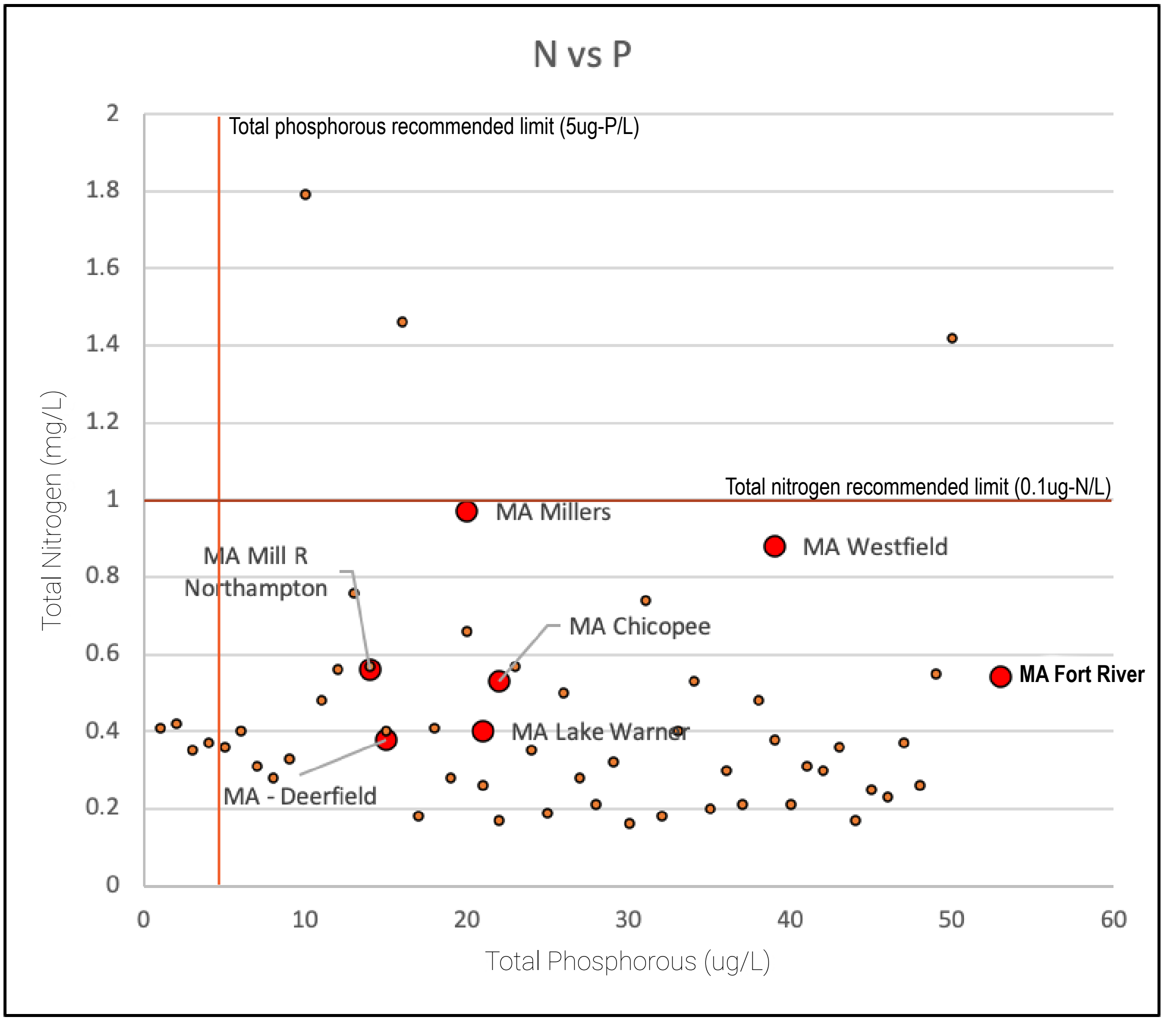


Figure 05. Samplepalooza Data

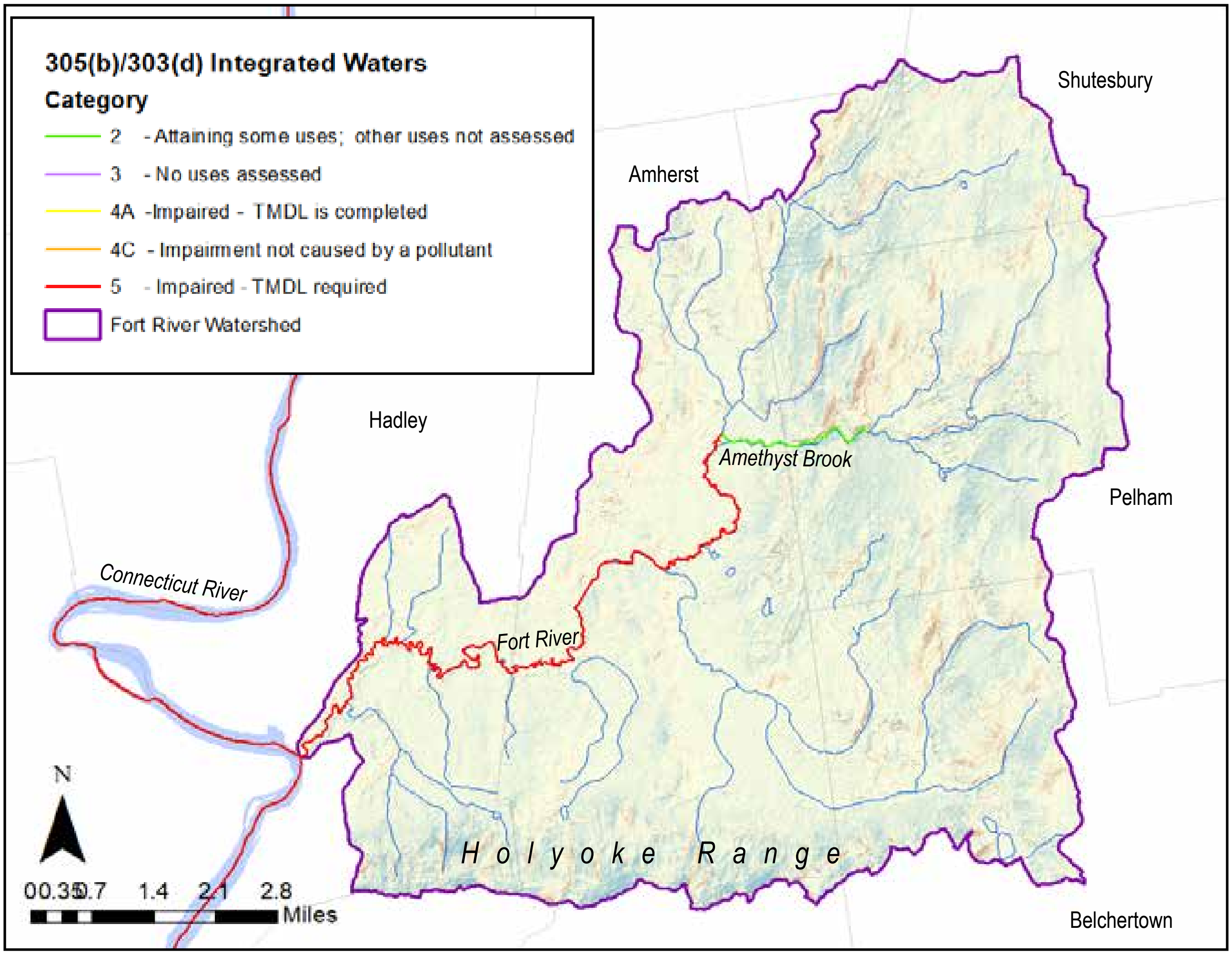
Samplepalooza is a large scale, one-day water testing event throughout the Connecticut River basin. It is a coordinated effort between the Connecticut River Conservancy, multiple states, and citizen scientists to collect data to support a multi-state effort to reduce nitrogen pollution in Long Island Sound. In 2015, more than 65 locations covering more than 1,000 river miles across four states were sampled (Second Annual Samplepalooza 2015). Compared to other rivers and streams tested that day, the Fort River had the highest levels of phosphorous, far exceeding the recommended limit of 5ug-P/L. Source: Connecticut River Conservancy

Impaired Streams

Statutes 305b and 303d of the Federal Clean Water Act "aim to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (MassGIS: Integrated). The Federal Clean Water Act requires states to administer a program to monitor and assess the quality of its surface waters. The Massachusetts Department of Environmental Protection (DEP) has established the minimum criteria required to support a waterbody's designated uses. Within the Fort River watershed, the only designated impaired stream is the Fort River, which is impaired because of E. coli (**Table 2**). Amethyst Brook is identified as a Category 2 integrated stream (**Map 01**), meaning it is unimpaired for some uses and has not been assessed for others (**Table 3**). The Long Island Sound Total Maximum Daily Load (TMDL) for nitrogen also applies to the Fort River (**Map 01**) because it is a tributary to the Connecticut River, which ultimately ends up in Long Island Sound.

A TMDL is a plan for restoring impaired waters that identifies the maximum amount of a pollutant, determined by state environmental agencies, that a body of water can receive while still meeting water quality standards. Because the Fort River falls under the nitrogen TMDL for Long Island Sound, measures must be taken to ensure that nitrogen levels in the river do not exceed the maximum allowable amount of nitrogen.

Although the Fort River has been identified as an impaired stream due to elevated levels of *E. coli*, a specific source of that impairment has not been identified and may actually be a result of non-point source pollution, which is "pollution caused when rainfall or snowmelt, moving over and through ground, picks up and carries natural and human-made pollutants, depositing them into lakes, rivers, wetlands, coastal waters and ground waters" ("Polluted Runoff"). Because *E. coli* is a bacteria found in the intestines of warm-blooded organisms, land uses involving the management of animal and human waste may be contributing to the Fort River's impairment. Further analysis of land use within the watershed in conjunction with rigorous water testing is needed to identify potential non-point sources of pollution.



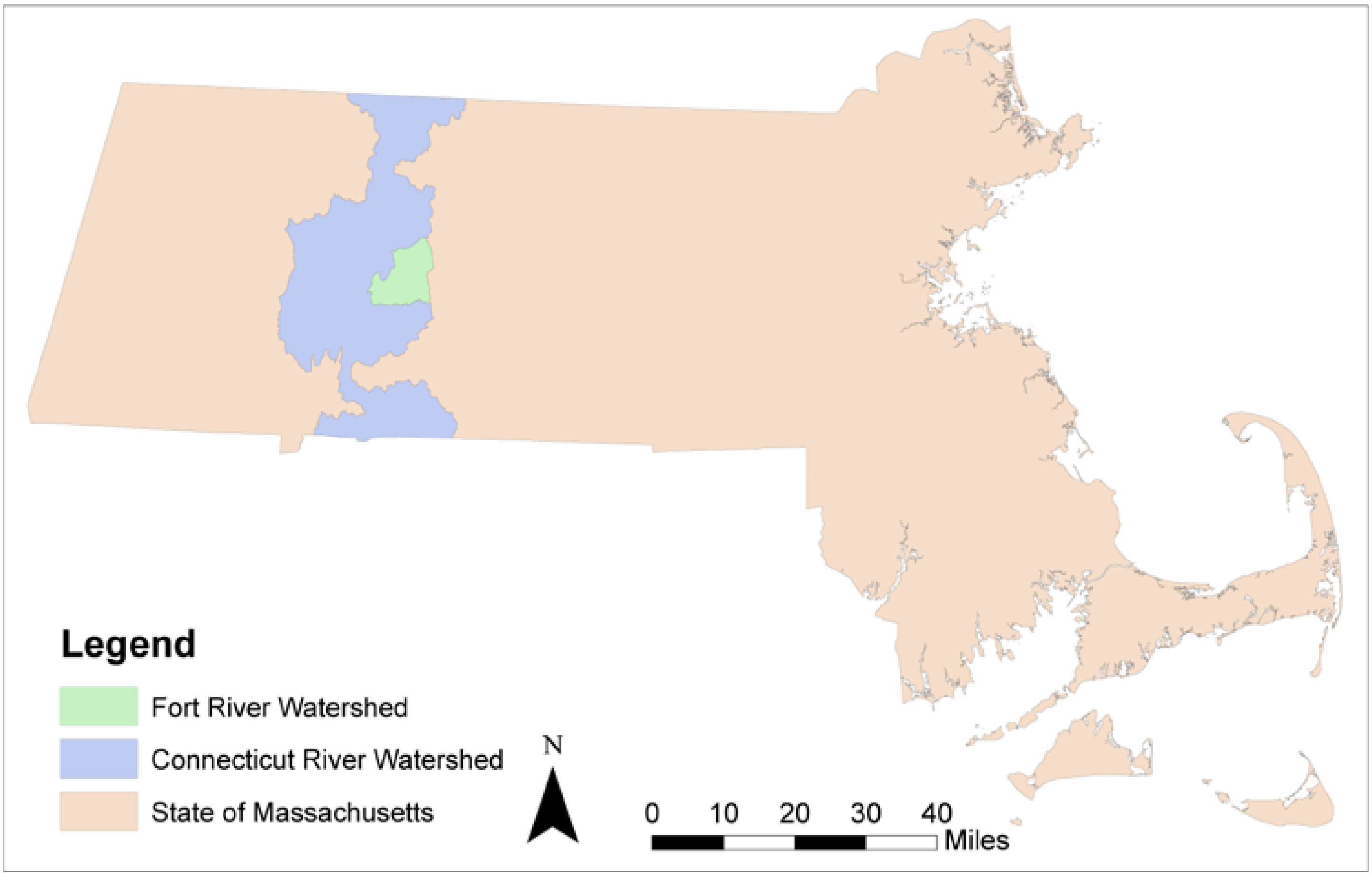
Map 01. 305b and 303d Impaired Streams. Source: MassGIS.

Assessment Unit ID	Waterbody	Integrated List Category	Designated Use	Impairment Cause	Impairment Source
MA34-27	Fort River	5	Primary Contact Recreation	Escherich-ia coli	Source Unknown

Table 2. Impaired waters within the Fort River watershed (Geosyntec, Inc. 12)

Integrated List Category	Description
1	Unimpaired and not threatened for all designated uses.
2	Unimpaired for some uses and not assessed for others.
3	Insufficient information to make assessments for any uses.
4	Impaired or threatened for one or more uses, but not requiring calculation of a Total Maximum Daily Load (TMDL), including: 4a: TMDL is completed 4b: Impairment controlled by alternative pollution control measures 4c: Impairment not caused by a pollutant - TMDL not required
5	Impaired or threatened for one or more uses and requiring preparation of a TMDL.

Table 3. Description of Integrated List Categories (Geosyntec, Inc. 12).



Map 02. Location of the Fort River watershed, a subbasin of the Connecticut River watershed in western Massachusetts. Source: HUC 12 watershed and Major Basins datasets available on MassGIS.

Chapter 1: Ecological Assessment of the Fort River Watershed

Available water quality data paints a picture, though incomplete, of water quality impairment in the Fort River watershed. Based on this data, water quality impairments include nitrogen, phosphorous, and *E. coli*. This ecological assessment explores potential sources of these pollutants and other factors related to stream health.

The watershed shows signs of good, ecological health, in its diverse array of habitats that not only provide refuge for wildlife but also play an important role in the water cycle. Much of the watershed's aquatic wildlife depend on the free-flowing nature of the Fort River and its tributaries to survive, including Eastern brook trout (*Salvelinus fontinalis*), sea lamprey (*Petromyzon marinus*), and nine species of freshwater mussels including the federally recognized, endangered dwarf wedge mussel (*Alasmidonta heterodon*). The habitats in which they reside—including multiple types of wetlands, floodplains, vernal pools, and a rare, black gum, pin oak, swmap white oak perched swamp—also provide important ecosystem services such as attenuating floods and cleaning and filtering stormwater runoff. Conservation of these key habitat is crucial for maintaining water quality and protecting the diversity of wildlife that inhabit the watershed.

Figure 06. The Fort River at Silvio O. Conte National Fish and Wildlife Refuge.

Land Cover

A Forested Watershed

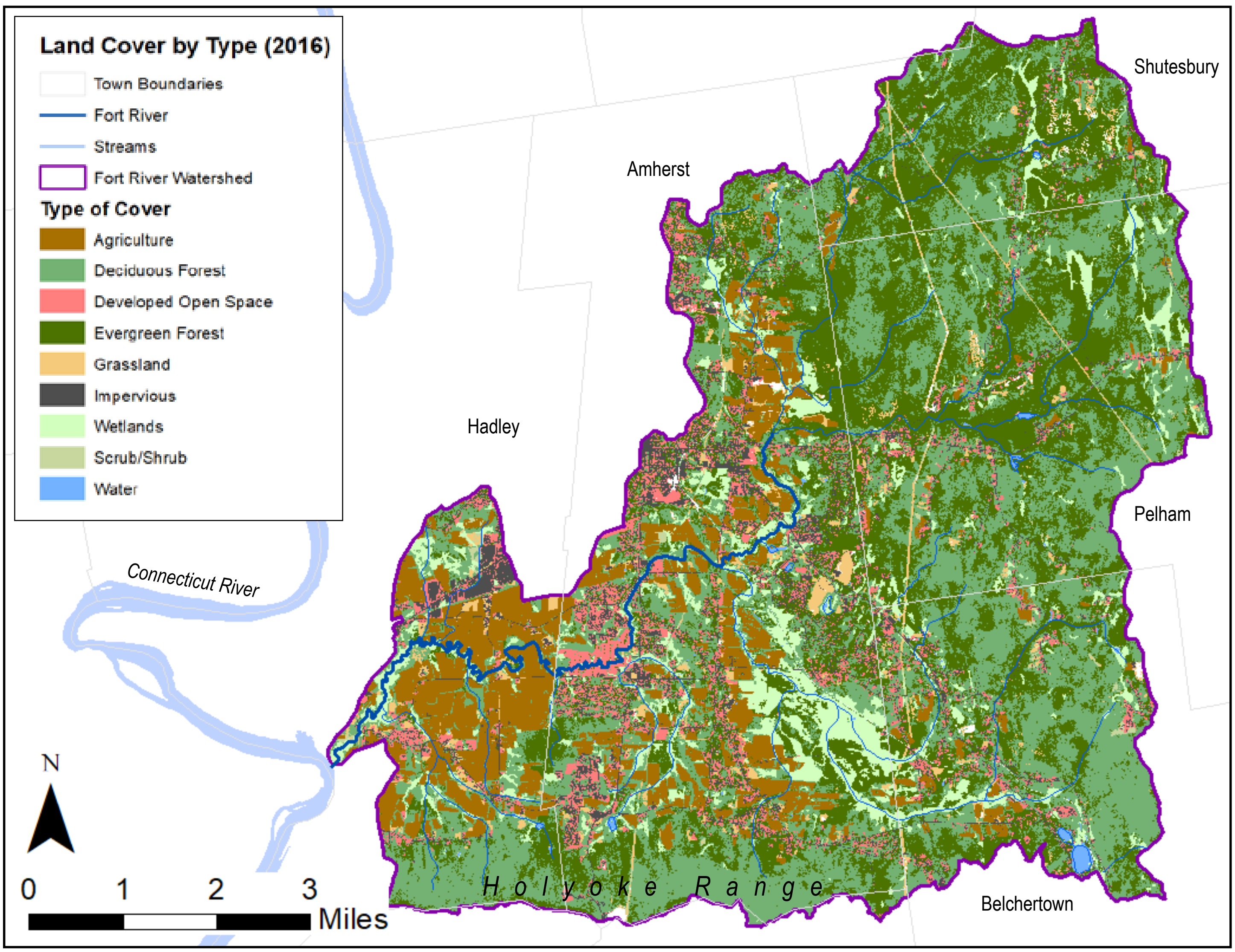
The major types of land cover within the Fort River watershed composing greater than five percent of total land area include forest, agriculture, wetlands, impervious surface, and developed open space (**Chart 1**).

Forest cover makes up seventy percent of total land area within the watershed and is composed of approximately equal parts of deciduous and evergreen forest. Forest cover is concentrated in the northern headwaters region of the watershed in Pelham and Shutesbury and extends south along the eastern watershed

Agriculture, which makes up ten percent of the total area, is concentrated in the western half of the watershed, particularly along lower elevations of the main branch of the Fort River and adjacent to its tributaries in Amherst (**Map 03**).

Forests protect and improve water quality by reducing stormwater runoff, shading surface waters, cycling nutrients, and filtering pollutants from runoff (Furniss et al 2010). Many of these forest functions are due to the hydrologic cycle in forests. This cycle begins when rain falls on a canopy of trees and adheres to leaves and branches, known as interception. It then gently flows down tree trunks to the ground, which is termed stemflow, or will drip onto the ground, which is called throughfall. Through infiltration, water percolates through decomposing leaves on the forest floor (duff). Forest soils contain large root systems from the trees above and are highly permeable. They experience very little evaporation due to canopy cover and an insulating layer of decomposing leaves on the forest floor. Water leaves a forest ecosystem through streams, subsurface flows, and transpiration. When water enters the soil, it can then flow to areas with the lowest hydrologic gradient, which could be a stream, a seep, or through subsurface flow. Transpiration is when water taken up by the roots of trees is released by foliage as vapor into the atmosphere. The hydrologic cycle in forests improves water quality and water, either through subsurface or surface flow, from forested areas is often of higher quality than lower points in a watershed (Ward 2004). This also creates high quality habitat in forest streams for sensitive aquatic species.

Impervious surface, which accompanies commercial and residential development and makes up five percent of land cover, is concentrated along the western boundary of the watershed, in Hadley and Amherst, but extends south and west into South Amherst and Belchertown.



Map 03. Fort River watershed Land Cover by Type. Source: MassGIS 2016 Land Cover data.

According to the National Oceanic and Atmospheric Administration's C-Cap program, which provides a framework for assessing water quality on a watershed scale, "watersheds that are over 65% forested have been found to be productive of a stream's biological community" (4). In its 2020 *Losing Ground* report, Mass Audubon states that when impervious cover exceeds seven percent within a watershed, decline of river fish populations by up to thirty-five percent may be observed; above twelve percent impervious cover causes "failure by most streams to meet water quality standards for aquatic life" (22).

Forest cover in the Fort River watershed exceeds sixty-five percent and impervious surface falls below seven percent. These conditions would typically indicate good overall water quality. However, the fact that the Fort River is impaired by *E. coli* and that water testing has shown high phosphorus levels indicates that localized areas that do not meet these standards may be disproportionately affecting the watershed's water quality. This is most evident in the uneven distribution of forest cover throughout the watershed, and suggests that different interventions to improve water quality will be necessary depending on the type and distribution of land cover throughout the watershed.

Developed open space, which makes up five percent of land cover, is concentrated in Hadley and Amherst but is also scattered throughout the watershed. It includes managed open space in developed areas like residential lawns, town greens, parks, and golf courses, and is typically characterized by mown grass.

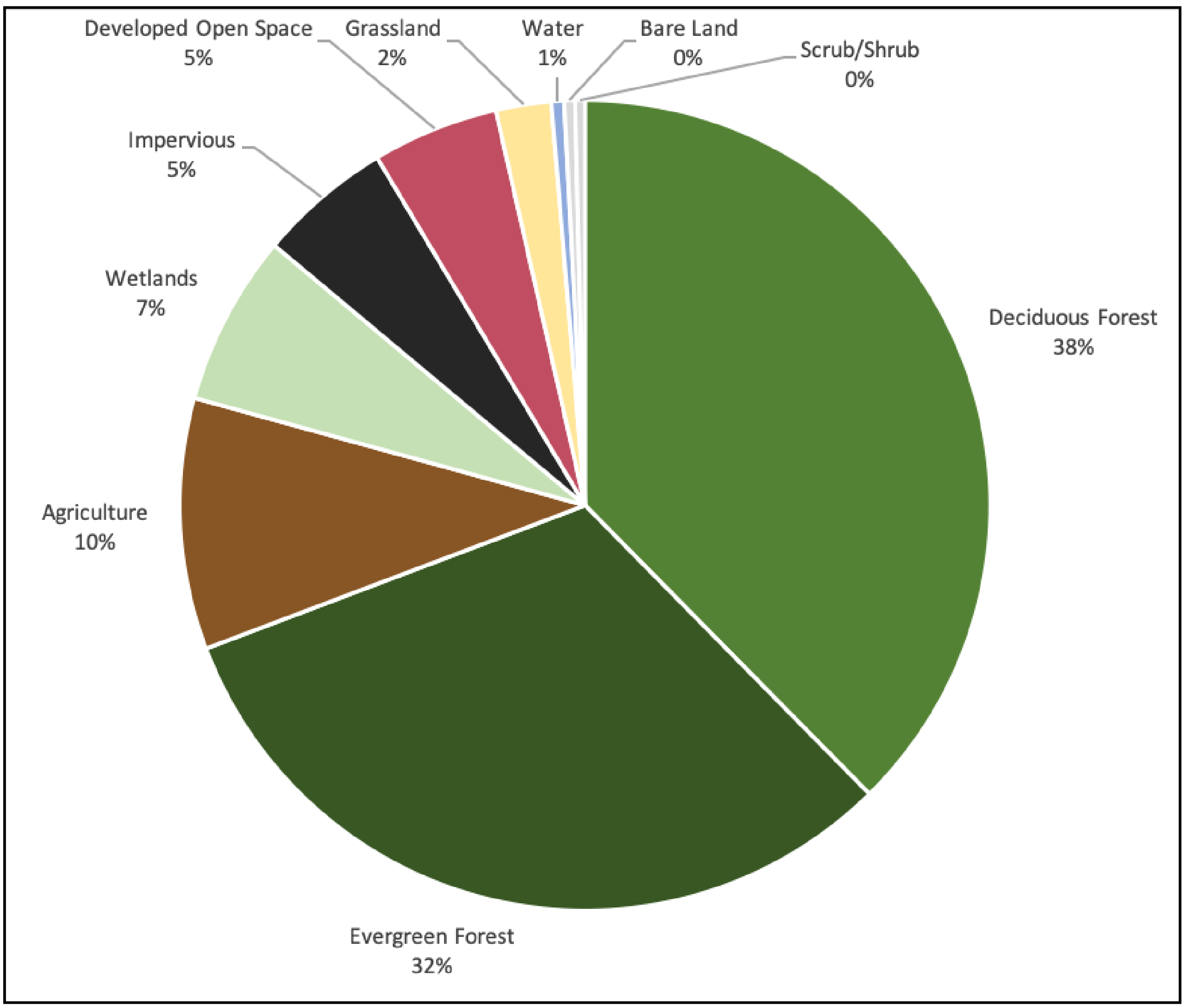


Chart 1. Percent land cover by type within the Fort River watershed. Source: MassGIS 2016 Land Cover data.

