Division of Water Supply Protection:
2017 Land Management Plan

Clockwise from top left: A view of Quabbin Reservoir looking north from the Administration building; Wachusett Reservoir from South Bay looking north; an aerial view of the Ware River watershed with the river and prison camp fields visible; a view of Sudbury Reservoir from Framingham Road looking north.

Massachusetts Department of Conservation and Recreation
Division of Water Supply Protection
Office of Watershed Management
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Review and comments were provided by Pat Austin (Environmental Quality Chief – Wachusett/Sudbury), Derek Beard (Forester – Quabbin), Ken Canfield (Forester – Ware), Dan Crocker (Environmental Analyst – Wachusett/Sudbury), Rebecca Faucher (Environmental Analyst – Quabbin), Sean Fisher (DCR Archivist), Lisa Gustavsen (Assistant Regional Director – Quabbin/Ware), Helen Johnson (Forester – Quabbin), Paul Lyons (Environmental Analyst – Quabbin, retired), Bill Pula (Regional Director – Quabbin/Ware, retired), John Scannell (Regional Director – Wachusett/Sudbury), Kim Turner (Parks Supervisor – Quabbin), Russ Wilmot (Forester – Wachusett/Sudbury), Steve Wood (Forester – Quabbin), and Maria Janowiak (US Forest Service, Northern Institute of Applied Climate Science).

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Charles D. Baker, Governor
Karyn E. Polito, Lt. Governor
Matthew A. Beaton, Secretary, Executive Office of Energy and Environmental Affairs
Leo P. Roy, Commissioner, Department of Conservation and Recreation
Jonathan L. Yeo, Director, Division of Water Supply Protection

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1 Executive Summary

The Massachusetts Department of Conservation and Recreation (DCR), Division of Water Supply Protection, Office of Watershed Management (DWSP) manages and protects the drinking water supply watersheds that provide source water for approximately 2.5 million Massachusetts residents in 51 communities.

The mission of DWSP is to utilize and conserve water and other natural resources; to protect, preserve and enhance the environment of the Commonwealth; and to assure the availability of pure water for future generations.

The water supply watersheds under DWSP's care and control cover over 400 square miles. The system is comprised of three active watersheds – Quabbin Reservoir, Ware River, and Wachusett Reservoir – and one emergency source watershed system – Sudbury and Foss Reservoirs. DWSP owns or controls approximately 130,000 acres (39%) in the three active watersheds, which includes the area of the two source reservoirs, Quabbin (24,600 acres) and Wachusett (4,200 acres). The majority of DWSP lands are forested (87%), while a relatively small percentage of lands are non-forested (3%), open water (2%), wetlands (4%), or administrative areas (4%).

DWSP produces a variety of written plans to guide its activities. Approximately every five years, a Watershed Protection Plan is developed (www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/plans.html). This overarching plan identifies water quality threats, describes DWSP's programs and activities that mitigate these threats, and provides a foundation for the majority of DWSP's activities. Within the context of the Watershed Protection Plan, DWSP develops additional plans that address specific topics. Public access plans for each watershed are written at regular intervals to describe what type of activities are allowed or prohibited. In addition, invasive species plans have been developed that outline DSWP's approach to managing terrestrial and aquatic invasives. Finally, DWSP develops land management plans that specifically outline activities occurring on DWSP owned property. This comprehensive *2017 Land Management Plan* (LMP) replaces the individual land management plans DWSP produced for each watershed in the past and serves as the guiding document for a variety of management activities on its properties. The plan details a wide range of programs that DWSP has developed to fulfill its mission, which include Land Protection, Management of Forested Areas, Management of Non-Forested Areas, Wildlife Management, and Protection of Cultural Resources.

Land Protection

Control over harmful activities on the watersheds is best achieved, in both short- and long-term, when the Commonwealth has actual ownership or other direct control over allowable activities on the land, and is the environmental protection standard for unfiltered water supply systems. Thus,

DWSP has an active land acquisition program geared towards acquiring ownership of key parcels on the watersheds – primarily those near the reservoirs and their principal tributaries and wetlands. Once acquired, these lands can then be managed to establish and maintain optimal cover types that provide for the long-term protection of water quality.

Increasing the amount of watershed land that DWSP owns or controls has been a priority for more than 30 years. DWSP has spent more than $130 million (bonded and paid for by the Massachusetts Water Resources Authority (MWRA)) since the late 1980s purchasing land or easements in the three active watersheds. In that time period, DWSP controlled land has increased from 7.9% to 28.4% in the Wachusett watershed, 42% to 46.8% in the Quabbin watershed, and 32% to 39% in the Ware River watershed.

An alternative to purchasing land in fee is acquisition of a Watershed Preservation Restriction (WPR). Purchasing a WPR prevents development and other potentially harmful activities (e.g., livestock, septic systems, storage of hazardous materials) while allowing the current landowner to retain ownership and use of the land.

In recent years, there has been a strong preference for acquisition of WPRs rather than acquiring land in fee because WPRs still protect water quality while being more cost-effective. As of February, 2017, DWSP held 127 WPRs, totaling approximately 7,343 acres across all three active watersheds.

Land Protection Goal

Continue land acquisition and purchase of Watershed Preservation Restrictions for the foreseeable future, with a focus on land in the Wachusett Reservoir and Quabbin Reservoir watersheds.

Management of Forested Areas

Forests provide exceptional water quality protection and yield high quality water while also providing other benefits such as wildlife habitat, temperature regulation, carbon sequestration, local economic opportunities, and passive recreation. While DWSP watershed forests are generally healthy, they are routinely threatened from physical (ice, strong winds, fire) and biological (insects, diseases, invasive plants, herbivore browsing) disturbances. Active forest management can increase the resistance and resilience of these watershed protection forests to disturbance by deliberately diversifying forest age structure and species composition.

DWSP forests are comprised of trees of many ages but are dominated by stands older than 75 years. Diversifying this age structure can be accomplished using a variety of regeneration cutting methods.

Managed Forested Areas Goals

- ***Diversify forest age structure and species composition.***
    - ***Regenerate up to 1% of DWSP's manageable forest annually, producing young trees and thus increasing age class diversity.***
    - ***Create canopy openings that vary in size and shape, complement site conditions, and provide a full range of shade environments to promote a diversity of tree species regeneration. Retain native species, while favoring those that are long-lived and adapted to site conditions.***
    - ***Utilize larger regeneration openings as needed for certain situations such as plantation removal, restoration of degraded stands, poor quality, or low vigor stands, sanitation cuts of diseased/infested stands, conversion of old field white pine, and creation of early successional forested habitat.***
- ***Protect water quality and prevent changes in water yield.***
    - ***Meet or exceed required Best Management Practices (BMPs) to prevent erosion.***
    - ***Limit harvesting at subwatershed level to prevent changes in water yield.***
    - ***Apply sensitive treatments in riparian areas.***
- ***Incorporate responsible forestry practices that consider aesthetics, maintain healthy diverse forests, and protect other ecological functions.***
    - ***Consider aesthetics when planning openings to take advantage of the natural contours of landscape features; "feathered edges" and irregular shapes will be used when conditions allow.***
    - ***Green tree retention will be used in most openings larger than ½ acre; retain 5-10 ft^2 of live tree basal area per acre (BA) dispersed as single trees or in small groups.***
    - ***Allow for the development of late-seral forest characteristics.***
    - ***Apply intermediate treatments as appropriate to promote individual tree vigor.***
    - ***Follow recommendations that protect common and rare wildlife species and their habitats; protect known rare plant populations.***
    - ***Work to identify new invasive species and prevent their spread, and identify areas where existing invasives may be reduced or eliminated.***

- ***Strengthen internal review, public notification/participation, and monitoring programs.***

    - ***Present all internally reviewed forestry proposals annually to the public for comment and post active forestry projects on the internet.***

    - ***Monitor the use and effectiveness of BMPs using a modified version of U.S. Forest Service protocols.***

    - ***Monitor water quality at some active forestry sites.***

    - ***Continue to study the long-term effects of active forest management on water quality.***

    - ***Monitor regeneration resulting from harvesting operations, and post reports and photos online to document forest response.***

Non-Managed Forested Areas: DWSP has formally designated two reserve areas where no active forest management will occur. Additionally, there are thousands of acres of smaller patches where harvesting is restricted by slope, hydrology, and other factors. In total, approximately 20-25% of DWSP forested lands will be allowed to develop naturally into older forest, with the overall goal to conserve regional biodiversity. Management in these areas will be limited to road maintenance, wildfire suppression, rare species and habitat protection, and invasive species control.

Management of Non-forested Areas

While non-forested areas comprise a relatively small percentage of DWSP's landholdings, they encompass many important landscape features. These include about 1,000 acres of fields, which provide landscape diversity and critical wildlife habitat. Approximately half of these fields are managed by DWSP staff using mowing guidelines that maximize habitat value. The remaining fields are leased to local farmers for hay production and are subject to a variety of restrictions that protect water quality and benefit wildlife. Many of DWSP's public access areas are non-forested, including the Old Stone Church, Dana Common, Stillwater Farm, and the three Quabbin Boat Launch areas.

Non-forested Areas Management Goals

- ***Ensure that the maintenance of non-forested upland habitats protects water quality. Use BMPs, including the maintenance of forested buffers along adjacent water resources.***

- ***Maintain early successional non-forested habitats on DWSP lands, where feasible and applicable, for species of wildlife that are considered uncommon, rare or unique on a regional or statewide basis.***

- ***Maintain the aesthetic diversity of the local landscape, where appropriate and not in conflict with water resource protection.***

- ***Work to identify new invasive species and prevent their spread, and identify areas where existing invasives may be reduced or eliminated.***

Wildlife Management

The primary focus of DWSP's wildlife program is to protect the water supply from potential adverse impacts caused directly or indirectly by wildlife, while also protecting and enhancing wildlife and habitat diversity.

In general, it is DWSP policy not to interfere with natural wildlife activity. However, when those activities have the potential to impact either water quality or the integrity of watershed structures or resources, then DWSP takes action to prevent, reduce, or mitigate the damages. The species of highest concern and their associated risks are:

1. Gulls, geese and other waterfowl, which can negatively impact water quality.
2. Beaver, which can cause damage to watershed structures and property, and depending on their location and site conditions, can negatively impact water quality.
3. White-tailed deer, which can alter forest structure and function, and impact successful forest regeneration.
4. Moose, which can alter tree species diversity and abundance.

DWSP's goal of maintaining biodiversity starts with avoiding adverse impacts to rare or uncommon wildlife species and their habitats during land management activities. This will be accomplished primarily through:

1. Inventory and survey work to locate rare species and habitats.
2. Coordination with MassWildlife's Natural Heritage and Endangered Species Program (NHESP).
3. Following NHESP's Massachusetts Forestry Conservation Management Practices (CMPs) for Listed Wildlife Species.

When possible and appropriate, DWSP will also proactively manage habitat for the benefit of wildlife species or habitat types that are deemed rare or of special concern on a regional or statewide basis. Treatments could include mowing, cutting, and/or prescribed burns to enhance or maintain a field, barren, or meadow, old field reclamation, creation of early-successional forest, removal of exotic/invasive plants, and/or erecting nesting platforms for uncommon species of birds.

DWSP forest management incorporates many specific practices that maintain or enhance biodiversity at the micro or stand level. Recommended forestry practices for conservation of wildlife habitat features include:

- identification of vernal pools, seeps, and springs;
- retention of den and snag trees, diverse native mast-producing trees and shrubs, downed woody material in a range of sizes and types, and old apple and other fruit trees;
- preservation of wildlife wintering areas;
- maintenance of suitable nesting sites for woodland raptors across the landscape and avoiding disturbance of nesting pairs of raptors.

While directly protecting rare or endangered wildlife is a priority, DWSP recognizes that its management activities have the potential to temporarily impact more common wildlife. It is important to assess the impacts of these land management activities on the general wildlife communities on DWSP lands. This assessment can be used to help keep common wildlife "common" by minimizing adverse impacts. This will be accomplished through long-term monitoring programs and an in-house review process for all planned management activities.

Wildlife Management Goals

- ***Mitigate adverse impacts of wildlife on water quality, infrastructure, and other watershed resources.***
- ***Maintain and enhance ecosystem biodiversity:***
  - ***Identify and protect uncommon or rare species present on DWSP lands***
  - ***Actively manage for selected wildlife species or suites of species that are considered to be uncommon, rare, or unique on a regional or statewide basis***
  - ***Incorporate practices that generally benefit wildlife***
- ***Assess and mitigate impacts of watershed management activities on common wildlife through site visits, long-term monitoring, review of records and literature, and recommendations to appropriate management staff.***

Protection of Cultural Resources

As a large landowner, identifying and protecting the State's cultural resources is a serious responsibility. Each of the four watersheds is rich in both pre-Contact (before European colonization) and historical (post-European colonization) resources. Accordingly, safeguards have been built into DWSP's land management program to protect cultural sites and artifacts, both through the review of proposed silvicultural projects to identify and mitigate possible impacts of management activities on pre-Contact resources, and through a program of pro-active vegetative management around significant historical sites.

Protection of Cultural Resources Goals

- ***Identify significant cultural resources on watershed lands.***
- ***Prevent degradation of cultural sites and resources.***

The *2017 Land Management Plan* is part of the ongoing planning process performed by DWSP. Information from the LMP, along with Public Access Plans, Environmental Quality Assessments, and other specialized studies, are integrated into DWSP's Watershed Protection Plan, a five-year document that is the basis for the annual Work Plan submitted to the Water Supply Protection Trust. The previous individual watershed Land Management Plans were written with a ten-year time frame. This LMP is considered an adaptive management plan. A wide range of issues will be examined annually – which can be addressed in the annual Work Plan – with a significant review in five years.

2 Agency Mission and Organization

2.1 Introduction

The Department of Conservation and Recreation (DCR), Division of Water Supply Protection, Office of Watershed Management (DWSP) historically produced Land Management Plans on a rotating ten-year schedule for each of the watersheds under its care and control – Quabbin Reservoir, Ware River, Wachusett Reservoir, and Sudbury Reservoir (Figure 2-1). This plan marks the transition from individual watershed plans to a comprehensive five-year Land Management Plan (LMP) that will detail management activities or programs common to all the watersheds while still allowing individual differences to be highlighted. This LMP provides principles from the current state of the science of watershed and natural resources management, agency goals for a five-year period, and specific objectives for accomplishing these in the areas of Forest Management, Wildlife Management, Management of Non-Forested Lands, and Cultural Resource Protection. The LMP builds on advancements in science and management techniques, the agency's own experience over seven decades of managing the watershed and its resources, and accumulated input from advisory groups and the general public. It is designed as an adaptive plan, utilizing annual reviews to build immediately on new information and changes in the science that supports management decisions, and to revise objectives, as necessary, within the five-year time frame of the plan.

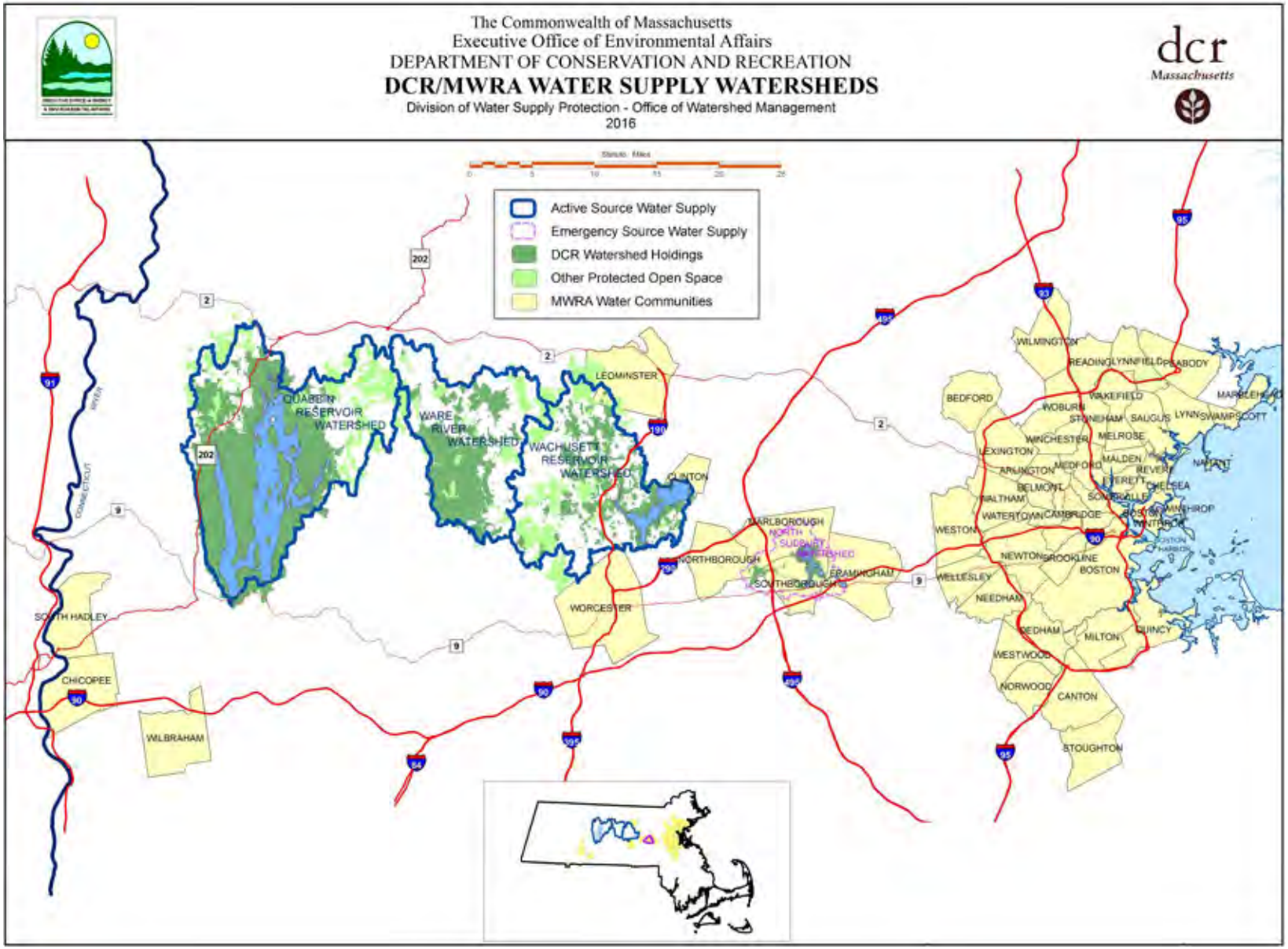
2.2 Organizational Structure

DWSP and its predecessors have had a long tenure of providing high quality drinking water to the citizens of Massachusetts. There are a variety of laws under which DWSP must work as a drinking water supply manager. DWSP is also responsible for implementing its own regulations in its efforts to protect the drinking water source for more than a third of the citizens of the Commonwealth.

2.2.1 The Department of Conservation and Recreation

The Department of Conservation and Recreation (DCR) was created in July 2003 when the legislature merged the Metropolitan District Commission (MDC) and the Department of Environmental Management (DEM). Chapter 26 of the Acts of 2003, §290 transferred the responsibilities of the former MDC Division of Watershed Management entirely to the Office of Watershed Management within the Division of Water Supply Protection. While the names have changed several times over the past century, the primary mission of DWSP remains constant: to provide 'pure' water through responsible watershed management. DWSP is legislatively mandated to manage and protect the drinking water supply watersheds, providing drinking water that meets or exceeds all state and federal standards, for distribution by the Massachusetts Water Resources Authority (MWRA) to approximately 2.5 million residents of Massachusetts.

FIGURE 2-1. DCR/MWRA WATER SUPPLY WATERSHEDS



DWSP staff concentrates on the management, operation, and maintenance of the DCR/MWRA water supply system watersheds, reservoirs, dams, and dikes. The MWRA is responsible for water treatment and distribution. MWRA finances the Water Supply Protection Trust, which funds DWSP, as well as major capital infrastructure, including the Winsor and Wachusett Dams. DWSP and MWRA work closely together, as defined in a 2004 Memorandum of Understanding. DWSP staff includes professional engineers, analysts, planners, watershed rangers, foresters, aquatic biologists, natural resources specialists, geographic information specialists, wildlife biologists, and support staff with a variety of skills and training. DWSP staff carry out specific watershed protection programs, provide public outreach and environmental education to watershed communities and visitors, and administer and enforce watershed protection regulations (313 CMR 11.00). Staff activities are guided, integrated, and prioritized by DWSP's five –year Watershed Protection Plan and an annual Work Plan.

In most cases throughout this document the acronym DWSP is used to reference both the current and former watershed management agency within the Department of Conservation and Recreation. In some contexts, particularly in historical discussions or referencing studies and publications, the terms "Metropolitan District Commission/Division of Watershed Management," MDC and MDC/DWM remain accurate. The term "DWSP lands" refers to properties that are owned by the Commonwealth of Massachusetts and are under the care and control of DCR's Division of Water Supply Protection, Office of Watershed Management.

2.2.2 Water Supply Protection Trust

The legislature further enhanced the ability of the Office of Watershed Management to maintain the drinking water supply by establishing a Water Supply Protection Trust, created by Chapter 149 of the Acts of 2004, §27, and written into the general laws at Massachusetts General Laws Chapter 10, Section 75 (M.G.L. c. 10, §75). The trust provides a more efficient mechanism for MWRA's funding of the Office of Watershed Management. The Trust has also allowed the Office of Watershed Management to fill a wide range of critical positions.

The Water Supply Protection Trust has a five-person board of trustees responsible for approving DWSP's annual work plan and budget each spring for the following fiscal year beginning July 1. The members of the board of trustees are the Secretary of the Executive Office of Energy and Environmental Affairs; the Executive Director of the MWRA; the chairperson of the MWRA Advisory Board; a representative jointly selected by the North Worcester County Quabbin Anglers Association, Inc. and the Quabbin Fishermen's Association, Inc.; and a representative from the Swift River Valley Historical Society.

2.3 Mission

The Office of Watershed Management within the Division of Water Supply Protection of the Department of Conservation and Recreation, a state agency within the Executive Office of Energy and Environmental Affairs (EOEEA), has been charged by Chapter 26 of the Acts of

2003, §290 with protection of the Quabbin Reservoir, Ware River, Wachusett Reservoir, and Sudbury Reservoir watersheds. M.G.L. c. 92A ½, §2 directs the DWSP to:

> ...construct, maintain and operate a system of watersheds, reservoirs, water rights and rights in sources of water supply [to] supply thereby a sufficient supply of pure water to the Massachusetts Water Resources Authority, and [to] utilize and conserve said water and other natural resources to protect, preserve and enhance the environment of the Commonwealth and to assure the availability of pure water for future generations.

The body of legislation makes directives on specific management aspects of the watersheds, authorizing DWSP to:

- Have the exclusive right and control over all ponds, reservoirs, and other property within the watershed system, and [may] order all persons to keep from entering in, upon or over the waters thereof and the lands of the commonwealth or towns surrounding same.
- Make rules and regulations for the protection of the watersheds.
- Establish the Quabbin Watershed Advisory Committee, the Watershed System Advisory Committee (covering Wachusett and Sudbury watersheds), and the Ware River Watershed Advisory Committee.
- Adopt periodic watershed management plans to provide for forestry, water yield, and public access among other purposes.

Building on the legislatively-defined mission, DWSP's charge today is:

- To maintain and operate the source facilities (including dams) safely and efficiently.
- To preserve and improve water quality of the supply sources, through regulation, direct action, and cooperation, as needed to protect public health and to meet state and federal water quality standards.
- To fulfill the watershed protection and management requirements associated with drinking water regulations.
- To implement the specific directives of the legislature, such as providing recreation opportunities balanced with the protection of the water supply sources and promulgating and enforcing rules and regulations for DWSP lands and for protected zones.
- To involve watershed towns, residents, and the public in appropriate ways in the conduct of the DWSP's watershed management functions.

2.4 Regulatory Overview

Public drinking water supplies are highly regulated in the United States to protect public health. Both federal and state laws (including the U.S. Safe Drinking Water Act along with its 1996 Amendments, the Surface Water Treatment Rule, and the Massachusetts Drinking Water

Regulations (310 CMR 22.00) require water providers to meet rigorous water quality standards for source waters. Public water systems have responsibilites under 310 CMR 22.00 to control activities and to take enforcement to protect sources. These standards change over time based on research and testing. The U.S. Environmental Protection Agency (EPA) administers federal water quality regulations throughout the country. In Massachusetts, the Massachusetts Department of Environmental Protection (DEP) has been given primary responsibility for assuring compliance with state and federal drinking water regulations, and consistently monitors water quality throughout the DCR/MWRA water supply system to ensure compliance with these regulations.

The DCR/MWRA water supply system comes under further scrutiny because it is an unfiltered water system. The Federal Surface Water Treatment Rule (SWTR, 1989) and Interim Enhanced SWTR (1998) essentially requires filtration for all surface water supplies across the country, but does allow for a waiver from this expensive infrastructure for the highest quality source waters that maintain effective watershed control programs which demonstrate "substantial control" over all pollutant sources. DEP's Watershed Resource Protection Plan Policy (89-09) set standards for the information required in a Watershed Control Program plan for SWTR filtration avoidance, including: maps; description; activities (natural and manmade); control of activities; land agreements and ownership; and management and operations. DEP also established in 1996 a set of "Measures of Success" for Unfiltered Watershed Protection Efforts, requiring programmatic milestones in several categories: Watershed Control; Public Access/Recreation; Wildlife Management; Infrastructure Improvements; In-lake Problems; Sampling; System Operation/Maintenance, Staffing; Emergency Planning/Response; and Education/Multi-town Coordination.

DWSP and its predecessor agency have successfully met DEP's "Measures of Success" since the first comprehensive Watershed Protection Plans were developed for the Quabbin Reservoir and Wachusett Reservoir watersheds in 1991. The watershed protection program, including the Watershed Protection regulations, 313 CMR 11.00, were a key factor in the successful defense against a federal lawsuit that attempted to require the MWRA to build a filtration plant (*USA v. Massachusetts Water Resources Authority and Metropolitan District Commission (Civil Action Number 98-10267*).

Both DEP and EPA maintain strict oversight of DWSP operations and watershed protection activities. DEP conducts annual inspections of the system because MWRA is a public water supplier. DEP uses four distinct criteria in its evaluation of DWSP's watershed protection efforts:

- Demonstration and implementation of watershed control.
- On-site inspection of the water supply system.
- Documented absence of waterborne disease outbreaks.
- Compliance with the existing U.S. Safe Drinking Water Act's maximum contaminant levels.

Each year DEP conducts a thorough inspection of DWSP's watershed control programs at both Quabbin Reservoir and Wachusett Reservoir. Inspection of the watersheds and review of drinking water treatment processes include evaluation of specific criteria to measure the system's ability to produce safe drinking water. Inspection elements included the following:

A. A review of the effectiveness of the Watershed Protection/Control Program Plan.
B. A review of the physical condition of the source intakes and how well they are protected.
C. A review of the appropriateness of the system's disinfection equipment and maintenance program in order to ensure a high operating reliability.
D. An inspection of the disinfection equipment and review for appropriateness and physical deterioration.
E. A review of management/operating procedures.
F. A review of data records that included source water total and fecal coliform bacteria data and turbidity levels with the objective of ensuring that all required tests were conducted and recorded.
G. A separate review of bacteriological data for the occurrence of coliform in the distribution system in order to ensure that the disinfection process is effectively applied.
H. A review of disinfection byproduct data from the distribution system.
I. An identification of any improvements that are needed in the equipment, system maintenance, system operation, or data collection processes.
J. A review of the status of any Safe Drinking Water Act compliance issues previously identified.
K. Confirmation that the system is using a laboratory certified by MassDEP for the required analytical methods.

The annual inspection reports carefully document issues in the watershed and makes clear that complete implementation of the Watershed Protection Plan, including the components from the Land Management Plan, is key to retaining filtration avoidance and ensuring that 2.5 million people continue to enjoy an abundant and high-quality water supply.

2.5 STAC and From Here Forward

In 1996, DWSP assembled a group of natural resource professionals from local universities, federal agencies, and Non-Governmental Organizations to discuss natural resource management issues and to advise DWSP on focused research opportunities. The STAC (Science and Technical Advisory Committee) group met several times through 2000. In April 2010, the Secretary of EOEEA directed STAC to review the scientific principles that guide DWSP's forest management activities. The STAC report was presented in 2012 (www.mass.gov/eea/docs/dcr/news/public-meetings/materials/watershed/review-of-mass-dwsp-watershed-forestry-progarm.pdf). In response to the STAC report, DWSP released *From Here Forward: Changes to the Department of Conservation and Recreation Division of Water Supply Protection's Watershed Forest Management Program* in August of 2013

(www.mass.gov/eea/docs/dcr/news/public-meetings/materials/watershed/dcrstacresponse8-2013-3.pdf). This document outlined a variety of changes to DWSP's forest management program which have been incorporated into this LMP:

- Improvements in public information and opportunities for input
- Improvements in the internal lot review and oversight procedures
- Revisions in the spatial and aesthetic characteristics of canopy openings
- Inclusion of live tree retention standards, and enhanced practices for the development of old growth characteristics
- Enhancements in monitoring of BMP effectiveness and water quality impacts
- Strategies for the management of terrestrial invasive plant species
- Strengthened efforts to protect land within the Wachusett Reservoir watershed

2.6 Sources of Information

DSWP writes a variety of plans related to watershed management, including a Watershed Protection Plan, Public Access Plans, and previous Land Management Plans. In many cases, detailed information on an assortment of specific topics can be found in these varied plans. Past Land Management Plans included a lot of this detailed information. However, in this LMP, many of these sections have been eliminated or greatly condensed. Though this information is not contained in this LMP, all the information exists in either previous Land Management Plans or one of the other DWSP plans. Readers are urged to explore these plans (most available online) for a more detailed discussion:

- Quabbin Land Management Plan (2007): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/quabbin-reservoir-watershed-land-management-plan.html

- Ware River Land Management Plan (2003): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/ware-river-watershed-land-management-plan.html

- Wachusett Land Management Plan (2001): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/wachusett-reservoir-land-management-plan.html

- Sudbury Land Management Plan (2005): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/sudbury-reservoir-watershed-land-management-plan.html

- Watershed Protection Plan (2013): www.mass.gov/eea/docs/dcr/watersupply/watershed/2013dcrwatershedprotectionplan.pdf

- Quabbin Public Access Plan (2017): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/quabbin-reservoir-watershed.html

- Ware River Public Access Plan (2010): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/2010-ware-river-watershed-public-access-management-plan.html

- Wachusett Public Access Plan (2011): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/wachusett-reservoir-watershed-public-access-plan.html

- Sudbury Public Access Plan (2010): www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/sudbury-and-foss-reservoirs-2010-public-access-plan.html

- Terrestrial Invasive Plant Management Strategy (2011): www.mass.gov/eea/docs/dcr/watersupply/watershed/dcrwatershedterrestrialinvasivesstrategy.pdf

- Aquatic Invasive Species Plan (2010): www.mass.gov/eea/docs/dcr/watersupply/watershed/2010aismgtplan.pdf.

3 Description of Watershed Resources

3.1 Watershed Ownership and Land Use

Land use and development patterns in a watershed influence the hydrology and water quality of its streams and lakes/reservoirs, and are important considerations in determining the appropriate protection measures for the watershed. The following sections detail current land uses and the protection status of watershed lands.

3.1.1 Current Land Uses

Land cover and land use for the Quabbin, Ware, Wachusett and Sudbury watersheds, as of 2005, are shown in Table 3-1. Overall, the watershed system is sparsely developed. The level of developed land is lowest in the Quabbin watershed and becomes more developed and populated moving eastward to the Sudbury watershed. No wastewater treatment plants or industrial discharges exist within any of the four watersheds.

TABLE 3-1. LAND COVER AND LAND USE OF DCR/DWSP WATERSHEDS

	Land Cover/Land Use (%) Excluding the Reservoirs						
WATERSHED	FOREST	WETLAND	AGRICULTURE	RESIDENTIAL	COMMERCIAL/ INDUSTRIAL	OPEN WATER	OTHER
Quabbin Reservoir	88.3	5.6	2.2	1.5	0.1	0.3	2.0
Ware River	75.6	11.4	3.2	4.2	0.3	2.6	2.7
Wachusett Reservoir	70.2	1.2	7.3	13.1	1.6	2.2	4.4
Sudbury Reservoir	40.8	1.3	6.2	30.5	12.2	0.2	8.8

The main land covers in all watersheds, forests and wetlands, is also the most protective of water quality. Forests and wetlands total 94% on Quabbin, 87% on Ware, 71% on the Wachusett watershed and 42% on the Sudbury. Agriculture accounts for 2% of the land use, and residential area is 6%. Residential land use is mostly low density and is most extensive in the Sudbury watershed, where housing density tends to be greater near the town centers. Commercial and other land uses (highways, recreation, and waste disposal) are less significant in the watersheds. The present commercial areas tend to be located near the town centers and along major roads.

Agriculture was a historically significant land use in this region, and was considered a high threat to water quality through 1998. However, by the time of the *2013 Watershed Protection Plan,* agriculture was considered only a low threat as the percentage of land in agricultural use was now very low in all watersheds and most of the agricultural operations were also very small. The reduction in agricultural impacts is due to several factors: purchase by DWSP of critical lands, conversion of other areas to residential development, close monitoring of the remaining sites, and an extensive outreach program by DWSP to promote Best Management Practices.

Animals with direct access to tributaries and wetlands are a source of nutrients and pathogens, and can cause dramatic increases in turbidity. Improper manure management can also lead to elevated concentrations of nutrients and pathogens, and is a possible source for emerging contaminants such as antibiotics. The cultivation and harvesting of crops is a potential source of nutrients, pesticides, herbicides, and elevated turbidity, especially during storm events. The use of Best Management Practices can reduce these threats.

3.1.2 Protected Lands

Overall, the DWSP owns and/or directly controls about 44% of the entire watershed system: approximately 60% of the Quabbin watershed, 40% of the Ware River watershed, 28% of the Wachusett watershed, and 15% of the Sudbury watershed (Table 3-2). Other state agencies, non-profit land conservation organizations and municipalities own and protect another 16% of the combined watersheds (Figures 3-1, 3-2, 3-3, and 3-4).

TABLE 3-2. DWSP AND OTHER PROTECTED OPEN SPACE

	Watershed	DWSP Fee	DWSP WPR	Other Protected	Total Protected	Land Area	Off-Water-shed
Active System	Quabbin Reservoir	53,915	3,684	15,362	72,961	95,466	4,301
	Ware River	23,516	1,078	7,430	32,024	61,737	
	Wachusett Reservoir	17,191	2,531	12,446	32,168	70,678	636
	Total	**94,664**	**7,293**	**35,238**	**137,195**	227,881	
Emergency System	Sudbury and Foss Reservoirs	2,381	0	1,715	4,096	16,350	

		Ownership as % of Watershed		
	Watershed	DWSP Controlled	Other Protected	Total Protected
Active System	Quabbin Reservoir	60.3%	16.1%	76.4%
	Ware River	39.8%	12.0%	51.9%
	Wachusett Reservoir	27.9%	17.6%	45.5%
	Total	**44.7%**	**15.5%**	**60.2%**
Emergency System	Sudbury and Foss Reservoir	14.6%	10.5%	25.1%

Data from MassGIS and DCR Records. Land area excludes reservoir surface.

3.1.3 Rights-of-Way

A variety of infrastructure corridors traverse the DWSP watersheds, including overhead power lines, underground communications lines, railroads, rail trails, roads, and highways. Management of these areas is the responsibility of the owner, but DWSP does provide direction and coordination to ensure water resources are adequately protected. For further discussion, see Section 4.1.7.

FIGURE 3-1. QUABBIN RESERVOIR WATERSHED

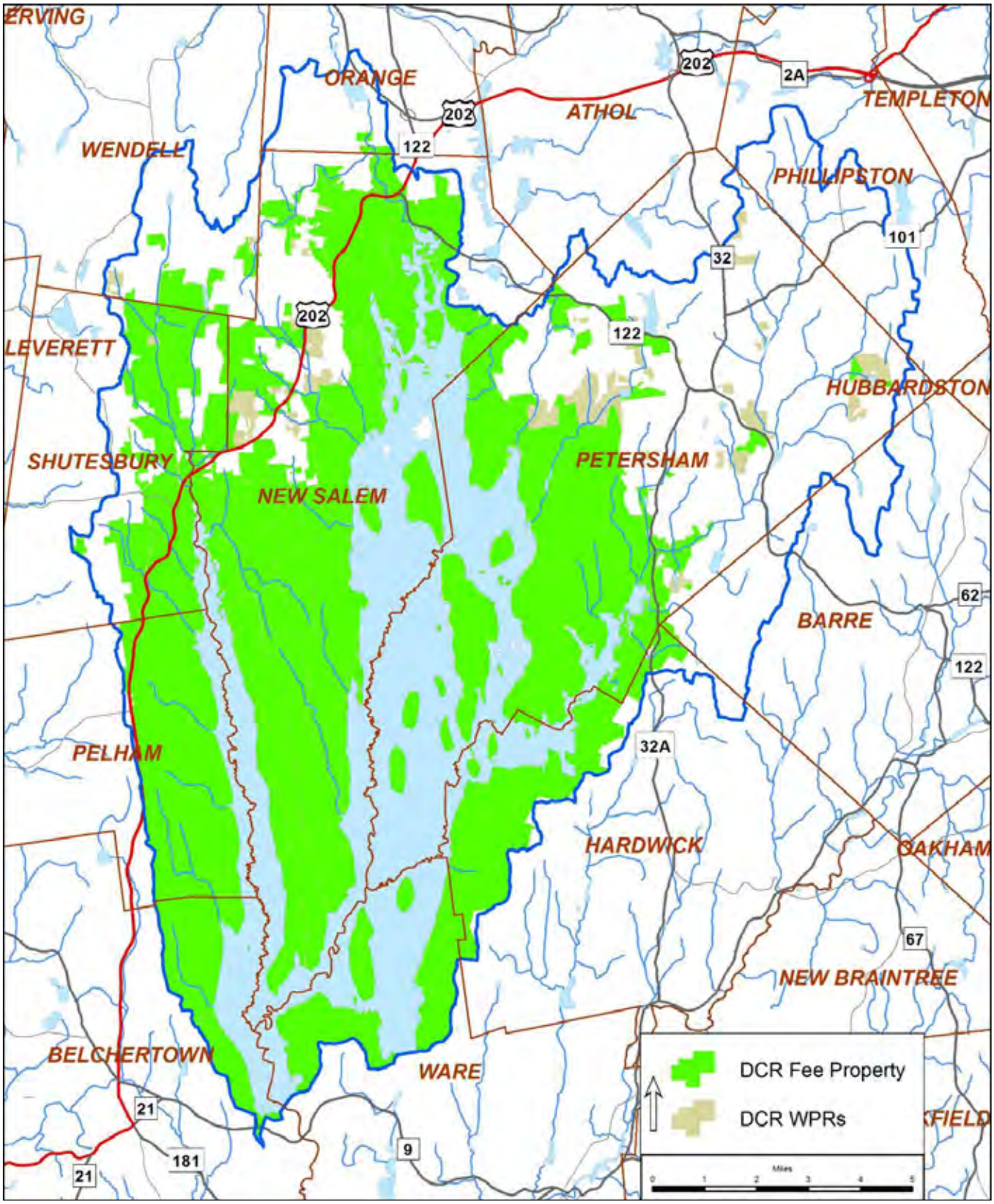


FIGURE 3-2. WARE RIVER WATERSHED

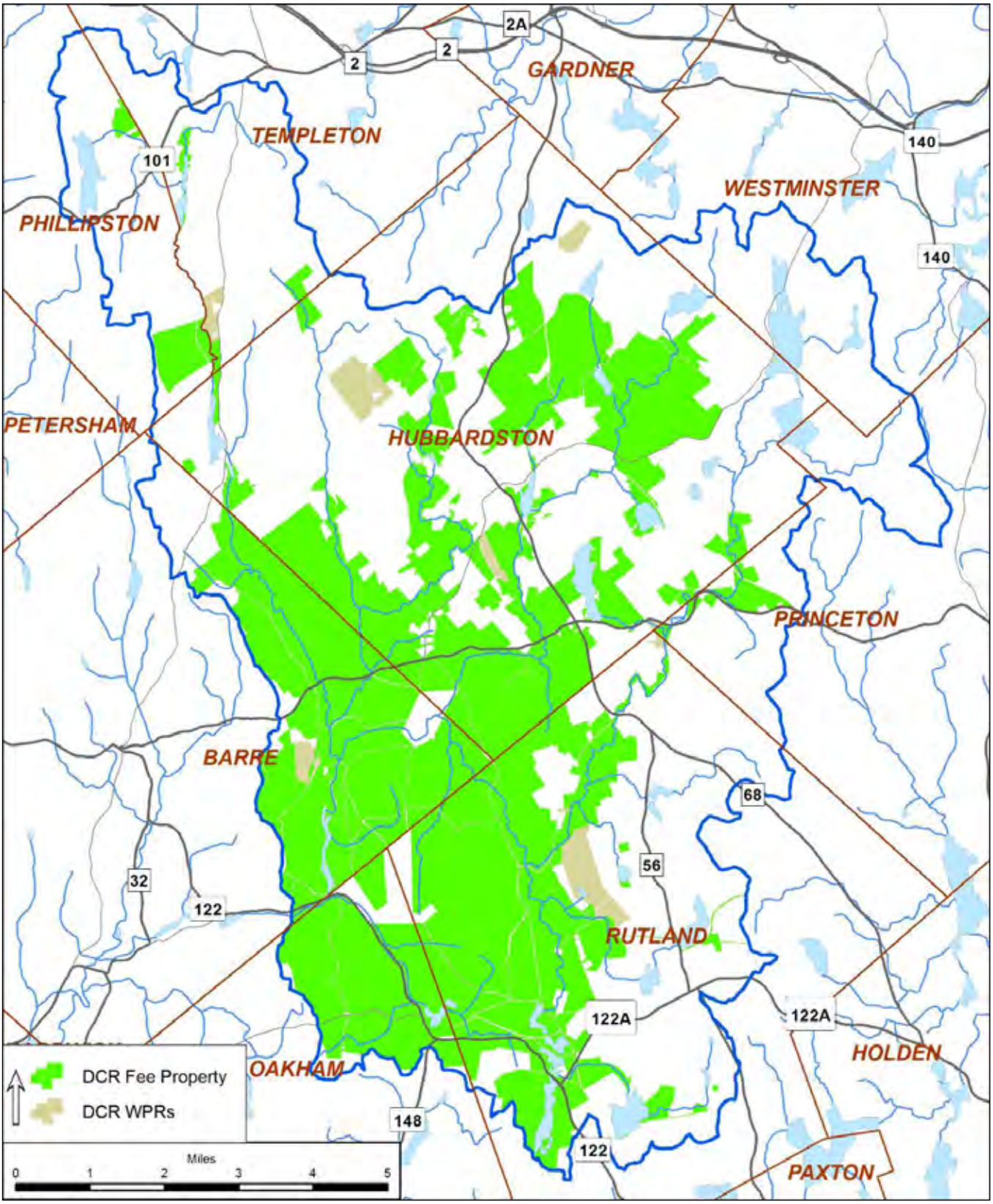


FIGURE 3-3. WACHUSETT RESERVOIR WATERSHED

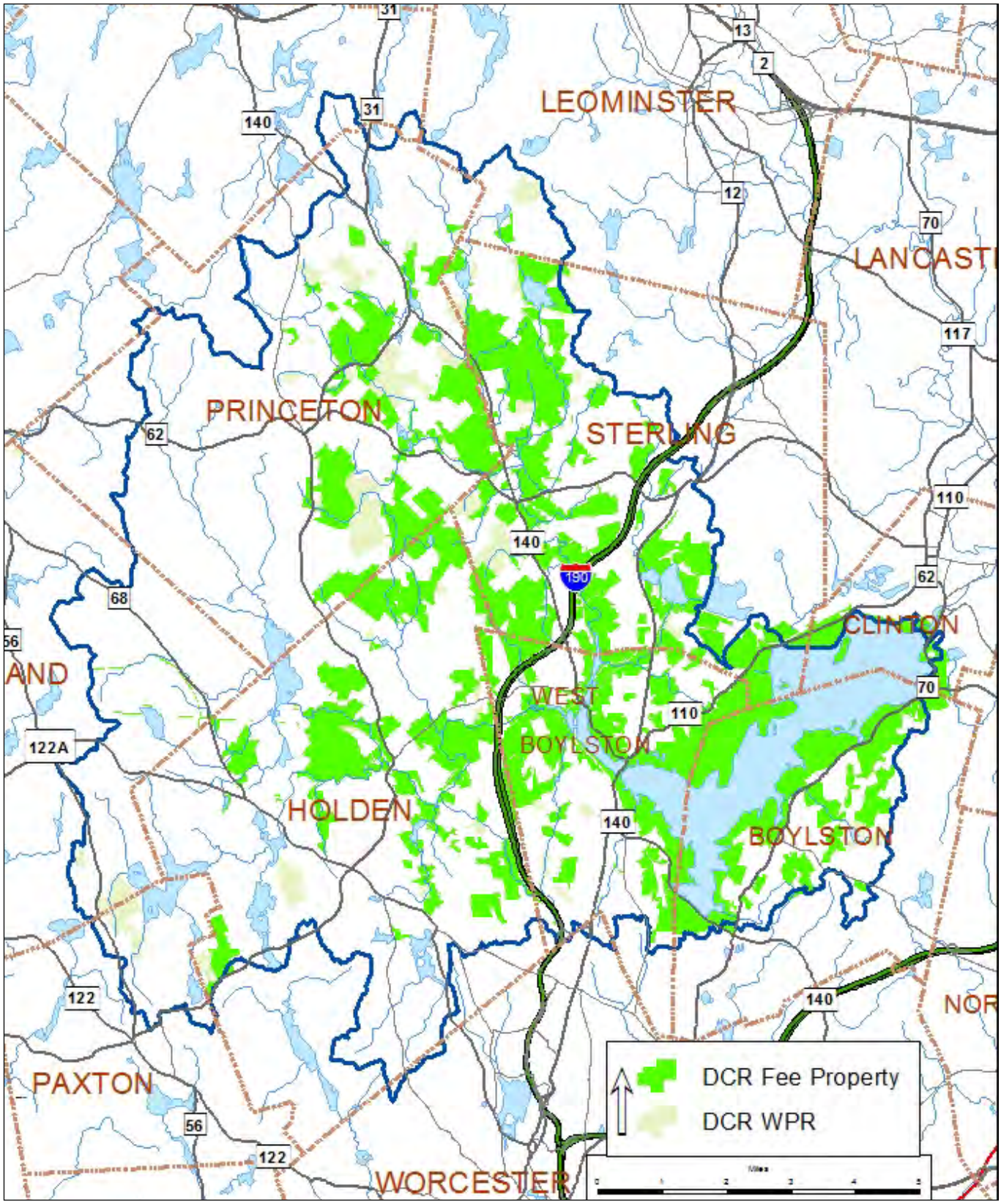
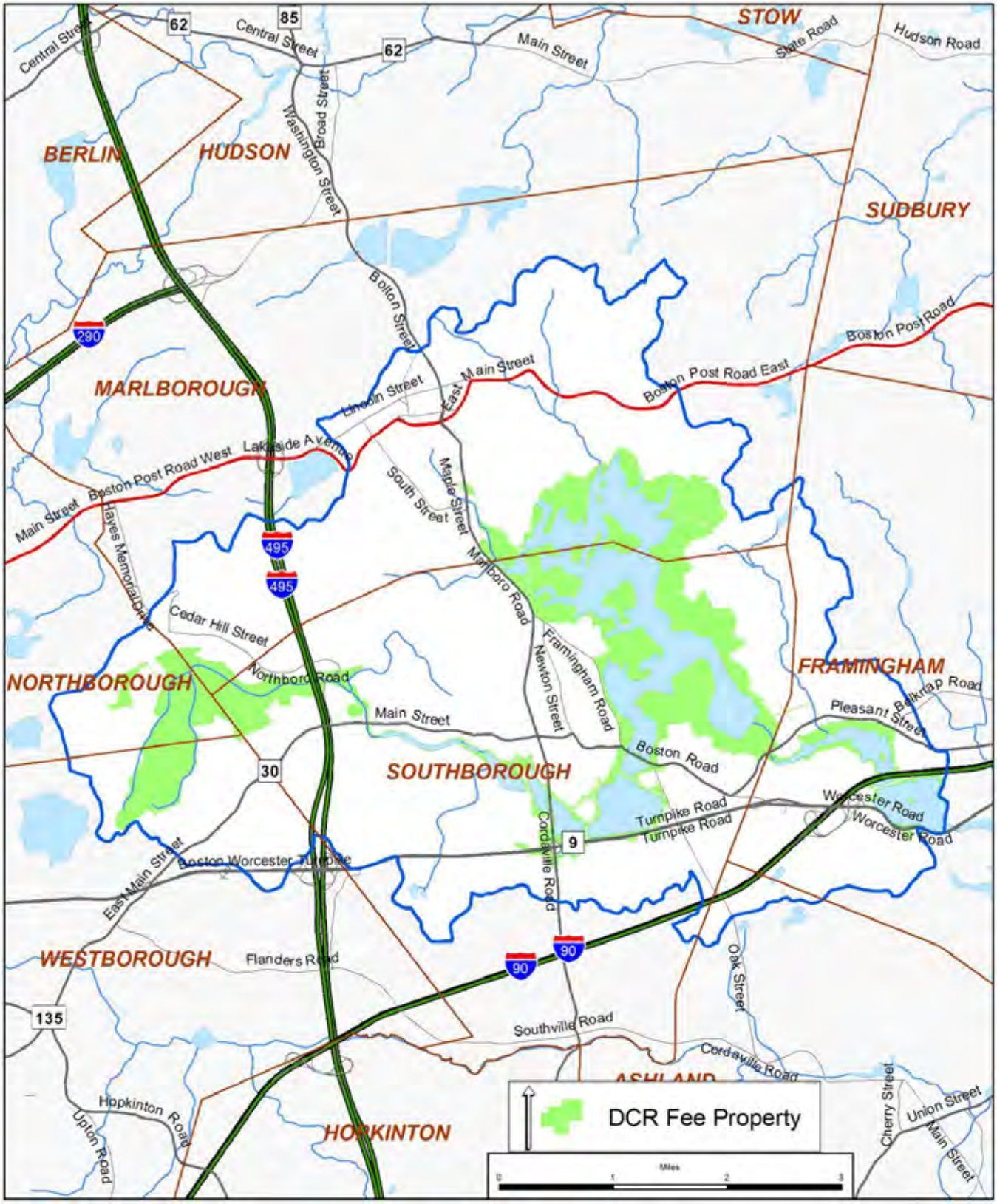


FIGURE 3-4. SUDBURY RESERVOIR WATERSHED



3.2 Physical Characteristics of Watershed Lands Under DWSP Control

3.2.1 Soils

Soils are an important functional component of the forest, and management on the watershed protection forests work to promote, preserve and maintain soil quality and health. Soil quality is the capacity of a soil to function, and healthy soil is able to perform at least the following five essential functions (http://soils.usda.gov/sqi/concepts/concepts.html):

- Regulates water by holding, storing and releasing rainwater and snowmelt.
- Sustains plant and animal life and enhances biodiversity.
- Filters potential pollutants by immobilizing and detoxifying organic and inorganic materials.
- Cycles nutrients such as carbon, nitrogen and phosphorous.
- Supports structures such as roads, buildings and cultural resources.

For the purposes of watershed management, DWSP soils have been grouped by depth and drainage characteristics into the following five classes, based on US Department of Agriculture's National Resource Conservation Service (NRCS) soil series descriptions (Table 3-3). These groupings provide a general framework for management considerations such as site quality, species composition, equipment operability and BMP requirements, ensuring the maintenance of soil quality and sustained soil function. Specific capabilities and limitations for each soil series are detailed in the NRCS Soil Survey.

TABLE 3-3. ACRES BY COMPOSITE SOIL TYPE, DWSP WATERSHED LANDS

Soil Type	Watershed, Acres (%)			
	Quabbin	Ware River	Wachusett	Sudbury
Excessively Drained	4,962 (8)	4,497 (19)	4,523 (26)	245 (11)
Well-drained thin	18,137 (31)	4,434 (18)	2,055 (12)	121 (5)
Well-drained thick	19,915 (34)	1,959 (8)	5,629 (33)	685 (31)
Moderately well-drained	10,777 (18)	8,089 (33)	2,265 (13)	203 (9)
Poorly to very poorly drained	4,707 (8)	5,238 (22)	2,743 (16)	991 (44)

3.2.2 Topography

The topography of the eastern part of the Quabbin watershed is irregular with moderate slopes, while the western part is characterized by two well defined, steeply sloped ranges oriented north and south through the length of the watershed. Elevation of the watershed ranges from 530 feet (reservoir's full pool elevation) to 1,383 feet above mean sea level, (the summit of Prospect Hill in Phillipston). The topography is characterized by north and northeast trending hills and relatively narrow valley bottoms.

Just to the east, the Ware River watershed is characterized by rolling hills separated by broad river valleys. Elevation of the watershed ranges from 650 feet at Shaft #8 at the southwest edge, to 1,720 feet near the summit of Mount Wachusett on the northeast edge, for a difference in elevation of 1,070 feet.

Similar to Ware River, the topography of the Wachusett watershed is generally hilly, but conditions range from broad valleys containing wetlands and flood plains, to mountainous terrain with exposed bedrock. Elevations vary from 395 feet above sea level at Wachusett Reservoir (full pool elevation) to 2,006 feet at Wachusett Mountain.

The topography of the Sudbury watershed varies from level to moderately sloped. Steep slopes are few and limited in extent. In contrast to the other watersheds to the west, elevation variance here is much lower, ranging from 259 feet (full pool elevation) to 464 feet at Pine Hill, for a total elevation difference of 205.

3.2.3 Precipitation and Evaporation

Annual precipitation is variable in Central Massachusetts (Table 3-4). Rain gauges placed throughout the region indicate a range from about 26 inches to over 78 inches of annual rainfall, with an average of around 45 inches. Monthly rainfall in all the watersheds is nearly uniform, although it can vary significantly from year to year. Summer precipitation generally comes in high-intensity thunderstorms. For more information, please see the precipitation spreadsheet available through the DCR website: http://www.mass.gov/eea/agencies/dcr/water-res-protection/water-data-tracking/rainfall-program.html. (Quinapoxet and Stillwater gauge data available from USGS: https://waterdata.usgs.gov/ma/nwis/current/?type=precip&group_key=basin_cd.)

TABLE 3-4. PRECIPITATION DATA FOR CENTRAL MASSACHUSETTS

Rain Gauge Station	Years with Data	Annual Precipitation (inches, for years with complete records)		
		Low	High	Average
Belchertown	1940-2014	29.7	65.4	46.4
Athol	1912-2014	29.9	61.9	43.1
Barre Falls	1985-2014	36.3	60.8	46.9
Princeton	1984-2014	45.7	78.1	56.3
West Boylston	1945-2014	26.3	66.7	48.8
Marlboro	1900-2014	26.8	62.2	43.2
Quin./Stillwater	2000-2016	31.1	61.6	43.7

Annual potential evapotranspiration in central Massachusetts has been estimated between 22 and 28 inches (Thornthwaite et al., 1958). While evaporation measured with an evaporation pan is about 39 inches in Massachusetts (Higgins, 1968), evaporation from the surface of lakes and reservoirs is usually lower. Annual evaporation from the surface of the Wachusett and Quabbin

Reservoirs has been estimated as 22 inches (Brackley and Hansen, 1977), and more recently, as 24.5 inches (Camp Dresser & McKee and FTN, 1995). See Section 4.2.5 for a discussion regarding future precipitation amounts and patterns under current climate change prediction models, and suggested forest management adaptation strategies.

The hydrology of the watersheds is strongly influenced by the amount of forest cover, which can have both positive and negative effects on water yield. Net water yield (the amount of liquid water discharging from a defined basin over a given period of time) is the result of precipitation less evapotranspiration, interception, soil moisture and ground-water storage change. Watershed studies show that evapotranspiration losses from forests are significant, but highly variable, with water yield increases occurring when part or all of a forest cover is removed or replaced by herbaceous vegetation. The most significant yield differences among forest covers are between conifers and deciduous trees. In general, forest canopy interception and evapotranspirational losses are greater for conifers than for deciduous species, although this varies with stocking and with storm characteristics (deciduous forests average 13% overall interception losses, while coniferous forests average 28% (Dunne and Leopold, 1978)). The creation and maintenance of open land generally reduces interception and evapotranspiration losses and can result in a significant increase in yield.

3.2.4 Streams and Wetlands

Streamflow in the watersheds, as in most of New England, changes significantly by season. Flows tend to be highest in the spring, due to snowmelt and high groundwater; and lower in the summer and early fall. These seasonal changes are important since high-flow water quality threats (streambank erosion) tend to occur in the spring, whereas low-flow water quality threats due to lower dilution (higher bacteria levels) tend to occur in the summer and early fall. There are many perennial and intermittent streams in the four watersheds (Table 3-5). In addition, a variety of small and large ponds can be found in each watershed. In some cases, DWSP controls part or all of the entire shoreline, while some are owned by other agencies or municipalities and the rest are privately owned.

TABLE 3-5. SUMMARY OF WATER RESOURCES IN DWSP WATERSHEDS

Water Resource	Quabbin	Ware River	Wachusett	Sudbury/Foss
Watershed (acres, excluding Reservoir)	95,466	61,737	70,678	16,350
Reservoir (acres)	24,469	N/A	4,122	1,432
DEP Mapped streams (miles in watershed)	197	159	289	50
Wetlands (acres in watershed)	5,750	6,547	5,557	1,564
Wetlands (acres owned by DWSP)	2,694	3,281	1,764	502
Open Water (non-Reservoir acres)	592	1,854	1,654	94
Open Water (non-Reservoir acres owned by DWSP)	125	562	375	62

Source: MassGIS and DWSP (2015)

3.3 Forest History and Conditions

3.3.1 Regional Land Use and Disturbance History

The current New England forest carries the imprint of changes ranging from major climatic shifts thousands of years ago to the abandonment (and successional reclamation) of agricultural land within the past 150 years. See earlier watershed Land Management Plans for a description of the evolution of post-glacial forests and environmental conditions, pre-Contact human land use and disturbance patterns, the effects of European colonial settlement, reforestation following agricultural abandonment, and recent historical biotic (gypsy moth, chestnut blight) and abiotic (hurricane of 1938) disturbances that have affected DWSP forests.

3.3.2 Watershed Forest Histories

Each watershed's forest history has been well documented in prior Land Management Plans, and reference may be made to those plans for further detail. Highlights are summarized in the following sections.

Quabbin Reservoir Forest History

Land was taken for the creation of Quabbin beginning in 1928, and shortly thereafter tree planting was undertaken on much of the open land. Fires, floods, and a major hurricane had great influence over the early forests that developed on these lands. In the 1930s, over 8 million pines were planted on 6,760 acres; some of these plantations were thinned in the 1960s and 1970s, but most stagnated through overcrowding. Several hundred acres of these were cleared and converted to fields in the 1980s as a measure to enhance water yields following years of drought concerns. Naturally grown timber has been harvested on Quabbin lands since the late 1940s, at first to generate revenue and lumber needed for the MDC itself. Eventually silvicultural efforts shifted towards thinnings to improve the vigor of residual trees. During the 1980s efforts were directed more towards regeneration establishment using group selection and irregular shelterwood silviculture. Some even-age silviculture was done, mainly with the start of the conversion of red pine and spruce plantations. Most recently emphasis has been redirected towards regeneration release harvesting, including the conversion of remaining conifer plantations to more natural conditions.

Since management of the forest resource began in the 1960s, foresters have conducted a total of nearly 1,100 harvest operations covering an average of about 1,000 acres each year.

Ware River Watershed Forest History

The majority of the present DWSP holdings on the Ware River watershed were purchased between 1927 and 1940, at which time land use/cover in the area was a combination of active agricultural land, abandoned fields, and forests. The removal of most structures from the purchased land was completed by 1932, and the labor force was directed to plant the open agricultural lands to softwood species. Approximately 1,700 acres were planted to white, red,

and Scotch pine, Norway and white spruce, and European larch between 1931 and 1945. The major portion of this acreage was planted with red pine, with lesser amounts of the other species or species combinations.

The first harvest operations conducted on DWSP-controlled lands were salvage operations of timber damaged by the hurricane of 1938. From field observations, this salvage work was extensive, but only a portion of the vast amount of damaged timber was removed. Following these salvage harvests, the first silvicultural operations began in the late 1950s. Low thinnings were conducted in a number of red pine plantations to improve growth and quality. Management activities gradually intensified, with an emphasis on the removal of low-quality, second-growth white pine stands. These harvests did not produce large amounts of revenue, but the improved vigor, increased oak component, and greater age and species diversity have collectively made the watershed forest more resilient and resistant to natural disturbances.

Ware River silviculture has generally stood out from the other watersheds in recent decades for the more extensive use of even-aged harvesting methods to accomplish regeneration goals. These larger patches (averaging 5 acres) have allowed DWSP to meet additional secondary goals for enhancing biological diversity through the development of early successional forested habitat. .

Wachusett Reservoir Forest History

The history of forest management at Wachusett is fairly similar to that of Quabbin, except that it began about 30 years earlier and on a much smaller land base. Only about 4,000 acres of land outside the reservoir were initially taken for protection, and pine plantations were established on a little more than 1,000 acres. A full description of plantation history can be read in the *Wachusett Reservoir Land Management Plan, 2001-2010*.

Most of the DWSP owned forest at Wachusett today grows on lands purchased since the mid-1980s. (See Section 4.1.2) The forestry history of these newer lands varied at the time of acquisition from completely unmanaged to heavily cut over. Since active harvesting silviculture re-started in 1979, foresters have conducted over 250 regular operations, covering over 8,300 acres, that have included cordwood thinnings, plantation removals, and regeneration harvests. In addition, a number of salvage operations following large wind events, fires, and insect infestations have occurred on a total of 472 acres.

Sudbury Reservoir Forest History

Much of the current Sudbury forest originates primarily from plantation establishment from 1907 to 1947. Approximately 1.75 million seedlings were planted, the majority between 1913 and 1921. The balance of the Sudbury forest is the result of farm abandonment following the takings of the land prior to reservoir construction, and stands replaced following the 1938 hurricane. Few acres were recruited to new age classes in the mid-20th century. The largest modern stand

origin events are Hurricane Gloria in 1985 (38 acres) and Timber Sale #1 at Walnut Hill in 1988 (75 acres of plantation removed). See Figure 3.7 in Section 3.4.1.5.

There have been 32 silvicultural operations completed on DWSP property in the Sudbury watershed from 1984 through 2014. Salvage operations accounted for eight of these operations and occurred on 49 acres. These operations were performed to clean up damaged trees following Hurricanes Gloria and Bob and dead and dying trees resulting from gypsy moth defoliation and subsequent diseases. The remaining 24 silvicultural operations occurred on 678 acres and included thinnings, removal of diseased and declining plantation overstory trees, and regeneration cuts of varying size to encourage tree regeneration and forest diversity.

3.4 Current Forest Conditions

3.4.1 Assessing Forest Conditions

Continuous Forest Inventory at Quabbin

A detailed description of the history of Continuous Forest Inventory (CFI; also see Section 4.2.4) measurements on DWSP lands in the Quabbin watershed can be found in the Quabbin Reservoir Land Management Plan, 2007-2017. In summary, the CFI plot system in use here is a pared down version of the USDA Forest Service design, with the intent to periodically gather updated information on the current condition of the forest sufficient to guide managers toward the improvement of forest assets on the watershed, ultimately to help better protect water quality. The objectives include an assessment of the current vegetative cover against an ideal composition and structure, and the calculation of sustainable periodic yields that might be attained in the process of managing toward that ideal. This system of 1/5-acre plots, permanently located with stakes on a 1/2-mile grid (one plot per 160 acres) has been re-measured at least every ten years since 1960, producing a valuable, unique record of the growth and change in a large, contiguous, actively managed forest in central New England.

Full details of the 1960 CFI measurement are included in Fred Hunt's Master's thesis at the University of Massachusetts. It is important to note that CFI plots are not spared during forest management activities; they are treated according to the prescription for the surrounding stand, and thus can help track harvesting rates to some extent. The Quabbin CFI plots were re-measured in 1965, 1970, 1980, 1990, 2000, 2010, and partially re-measured in 1995. The variables measured from year to year have changed somewhat, but all trees greater than 5.5" in diameter at breast height (DBH) on all plots have been measured since 1965. Diameter at breast height (DBH) and some measurement of height and vigor have been recorded consistently, and subplots to measure seedlings and saplings have been added in recent years. As a water supply management agency, DWSP's priority for information from CFI has focused on changes in species composition and size- or age-class distribution, but the data also allow calculations of growth in volume and value.

As technology has changed over time, the collection and analysis of this data has undergone many transitions. Carefully stacked, laboriously prepared punch cards being fed into a reader on a mainframe at the University of Massachusetts have been replaced with field data collectors and powerful desktop relational databases. Old data are slowly being checked and converted into these new formats, and over the course of this plan period a new and more complete analysis for the entire dataset will be possible.

Continuous Forest Inventory at Ware River

The history and purpose of CFI on DWSP lands in the Ware River watershed parallels that of Quabbin, and was initiated at nearly the same time. CFI plots were established throughout DWSP lands on the Ware River watershed in 1962, and were re-measured in 1967, 1979, 1989, 1999, and 2009. Like Quabbin, new plots have been added as land is acquired, and plots that have been converted to treeless wetlands have been abandoned (although old data have been saved).

A partial analysis of the 1999 and prior datasets was included in the 2003 Ware River LMP, and a more complete analysis will be completed during this plan period, as old data are located and added to a current database, and long-term growth and mortality can be better assessed.

Inventory Methods at Wachusett and Sudbury

Permanent CFI plots were not established on either the Wachusett or Sudbury forest lands, and thus no data exists to document the growth and changes in those earlier forests until the first 'snapshot' inventories were completed in the 1980s. Reference may be made to the individual land management plans for Wachusett and Sudbury Reservoirs for details and results from those inventories. Briefly, plots were systematically taken (but not permanently monumented) at the rate of about 1 plot for every 5 acres, and stratified by cover type; live trees were counted on a variable-radius plot using a 10-BAF prism, and merchantable heights of each stem were estimated; and saplings down to 1" were counted in a fixed-radius 1/100th acre plot.

The results from these inventories are presented in the previous plans, with the most recent plots at Sudbury taken in 1989 and at Wachusett in 1997.

Cover Type Mapping: GIS, Aerial Photographs, and LiDAR

Table 3-6 was derived from various mapping efforts at each watershed. For decades prior to the year 2000, these cover type acreages would have been painstakingly estimated and tallied by hand from paper maps. Since the late 1990s, all land boundaries and cover types have been digitized either by scanning large-format hand-drawn plans or by careful on-screen editing by foresters at their desktops. DWSP staff utilize ESRI's ArcMap desktop Geographic Information System (GIS) software for creating, maintaining, and analyzing all mapped information. DWSP has been able to utilize a periodically updated series of increasingly higher resolution statewide color orthophoto maps to aid in refining the mapping of stand boundaries and other features such as roads, streams, and stone walls.