Freshwater Resources

Wetlands

Wetlands are ecosystems that are characterized by the presence of abundant water, saturated or hydric soils, and vegetation that is adapted to grow in these conditions. Wetlands slow down, store, and filter water from snowmelt, storms, and flooding. As water slows down, sediments precipitate out and nutrients are absorbed by wetland vegetation and soil. Water in wetlands is filtered as it is gradually released into nearby streams, waterbodies, or groundwater. Depending on the location and size of a wetland, downstream flooding and erosion can be reduced due to the ability of the wetland to trap and store large volumes of water. Additionally, vegetated wetlands bordering streams stabilize soils and banks, minimizing erosion. Wetlands also provide habitat for numerous amphibian and aquatic species and other wildlife.

The Fort River watershed contains about 2,619 acres of wetlands (**Chart 2**). Based on available data from MassGIS, the wetland types found in the watershed include bogs, deep marshes, shallow marshes or fens, shrub swamps, deciduous wooded swamps, coniferous wooded swamps, and mixed tree swamps (**Map 04**).

The most common type of wetland is the deciduous wooded swamps that are located near Hop and Adams Brooks and along the Fort River near its mouth at the Connecticut River (**Map 04**). Deciduous wooded swamps are composed of woody vegetation taller than twenty feet and includes deciduous tree species such as American elm (*Ulmus americana*), red maple (*Acer rubrum*), swamp white oak (*Quercus bicolor*), and ash (*Fraxinus pennsylvanica*). Shrub marshes are the second most common type of wetland in the Fort River watershed. This wetland type is marked by woody vegetation under twenty feet and includes obligate species, or those adapted to grow in saturated conditions with low oxygen levels. These species include buttonbush (*Cephalanthus occidentalis*), alders (*Alnus spp.*), and red osier dogwood (*Cornus stolonifera*) (Cowardin et. al, 1979).

Most of the wetlands in the Fort River watershed are in Amherst, particularly in the southeast portion of the town. This wetland area is significant for absorbing and filtering nutrients and bacteria from water before it flows into the Fort River. It is also a relatively large area to attenuate stormwater, potentially reducing peak flow and erosion downstream. Belchertown has wetlands that connect to the wetland network in southeast Amherst. Hadley also contains many wetlands that are mainly along the Fort River and along its tributaries. These riparian wetlands aid in filtering water before it enters stream flows and provide areas to capture, slow down, and filter flood waters. There are headwater wetlands in the higher elevations of Pelham and Shutesbury where surface and groundwater discharge to form streams. These are flooded seasonally during the spring and during storm events and, therefore, are important catchments for surface water.

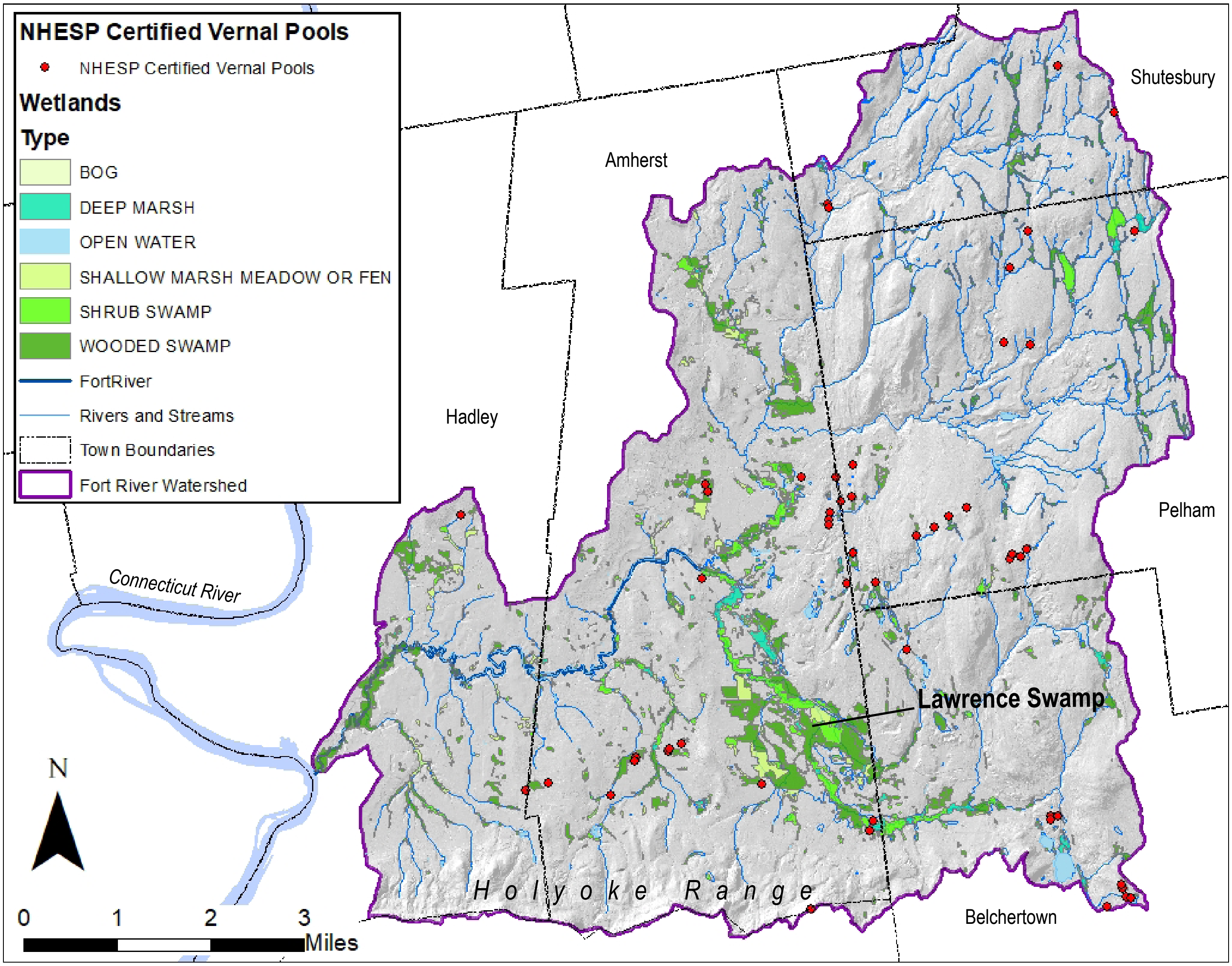
In Massachusetts, wetlands are legally protected through Massachusetts General Law Chapter 131, Section 40 Wetlands Protection Act, and the associated regulations 310 CMR 10.00. In inland areas, this law designates freshwater wetlands, land under streams, rivers, and lakes, land subject to flooding, and Riverfront Areas as protected Resource Areas. It also establishes a 100-foot Buffer Zone adjacent to wetlands, in which proposed work is evaluated for its potential impact on the wetland. Town Conservation Commissions are responsible for conducting these evaluations and ensuring that projects comply with the Wetland Protection Act and associated regulations.

Towns in Massachusetts can implement local wetland protection bylaws to further protect wetlands. All the towns in the Fort River watershed towns have a wetland bylaw that regulates activities within the 100-foot buffer zone by requiring permission through the Conservation Commission. Only Amherst and Hadley have local wetland bylaws that protect areas of land bordering wetlands through no disturbance zones (**Table 4**). These no-disturb zones are areas where any work is prohibited so that vegetation and soil remain undisturbed in order to protect the wetland resources they surround.

Town	Wetland Bylaw	Buffer	No Disturb Zone
Amherst	Yes	100 feet	Vernal Pool: 100ft Residential: 30ft
Belchertown	Yes	100 feet	None
Hadley	Yes	100 feet	35 feet
Pelham	Yes	100 feet	None
Shutesbury	Yes	100 feet	None

Table 4. Wetland buffer zones by local wetland bylaw

Figure 07. A bird box provides shelter along the edge of one of Lawrence Swamp's meadows. At 425 acres, the swamp is a mixture of wooded swamp, forest, river floodplain, and open meadows at its edges. Edge habitat provided by this mix attracts a diverse array of wildlife. Hop Brook, the largest tributary of the Fort River, flows through the conservation area which protects drinking water for the Town of Amherst.



Map 04. Fort River watershed wetlands and vernal pools. Data extracted from MassGIS.

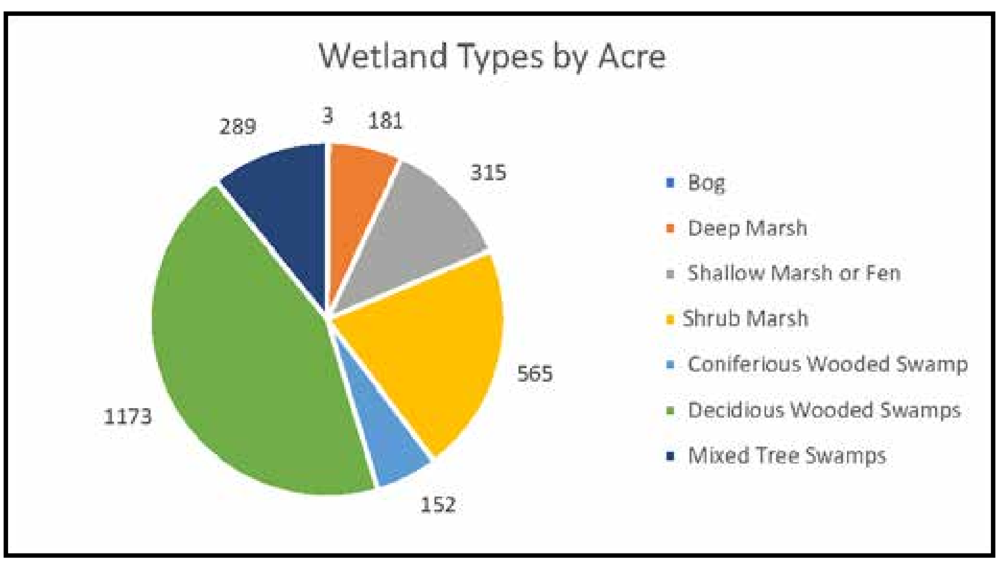
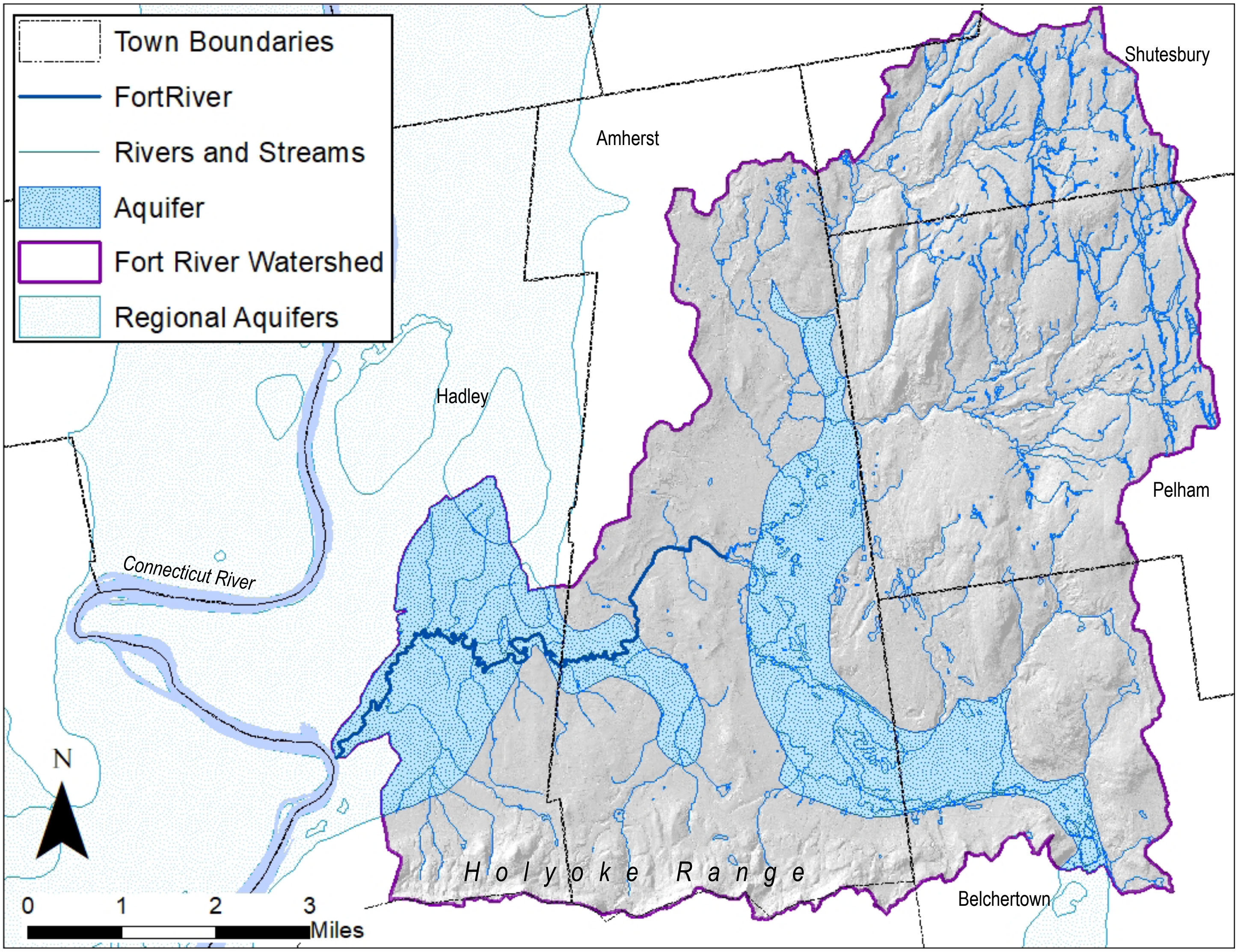


Chart 2. Fort River watershed wetland types by acre.



Map 05. Fort River watershed with aquifers. Data extracted from MassGIS data layers.

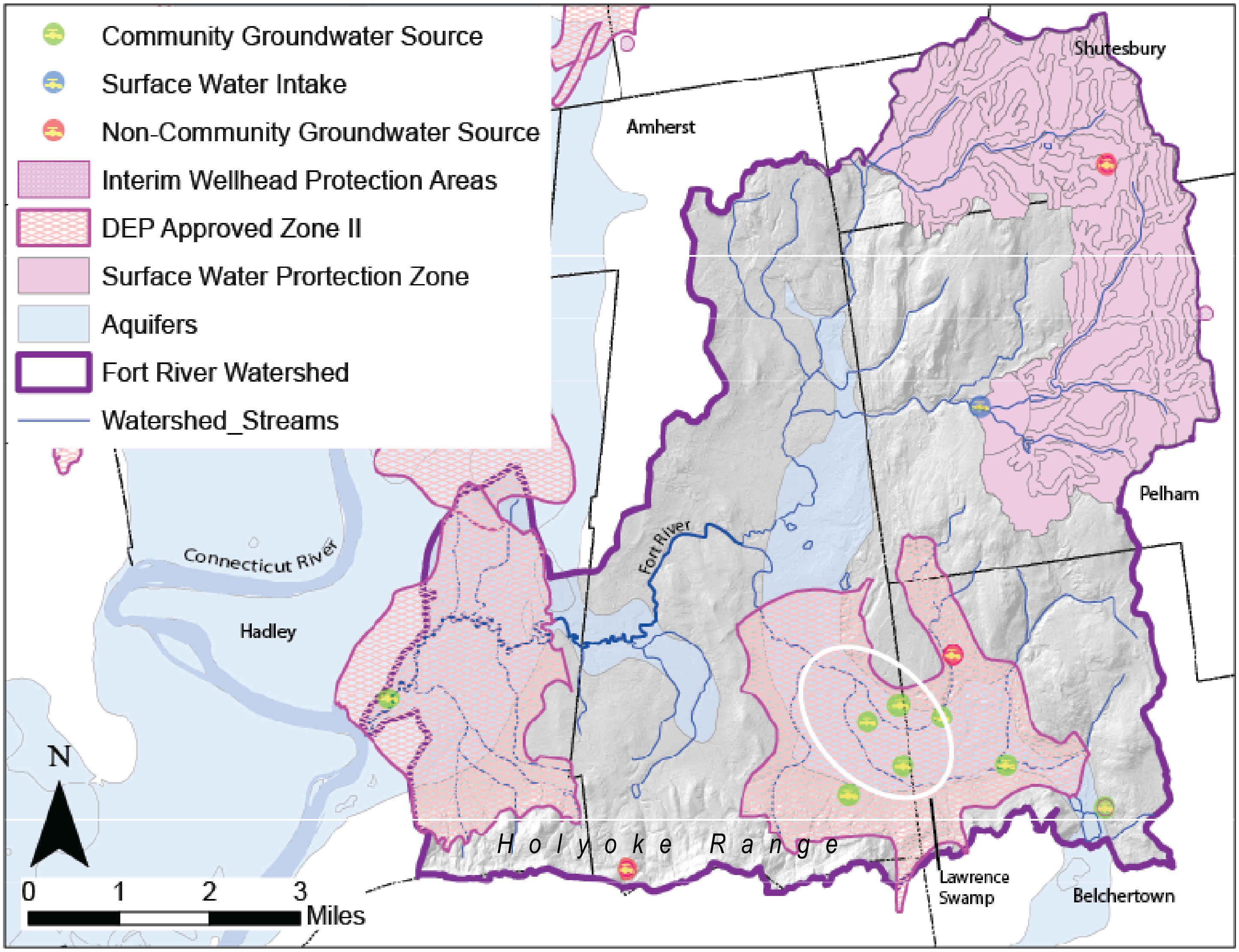
Aquifers and Groundwater

Aquifers are underground reservoirs of groundwater. When precipitation infiltrates the soil, any that is not taken up by plants or evaporated continues downward into a saturation zone that forms the water table. Water in this zone fills up spaces between rocks and gravel, moving slowly in undefined ways to reach discharge points like springs, streams, and drinking water supply wells. Aquifers can be polluted from leaking underground storage tanks, pesticide applications, and other chemical spills that leach into groundwater. Aquifer water quality can also be affected by pollution in streams.

Water quality and the volume of available water in aquifers is related to the hydrologic cycle and how much is pumped out for drinking water and irrigation. Decreases in precipitation can lead to lower amounts of available groundwater. Large amounts of impervious surfaces reduce infiltration in areas that would otherwise be vegetated and allow for the infiltration of large amounts of water.

Impervious surfaces can impair water quality of groundwater by increasing surface runoff that may intersect with the water table where it is discharged, which is heated by dark surfaces and often polluted with chemicals and nutrients. Water withdrawals also lower available groundwater. Drinking water supply and irrigation wells pump water out of aquifers, potentially at times of drought and already low groundwater supply.

There are two aquifers in the Fort River watershed, one in Hadley near the Connecticut River and one in east Amherst and north Blechertown (**Map 05**). The Town of Amherst has five drinking water supply wells from the Lawrence Swamp aquifer (**Map 06**). Much of this land is currently protected from development. Three zones of protection are delineated around these wells, including a primary zone of 400 feet radii around the wells. The Town of Amherst also has two zoning bylaws that regulate land use activities in water supply areas. Section 3.24 and 3.25 of Amherst's zoning code establishes a watershed protection district and an aquifer Recharge Protection district, both of which prohibit and regulate various uses within the district (Amherst Bylaws 2019).



Map 06. Drinking water supply areas in the Fort River watershed. Source: MassGIS.

Drinking Water Supply

Drinking water is sourced from freshwater resources like streams, groundwater, and aquifers. Water must be treated prior to distribution so that it is safe for human consumption. Natural processes provided by riparian vegetation and wetlands like filtration, sedimentation, nutrient uptake, and infiltration can help provide cleaner water to communities.

There are two types of public drinking water supplies in the Fort River watershed. First, two surface water supply zones are in the northeastern portion of the watershed, draining from the higher elevations of Pelham and Shutesbury. The land that supplies the surface water intakes is marked on the map in pink. This area is regulated by state law and local ordinances to protect water quality. These surface water resource areas provide drinking water for the towns of Pelham and Amherst.

The second type of public drinking water supply in the Fort River watershed is wells. These are in Amherst, Hadley, and Belchertown, and are marked on the map as green dots. Wells and associated protection zones are located along the Hop Brook wetland complex, in the southeast corner of the watershed, and on the Fort River near the Connecticut River.

Pollution prevention is important for protecting water used for drinking and other human uses. Even though land use activities are regulated in drinking water supply areas, ensuring that freshwater resources are protected from contamination and sedimentation will help to reduce local costs and ensure a reliable supply.

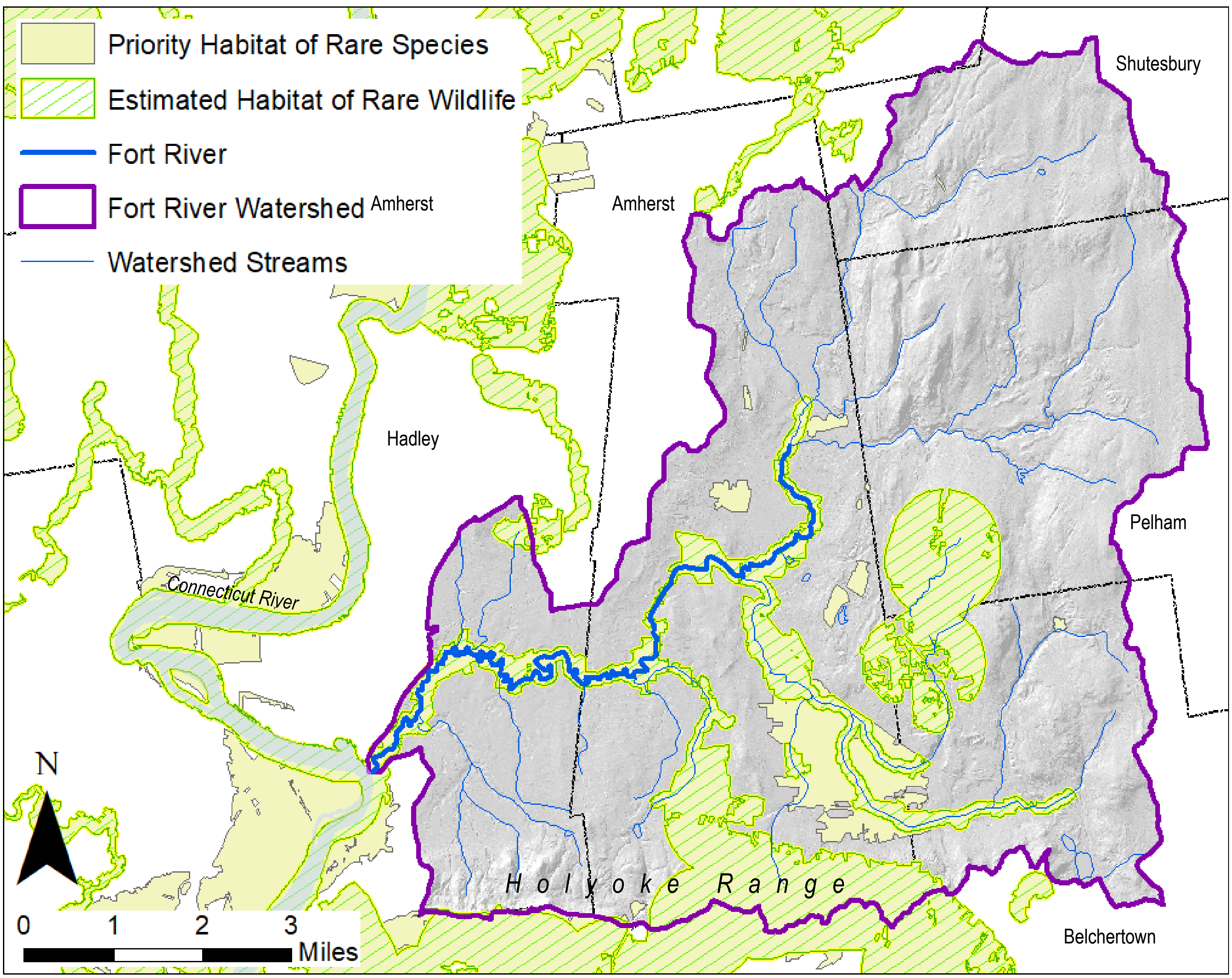
Habitat and Water Quality

Natural Heritage and Endangered Species Program

The Fort River watershed contains a broad variety of habitats that include forests, wetlands, grasslands, and aquatic and riparian areas. These habitats are all closely related to local hydrology and can be affected by changes to the quality and quantity of water flowing through them. In other words, the way in which water moves throughout the Fort River watershed influences the landscape and creates ecosystems that provide diverse habitat for plants and wildlife. By protecting key habitats, ecological functions that maintain and improve water quality can also be sustained. These ecological functions of various habitats include interception of rain, filtration of water by plants, and infiltration of water into the ground, all of which serve to improve water quality for human uses and biodiverse ecosystems.

In the Fort River watershed, a number of habitats are identified using the Natural Heritage and Endangered Species Program (NHESP) and BioMap2. NHESP identifies priority and estimated habitats for rares species. BioMap 2 identifies core habitats that support rare species, natural communities, species of conservation concern, and intact ecosystems. Identifying these habitats in the Fort River watershed can assist in identifying areas that not only are important to species conservation, but also function to improve and maintain water quality. When a location has both these qualities, critical habitat and hydrologic function, conservation efforts are mutually beneficial.