TABLE 3-6. COVER TYPES BY WATERSHED

Cover type	Description	Total Acres (and %) by Watershed			
		Sudbury	Wachusett	Ware River	Quabbin
Forested Cover Types					
White pine	Eastern white pine is pure or predominant. Generally moist sandy loam soils.	368	1,122	674	6,518
		15%	6%	3%	11%
White pine / Hemlock	Eastern white pine and eastern hemlock and a large assortment of hardwoods. Pine usually dominates.	0	30	4,219	2,586
		0%	< 1%	18%	4%
White pine / Hardwood	Eastern white pine, northern red oak, and other hardwoods predominate with red maple as the chief associate. Tends to develop into White pine/hemlock.	123	2,252	6,729	7,901
		5%	13%	29%	14%
White pine / Oak	Eastern white pine and northern red oak or black oaks predominate. Type has some chestnut oak but usually black, red, or scarlet oaks plus assorted other hardwoods.	197	2,415	1,428	3,770
		8%	14%	6%	6%
White pine / pitch pine	Past history of fire on dry, sandy soils has established a pitch pine component in this otherwise predominantly white pine type.	n/a	n/a	35	9
		-	-	< 1%	< 1%
Hemlock	Eastern hemlock is pure or predominant over many other associates.	0	0	2	1,654
		0%	0%	< 1%	3%
Hemlock / hardwood	Hemlock and yellow birch dominate, with sugar maple, beech, and red oak as associates. Moist sites.	0	124	146	2,922
		0%	1%	< 1%	5%
Norway spruce	Planted Norway spruce	32	34	147	-
		1%	< 1%	< 1%	< 1%
Red / white spruce	Plantations of red and/or white spruce with associated minor component of yellow birch, sugar and/or red maple, and beech	n/a	n/a	49	79
		-	-	< 1%	< 1%
Larch (tamarack)	Planted larch is pure or predominant. Moist sites.	0	0	8	5
		0%	0%	< 1%	< 1%

Cover type	Description	Total Acres (and %) by Watershed			
		Sudbury	Wachusett	Ware River	Quabbin
Red pine	Although able to reproduce naturally, most of this type was planted, sometimes in alternating rows with white pine.	49	126	314	1,550
		2%	< 1%	1%	3%
Northern red oak	Northern red oak is predominant with other oaks as chief associates.	54	1,158	221	6,907
		2%	6%	1%	12%
Oak / hardwood	Oaks and hickories dominate stands containing red, white, black, and scarlet oak and other associated hardwoods. Sites are usually moderately well-drained, with average soil depths. Usually not ridgetops.	84	1,191	4,023	8,673
		3%	7%	17%	15%
Oak, mixed: dry site	Black and white oaks predominate, although red oak is present, along with red maple and birches. These are frequently poor sites with thin, excessively drained soils, found toward the tops of ridges.	116	1,973	737	7,005
		5%	11%	3%	12%
Wooded wet – deciduous	Forested wetlands dominated by red maple with a large number of other associated species.	493	1,535	789	732
		20%	9%	3%	1%
Black birch/red maple/cherry	Black birch and red maple predominate. Generally a pioneer, early-successional type.	221	2,008	7	1,617
		9%	11%	< 1%	3%
Poplar/grey birch	Also a pioneer type, with paper birch, pin cherry, and red maple as common associates.	n/a	n/a	147	225
		-	-	< 1%	< 1%
Northern hardwoods	Moist, rich sites dominated by white ash, sugar maple, yellow birch.	8	132	53	1,973
		< 1%	1%	< 1%	3%
Wooded wet – coniferous	Wetlands with a coniferous overstory.	14	84	604	188
		< 1%	< 1%	3%	< 1%
Wooded wet – mixed	Wetlands with a mixed conifer/deciduous overstory.	43	461	580	418
		2%	2%	2%	1%
Red maple	Red maple dominates; hardwood associates include oaks and birches.	119	357	85	1,028
		5%	2%	< 1%	2%

Cover type	Description	Total Acres (and %) by Watershed			
		Sudbury	Wachusett	Ware River	Quabbin
Non-Forested Non-Administrative Types					
Abandoned orchard	Planted fruit trees which persist despite competition, or have been retained by management.	n/a	n/a/	73	8
		-	-	< 1%	< 1%
Grasses/herb cover	Land which is maintained in grasses or herbaceous cover but not associated with administrative areas.	0	604	210	311
		0%	3%	1%	1%
Upland brush	Recently abandoned fields in a wide mix of tree, shrub, and herbaceous cover.	45	390	320	111
		2%	2%	1%	< 1%
Non-Forested Wetland Types					
Marsh	Soil is saturated and often covered with six inches to as much as three feet of standing water during the growing season. Wetland and aquatic vegetation may include sedges, cattails, pickerelweed, water lilies, or duckweed.	n/a	n/a	80	257
		-	-	< 1%	< 1%
Shrub swamp	Soil saturated during growing season. Common woody species include alder, buttonbush, dogwood, willow. Tussock sedges also common.	113	494	259	459
		5%	3%	1%	1%
Bog	Typically acid, peaty, saturated soil with characteristic mat of sphagnum. Black spruce, tamarack, red maple may be present. Also heath shrubs, cranberries, pitcher plants, sedges.	n/a	n/a	32	75
		-	-	< 1%	< 1%
Beaver meadow	Conditions may resemble other type classes, but originated by beaver.	n/a	n/a	1,049	883
		-	-	4%	2%
Pond, open water	Open water not part of a Reservoir	92	403	332	
		4%	2%	1%	
Administrative Types					
Power line	Power line on poles or buried telephone or pipe lines.	46	208	100	289
		2%	1%	< 1%	< 1%
Administration areas	Structures, parking areas, boat launch areas, others.	118	563	12	154
		5%	3%	< 1%	< 1%

Cover type	Description	Total Acres (and %) by Watershed			
		Sudbury	Wachusett	Ware River	Quabbin
Lawns, ornamental plantings	Areas around administrative buildings, within Quabbin Park, on and adjacent to dams and dikes that are dominated by mowed grass and ornamental plantings.	94	21	0	88
		4%	< 1%	0	< 1%
Gravel pit	Areas from which gravel is currently or has been historically extracted and are not currently forested.	0	28	74	17
		0%	< 1%	< 1%	< 1%
Totals					
Forested total		1,921	15,002	20,994	55,760
		79%	85%	89%	95%
Non-Forested Non-administrative total		45	994	603	430
		2%	5%	3%	1%
Non-forested Wetland total		113	494	1,420	1,674
		5%	3%	6%	3%
Open Water (non-Reservoir) total		92	403	332	
		4%	2%	1%	
Administrative total		258	820	186	548
		10%	5%	< 1%	1%
Grand Total		**2,429**	**17,713**	**23,535**	**58,412**

Future mapping will undoubtedly be further enhanced through the use of LiDAR (Light Detection and Ranging) technology, which measures minute differences in return times of laser pulses emitted from an aerial (i.e., manned or unmanned aircraft) platform to calculate very precise ground elevations as well as the locations/heights of above-ground features like tree canopies and stone walls. As of this writing, LiDAR data exist for most of DWSP properties. DWSP will try and acquire newer and more detailed LiDAR data for watershed properties to aid in land management tracking.

Carbon Sequestration

Forested ecosystems play a significant role in limiting carbon dioxide in the earth's atmosphere through sequestration. Approximately 75% of the earth's biomass is contained in forests, and in Massachusetts, vegetation (forested and non-forested) sequesters about 8% of the carbon emitted by humans each year (Commonwealth of Massachusetts, 2004). DWSP properties are primarily forested, and CFI data indicate that most of our forests are mature and relatively healthy. Perhaps equally important in terms of carbon storage in the watershed region is DWSP's active

land protection program which has prevented thousands of forested acres from conversion to development.

Carbon stocking calculations for DWSP properties will be prepared once analysis of CFI data from the Ware River and Quabbin has been completed. For the purpose of providing a rough estimate for this plan, a simpler approach to estimating carbon stocks was done using COLE (Carbon On Line Estimator), developed by the USDA Forest Service. COLE calculations are based on USDA Forest Service Inventory and Analysis and Resource Planning Assessment data, which can be selected on a state, county, or 20-km plot radius. For this example, the estimates of carbon stocks by forest type generated by COLE for a 20-km plot radius centered on Quabbin Reservation are shown in Table 3-7. With updated data from 50 years of CFI, DWSP will be able to present biomass and carbon stocking changes as the forests have aged and been actively managed.

TABLE 3-7. CARBON STOCKS BY FOREST TYPE FOR STATE LAND WITHIN A 20KM QUABBIN CENTERED PLOT

Forest Type	Mean Volume (m^3/ha)	Tons Carbon/acre						
		Live Tree	Dead Tree	Understory	Downed dead wood	Forest Floor	Soil	Total non-soil
WP/RO/WA	91.3	96.9	12.4	10.6	8.4	84.3	166.3	212.3
WO/RO/SH	267	325.9	0	4.4	25.2	25.0	131.2	380.5
RM/Oak	217.3	300.0	5.2	4.4	23.0	23.7	131.2	356.3
SM/BE/YB	198	239.0	2.7	7.7	19.8	72.9	171.7	341.7

3.4.2 Current Forest Conditions – Quabbin

Age Structure

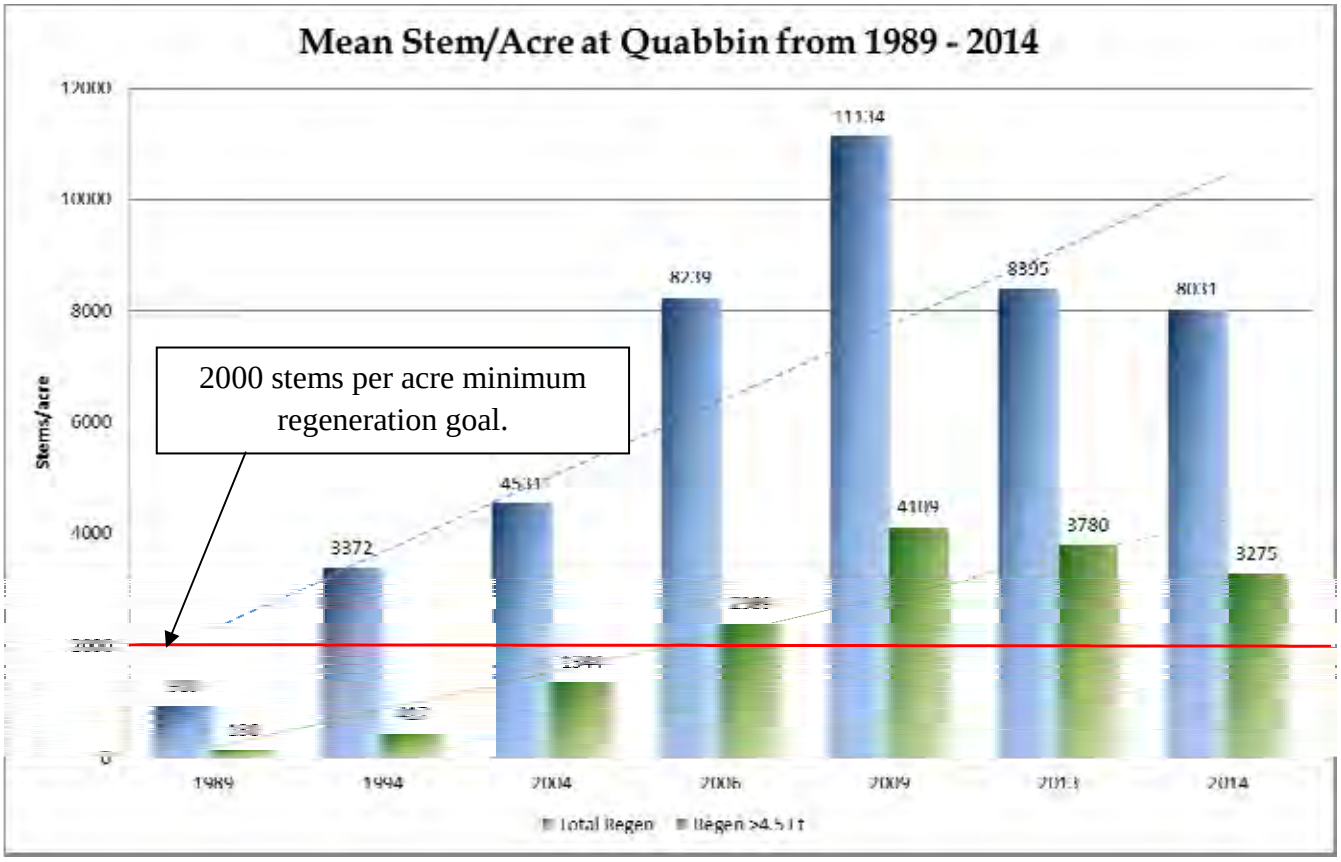
The majority of the current forest on DWSP lands in the Quabbin watershed resulted from forests returning to lands that were cleared for agriculture following European settlement of the region. At the time of the 1938 hurricane, thousands of acres of the oldest of these re-growing pine forests were severely damaged or destroyed, and regenerated to mixed species afterwards. Many more acres were still too young to be severely damaged, and survive today as stands over 100 years old. Plantations dating to the 1940s survive on about 1,600 acres. Acres of young forest created during more recent silvicultural operations are being mapped as they are treated, and at the time of writing amount to 1,721 acres.

Regeneration

DWSP has been monitoring the conditions of tree regeneration in the forest understory at Quabbin intensively since 1989. Initially, the primary purpose was to understand and document the impact of deer overabundance, and then to track the changes that developed in the forest understory as the deer impact control program progressed following the initial hunt in 1991. The deer impact control

program has been very successful in restoring the capability of the forest to regenerate. In the 24 years since the deer impact control program began, regeneration has recovered steadily and dramatically (Figure 3-5). The number of young trees that have surpassed 4.5 feet (the upper height of deer browsing) has increased over 25-fold on areas within Quabbin Reservation where hunting had been prohibited until 1991. Now surveys of openings 3-7 years post-harvest consistently show stem counts well above the 2,000 stems per acre threshold needed for regeneration success.

FIGURE 3-5. REGENERATION SAMPLING RESULTS FROM DWSP LANDS IN THE QUABBIN WATERSHED.



In terms of species diversity, all the expected species are present, but there remain shortfalls in some of the species that are most highly preferred by deer. Black birch and white pine, which are less palatable to deer, continue to be the strongest component of the on-Reservation regeneration response. Table 3-8 compares a brief subset of Quabbin regeneration sampling results from 2004 and 2014, alongside Ware River and Wachusett, showing relative species shifts in abundance and importance for stems greater than 4.5 feet tall. Although these data come from a limited set of selected sites, they suggest that white pine is declining in importance, birch is increasing and oaks are steadily gaining ground.

TABLE 3-8. REGENERATION RESULTS BY WATERSHED

	Regeneration stems/Acre > 4.5' tall			
	Quabbin 2004 (1,344/acre)	Quabbin 2014 (3,275/acre)	Ware 2014 (1,233/acre)	Wachusett 2010 (3,618/acre)
Species	*(transect lines)*	*(sampled regen openings only)*		
Black birch	25%	35%	17%	12%
White pine	44%	28%	20%	28%
Red maple	11%	18%	20%	24%
Oaks	4%	11%	7%	13%

Moose are present on DWSP watershed lands. Because little is known about the potential impacts of moose on forest ecosystems in southern New England, DWSP will continue to monitor moose populations over time and gather as much information as possible. See Section 4.4.2 for a more complete discussion of moose.

3.4.3 Current Forest Conditions – Ware River

The current forests on DWSP lands on the Ware River watershed are made up of a range of low to high quality stands, both managed and unmanaged, with an abundance of forest regeneration. A large portion of the upland forest occurs on dry outwash and dry washed till soils, which are less productive than moist till soils, but also support logging equipment better for a longer portion of the year. Some of the most productive sites are still occupied by low-quality stands that developed after pasture and tilled land was abandoned.

Age Structure

Nearly all of the uplands controlled by the DWSP on the Ware River watershed are forested (99%), with the remainder in field. Ninety-four percent of the forest is more than seventy years old, and sixty percent is over ninety years old. A small portion of the forest area is comprised of the remainders of plantations of white, red, and Scotch pine, Norway and white spruce, and European larch, established in the 1930s and 1940s. Most of these plantation areas have now been either converted to open fields or regenerated to natural stands. The remaining mature forest originated from past land use and natural disturbance. The largest portion of the forest

originated from agricultural lands abandoned in the late 1800s and early 1900s. These developed as under-stocked white pine stands ("old field white pine") that matured into low quality mixtures of pine and hardwood. Past land use has resulted in mostly even-aged stands, but in some areas there are remnants of trees that were present in the original pasture and/or trees that regenerated following the 1938 hurricane, giving them a two-aged or multi-aged structure.

Regeneration

Ware River areas regenerated through silviculture contain more diverse species mixtures than the stands they replaced. Compositional variation in regenerated areas is determined by many factors, including site, seed sources, harvest timing, advance regeneration, herbivores, and opening size. Most regeneration on DWSP properties at Ware River includes more hardwood than the stand that was regenerated (frequently either plantation or old-field white pine), and shade-intolerant species such as gray birch and poplar are common where light levels are high. There are also exceptional examples of red oak regeneration.

Since 2008, foresters have conducted annual regeneration sampling similar to that at Quabbin (see Figure 3-5). The Ware River has been continuously hunted; the chart demonstrates that regeneration numbers have consistently met DWSP goals on these lands.

3.4.4 Current Forest Conditions – Wachusett

Age Structure

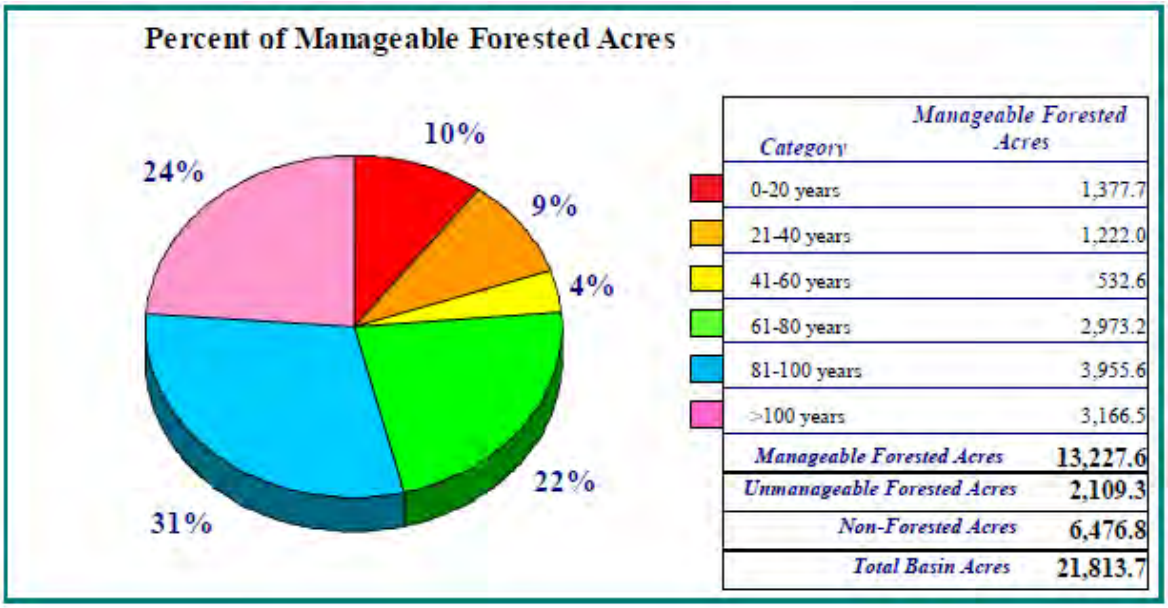
In the 2001 Wachusett LMP, the foresters inferred age structure from a height-class designation in the forest cover type coding being used, often rather loosely and inaccurately. In order to fully manage the forest structure by age class, it became clear that DWSP foresters needed to understand the existing age structure of the entire forest as well as continue to document changes made through silviculture. Plantations were well-documented, but beyond the plantations, forests had been subject to natural development and disturbance patterns. More recently, large acreages of new lands have been added to DWSP ownership without any documentation of land use history. A major investigation was launched to piece together the complete picture of the age structure of the entire Wachusett forest.

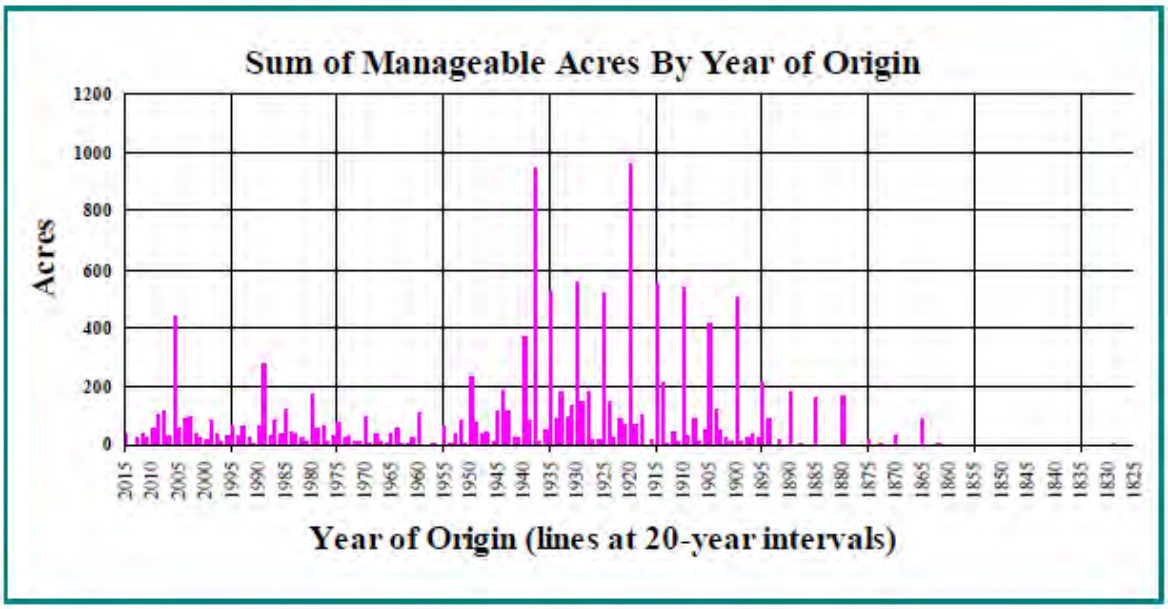
Over the course of two years, DWSP foresters visited every mapped stand, no matter how small, to assess its year of origin. In some cases, evidence of the 1938 hurricane was clear enough to set that year as the origin. In others, increment borers were used to extract cores from several trees; rings were counted in the field or with help from dyes back in the lab, and a date of origin was inferred. This date was often an average of a range of ring counts in a stand that may have taken a couple of decades to regenerate and fill in. This process of stand reconstruction is now standard procedure as new forested lands are added to DWSP ownership at Wachusett.

To analyze the age structure, the year of origin for each stand is entered in the table for the GIS cover-type polygon layer. A master table is then created by intersecting cover types, sub-basins,

soils, unmanageable lands, and working unit layers in ArcView. DWSP foresters developed a database that uses this table to summarize age structure, cover types, and soils at the Working Unit, sub-basin, and watershed levels. Results for age diversity over the entire Wachusett ownership are shown in Figure 3-6.

FIGURE 3-6. AGE STRUCTURE SUMMARY FOR WACHUSETT WATERSHED





Regeneration

During the summer and fall of 2010, Wachusett foresters carried out the first systematic survey of the tree regeneration in the silvicultural openings that had been created during the period of the 2001-2010 Wachusett Reservoir Land Management Plan. Seventy-one of the 642 openings created during this time frame were sampled using a system of randomly distributed sample plots within each opening. The openings were stratified by age (years since harvest) and acreage category. In addition to tree regeneration information, data was collected relating to invasive species, native interfering shrubs and green tree retention.

One DWSP objective is to release adequate advance regeneration and to protect as much of this regeneration as possible from damage during harvesting operations. The "adequacy" of regeneration is ultimately dependent on a variety of site conditions. DWSP has defined adequate regeneration as the presence of at least 2,000 stems per acre greater than 4.5 feet tall and of a diverse mixture of species appropriate to the site within 3-7 years following a disturbance (QLMP, p.144). Regeneration studies at Quabbin also discussed the importance of regeneration distribution via frequency analysis of its occurrence on milacre plots. The results of the Wachusett regeneration survey show that regeneration is fully adequate by these standards in the openings that have been created during the past decade (Table 3-9).

TABLE 3-9. WACHUSETT RESERVOIR 2010 REGENERATION SURVEY, SUMMARY RESULTS

Size Categories	1 ft. – 4.5 ft tall	4.5 ft tall – 5.5 inches diameter	All Stems
Grouped by Opening Size (*stems/acre)*			
< 0.5 acres	3,766	3,228	6,994
0.5 – 1.0 acres	3,595	3,091	6,687
1.0 – 1.5 acres	4,565	2,926	7,491
1.5 – 2.0 acres	4,916	4,619	9,535
> 2.0 acres	3,991	2,883	6,874
Grouped by Opening Age (*stems/acre)*			
1 – 2 years	5,203	1,091	6,294
3 – 5 years	5,256	4,096	9,355
6 – 9 years	3,447	5,358	8,804
Overall (*stems/acre)*			
	4,750	3,618	8,188

Twenty-seven tree species were encountered in the 809 mil-acre plots with four species comprising over 76% of all stems counted (i.e., white pine, red maple, red oak and black birch) (Table 3-10).

TABLE 3-10. TREE SPECIES DISTRIBUTION IN 2010 WACHUSETT REGENERATION SURVEY

Common Name	% of Stems Counted	Common Name	% of Stems Counted
White Pine	27.7	Yellow Birch	0.4
Red Maple	24.4	American Beech	0.4
Red Oak	12.7	American Elm	0.3
Black Birch	11.7	Blackgum	0.2
White Oak	4.8	Hickory	0.2
Gray Birch	4.1	White Ash	0.2
Black Oak	3.5	Red Pine	0.1
Black Cherry	2.9	Eastern Hemlock	0.1
Paper Birch	1.9	Striped Maple	0.1
Sassafras	1.1	Norway Maple	< 0.1
Sugar Maple	1.1	Eastern Hophornbeam	< 0.1
American Chestnut	1.0	Chestnut Oak	< 0.1
Pin Cherry	0.7	Ailanthus	< 0.1
Quaking Aspen	0.4		

3.4.5 Current Forest Conditions – Sudbury

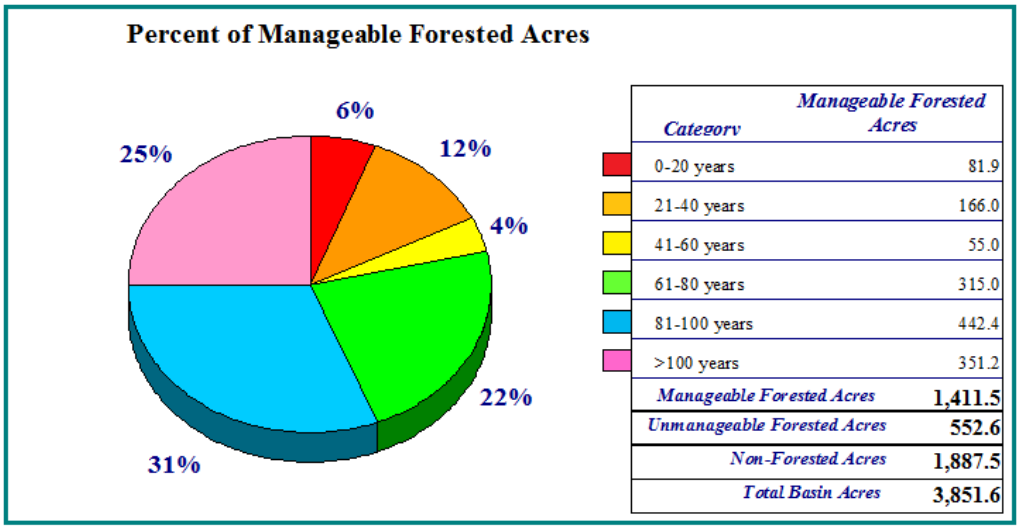
Age Structure

Reference may be made to the *Land Management Plan for the Watersheds of the Sudbury Reservoirs: 2005-2014* for a discussion of species composition and stocking levels based on an earlier inventory. No subsequent timber inventory has occurred. However, stemming from a more recent focus on age structure diversity at both Sudbury and Wachusett, DWSP foresters recently assessed the year of origin for all stands, and the results are shown in Figure 3-7. The era of plantation establishment from about 1910 to 1940 is clearly seen in the histogram at the bottom. Note also the spike in 1988, explained by the large strip removals at the pine plantation on Walnut Hill. Even including that cut, only 18% (248 acres) of the manageable forest has been regenerated in the last 40 years, which is only about half the rate that in general DWSP would prefer to achieve.

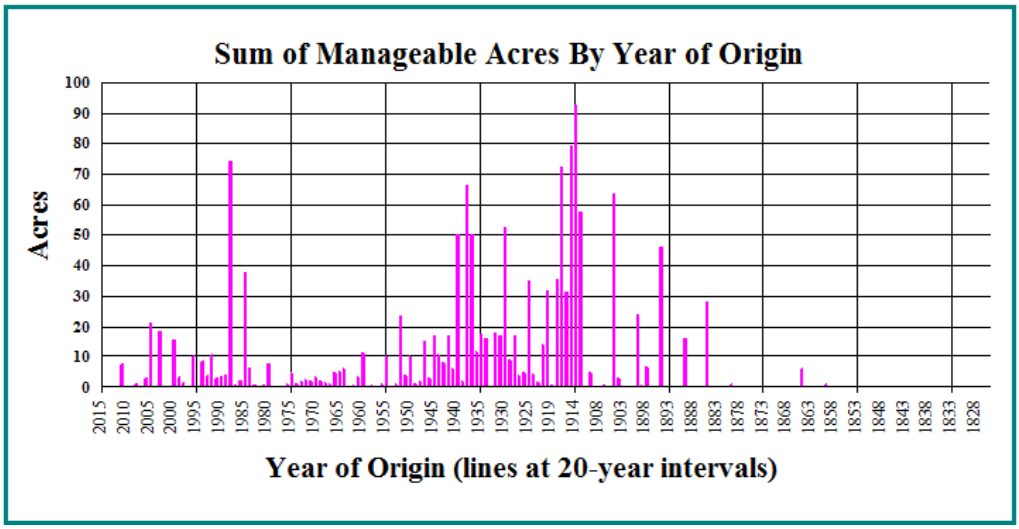
Regeneration

No systematic regeneration surveys have been undertaken at Sudbury, mainly because regeneration is generally abundant and diverse in silvicultural openings created during this previous management period. However, there are significant areas where regenerating the forest may not be achievable without invasive plant control. Most notable is the Stony Brook compartment at the south end of the reservoir, where on some of the moister soils support spruce plantations and failing stands of white ash, while a mix of Oriental bittersweet, winged euonymus, non-native honeysuckle, and garlic mustard comprise almost the entire understory.

FIGURE 3-7. AGE STRUCTURE SUMMARY FOR SUDBURY WATERSHED



Category	Manageable Forested Acres
0-20 years	81.9
21-40 years	166.0
41-60 years	55.0
61-80 years	315.0
81-100 years	442.4
>100 years	351.2
Manageable Forested Acres	1,411.5
Unmanageable Forested Acres	552.6
Non-Forested Acres	1,887.5
Total Basin Acres	3,851.6



3.5 Wildlife Conditions

3.5.1 Overview of Wildlife Community

The type and extent of available habitats drive the wildlife community in any particular area. Specific wildlife species each have unique habitat requirements. Watershed lands represent a mosaic of habitat types and conditions. DWSP-owned land within the watershed system is primarily forested, while privately owned lands are comprised of small farms, woodlots, residential areas, and industrial or commercial areas. This patchwork of habitats is both a benefit and detriment to

Fringed polygala, *Polygala paucifolia*

wildlife species. Greater species richness may exist because of the diversity of habitats. However, the fragmented nature of the watersheds makes it more difficult for animal species to travel and interact, and in some cases, the different habitat areas may be too small to support individual animals or breeding populations. However, the undeveloped and relatively contiguous DWSP-owned lands within the fragmented watersheds provide a tremendous benefit to all wildlife species.

Overall, DWSP-owned lands support an abundance of wildlife species. Wachusett and Quabbin Reservoirs support many water-based species (common loons, spotted sandpipers, bald eagles), and the many streams, lakes, and beaver ponds within the watersheds host a variety of birds, amphibians, and reptiles. DWSP forests provide habitat for a diversity of birds and mammals including white-tailed deer, turkey, grouse, raccoons, bobcat, and fisher. In addition, songbirds, including black and white warblers, black-throated green warblers, and scarlet tanagers utilize DWSP forests for breeding and migratory rest stops. Probably the most important feature of DWSP-owned land is that it is permanently protected from development. As urban and suburban areas continue to sprawl, there remain fewer and fewer acres of non-developed land. The protection DWSP lands provide to wildlife species is critical to their long-term survival.

Although a majority of DWSP-owned lands in the watersheds are forested, there are also several large tracts of early successional habitat. These grassy or shrubby areas provide critical habitat for species dependent on open habitat, including various insects, rabbits, and birds such as eastern meadowlarks, bobolinks, and a variety of sparrows.

DWSP conducts surveys to monitor various species of wildlife in the watersheds. An annual loon productivity survey is done each summer and bald eagles are counted each winter and monitored during the breeding season. In the spring, DWSP Wildlife Biologists sample and verify vernal pools. A long-term monitoring program was established in 2001 that created 30 permanent monitoring plots on DWSP land within the Wachusett watershed. At these plots, DWSP staff document breeding songbirds, small mammal communities, as well as reptiles and amphibians. Additionally Canada geese and beaver are surveyed at each reservoir every year. DWSP also cooperates with other state agencies to conduct research on the watersheds, as well as sampling for fish, waterfowl, and some mammals.

While a great deal of information exists about certain wildlife taxa through information collected from surveys and observations (e.g., birds and mammals), very little is known about other watershed wildlife. A complete species list for DWSP-owned land does not exist, and there is a paucity of information about insects, butterflies, dragonflies, and other less visible species. It is likely that DWSP lands harbor state listed species that have yet to be documented.

3.5.2 Results From Periodic Wildlife Surveys

Annual Prescott Beaver Survey Results

Beaver populations in Massachusetts have undergone dramatic changes. By the mid-1700s beaver were extirpated from the state. They were absent from the landscape for close to 200 years until their gradual return in the early 1920s. Beaver were first observed on the Prescott Peninsula in 1952.

In 1952, 1960, 1966, and 1968 the number of beaver colonies on the Peninsula was noted through anecdotal records and aerial photographs. From 1969 until the present, annual autumn food cache surveys have been conducted.

Annual surveys of the Peninsula are typically conducted during November each year. A complete shoreline survey is conducted by boat. In addition, all streams, ponds, and other potential habitats on the interior are walked. Active sites are determined by the presence of a food cache and other activity. Active sites are noted, and coordinates are recorded.

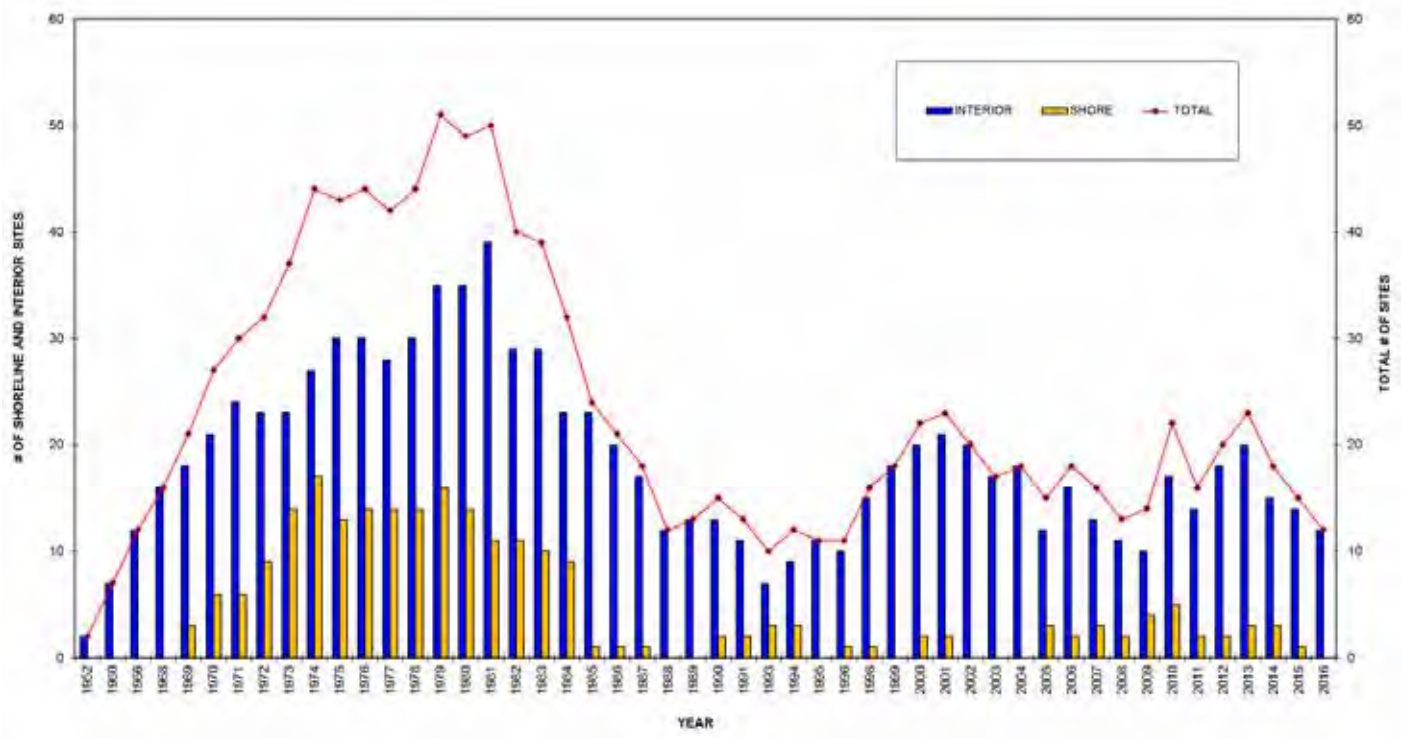
Beaver populations on Prescott Peninsula experienced six phases of growth and decline (Figure 3-8). From 1952 until approximately 1966, beaver populations on the Peninsula increased gradually. The number of colonies grew from two to twelve. From 1967 until 1974, beaver populations entered their second phase which was characterized by a rapid increase in population. In only seven years, beaver colonies increased from 12 to 44 colonies.

Between 1975 and 1982, the population was in its third phase, characterized by high densities with some year to year fluctuation. The fourth phase of the population took place during 1983 to 1988. During this period, the number of beaver colonies decreased dramatically, from a high of 44 to a low of 12. Contributing to this overall decline was a reduction in the number of shoreline colonies. In 1983, there were 10 shoreline colonies, in 1987 there was only one and by 1988 there were no shoreline colonies present.

The fifth phase of the population lasted between 1988 and 1996. This phase is distinguished by relatively stable populations at low levels. The number of colonies during this period ranged between 10 and 15. In addition, this period had very few shoreline colonies.

The beaver population is currently in its sixth phase which has lasted since 1997. During this phase, populations increased slightly to a high of 23 in 2001. Since 2001, populations have fluctuated around 20 colonies, from a low of 12 in 2016 to a high of 23 in 2013. As in phase 5, the number of shoreline colonies in phase 6 has remained relatively low.

FIGURE 3-8. NUMBER OF ACTIVE BEAVER COLONIES, PRESCOTT PENINSULA, QUABBIN RESERVATION, 1952-2016



Quabbin Moose Survey

Breeding populations of moose are a relatively recent occurrence in Massachusetts. DWSP estimates that breeding moose first appeared in the Ware River watershed around 1993. It is likely they were also present in the Quabbin Reservoir watershed about the same time. Moose are likely present on the Wachusett watershed, but in much lower densities and are a rare visitor to the Sudbury watershed.

DWSP began a formal moose survey in 2006 during the annual Quabbin Controlled Deer Hunt, and it has continued annually since then. Moose surveys are conducted on the first day of the hunt in each hunt area. Each hunter is given a survey card which is collected at the end of that day as hunters exit the area. Each hunter is asked to keep track of any moose they see, and hunters that see moose are briefly interviewed and moose sightings locations are mapped. Each sighting location is given a reference number that summarizes the sighting information (e.g., number seen, age, sex, and time of observation). To determine which sightings represent individual moose, DSWP staff looked at the time of the sighting and location. For example, if a cow and calf were seen at the top of the Prescott Peninsula at 8:00 am and another cow and calf were seen near the bottom of the Prescott at 8:00 am these two groupings are counted as four individual moose (i.e., two cows and two calves).

Moose estimates ranged from 65-138, with an eight year average of 98 moose on Quabbin Reservation. Using a conservative estimate, moose populations at Quabbin appear relatively stable and are estimated at 0.44 (SE=0.08) moose/km^2. DWSP staff will continue to refine this estimate as more information becomes available.

Common Loons

Nesting common loons returned to Massachusetts in 1975 after being extirpated from the state in the early 1900s. The first nesting pair was located on Quabbin Reservoir, and today 66% (25 of 38 pairs) of all nesting loons in Massachusetts are located on DWSP-owned reservoirs (Quabbin, Wachusett, and Hycrest). DWSP has been actively monitoring and managing loons since 1982. Ten nesting rafts were deployed on Quabbin in 2017 and eight were placed on Wachusett.

DWSP staff spend up to 80 hours each summer identifying and surveying loon pairs to document nesting, identify marked individuals, determine the fate of eggs, and monitor the survival of chicks. In addition, DWSP staff work closely with consultants from Biodiversity Research Institute to capture and band loons each summer. Captured loons are sampled (blood, feather) to determine levels of various contaminants, including mercury and lead. Further, abandoned or flooded eggs are collected and tested for similar contaminants.

A banded loon leaving its nest on Crescent Island, Wachusett Reservoir.

3.6 Biological Diversity

3.6.1 Rare and Uncommon Flora

Plants are considered rare for a variety of reasons. In some cases, it is simply that Massachusetts is currently at the northern limit (e.g., Black maple, *Acer nigrum* or River birch, *Betula nigra*) or the southern limit (e.g., Dwarf rattlesnake plantain, *Goodyera repens* or One-flowered pyrola, *Moneses uniflora*) of their range. For species that are generally associated with the eastern deciduous forest, which dominates central and western Massachusetts, plants may be rare simply because they are poor colonizers and thus populations remain widely scattered and sparse. Loss of habitat is also a common cause of plant species loss. It is estimated that 72% of the species extirpated from the state have been lost due simply to the loss of early successional or recently disturbed habitat (Sorrie, 1989). Thirteen percent of the rare species likely to occur on DWSP properties rely on early successional habitat or disturbance such as fire to persist (Searcy, 1995). Animal populations are responsible for some losses, either through heavy browsing or through dramatic habitat alterations such as those caused by beaver. While beaver wetlands may provide habitat for some rare plants, they also flood bogs and other uncommon habitats that may have contained rare plant populations. Some species (e.g., Ginseng, *Pallax quinquefolius L.*) have declined directly because of over-collecting. Others may remain rare simply because they prefer or are competitive in a very specific and regionally limited habitat type, such as bogs or exposed talus slopes. Invasive, non-native plants have also been implicated in the decline of some uncommon native species, and on at least two sites Natural Resources staff have conducted manual removal of invasive plants.

During 1995 and 1996, DWSP contracted with the University of Massachusetts Herbarium to inventory proposed harvesting areas for the presence of rare plant species. During this inventory, the Herbarium also compiled a general list of all species encountered. Within this list, a small number of rare or uncommon species were encountered. Independent surveys have also documented rare species.

In addition to the rare or uncommon species that have been documented, there are uncommon species that have some likelihood of being found on DWSP lands, were a comprehensive search initiated. These are listed in Table 3-11, and are based on historic records from the herbarium and other sources. Table 3-12 presents the habitat/rare species relationships DWSP has identified working with the University of Massachusetts herbarium.

TABLE 3-11. UNCOMMON PLANTS POTENTIALLY OCCURRING ON DWSP PROPERTIES

Family	Species	Common Name	Status	Flowering
Apiaceae	*Conioselium chinense*	Hemlock Parsley	SC	Jul/Sep
Apiaceae	*Sanicula trifoliata*	Trefoil Sanicle	WL	Jun/Oct
Asclepiadaceae	*Asclepias verticillata*	Linear-leaved Milkweed	T	May/Jul
Asteraceae	*Aster radula*	Rough aster	WL	Jun/Aug
Brassicaceae	*Arabis drummondii*	Drummond's Rock-cress	WL	May/Aug
Brassicaceae	*Arabis missouriensis*	Green rock-cress	T	Jul/Oct
Brassicaceae	*Cardamine bulbosa*	Spring Cress	WL	Jun/Aug
Caryophyllaceae	*Stellaria borealis*	Northern Stitchwort	WL	May/Aug
Cyperaceae	*Eleocharis intermedia*	Intermediate spikerush	T	Aug/Oct
Cyperaceae	*Scirpus ancistrochaetus*	Barbed-bristle bulrush	E	Jun/Jul
Fabaceae	*Lupinus perennis*	Wild Lupine	WL	May/Jul
Gentianaceae	*Gentiana andrewsii*	Andrew's Bottle Gentian	T	Apr/Jun
Gentianaceae	*Gentiana linearis*	Narrow-leaved Gentian	WL	Jun/Aug
Haloragaceae	*Myriophyllum alterniflorum*	Alternate leaved Milfoil	T	Jun/Aug
Juncaceae	*Juncus filiformis*	Thread rush	T	Aug
Lentibulariaceae	*Utricularia minor*	Lesser bladderwort	WL	May/Nov
Liliaceae	*Smilacina trifolia*	Three-leaved Solomon	WL	Apr/Jun
Loranthaceae	*Arceuthobium pusillum*	Dwarf mistletoe	SC	May/Sep
Orchidaceae	*Coeloglossum viride v. bracteata*	Frog orchid	WL	May/Sep
Orchidaceae	*Corallorhiza odontorhiza*	Autumn coralroot	SC	Apr/Jul
Orchidaceae	*Cypripedium calceolus v. parviflorum*	Small Yellow Lady Slipper	E	May/Aug
Orchidaceae	*Cypripedium calceolus v. pubescens*	Large Yellow Lady Slipper	WL	Jun/Sep
Orchidaceae	*Isotria medeoloides*	Small whorled pogonia	E	May/Jul
Orchidaceae	*Isotria verticillata*	Large whorled pogonia	WL[1]	
Orchidaceae	*Platanthera hookeri*	Hooker's Orchid	WL	Mar/Jun
Orchidaceae	*Platanthera macrophylla*	Large leaved Orchis	WL	Apr/Jul
Orchidaceae	*Platanthera. Flava var. herbiola*	Pale Green Orchis	T	Jun/Sep
Orchidaceae	*Triphora trianthophora*	Nodding Pogonia	E	Jul/Sep
Poaceae	*Panicum philadelphicum*	Philadelphia Panic Grass	SC	Jul
Poaceae	*Trisetum pensylvanica*	Swamp Oats	T	Aug/Oct
Poaceae	*Trisetum spicatum*	Spiked False Oats	E	Jul/Sep
Ranunculaceae	*Ranunculus alleghaniensis*	Allegheny buttercup	WL	Jun/Sep
Sparganiaceae	*Sparganium angustifolium*	Narrow-leaved Bur Weed	WL	May/Nov
Urticaceae	*Parietaria pensylvanica*	Pellitory	WL	Aug/Sep
Fabaceae	*Lupinus perennis*	Wild lupine	WL[1]	May/Jun
Viscaceae	*Arceuthobium pusillum*	Eastern dwarf mistletoe	SC[1]	Apr
Juglandaceae	*Juglans cinerea*	Butternut	WL[1]	Apr/May
Araceae	*Orontium aquaticum*	Golden club	E[1]	Apr/May

NOTE: For Status, E = endangered, T = threatened, SC = special concern, WL = watch list; [1] Species documented on DWSP property.

TABLE 3-12. HABITATS IN WHICH RARE SPECIES ARE LIKELY TO BE FOUND

Species	Common name	Comments
Forested Areas		
Rich Mesic Woods		
Acer nigrum	black maple	
Cerastium nutans	nodding chickweed	
Coeloglossum viride v. bracteata	frog orchid	to dry rocky woods
Corallorhiza odontorhiza	autumn coralroot	to dry/seasonally wet streamlets
Cypripedium calceolus v. pubescens	large yellow lady slipper	slopes and talus
Equisetum pratense	horsetail	sandy places
Panax quinquefolius	ginseng	talus and base of ledge areas
Platanthera hookeri	hooker's orchid	often rocky or swampy
Ranunculus alleghaniensis	Allegheny buttercup	rocky
Ribes lacustre	bristly black current	
Sanicula canadensis	Canadian sanicle	
Sanicula gregaria	long-styled sanicle	
Sanicula trifoliata	trefoil sanicle	
Moist Coniferous / Pine Woods		
Goodyera repens	dwarf rattlesnake plantain	pine woods
Moneses uniflora	one-flowered pyrola	moist rich woods
Hemlock-Northern Hardwoods		
Isotria medeoloides	small whorled pogonia	vernally moist areas
Platanthera macrophylla	large-leaved orchis	moist ravines, limey
Rhododendron maximum	rhododendra	hemlock island in swamp
Triphora trianthophora	nodding pogonia	depressions under beech
Viola renifolia	kidney-leaved violet	damp rich woods
Non-forested Habitats		
Boulder/Talus Slope/Ledges		
Adlumia fungosa	climbing fumitory	Shaded limey talus
Amelanchier sanguinea	roundleaf shadbush	Ledges & ridge tops
Arabis drummondii	Drummond's rock-cress	
Arabis missouriensis	green rock-cress	open rock and scree
Chenopodium gigantospermum	maple-leaf goosefoot	shaded dry ledges
Clematis occidentalis	Purple Clematis	exposed ledges & talus
Parietaria pensylvanica	pellitory	shaded shelves
Pinus resinosa	red pine	exposed, rocky ridge tops
Rosa blanda	Smooth rose	dry to mesic rocky slopes
Trisetum spicatum	spiked false oats	Exposed
Sandplain / Open Meadow		
Asclepias verticillata	linear-leaved milkweed	open rocky
Eragrostis capillaris	lace love grass	open sandy soil
Gentiana andrewsii	Andrew's bottle gentian	open/meadow
Liatris scariosa var novae-angliae	New England blazing star	sandy open pine wds.

Species	Common name	Comments
Lupinus perennis	wild lupine	sandy open pine wds.
Paspalum setaceum	Paspalum	sandy soil
Penstemon hirsutus	beard-tongue	dry or rocky ground
Polygala verticillata	whorled milkwort	open woods/old field/stony shores
Aquatic Habitats		
Ponds / Streams		
Species	Common name	Comments
Aster tradescantii	Tradescant's aster	Fields/swamps
Betula nigra	river birch	Swamps & stream banks
Cardamine longii	Long's bitter-cress	Swampy streams
Eleocharis intermedia	intermediate spikerush	Exposed shores
Juncus filiformis	thread rush	Meadows/springs/riverbank
Megalodonta beckii	water marigold	
Myriophyllum alterniflorum	alternate leaved milfoil	
Nuphar pumila	tiny cow-Lily	
Panicum philadelphicum	Philadelphia panic grass	Exposed shores
Scirpus ancistrochaetus	barbed-bristle bulrush	Swales and shores
Sparganium angustifolium	narrow-leaved bur-reed	
Sparganium fluctuans	bur-reed	
Utricularia minor	lesser bladderwort	Seepy stream sides
Utricularia resupinata	bladderwort	Swamps, swales, shores
Seeps/Seepage Areas		
Cardamine bulbosa	spring cress	
Conioselium chinense	hemlock parsley	Black ash seepage swamps
Cypripedium calceolus v. parviflorum	small yellow lady slipper	Black ash seepage swamps
Elatine americana	American waterwort	Wet clay soil
Mimulus moschatus	muskflower	Open seepage area
Pedicularis lanceolata	lousewort	Open areas
Platanthera flava var. herbiola	pale green orchis	Vernal streams in hardwoods
Stellaria borealis	northern stitchwort	
Trisetum pensylvanica	swamp oats	
Bogs/Boggy Areas		
Arceuthobium pusillum	dwarf mistletoe	On black spruce
Arethusa bulbosa	dragon's mouth	
Aster radula	rough aster	beaver meadows/swamp borders
Gentiana linearis	narrow-leaved gentian	boggy meadows
Scheuchzeria palustris	pod grass	
Smilacina trifolia	three-leaved Solomon's seal	boggy woods
Viola nephrophylla	northern bog violet	
Xyris montana	northern yellow-eyed grass	

3.6.2 Rare Wildlife Species

DWSP property is inhabited by a number of state-listed vertebrate species (Table 3-13). Rare species surveys often (and logically) focus on lands that are most actively threatened by development, rather than on large protected public holdings. DWSP conducts general and some targeted surveys that discover new populations of "listed species" (plant and animal), but it is likely that there are undiscovered populations of "rare and endangered species" on DWSP property. Although land protection is the most critical factor for their survival, DWSP recognizes the value in knowing where these species are located, in order to set priorities for specific protection measures and to guide management activities in or near critical habitats.

In order to ensure that land management activities do not disrupt or destroy listed species or their habitats, it is a DWSP objective to develop a more complete and current species occurrence database. DWSP's Natural Resources Section keeps records of listed plant and animal species on DWSP land that were discovered by in-house personnel or passed along by other professionals or the public. The MA Natural Heritage and Endangered Species program (NHESP) maintains more complete and detailed databases of listed species.

Timber harvesting on DWSP land is reviewed by a DCR Service Forester, who passes the cutting plan to NHESP when the harvesting map intersects a mapped Priority Habitat or Estimated Habitat for rare species (NHESP, 2006). NHESP sets restrictions on the harvesting activity if necessary to protect the species of concern. Routine maintenance (mowing, brush cutting) or watershed maintenance activities (road building/repair) are not required to file with NHESP. In these situations, it is possible to unknowingly and negatively impact rare or endangered species, but DWSP is working to prevent this from happening through cooperation with NHESP to identify and map areas of concern that may be impacted. DWSP is working with NHESP to improve staff awareness of rare species presence in order to prevent unintended impacts.

In many cases, species became rare because of loss of habitat or are further threatened by these losses. One of the greatest benefits of DWSP land to rare species is that it will remain undeveloped in perpetuity. As the majority of this land is covered by forest, it is of greatest benefit to uncommon species requiring forested habitat (e.g., sharp-shinned hawk, Cooper's hawk, Acadian flycatcher). Approximately half the species listed in Table 3-13 are either dependent on wetlands or utilize them during some portion of their lives. Protecting and maintaining functioning wetland systems is a priority for DWSP, which will benefit wetland species. Poutwater Pond (Holden) is one of the best examples in the state of an acidic fen. A floating bog mat provides very rare habitat for a number of uncommon species.

TABLE 3-13. STATUS OF STATE-LISTED VERTEBRATE SPECIES WHOSE RANGES OVERLAP WITH DWSP LANDS

Common Name	Scientific Name	Status[1]	Occurrence[2]	Last Observed
Mammals				
Water Shrew	*Sorex palustris*	SC	Documented	2009
Southern Bog Lemming	*Synaptomys cooperi*	SC	Documented	1994
Birds[3]				
Common Loon	*Gavia immer*	SC	Documented	2016
Pied-billed Grebe	*Podilymbus podiceps*	E	Potential	
Bald Eagle	*Haliaeetus leucocephalus*	E	Documented	2016
Least Bittern	*Ixobrychus exilis*	E	Documented	2000
American Bittern	*Botaurus lentiginosus*	E	Documented	2009
Northern Harrier	*Circus cyaneus*	T	Potential	
Sharp-shinned Hawk	*Accipiter striatus*	SC	Probable	
Peregrine Falcon	*Falco peregrinus*	E	Historic	
King Rail	*Rallus elegans*	T	Potential	
Common Moorhen	*Gallinula chloropus*	SC	Potential	
Upland Sandpiper	*Bartramia longicauda*	E	Historic	
Common Barn Owl	*Tyto alba*	SC	Historic	
Long-eared Owl	*Asio otus*	SC	Probable	
Short-eared Owl	*Asio flammeus*	E	Historic	
Sedge Wren	*Cistothorus platensis*	E	Historic	
Golden-winged Warbler	*Vermivora chrysoptera*	E	Probable	
Vesper Sparrow	*Pooecetes gramineus*	T	Probable	
Grasshopper Sparrow	*Ammodramus savannarum*	T	Probable	
Henslow's Sparrow	*Ammodramus henslowii*	E	Historic	
Eastern Whip-poor-will	*Caprimulgus vociferus*	SC	Documented	2016
Reptiles/Amphibians				
Wood Turtle	*Clemmys insculpta*	SC	Documented	2017
Blanding's Turtle	*Emydoidea blandingii*	T	Documented	2009
Eastern Box Turtle	*Terrapene carolina*	SC	Documented	2009
Marbled Salamander	*Ambystoma opacum*	T	Documented	2005
Blue-spotted Salamander	*Ambystoma laterale*	SC	Documented	2009
Jefferson Salamander	*Ambystoma jeffersonianum*	SC	Potential	
Eastern Spadefoot	*Scaphiopus holbrookii*	T	Potential	
Eastern Wormsnake	*Carphophis amoenus*	T	Potential	
Eastern Ratsnake	*Pantherophis alleghaniensis*	E	Potential	
Copperhead	*Agkistrodon contortrix*	E	Historic	
Timber Rattlesnake	*Crotalus horridus*	E	Potential	

[1] Species status in Massachusetts: SC= species documented to have suffered a decline that could threaten the species if allowed to continue unchecked; T=species likely to become endangered within the foreseeable future throughout all or a significant portion of its range; E= pecies in danger of extinction throughout all or a significant portion of its range.

[2] Occurrence of species on DWSP land within the watershed: Documented=species actually observed; Probable=species not documented, but given available habitat, species' range, and/or observations within the watershed, they are likely to occur; Potential=species not documented, and current habitat conditions may not be suitable, but with habitat enhancement they may occur; Historic=documented presence in the past, but has not recently been seen and may not be supported by current conditions.

[3] Occurrence of birds is limited to breeding pairs, not migratory or seasonal residents.

DWSP lands contain a large number of vernal pools. Although seemingly abundant on DWSP-owned land, these unique breeding areas are increasingly rare on a regional level. Vernal pools on DWSP land receive particular attention and protections (see Section 4.2.8 and Figure 4-15). Further, current MA Conservation Management Practices (CMPs) for vernal pools have recently been revised to improve their effectiveness in protecting vernal pool dependent species.

Non-forested upland habitat is much rarer on DWSP property and is limited to maintained open spaces. There are several species in Table 3-13 that require open fields or meadows. Although DWSP will not create new field habitat, the importance of this habitat in the landscape is recognized. Therefore, where feasible, DWSP will reclaim, maintain and enhance this habitat where it exists on its land (see Section 4.3.3).

Areas with highly disturbed soils represent important habitat for several species listed in Table 3-13. On DWSP land there are several large active and inactive gravel and sand pits and areas of exposed stream banks and shoreline. Wood, Blanding's, and Box turtles use sandy or gravelly areas to lay their eggs. In addition, some invertebrates such as the Big Sand Tiger Beetle, Dune Ghost Tiger Beetle, Oblique-lined Tiger Beetle, Frosted Elfin, and Hoary Elfin utilize areas of highly disturbed soils. DWSP recently documented Wood Turtles laying eggs in an abandoned DWSP sand pit. In many cases, however, these highly disturbed areas are scheduled for restoration. DWSP recognizes the potential wildlife value some of these areas have, and in the future DWSP will examine each site on a case-by-case basis to determine: 1) actual erosion threat, and 2) habitat suitability for selected wildlife species. In some cases, where erosion is not a threat, the site may be abandoned and left in its disturbed state.

3.6.3 Rare, Uncommon, and Exemplary Natural Communities

Natural communities have been defined in a variety of ways. Some definitions include only abiotic features, while other definitions rely primarily on the dominant vegetation of an area. Combining these approaches, natural communities can be defined as an assemblage of both biotic and physical conditions that occur together to form a functionally distinct area of the landscape. These unique assemblages caused by the combination of physical environment, biological interaction, and disturbance will dictate the type and extent of vegetation present, which in turn will shape the faunal community.

The Quabbin watershed harbors a wide array of unique natural communities. Some of the communities are rare on a regional or global level. From 1997 to 2000, in response to a recommendation by the FSC forest certification auditor that the biological diversity at Quabbin should be better characterized, the University of Massachusetts Department of Natural Resources Conservation, under the primary direction of Associate Professor Kevin McGarigal, assessed the watershed for rare, uncommon, and exemplary natural communities. The purpose of this study is described in a September 2000 report entitled *Rare, Uncommon, and Exemplary Natural Communities of Quabbin Watershed*: "to identify, classify, and describe the rare, unique, and

exemplary natural communities in the Quabbin watershed area of Massachusetts and to provide recommendations for their management." The report identifies, and describes in detail, 22 rare communities in the Quabbin watershed, as show in Figure 3-9, which indicates the communities by bold type. The status of these communities at Quabbin and globally has been evaluated and is shown in Table 3-14.

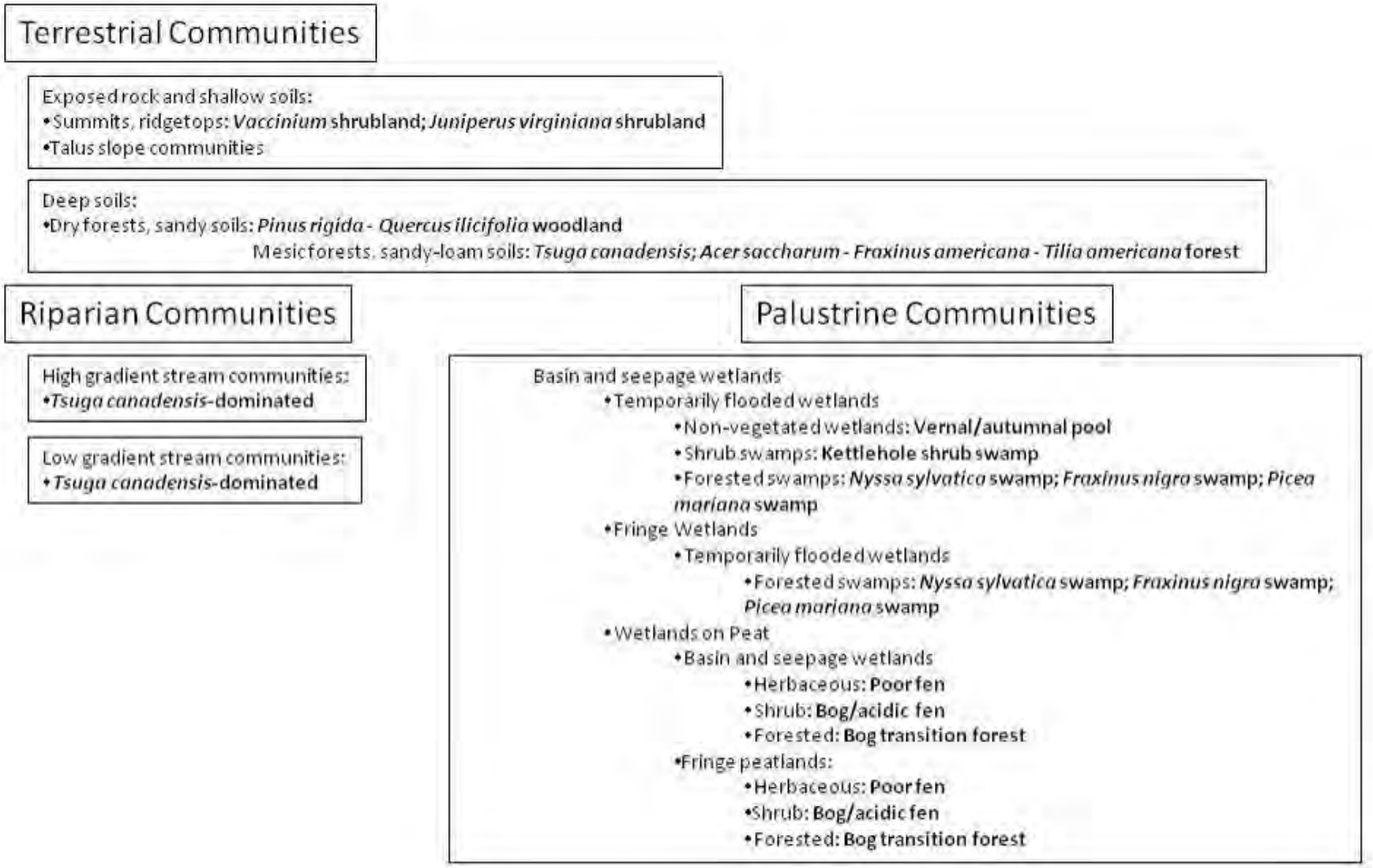
TABLE 3-14. STATUS OF RARE COMMUNITIES ON THE QUABBIN RESERVOIR WATERSHED

COMMUNITY	Global Status	Status at Quabbin	Threats
Terrestrial			
Vaccinium shrubland	Secure	Rare	Foot traffic, invasive plants
Red Cedar shrubland	Regionally rare	Rare	Foot traffic; invasive plants
Talus slope	Unknown	Uncommon	Disturbance above slope, invasive plants
Pitch Pine – Scrub Oak	Regionally rare	Rare	Fire suppression
Hemlock dominated forests	Unknown	Common	Hemlock wooly adelgid
Sugar Maple-White Ash-American Basswood forest	Secure	Uncommon	Invasive plants
Riparian			
Hemlock stream communities	Unknown	Common	Hemlock wooly adelgid
Palustrine			
Black Tupelo swamp	Very rare	Extremely rare	Beaver flooding; physical disturbance
Black Ash swamp	Very rare	Uncommon	Beaver flooding; physical disturbance
Black Spruce swamp	Uncommon	Uncommon	Beaver flooding; physical disturbance
Vernal pools	Unknown	Common	Disturbance to adjacent uplands
Peat, bog, fen, swamp shores	Very rare	Uncommon	Beaver flooding; invasive plants; trampling

Although the community classification system was tailored to Quabbin, many of the communities are rare or unique on a statewide or regional level. For example, talus slopes, pitch pine-scrub oak, hemlock ravines, tupelo swamps, vernal pools, and peat wetlands were identified as rare communities at Quabbin that also occur on other DWSP watersheds. A complete census of DWSP land needs to be done to accurately inventory rare and exemplary community types.

Many of these rare communities are threatened to some extent by invasive plants or insects, as well as by pressures from increasing populations of native wildlife, such as beaver, deer, or moose. In some cases, watershed management activities have the potential to affect these areas positively or negatively. It is an abiding objective of DWSP to work to better understand these communities and to avoid negative impacts resulting from watershed management practices.

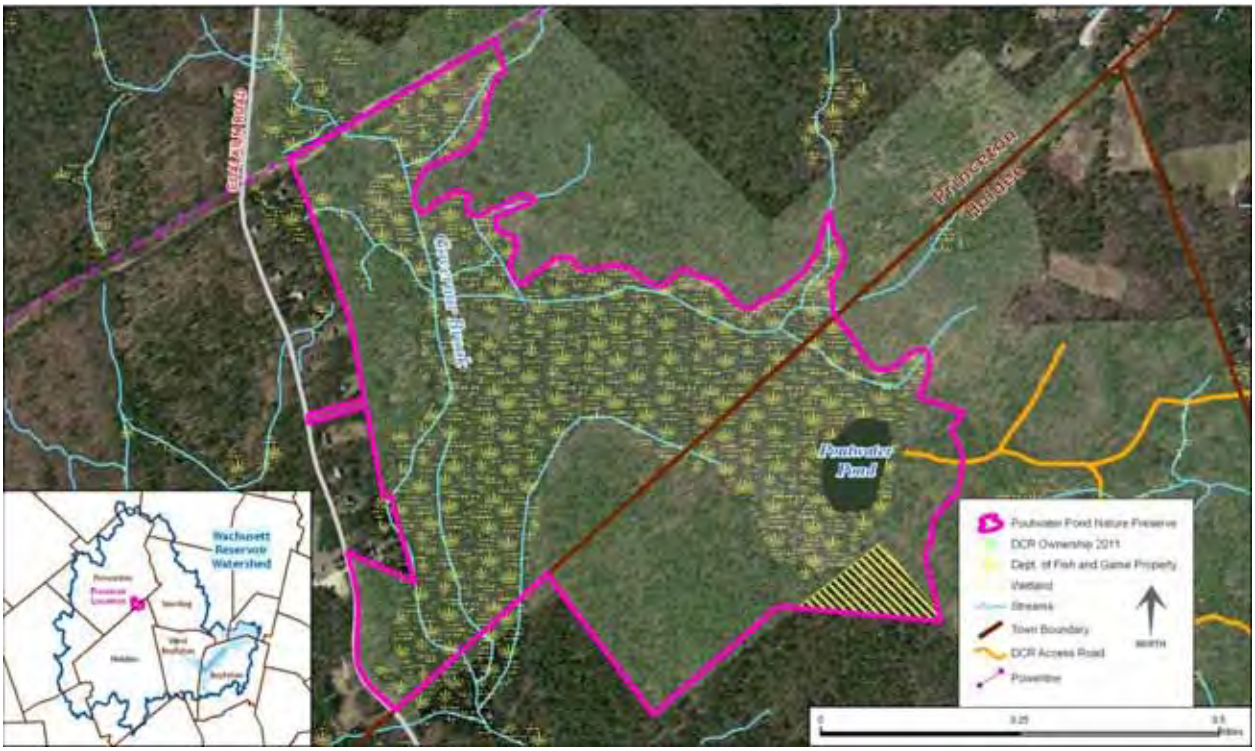
FIGURE 3-9. QUABBIN RESERVOIR WATERSHED RARE COMMUNITIES



Poutwater Pond Nature Preserve: An Exemplary Rare Natural Community

Located in the Wachusett Reservoir watershed, the 243 acre Poutwater Pond Nature Preserve includes the Poutwater Pond, the Poutwater Pond Bog, and associated wetlands and upland areas. The area includes 232 acres under the care and control of DWSP that encompasses the pond and the majority of its watershed and adjacent downstream wetland areas, and 11 acres under the control of DFW that encompasses an upland area that drains to the pond (Figure 3-10).