Priority Habitats of Rare Species are locations identified by the state of Massachusetts NHESP that have certain habitats needed to support rare and endangered species, including plants and animals. This information is based on the documented geographic extent of state-listed rare species. These areas are protected in Massachusetts and activities in these areas require permission through Conservation Committees and/or NHESP approvals. In the Fort River watershed, the Fort River and its main tributaries have priority habitat for rare species. For example, the federally listed endangered dwarf wedge mussel (*Alasmidonta heterodon*) has a historical presence in the watershed. The Eastern pondmussel (*Ligumia nasuta*), a state-listed species of concern, also has a historical presence in the Fort River. These mussel species are vulnerable to poor water quality conditions and are unable to escape sedimentation because they are sedentary filter feeders. Their presence generally indicates good water quality (NHESP Dwarf



Map 07. NHESP Priority and Estimated Habitats of Rare Species. Source: MassGIS

Wedge Mussel 2015).

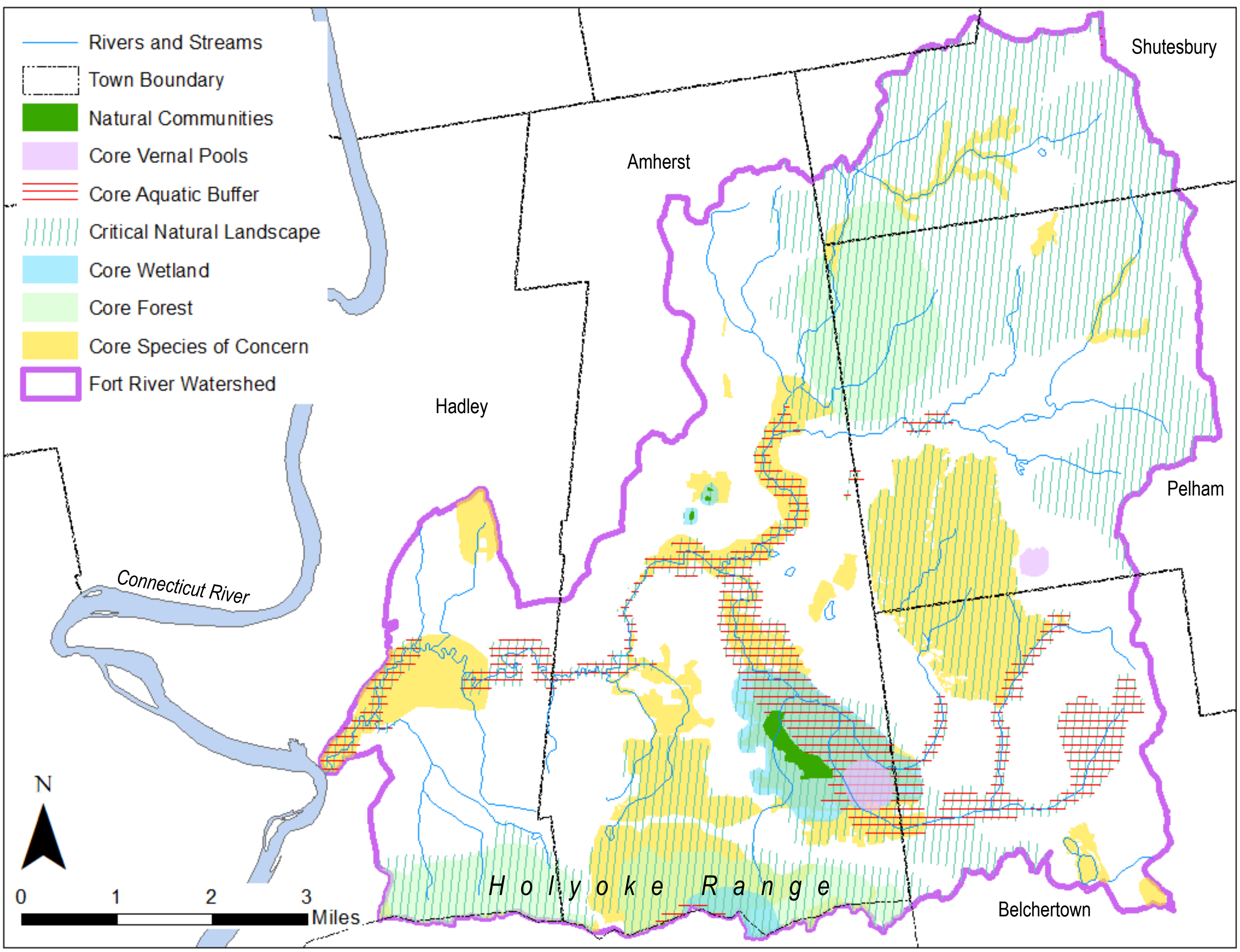
Estimated Habitats of Rare Wildlife are a subset of Priority Habitat for Rare Species that is based on documented cases of rare wetland species as recorded in the NHESP database. State listed wetland species are protected under the Massachusetts Wetland Protection Act and the Massachusetts Endangered Species Act. The Fort River watershed contains this habitat along the Fort River and in the southern and southeastern portions where wetlands and the Holyoke Range are located. An example of a wildlife species with estimated habitat in the Fort River watershed is the wood turtle, *Glyptemys insculpta*. This turtle prefers streams with sandy bottoms and densely vegetated riparian areas (NHESP Wood Turtle 2015).

In the Fort River watershed, rare species habitats are found in aquatic, riparian, and wetland areas (**Map 07**). These habitats also connect regionally along rivers and forested areas to other areas with estimated and priority habitats of rare and endangered species. These habitats are important lands to protect from development and other disturbances. A healthy ecosystem supports a diversity of species and through protecting the critical habitats needed to support rare species, other species and water quality will be supported.

BioMap 2

In 2010, the Massachusetts Natural Heritage & Endangered Species Program (NHESP) and The Nature Conservancy's Massachusetts program developed BioMap2 as a conservation plan to protect the state's biodiversity. BioMap 2 identifies Core Habitat as "specific areas necessary to promote the long-term persistence of rare species, other species of conservation concern, exemplary natural communities, and intact ecosystems" (NHESP: Forest Core 2010).

According to BioMap2, five core habitats are found in the Fort River watershed (**Map 08**). These core habitats include forest core, core habitat for species of concern, vernal pool habitat, core aquatic habitat, and core wetland habitat. Forest core habitats are large contiguous blocks of forest that are not fragmented by roads or development. In Massachusetts, forest core areas make up only 10% of the total land cover in the state. These large blocks of forest land provide important habitat to woodland and several bird species. They also function to reduce flooding by dissipating rainfall and absorbing runoff. The southern boundary of the Fort River watershed has two forest core blocks, which are connected regionally along the Holyoke Range to forest core habitat. A



Map 08. Natural Communities and BioMap 2. Source: Mass GIS.

large area of forest core habitat is found in the western portion of Pelham.

Core habitat for species of conservation concern is also present in the Fort River watershed. This is the habitat needed to support aquatic and terrestrial species that are listed in Massachusetts as species of concern. These species are vulnerable to habitat loss or other threats to their populations, but are not listed as threatened or endangered in Massachusetts.

The Fort River watershed has two locations of vernal pool core habitat, located near the Lawrence Swamp. Vernal pools are small seasonal wetlands typically forming in forested, low areas in times of high water or seasonal snow melt. Some niche species breed in vernal pools, including amphibians and macroinvertebrates. Protecting vernal pool habitats also allows them to function as sponges for surface runoff from undeveloped land because they can retain and absorb large amounts of water. This reduces the volume of water running downslope and associated erosion during a precipitation event or spring snow melt.

Core aquatic habitat—habitat for fish and species of concern in Massachusetts—is present along the Fort River and its tributaries. Aquatic cores identify the intact river corridors where important physical and ecological processes occur and include a 30-meter buffer along streams. Protecting these areas from the impacts of development and stormwater will help protect species that have all or part of their life cycle in aquatic systems. Additionally, stream channels meander through natural scour and deposition processes, creating new riffle pools and habitat. Protecting core aquatic habitats from development can preserve or improve water quality because the natural processes of aquatic ecosystems are not constrained. For example, protecting aquatic buffers promotes vegetation and tree growth; subsequent shade cools streams while roots trap nutrients and stabilize riparian slopes.

There is one wetland core habitat in the Fort River watershed, located in the Lawrence Swamp. Wetland core habitats are wetlands that are the least disturbed in a developed landscape and the most likely to continue their ecological function if they remain protected. Wetlands capture flood water, encourage infiltration, and release water slowly back to streams. They filter water as it runs off land by allowing for sedimentation to occur as water slows down. Wetland plants absorb nutrients in flood waters to provide further filtering of water.

Natural Communities

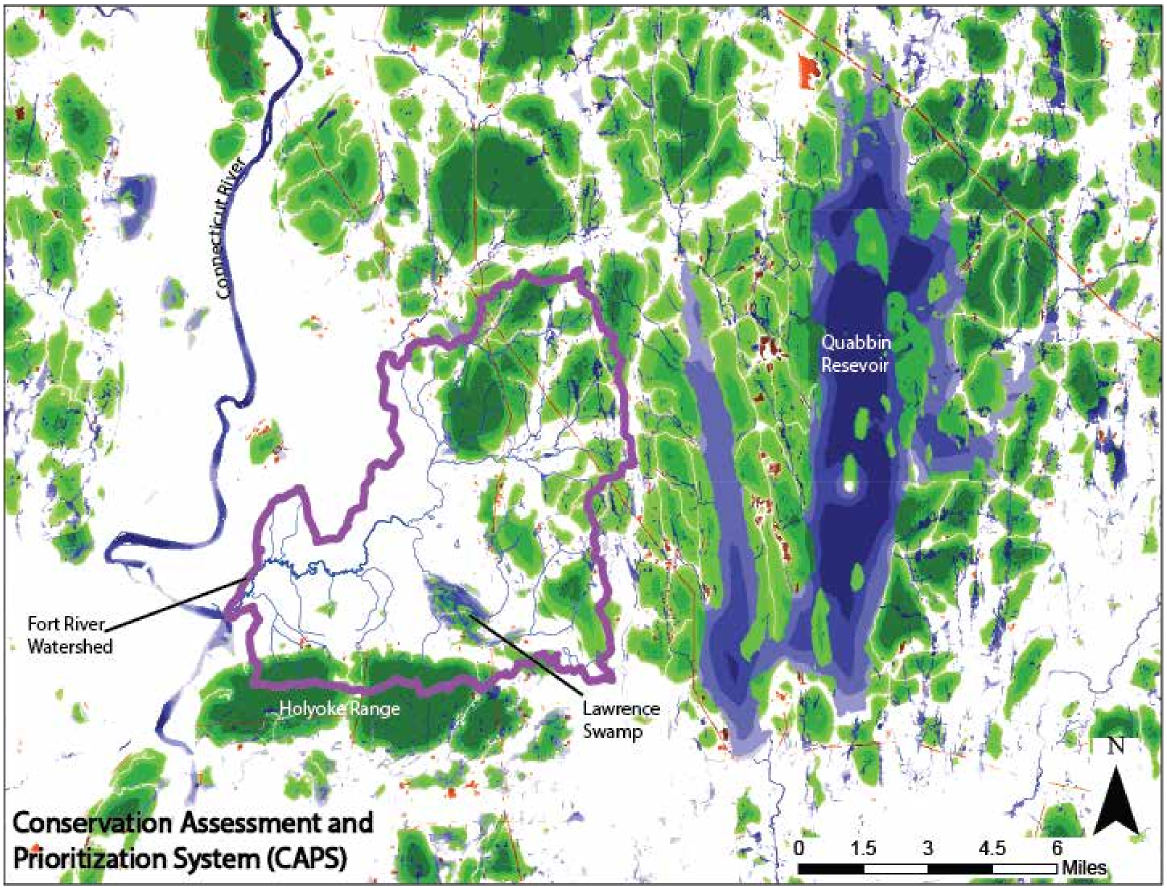
Natural communities are groups of plant and animal species that are found together in certain environmental conditions across the landscape. In the Fort River Watershed, there is one natural community identified by a black gum, pin oak, swamp white oak perched swamp (**Map 08**). It is an unusual type of wetland, which in Massachusetts is only found in a few areas of the Connecticut River Valley. This natural community occurs on flat former lake beds of Glacial Lake Hitchcock where there are deposits of clay, isolating this wetland from the floodplain and water table. It typically is wet in the spring and dries out over the summer. This natural community provides seasonal flood storage in addition to habitat for salamanders, amphibians, and other species that breed in seasonal wetlands.

Conservation Assessment and Prioritization System (CAPS)

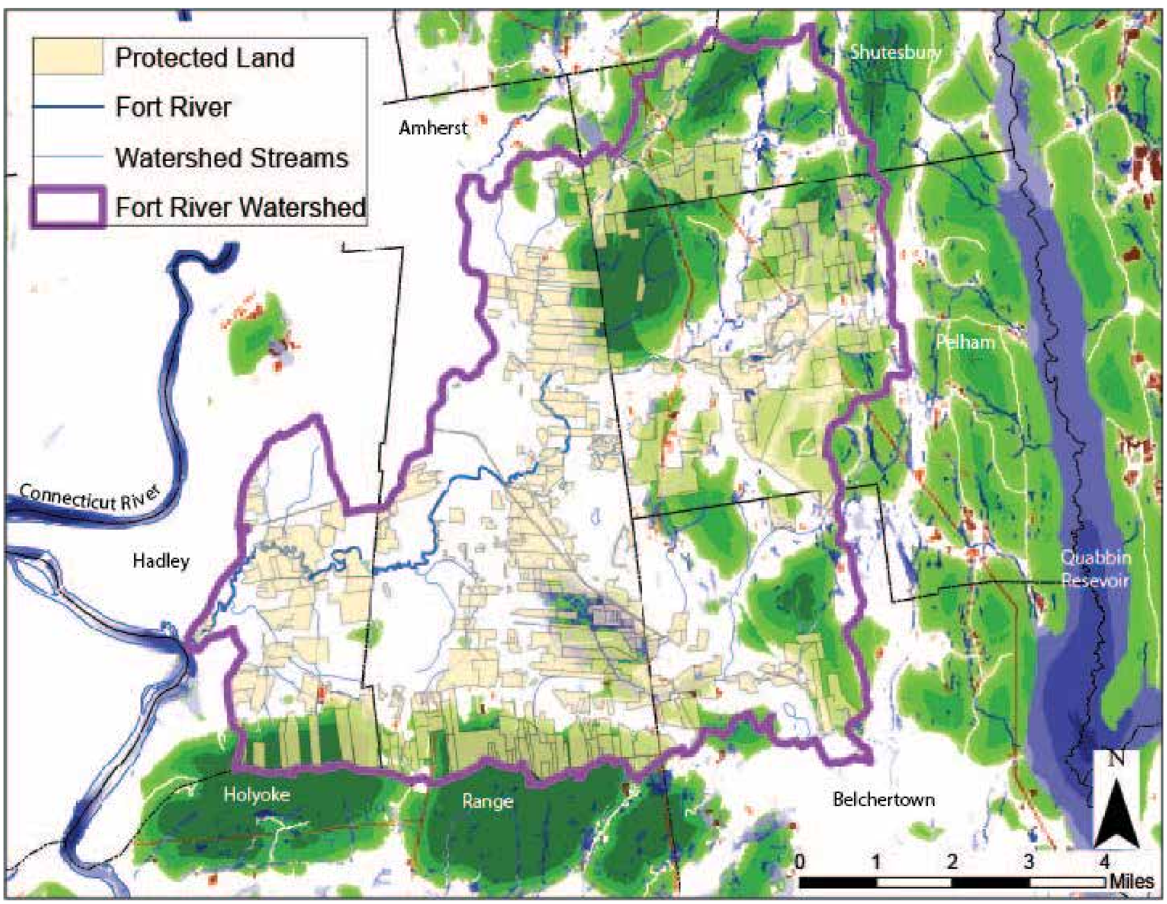
In 2011, the University of Massachusetts, Amherst, developed the Conservation Assessment and Prioritization System (CAPS). CAPS is an ecosystem-based approach for assessing the ecological integrity of lands and waters and subsequently identifying and prioritizing land for habitat and biodiversity conservation. CAPS defines ecological integrity as the ability of an area to support biodiversity and the ecosystem processes necessary to sustain biodiversity over the long term. It considers the ecological integrity of the whole landscape, not just the locations of rare species (McGarigal 2011).

The CAPS program is based on 2005 land use, Massachusetts Department of Environmental Protection (DEP) mapped wetlands, BioMap2, and other available data to build a GIS system for identifying land for conservation. It uses a color scheme to represent its index of ecological integrity (IEI): darker colors represent higher valued cells and white areas are developed land (McGarigal 2011).

Within the Fort River watershed, the CAPS assessment identifies the Lawrence Swamp and areas around headwater streams as areas with a high IEI (**Map 09**). Lawrence Swamp is important to protect for biodiversity and wetland habitat. It is also a key area to preserve for protecting water quality due to this large wetland area functioning to store and filter surface water. Headwater streams are important to protect as key habitat and as a flood mitigation technique. In the Fort River watershed, parcels of land that are identified by CAPS to have a high ecological integrity are parcels to prioritize for protection from development, if they are not already (**Map 10**).



Map 09. Conservation Assessment and Prioritization System (CAPS) identifying darker colors with greater ecological integrity. Information from umasscaps.org.



Map 10. Conservation Assessment and Prioritization System (CAPS) and protected parcels in the Fort River watershed. Information from umasscaps.org and MassGIS.

Figure 08. Dwarf wedge mussels (*Alasmidonta heterodon*), a federally listed endangered species that has been observed in the Fort River watershed.

"Riparian disturbance, pollution, sedimentation, impoundments, artificial flow regimes, and stream fragmentation disrupt mussel life cycles, prevent host fish migration...resulting in decreased population densities and increased probability of local extinctions. Toxic effects from industrial, domestic, and agricultural pollution are the primary threats to this mussel's survival. Increased acidity, caused by the mobilization of toxic metals by acid rain, is thought to be one of the chief causes of the species' extirpation from the Fort River in Massachusetts." (USFWS)

Fearing Brook, Amherst, MA

Fearing Brook is a one-mile-long stream that collects runoff from half of downtown Amherst, depositing it into the Fort River (Fig. 09). The Fearing Brook watershed is a densely developed urban area, with ninety-percent of land covered with impervious surfaces. Stormwater pipes convey runoff from these surfaces directly into daylighted sections of Fearing Brook. Sections of the brook were straightened and buried as Amherst developed (Fearing Brook Update). Today, Fearing Brook remains buried in the upper part of the stream and near the end under East Amherst Road. It is a source of untreated stormwater entering the Fort River because much of the Fearing Brook's urbanized watershed drains directly into the stormwater pipes that discharge into Fearing Brook.

Additionally, Fearing Brook water tests indicate high levels of fecal contamination. A report in 2016 by the University of New Hampshire's Jackson Estuarine Laboratory found that the Fearing Brook watershed was impacted by fecal pollution, particularly human contamination at the downstream end, and that of mammals (pets and rodents) and gulls throughout. A report in 2015 by New England Environmental, Inc., found that ruminant contamination was not present in the locations tested in Amherst (Geosyntec Consultants, Inc 2019).

In 2017, the Town of Amherst partnered with the Massachusetts Division of Ecological Restoration (DER) to assess Fearing Brook and determine possible restoration projects that would improve water quality and increase habitat. It was determined that the first project to restore Fearing Brook would be to recreate 400 feet of floodplain on either side of the brook before it enters the Fort River (Interview with Beth Willson, February 14, 2020).

The floodplain restoration will de-channelize the brook and establish vegetation that will stabilize the banks. It is intended to allow for water to spread out over the new floodplain and, in doing so, encourages a decrease in stream flow velocity, allowing for suspended sediment to settle out of the water, improving water quality as the brook meets the Fort River. The restoration project will increase habitat and it is intended to reduce the volume of stormwater, the levels of nutrients, and *E. coli* entering the Fort River by providing areas for infiltration and sedimentation (Geosyntec Consultants, Inc. 2019).

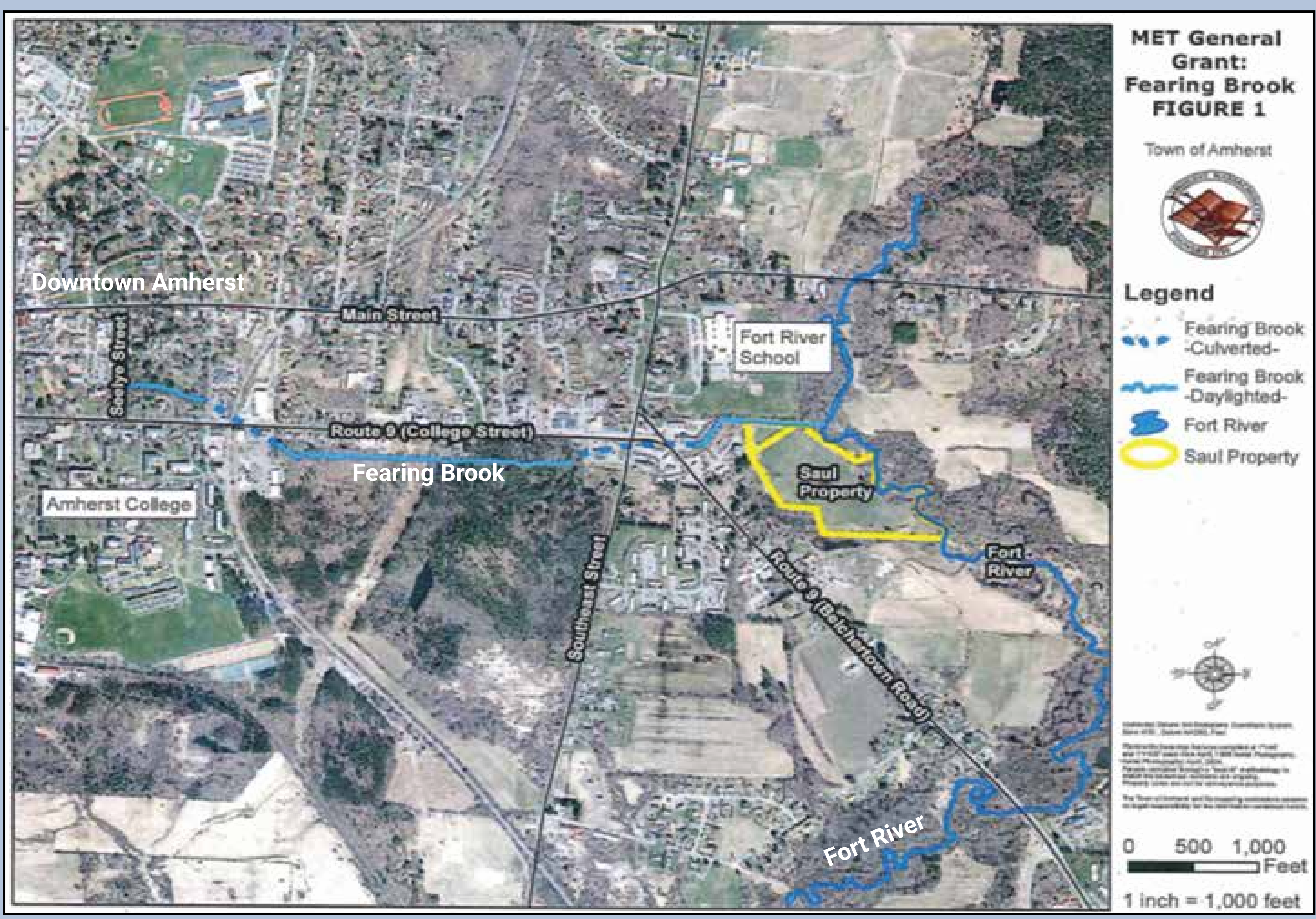


Figure 09. Fearing Brook flows west to east from downtown Amherst to the Fort River. Culverted sections shown as dashed line. Source: Town of Amherst and Milone & MacBroom 4/5/2019.

Figure 10.. Stormwater outfall to Fearing Brook. Source: Massachusetts Division of Ecological Restoration

Figure 11. Restoration of the Fearing Brook floodplain would involve regrading the banks of the stream channel, removing invasive vegetation, and stabilizing banks and soils with native shrubs, trees, coir logs, and rocks. Source: Town of Amherst and Milone & MacBroom 4/5/2019.

Figure 12. Agriculture, commercial, and residential development along Route 9 in Hadley. Under a tree canopy, the Fort River winds through farmland. Source: Google Earth.

Chapter 2: Land Use

The diverse habitats of the Fort River watershed play an important role in the water cycle by filtering and cleaning water as it travels from the highest elevations to the lowest, from the Mount Holyoke Range and hillsides of Pelham and Shutesbury, to the Fort River. Land use activities within the watershed, however, intervene in the natural hydrologic cycle affecting water quality. Conservation, for example, protects natural resources, contributing to healthier ecosystems and improved water quality, while development fragments habitat and disrupts the water cycle by laying down impervious or semi-impervious cover that redirects and accelerates the flow of stormwater, which may contain pollutants that diminish water quality. Some land use activities, such as agriculture, simultaneously create wildlife habitat and potentially contribute to decreased water quality depending on the management practices being used. This chapter assesses the major land uses within the Fort River watershed and their potential impacts on water quality.

Conservation and Chapter Lands

The two primary ways landowners can protect their land is through a conservation easement or by enrolling in the Massachusetts Chapter 61 tax program. A conservation easement is a legal restriction on a deed that limits the development of that parcel by permanently restricting the property to open space, a strategy that can help to sustain water quality in critical natural resource areas such as wetlands, riparian zones, and forests. Chapter 61 "give[s] preferential tax treatment to landowners who maintain their property as open space for timber production, agriculture, or recreation" (mass.gov). About forty percent of the watershed is protected in perpetuity through conservation restrictions, and while this percentage is quite high, there is still land critical to maintaining water quality in the watershed that remains unprotected, including lands enrolled in Chapter 61.

Protected Land

In Massachusetts, land is considered protected if the deed for the property has a restriction placed on it that prevents development. Land owned by municipalities that was acquired for conservation purposes is also considered protected under Article 97, even if it does not have a recorded restriction. Private landowners, like individuals and land trusts, and public state agencies and municipalities that own land can place permanent development restrictions on land that they own. In accordance with Massachusetts General Law Part II, Chapter 184, Section 31, five types of restrictions are found within the Fort River watershed. These include historical, conservation, agricultural preservation, and watershed preservation restrictions.