FIGURE 3-10. POUTWATER POND NATURE PRESERVE



The Poutwater Pond site is significant for its unique geologic, hydrologic, and botanical characteristics. These diverse natural features and soils support an equally diverse plant community: at least 73 species of vascular plants in 34 families (Searcy, 1996), representing a series of successional stages in one compact area. Plant communities include two forested wetland communities dominated by either larch or spruce, three tall shrub wetland communities, two low shrub wetland communities, a red maple swamp forest, and upland second growth white pine, red maple, and oak forest.

Poutwater Pond Bog is the best example of a well-preserved New England level bog within the 100,000 acres of land under care and control of DWSP and probably one of the best examples in the Commonwealth. Due to its significant features, the bog was classified as a National Natural Landmark in 1972 by the National Park Service. Poutwater Pond is probably best characterized as an early-stage ombrotrophic mire, with key plants including sphagnum, ericaceous shrubs such as leatherleaf and cranberry, and coniferous tree species (larch and black spruce).

Insectivorous plants occurring in the bog include pitcher plant, sundews, and bladderworts. Two plants on the state threatened and endangered species list and one on the unofficial watch-list are known to occur in the bog and adjacent wetlands.

In 1998, the Poutwater Pond area was officially designated a Nature Preserve, the first in the state under the Nature Preserves Program which was created by a 1990 amendment to M.G.L. ch. 131, §10. Under the act, state lands within the jurisdiction of the Executive Office of Energy and Environmental Affairs (EOEEA) may be nominated to become a nature preserve. Nature preserves are intended to serve in perpetuity as examples of the state's native natural heritage. M.G.L. ch. 131 states that any lands, waters, or shores under EOEEA control that contain rare, exemplary, or other significant natural or biological communities, or that contain significant features of native biological diversity are eligible to be considered for nature preserve status. Nature preserves are dedicated to the public benefit for the conservation of natural communities and native species of plants and animals, and for scientific research and education. By statute, nature preserves are to be recognized as areas to be monitored and maintained in a natural condition. They should be used and managed in a manner consistent with protecting and perpetuating that condition.

DWSP's 1997 Protection Plan for Poutwater Pond Nature Preserve contains a detailed inventory of the preserve's flora and fauna as well as the cultural history and resources of the area, a description of the public uses of this area, and recommendations for controlling access, serving public education needs, and protecting the natural resources of the preserve. Within this plan, DWSP stipulates that no commercial forestry management will take place in the Preserve. In certain situations (salvage operations), forestry activities may take place. If managed carefully, Poutwater Nature Preserve can be an excellent educational resource for local schools, ranging from elementary to the college level.

Two current concerns at Poutwater include the continued maintenance of the boardwalk trail and the presence of beaver (a species not listed as present in the 1997 protection plan). The boardwalk was completely repaired in 2013 and maintained in 2014 but will require periodic future maintenance as the bog's vegetation continues to grow over the boardwalk panels. Beaver activity has caused water levels to fluctuate and influenced the large red maple swamp west of the bog. Very recently, beaver activity has been documented on the bog mat itself, and DWSP will seek advice from botanists regarding possible impacts to the rare plant communities and if control measures are warranted.

3.7 Cultural Resources

Cultural resources may be divided into four principal categories: historic records and documents, archaeological resources (pre-Contact and historical), historic buildings and structures, and historical or cultural landscapes. Due to their varied nature, describing and interpreting the many features and materials that can be classified as "cultural resources" on DWSP lands requires a multi-disciplinary management approach. Cultural resources range from individual historical documents to artifacts of ordinary life generated during many centuries of human occupation, to entire landscapes. In some cases, there is overlap between categories; for example, a stone wall is a historical structure but may also be a significant component of a cultural landscape. In many cases, there is room for interpretation and debate about the value of specific cultural resources and the importance or feasibility of preservation.

3.7.1 Records and Documents

The surviving records of the design, construction, operation and management of the metropolitan water supply system beginning in the 1890s are voluminous and mainly located at three state agencies: DCR, MWRA, and Massachusetts State Archives. Within the two operating agencies, records are stored in multiple office locations.

Records in the form of the original survey "Taking Sheets" or "Land Plans" for properties purchased in order to develop the reservoirs and associated water works for Sudbury, Wachusett, Ware River, and Quabbin, are archived in the Quabbin Engineering Office (Quabbin and Ware River) and Wachusett Engineering Office (Wachusett and Sudbury). The archives include more than 4,800 photographs of the buildings that stood on properties in the Quabbin Reservoir and Ware River watersheds, and 2,000 cemetery photographs. The Quabbin and Ware watershed photograph documentation resides mostly at the Quabbin Administration Building and at the MA State Archives.

In addition, the Massachusetts Metropolitan Water Works (MWW) Photograph Collection is available on line at www.digitalcommonwealth.org/collections/commonwealth:g732dh56k. A collaborative project between DCR, MWRA, and the MA State Archives digitized this collection that documents the construction of the Boston metropolitan water supply as it expanded westward between 1876 and 1925. Over 8,800 carefully labeled photographs of each phase of the construction, from real estate takings through completion, were taken by staff photographers and engineers. Construction of dams, reservoirs, aqueducts, pipelines, standpipes and many architecturally significant pumping stations and gatehouses are represented. Noted facilities include the Wachusett Reservoir, Wachusett Dam, and Wachusett Aqueduct. The original photographs in this collection, produced using various photographic formats including dry plate glass negatives, glass lantern slides, and photographic prints, were obtained from MDC, DCR, and MWRA and are now in the safekeeping of the Massachusetts State Archives. There are more than 1,400 real estate photographs of the Wachusett watershed within the photo collection.

Other subjects include forestry management around Wachusett Reservoir, sanitary improvement, protection of the watersheds, and brook and swamp drainage management.

The Quabbin Superintendent was designated Town Clerk for the Swift River Valley towns of Dana, Greenwich, Prescott and Enfield when they were dis-incorporated during the construction of the Quabbin Reservoir. Each subsequent Superintendent (now Regional Director) has held this office and been responsible for maintaining the vital records of previous inhabitants of these former valley towns. These birth, marriage and death records are stored at the Quabbin Administration Building and are available to the public for research purposes. Researchers now can access these same records online through Ancestry.com, which digitized the 1984 microfilm of these records.

The still active Quabbin Park Cemetery, located in Ware, MA, was created to accept the remains disinterred from 34 cemeteries in the four Swift River Valley Towns. The official records of the cemetery are located at the Quabbin Administration Building and duplicated in the DCR Archives. The records of the cemetery's early development and operation (1927-1940s) are also located at the Quabbin Administration Building.

A large body of aerial photographs commissioned by the MDWSC for the Quabbin and Ware watersheds during three separate intervals (1926/27; 1930; 1936/38) are currently divided among the Quabbin Administration Building, DWSP's Oakham Office, DCR Archives, and Mass. State Archives. The photographs from 1936/38 also include the Wachusett and Sudbury watersheds.

3.7.2 Archeological Resources

Pre-Contact Archaeological Resources

The Massachusetts Historical Commission (MHC) currently has records for approximately 50 pre-Contact sites on Quabbin lands. Twenty-five of the 50 recorded sites are known by location only, with no indication of the type or range of artifacts and features that were encountered. All of the sites currently recorded in the Quabbin watershed were discovered by local artifact collectors exploring areas exposed when the waters of the reservoir were unusually low.

There are a total of 27 MHC-recorded pre-Contact Native American sites within, or in close proximity to, the Wachusett watershed. Within the greater Nashua River Basin, of which Wachusett is a part, at least another 35 sites have been recorded.

Historical Archaeological Resources

A "historical sites inventory" for the Quabbin Reservoir watershed was created between 1994 and 1998 by a succession of graduate students from the Department of Archaeology at Boston University, which recorded 867 sites, many of which were visited in the field. DWSP staff digitized the site locations, and the presence and preservation of these features is included in

planning for all forestry operations. DWSP also digitized nearly 1,000 additional historical site locations, most of which are now under water.

An inventory of historical archaeological resources similar to that completed at Quabbin has not been undertaken for the other watersheds. The results of such an inventory would probably be similar to Quabbin's in terms of the range and type of sites.

Many of the stone walls on DWSP lands have been mapped using GIS, but the task is incomplete. Additional mapping occurs as foresters develop maps for the annual round of forestry lot proposals. New information is also being collected through Light Detection and Radar technology (LIDAR, see Section 5.1.5) .

3.7.3 Historic Buildings and Structures

A long list of historic DWSP buildings was accepted to the National Register of Historic Places in January, 1990. The listing includes the 89 individual buildings and structures that comprise the entire Metropolitan Water Supply System (excluding Quabbin, which was not yet 50 years old at the time of the listing). The Wachusett Reservoir watershed is represented in the National Register by the Wachusett Aqueduct Linear District, which contains 15 buildings and structures, and the Wachusett Dam Historic District, which contains six individual buildings and structures. The Sudbury Reservoir Watershed is represented by the Sudbury Aqueduct Linear District (eight individual buildings and structures) and the Sudbury Dam Complex District (nine individual buildings and structures). The remainder are associated with the Cochituate Aqueduct Linear District, the Weston aqueduct, the Walnut Hill Reservoir, the Middlesex Fells Reservoir, and other miscellaneous buildings and structures.

4 Management Plan Goals, Objectives and Methods: 2015-2020

The DCR DWSP Watershed Protection Program provides a drinking water source of exceptionally high quality. DWSP is committed to the goal of protecting and maintaining this level of quality for future generations. The *2013 DWSP Watershed Protection Plan Update* (www.mass.gov/eea/docs/dcr/watersupply/watershed/2013dcrwatershedprotectionplan.pdf) provides a systematic approach to evaluate potential water quality threats and to develop and implement programs that eliminate or minimize these threats.

The *2013 Watershed Protection Plan Update* provides a system-wide, integrated approach to managing a dozen potential contaminant sources through 16 DWSP programs (Table 4-1). The overall goal of the control programs is to develop proactive strategies to prevent water quality problems wherever possible and to respond to detected problems quickly to limit their potential impact.

This *Land Management Plan* specifically addresses five of these programs – Land Procurement, Watershed Preservation Restrictions, Land Management, Wildlife Management, and Infrastructure (grey highlighted in Table 4-1). These programs cover practically every potential source of water quality contamination identified in the *2013 Watershed Protection Plan Update*.

Water quality issues are discussed in detail in DWSP's annual Work Plans (www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/plans.html) and Water Quality Reports (www.mass.gov/eea/agencies/dcr/water-res-protection/water-quality-monitoring/water-quality.html), as well as several reports issued by the MWRA (www.mwra.com/monthly/wqupdate/qual3wq.htm).

Water quality concerns encompassed by this *Land Management Plan* include:

- **Pathogen introduction and transport to the reservoirs and intakes**. Pathogens are biological agents, such as bacteria and viruses, that can cause illness or disease. The continuation of the Gull Harassment Program and the Aquatic Mammal Pathogen Control Program, as well as maintaining a vigorous forest cover throughout the watershed are the primary land management related methods for limiting pathogen impacts to source water quality.

- **Nutrient transport to the reservoirs.** DWSP uses the term nutrients as a category of chemical compounds, primarily certain forms of phosphorus and nitrogen, that promote aquatic plant growth. Elevated levels of nutrients that lead to excessive aquatic

TABLE 4-1. POTENTIAL CONTAMINANT SOURCES AND WATERSHED CONTROL PROGRAMS

	DWSP Watershed Protection Program															
Potential Contaminant Sources	**Land Procurement**	**Watershed Preservation Restrictions**	**Land Management**	**Wildlife Management**	**Public Access Management**	**Watershed Security**	**Infrastructure**	**Watershed Protection Act**	**Interpretive Services**	**Water Quality/Quantity Monitoring**	**Watershed Monitoring**	**Aquatic Invasive Species**	**Environmental Quality Assessments**	**Wastewater Management**	**Stormwater Management**	**Emergency Response**
Wildlife			✓	✓						✓	✓	✓	✓		✓	
Public Access/ Recreation			✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓
Timber Harvesting/ Forestry			✓					✓	✓	✓	✓	✓	✓	✓	✓	✓
Wastewater	✓	✓						✓		✓	✓		✓	✓		
Roadways, Railways and Rights-of-Way										✓	✓	✓	✓	✓		✓
Agriculture	✓	✓						✓		✓	✓		✓	✓	✓	
Construction	✓	✓						✓		✓	✓		✓	✓	✓	
Commercial, Industrial, and Governmental Sites	✓	✓						✓		✓	✓	✓	✓	✓	✓	
Residential Sites	✓	✓								✓	✓	✓	✓	✓	✓	
Future Growth	✓	✓	✓	✓	✓					✓	✓	✓	✓	✓	✓	
Climate Change	✓	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓	✓
Security Threats					✓	✓	✓			✓	✓		✓			✓

Source: 2013 DCR Watershed Protection Plan Update

plant growth can be deleterious to aquatic life and can impact drinking water quality. Although Quabbin and Wachusett Reservoirs on the whole are oligotrophic (low in dissolved nutrients and rich in dissolved oxygen), taste and odor events from algae growth that may be related to the levels of available nutrients have occurred in some years. Nutrient transport to the reservoir will be limited through protection of riparian zones and by maintaining vigorous forest growth throughout the watershed.

- **Turbidity and sediment transport.** Turbidity is a measure of the cloudiness of a solution. Material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. Ensuring that the watershed can control sediment transport during and following major disturbances is a guiding goal of the Land Management Plan. The size of the reservoirs and the location of the intakes do prevent localized sediment transport from affecting drinking water quality during normal events. In addition to addressing major events, control methods focus on preventing sediment transport from the road system and during active forest management activities.

- **Anthropogenic compounds entering the water supply.** There are many non-natural chemicals that pose potential threats to the drinking water supply, including hazardous materials, pesticides, and pharmaceuticals and personal care products. While these contaminant sources are minimized by DWSP's land ownership, there are still opportunities to limit potential impacts from fuel and lubricants used in vehicles and equipment, utility Rights-of-Way management, and transportation throughout DWSP property.

- **Invasive species impacts.** The US Department of Agriculture defines an invasive species as a species that is: 1) non-native (or alien) to the ecosystem under consideration and 2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes). For water quality considerations, DWSP is primarily concerned with aquatic invasive species. DWSP land management strategies attempt to curtail the problems posed by Terrestrial Invasive Species to biodiversity and the landscape, which could eventually have water quality impacts.

This chapter provides DWSP's goals, objectives, for the management of forested lands, non-forested lands, wildlife, and cultural resources with a thorough description of these issues.

4.1 Land Protection

4.1.1 Goals

- *Continue to acquire priority properties in the active water supply watersheds with cooperative landowners in either fee or as a Watershed Preservation Restriction.*
- *Maintain oversight of existing properties with Watershed Preservation Restrictions.*
- *Administer the Payments in Lieu of Taxes Program.*
- *Maintain boundaries of DWSP property.*
- *Maintain an adequate road system for watershed protection.*

4.1.2 Land Acquisition

View of Mt. Wachusett from Tower Hill

The purpose of the land acquisition program is to 1) acquire sensitive watershed lands; 2) protect the lands from urbanization; and 3) restore and/or maintain stable forest cover on these lands. Relatively undisturbed lands are purchased as a preventative measure to counter potential threats to water quality that would result from development of these lands. Sites already developed or significantly disturbed are seldom acquired. DWSP's land acquisition program covers the three active DWSP watersheds. The program does not include the Sudbury Reservoir emergency supply watershed, which is protected by the 2,381 acres originally acquired in the 19th century. While a preponderance of the available acquisition resources have been used to acquire acreage on the Wachusett Reservoir watershed, sensitive lands have also been protected on the Quabbin Reservoir and Ware River watersheds.

The Commonwealth purchased 4,170 acres of land to be flooded and 5,608 acres of watershed land, or just 7.9% of the total watershed excluding the reservoir when the Wachusett Reservoir was completed in 1905. Officials had realized the mistake of not protecting significantly more of the watershed when acquiring lands in the Quabbin Reservoir and Ware River watersheds during the 1930s. About 50,000 acres (42%) of land in the Quabbin Reservoir watershed and 16,500 (27%) acres of the Ware River watershed were purchased for watershed protection. The next 50 years saw only limited and sporadic land acquisition in the three watersheds, usually triggered by impending development on critical parcels near the reservoirs. In several cases, original watershed holdings were sold out of state ownership for various municipal and private interests, although the majority of the original holdings have remained under DWSP control.

Passage of federal drinking water regulations in the 1970s and 1980s, and in particular the promulgation of the Surface Water Treatment Rule in 1989 requiring filtration of all but the most highly protected water sources, made state authorities realize that DWSP needed to demonstrate control over a larger part of the watershed system, particularly in the Wachusett Reservoir watershed. For the past 30 years, DWSP has conducted a robust watershed land acquisition program with the goal of protecting sensitive watershed land from development and restoring and maintaining stable forest cover on much of this land. The primary purpose of this program is to help maintain high water quality into the future. Land acquisition helps prevent urbanization-related water quality degradation by bacteria, pathogens, nutrients, sediments, heavy metals, and other pollutants associated with waste management and the increased storm water discharge caused by expanding impervious surface area.

The DWSP Watershed Land Acquisition Program has been funded from three state bonds and MWRA fiscal year budget allocations through their Capital Improvement Program. These include Commonwealth open space bonds of $3 million established in 1983, $30 million established in 1987, and a $135 million bond established by the Watershed Protection Act of 1992. All of the bonds since 1985 have been paid for by the MWRA. Recent funding has come directly from MWRA budget allocations; the program is funded at $1 million dollars per year through Fiscal Year 2018.

After the passage of the Watershed Protection Act, DWSP created the Land Acquisition Panel (LAP), consisting of DWSP and MWRA staff members representing broad watershed management expertise, to ensure the most effective watershed protection outcome for these land acquisition funds. While land acquisition funds are utilized in each of the system's watersheds, the highest priority for protection has consistently been the Wachusett Reservoir watershed, which is closest to the metropolitan Boston consumers, yet contains the lowest percentage of protected sensitive land.

LAP developed a unique and comprehensive GIS computer model for the Wachusett Reservoir watershed that scored the sensitivity (watershed index) of all land using twelve weighted criteria and three basin multipliers. The model is based on the fact that land in and around tributaries, aquifers, and wetlands contain the greatest proportion of a basin's water at any given time. Studies of small New England watersheds emphasize the importance of low-lying, water-rich areas in contributing the majority of runoff during storm events through saturated surface and subsurface flow (Dunne and Leopold, 1978; Hewlett and Nutter, 1969). As a precipitation event continues, the area contributing to saturated flow increases. Pollutants introduced to these water-rich sources are more likely to impact tributary water quality than those introduced on non-source areas.

The watershed index, calculated by the computer model, indicated areas that were rich in water resources and sensitive to degradation caused by human activity. The criteria included proximity to the reservoir and tributaries, slopes, zoning, aquifers, habitat protection, and threat from development. Overlapping weighted criteria multiplied by one of three overlay basins in which they fall results in a Land Sensitivity Index.

After subtracting already developed land and Other Protected open space, the model determines the remaining available privately owned land that might be purchased on the watershed. The model then scores and maps this undeveloped private land on a scale from one (low) to seven (high), allowing DWSP staff to better estimate the amount of high priority acreage that can be purchased with remaining land acquisition funds. DWSP pursues those parcels that are considered high priority, with scores from four to seven. Due to the large areas under DCR control in the Quabbin and Ware watersheds, modeling was not necessary to focus the small percentage of funds expended in these two watersheds.

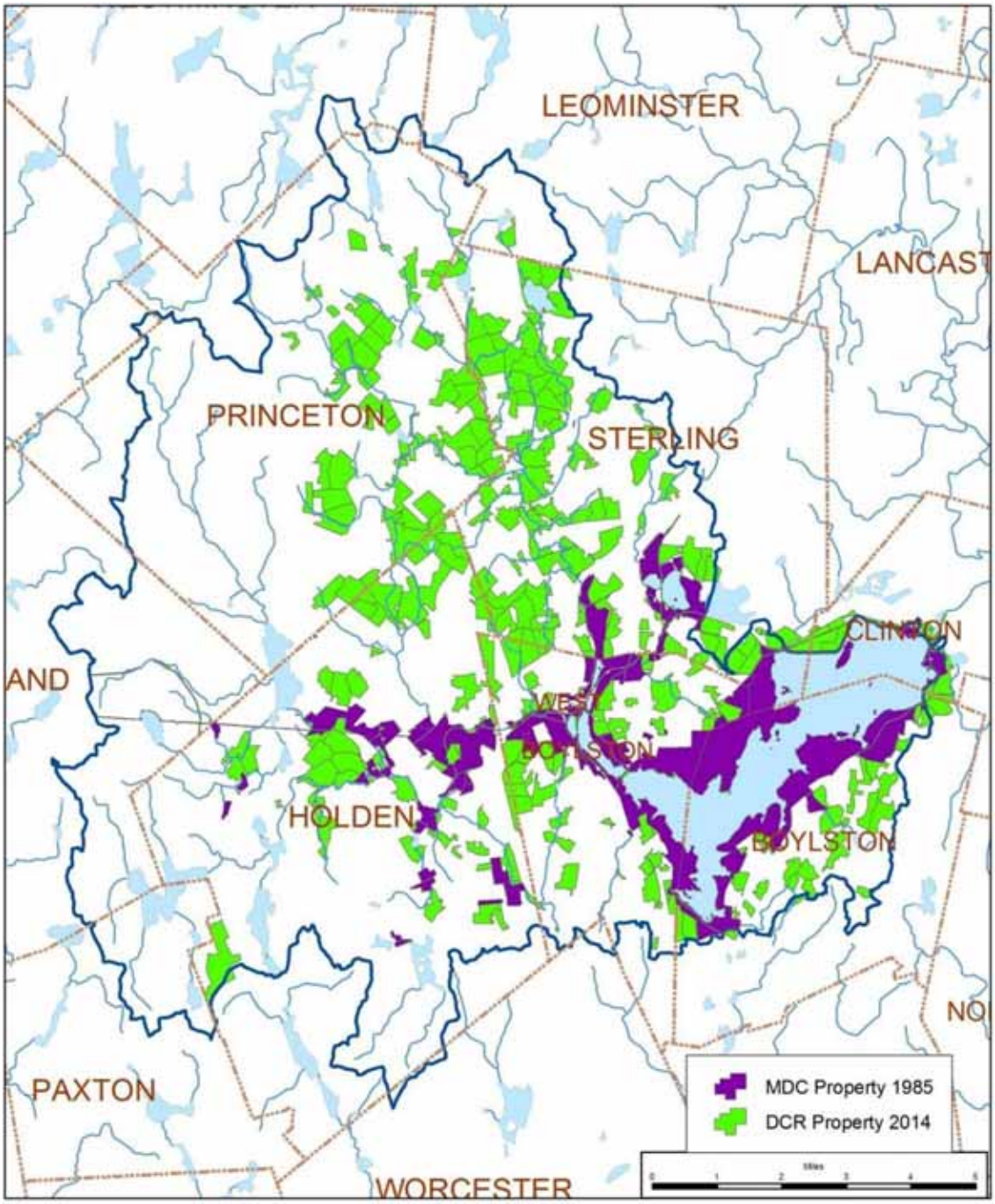
LAP meets regularly to review proposed acquisitions, utilizing a wide-range of information at their disposal, including the Wachusett model, remote sensing data, site review, and professional judgment, to determine which projects are worth pursuing. Many proposals do not pass this LAP review process.

Land acquisitions can either be in fee, where the state holds title to the property, or as a Watershed Preservation Restriction (WPR – Section 4.1.3), which is a voluntary agreement between a landowner and DWSP in which the landowner gives up certain rights to his or her land. In recent years, there has been a strong preference for acquisition of WPRs rather than purchasing land in fee, as WPRs are less costly than outright acquisitions and do not involve annual payments in lieu of taxes (PILOT – Section 4.1.4).

From the beginning of the program (1985) through January 2015, DWSP increased the percentage of the Wachusett watershed in agency-controlled land from 7.9% to 28.4% with the purchase of 352 properties (Figure 4-1). This represents the acquisition of 11,940 acres in fee

and 2,460 acres in WPRs. Including the original 5,608 acres plus 115 acres acquired prior to 1985, DWSP now has care and/or control of 20,123 acres or 28.4% of the Wachusett Watershed, excluding the reservoir. When the reservoir is included, the total rises to 24,293 acres, or 34.2% of the watershed.

FIGURE 4-1. DWSP WACHUSETT WATERSHED OWNERSHIP, 1985 VS. 2014



From 1985 to 2015, DWSP acquired 3,381 acres in fee and 2,148 acres in WPR for watershed protection on the Quabbin watershed, bringing the total holdings to 55,904 acres, or 46.8% (up from 42% in 1985) of the watershed. When Quabbin Reservoir is included, the total area under DWSP care and control is 80,496 acres or 67.4% of the watershed. During the same time period, DWSP acquired 3,543 acres of land in fee in the Ware River watershed. An additional 919 acres in WPRs were also acquired, bringing the total holdings in the Ware River to 24,278 acres of 39.3% of the watershed (Table 4-2).

TABLE 4-2. DWSP-CONTROLLED LAND 1905-2015

Additions to DWSP-controlled holdings	Quabbin		Ware River		Wachusett	
	Acres	% Watershed	Acres	% Watershed	Acres	% Watershed
Original land purchase	50,290	42%	16,593	27%	5,608	7.9%
Additional land acquisition up to 1985	85	0.0007%	3,223	5.2%	115	0.2%
Land acquired in fee, 1985 to 2015	3,381	2.8%	3,543	5.7%	11,940	16.8%
WPRs, 1985 to 2015	2,148	1.8%	919	1.5%	2,460	3.5%
Total (excluding reservoir)	55,904	46.8%	24,278	39.3%	20,123	28.4%
Reservoir area	24,592	20.6%	-	-	4,170	5.9%
Total area controlled by DWSP	80,496	67.4%	24,278	39.3%	24,293	34.2%

Close to $135 million has been expended on land purchases from 1985 to 2015. The vast majority, $113 million or 84%, has been spent in the Wachusett watershed; $13 million (10%) has been spent in the Ware River and $9 million (6%) in the Quabbin watershed. Approximately 75% of the area acquired has been land in fee, and the remaining quarter as WPRs. DWSP has also benefitted from gifts of land and partnering with federal, state, local, and non-profit agencies to secure conservation property.

DWSP will continue to concentrate on purchasing land on the Wachusett watershed, which is still the least protected basin, with 28.4% under DWSP control. The present combined total of DWSP and Other Protected Open space on the Wachusett watershed stands at 40,172 acres or 56.7% of the watershed, excluding the reservoir. Approximately 6,223 acres of the watershed is private but unoccupied, and 19,000 acres are private and occupied. The remaining privately owned unoccupied land will be the focus of a revised and updated land acquisition modeling effort to best prioritize parcel selections based on watershed sensitivity indices and available funds.

Efforts will also continue toward purchasing key parcels throughout the Quabbin Reservoir and Ware River watersheds. Future land acquisition in the Quabbin Reservoir watershed is expected to be limited and very selective, given the available funding and the fact that much of the watershed is already protected lands. Particular emphasis will be given to projects that address the acquisition of inholdings in order to consolidate boundaries, and Watershed Preservation Restrictions on prioritized parcels that, when protected, will prevent adverse changes in land use LAP considers a

significant threat to water quality. Gifts, bargain sales, and partnering opportunities in land acquisition will contribute to a more favorable prioritization status. Land acquisition opportunities within the Ware River watershed will be limited to exceptional circumstances, and no efforts are planned within the Sudbury watershed.

4.1.3 Watershed Preservation Restrictions

A Watershed Preservation Restriction (WPR) is a voluntary agreement between a landowner and DWSP in which the landowner gives up certain rights to his or her land. These rights are then permanently removed from the property, even when it is subsequently sold. In recent years, there has been a strong preference for acquisition of WPRs rather than acquiring land in fee, because WPRs still protect water quality while being more cost-effective for several reasons: 1) the costs of acquisition are generally less; 2) DWSP does not have all of the land management responsibilities that it does for fee lands, such as forest management, roads maintenance, etc.; and 3) because WPRs are still privately owned, DWSP does not have to make payments in-lieu of taxes on the parcels. However, because WPRs are still privately owned, DWSP has ongoing stewardship obligations to make sure there are no violations of this legal covenant.

As of February, 2017, DWSP holds 127 WPRs, totaling approximately 7,343 across all three active watersheds. In 2009, a Watershed Preservation Restriction Coordinator was hired to oversee WPR stewardship in the three watersheds. DWSP was able to catch up on the backlog of stewardship activities, revise procedures in light of best practices that had been developed in other organizations since 2005, and perform stewardship according to those nationally-recognized standards. The WPR Coordinator maintains a working relationship with WPR landowners, including a bi-annual newsletter.

4.1.4 Payments In-Lieu of Taxes

Massachusetts General Laws ch.59 §5G mandates that DCR's Division of Water Supply Protection make Payments In-Lieu of Taxes (PILOT) on the Commonwealth property managed by the Office of Watershed Management. The current law was ratified in 1984 for the Quabbin Reservoir and Ware River watersheds and was amended in 1987 to include communities in the Wachusett and Sudbury Reservoir watersheds. Two towns that have aqueduct infrastructure are also covered by this legislation. These DWSP PILOT payments compensate the towns for taxes lost as a result of the taking or purchase of the land for water supply production, protection and storage. The PILOT program guarantees regular and stable payment to the 29 affected watershed communities.

The base information used for determining DWSP PILOT is the valuation performed every four years by the Department of Revenue (DOR) on all State Owned Lands; the latest revaluation was completed in 2013 and was the basis of the FY2014 PILOT. It is strictly DOR's responsibility to set the value for this land. New acquisitions are incorporated into the PILOT program through this

revaluation process. PILOT is not paid on Watershed Preservation Restrictions (or any other type of Conservation Restriction), as those lands are still private property.

DWSP works diligently with the watershed communities, MWRA, and DOR to comply with the PILOT law. Since 1985, more than $117 million has been distributed in Watershed PILOT payments (Table 4-3). Details of the program are available at www.mass.gov/eea/agencies/dcr/water-res-protection/watershed-mgmt/payment-in-lieu-of-taxes-pilot-program.html.

4.1.5 Land Disposition Policy

DWSP must contend with ongoing pressure from both private and municipal parties for disposition of lands for purposes inconsistent with water supply protection. While there are certain portions of DWSP lands in the watershed that are less sensitive to disturbance, these areas require careful and consistent scrutiny prior to disposition. DWSP will consider land disposition only under exceptional circumstances.

The DWSP Land Disposition Policy, approved in April, 1998, provides a framework for the agency to properly discharge its obligations to protect the water supply and to protect the Commonwealth's broader interests in open space protection under Article 97 of the Constitution of the Commonwealth. The intent of the DWSP Land Disposition Policy is to provide additional watershed-specific instructions to the Executive Office of Energy and Environmental Affairs on disposition of Article 97 lands. DWSP follows EOEEA's land disposition guidelines and DWSP is extremely stringent about agreeing to land dispositions and will pursue them only if the disposition can be a benefit to the Commonwealth and the protection of water resources.

4.1.6 Property Boundaries

Location and Maintenance

DWSP property boundaries are the "front line" of watershed protection, in that they are immediately adjacent to private land on which DWSP's watershed protection principles may or may not be followed. The protection provided by boundaries is therefore enhanced by regular maintenance to keep them visible, and by immediate identification and resolution of encroachments. A well maintained, obvious boundary is far less likely to be unknowingly crossed, and also aids in policing and rules enforcement.

The boundaries of all watershed lands originally acquired at Sudbury and Wachusett Reservoirs were fenced, and a forty-foot wide firebreak was constructed along the inside of the boundary line (fire breaks were also cleared along Quabbin land boundaries, but not at Ware River). Annual mowing of the firebreaks and maintenance of the fences made it very clear when one was crossing onto DWSP land. Dwindling labor resources over the last fifty years has made the maintenance of most of the fence and firebreaks unfeasible. The vast majority of the mowing of the firebreaks at the Wachusett and Sudbury Reservoirs ended during the 1970s and early 1980s.

TABLE 4-3. ANNUAL PAYMENTS IN LIEU OF TAXES TO TOWNS IN DWSP WATERSHEDS, 2010-2014

Community	2013	2014	2015	2016	2017
Quabbin Reservoir/Ware River Watersheds					
Barre	$167,003	$167,003	$177,209	$177,209	$186,169
Belchertown*	$302,458	$302,458	$302,458	$303,811	$307,699
Hardwick*	$116,672	$116,672	$116,699	$116,699	$118,401
Hubbardston	$318,970	$318,970	$318,970	$318,970	$318,970
New Salem*	$592,675	$617,485	$631,305	$722,075	$722,075
Oakham	$121,417	$121,417	$128,162	$130,223	$133,502
Orange	$3,791	$3,791	$4,188	$4,375	$4,375
Pelham*	$368,734	$368,734	$368,734	$376,183	$376,183
Petersham*	$500,027	$500,027	$500,027	$500,027	$500,027
Phillipston	$11,913	$11,913	$11,913	$11,913	$11,913
Rutland	$458,918	$525,860	$525,860	$525,860	$525,860
Shutesbury	$283,212	$283,212	$283,212	$290,447	$299,392
Templeton	$1,082	$1,082	$1,082	$1,082	$1,082
Ware*	$341,384	$341,384	$351,016	$355,534	$360,842
Wendell	$22,895	$24,077	$24,077	$24,328	$24,328
Sub-Total Quabbin/Ware	*$3,611,150*	*$3,704,085*	*$3,744,911*	*$3,858,736*	*$3,890,818*
Wachusett Reservoir Watershed					
Boylston	$595,254	$595,254	$595,939	$595,939	$595,939
Clinton	$189,352	$195,912	$202,726	$204,088	$205,949
Holden	$900,838	$900,838	$919,616	$919,616	$919,616
Leominster	$8,561	$8,561	$8,561	$8,622	$8,688
Princeton	$255,315	$255,315	$255,315	$255,315	$255,315
Sterling	$587,714	$693,085	$707,823	$750,399	$750,399
West Boylston	$642,130	$642,130	$666,856	$670,855	$683,582
Sub-Total Wachusett	*$3,179,164*	*$3,291,095*	*$3,356,834*	*$3,404,834*	*$3,419,487*
Sudbury Reservoir Watershed					
Framingham	$261,931	$261,931	$261,931	$261,931	$261,931
Marlborough	$109,727	$109,727	$109,727	$109,727	$112,802
Northborough	$102,158	$102,158	$102,158	$102,158	$103,467
Southborough	$284,149	$284,149	$284,149	$284,149	$294,207
Westborough	$48,788	$50,656	$50,656	$50,656	$50,741
Sub-Total Sudbury	*$806,753*	*$808,621*	*$808,621*	*$808,621*	*$823,149*
Aqueduct Only					
Berlin	$46,426	$46,426	$46,426	$46,426	$47,008
Ludlow	$9,820	$9,820	$9,820	$10,297	$10,524
Sub-Total Aqueduct	*$56,246*	*$56,246*	*$56,246*	*$56,723*	*$57,532*
TOTAL	**$7,653,312**	**$7,860,046**	**$7,966,612**	**$8,128,913**	**$8,190,986**

*Includes second payment for lands annexed from disincorporated towns of Dana, Enfield, Greenwich, and Prescott.