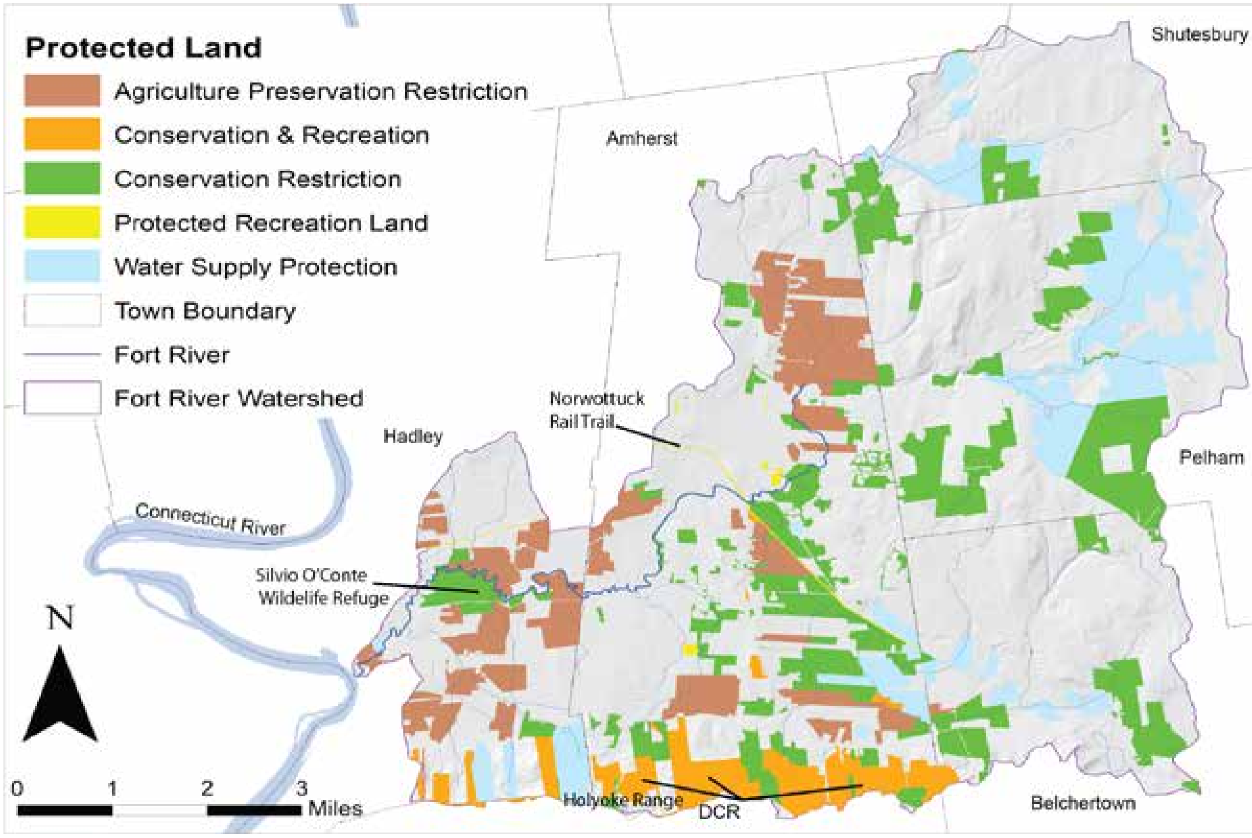
A conservation restriction (CR) preserves land in its natural condition and limits any future uses that negatively affect maintaining this state. It is "a legal agreement between a land owner and a government agency or land trust that permanently protects open space by limiting future uses of the land, usually including the amount and type of development that can occur, but continues to leave the land in private ownership" (Office of Energy and Environmental Affairs, 2020). Land with a conservation restriction is intended for habitat protection and, depending on what is specified as a permitted use in the restriction, recreational uses such as trails can be allowed. Lands that are protected through conservation restrictions also function to improve and maintain water quality.

An agriculture preservation restriction (APR) protects agricultural or forestry land from development. In Massachusetts, the program offers to pay farmers or landowners the difference between the agricultural value and the fair market value, which can be higher. The deed restriction placed on a property is held in permanence by the state of Massachusetts Department of Agricultural Resources. The aim of this voluntary program is to protect productive farmland and farmland soils by preventing any use of the property that would negatively impact its future agriculture potential (MA APR Program).

A water supply preservation restriction is a deed restriction placed on property to protect water supplies. The intent is to preserve the natural infrastructure that forests and other ecosystems provide by filtering water that drains into drinking water supplies and, thereby, reducing the human-engineered systems needed to provide clean drinking water.

A historical restriction is a deed restriction intended to preserve a site or structure with historical significance. This type of restriction does not significantly affect water quality or habitat in the Fort River watershed.

Using the February 2020 Protected and Recreational Open Space data layer from MassGIS, five types of land protected in perpetuity were identified in the Fort River watershed by excluding



Map 11. Permanently and temporarily protected land. Source: MassGIS.

all temporary forms of land protection. These types include agricultural preservation restrictions, conservation and recreation, conservation, recreation, and water supply protection. In total, approximately 15,076 acres are protected, which is about forty percent of the Fort River watershed (**Map 11**).

Conservation Restrictions

There are about 5,746 acres of land in conservation with a deed restriction in the watershed. These areas include the Silvio O. Conte National Fish and Wildlife refuge, town-owned conservation areas, and privately held parcels, including those held by land trusts. As shown in green on **Map 11**, parcels with conservation restrictions are found throughout the Fort River watershed. CR parcels help protect water quality by preventing development and thereby helping to protect forested, riparian, and wetland areas that capture, store, and filter stormwater.

Agricultural Preservation Restrictions

There are about 3,089 acres of permanently protected agricultural land in the Fort River watershed. This acreage is enrolled in APR programs through Massachusetts Department of Agricultural Resources. APR land in the Fort River watershed is shown in brown in the Protected Land map (**Map 11**). Most of the APR land is in Hadley and Amherst, and most of this land is abutting or near streams. While APRs do protect these lands from development, agricultural uses can also negatively impact water quality and habitat. Due to the proximity to the streams, APR lands and associated land use activities, depending on how land is managed, could negatively impact water quality due to surface runoff and subsurface flow. Water that runs over land and into streams could carry sediments and nutrients directly into streams. Water that infiltrates the soil and flows underground to streams can also carry nutrients into the stream. Additionally, water that is pumped out of the ground or river has the potential to lower stream flow, particularly in summer months.

Protected Recreation Land

Based on data available from MassGIS, there are about 85 acres of recreation land that is accessible by the public and protected in perpetuity. The majority of these acres are owned by the Town of Amherst and the Massachusetts Department of Conservation and Recreation, which owns the Norwottuck Rail Trail that extends through the region.

Protected Conservation & Recreation Land

In the Fort River watershed, about 2,827 acres of land is preserved in perpetuity through conservation restrictions that permit recreation. The major owner of these parcels, as notated in orange on the map, is the Massachusetts Department of Conservation and Recreation (DCR), which manages Skinner State Park in the Holyoke Range in the southern portion of the watershed. The conservation and recreation lands in the Fort River watershed are in the higher elevations along the Holyoke Range and are used primarily for hiking. This land is important to protect not only for recreation, but also for maintaining natural vegetation on the steep, northern slopes of the Holyoke Range. This vegetation helps slow down runoff and reduces erosion downstream.

Water Supply Protection

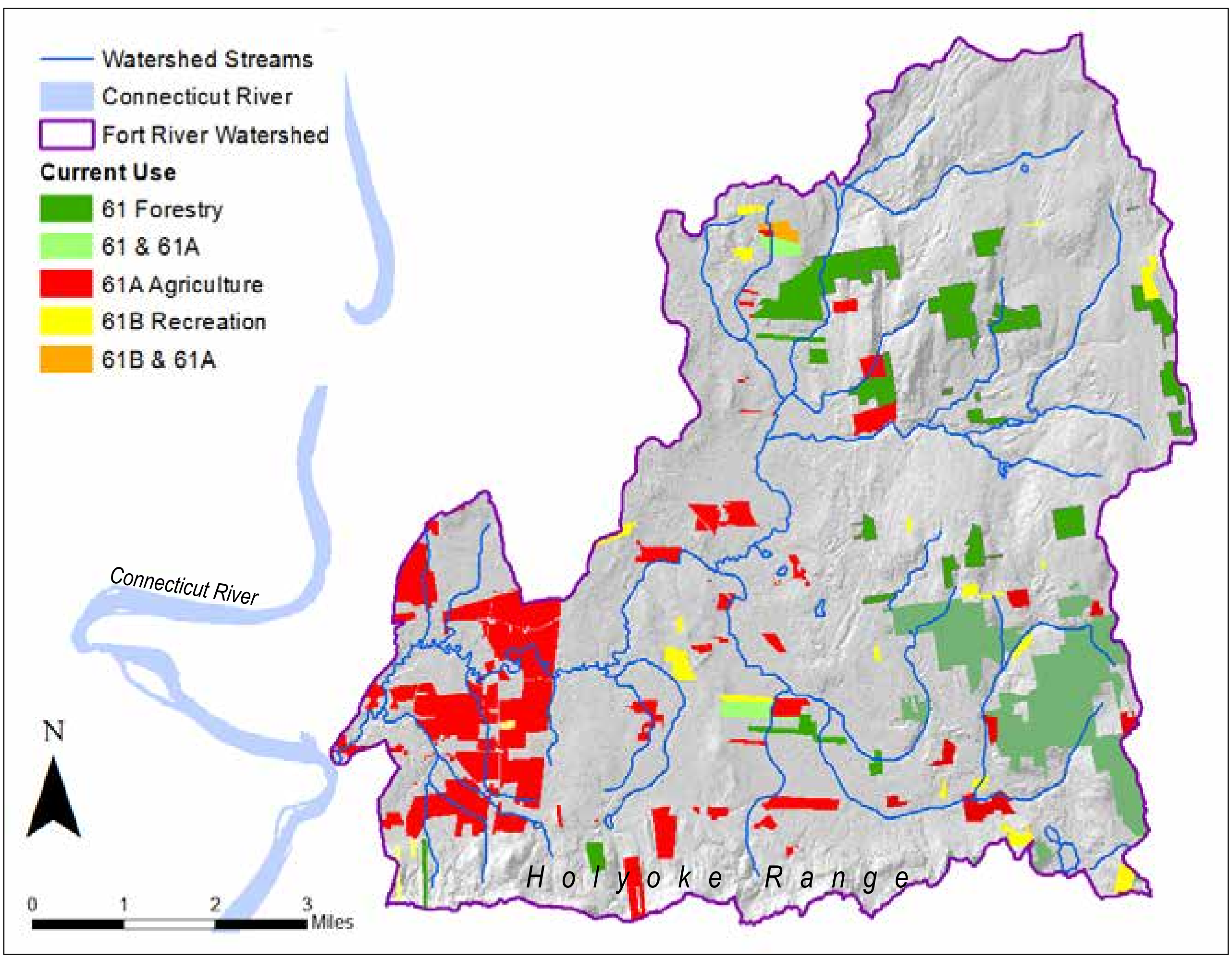
Based on data available from MassGIS, about 3,330 acres of drinking water supply land in the Fort River watershed is permanently protected in accordance with Massachusetts General Law Part II, Chapter 184, Section 31 and Article 97. This land is shown in blue on the map and is mostly located in the higher elevations of the watershed. Preventing development of this land and regulating activities on it helps to protect the source of drinking water supplies, both surface water and groundwater, from contamination.

Current Use Programs

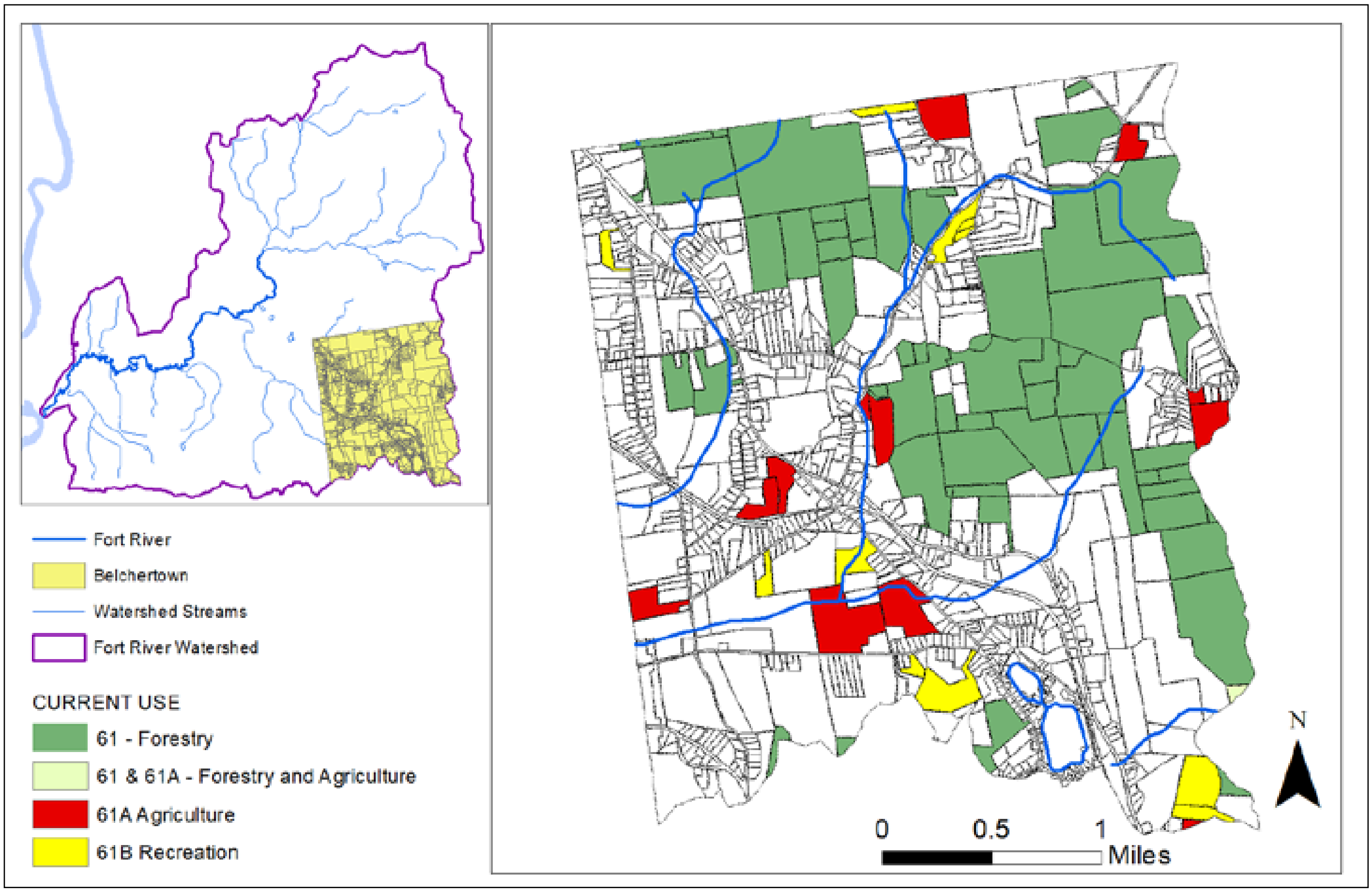
In Massachusetts, private landowners may enroll their land in Chapter 61 tax programs (Chapter 61, 61A, and 61B), which offers temporary protection by restricting land use to forest management, agriculture, or recreation. These programs were developed to help landowners maintain natural and working lands despite increases in property values. Parcels enrolled in Chapter 61 programs qualify for a discount in property taxes because the value is assessed on the value of the land for specific uses, not the development potential, which is usually higher.

In order to qualify for Chapter 61-Forestry enrollment, parcels must contain a minimum of ten acres in active forest management. Chapter 61A (Agriculture) requires a minimum of five acres of land that has been used for commercial agricultural purposes for at least two years, making a profit of at least $500 per year. Chapter 61B (Open Space and Recreation) restricts the property's use to activities like hiking, swimming, hunting, and camping. Once land is enrolled in Chapter 61, towns hold a lien on the property and the right of first refusal if the property comes up for sale, giving the Town the opportunity to acquire and protect the land.

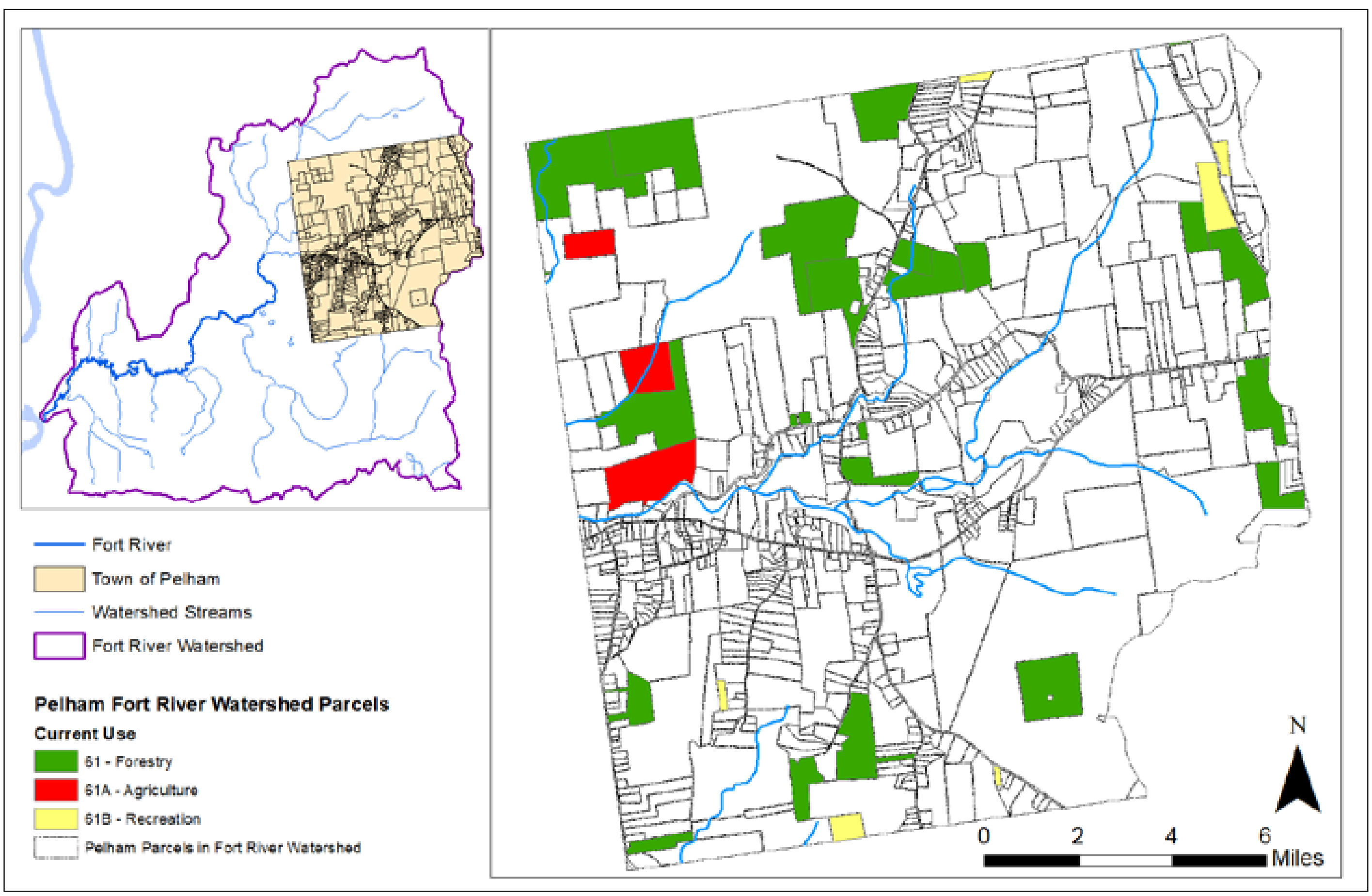
Each of the watershed towns have parcels enrolled in Chapter 61 programs (data for Chapter 61 lands in Shutesbury was not available of the time of study). While these programs protect the land from development, this protection is only temporary. Landowners are required to re-enroll every ten years and can withdraw at any time if they are willing to pay back taxes on the difference offered by the program. When land is withdrawn from the program, it becomes vulnerable to subdivision and potential future development. These currently undeveloped parcels could be possible candidates for permanent protection, particularly if they include or are near a water source.



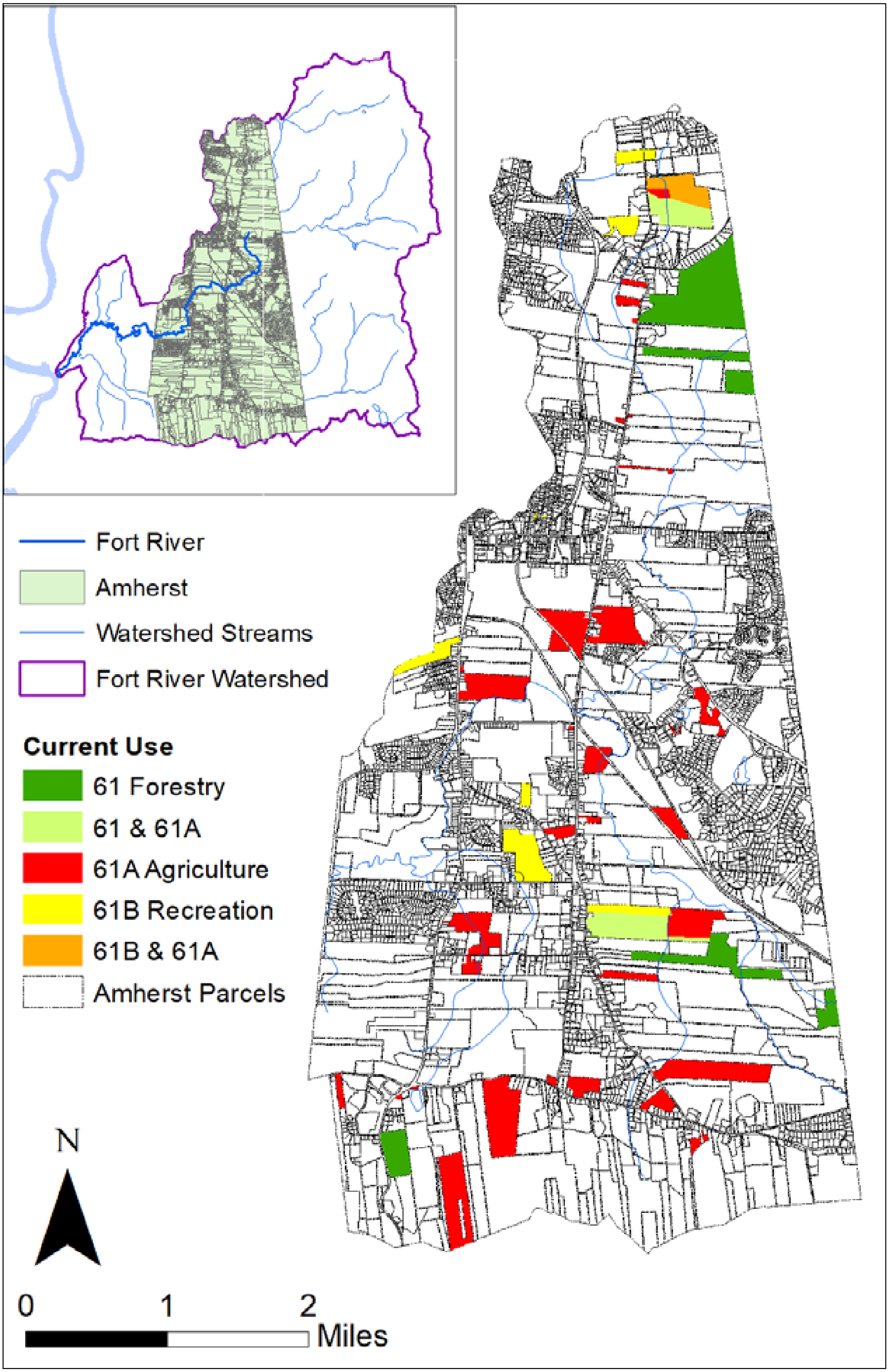
Map 12. Chapter 61 Lands. Source: MassGIS



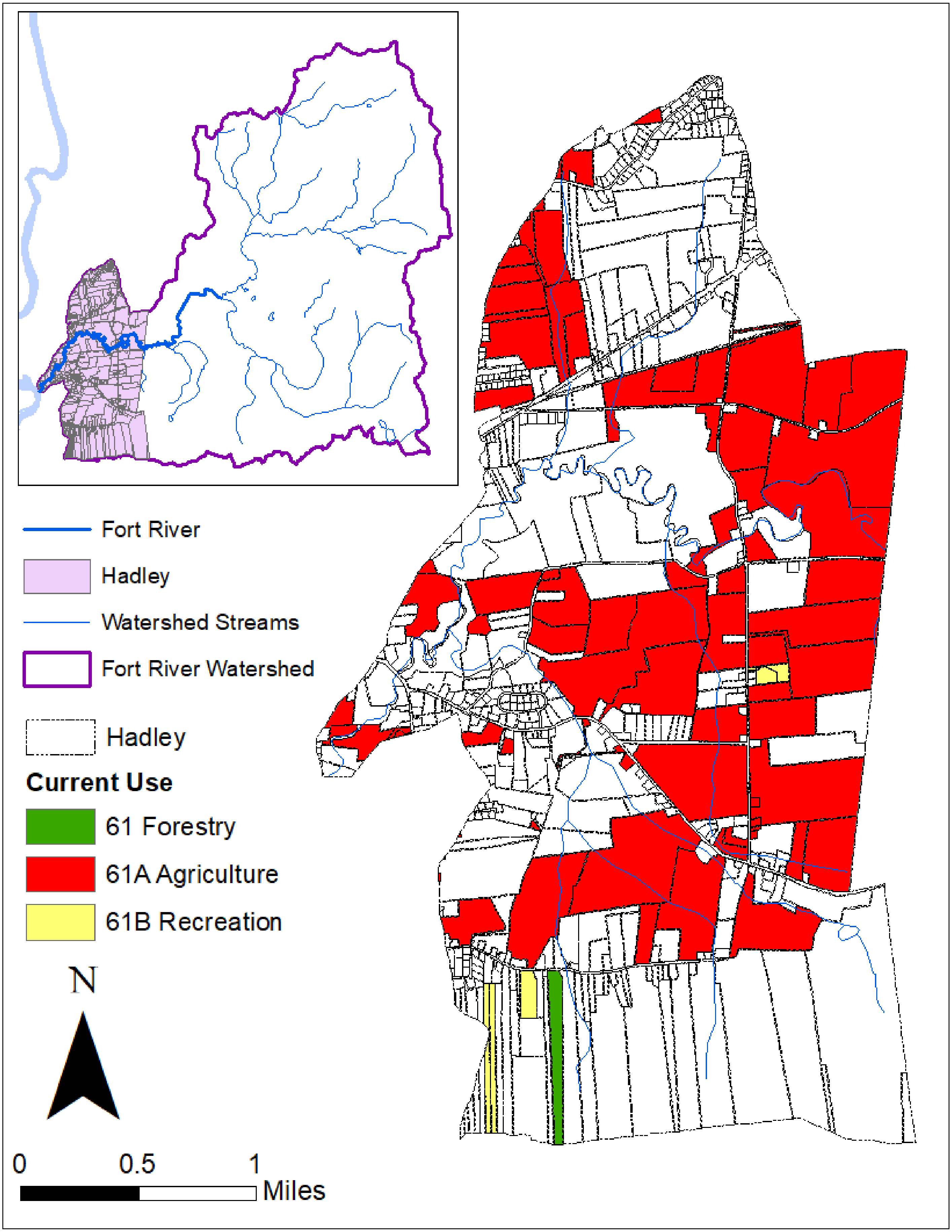
Map 13. Belchertown Chapter 61 Lands. Source: Town of Belchertown



Map 14. Pelham Chapter 61 Lands. Source: Town of Pelham



Map 15. Amherst Chapter 61 Lands. Source: Town of Amherst



Map 16. Hadley Chapter 61 Lands. Source: Town of Hadley

Flow Accumulation Analysis

The following pages include flow accumulation analyses applied to different types of land cover, including agriculture, impervious surface, and developed open space, in order to determine where in the watershed stormwater runoff from these types of cover may be having the greatest impact on water quality. Flow accumulation is a GIS algorithm that uses a Digital Elevation Model (DEM) to create stream networks by calculating where water accumulates as it travels over the landscape from higher to lower elevations. The algorithm can be applied to particular types of land cover (extracted from MassGIS 2016 Land Cover/Land Use dataset).

For the following analyses, the flow accumulation over particular land cover types was divided by the flow accumulation of the entire watershed to determine what percentage of total watershed flow each land cover type is contributing. This allowed a assessment of localized areas in the context of the watershed-scale thresholds of cover types and their influence on water quality as reported in Mass Audubon's *Losing Ground* report. For example, the results allow us to see where the contribution of flow over impervious surfaces exceeds the seven percent at which diminished water quality is seen. The results presented in the following pages suggest where potential stormwater management interventions may be needed in order to mitigate the negative influences of major land use in the watershed.

Agriculture

New England has a long history of agriculture due to its geography, glacial history, and soils (Pottern 7), and the Fort River watershed is no exception. The Fort River powered mills historically and the watershed's fertile floodplains also provided ideal conditions for growing crops and raising cattle near a water source. The patterns of colonial settlement adjacent to streams and rivers are still visible today with many farms—some of which have been in existence for over two hundred years, like Hartsbrook Dairy Farm—still populating land adjacent to the Fort River and its tributaries.

Agriculture continues to be an important part of the region's identity and economy, particularly in the Fort River watershed, which, along with other subbasins within the Connecticut River watershed, is one of the most farmed watersheds in Massachusetts (**Map 17**). From a statewide perspective, preserving prime agricultural soils ensures land is available to produce food in a time when agricultural land is rapidly being lost to development on a national scale (Pottern 1). Preserving these lands also has the added benefits of protecting the livelihood of farmers, supporting the local economy, and contributing to higher quality water depending on the agricultural practices used.

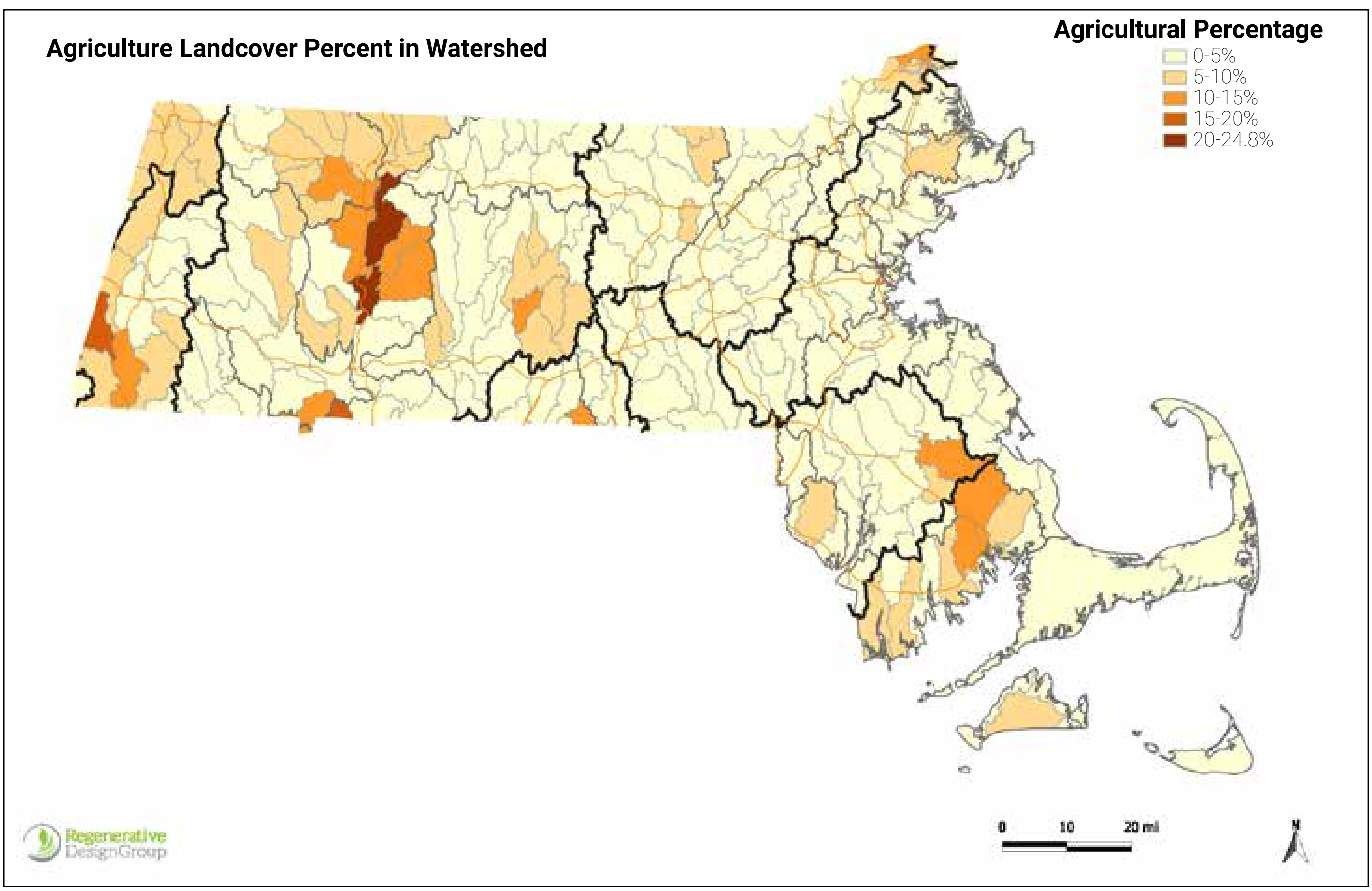
Prime Farmland

The soils of the Connecticut River Valley are particularly well-suited to agricultural use because of the deep, lake-bottom sediments that were left behind when glacial Lake Hitchcock drained nearly 12,000 years ago. More than half of the Fort River watershed has been identified as containing prime farmland soils of local or statewide importance, which is defined by the U.S. Department of Agriculture as "land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops" (NRCS). Most of this land is concentrated in the western half of the watershed at lower elevations lining the main branch of the Fort River and its tributaries but also includes pockets of low elevation land in the northernmost area of the watershed (**Map 18**).

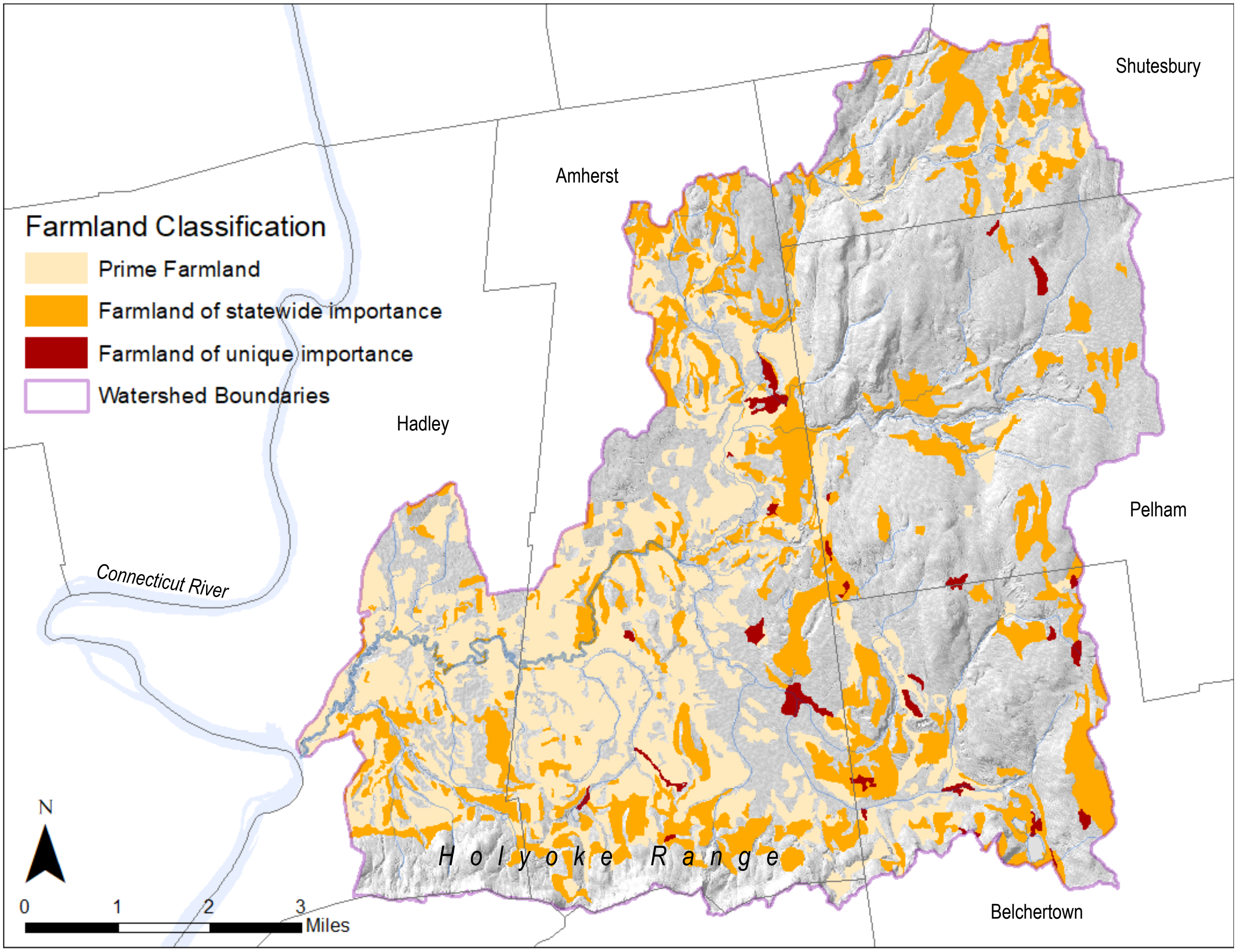
Agricultural Soils & Water Quality

While prime agricultural soils are ideal for agriculture, they also play in an important role in the hydrologic cycle and can affect water quality. The soils within the Fort River watershed, particularly in lower elevations, are composed of well-draining, sandy loam, making them excellent for capturing, filtering, and cleaning stormwater as it infiltrates to groundwater if managed properly.

In many ways, farmers throughout the region are leading the way in applying regenerative practices and improving soil (Pottern 7). However, some agricultural practices can have a detrimental effect on water quality.



Map 17. Cultivated and Pasture classes from the 2016 Landcover dataset as a percentage of land area per NRCS HUC level 12 watershed. Source: Regenerative Design Group.



Map 18. Agricultural lands within the Fort River watershed are concentrated around the Fort River and its tributaries. Source: 2016 Land Cover/Land Use MassGIS Data

Some of these practices include:

- repeated tilling with heavy machinery, leading to poor soil structure and compaction;
- leaving soil bare between plantings, making it more susceptible to erosion and contributing to the sedimentation of waterways;
- application of excessive fertilizers, pesticides, and herbicides that can be carried away by stormwater runoff or make their way to groundwater supplies;
- grazing livestock up to the edges of streams and rivers;
- improper management of manure, including applying it to croplands during wet weather and maintaining manure pits without overflow capture.

While healthy farmland soils can do the work of capturing and filtering stormwater in place, degraded or compacted soils may prevent infiltration and contribute to higher volumes of stormwater runoff reaching streams, which may be carrying pollutants. These practices can be especially detrimental to water quality when implemented on land adjacent to rivers and streams—where many of the farms within the watershed are located—without adequate riparian buffers to slow the flow of and filter stormwater before it reaches streams and rivers, or infiltrates into groundwater aquifers.

Best management practices for agriculture not only contribute to healthier waters but also benefit farmers. Keeping nutrients and soil on site reduces input costs and increases the fertility of soils, which can increase crop yields. The USDA Natural Resources Conservation Service (NRCS) offers to farmers a voluntary conservation program called the Environmental Quality Incentives Program, which provides technical and financial assistance to implement improvements to agricultural operations that also yield environmental benefits like improved water and air quality and improved wildlife habitat (NRCS EQIP).

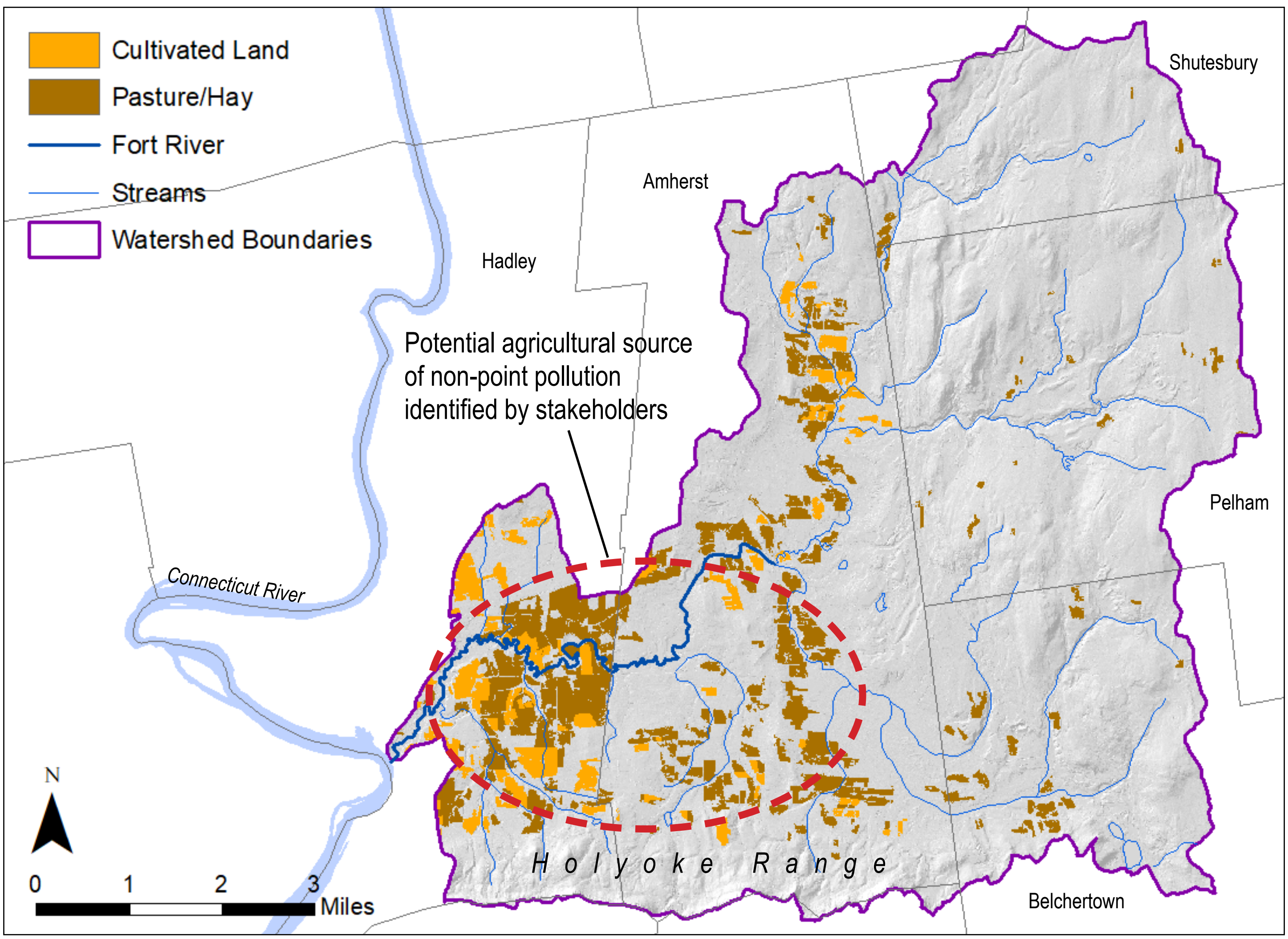
Agriculture and Non-point Source Pollution

During a community meeting on March 7, 2020, stakeholders identified several farms located in Hadley that may be contributing to poor water quality. Because of the high levels of *E. coli* found in Amethyst Brook and the Fort River and high levels of phosphorus in the Fort River, stakeholders expressed concern about dairy farms as a potential source of water pollution (**Map 19**). In 2016, researchers tested water in Fearing Brook, a tributary to Amethyst Brook, and identified the source of fecal matter containing *E.coli* as coming from "mammals (pets and rodents), human, and gull sources" (Geosyntec, Inc. 4). Testing of the Fort River in Hadley indicated elevated levels of *E.coli* but its source was not identified. While E.coli from Amethyst Brook may be traveling downstream to the Fort River, the high concentration of pasture and dairy farms adjacent to the river indicates that there may be additional sources of *E.coli* contributing to the river's contamination.

Dairy farms along streams and rivers pose a potentially high threat to water quality because the animal waste, or manure, being produced by these farms may be introducing excessive levels of nutrients and pathogens directly into waterways through stormwater runoff. Manure is high in nutrients such as nitrogen, potassium, and phosphorus and is an important soil amendment used by farmers to increase soil health and fertility. Manure can also contain several types of coliform bacteria including *E. coli*, which lives in the digestive tracts of warm blooded animals like cows. *E.coli* poses a threat to human health if people come in contact with contaminated water or crops irrigated with contaminated water from the Fort River.

Besides the threat to human health, the presence of *E.coli* and other bacterial pathogens in waterways may also indicate low water quality because pathogens compete with aquatic microorganisms for limited nutrient sources. In a study looking at the ways in which *E.coli* interacts with the environment, it was found that stream populations of *E.coli* have an inverse relation to the population of indigenous microbial communities; higher levels of *E.coli* in streams may indicate lower microbial populations that play an important role in the health of stream ecosystems (Ishii).

A flow accumulation analysis looking at the flow of water over agricultural land cover within the watershed (**Map 20**) suggests that much of the flow over agricultural land in the watershed is, in fact, occurring in the area of concern to stakeholders.



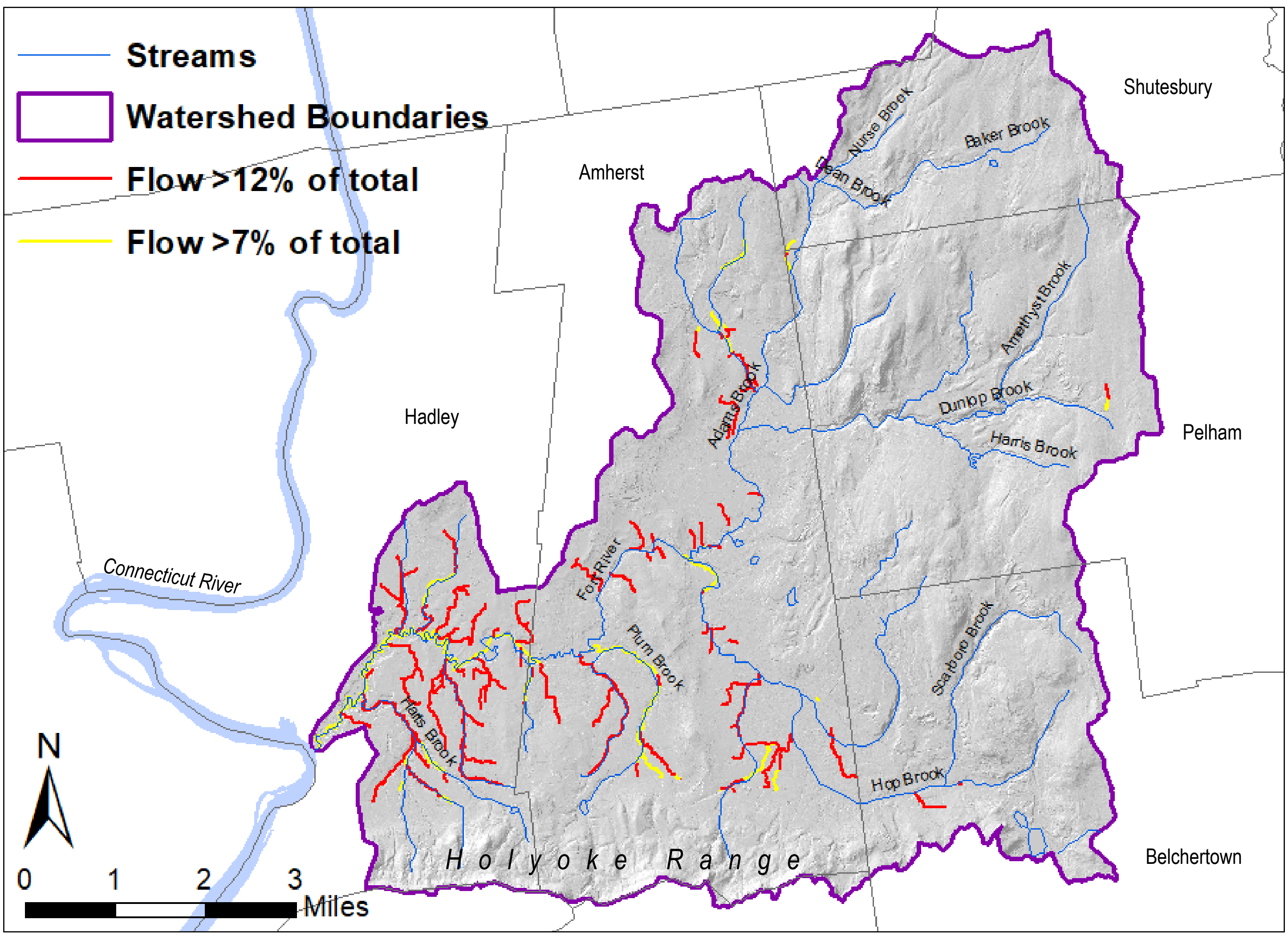
Map 19. Agricultural lands within the Fort River watershed are concentrated near the Fort River and its tributaries. Cultivated Land includes areas intensely managed for the production of annual crops. It also includes all land being actively tilled. Pasture/Hay includes areas of vegetation planted for livestock grazing or the production of seed or hay crops and is usually not tilled. Source: Extracted from 2016 Land Cover/Land Use MassGIS Data

The analysis indicates where the greatest volumes of stormwater runoff from agricultural land may be occurring but does not account for specific practices employed by individual farms and whether or not runoff contains pollutants. Further analysis of individual farm practices and ground-truthing may reveal sources of pollution and possible interventions for mitigating the effects of stormwater runoff from agricultural land.

Water Withdrawal

Stakeholders also reported instances of water withdrawal directly from the Fort River during its low-flow period in the summer and fall to irrigate crops, which could negatively impact aquatic habitats of small fish and invertebrates if not practiced correctly. Withdrawal from waterways lowers the volume and quality of water available for fish and invertebrate habitat. Shallower water can lead to increased water temperatures and decreased dissolved oxygen during warmer months when the river is already critically low and when crops need to be irrigated. Direct examination of water pipes by Boyd Kynard, a scientist who studies sea lamprey, inserted into the Fort River found they were not designed to exclude small fish and aquatic invertebrates, such as larval sea lamprey (*Petromyzon marinus*) (**Fig. 13**), from being drawn into them. This is particularly concerning and in conflict with conservation efforts in the watershed for riverine fish and sea lamprey, such as the removal of Bartlett Dam on Amethyst Brook to restore nine miles of upstream, cold water spawning habitat (Kynard).

Although the Watershed Management Act of 1986 authorizes the Department of Environmental Protection to regulate withdrawal of surface and groundwater supplies within Massachusetts, regulations are difficult to enforce without frequent and consistent monitoring of withdrawal pipes and enforcement currently relies on self-reporting. For seasonal water use, like agriculture, a permit is required if more than an average of 100,000 gallons of water per day is withdrawn over three consecutive months but withdrawal volumes below this threshold are unregulated. The act also does not establish best practices for withdrawal, such as using perforated water intake pipes below the stream bottom, and requires a $4,100 application fee, a number cost prohibitive to many small farmers (mass.gov).



Map 20. Channels in red and yellow indicate where the flow of stormwater runoff over agricultural land accumulates when not absorbed by soils. Yellow channels show where the flow accumulation over agriculture land is greater than seven percent of total stream flow and channels in red show where it is greater than twelve percent.