About 50 miles at Quabbin Reservoir were still being mowed on a 3-year cycle until the late 1990s, but that effort has also since ceased. The firebreaks long ago lost their effectiveness as obstacles to wildfire, as fields and pastures on both sides of the line have been replaced by forest. Thus, once prominent visual aids are now growing difficult to see.

Adding to the problem, most of the new boundary associated with acquisitions over the past 25-plus years had never been maintained. Locating these property corners and then determining the resulting boundary lines has been a major undertaking; these efforts continue with new acquisitions. Deeds and plans of the acquired parcels along with deeds and plans of the abutting parcels are all used to aid in locating the property corners. In certain circumstances, DWSP has contracted for additional survey work to locate and monument property corners where deed descriptions were vague or conflicting.

Typical marking of boundary lines involves clearing brush and branches that interfere visually with the line, applying small metal boundary signs to trees on the DCR side at frequent intervals, and blazing and painting trees so that the line can be followed easily and seen readily when crossed at nearly any point along the boundary. Corner monuments may or may not be painted, but usually two to three witness trees are triple-blazed to help someone triangulate the location of an obscured stone, pipe, or drill hole. DWSP foresters, with help from other DWSP staff, have marked the vast majority of the boundary lines in all four watersheds.

Tracking

GIS is becoming an indispensable tool to assist in the mapping and future maintenance of DWSP property line information. An accurate polyline datalayer has been created to show property lines for almost all DWSP land. Depending on degree of available information and effort, line segments have been coded with attributes for the type of boundary (e.g., maintainable, un-maintainable, road frontage, stream frontage, etc.), whether or not the boundary is a stone wall, and the date last maintained. A point datalayer has also been created for many DWSP properties, which contains a record of each property corner, including the type of corner monument (e.g., concrete bound, drill hole, iron pipe, etc.) and comments on the condition of the monument or anything that may help staff find the property corner in the future. Both data layers are updated as new properties are acquired, either by foresters or GIS staff, and are made available through GIS staff to other DWSP employees. Table 4-4 shows a breakdown of DWSP property boundaries.

TABLE 4-4. DWSP WATERSHED PROPERTY BOUNDARY TYPES

Type	Miles of Boundary Type			
	Quabbin	Ware River	Wachusett	Sudbury
Maintainable	134.4	123	233.9	26.5
Unmaintainable (crosses very wet areas)	1.2	3.7	9.5	3.7
Stream course, pond shoreline	2.7	16.8	8.9	0.1
Road Frontage	81.8	93.3	84.2	17.1
Railroad Frontage	0.0	5.1	12.3	3.4
Major Highway Boundary	0.0	0.0	5.5	1.0
Total	**220.0**	**241.9**	**354.3**	**51.8**

Once any particular DWSP property boundary line has been located and witnessed at least once, ongoing maintenance will be less time consuming, consisting of repainting blazes, hanging new tags, inspecting the corner monuments and clearing brush when necessary. It is anticipated that all boundary lines and corner monuments will be visited and maintained on no more than a 10-year interval. Some lines may receive more frequent attention depending on land management activities or concerns with abutters.

Encroachments

The following is a list of the types of boundary encroachments that have been discovered on DWSP property:

- Water and soil impairment
  - Dumping of debris and hazardous materials
  - Storage of hazardous materials
- Forest and land destruction
  - Cutting, removal, and damage of trees and plants
  - Disturbance or removal of soil and ground cover
  - Paving or covering of soil and ground cover
  - Grading or filling land
- Construction
  - Installation of fences
  - Construction of sheds, walls, signs, and buildings
- Boundary destruction
  - Removal or destruction of stone and concrete bounds, iron pipes and witness trees.

Resolving encroachments is an on-going process. Most encroachments are uncovered during regular boundary marking activities. In addition, Watershed Rangers, foresters, Environmental Quality, and other staff often identify encroachments while in the field performing other duties. . Most situations are resolved through a series of letters and meetings following field investigation. Only a few court actions have been required, all due to significant forest damage.

In some cases, resolution only occurred after DWSP erected physical barriers, such as boulders, fences and earth movement. However, these are labor-intensive activities that may require future maintenance, so barriers are used only in extreme cases.

Cooperation with Abutters

DWSP staff work diligently to educate abutters about the agency's objectives for watershed protection. As the largest landowner within the region, it is extremely important for DWSP to maintain a good relationship with abutters to DCR property. Setting a good example of proper land stewardship for neighboring property owners may positively influence an owner's actions on their own property. By having a good relationship with abutters, it is more likely that neighboring landowners will report unauthorized uses or encroachment problems that may occur on DWSP land. This occurs on a regular basis, with many encroachments being reported by neighbors and other nearby residents.

Section 42 of Chapter 132 of Massachusetts General Laws, also known as the Forest Cutting Practices Act, includes the following requirement for notification of abutters:

> Every owner of land who proposes to cut forest products on land devoted to forest purposes, or to cause such products to be cut, except as provided in section forty-four, shall send by certified mail or hand deliver written notice of his intention to begin any cutting operation to the abutters of record on file with the assessors of the town in which the land lies, and whose closest boundary is within two hundred feet of the edge of the cutting area, at least ten days prior to operations

DWSP carefully adheres to this law, notifying abutters when harvesting on portions of the property within 200 feet of abutting private or other public property. Much of the work on DWSP properties, especially at Quabbin and Ware River, occurs greater than 200 feet from adjacent lands, so that notification is not required. The number of notified abutters usually increases significantly for Wachusett and Sudbury harvests, given the smaller land base, smaller average parcel size, and the pattern of recent land acquisitions.

Long-term Land Use and Access Agreements

Several DWSP owned parcels are under long-term use or access agreements with other state or municipal entities or with private parties. Examples exist at each watershed, and include parks and recreation areas, municipal well sites, landfills, gravel pits, flood control easements, and passage rights to access landlocked parcels. Monitoring of these sometimes decades-old agreements is required, but documentation is frequently absent or difficult to locate. DWSP will develop a complete listing and a monitoring protocol for these agreements. The listing will include locations mapped using GIS.

4.1.7 Rights-of-Way

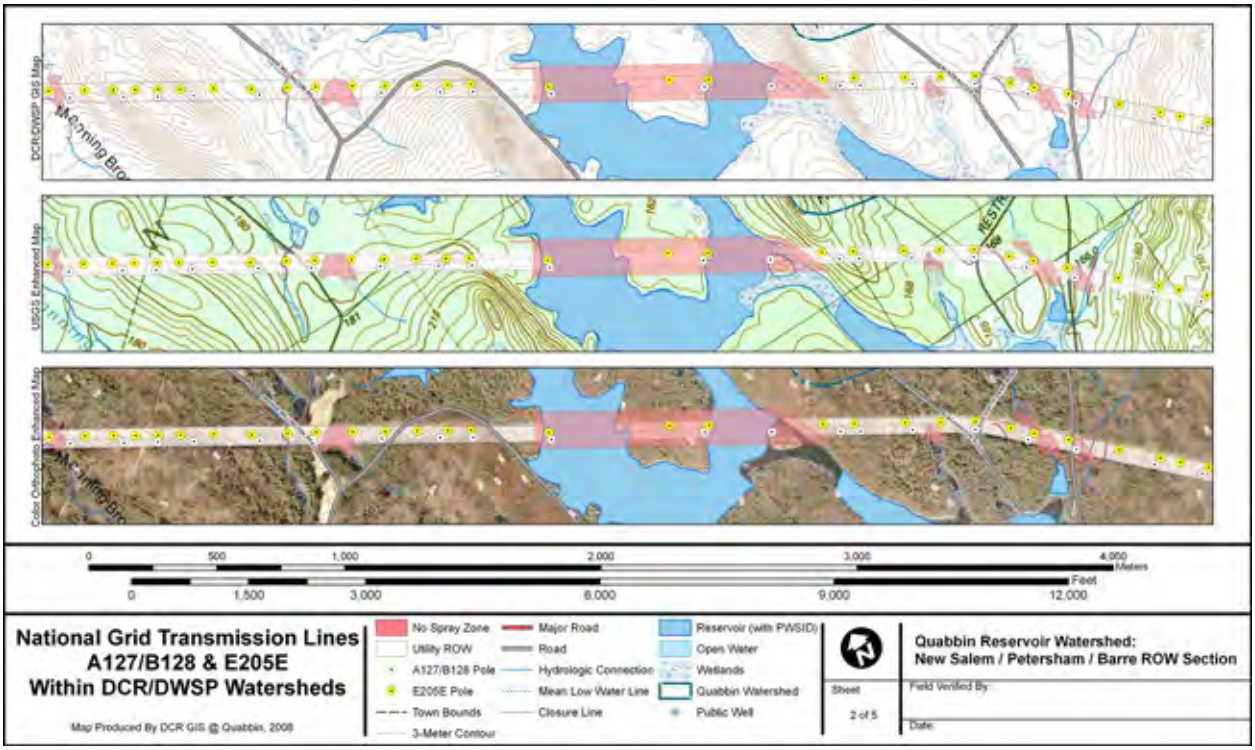
When the reservoirs were constructed, railroads, secondary roadways, power lines, and other public utility facilities already existed throughout the watersheds. Many of these facilities were relocated or discontinued due to the construction of the reservoirs. Rights-of-Way (ROW) were granted to the various entities to relocate, maintain, repair, upgrade, and replace utilities, which now pass through DWSP property.

Over the years, numerous requests have been received for new ROW or changes to existing ones. These requests are addressed through permits, leases, and easements on, over, or through DWSP watershed property. Requests for new or revised ROW are primarily received from electric power companies, railroads, telephone companies, and town utilities. Requests are considered on a case-by-case basis. The primary consideration of the review is to prevent adverse environmental impacts to any watershed resource. The applicant must agree to follow all applicable regulations and specific terms and conditions proposed by DWSP before the ROW is approved and any construction is permitted to proceed.

DWSP maintains site-specific watershed protection controls within ROWs of utilities, railways, and highways crossing DWSP watersheds. These controls are designed to minimize risks to water quality associated with the maintenance and use of these corridors in the watershed. Power line ROW are typically vegetated and maintained in a constant state of early succession to prevent contact with the wires, which could cause possible disruption of service. In order to conduct this maintenance, utilities in Massachusetts are regulated by 333 CMR 11.00, administered by the Massachusetts Department of Agricultural Resources (DAR). DWSP staff contributed to a significant review and update of these regulations, which was adopted in March, 2007. This law sets standards for managing ROWs, including use of herbicides and no-spray or limited spray setbacks from environmentally sensitive areas. ROW managers are required to develop and submit for approval both a five-year Vegetative Management Plans (VMP) as well as a Yearly Operational Plan (YOP).

As part of the approval process, DWSP specifically reviews and comments on the annual planned activities to apply herbicides to control vegetation. DWSP focuses on resource identification (public surface water supplies) and associated no spray and limited spray areas delineated on maps and in the field. Figure 4-2 presents a sample set of maps that identifies a power line ROW in relation to water resources. These maps were developed by DWSP staff to aid in the YOP review process prior to field visits. Monitoring is primarily targeted at buffer zone maintenance documentation and reporting. Staff work closely with DAR and utility representatives to ensure adherence to the regulations. DWSP staff also represent DCR on the Rights-of-Way Advisory Panel, established under 333 CMR 11.11, in the capacity as a public water supplier, to help review each VMP submitted to DAR.

FIGURE 4-2. RESOURCE MAPS FOR ROW SETBACK REVIEW



4.1.8 Hazardous Trees

With dozens of miles of forested frontage along roads and hundreds of miles of forested boundary along private property, hazardous trees are a topic of frequent concern to abutters of DWSP land, as well as emergency and road maintenance personnel in the various watershed towns. The cost of safely removing these hazards will surely rise as DWSP's forests continue to mature and increasing numbers of individual trees begin to decline.

Landowners abutting DWSP lands vary in their acceptance of the risk that accompanies dwelling near a forested edge. DWSP does not plan to establish (or re-establish) non-forested perimeters to eliminate all the potential hazards trees may pose to abutters and their property. However, valid concerns about dead or unhealthy trees are treated quite seriously. Current policy is to treat each request to remove a tree on a case-by-case basis. A forester is usually sent to assess the situation, and if the tree is determined to pose a hazard, then DWSP will try to get it felled and/or removed in a timely manner. Trained DWSP labor staff or DCR Bureau of Forestry's Forest Health program staff are able to handle some of the work, but usually the more dangerous trees are cut by a contracted, insured tree-removal company. On occasion, a landowner unwilling to wait has been given special written permission to have a tree removed at their own expense.

Roadside trees that appear to pose a threat to public safety are usually spotted by DWSP staff as they drive between worksites around the watersheds, but reports also come in from other sources. Periodically, state-approved tree removal companies will be requested to submit bids to fell

and/or remove hazardous trees. For example, during FY2010 through FY2015, DWSP spent on average $10,000 per year for tree removal work in the Wachusett and Sudbury watersheds.

Power line rights-of-way that pass through DWSP forests are also vulnerable to trees and their limbs. The companies that maintain the lines will contract with professional tree companies to periodically prune limbs and remove trees that may become hazardous to the lines, under the supervision of a professional arborist with notification and coordination as necessary with DWSP foresters.

4.1.9 Fire Protection

Threat, History, and Use of Fire on DWSP Lands

Forest fire is a potentially significant threat to water quality, forest health and public safety. Serious fires are capable of killing overstory and understory vegetation, consuming soil organic matter thereby exposing mineral soil, increasing nutrient loading to tributaries, as well as destroying personal property and endangering people's lives. Fortunately, large devastating fires are very rare occurrences in the forest types in this part of the country. Except in periods of severe drought, wildfires do not pose a serious threat to the central New England forest. Due to the high moisture content of our forest stands, downed wood and other organic matter decompose quickly and limit the accumulation of fuels. Thus, the vast majority of our wildfires are low-intensity, low flame-height, relatively cool fires that burn little more than a portion of the leaf litter and kill little of the understory or groundcover vegetation.

Local firefighters respond to a brush fire at Wachusett Reservoir, 2015

In drought years, though, large-scale uncontrolled wildfire can pose a serious threat to the watershed protection values provided by the forest, depending on the scale of the burn and its proximity to water resource areas. In dry years, the cumulative effects of many small burns may also present a water quality threat, especially if these are concentrated on individual sub-watersheds. Potential impacts may include increases in overland flow, erosion, and nutrient loading. Where organic layers are destroyed by fire, these effects may be prolonged during the protracted recovery of vegetative cover on the burn site.

Forest fire frequency over the last decade has decreased to very few, if any, incidents per watershed per year and these have all been less than 10 acres in size. Nearly all recent wildfires on DWSP lands have been caused by the visiting public and were associated with illegal campfires or improper disposal of smoking materials, though a few do occur as the result of escaped permitted spring burns on adjacent property. Some remote fires have been set by fishermen ignoring the prohibition against landing of boats on islands and the shoreline of Quabbin reservoir. Because of the limited acreage, most of these fires have little impact on the system's water quality. However, any fire carries many potential threats, both on and off watershed land, and therefore it is in the public interest to control all wildfires on DWSP property.

Controlled fires, however, can serve as useful management tools. DWSP staff participated in controlled management burns on DWSP lands in the 1980s. Controlled burns are deliberately ignited, controlled, and extinguished; they are designed to burn over a designated area for a specific management reason while minimizing negative impacts to water quality. Conducted by DCR state wildland firefighting crews, these burns provided valuable training for DWSP staff in equipment handling and in fire behavior, and served to create or maintain desired fire dependent habitat conditions that would be difficult to manage using other techniques. DWSP will resume us of prescribed fires to maintain habitat conditions and may also be used to establish regeneration or control invasive plant species in forest stands.

DWSP Roles and Responsibilities: Policy, Communication, Access, Support

The legal responsibility for the suppression of all wildfires, even on DWSP property, resides with the local fire departments. All suppression activities performed by DWSP staff will be in a supporting role under the direction of the town Fire Chief. Typically, the initial suppression is performed by the local fire department; in some cases the responsibility for mop-up, at least in part, is turned over to the DWSP. DWSP staff, especially the Watershed Rangers, have been trained in the Incident Command System, and often discover fires early and can remain on scene and assist local authorities with communication, gate access, and other logistics related to fire suppression.

The recent upgrade of the DWSP radio system provides direct communication to DCR Bureau of Forestry fire control personnel and the Massachusetts Emergency Management Agency (MEMA), which should greatly improve communication during wildfires.

The internal road system on DCR property is the link that allows fire-fighting equipment to get to the fire. Therefore, the continuing improvement and maintenance of these roads is key to the ability to suppress wildfires. Although much improvement of the existing gravel road networks has occurred, a concern is the vast acreage acquired since the 1980s and the often insufficient access into these lands (see Section 4.1.10 for a discussion of interior road maintenance)

DWSP has provisions to close all watershed lands to all visitors during conditions of extreme fire danger. This measure may be taken during drought periods when the DCR Division of Fire Control has rated fire risk as "Extreme" for five consecutive days. DWSP did close the watersheds to public access during a brief period in October, 1984, due to extreme fire danger conditions. In a March, 1994, meeting between the then-DEM and MDC, it was agreed that during periods of extreme fire danger, the two agencies would cooperate to provide trained personnel to keep fire watch from the tower at Mt. Grace in Warwick State Park. This site provides an excellent view of Quabbin and is best situated for triangulation with the Pelham and Princeton towers.

4.1.10 Access Roads

The access road network on DWSP property is integral to the proper management of watershed resources. The primary objective of watershed road maintenance is to provide vehicle access to support key management activities while minimizing adverse water quality impacts associated with these roads. The proper maintenance of these roads controls the deposition of sediment and organic matter into nearby tributaries and is among the most critical land management practices conducted by DWSP. Watershed Maintenance staff maintain the internal DWSP access roads and water structures.

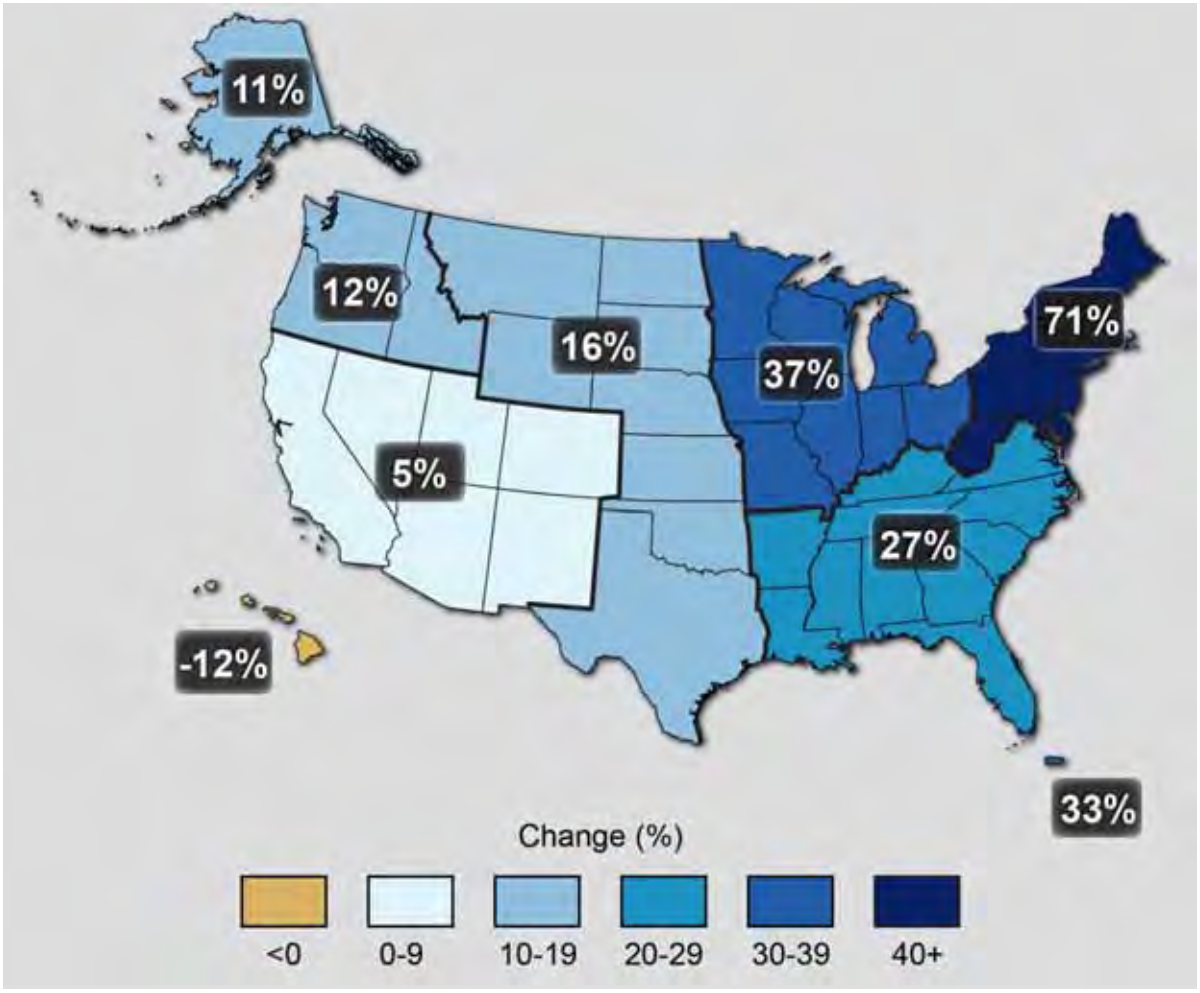
Environmental Quality staff use the roads to access water quality sampling sites. Forestry and Natural Resource staff use roads for watershed management, inspection and inventory activities. Civil Engineering staff require road access to inspect the various structures around the watershed. The Watershed Rangers require unhindered access to ensure the security of the water supply. Timber harvesters use the roads to access forest products purchased through DWSP's watershed management forestry program. In addition, the general public uses DWSP roads for various permitted recreational activities, including walking, biking, fishing, and hunting.

DWSP roads are also necessary during emergency situations. Emergency vehicles must be able to access the watershed in case of an accident or critical event to reach injured people. A quick response to environmental contamination is a critical component of watershed management, and the road system must be prepared for rapid responses to spills or other contamination. Finally, there is always the potential for wildfires that would require firefighting crews to access DWSP lands.

The amount of road maintenance needed is difficult to predict, but is dependent on weather conditions, the seasonal stability of the roads, and the level of use. Site characteristics such as topography, landscape position, or proximity to wetlands also factor into maintenance requirements. Storm events can make roadways impassable, either through fallen trees or limbs, or washouts due to blocked culverts. Recent trends suggest an increase in numbers as well as extremity of precipitation events, especially in the northeast U.S., as global temperatures rise

(Coumou and Rahmstorf, 2012; also see Figure 4-3), which could result in larger impacts to improperly maintained roads and undersized culverts.

FIGURE 4-3. PERCENT INCREASE IN PRECIPITATION FALLING IN VERY HEAVY PRECIPITATION EVENTS (1958-2012)



Source: NE Regional Climate Center, Cornell University

The vast majority of DWSP roads were county, town, or private farm/woods roads that existed before the land was purchased for water supply purposes. Many of these roads have been upgraded by DWSP over the years to meet the demands of current vehicle use. Other roads have been constructed more recently for various reasons. All DWSP roads are categorized based on their current condition and use. In some cases, the prioritization of road maintenance will coincide with access needs for forest management activities. In these cases, the Chief Forester will identify road work needs to the appropriate staff in April each year to help prioritize annual road maintenance work plans.

Road Categories

All four watersheds utilize roads for active forest management and other watershed operations. However, the Quabbin/Ware road network is much larger and used for more purposes than at Wachusett/Sudbury. The differences lie mainly in the requirements for public vehicle access. Extensive road mileage in Quabbin and Ware is seasonally open for public travel, including many of the roads at Ware River, the roads leading to the three Boat Launch Areas at Quabbin, and the gravel roads permitted for use during Quabbin's controlled deer hunt. In contrast, the mileage of DWSP roads at Wachusett/Sudbury is much less, and sees a more limited amount of activity, since these are permanently gated roads and do not allow unrestricted public vehicle access. These fundamental differences have resulted in differing road construction standards and maintenance schedules. Tables 4-5 and 4-6 present the classification that each operational section utilizes for the roads in their respective watersheds. The current classification of roads is adaptable and may be revised as access requirements change. The various watershed road systems will continue to evolve to best meet DWSP needs.

A special category is designated for Tractor Trailer Access Roads in the Quabbin Reservoir and Ware River watersheds. These roads generally include all Type I Roads, many of the Type II Roads, and some of the Type III Roads. Examples of Tractor Trailer Access Roads include the Gate 17 road, used to access Prescott Peninsula on Quabbin Reservation, and East Street inside Gate 49, accessing much of the Hardwick shoreline at Quabbin.

These roads are designed to be used by heavy equipment, such as tractor trailers, and contain specific design elements to accommodate the longer wheel base (a wheel base of 50 feet was chosen for design). Special considerations must be given to the maneuverability of the trailers accessing these roads; trucks must have the ability to turn around or seek other means of egress, to gain traction on steep grades, and to maneuver curves within the vehicle's tracking limits. These roads typically serve as a principal access point for very large blocks of land and therefore must be designed to accommodate a concentrated and higher volume of truck traffic with heavier loads than might be expected of roads designed for standard tri-axle logging trucks accessing smaller areas. Changes that have occurred within the forest products industry (e.g., local mill closings) makes trailer access more critical as these larger vehicles are needed to economically transport forest products long distances.

DWSP recognizes that the differences between standard tri-axle logging trucks and trailers may extend beyond simple physical dimensions. As tractor trailer loads are frequently 'back-hauls' of logs by French Canadian drivers, there may be language barriers as well as a lack of familiarity with the DWSP woods road system. Over the last several years, DWSP has improved road name signage at the Ware River and Quabbin, and installed intersection numbering signage at Quabbin and Wachusett. In addition, information given to loggers includes maps identifying critical resources areas, like stream crossings, and Spill Notification written in both English and French. An improved knowledge of the road system will serve to improve traffic safety and spill prevention/response capabilities.

TABLE 4-5. DWSP ROAD CATEGORIES FOR QUABBIN AND WARE RIVER WATERSHEDS

Classification	Miles	Description	Maintenance
Type I Critical	50	Critical roads, which include the Quabbin Park roadways, Shaft 12 Road, and Coldbrook Road, that are open year-round and are available for use 24 hours a day, seven days a week. They are all paved, except for Coldbrook Road, which is gravel (and closed during mud season). Type I roads provide restricted access to administrative and infrastructure facilities, including MA State Police. The drainage systems are adequate to protect roadway in most climatic conditions.	• Ditches and culverts checked and cleared during the spring and fall; culverts replaced as necessary. • Winter plowing. • Storm damage (tree removal) remediated. • Roadside brush mowed yearly. • Road surface problems repaired as encountered. • Grading as needed.
Type II Primary	142	Main roads that are used for DWSP and Army Corps of Engineers operations and emergencies and provide limited access for permitted public use with seasonal restrictions. They include Quabbin internal loop roads connecting Gate 4 to Gate 12, Gate 22-50, and Gate 17-22, as well as Ware internal roads. The roads are primarily gravel, though some are paved. Most Type II roads will be closed during the spring mud season. The drainage systems are adequate to protect roadways throughout most of the year.	• Mowing at least twice per growing season. • Ditches and culverts checked and cleared during the spring, fall, and storm events; culverts replaced as necessary. • Roadside brush mowed biannually. • Road surface problems repaired as encountered. • Grading as needed.
Type III Secondary	130	Secondary gravel roads that spur off internal loop roads. These processed gravel roads need to be passable for watershed management activities, such as the annual Quabbin controlled deer hunt, and emergency response vehicles. Most Type III roads will be closed during the spring mud season. The drainage systems are adequate to protect roadways throughout most of the year.	• Mowing at least once during summer. • Ditches and culverts cleaned during fall and kept free of debris; culverts replaced as necessary. • Roadside brush mowed biannually. • Road surface problems repaired as encountered. • Grading as needed.
Intermittent	27	Intermittent use roadways that are gravel or grass covered. These roads are opened for vehicle access for special projects only, such as boom shack installation and timber harvests. Adequate for use except when conditions are wet or trees are in the road.	• Mowing at least biannually. • Cut back brush as needed. • Maintain road surface as problems are encountered. • Check/clean drainage structures as needed.

TABLE 4-6. DWSP ROAD CATEGORIES FOR WACHUSETT AND SUDBURY WATERSHEDS

Classification	Miles	Description	Maintenance
Type II Primary	22	Primary roads provide unrestricted access to areas of the watershed necessary for daily operations and emergencies with relation to the reservoir itself and any key tributaries. These roads need to be passable for most types of vehicles at all times.	• Mowing at least twice per growing season. • Cut back brush yearly. • Maintain smooth and dry road surface continuously. • Check/clean drainage structures during the spring and fall seasons.
Type III Secondary	14	Secondary roads provide unrestricted access to areas of the watershed during emergencies with relation to the reservoir itself and all tributaries. These roads need to be passable for emergency vehicles at all times.	• Mowing at least once during summer. • Cut back brush biannually. • Maintain road surface as problems are encountered. • Check/clean drainage structures during fall season.
Intermittent	48	Roads provide access that is not met by either Priority One or Priority Two roads. Examples include any outlying watershed land that does not immediately impact reservoir operations. These roads need to be passable with vehicles designed for off-highway travel at all times.	• Mowing at least biannually. • Cut back brush as needed. • Maintain road surface as problems are encountered. • Check/clean drainage structures as needed.

Operations and Maintenance

This section describes ongoing operations and maintenance processes for roads in the watershed system. General road maintenance occurring on a regular basis includes annual grading of some heavily-used roads, removal of hazardous roadside trees, roadside mowing (which facilitates drainage and keeps roads open), culvert replacement and the processing and spreading of gravel as needed to maintain access or for specific land management activities. The Wachusett / Sudbury Section is finalizing an Operations and Maintenance Plan for the Wachusett Watershed. A plan for the Sudbury Watershed will also be developed. DWSP will develop a Road Plan for the Quabbin Reservoir and Ware River Watersheds that addresses internal needs as well as the changes in the timber harvesting industry, identifying specific sections of roads that will need grading and other improvement work over the next ten years, such as the addition of bank run and processed gravel.

Routine Road Maintenance

DWSP roads require certain levels of routine maintenance to ensure good access, and this work is prioritized based on both need and use level. Routine maintenance includes: vegetation control, road surface maintenance and care, and drainage structure care. Routine maintenance does not include emergency repairs such as fallen trees or washouts, which are fixed as soon as possible based on road priority.

Vegetation Control

- ***Mowing*:** Many access roads in the watersheds are unpaved and typically support some grass and/or other vegetation cover. Without regular mowing these roads would eventually become overgrown and impassable. Mowing controls grass height and kills off woody vegetation but still allows the grass roots to resist erosion. Roads are mowed annually or more frequently if needed.

- ***Tree Removal*:** Roadside trees are typically not a major concern on most roads because roads are wide enough for their intended use and regular maintenance assures that small brush and saplings along the roads edge do not become a nuisance. Sometimes trees fall across roads, and such obstructions are removed as soon as possible by labor crews.

- ***Pruning and Overhead Clearance*:** Over time tree crowns will grow over the top of roads. Regular cutting of overhanging limbs is necessary to allow passage of high vehicles. Such conditions will be reported during the regular surveying of the road network.

Road Surface Maintenance and Repair

A variety of environmental factors can affect the condition of roads. Melting snow, heavy rains, or muddy conditions may make some roads impassible during certain times of the year, and require temporary road closure. Limiting traffic reduces damage to sensitive roads and allows them to be fully serviceable during others periods. Internal reporting of road issues to either Civil Engineering or Watershed Maintenance ensures that problems are identified and repaired in a timely manner.

- ***Grading*:** A properly graded road allows for satisfactory drainage. In some cases, a simple crowned road is not sufficient. For example, if a road is going along the side of a hill, pitch the road surface to the downhill side. This will reduce the likelihood of water collecting on the uphill edge of the road and creating a channel.

- ***Potholes*:** Potholes are caused by poor drainage. Once a puddle forms, traffic deteriorates the saturated portion of the road by washing away finer material from the road surface. Filling potholes with gravel makes the road passable but does not solve the

underlying problem. Potholes need to be cut out down to the sub-base. Bring new material up to grade and compact. Finally, address the drainage issue to reduce standing water on the road.

- ***Rutting*:** Rutting is a result of high moisture content in the road base that causes tire depressions in the road's surface. Once rutting occurs, the depressions continue to fill with water and the condition deteriorates further. Cut rutted sections of roads down to the sub base and have new material added up to grade and compacted. In extreme conditions, add geotextile fabric under the road base. Finally, address the drainage issue to reduce standing water on the road.

- ***Depressions*:** Depressions are low areas caused by settling or material loss. Fix depressions by filling the low area up to grade with suitable material and compacting.

- ***Snow Plowing***: Snow plowing is limited to certain roads that are needed for regular access throughout the year. Plowing other roads will be done only as needed. Snow events can greatly reduce the ability to travel on access roads, and roads may only be passable by four-wheel drive vehicles.