Figure 13. Sea lamprey (*Petromyzon marinus*)
Source: Cornell Fishtracker

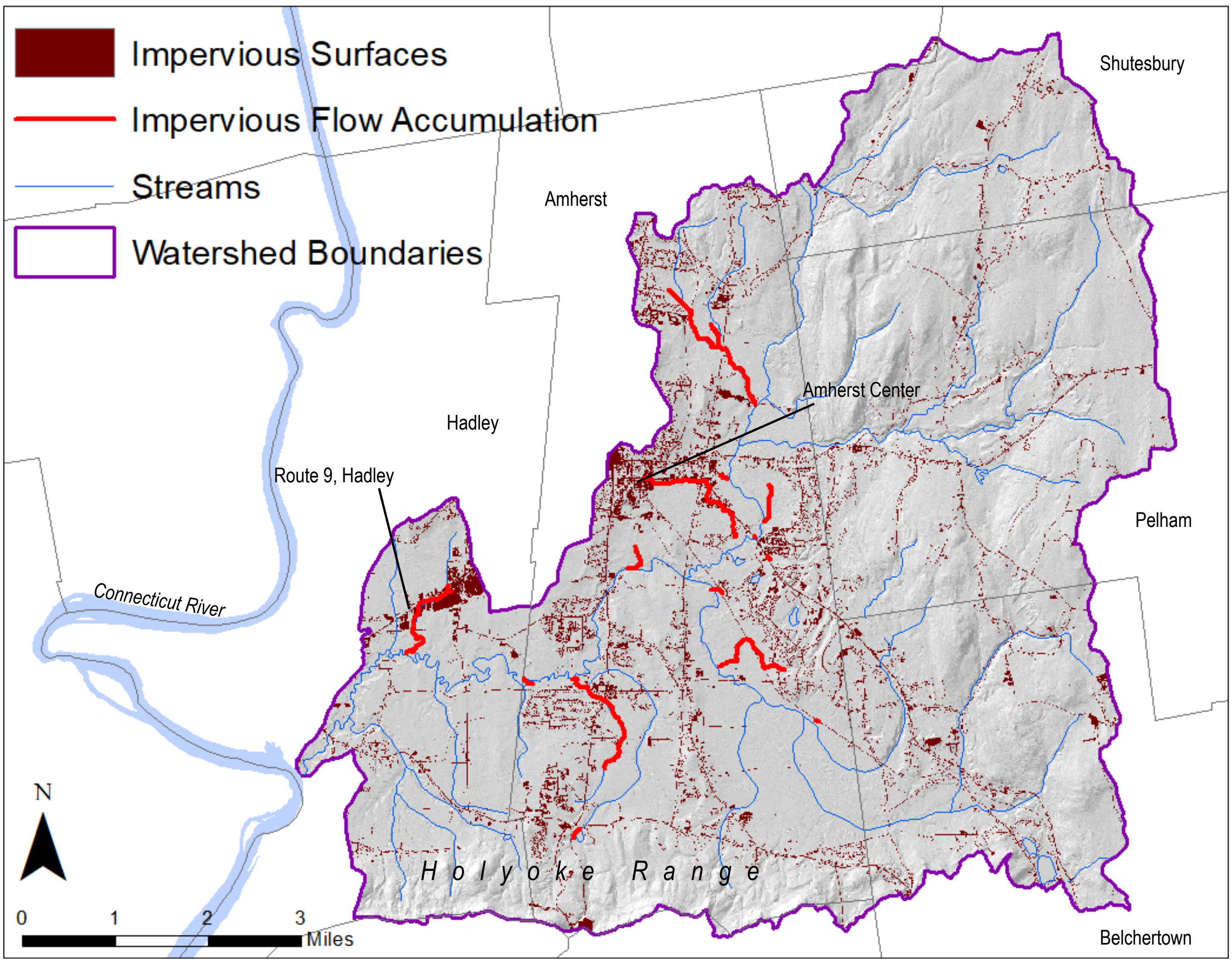
Impervious Surfaces

Impervious Surfaces and Water Quality

Impervious surfaces include all constructed surfaces such as buildings, roads, parking lots, asphalt, and concrete, surfaces through which almost no water penetrates (C-CAP). Impervious surfaces severely disrupt the natural hydrologic cycle, preventing stormwater from filtering to groundwater and redirecting it to another place, oftentimes through a stormwater system with outfalls near or directly into rivers, streams, and wetlands. Stormwater from impervious surfaces can carry pollutants such as gasoline, road salt, sand, lawn clippings, and pet waste among many more that, when introduced to streams, can negatively impact water quality. Impervious surfaces also tend to absorb heat, especially asphalt roads, warming stormwater runoff, which can be particularly damaging to cold water streams, raising their temperatures and affecting the aquatic wildlife that live within them.

Impervious Surfaces in the Fort River Watershed

In the Fort River watershed, impervious surfaces, which make up five percent of total land cover (see p. 11), are concentrated in the lower elevations nearest the Fort River in Hadley and Amherst. Although impervious coverage falls under the seven percent threshold at which it tends to negatively impact water quality (Ricci 22), the uneven distribution of impervious cover, with a high density of coverage along the northwestern edge of the watershed and lower density coverage extending out from there, shows that impervious coverage may exceed this threshold in localized areas. Route 9 in Hadley and the town center of Amherst are densely covered with impervious surface but significant, if not scattered, coverage extends into Belchertown along Hop Brook, and into Pelham along Amethyst Brook. Shutesbury exhibits a low coverage of impervious surface but shows a similar pattern in following the path of streams. Although logic would suggest that higher density coverage of impervious surfaces would be more damaging to water quality, low density development can have a disproportionately



Map 21. The red channels indicate where the flow of stormwater runoff over impervious land cover contributes to greater than seven percent of total watershed flow. Source: 2016 Land Cover/Land Use dataset from MassGIS.

[illegible] the center of Amherst and Route 9 in Hadley, but also in low- to medium-density residential development extending into Belchertown, Pelham, and Shutesbury along tributaries of the Fort River. The results of a flow accumulation analysis applied to impervious cover, however, shows that flow over impervious cover is only exceeding the seven percent threshold in a handful of areas in Amherst and Hadley, represented by the red channels in **Map 21**.

Figure 14. Fort River at Hickory Ridge Golf Club. Source: fortriver.org.

Developed Open Space

Developed Open Space & Water Quality

Developed open space includes areas developed for recreation, erosion control, or aesthetic purposes including golf courses, athletic fields, cemeteries, parks, and residential lawns. These areas contain a mixture of some constructed materials like paved paths and buildings but are mostly covered by managed lawns or low-lying vegetation (C-CAP). Although properly managed lawns can be pervious and capture rainwater (NOAA 6), the use of heavy machinery in construction and landscape maintenance can compact soils, causing lawns to function somewhat like paved surfaces. The semi-impervious quality of lawns coupled with the fact that they are often managed with high inputs of fertilizers and pesticides could mean that stormwater from lawns may contain pollutants that negatively impact water quality within the watershed.

Fertilizers and pesticides improperly or excessively applied to lawns can be carried away by stormwater runoff and end up in streams, rivers, and other waterbodies, leading to decreased water quality. For example, an overabundance of nitrogen and phosphorous in waterbodies two key ingredients in fertilizer, can accelerate the process of eutrophication by fueling an overgrowth of vegetation that depletes dissolved oxygen, resulting in the death of aquatic wildlife (USGS). According to the Town of Amherst Conservation Department:

> In the late summer of 2007, the Fort River experienced significant growth of algae associated with drought-induced flow. A pilot water quality study conducted in September identified high phosphorus concentrations as a possible cause of algal growth, with levels up to or twice that identified by the EPA as advisable for river ecosystem health. Such high phosphorous concentrations may imperil freshwater mussels, which are among the most endangered groups of animals in the United States. For instance, a USGS study linked a major decline in mussel populations and species diversity to increased stream phosphorous concentrations at levels similar to those found for the Fort River, suggesting that Fort River may also be jeopardized by future periods of low flow and high nutrient concentrations. (Mill & Fort Rivers)

Stormwater runoff from lawns in neighborhoods with dogs or recreational areas where dogs are walked may also contain pet waste, a potential source contributing to elevated *E. coli* and other pathogens in the watershed's streams (Willson, Elizabeth. Personal interview. 14 February 2020).

Additionally, irrigation of lawns to keep them green during dry, summer months decreases water quality by draining groundwater supply when stream flow is sustained by groundwater discharge and water temperatures are highest (USACE 36). Watering lawns during this time exacerbates the effects of drought by creating a positive feedback loop where already low flow is lowered even further and already warm streams become warmer. Water temperature has a significant influence on water quality because it affects water chemistry and dictates the kinds of organisms that can live in water. Warm stream water exhibits lower concentrations of dissolved oxygen, limiting the availability of oxygen to aquatic life. Similarly, aquatic life such as fish, insects, planktons and others, have evolved to live within preferred temperature ranges; fluctuations in water temperature above or below these ranges could lead to declines in populations of these species ("Temperature and Water").

Developed Open Space in the Fort River Watershed

Within the Fort River watershed, developed open space accounts for five percent of land cover and includes recreational areas such as the Hickory Ridge Golf Club, a 150-acre golf course bisected by the Fort River on the Hadley-Amherst town line, college campuses, and residential lawns. Large areas of developed open space, including recreational areas, college campuses, and medium- to high-density residential development is concentrated near the main branch of the Fort River and its tributaries, like Harts Brook, in Hadley and Amherst. Sparse cover of developed open space mostly consisting of small lawns extends into Belchertown, Pelham, and Shutesbury, primarily along the Fort River's tributaries where low- to medium- density residential development and the lawns that accompany it are more common (**Map 22**). If the increased rate of residential development within the watershed over the past fifty years continues, implementing stormwater infrastructure that reduces volumes and filters runoff in these neighborhoods will be crucial for maintaining water quality within the watershed. Large areas of developed open space that replace floodplain habitat adjacent to the Fort River and its tributaries may be directly contributing to the streams' impairment and call for more impactful interventions such as habitat restoration projects or relocating recreational activities to other areas where the open space they require will have less of an effect on water quality.

Where is Developed Open Space Having the Biggest Impact?

A flow accumulation analysis of flow over developed open space (**Map 22**) shows where developed open space is contributing to greater than seven percent of total watershed flow. The areas of developed open space showing the greatest contribution to watershed flow include the center of Amherst, the campuses of Amherst College and Hampshire College, Hickory Ridge Golf Club, and residential neighborhoods near tributaries to the Fort River. The channels in red show where sheet runoff from developed open space may be occurring and the areas in light green show the areas draining to these channels.

The results of this analysis provide a road map for interventions to maintain or improve water quality within the watershed. Further analysis of each of these areas is needed, including a ground-truthing process to identify the particular characteristics of each area to determine appropriate interventions. For example, the flow accumulation model does not account for stormwater management systems like underground pipes, catch basins, or culverts that are not identifiable by LIDAR in the creation of elevation models. Nor does it consider current management practices of developed open space. A handful of selected sites provided by this analysis are explored below.

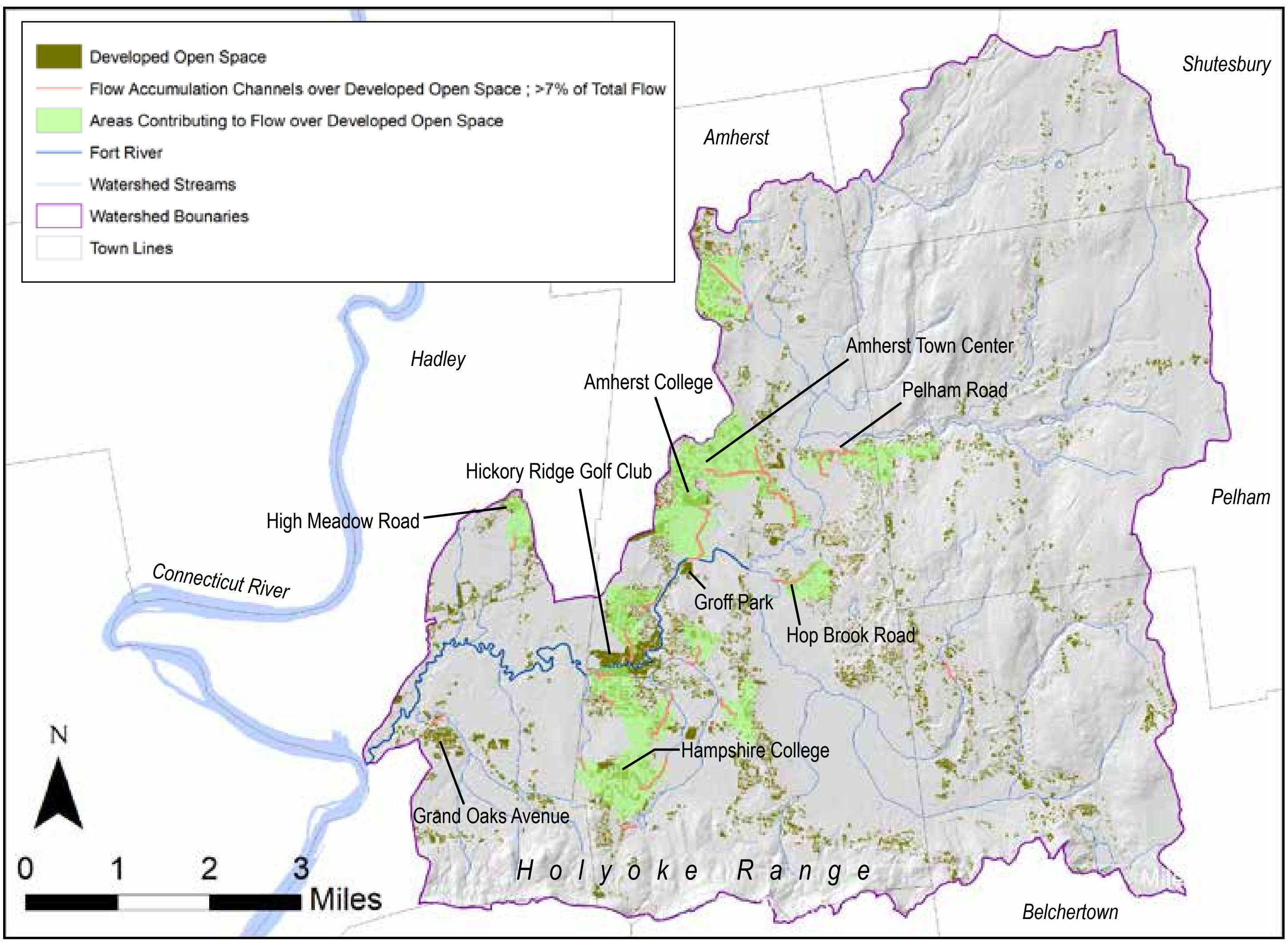
Hickory Ridge Golf Club

Approximately one and a half miles of the Fort River flows through the 150-acre Hickory Ridge Golf Course in Amherst, the largest area of developed open space within the Fort River Watershed (**Map 23**). The Fort River enters the northeast corner of the golf course and flows out in the southeast corner near a confluence with Muddy Brook. Plum Brook, an intermittent stream, meets the Fort River in the southeast corner of the property.

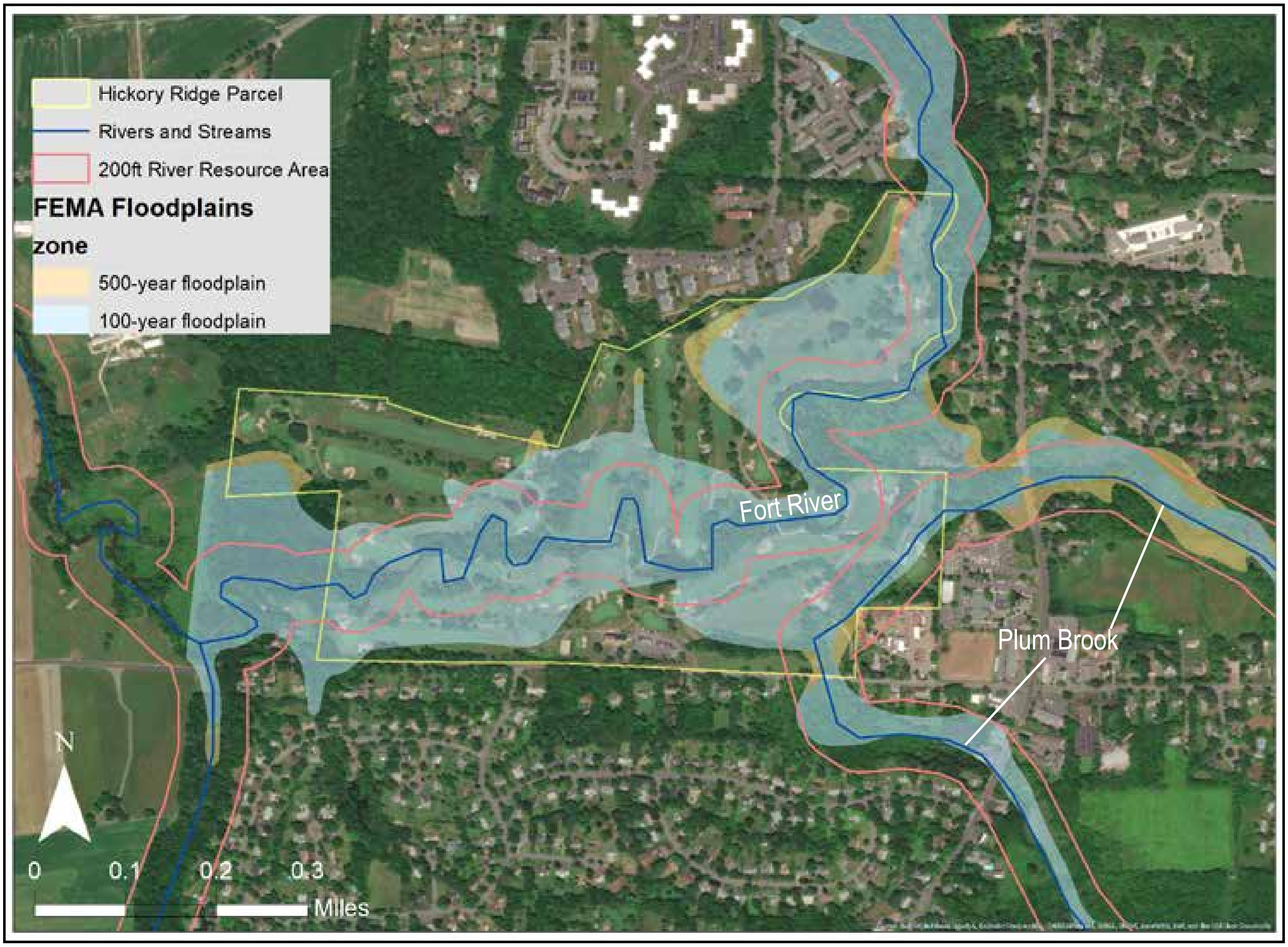
The property also contains wetlands, intermittent streams such as Plum Brook, and National Heritage-designated Priority Habitat for Rare and Endangered Species. Because waterways flow through the site and their associated floodplains cover most of the property, land use and management of the property has a direct impact on water quality of the Fort River.

The 18-hole golf course contains an asphalt parking area centered along the southern property boundary, several buildings including a restaurant, small bridges for river crossings, small storage sheds, and cart paths. Stormwater runoff from the residential neighborhoods surrounding the golf course passes through it before reaching the Fort River. Golf courses often require intense management of turf including frequent mowing, fertilization, and irrigation. Machine mowing not only contributes to the compaction and imperviousness of soils but can also introduce pollutants and nutrients to the hydrologic cycle in the form of hydrocarbons from gasoline and phosphorus from grass clippings that get washed into stormwater systems, streams, and rivers. Fertilization of turf grass encourages green, vegetative growth but may also introduce high levels of nitrogen and phosphorus to streams and rivers.

Currently, a proposed 5.29-megawatt solar project that would fence off and occupy 29.3 acres of the golf course is under review by the Town of Amherst Zoning Board of Appeals. While the proposed solar development plans call for the installation of solar modules outside of wetland buffer zones, the plans would disturb two acres of NHESP Priority Habitat, affecting Massachusetts state-listed wildlife species and one-half to one acre of Bordering Lands Subject to Flooding (BLSF). Additionally, the proposed 7-foot-high chain-link fence enclosing the solar project could limit movement of wildlife through the site and the removal of 198 trees would further remove potential wildlife habitat (Town of Amherst Zoning Board of Appeals). Although the impacts of solar development on water quality are little researched, the destruction of important habitat,



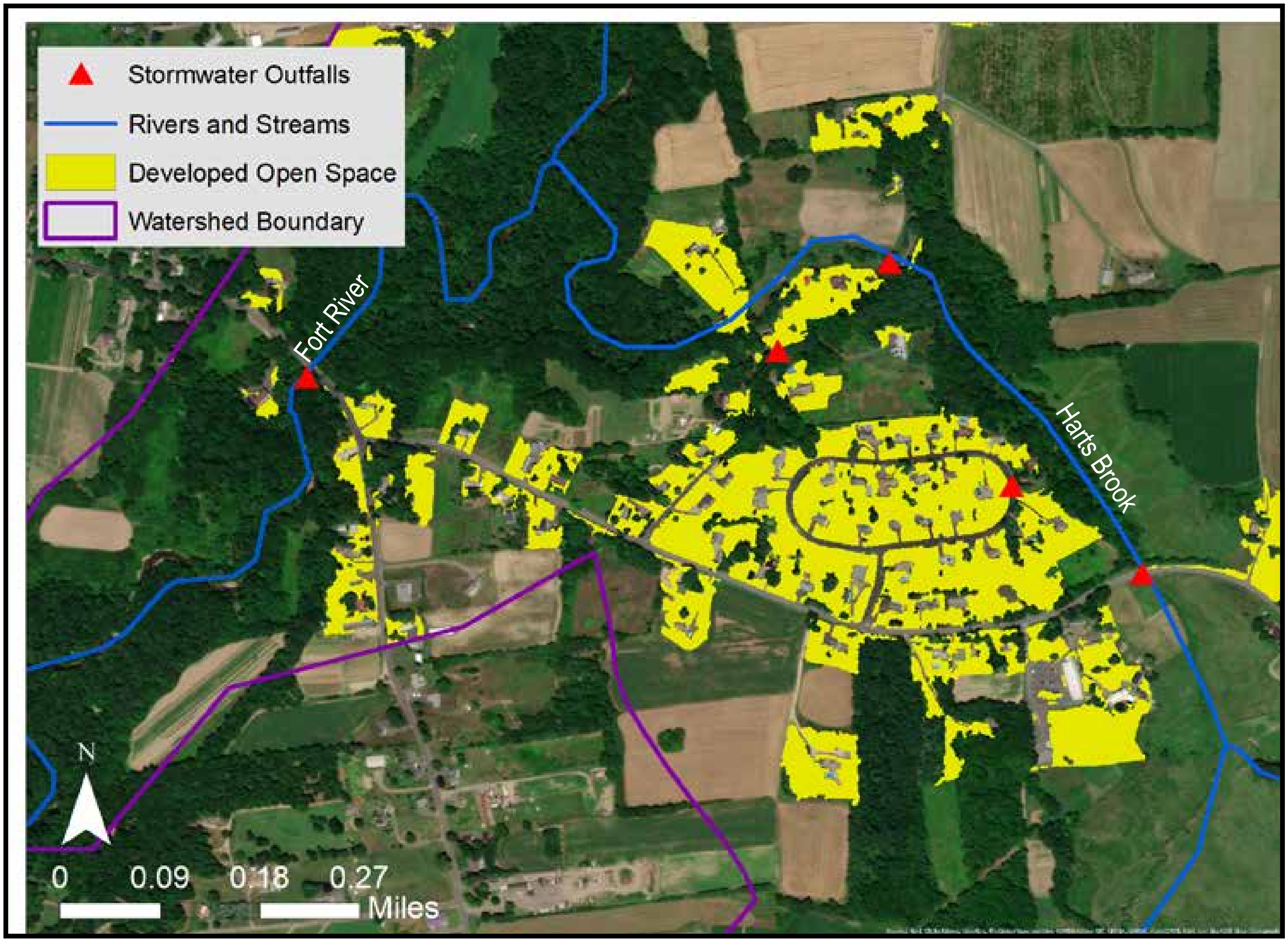
Map 22. The channels in red indicate where flow of stormwater runoff over developed open space land cover contributes to greater than 7% of total watershed flow; light green highlights the areas contributing to that flow. Source: 2016 Land Cover/ Land Use dataset from MassGIS.



Map 23. The Fort River runs through the 150-acre former Hickory Ridge Golf Club. Approximately 30 acres of the property is slated for solar development but the remaining land presents an opportunity for improving the water quality of the river.

and common management practices of solar fields such as mowing all indicate that it is imperative to establish a buffer between the proposed development and the Fort River.

Restoring the golf course to native, riparian habitat would not only improve water quality and provide habitat for wildlife, but could also provide scenic recreational opportunities for nearby residents, particularly those who live in residential developments adjacent to the golf course. Restoring the Fort River's floodplain and opening it up to recreation would also provide an opportunity to educate the public about the importance of native habitat to water quality and wildlife. However, further study of the impacts of various recreational activities on water quality should be conducted to determine appropriate uses of this area.



Map 24. Stormwater from the Grand Oak Farm neighborhood is collected by drain pipes and released directly into Harts Brook and the Fort River.

Grand Oak Farm Road Neighborhood

In a small, residential development in the southwest corner of the watershed, near the mouth of the Fort River, stormwater is collected and released by outfalls directly into Harts Brook and the Fort River (**Map 24**). Neighborhoods like these, composed of low- to medium-density residential development containing impervious roads and driveways and small lawns, are scattered throughout the watershed and contribute significant volumes of stormwater runoff into streams within the watershed, diminishing water quality.

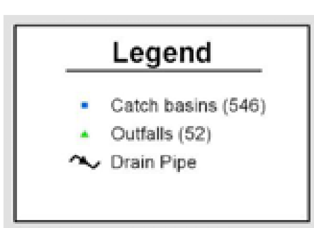


Figure 15. Stormwater system for Grand Oaks Avenue. Source: Comprehensive Environmental, Inc.

Chapter 3: Strategies for Improving Water Quality in the Fort River Watershed

This chapter explores strategies for improving water quality within the watershed where the land uses identified in Chapter 2 may be having a negative influence. Many of these recommendations focus on stormwater management in order to slow and prevent potentially contaminated stormwater before it reaches waterways, but also included are recommendations for preserving biodiversity and engaging the community in efforts to improve water quality. Increased water testing throughout the watershed will help focus future efforts to improve water quality.

Increase Water Quality Testing

Creating Stream Teams

Currently, water sampling efforts by the state, towns, universities, and the Connecticut River Conservancy are focused on specific sites or testing parameters. A comprehensive approach, including headwater streams and tributaries of the Fort River, to testing the water quality of the Fort River watershed would yield a better understanding of water quality and sources of pollutants. Regular monitoring of water quality throughout the watershed could provide evidence that would guide decisions to improve it. Additionally, organizing water quality testing could make information more accessible to decision makers across the Fort River watershed.

In order to collect water quality data across political boundaries, the Fort River Watershed Association could establish a program in which trained volunteers test water and document conditions and activities along streams over time. What is the correlation between existing land use practices and their impact on water quality? Where is bank erosion greatest? Are there places safe to swim in the Fort River? Is a culvert causing scour and erosion? Volunteer groups like citizen scientists or stream teams may also improve community awareness about water quality issues and connect people to each other and the place they live. The Fort River Watershed Association could provide the leadership and receive funding needed to successfully implement such a volunteer program. How the data is used and shared, both at the local policy level and with local property owners, is another component of the monitoring program that should be addressed by the watershed association.

The Fort River Watershed Association could implement the volunteer watershed monitoring program that the United States Environmental Protection Agency (EPA) has developed. It establishes guidelines for conducting watershed assessments, collecting water quality data, and documenting results. First, a plan for the monitoring program is developed to identify what types of data should be collected. This plan considers local, state, and federal water quality standards and total maximum daily loads (TMDLs). Second, a training program is developed for volunteers to train them on what to do and how to collect data. Next, a historical and visual assessment of the watershed is conducted, which can be achieved through walking streams and "windshield surveys" conducted while driving through the watershed. Lastly, a biological survey and habitat assessment is conducted to collect information on macroinvertebrates and habitat quality in and along streams. This information can help determine the health of the stream and indicate good or poor water quality. The EPA's volunteer monitoring program supplies instructions on how to properly collect samples of water and other data.

More information can be found at:
www.epa.gov/sites/production/files/2015-06/documents/stream.pdf

Protect the Land Adjacent to Rivers

Establish a River Corridor Overlay District

A river corridor overlay district increases land use regulations within a designated area surrounding a waterway to allow for natural fluvial processes and the meandering of streams. The area protected in this district would likely extend beyond the Massachusetts Rivers Protection Act, which regulates only a 200-foot riverfront area and not the wider area of land through which the river meanders over time. Rivers are not static, but are dynamic in nature. A river corridor protection area takes into consideration active river processes like scour and deposition over time by accounting for riparian buffers and channel movement in the protected area (Kline 2008).

In the Fort River watershed, a river corridor would be delineated using a stream geomorphic analysis that considers surficial geologic materials and soils, land cover and use, and roads. The Vermont Agency of Natural Resources defines a river corridor as "a width of

Overlay Zones

Overlay Zones are used to protect sensitive resources like floodplains or wetlands. They are also used to protect historical landmarks or to revitalize neighborhoods. Created by towns or regional planning commissions, overlay districts are applied over a base zone and do not necessarily follow property boundaries. They impose a second set of development review standards. If the two zones conflict, the overlay district takes precedence.

In Massachusetts, a new zoning overlay district requires a two-thirds majority vote by residents to be ratified into town or city code. Massachusetts General Law c. 40A specifically authorizes "cities and towns authority to adopt ordinances and bylaws to regulate the use of land, buildings and structures." Getting the majority vote can be a hurdle and public education of the benefits of the proposed district is important (MGL Chapter 40A).

land on either side of the river that will capture factors influencing runoff and erosion, factors influencing floodplain function, and a minimum width of land within the overall valley width that may be occupied by the active stream channel, as slope and dimension remain in balance with the watershed inputs" (VT ANR May 2007). By accounting for the dynamic nature of rivers through corridor delineation, Fort River watershed towns can reduce the hazards associated with flooding and erosion.

Once a river corridor is delineated for the Fort River watershed, each watershed town and city needs to adopt a zoning by-law to regulate development and activities within this corridor through an overlay district. The width of the river corridor may vary from town to town in conjunction with changing geologic conditions in each town, yet the belt in which the river meanders would be protected along the length of the river.

A river corridor protection overlay district is different from the regulated National Floodplain Insurance Program, a program in which towns must adopt floodplain ordinances in order to receive funding, in that it exceeds the minimum standards of the Federal Emergency Management (FEMA) floodplains and prohibits most new development in river corridors. Additionally, encroachments that limit the active river channel areas or floodplain storage capacity would not be permitted (Chapter 2.9 Fluvial Hazard Area Zoning 10).

Existing Fort River Watershed River Protection Districts

The town of Amherst has a Flood Prone - Conservancy District (FPC) that regulates activities along streams such that they will not reduce flood storage capacity or interfere with natural flow or drainage of this area. The land protected by the FPC varies depending on the stream, but a minimum of 25 feet from the crest of the bank is regulated.

The town of Hadley has a Flood Overlay District (FOD) that essentially establishes the one-hundred-year floodplain boundary and prohibits activities that would increase flood impacts during a one-hundred-year flood. Permitted uses include farming, horticulture, forestry, land conservation, and temporary nonresidential structures.

Riparian Buffers

Riparian zones are transitional vegetated areas between water bodies and areas upslope from them. Vegetated riparian buffers function to prevent erosion, filter pollutants, and trap sediments. Multiple layers of vegetation create the riparian ecotone (the transition area between two natural communities), including trees, shrubs, and ground covers, and contribute to the water quality of the nearby stream. The roots of woody plants stabilize soils, which helps to prevent erosion and minimize the movement of sediment into the water. Tree canopies create shade over streams, which reduces temperature pollution. Grasses and groundcovers capture sediment from runoff before stormwater enters water bodies. Shrubs provide habitat and stabilize the soil. In combination, these layers of vegetation help maintain and improve water quality through reducing pollution, sedimentation, and the volume and velocity of runoff directly entering streams.

Riparian zones are also prone to flooding during large storm events or seasonal high water and can capture and slow flood waters. They also receive inputs from adjacent upland sources, including surface water runoff.

The water quality of the Fort River watershed would benefit by maintaining and increasing riparian buffers along streams and water bodies. Google Earth aerial images show that many of the streams in the Fort River watershed do have riparian buffers of various sizes. A few examples of locations with little to no buffers are shown on pages 39-40. These areas are mostly in residential and agricultural areas where there is an increase in impervious surfaces and croplands respectively, which both contribute to an increase in stormwater and sediment entering streams.

A community-based program through the Fort River Watershed Association that educates the residents of the Fort River watershed of the many benefits of riparian buffers along streams would increase awareness and potentially lead to an increase in riparian vegetation. Additionally, engaging local farms, schools and municipalities in riparian buffer programming like tree planting projects and riparian restoration projects would increase awareness of water quality, as would informational brochures, volunteer work parties, and information on riparian plants. Further protections for riparian buffers could be accomplished through adopting an aquatic buffer ordinance at the town level.

Fluvial Hazard Erosion District

A Fluvial Erosion Hazard District (FEH) is one type of river corridor protection district that towns in New Hampshire are encouraged to adopt. This type of overlay district would need approval from the state of Massachusetts to be implemented, yet the concept of river corridor protection is relevant. The FEH overlay district is applied to river corridors in order to protect water quality, allow for fluvial dynamics, and reduce hazards associated with flooding and erosion. This type of overlay district could be adopted by towns in the Fort River watershed.

The purposes of the Fluvial Erosion Hazard Overlay District are to:

- Protect public and private property, and public safety and welfare.
- Address fluvial erosion hazards in the existing built environment.
- Minimize or prevent fluvial erosion hazards in the future.
- Protect mapped river and stream corridors that are highly subject to erosion due to naturally occurring stream channel migration and adjustment.
- Limit new development within fluvial erosion hazard zones to minimize property loss and damage due to fluvial erosion.
- Allow rivers and streams to maintain or re-establish their natural equilibrium to avoid the need for costly and environmentally degrading stream channelization and bank stabilization measures.
- Implement related goals and objectives of the adopted masterplan, and supporting river corridor management plans.
- Encourage activities that increase awareness of stream processes and the development of river mitigation practices.

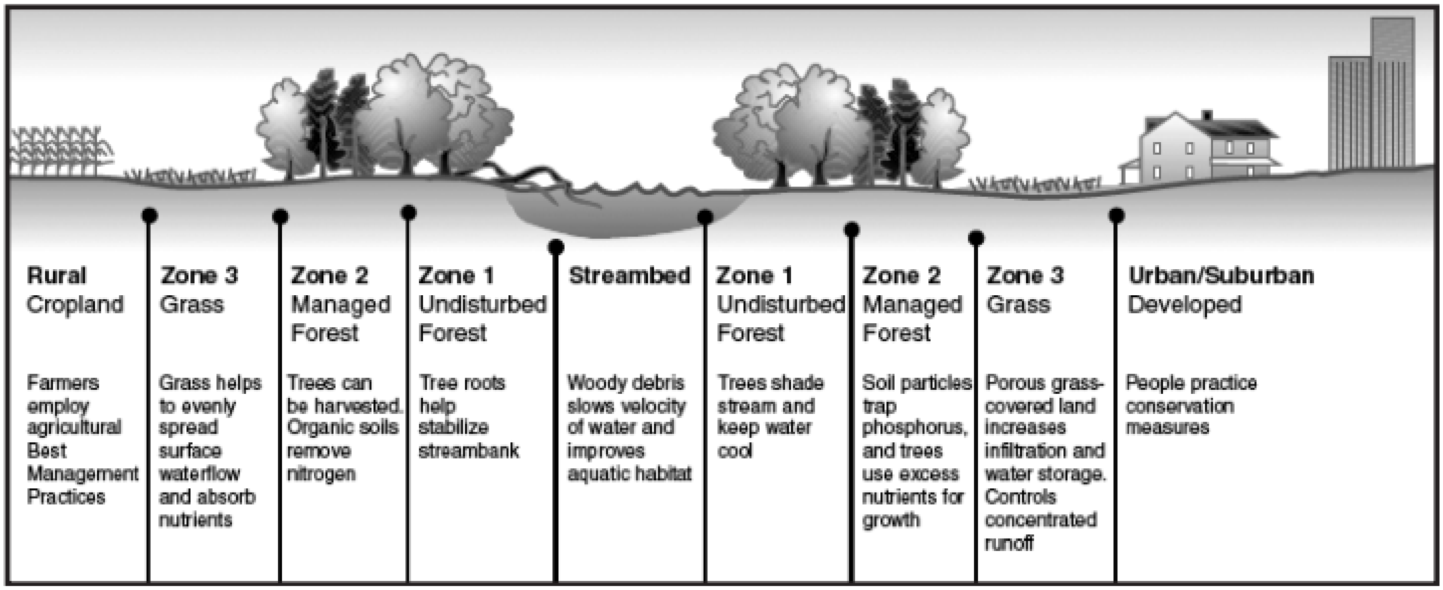


Figure 16. Structure of a riparian buffer that supports water quality. Source: smithceeds.wordpress.com.

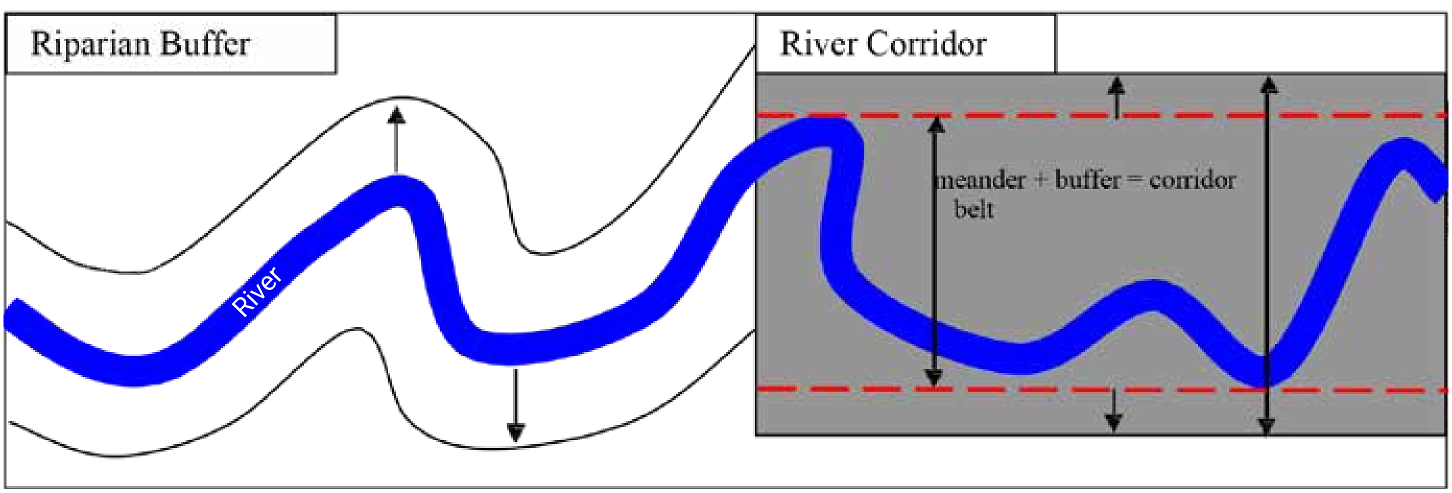


Figure 17. Comparing a buffer setback to a river corridor. Source: Vermont River Corridor Protection Guide, p. 6.

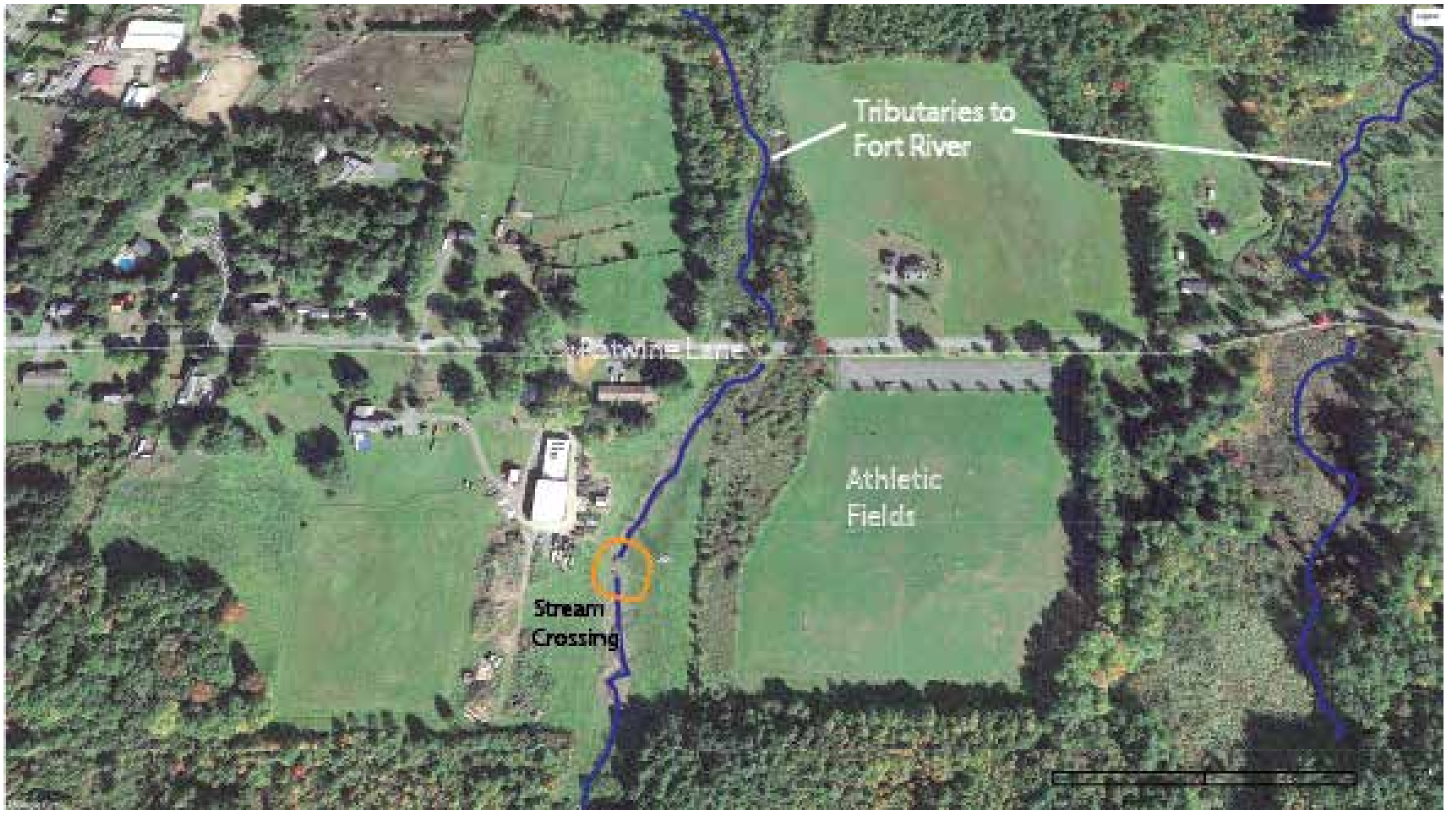


Figure 18. Potwine Road in Amherst, MA. An exposed stream channel near athletic fields along Potwine Road; a stream crossing intersects a tributary of the Fort River.

Figure 19. South East Street in Amherst, MA. The Fort River flows through land that appears to be mowed with limited riparian stream buffer.

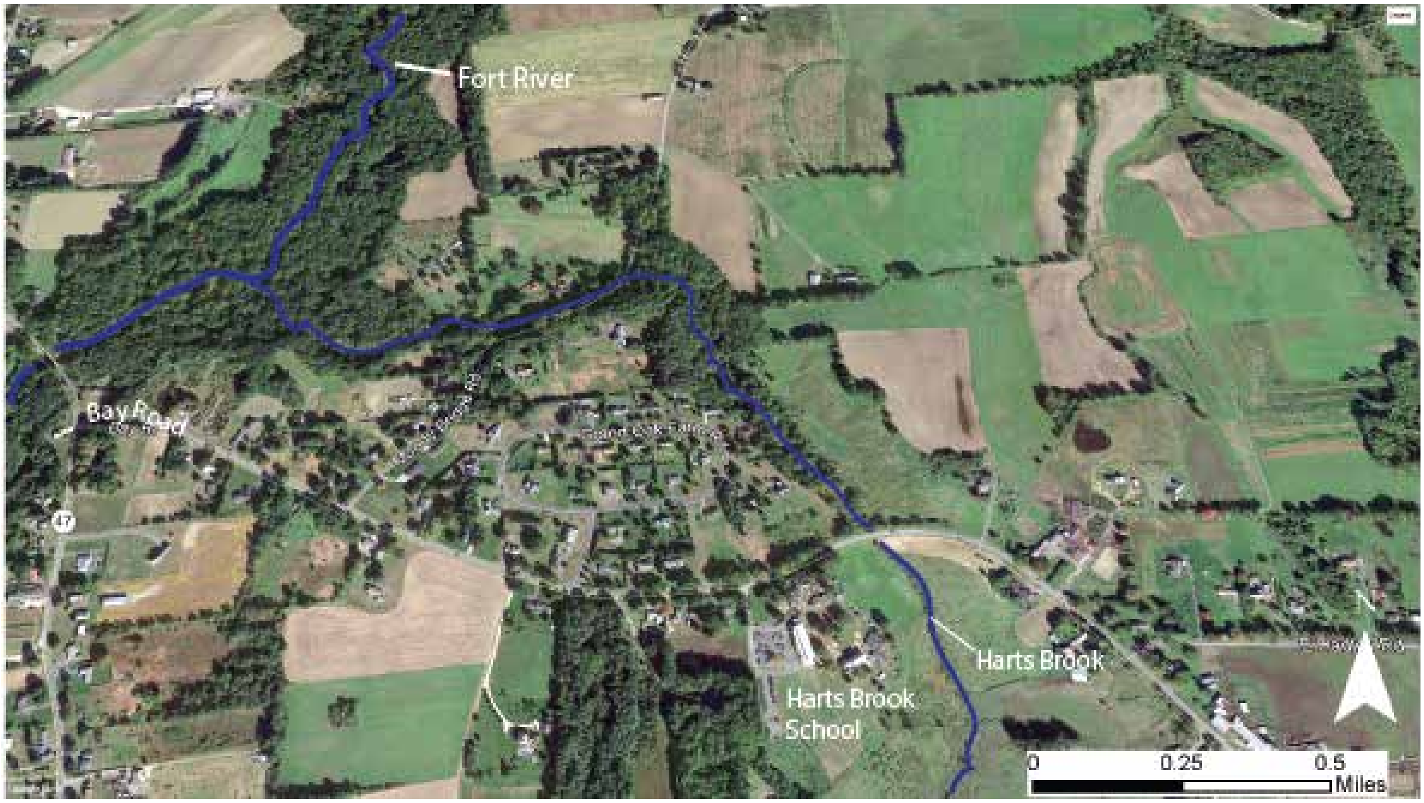


Figure 20. Harts Brook, Hadley, MA. Harts Brook flows east of the Harts Brook School with little to no tree canopy cover and sections that appear to be mowed close to the stream. Across the road is a development with lawns and impervious surfaces.

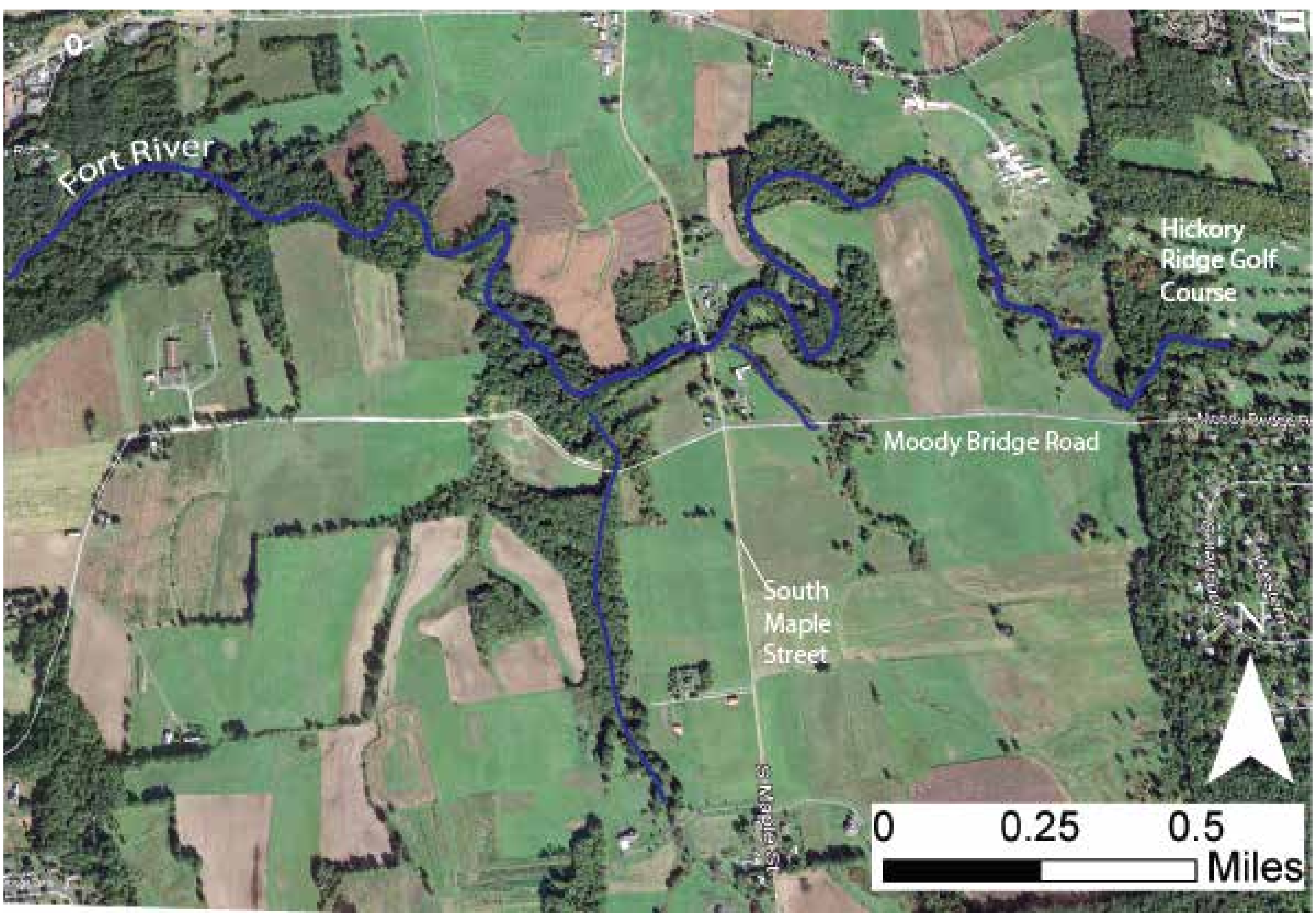


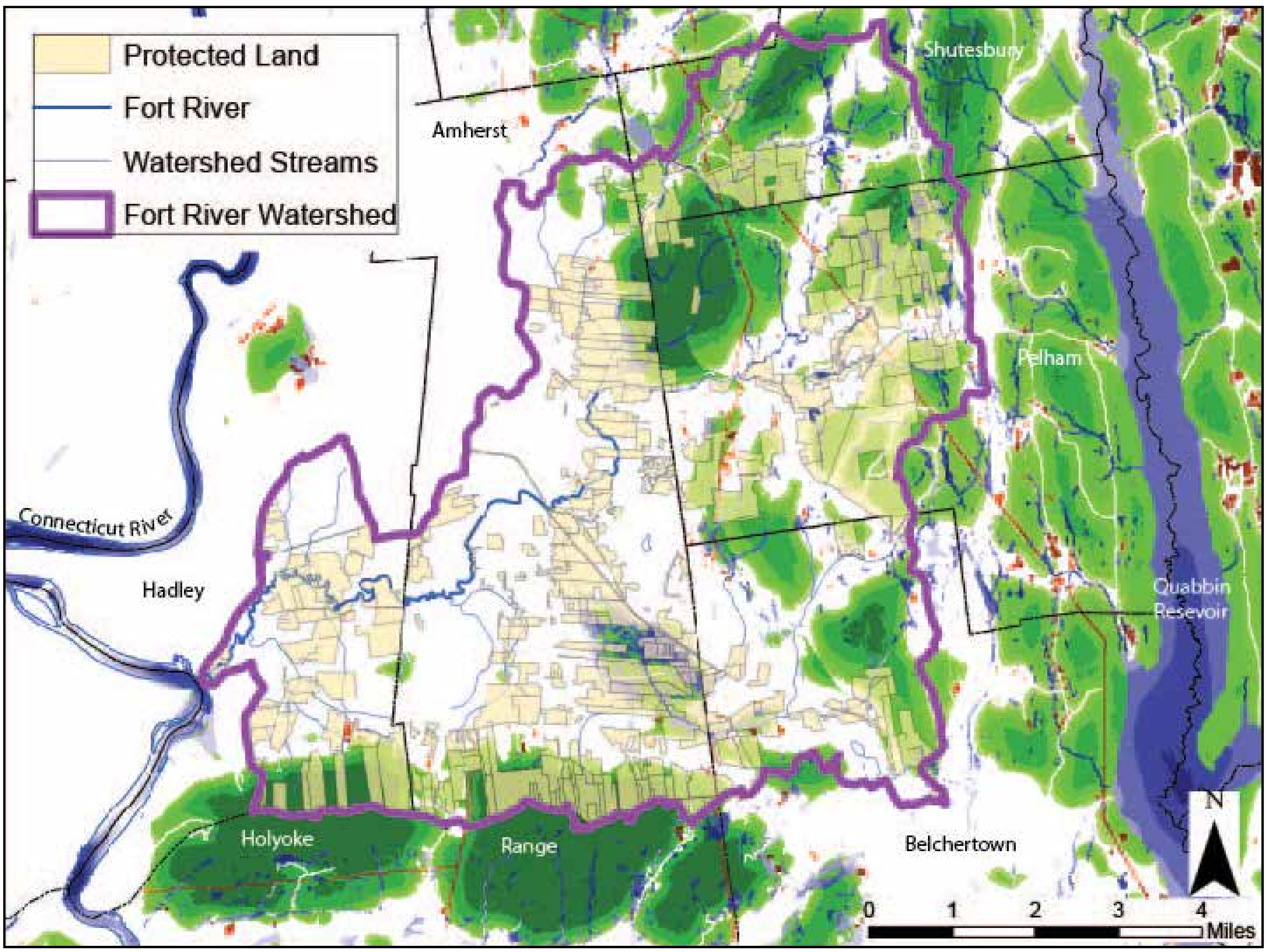
Figure 21. Moody Bridge Road and South Maple Street in Hadley, MA. Tributaries of the Fort River flow through agricultural land and have minimal buffers.