Water Control and Conveyance Structures: Maintenance and Repair

- ***Roadside Ditches*:** Roads may be surrounded by higher ground on one side or both sides. In order for the road surface to drain properly, a ditch may be necessary to carry the water. Ditches are simply a channel that is cut along the edge of the road. Separate the ditch from the road to allow for adequate support to the road shoulder. Inspect ditches annually and clean at least twice a year to ensure water flows properly.

- ***Water Dips/Bars and Relief Culverts*:** In some cases, grading a road surface may not be enough to remove the water from the road. Water bars may be installed at points along the road to force water to one edge. Water bars in their simplest form can be either a depression/dip or a mound of gravel that runs across the road. In some cases a structural member, such as a wood pole or open topped box culvert, may be necessary. Angle water bars approximately 30 degrees from perpendicular in the downhill direction. The frequent removal of stormwater runoff from the roadside ditch is important to limit the amount of soil and gravel that is washed from an area during an event. Relief structures include culverts that carry water under and across a road from a ditch on the uphill side, as well as simple cuts through a raised bank to send water from a ditch off into the adjacent woods.

  The spacing of the relief structures is determined by combining site data such as slope of the road, slope of adjacent woodland, soil type and depth, and physical structure of the

road. The general rule of thumb is to place relief structures as often as the landscape allows on most slopes. Relief structures, wherever possible, will discharge the storm runoff not less than 50 feet from streams or wetlands.

- ***Sediment Traps*:** These small basins are installed as part of road reconstruction activities to reduce the velocity of stormwater and to collect larger sediments. The traps are made by excavating a shallow depression adjacent to the road or by placing an earthen or stone berm across a low area or swale. The traps are sized to store 67 cubic yards per acre of road drainage area. Sediment collected inside of the trap is removed when it has accumulated to one-half the design depth.

- ***Culverts*:** Culverts are subsurface conduits that convey water from one side of the road to the other. Most culvert work on DWSP property involves replacing old, undersized culverts that have failed due to age, wear and tear, blockage from beavers or fallen trees. Allow the length of the pipe for headwalls to be constructed on the inlet and outlet. For new road construction, Civil Engineering staff will determine the proper size culvert based on a 50-year storm event. Most culverts in the watersheds are 12" to 24" in diameter. Culverts will be placed to match the slope and orientation of the existing channel. Height of cover (depth of soil above the pipe) of suitable material will be determined by road type and expected uses.

  Both ends of a culvert need to be treated appropriately to reduce the effects of erosion. In most cases, a stone or concrete headwall will be built around the ends of a culvert. The headwall not only reduces scouring around the pipe but also guides water into the opening and supports the road base from collapsing around the openings. On the outlet end, heavy angular rocks (rip rap) can be piled to create a pooling area for the water to dissipate its energy.

  - **Culvert Replacement/Removal:** When a culvert needs to be replaced, evaluate the situation to determine if the existing culvert is appropriately sized and meets stream crossing guidelines or if it should be replaced with an alternate crossing. Recent history has shown that storm events are increasing in magnitude and frequency.

  - **Stream Crossing Guidelines:** Replacement culverts will also be chosen and designed to meet recently revised requirements for the protection of fisheries and other wildlife use of streams. DWSP will design, when possible, replacement stream crossings on fish-bearing, perennial streams and/or where critical habitat has been identified that are consistent with the fish-passage standards established under the Massachusetts Riverways Program, Massachusetts River and Stream Crossing Standards dated August 6, 2004. The standards can be found at www.streamcontinuity.org.

Road Project Planning and Review

Internal Review

The vast majority of road maintenance and repair on DWSP properties is accomplished by DWSP staff and equipment. DWSP crews use various mitigating procedures to protect stream water quality during routine maintenance activities. Prior to any road work proceeding, a work plan will be developed and reviewed by the appropriate DWSP section to insure that the work is in compliance with management plans and all applicable federal, state, and local regulations.

- ***DWSP Environmental Quality***: Environmental Quality section staff will be consulted for road work near sensitive areas, including land within 100 feet of bordering vegetated wetland (BVW), land within 200 feet of a perennial stream, and any work that may potentially impact a water or wetland resource.

- ***DWSP Natural Resources***: The Natural Resources section will be consulted to determine if there are any known endangered, rare, or threatened species within proximity of the proposed road work. If species are identified then the Natural Resources section will consult with the Natural Heritage and Endangered Species Program to determine if there are any potential impacts and ensure proper mitigation procedures are followed.

- ***DWSP Foresters***: The foresters are consulted to determine if the road work may assist or interfere with forestry operations.

- ***DWSP Civil Engineering and Watershed Maintenance***: Both Civil Engineers and Watershed Maintenance staff have a role in design and operations of watershed roads.

- ***DCR Archaeologist***: Historical and archaeological sites will be protected during road repair or construction. The DCR Archaeologist will be notified before any projects begin. A map of the location will be reviewed and a site visit may be required. The Archaeologist will determine whether the site has historical significance. Projects may need to be redesigned to avoid conflicts.

External Permitting

Based on the project scope and the area of work, a variety of notifications or permits may need to be obtained prior to the commencement of work. Staff from DWSP's Natural Resources and Environmental Quality sections as well as the DCR Archaeologist will need to be consulted to determine if any permits or notifications would be required. The following regulations may be jurisdictional for road work projects.

- ***Dig Safe*:** Dig Safe (220 CMR 99) is to be notified before any road project involving ground disturbance. Dig Safe requires that any excavation work be reported to their call center three business days prior to the commencement of any work.

- ***Wetlands Protection Act:*** The Wetlands Protection Act (310 CMR 10) is administered by local conservation commissions. Any activity that may impact a wetland resource or area within 100 feet of a wetland resource area or 200 feet of a perennial stream will require the filing of a Request for Determination of Applicability (RDA) or Notice of Intent (NOI) with DEP and the conservation commission.

- ***Massachusetts Endangered Species Act:*** The Endangered Species Act (312 CMR 10) is administered by the Natural Heritage and Endangered Species Program (NHESP) in the Department of Fish and Game. The DWSP Natural Resources section shall be consulted to determine if there are any endangered, threatened, or special concern species within the proposed area of work. Any project taking place within a Priority Habitat will require review by the NHESP. DWSP complies with these regulations and will avoid or minimize damage to the species or habitats.

- ***Massachusetts Historical Commission:*** 950 CMR 71 requires projects that impact historical, archeological or cultural sites on state property to file a Project Notification Form with the Massachusetts Historical Commission. The DCR Archeologist is consulted for projects that may have a potential impact to determine whether a Project Notification Form will need to be submitted.

- ***US Army Corps of Engineers:*** Any project or activity that involves work or structures in navigable waters (33 CFR 329) or the discharge of fill into navigable waters (33 CFR 328) may fall under the criteria for a General Permit from the US Army Corp of Engineers. DWSP will obtain all required permits.

- ***401 Water Quality Certification:*** The 401 water quality certification (314 CMR 09) regulation is administered by the Massachusetts Department of Environmental Protection. The regulation applies to the discharge of dredge or fill materials into waters of the Commonwealth. Of particular note is the stricter criteria for Outstanding Resource Waters which includes the Quabbin, Ware, and Wachusett watersheds. There are some exemptions to the regulations that could apply to watershed maintenance activities, but DWSP will obtain certification as required.

- ***Stormwater:*** Any construction site where one acre of land or greater is being disturbed will require the development and implementation of a Stormwater Pollution Protection Plan (SWPPP) and filing for approval with the EPA and MA DEP. Some local

municipalities have stormwater by-laws that may require additional local approval by the conservation commission or the local Department of Public Works.

- ***Access to Public Roadways:*** In some cases, road work activities may require creating new permanent access to a public roadway. If the roadway is a state road then DCR would need to obtain official approval from the Massachusetts Department of Transportation; if it is a local road then from the local Department of Public Works.

- ***Massachusetts Environmental Policy Act:*** If the project is large enough and meets certain criteria, it may fall under the jurisdiction of the Massachusetts Environmental Policy Act (301 CMR 11). Examine the thresholds for review to determine if the project meets the requirement to file with the MEPA office.

Road Construction

Much of the roadwork conducted on the watershed is routine maintenance. Occasionally however, the condition of some roads may require additional work beyond regular maintenance to make them passable or accommodate more intensive use. In addition, new access roads may be needed and new sources of gravel may need to be developed to accomplish road work. In these cases, since the operations may result in habitat changes and possible impacts on water quality, wildlife, or cultural resources, the following procedures will be followed:

- Develop a plan by Civil Engineering staff showing the location to be affected, time sequence of removals, and procedures to be employed to ensure roads and/or gravel deposits provide quality long-term use.

- Consult with DWSP Regional Directors, Natural Resources, Environmental Quality, and the DCR Archaeologist to determine that no significant impacts will occur to water quality, wildlife, or cultural resources.

- Consult with, and complete all necessary approvals from, the Department of Environmental Protection, the Department of Fish and Game, Division of Fisheries and Wildlife (for information on both fisheries and rare species impacts), the local town conservation commission, and any other governmental entity with jurisdiction over the chosen site.

Best Management Practices for road construction include:

- ***Timing*:** Synchronize timing of projects with dry conditions at the work site. Conduct road work during dry weather if possible. Secure work sites during rain events in order to control erosion and runoff. Schedule projects that involve disturbances near or within wetlands and streams for the dry season, typically in August and September.

- ***Erosion Controls*:** Ground disturbance creates the potential for excessive runoff and the washing of loose material. Erosion control devices, such as biodegradable straw wattles, straw bales, or industry standard silt fence, slow the water and retain sediment. These devices are placed on grades where runoff is expected to collect and travel, thereby reducing the chances that untreated water will enter wetlands or other resource areas. Areas of disturbed soil will be graded and seeded with quick-growing grass species upon completion of road maintenance projects. DWSP has purchased a "hydro-seeder" for this purpose.

- ***Sediment Basins*:** Water leaving a worksite may also be treated in a sediment basin. A sediment basin is typically a permanent earthen structure in which water is impounded and suspended solids are allowed to settle out. Basins also reduce peak water flow leaving the site.

- ***Diversion Structures and Methods*:** To protect water quality while repairing or replacing a culvert in a perennial stream, water may need to be diverted around the active work area. Diversion can be accomplished by temporarily rerouting the stream through a pipe or dug channel, or by pumping from a protected pooling area above the work site through a pipe to a discharge site downstream of the site. To divert the water with pumps, the site is first protected with cofferdams and then a pooling area is created for the pump intake. The water is then pumped to the other side of the crossing and discharged into the downstream waterway. In either of these methods, a silt boom would be strung across the downstream water to capture any material carried off the work site by the water. Care must be taken not to trap any wildlife in the work site. Remove any animals from the site and release downstream.

- ***Spill Kits*:** A spill kit contains a variety of products used to contain small spills. Most DWSP vehicles carry a spill kit. All construction operations have spill kits on site. The spill kits can be utilized until more substantial cleanup equipment can be mobilized (see Section 4.2.6 on spill response BMPs).

Sand and Gravel

Sand and gravel is a limited, non-renewable natural resource used for maintenance and repair of roads and associated structures. There are several sand and gravel deposits utilized by DWSP on its property in the Quabbin and Ware River watersheds; there are extremely limited deposits used for routine operational activities in the Wachusett and Sudbury watersheds.

The towns of New Salem and Petersham also use sand and gravel from the Quabbin deposits. Permission for these towns to use sand and gravel from DWSP property comes from the Acts of 1938, Chapter 240, Section 4, which allows the towns to "remove, without cost, gravel in such amount as may be necessary for its municipal purposes from lands annexed" for the construction of the Quabbin Reservoir at places designated by DWSP. DWSP cannot indefinitely meet this requirement without careful planning and control of resources.

Most of the remaining sand and gravel in the watersheds, due to its depositional nature, is in valleys or underwater. This presents a significant challenge for DWSP to meet both the towns' requirements and its own infrastructure management needs. Site-specific issues regarding gravel removal include the presence of rare or endangered species, cultural and historical resources, areas of high public use, and areas close to water and wetlands. Even in suitable areas, challenges include topography, thin or inconsistent deposits, and limited work space or access.

The use of existing deposits is preferred over extraction from new sites. There is a low potential for water quality impacts at these existing locations, which have been in use for decades, as the vast majority of any water on the site percolates into the groundwater table. Utilizing a new site, depending on location, would involve planning and consultation with appropriate staff and outside agencies. Other options for material include the purchase of gravel from private land off-watershed and utilizing resources from aqueduct spoil piles.

DWSP will ensure the environmentally sound extraction of sand and gravel resources from its property. Water quality will continue to be maintained while meeting watershed management operational needs as well as legal obligations to the towns of New Salem and Petersham.

Beaver Effects on Road Conditions

Beaver populations in the state (and throughout the Northeast) remain relatively high as the number of trappers and mortality levels remain low. DWSP constantly deals with plugging of road culverts by beaver. In some situations, DWSP has successfully installed fences and water level control devices. These solutions, however, require periodic maintenance and do not offer permanent relief. Further, fencing and/or water-level control devices may not be useful in all problem situations on the watersheds. In situations where water level control devices are not an option, DWSP removes beaver either by trapping or shooting individual animals. Although this

solution may offer immediate relief, the habitat and conditions that attracted beaver initially have not been altered and these sites are often re-colonized within a short period of time. DWSP recognizes the limitations of these various techniques and is working to develop a long-term plan for beaver management along roads.

Both research and general observations suggest that beaver are more likely to occupy sites with lower gradient and smaller-width streams (i.e., first or second order), as well as abundant woody vegetation. In areas with flat topography, the total amount of woody vegetation was the primary predictor of beaver presence in New York State (Jensen et al., 1999). Because each site can be evaluated for potential beaver habitat and the probability of culvert plugging, DWSP will incorporate beaver considerations in choosing stream crossing methods. In addition to evaluating watershed area, road classification, and stream size and gradient, DWSP personnel will also consider potential beaver habitat during replacement or installations of culverts. Culverts that may already be experiencing chronic beaver plugging will be prioritized for upgrading or replacement.

Management Guidelines for Beaver at Road Stream Crossings

DWSP will incorporate beaver management considerations into road and culvert planning, when possible, to reduce the probability of culverts being plugged by beavers. Recommended practices include the following:

- Replace existing smaller culvert pipes with larger, oversized pipes, where feasible and applicable.
- Use box or pipe-arch culverts, when possible, with a minimum inlet opening area of 18 ft^2 (smaller sizes are easily plugged).
- Size the culvert so that that the width of inlet is at least equal to or greater than the width of the stream. This will decrease noise and minimize the potential for altering flow.
- Avoid creating a depression or pond at the inlet when installing culverts, as these are attractive to beaver.
- Do not install multiple smaller pipes at a site instead of a larger pipe. It is not a workable alternative, as smaller pipes are much more likely to be plugged.
- Utilize other management options, as needed in situations where beaver have a history of plugging even large culverts (see Section 4.4.2).

4.2 Forested Lands

4.2.1 Watershed Forest Management: A Protection Approach for Water Quality

Why forest?

DWSP has extensively reviewed the science behind watershed management and agrees that forest cover is the optimal land use to ensure the reliable protection of drinking water supplies and should be maintained on the vast majority of its lands. Trees, both individually and collectively:

- Intercept and absorb the energy of falling precipitation via leaves, bark, and litter, preventing soil particles from dislodging and eroding into streams.
- Develop organic soil structure that increases water infiltration rates and prevents erosional overland flow.
- Capture soil nutrients as they take in water through their roots.
- Accumulate biomass rapidly for long portions of their lives.
- Provide shade that regulates decomposition processes and the temperature of streams.
- Provide seed to perpetuate their occupancy on the landscape.

Forests multiply the effects of individual trees. Through the accumulation of organic matter, the growth of fine and coarse roots, the actions of soil-dwelling fungi, microbes, invertebrates and vertebrates, and other natural processes, forest soils develop unique properties of infiltration, hydraulic conductivity, and water storage (porosity) and contribute to the protection of water quality. Collectively, these soils serve as 'sinks' for various environmental pollutants, retaining them and slowing their movement into water supplies.

Are disturbances to the forest a concern for water quality?

DWSP watershed forests regularly experience moderate disturbances and occasionally experience catastrophic disturbances. These forests have been repeatedly impacted by: **snow and ice** storms; strong **winds** that accompany thunderstorms, 'nor'easters', microbursts, tornados, and hurricanes; occasional **fires**; intense **precipitation** events; chronic environmental changes including **air pollution** and **global warming**; and a very broad spectrum of both native and alien **insects and diseases**. Runkle (1985) calculated that between major disturbances, regular endogenous disturbances regenerate on average 0.5% to 2.0% of the temperate forest annually.

Occasional losses of individual or small groups of trees are not generally a problem for water supplies. The loss of a block of trees on a stable site that is not adjacent to the water supply may

result in only gradual, relatively minor adjustments to ecosystem processes, including nutrient losses from the site (Foster et al., 1997). On the other hand, the effects of catastrophic events that damage large or sensitive areas of the watershed forest may present potential water quality risks. For example, the uprooting of streamside canopy trees by hurricane force winds was shown to result in a four-fold increase in groundwater nitrate and a doubling of stream water nitrate (Yeakley et al., 2003); severe forest fires can significantly reduce soil infiltration, thereby increasing overland flow of water, sediments, organic materials, and nutrients (Dissemeyer, 2000); and higher peak stream flows resulting from snowmelt or intense precipitation events often correlate to bank scouring and erosion of sediments and nutrients to tributaries and receiving reservoirs (Thornton et al., 2000).

Is there a 'best' forest for watershed protection?

A *protection forest* has been defined by the Society of American Foresters as "an area, wholly or partly covered with trees, managed primarily to regulate stream flow, maintain water quality, minimize erosion, stabilize drifting sand, conserve ecosystems, or provide other benefits via protection" (SAF, 2008). Given the full suite of potential disturbances likely to influence DWSP watershed forests, a prudent and conservative approach to maintaining water quality is to deliberately create and maintain a protection forest that is both resistant and resilient in the face of a range of such disturbances.

A forest that is diverse in age structure limits the impacts of age-specific disturbances:

- Younger, shorter trees sustain less damage from severe windstorms than taller, older trees. The impact of the hurricane of 1938 on the forest canopy was documented by researchers at the Harvard Forest in Petersham, MA. On level or windward slopes, more than 75% of softwoods taller than 34 feet and hardwoods taller than 74 feet were damaged. The landscape pattern of disturbance ranged from individual trees to areas as large as 35 hectares (Foster and Boose, 1992).
- Forests with advance tree regeneration in the understory will maintain continuous soil protection and recover more quickly from disturbances to the forest overstory than will forests with poor understory development.
- Verry (1986) observed that harvesting will desynchronize snowmelt within a forested area and actually reduce flood peaks by 30 percent when a mosaic of young and older stands exists in the same area. Satterlund and Adams (1992) also concluded that management systems that are designed to increase the natural heterogeneity of a watershed will flatten and broaden the snowmelt hydrograph.
- Young, established stands of any species mix are accumulating biomass more rapidly than older, maturing stands, and therefore assimilating available nutrients more aggressively due to higher biotic demand for these nutrients (Bormann and Likens, 1979; Vitousek and Reiners, 1975; Smith et al., 1997).

Likewise, a forest that is diverse in species composition limits the impacts of species-specific disturbances:

- A forest that is high in species diversity is less susceptible to severe mortality than a single species forest when species-specific pests or diseases arrive (e.g., gypsy moth in an oak-dominated forest, red pine scale or white pine blister rust in monoculture plantations).
- Mature white pines were found to be more susceptible than hardwoods to damage from the Hurricane of 1938.
- As climate change affects our region, the natural ranges of tree species are predicted (with varying levels of confidence) to adjust in response to regional shifts in habitat suitability. Maintaining healthy, diverse, resilient forests in these rapidly changing conditions will require monitoring for negative responses -- difficulty in regenerating, or declines in general -- in the current suite of tree species, and may ultimately require planting to quickly establish those species expected to thrive here well in advance of their natural range expansions.

Do DWSP forests meet these conditions? What are the deficiencies?

DWSP forests are comprised of a mixture of stands of both natural and human-induced origin. Although many age classes are represented, the structure is heavily skewed towards stands 75 years or older. A large majority of forested acreage at all the watersheds can be dated to late 19th century farm abandonment, to the hurricane of 1938, or to plantations created just after the original land takings at each watershed. At Wachusett and Sudbury for example, less than 20% of manageable forest is younger than 40 years, and 25% is older than 100.

The planting of conifers on agricultural fields when the reservoirs were built created hundreds of acres of artificially homogenous forest stands. Many of these new forest stands were planted on sites where they have been susceptible to root rot and wind throw. Newly arrived pests have resulted in severe mortality. While many acres of plantations have been converted to natural diverse forests, more still remain across all DWSP watersheds.

At Quabbin, high levels of deer browsing had long interfered with successful tree regeneration. After over two decades of deer hunting at Quabbin, deer herds are being maintained at levels typical for the rest of central Massachusetts and the other DWSP watersheds. The Quabbin forest has recovered the ability to regenerate, but species diversity is still lacking. In addition, growing resident moose populations in central Massachusetts have added additional herbivory pressure on understory trees and vegetation.

Terrestrial invasive plant populations are expanding on all DWSP watersheds. A relatively small number of aggressive non-native plant species, if left to grow unchecked, could come to

dominate open areas and forest understories, and ultimately threaten both the long-term stability of the watershed protection forest as well as regional biodiversity.

What has been accomplished, and what should be the focus of forest management?

Building a watershed protection forest incorporating enhanced vigor as well as age, size, and species diversification that maximizes resiliency without impacting water quality will take time. Maintaining this forest structure requires steady recruitment and release of young vigorous trees to replace predominantly mature stands. Employing silvicultural methods that range from single-tree to small group and patch regeneration cutting will develop forests comprised of a range of size and age classes, as well as a mix of species across the continuum from shade tolerant to shade intolerant. While infrequent catastrophic disturbances will still happen on the watersheds, the forest that these will affect will include well-distributed patches of trees that are resistant to these disturbances.

Removing plantations has resulted in new age classes of diverse, site-suited species. This activity will continue until artificial monoculture conditions have been eliminated.

Several decades of improvement thinnings have reduced overstory competition within managed stands throughout watershed forests, shifting available resources to the most vigorous individuals and reducing their susceptibility to some forms of disturbance. When conditions warrant (i.e., dense stocking impacting good growth and vigor), these practices should continue to be used in conjunction with regeneration harvests as an additional means of building resistance and resiliency into the watershed forests.

A suite of well-established planning and logging practices has been used to minimize threats to water quality from management activities. These will continue along with additional monitoring of water quality effects/impacts resulting from harvesting.

The proper management and protection of wetland and riparian zones will continue to be a critical component of watershed protection, in part because these frequently are concentrated water supply source areas and because they represent the final opportunity to capture mobile sediments/nutrients before they enter surface waters.

The protection of regional biodiversity is mandated for Quabbin and Ware River watershed forests, and is desirable throughout the watershed system. Silviculture continues to be used to enhance important habitat features, while other features may be improved where deliberate non-silvicultural management is employed.

4.2.2 Goals for DWSP Controlled Forested Areas

The desired future condition for the watershed protection forest is a mosaic of managed and unmanaged areas incorporating both planned and inherent diversity, which together enhance long-term forest stability, ensure the continued production of high quality drinking water, and promote and maintain regional biodiversity.

Actively Managed Forested Areas Goals

- ***Create and maintain a watershed protection forest, resistant to and resilient from disturbance***
  - *Monitor, maintain, and enhance overall forest health.*
  - *Encourage diversity of native species, while favoring those that are long-lived and adapted to site conditions.*
  - *Create and maintain diversity of forest structure.*
  - *Maintain the ability of the forest to establish abundant, diverse regeneration.*

- ***Prevent negative impacts to water quality***
  - *Maintain and improve access roads in order to protect water quality at stream crossings while further improving access for all watershed management needs.*
  - *Prevent soil degradation and erosion of sediments and nutrients by complying with or exceeding environmental regulations for timber harvesting and by matching harvest systems with site conditions.*
  - *Limit cutting to no more than 25% of the total stocking within DWSP forest on any given subwatershed during any given 10-year period.*
  - *Maintain riparian forest areas to promote nutrient assimilation, filtration, and stream temperature regulation.*

- ***Protect and enhance biodiversity***
  - *Control invasive plants that impede the establishment of successful tree regeneration according to DWSP's Terrestrial Invasive Plants Management Strategy.*
  - *Protect and/or enhance known populations of uncommon or rare plant and wildlife species and their habitats through appropriate silvicultural planning, according to NHESP recommendations.*
  - *Maintain early successional forested habitats where feasible and applicable.*

DWSP's goal for managed forested areas is to steadily and systematically transition its generally older-aged forests to a more diverse and balanced multi-aged structure while supporting a diverse mix of native species. Forest management will continue to be used to promote healthy and vigorous trees of all ages throughout the existing range of growing conditions, from rich mesic forested areas adjacent to watercourses with their great capacity to consume nutrients and water, to upland areas with their increased exposure to damaging strong winds. Treatments include thinning to provide conditions that promote vigorous healthy residual trees during their phase of most active growth, and also include creating variously sized openings to allow new young trees to develop. All management activities are carefully designed, reviewed, and executed with the overarching goal of protecting short- and long-term water quality.

DWSP recognizes that its goal of managing watershed forests to be resistant and resilient can also be compatible with a variety of other important or ancillary benefits. For example, although economics have never driven DWSP's forest management, the various forest products harvested from these well-managed lands have value and an economic impact in local watershed communities. However, long-term ecological impacts may be perhaps even more valuable. In order to ensure biodiversity, providing a range of habitat conditions for indigenous plant and wildlife species - both common and rare - can be accomplished in the context of good watershed forest management. For example, early successional forested habitat has been clearly identified as a rare habitat type within the state (Massachusetts State Wildlife Action Plan 2015; Dettmers and Rosenberg, 2000). By its nature, early successional forested habitat is dynamic both spatially and temporally. It must either be continually created or maintained at that successional stage or it will mature into older forest. This plan discusses how DWSP will use carefully reviewed even-aged management techniques to create and/or maintain this habitat within designated focus areas on its lands. In contrast, the plan also discusses methods that are used to promote characteristics common to much older forests, for the benefit of those species that prefer such habitat.

To ensure continuity of all parts of the protection forest, tree regeneration needs to proceed without excessive interference by herbivores and invasive plants in order to assure the rapid replacement of forest cover when it is reduced by disturbances. DWSP uses deer population control and terrestrial invasive plant control as tools to help meet this goal.

Rare and uncommon species contribute to the biological complexity of a landscape or region. Efforts to identify and protect rare or endangered species or habitats will continue on DWSP land. Future studies to locate and classify rare natural communities may be initiated. Actions to protect and enhance these species and habitats will provide critical protection of important components of biodiversity.

Progress towards achieving all of these goals and objectives will vary with many factors, including the size of the watersheds, staffing levels, harvester availability and productivity rates, self-imposed and mandated restrictions on management practices, invasive plants, insects and diseases, the pace of plant succession and growth, fluctuations in both economic and public values, and uncertainties about the effects of global climate change. The approach in this plan is based on DWSP's most recent experiences and their influence on practical expectations, and a conservative interpretation of the science of watershed forest management.

Limited Management Forested Areas and Reserves Goals

- ***Protect water quality***
  - *Maintain access roads in order to facilitate emergency response to fires, recreational accidents*
  - *Prevent the spread of wildfire, to the extent possible, into or out from these areas.*
- ***Conserve regional biodiversity***
  - *Maintain forest reserves on a portion of DWSP's holdings.*
  - *Control the establishment and spread of invasive species in these areas according to DWSP's Terrestrial Invasive Plants Management Strategy.*
  - *Inventory and protect rare, endangered, and other state-listed species and their habitats within these areas with guidance from the Natural Heritage and Endangered Species Program.*

Forest management is limited to non-extractive silviculture treatments on approximately 25% of the DWSP properties on the Quabbin Reservoir, Ware River, and Wachusett Reservoir watersheds, and on 42% of DWSP properties on the Sudbury Reservoir watershed. Several factors are considered when identifying these locations, including accessibility and operability (steep slopes, islands), historic or ecological sensitivity (in areas defined as historically or naturally rare or significant), environmental regulations (wetlands), or deliberately defined reserves (Poutwater Pond Nature Preserve, Pottapaug Natural Area, portions of Quabbin Park). The goals for these non-management areas vary somewhat from site to site.

The primary reason for incorporating forest reserves into land management planning is to ensure representative indigenous flora and fauna are protected (Norton, 1999). Forest reserves are important to a species adapted to natural forest disturbance regimes. In addition, forest reserves can act as a reference or "control" site in which to assess the impact of management activities. Further, reserves also provide a different aesthetic opportunity and have a different character than managed forests.

DWSP has set aside a 232-acre Poutwater Pond Nature Preserve in the Wachusett Reservoir watershed and the 1,183-acre Pottapaug Natural Area in the Quabbin Reservoir watershed. In addition to these formally designated reserves, there are thousands of additional acres that are challenging to manage and thus currently function as small reserves. Examples include islands, steep slopes, wetlands, etc. All together, these areas with restricted management total as much as 20-25% of DWSP holdings.

4.2.3 Watershed Forest Management Planning and Activities, 2001-2014 Management Plans

Ten-year Land Management Plans have been produced since 2001 for all four DWSP watersheds; while each plan addressed situations and challenges unique to its watershed, many fundamentals were carried over from one plan to the next.

Quabbin

In 2007, the last of four individual Quabbin Reservoir plans was produced. Prior Quabbin plans emphasized thinnings to enhance tree vigor and advocated for an uneven-aged approach to regenerating stands. By 2007, deer populations had been reduced and forest regeneration was possible, although still influenced by decades of overbrowsing. The 2007 plan increased the maximum opening size to two acres and initiated the practice of careful mapping of openings to calculate new age class acreage. At the same time, a zoning system was put in place to vary opening sizes with distances from surface water resources matching those from the Watershed Protection Act, and a subwatershed-level check was implemented to ensure that the harvest rate remained below a level that might lead to detectable water yield changes, as shown in the forest hydrology literature.

Ware River

In 2003, the Ware River Land Management Plan was written, and it emphasized developing a vigorous, diverse, low-maintenance protection forest and shifted focus away from trying to increase water yields. Three management areas were identified: 1) unmanageable or non-managed areas; 2) areas harvestable but limited by legal regulations; and 3) all other manageable lands. Ecological functions beyond the primary DWSP goal of water quality were given more consideration, and silvicultural options included more even-aged management with openings up to 10 acres. Regenerating 1% of the forest each year was a goal, and of that acreage about 46% would be in single-tree to two-acre openings, 37% in full overstory shelterwood removals up to five acres, and 17% in overstory removals up to ten acres with 20-30 ft basal area (BA) in retained trees.

Wachusett

In 2001, the first ever Wachusett Reservoir Land Management Plan was written. The forest management approach was based partly on the 1995 Quabbin plan, but was adapted to a forest with a much different scale and history. Regeneration silviculture was emphasized as the approach to systematically diversify age structure. The objective for each treatment was to regenerate up to one-third of the area using opening sizes ranging from 1/4 to two acres (averaging about an acre), with expected return cutting periods averaging 20 to 30 years. Over time, three age classes would be developed in any given area. The plan called for aerial photos to be retaken every five years to assist in the tracking of openings.

Sudbury

In 2005, the first ever Sudbury Reservoir Land Management Plan was written. Although the oldest part of the current water supply system, it was the last to enter the current era of active forest management, receiving its first silvicultural treatment at the Walnut Hill pine plantation in 1988. The silvicultural approach in the plan closely followed the Wachusett Reservoir Land Management Plan from 2001. The same range of opening sizes were used, and the goal of regenerating one-third of the forest in about 30 years was the same. In this plan however, GIS mapping was set as the standard for keeping track of progress towards age-structure diversity.

Changes and Controversies

The 21st century began with a period of transition in the agency and its approach to forest management. The Metropolitan District Commission (MDC) was merged with the Department of Environmental Management (DEM) into the DCR. This merger has led to both a stronger relationship between DWSP and the Bureau of Forestry within DCR's Division of State Forests and Parks, and to a closer alignment of harvesting standards and permit language within the agency. Both Divisions were included, along with the Department of Fish and Game's Division of Fisheries and Wildlife, in a state-lands Green Certification process in 2004. DWSP's forest management had been certified under Forest Stewardship Council standards since 1997, and it provided a framework for creating and implementing management plans on many other state lands. After a controversial 5-year Certification review audit process in 2009, all three state land agencies ultimately withdrew from the process, and no plans exist to pursue state-wide certification.

DWSP forestry continued under existing management plans until a temporary hiatus of any new forest management activities was initiated in the spring of 2010. Based on the recommendations of the Forest Heritage Plan presented by the EOEEA Secretary, a scientific review of the principles guiding DWSP forest management was to be conducted (see Section 2.4). That review concluded in February 2013, and with many revised procedures embodied in this plan, new lots were again offered for bid in the spring of 2014.

Table 4-7 summarizes the acreages treated in each of the four watersheds between 2001 and 2014.

TABLE 4-7. ACRES TREATED IN DSWP WATERSHEDS, 2001-2014

Treatment	Quabbin	Ware River	Wachusett	Sudbury
Acres regenerated to a new age class	1,761	1,122	764	45
Acres of partial harvesting (Thinnings, improvement cuts, regeneration establishment cuts, etc.)	8,563	560	704	22
Total Number of Silvicultural operations	219	140	82	4

4.2.4 Forest Management Objectives

The primary goal of forest management on DWSP lands is to create and maintain a healthy forest that best supports the protection of a high-quality drinking water source. DWSP's working hypothesis is that the forest that best meets this goal has the following characteristics:

- Comprised of vigorously growing trees, actively accumulating biomass and assimilating nutrients.
- Growing a diversity of site-suited species, adjusted to present conditions but adaptable to future conditions that may come with anticipated climate changes.
- Deliberately patterned with a mosaic of variably sized and shaped groups of trees from a multitude of age classes, well-distributed across each watershed.
- Harvested below levels that would trigger increases in water yield, thereby protecting surface waters from potential increases of sediments and nutrients.
- Capable of rapid regeneration and active growth following a wide range of both natural and deliberate disturbances.

These conclusions were reached after a critical review of research literature, consultation with an extensive array of academic and field professionals in natural resources management and related disciplines, and more than five decades of direct experience with watershed forest management. DWSP will continue to solicit public input as adaptive revisions are proposed during annual progress reviews, based on additional experiences and changing objectives.