Conserve for Habitat

The Fort River watershed is home to an abundance of wildlife and the diverse habitats in which they reside, including forests, various wetland types, and floodplain habitat along the river and its tributaries. Protecting habitat not only increases levels of biodiversity but also preserves ecological functions that maintain and improve water quality by keeping ecosystems intact. More diverse ecosystems are more resilient ecosystems better able to withstand pollution pressure, rebound after disturbances, and adapt to a changing climate.

Protecting core habitat from impacts of development will support the continued presence of wildlife in the region and the ecosystem services these habitats provide such as filtering and cleaning groundwater. These habitats include streams, wetlands, and vernal pools which are already protected to varying degrees by federal, state, and local legislation because they have been recognized for their vital role in protecting drinking water supplies and providing habitat to rare, endangered, and highly diverse communities of wildlife. Additionally, the Fort River watershed includes natural communities, like a black gum swamp, prioritized for conservation by the state of Massachusetts due to their limited distribution across the state and globe. However, further protection of these areas in the form of permanent conservation may be controversial in a watershed that already has a high amount of land under conservation. In cases where there is resistance to conservation, there are several strategies that landowners can voluntarily adopt to promote connectivity.

If ecological integrity is a priority goal, areas in green on the map below should be permanently protected. Larger "cores" are of highest priority and appear in darker green because they provide the greatest potential for supporting high levels of biodiversity. Further prioritization of parcels in the center of cores will help guide conservation decisions if further conservation proves difficult due to community resistance.



Map 25. CAPS and protected parcels in the Fort River watershed. Priority habitat for conservation are the dark green areas not already protected. Source: MassGIS.

Identify and protect wildlife corridors through conservation and landscape management

The greatest potential for maintaining connectivity within the Fort River watershed is in the northern parts of Pelham and Shutesbury, and along the eastern edge of the watershed to the south in Belchertown along the Mount Holyoke Range (**Map 26**). These are the upland, headwaters regions of the watershed, adjacent to a large block of forest to the east surrounding the Quabbin Reservoir. The Quabbin Reservoir and the surrounding forest support a great diversity of wildlife including wildlife of regional importance like bald eagles, moose, coyotes, and bobcats. The southern edge of the watershed along the Mount Holyoke Range is also an area to focus connectivity efforts because it connects wildlife and other species regionally to the south; however, except for a few parcels, much of this land has already been protected through conservation.

The areas with the highest conductance between habitat nodes are indicated in blue on **Maps 26 & 27**and should be prioritized for conservation, if possible. Conductance is a measure of the likelihood of wildlife passage between habitat nodes; the darkest blues represent high conductance, or high likelihood of wildlife passage, and light blues represent low conductance. Higher conductance suggests areas that may be functioning as wildlife corridors. Temporary protections of these areas, such as encouraging landowners to place their forests and farms under Chapter 61, could be used as an intermediary step and as a way to enroll landowners in cost-sharing programs that help them manage their land for wildlife. Voluntary stewardship programs offered through organizations such as NRCS can advise landowners on best agricultural and forest practices that also support wildlife.

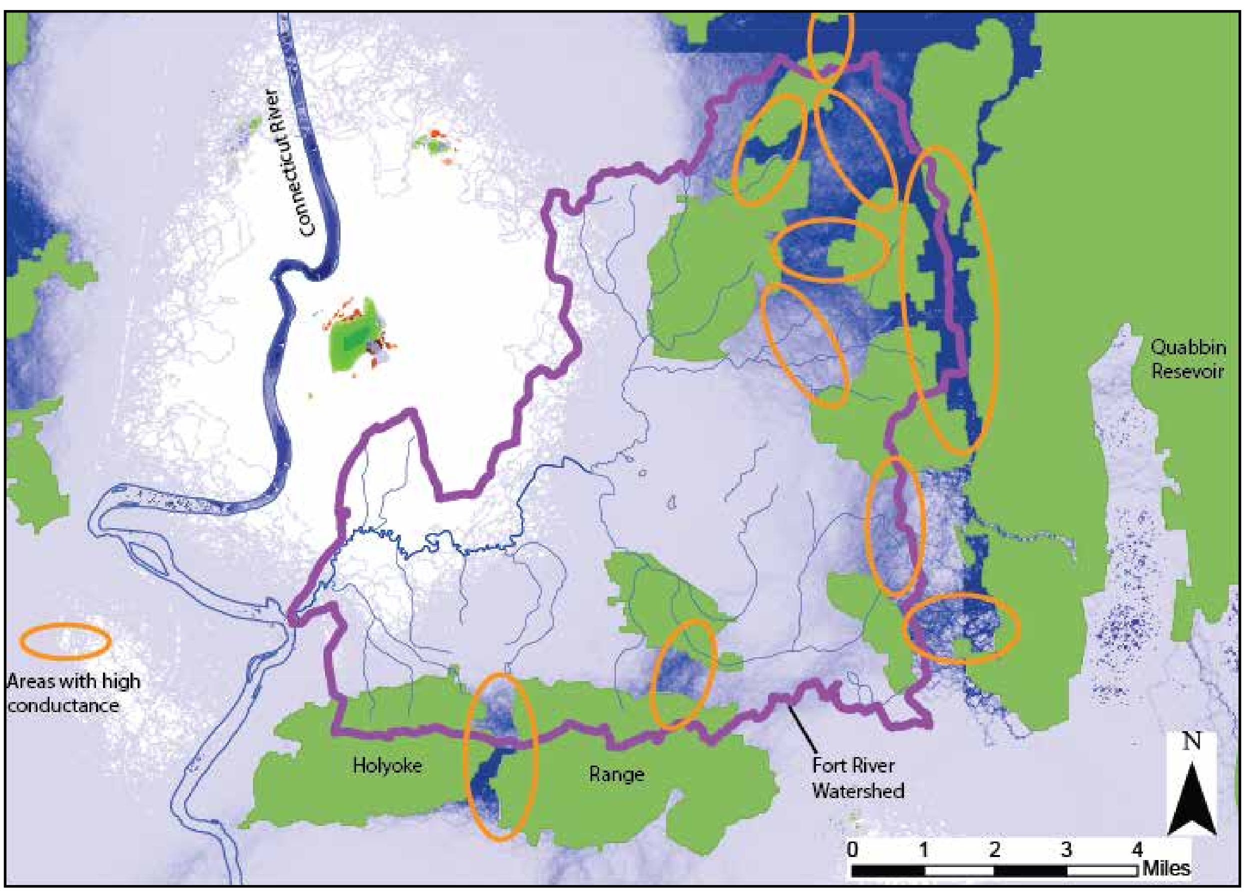
Protecting and connecting wildlife habitat within and outside of the watershed area will support a diversity of wildlife, particularly wildlife that requires large, continuous areas of undeveloped land.

Public outreach educating landowners about wildlife management

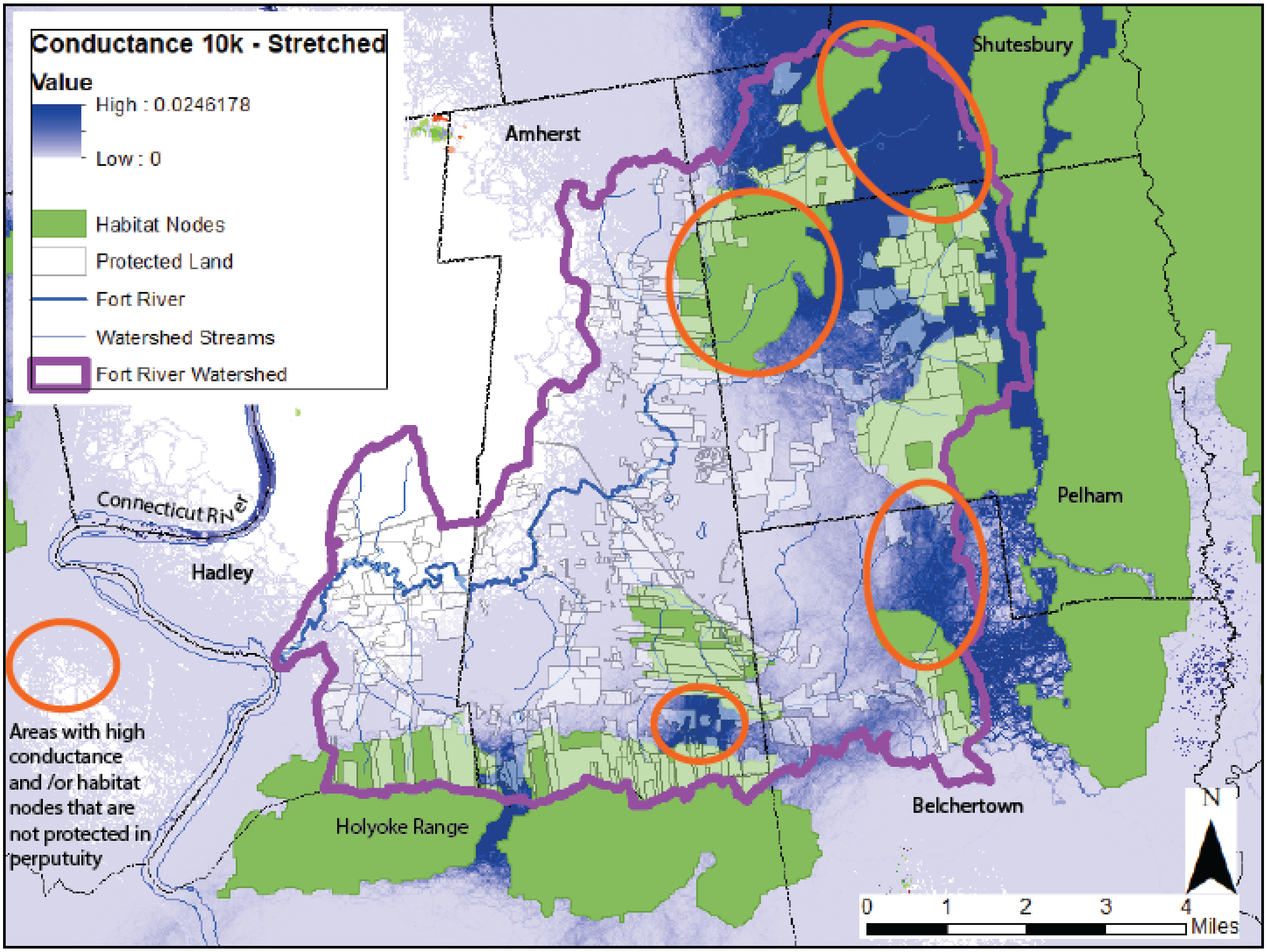
Highly illustrative pamphlets and/or websites with maps and other information about the particular conditions of the Fort River watershed, could help landowners understand steps that can be taken to support wildlife. Landowners may be unaware that their property is located in crucial areas for connectivity or may be actively managing their lands to deter wildlife crossings. However, public outreach explaining the importance of wildlife connectivity and the types of wildlife these areas support could motivate communities across political boundaries to be active stewards of their land.

Potential strategies for landowner stewardship that supports wildlife:

- Keep forested land forest
- Develop a forest management plan (masswoods.net)
- Add or widen hedgerows between agricultural fields
- Remove fences and other barriers to wildlife passage
- Implement a citizen science program that tracks and documents wildlife sightings in priority areas
- Encourage residential landscapers and homeowners to “Leave the leaves”
- Make brush piles for wildlife escape, rest, and nesting areas



Map 26. Conductance in the Fort River watershed. Source: umasscaps.org.



Map 27. Conductance compared to parcels protected in perpetuity in the Fort River watershed. Source: umasscaps.org.

Manage Stormwater

Stormwater Utility

The towns within the Fort River watershed could implement a stormwater utility that would be overseen by each town's Department of Public Works. The stormwater utility would be a fee-based service much like the drinking water supply or wastewater treatment. Revenue generated from the fee, which would be based on the impervious/pervious ratio of parcels, would be applied to the maintenance, repair, and improvements of the stormwater system in that town. Town-owned culverts, catch basins, and other stormwater infrastructure could be repaired or upgraded to reflect Best Management Practices (BMPs) as set forth in the Massachusetts stormwater handbook. The Pioneer Valley Planning Commission provides resources for towns in the region. See below for two examples of successful implementation of stormwater utilities in Northampton, MA, and South Burlington, VT.

Stormwater and Flood Control Utility

Northampton, Ma

The Northampton Stormwater and Flood Control Utility is managed by the Department of Public Works and issues a fee to residential and non-residential properties based on a rate that accounts for impervious and pervious areas of the lot. The purpose of the utility is to administer and generate revenue for the stormwater management and flood control programs for Northampton. A credit may be applied to a utility bill if steps to manage stormwater and reduce impervious surfaces are implemented by the landowner.

City of Northampton, MA. Code of Ordinances, Chapter 280 Stormwater and Flood Control Utility

Linwood Drive Infiltration Basin

South Burlington, VT

The city of South Burlington is using capital from its stormwater utility to help fund stormwater treatment systems. For example, at the end of Linwood Drive the city is building an infiltration basin that will treat stormwater from 2.5 acres of impervious surfaces that would otherwise flow directly into Potash Brook, an impaired stream. The infiltration basin on city-owned property is also designed to remove phosphorus.

Funding for this project is provided by a grant from VTrans through the Municipal Highway Stormwater Mitigation Program and the South Burlington stormwater utility. The grant will provide 80% of funding needed to completer this project and the stormwater utility will provide the remaining 20%. Construction of the Linwood Drive infiltration basin is planned for the fall of 2021 (City of South Burlington, VT).

Code Review

Improving water quality can be achieved by preventing pollution from entering public waters and streams. Pollution can be in the form of nutrients, sediment, temperature, and chemicals. Many pollutants enter waters directly through stormwater runoff and, therefore, managing stormwater can help reduce water pollution. Green infrastructure and Low Impact Design provide many opportunities to mitigate water pollution and to increase the aesthetics of a community.

Fort River watershed towns can work with the Pioneer Valley Planning Commission to use its Code Review Checklist tool to assess the ability of their town codes to promote green infrastructure. The code review process addresses the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit and determines if local ordinances are compliant with the federal requirements. Additionally, the code review process assesses how local ordinances affect the creation of impervious surfaces and how Low Impact Design techniques are integrated into code.

By allowing for infiltration basins, rain gardens, tree planting along streets, and other green infrastructure, stormwater can be treated before discharging into streams. Municipalities in the Fort River watershed can support water quality by making it easier for developers and homeowners to implement designs that reduce stormwater runoff and impervious surfaces.

Green Infrastructure (GI)

"Section 502 of the Clean Water Act defines green infrastructure as '...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." (United States Environmental Protection Agency)

Low Impact Design (LID)

"The term low impact development (LID) refers to systems and practices that use or mimic natural processes that result in the infiltration, evapotranspiration or use of stormwater in order to protect water quality and associated aquatic habitat." (United States Environmental Protection Agency)

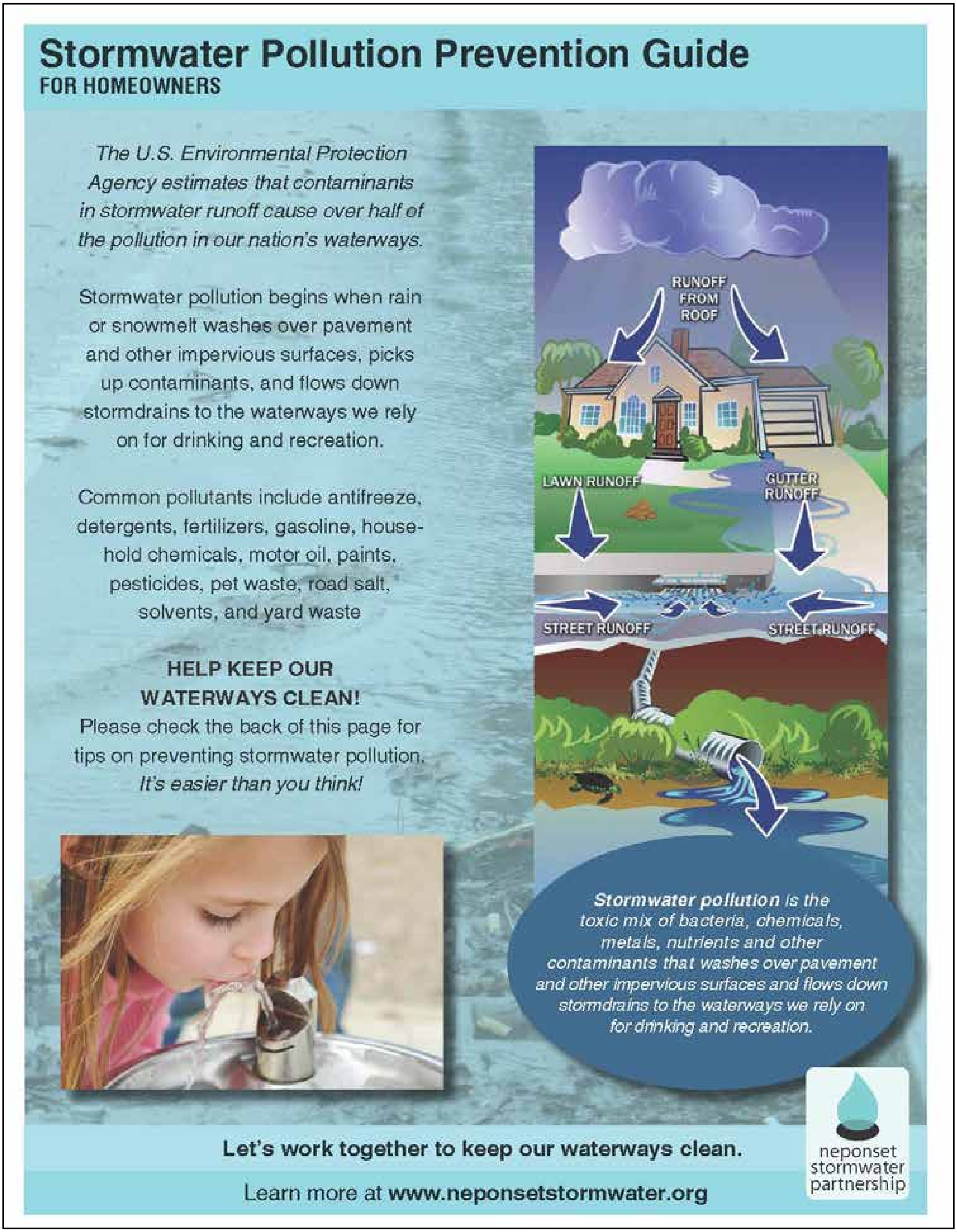


Figure 22. Example literature aimed at educating homeowners on the importance of managing residential stormwater and its impacts on water quality.

Appendix: Water Quality Data

Fort River Watershed Water Quality Attended Probe Data 2005 -2014 Massachusetts Department of Enivornmental Protection								
Stream Name	Date	Depth	Temperature	*pH*	SPCOND	TDS	DO	DOSAT
Amethyst Brook Hiking bridge northwest of Allen Mill Rd, Amehrst	**5/6/2008**	0.2	10.3	6.3	54	35	10.8	98
	6/03/2008	0.2	14.2	6.8	78	50	10.2	101
	7/1/2008	0	18.2	7	69	45	9.5	101
	7/29/2008	--	19	6	43	28	8.8	97
	9/9/2008	--	17.3	6	45	28	9.1	96
Hop Brook Station Road, Amherst	**5/6/2008**	1.1	14.2	6.4	91	58	8.7	86
	6/3/2008	0.8	18.7	6.5	118	76	6.5	71
	7/1/2008	0.6	22.6	6.6	132	86	4.9	56
	7/29/2008	--	21.5	6.1	82	52	4.1	47
	9/9/2008	--	18.2	5.9	71	46	5	53
Fort River Bike Path Bridge 50ft east of 116 crossing Amherst	**5/6/2008**	0.5	12.8	6.6	91	58	10.4	99
	6/3/2008	0.3	18.4	6.9	124	80	8.7	94
	7/1/2008	0.3	21.5	7	122	80	8.8	99
	7/29/2008	--	20.4	6.3	77	49	7	79
	9/9/2008	--	17.7	6.2	81	52	7.3	77
Fort River	**5/30/2008**	0.3	16.5	6.8	149	95	8.8	91
Rt 47, Hadley	**6/4/2008**	0.4	17.2	6.8	146	93	8	85
	6/27/2008	0.2	18.1	6.8	116	74	8.6	93
	7/2/2008	0.1	21.1	6.8	144	92	7.8	89
	7/25/2008	--	19.7	6.2	60	38	6.9	77
	7/30/2008	0.3	21.2	6.6	101	65	7.5	86

Fort River watershed data extracted from:
Massachusets Departement of Environmental Protection Water Quality Attended Probe Data 2005 -2014
https://www.mass.gov/doc/water-quality-attended-probe-data-2005-2014

Fort River Watershed Water Quality Laboratory Data 2005 -2014

Massachusetts Department of Enivornmental Protection

Stream Name	Date	Amonia- N (mg/L)	*Ecoli (CFU/100ml)*	Suspended Solids(mg/L)	Total Nitrogen (mg/L)	Total Phophorus (mg/L)	Ture Color (PCU)	Turbidity (NTU)
Amethyst Brook Hiking bridge northwest of Allen Mill Rd, Amehrst	**5/6/2008**	-0.02	-4	-1	0.18	0.005	-15	0.9
		-0.02	4	-1	0.28	0.005	-15	-0.05
	7/1/2008	-0.02	10	1	0.27	0.007	27	0.8
	7/29/2008	-0.02	-10	1.1	0.25	0.008	42	0.8
	9/3/2008		20					
	9/9/2008	-0.02	340	1.9	0.32	0.014	47	1.3
Hop Brook	**5/6/2008**	-0.02	14	2.2	3	0.014	26	2.1
	6/3/2008	0.03	88	3.3	0.56	0.037	57	4.7
	7/1/2008	0.05	30	2.4	0.57	0.04	69	8.5
	7/29/2008	-0.02	80	3	0.59	0.036	90	4.1
	9/3/2008		360					
	9/9/2008	0.02	140	3.5	0.56	0.037	93	3.8
Fort River Bike Path Bridge 50ft east of 116 crossing Amherst	**5/6/2008**	-0.02	24	1.4	0.25	0.011	17	1.3
	6/3/2008	0.04	60	2.3	4.5	0.031	39	3.5
	7/1/2008	0.03	100	2.2	0.4	0.024	47	3.2
	7/29/2008	-0.02	30	2.4	..42	0.029	53	3.3
	9/3/2008		140					
	9/9/2008	0.03	460	4.6	0.45	0.036	60	4.7
Fort River Rt 47, Hadley	**5/6/2008**	-0.02	52	12	0.36	0.022	16	3.9
	6/3/2008	0.04	208	3.5	0.54	0.033	32	3.9
	7/1/2008	0.04	240	10	0.52	0.038	39	6
	7/29/2008	0.03	210	18	0.52	0.053	47	12.5
	9/3/2008		240					
	9/9/2008	0.03	1500	25	0.54	0.07	45	13.5

Fort River Watershed data extracted from:
Massachusetts Departement of Envirornmental Protection
Water Quality Laboratory Data 2005-2014
https://www.mass.gov/doc/water-quality-laboratory-data-2005-2014

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