The managed forest that was regenerated in the past decade was distributed among all forest types and origins, with some emphasis on replacing failing pine plantations (either diseased or growing in unfavorable conditions). Managing this great diversity of stands, comprised of different mixes of species originating from a variety of different events, has necessitated the application of varied silvicultural systems. Generally, stands dominated by long-lived trees well

suited to the site have been treated with uneven-aged or irregular shelterwood silvicultural methods, ranging from single-tree to small group and patch harvests. In the small minority of stands dominated by poorly growing trees, various even-aged silvicultural methods have been used to more rapidly regenerate and replace entire stands with trees better suited to the site conditions.

Converting an older, generally even-aged forest into a multi-aged protection forest is a long process that will take decades to fully implement and will most certainly be disrupted by frequent small and infrequent large disturbances (Kelty et al., 2003). DWSP plans to regenerate approximately 1% of the manageable forest on each watershed annually, in order to deliberately and steadily condition the forest at a rate within the range of long-term natural disturbance patterns. The plan also allows for large and small sections of the watershed protection forest to remain unmanaged.

DWSP also considers the current condition of individual management units (such as the presence of significant insects or diseases) and evaluates the condition of the access network (roads, landing areas) when making forest management decisions, and if necessary places limits on the size and type of equipment that can operate the area. Areas with special management restrictions, such as rare species habitats or cultural features requiring enhanced protection, are routinely identified. All silvicultural prescriptions are proposed through the annual Lot Review process (see Section 4.2.7).

Forest Management Objective: Maintain a vigorously growing forest.

DWSP will continue to monitor the health and growth of the watershed forest, and promote improvements in tree and stand vigor through carefully applied silvicultural practices.

DWSP uses an area-based approach to regulate cutting rate and track changes in age structure. However, inventory systems that extrapolate from individual sampled tree measurements can provide useful immediate and long-term data regarding the condition and changing nature of the forest. A version of the state's Continuous Forest Inventory (CFI) system has been used to assess the Quabbin forest since 1960 and Ware River since 1962 (see Section 3.4.1). CFI plot centers are permanently fixed on a 1/2-mile grid, and trees are re-measured every 10 years. At a minimum, the data collected includes species, physical dimensions (diameter and height), and mortality; other, more subjective data has been variably collected over the years and included estimates of vigor, soundness, damage by various agents, and silvicultural needs/options. As of this writing,

CFI data are undergoing a thorough review for accuracy and continuity, and a more complete report will be forthcoming. Previous 10-year analyses have shown that management practices for watershed protection, including over 1,000 harvest operations in the previous 50 years, have resulted in the removal of only about half of the timber volume grown over the same time period (DCR, 2007).

CFI plots have not been established on DWSP lands in either the Wachusett or Sudbury watersheds, and no plans exist to implement that system there. However, single non-repeatable inventories were completed in the 1980s and 1990s for each watershed, and the results were discussed in their respective Land Management Plans. Species diversity, basal area, and volume were calculated, but no long-term measures of forest growth are available. DWSP will evaluate the need for a further inventory of these watershed lands.

Foresters regularly evaluate the health of the managed forest on a much finer scale as they walk and collect data needed to plan for silvicultural management. Regeneration levels are measured, infestations of pests and invasive plants are noted, and other conditions are observed that help assess the potential vigor of the trees and the forest. "Cut the worst first" is a phrase applicable to all good forest management, including watershed forestry. Poorly growing, damaged, or degraded trees provide fewer protection functions and can be targeted for removal to leave room for more vigorous trees and improve the capacity of the forest to protect water quality.

Forest Management Objective: Promote diverse species composition.

Diversity of species: Silvicultural planning and harvesting operatioins strive to maintain canopy tree species diversity within the area except where:

- ***Conifer plantations are converted to natural forest cover.***
- ***Infected/infested trees are removed or salvaged.***

Regeneration is monitored, and results measured against natural canopy diversity as well as species desirability.

Species/site suitability: The species combinations growing on any given site are assessed for their vigor and suitability and, if necessary, shifted towards more appropriate combinations.

The strength and value of our central Massachusetts forest for natural water protection is a consequence of the diversity of species that commonly occur here. With several species growing together, any of them could fill available gaps in the canopy should one decline as a result of some external disturbance or biological agent. Many of the monoculture plantations of white

and red pine that were established when the reservoirs were created are now in severe decline due to insects and diseases. DWSP has actively been converting these to more diverse mixtures of native species.

Not all native species occur or compete equally. CFI data from 2010 shows that just a few species account for the bulk of the Quabbin forest. White pine and red maple make up over 41% of the trees measured. The top 13 species comprise almost 97% of the trees, while 17 other species make up the remaining 3%; these percentages are typical for the other watersheds as well.

Diseases and insect infestations could cause hemlock, white ash, and red pine to drop significantly in importance by the next measurement in 2020. Also, as climate continues to change, growing conditions are likely to become less favorable for some species. Seedlings and saplings of species with more northern distributions (i.e., beech, yellow birch, sugar maple, and even white pine) may find it difficult to survive the predicted warmer, drier summers, whereas the more southern oak and hickory species may experience a competitive advantage. DWSP foresters will continue to keep current about potential species composition changes, and will manage stands to allow for as much diversity as may be required to adapt to a highly unpredictable future.

Species/site suitability incorporates the many environmental variables that determine how individual tree species regenerate and prosper, both by themselves and in the presence of other species. The science of *silvics* concerns itself with the environmental requirements of species. Most native trees in DWSP forests grow and compete on a wide range of sites, but to varying degrees of success. There are specific site conditions where each species grows best and sometimes different conditions in which that species will compete best against other species. For instance, while the most vigorous growth by white pine occurs on mesic, well-watered sites (often toward the base of hills), hardwoods also grow well on these sites and may out-compete white pine in the early stages. On drier, uphill sites, white pine grows moderately well and can out-compete the more moisture-dependent hardwoods.

Most DWSP soils are predominantly acidic in nature due to interactions between climate, vegetation, and parent material. Acidic soils support our most common trees: white pine, red and black oak, hemlock, and red maple. Trees that require more alkaline soils, such as sugar maple or basswood, are present but not common in this area, where they often represent a legacy of residual roadside trees. Soil moisture availability and soil drainage are also important factors in site suitability. Pines do well on well-drained soils where their extensive root system can capture moisture throughout much of the growing season. Optimal conditions for white pine are well-drained sandy loam soils in river valleys with available moisture three to four feet below the surface. The oaks do well on soils that are moderately well-drained and have moisture available for much of the growing season. Optimal conditions for oak occur on terraces at the base of

steep slopes, where moisture and nutrients accumulate. Black birch is highly competitive on moist well-drained sites, but out-competed by white pine and oak on dry or poor soils.

Site/species associations on this landscape have been influenced, sometimes dramatically, by human land-use practices. Deliberate and accidental fires in the past have favored the establishment of oak because it is capable of recovery (through vigorous sprouting) following fire. Tree planting that occurred in the 1930s and 1940s often placed non-native conifer species on sites where they would grow well (mesic agricultural fields), but where they also were more susceptible to such problems as *Heterobasidion annosum* (formerly called *Fomes annosus*) root-rot. Grazing practices left behind species that were not preferred by the grazing animals, but that might not be the native species best able to grow vigorously on these sites.

While DWSP has aggressively converted most off-site red pine plantations to mixed combinations of native species, a small amount of this acreage remains to be converted. Likewise, other plantations and poorly formed white pine growing naturally on former pasture and field sites will continue to be converted to mixed species combinations that are likely to persist longer in the face of both chronic and catastrophic stressors. Cover- type maps a century from now should show that those old human land-use influenced forest types will have shifted toward more naturally site-adapted (soil, moisture, slope, aspect) combinations.

Forest Management Objective: Enhance diverse forest age structure.

DWSP foresters will continue working to enhance and balance age diversity when prescribing regeneration treatments.

Overall, up to 1% of the manageable forest watershed-wide will be regenerated to a new age class each year.

DWSP will strive to have at least three age cohorts well represented in each working unit or compartment, and all age classes represented and well distributed across the landscape.

Catastrophic hurricanes have the ability to disturb a significant portion of the forest, changing species composition and age distributions suddenly. A forest's resistance to and resilience following such a large-scale stand disturbance can be enhanced by the presence of a range of differing tree ages and heights. This diversity can be *horizontal*, as a mosaic of well-defined areas (groups or patches) of young forest, containing trees free to grow and compete among

themselves for survival in the patch. Until they reach certain height thresholds, these areas should remain quite resistant to wind disturbance. Small naturally formed gaps in the forest can result from the death of a single tree; large blowdowns comprising hundreds of acres may appear during the largest hurricanes. For both ecological and operational reasons, DWSP will regenerate the majority of the watershed forest by creating openings of a variety of sizes but averaging overall about one acre. Section 4.2.4.1 for further explanation.

Diversity may also be *vertical*: young trees, either naturally or with encouragement, may be established and grow as a backup forest underneath a diverse and otherwise healthy overstory that is more vulnerable to windthrow. In the absence of a disturbance to the canopy, tolerance to shade will determine the longevity of these understory trees. Very shade-tolerant species such as hemlock, black birch, red maple, sugar maple, and beech may continue to grow under the main canopy, forming a sub-canopy of younger trees, creating a multi-aged, multi-layered stand. These shade tolerant sub-canopy trees may eventually replace the main canopy when the overstory is cut or dies due to age or natural disturbance. Shade-intolerant species (for example, gray birch and trembling aspen) may never have enough light to germinate or survive beyond seedling stage. Species of intermediate tolerance may establish and survive for years, but ultimately die in the absence of additional forest management activities that would release them from the understory.

Overall resistance to wind damage in DWSP forests should improve as more areas are managed and more age classes are created, thereby increasing the acreage with trees shorter than the critical height categories calculated in the hurricane research. Resilience should improve in areas where improved vertical diversity provides young trees in place to reoccupy the site should the overstory be destroyed. This combination of increased horizontal and vertical diversity strategies should translate to less impact to water quality in the event of a major windstorm. Fewer trees blown over means fewer breaks in the continuous root layer, less exposed soil, reduced fire hazard, and therefore a lower risk of subsequent nutrient, sediment, and pollutant influxes to tributaries and the reservoir.

Forest Management Objective: Protect water quality and prevent changes to water yield

Proposed harvests are analyzed to ensure that planned operations will not remove more than 25% of the total stocking in any given 10-year period for any subwatershed.

DWSP will utilize Best Management Practices that protect water resources during harvesting.

While the focus of DWSP's mission is the overall condition of the watershed and the quality of the water in the reservoir, those conditions reflect the collective conditions of a group of smaller drainages, or subwatersheds. DWSP subwatersheds are defined in most cases as the land area that drains to perennial tributaries of the reservoirs at specific points where regular water samples can be collected. For analysis purposes, lands that discharge groundwater directly into the reservoirs (for example, hillsides along the shoreline outside of mapped subwatersheds) are grouped together in convenient ways and treated as additional subwatersheds.

The general theory behind the use of subwatershed-based planning is to control the proportion of a drainage area that is "disturbed" by management activities (e.g., logging or roadwork) during a defined management period in order to reduce the chances of water quality impacts. This approach is based on research on experimental watersheds throughout the eastern US, which indicates that until approximately 25-30% of the watershed forest overstory stocking is harvested (assuming nearly 100% forest cover type), there is little to no detectable increase in water yield (Hornbeck and Kochenderfer, 2004; Hornbeck et al., 1993). Increases in water yield are directly related to increases in transport of sediments and mobilization of leached nutrients to tributaries and reservoirs. Water yield can increase in more heavily disturbed watersheds, but generally returns to pre-harvest levels as the harvested area regenerates – usually within 3-10 years.

Since this 25% standard was adopted in the 2007 Quabbin LMP (and simultaneously applied to all the watersheds), annual analyses have shown that cutting levels are consistently well below this threshold. This analysis will continue to be used annually by foresters before proposing logging operations for the current year. For ease of calculation, stocking removals are converted to land area (a ratio of 1:1 for openings, while partially cut acres are multiplied by the fraction removed) and compared against the land area of the subwatershed.

DWSP recognizes that many subwatersheds contain private properties outside of its control, especially on the Wachusett and Sudbury watersheds. While private forestland serves to protect water quality, there is no guarantee that this land could not be heavily harvested or even converted to other land uses, and thus it cannot be counted on to balance out DWSP harvesting levels. To minimize risk, the "25% rule" is calculated based only on DWSP-owned acreage in that subwatershed. DWSP monitors many activities on private lands in the watersheds, from

development to forest management, and this information could inform future decisions regarding subwatershed harvesting limits on DWSP lands.

Careful harvesting methods are necessary to prevent degradation of surface water quality. DWSP meets and typically exceeds the standards and practices required by Massachusetts forestry laws and regulations. These practices include the use of bridging for all flowing streams; increased filter strip widths and sensitive treatments within riparian zones; enhanced landing and equipment restrictions; avoidance of steep slopes and careful location and maintenance of skid roads and water bars; pollution prevention measures; spill response planning; weather-related suspensions; and increased protection for vernal pools.

Forest Management Objective: Maintain regeneration capacity on watershed forests.

DWSP will continue to monitor regeneration levels to evaluate the success of silvicultural activities and strive to control factors that negatively impact desirable tree regeneration.

Forests in New England are typically capable of self-regeneration. Mature trees produce seed annually, and in some cases produce copious quantities periodically. Some of this seed crop will germinate and persist beneath a mature forest canopy. Until these young trees die from lack of resources, they serve as a backup reserve forest in the event of canopy disturbances. Foresters apply silvicultural techniques to allow this seed to become established into young forest and transition into the next forest canopy in a more deliberate and controlled pattern than would appear naturally.

DWSP foresters have traditionally relied on natural seeding to regenerate these watershed forests. Several factors could threaten this critical forest process, including heavy and continuous browsing by large herbivores. Deer populations have been reduced at Quabbin to a point where tree regeneration is successful, although some desirable species are still at low numbers. Maintaining pressure on these herds through controlled hunting at Quabbin and open season hunting at Ware River and Wachusett will allow DWSP to continue its successful silvicultural work.

Interference from aggressive native and non-native plants will over time come to have a significant impact on the structure and diversity of these forests. Some of this effect has been influenced by deer browsing, especially at Quabbin, as seen in areas still dominated by Japanese barberry or hay-scented fern. In many cases however the spread of invasive plants is likely tied to past and current human land use patterns. The interface between residential or roadside areas

and forest tends to show heavier concentrations of these plants. Control of these plant populations will become vital where DWSP plans to regenerate forest.

Of particular concern is the difficulty successfully establishing oak regeneration in large areas of Quabbin watershed lands. Oaks are important both to humans and to a host of wildlife species (section 4.4.5 - *Hard Mast*). There are stands dominated by an oak overstory, that have been treated with partial overstory cuts in the past, often multiple times, that are nevertheless nearly devoid of oak in the understory. Black birch, white pine, hay-scented fern, and witch hazel are among the species dominant in the understory, as much of the silviculture to establish regeneration was done prior to deer population control (oak is a preferred browse species, those listed above are less so). Oak regeneration needs to be fostered in these areas to ensure the full diversity of long-lived, desirable species that comprise this protection forest.

4.2.5 Silvicultural Practices

Forest management activities will continue to emphasize the development of multi-aged or uneven-aged conditions on the majority of the managed forested area on DWSP property. With a goal of adequately regenerating the watersheds at a rate within the historic range of natural temperate forest disturbance patterns, DWSP aims to create young forests on up to 1% of the manageable acres each year. A parallel goal is to achieve a level of structural diversity that will condition the forest for resiliency at many scales. The size ranges and deliberate patterning of regenerated openings are discussed below.

Regeneration Silviculture

Developing Age Structure Diversity: Establishing and Releasing Regeneration

Adequate regeneration will be determined by the composition of species present and how well they are suited to the site, the overall numbers of seedlings/saplings, and their spatial arrangement within the stand. A high number of seedlings poorly suited to the site but well distributed is considered inadequate regeneration. Conversely, a patchy distribution of diverse species well suited to the site may only be adequate if these patches occupy enough of the area to warrant designation as a new age class.

An exhaustive literature review and surveys of regeneration in “off-Reservation” lands at the Quabbin were performed In DWSP’s 1991 *Quabbin Reservation Deer Impact Management Plan* (MDC, 1991) in order to define regeneration “success” following deer population control efforts. Adequate regeneration was defined as the establishment of at least 2,000 stems per acre of seedlings/saplings greater than 4.5 feet in height (above deer browsing height) of a diverse, site-suited species distribution. DWSP has accepted 2,000 stems per acre as its standard, to be present initially or within five years after overstory removal. Periodic regeneration surveys are showing that these numbers are being attained at all the watersheds, although a shift in relative species importance towards white pine and black birch is being seen, especially at Quabbin.

DWSP will continue periodic monitoring of post-harvest regeneration, and is evaluating the initiation of a uniform system-wide vegetation monitoring protocol.

On sites where regeneration is deemed inadequate, another option is to prescribe seed cuts. Ideally - though difficult in practice - these cuts are timed to coincide with good seed years for the desired species. Seed cuts partially open the canopy to increase light and heat levels at the forest floor enough to stimulate seed germination and seedling development. At the same time, the species composition of the overstory (and therefore the makeup of the seed sources), can be adjusted, the leaf litter can be disturbed to enhance the seedbed, and competing understory vegetation can be reduced.

Based in part on the recommendations of the 2013 final STAC report, many areas within DWSP forests will be treated using site-adapted irregular shelterwood regeneration methods (see *From Here Forward*, the 2014 DWSP response to the STAC recommendations). Trees will be removed either singly or in groups and patches in a range of opening sizes that average about one acre. This range in opening size allows for the successful regeneration of a diversity of species with varying tolerances to shade. The cutting cycle (the period between harvest entries to create additional regenerated acreage) for any given area will be determined and adjusted by the forester depending on several factors including site conditions, opening sizes, and regeneration success and vigor, with an understanding that minimizing the frequency of return entries will translate into a lighter overall impact from harvesting

This is neither an 'even-aged' management system, nor is it classic 'uneven-aged' management. Like the former, a new age class is fostered in easily discernible patches; however these are conservatively sized and not whole-stand treatments. Like the latter, options exist to work with fairly small gaps; however in most cases the smallest openings favor the survival of only shade-tolerant tree species regeneration.

Where conditions for the release of adequate advance regeneration exist, it is given light and space to grow by harvesting a portion of the overstory. Having desirable advance regeneration in place before an opening is created, and protecting it during the harvesting process, gives the forester some confidence in estimating future stand composition and will be one factor considered when choosing opening locations. However, experience has shown that in the absence of high deer densities, desirable regeneration (without having been deemed adequate in advance) often develops in remarkably good numbers shortly after a patch is cut. With relatively small openings and generally abundant seed sources, the irregular shelterwood and group/patch cutting methods create conditions allowing a diversity of natural regeneration to become established in a short time. DWSP will continue to monitor regeneration in openings pre- and post-harvest to provide the public with further documentation supporting this claim, and adapt practices as needed to ensure success.

In situations where a desired species is absent from the overstory and therefore a seed source is

unavailable, or other conditions exist that are persistently inhibiting desirable natural regeneration, planting may be considered. An example of this situation is a dry site, mixed oak stand with no white pine in the overstory. If it is desirable to include white pine as a part of the regenerating forest for diversity reasons, direct planting may be necessary. The amount of annual tree planting on DWSP property has dropped in recent years, but the option to plant is still available and will likely be needed in the future to restore areas following treatments to remove dominating terrestrial invasive plants.

Annually, at least 90% of the regeneration harvesting on DWSP lands on the Quabbin, Wachusett, and Sudbury Reservoir watersheds and at least 60% of the regeneration harvesting on the Ware River watershed will follow the typical approach described above. The remaining 10% of regeneration harvesting on the reservoir watersheds, and 40% on the Ware River watershed, may be in larger openings. These areas either require restorative silviculture**,** as described below and in the *From Here Forward* document, or are in specially designated focus areas where DWSP will create larger blocks of early successional forested habitat.

To track changes in forest structure, all openings will continue to be mapped in GIS and counted as a new age class if they are a minimum of one tree height in their smallest dimension (generally about 1/5 acre and larger). Groups smaller than 1/5 acre may be used in the establishment phase of irregular group shelterwood regeneration in order to foster advance regeneration, with the assumption that they will be enlarged in subsequent entries to improve growing conditions for the developing young trees. Very small groups are also appropriately used in stands where shade tolerant species dominate and the preference is to continue those stand conditions; these represent a small fraction of the forest stands on DWSP land. The area released to a new age class by each silvicultural operation is easily calculated by GIS software, allowing DWSP to determine the immediate impact of harvest openings on the distribution of age classes within the stand, working unit, sub-basin, and forest. GIS also allows the assessment of long-term impacts of years of successive management decisions, as well as acreage lost over time to canopy closure. As an example of the level of detail possible using GIS, silvicultural openings have been mapped at Wachusett Reservoir since 2001 and Figure 4-4 summarizes a 10-year effort of regeneration silviculture progress using this system to account for opening acreage.

Typical Opening Shape and Distribution

In response to STAC recommendations and public input, DWSP considers aesthetics when making forest openings. There are strong aesthetic differences between geometric, "cookie-cutter" openings and those that have been shaped and laid out less regularly. A greater sensitivity to the physiographic and vegetative variations within a forest is considered when laying out lots. Irregular openings can influence the operability of a harvest, the proportion of the timber sale area that can be included in openings, and regeneration diversity, but to some people they are visually more acceptable than geometric openings. The aerial photo in Figure 4-5 shows a wide range of regeneration openings on Prescott Peninsula that have been

implemented over the past decade or more. While each of these openings is regenerating well, there are differences in their aesthetics, especially from above (a perspective that is now commonly available through Google Earth). All openings will be distinct, with patches of retained forest between them. These patches can be locations for future regeneration openings as the current openings develop and mature.

FIGURE 4-4. OPENING SIZES ON DWSP WACHUSETT LANDS

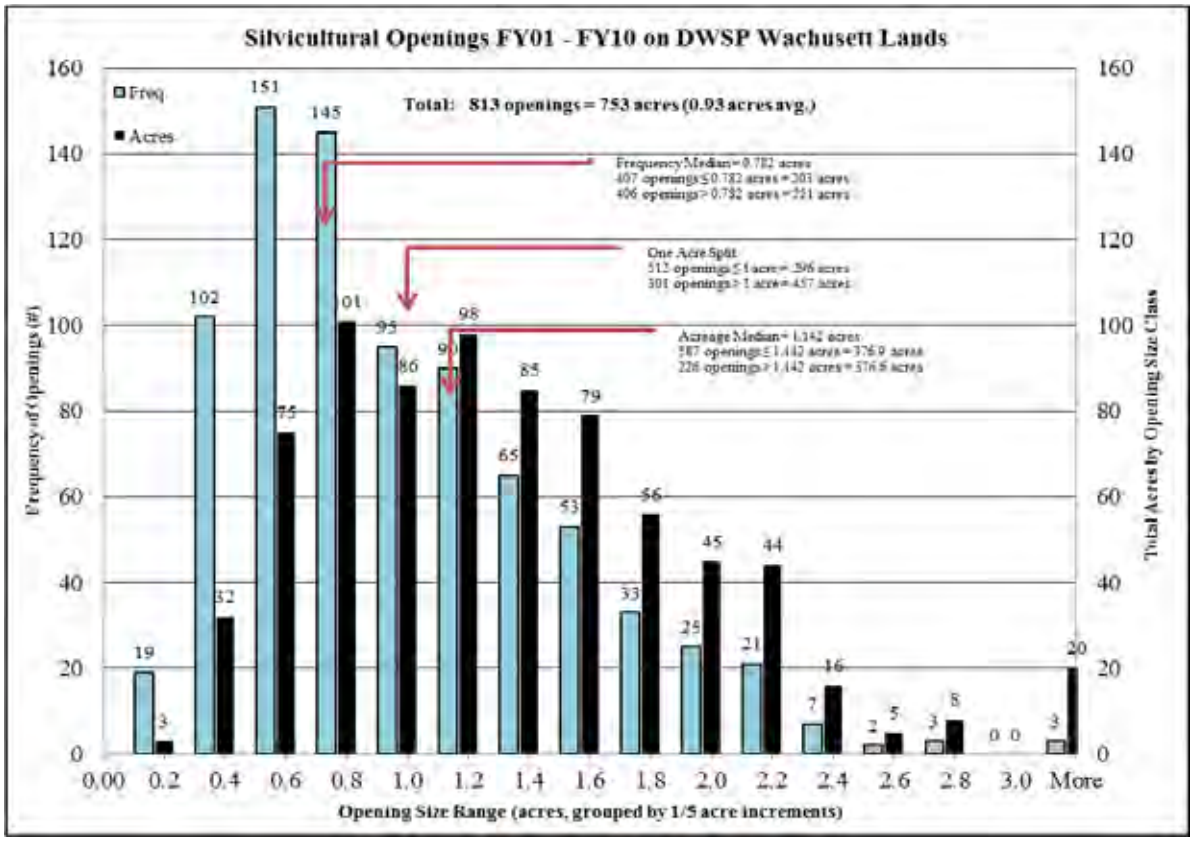


FIGURE 4-5. A RANGE OF OPENING SIZES AND SHAPES

Green-tree Retention

Green-tree retention, also known as structural retention, is the practice of retaining live trees within regenerated openings. Green-tree retention provides within-patch structure that more closely mimics natural disturbance patterns than does a uniform clearcut. It provides habitat diversity, ensuring the availability of snags, den trees, and future downed woody debris for a variety of wildlife. It can also improve the visual aesthetics of the recently regenerated patches. Varying levels of retention have been maintained in regenerated openings on DWSP lands over the past decade. While no specific standards were formalized, a few rules of thumb were variably applied:

- Retain trees in most openings that are 0.5 acre and larger.
- Retain trees in approximate proportion to the size of the opening.
- Retain trees from all size classes but with a disproportionate number of larger trees.
- Retain trees both singly and in small groups.

A recent survey quantified the results of applying these rules of thumb at Wachusett from 2001-2010 (Table 4-8). The vast majority of regenerated openings had retention, and the level of retention was fairly uniform across opening sizes. It is notable that the retention in the much larger 12.6 acre opening (Size Class 5, an early successional habitat project) was in line with the typical < 2.0 acre sized openings.

TABLE 4-8. WACHUSETT 2001-2010 GREEN-RETENTION SURVEY RESULTS

Opening Size Class	Average BA/Acre	Range BA/Acre	Average Trees/Acre	Range Trees/Acre	Percent Zero Retention
1 (< 0.5 acre)	15	0-53	14	0-25	10%
2 (0.5-1.0 acre)	14	1-26	17	2-34	0%
3 (1.0-1.5 acre)	14	0-25	17	0-48	10%
4 (1.5-2.0 acre)	9	0-18	9	0-21	4%
5 (12.6 acre)	18	na	19	na	0%
All Size Classes	12	0-53	14	0-48	5%

A common component of many green-tree retention standards (and typical of wildlife habitat best management practices) is retaining larger trees. Larger trees have greater wildlife habitat value including potential large cavities and dens, more attractive raptor nest sites, greater mast production, future large snags and future large coarse woody debris. The Wachusett survey showed consistently that across all opening size classes, trees 16" dbh and larger made up about 70% of the basal area of the retention.

Example of green-tree retention.

The STAC report acknowledged the value of increasing retention of mature trees, noting that retaining some mature 'legacy' trees would help influence microclimate and improve aesthetics without reducing the level of species diversity of regeneration. With that recommendation in mind, and guided by our previous informal efforts, DWSP has adopted green-tree retention standards applicable to all watershed properties.

DWSP Green Tree Retention Standards

- Most regenerated openings larger than 1/2 acre will contain at least 5-10 ft² per acre (but no more than 20 ft² per acre) in basal area of live trees retained.
- Trees of all sizes may be retained, but measured retention will include only pole-sized and larger trees, with an emphasis on large mature trees.
- Trees will be dispersed singly and/or left in small groups (rarely more than 6-8 trees).
- Advance regeneration, where it is present, will be protected to the extent possible.

Larger Regeneration Openings: Restorative Silviculture and Early Successional Habitat Management

Restorative Silviculture

In some DWSP forests, past land use practices have resulted in undesirable forest conditions that are best corrected through the removal of overstory trees in larger patches. These situations are very clearly described at the proposal stage, with ample opportunity for public comment and with full internal oversight; DWSP will also require approval from DCR's Commissioner for individual removal openings greater than 5 acres. Situations that recommend full overstory removals within short-term, restorative silviculture include:

- **Plantations**. Following the original taking of watershed properties for the creation of a water supply, large acreages of farmland were planted with trees (most often white or red pine or spruces) in an effort to rapidly improve the protective cover on these open lands. The original plantings were done with tight spacing with the expectation that the stands would be regularly thinned to prevent crowding and allow for vigorous growth. However, early thinnings were not completed in many stands, and the stands matured with too many individuals, insufficient growing space, and poor height-to-root ratios, leaving them susceptible to wind and snow/ice damage. Over recent decades, many plantations were converted to fields or restored to diverse native forest cover, but there are untreated plantations still remaining; red pine stands in particular are now also threatened by a recent and quick-killing red pine scale infestation.

  It is a priority for DWSP to regenerate these plantations to diverse mixes of site-suited native species, but partial overstory removals would leave residual trees highly susceptible to damage. Therefore, when appropriate, DWSP will continue to use full overstory replacement harvests for these areas that require larger openings. It is estimated that well under 1,000 acres remain in this condition across all DWSP forests, and only a portion of these would require openings greater than two acres.

- **Degraded stands.** DWSP occasionally acquires forest land that was "high-graded" by previous owners. This practice, while legal, removes the best quality, most vigorous trees (for their timber value) and leaves behind poorly formed, low value, and often low vigor trees. These long-suppressed residual trees do not respond well to release, and the most successful way to return quickly to a vigorous and diverse stand of well-formed trees is to remove most of the degraded overstory. This often requires larger regeneration openings. Not all stands that have been high-graded have been identified. Nonetheless, this practice will represent less than 1% of all of the silviculture conducted during the next decade.

- **Old field white pine.** Historically, many acres of abandoned farm fields regenerated to low density white pine (particularly on the Ware River watershed). White pine that grows in these open conditions is particularly susceptible to the native white pine weevil, which repeatedly kills the terminal bud, leading to the formation of multi-stemmed "cabbage pine." Although functioning to protect water quality, these individual trees are susceptible to wind and snow damage and have low commercial value due to their poor form. Furthermore, the stands that develop in old fields tend to be low in species diversity. The complete removal of the poorly formed overstory white pine in these stands provides for rapid regeneration to a more vigorous replacement stand with much greater species diversity. At the Ware River, approximately 2,800 acres of this type remained in 2017; stands ranged from less than one acre to 150 acres and averaged 10-12 acres. Significantly lesser amounts occur on the other watersheds.

Early Successional Habitat Management for Landscape Diversity

Early successional forested habitat refers to young regenerated stands of trees. Certain timber harvests will briefly (< 15 years) provide useful early successional forested habitat for a variety of wildlife species of conservation concern (e.g., songbirds, New England cottontail; Massachusetts State Wildlife Action Plan, 2015) as the stand progresses from young seedlings to saplings and poles. Woody growth usually occupies the site within a few years after harvest through a combination of advance regeneration (existing seedling trees and shrubs that quickly respond to increased sunlight), sprouting from cut deciduous trees and shrubs, germination of existing seeds within the soil seed bank (e.g., blackberry, raspberry, and pin cherry seeds can remain dormant yet viable in the forest soil for decades before germinating in response to warming soil temperatures after a harvest), and germination of new seeds deposited by mature trees and shrubs growing near the harvest area. Quite often there are small areas of these regenerating stands that first pass through a grass/forb stage (i.e., landings and skid trails where advanced regeneration and stumps from cut trees have been impacted), but they ultimately become re-stocked with woody plants from a combination of new and existing seeds . Blocks of this habitat type need to be relatively large (at least 10 acres) in order to support breeding populations of early successional wildlife species (Schlosberg and King, 2007). This type of silviculture is different than the typical system used on most DWSP lands. Water quality remains the primary focus for DWSP land management activities, however there are opportunities where forest management can provide secondary benefits without compromising water quality standards. This type of forest management will be conducted primarily in early successional focus areas.

Pitch pine-oak/heathland habitats are unique fire-adapted natural communities that provide specific types of early successional habitat characterized by highly diverse and dynamic assemblages of plant species (http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/natural-communities/). These unique communities include scrub oaks, tree oaks, pitch pine, heaths, grasses, and forbs (Massachusetts Division of Fisheries and Wildlife, 2015), and occur on sandy soils that drain

rapidly. Most inland occurrences of these communities are associated with large sandplains that formed during the last glacial era. All these communities are disturbance dependent and were formed through some combination of fire, storms, and past land use. In many cases, silviculture is used to remove undesirable overstory trees that become established due to human fire exclusion over the past century (i.e., white pine), and then the site is maintained through regular disturbance (prescribed fire, mowing, etc.). This type of habitat management will be conducted in barren focus areas identified in collaboration with the Massachusetts Natural Heritage and Endangered Species Program.

Regional Importance of Early Successional Forested Habitats

The New England landscape has changed dramatically over the past 350 years (DeGraaf et al., 2006). Although fire, major weather events, or beaver activity created or maintained early successional habitats across the landscape opportunistically, nothing influenced wildlife populations more than the land clearing for agriculture in New England during the early 1800s. Between 1820 and 1840, 75% of the arable land (land suitable for growing crops) in southern and central New England was in crops and pasture (Raup, 1966). In Massachusetts, 60% of the landscape was cleared (Harper, 1918). After the significant agricultural shift mid-century to the Midwest, the abandoned farms began to revert to forest. Over time these large areas of regenerating shrubs and trees created early successional habitat. This increase in habitat caused a similar increase in wildlife species that use shrubland and regenerating forest as habitat.

By the turn of the 20th century, most sites had grown up to the mixed hardwood forests we see today and no longer provided important habitat used by early successional species (DeGraaf, 2006). A survey conducted in 1998 in Massachusetts concluded that only four percent of all available timberland was in a seedling-sapling (early-successional) stage (Trani et al., 2001). As a result, species dependent on these early successional habitats have been declining and the amount of available habitat continues to shrink (Massachusetts State Wildlife Action Plan, 2015). For example, the Partners in Flight Species of Concern List includes many bird species associated with early successional forested habitat (i.e., blue-winged warbler, Eastern towhee, and prairie warbler).

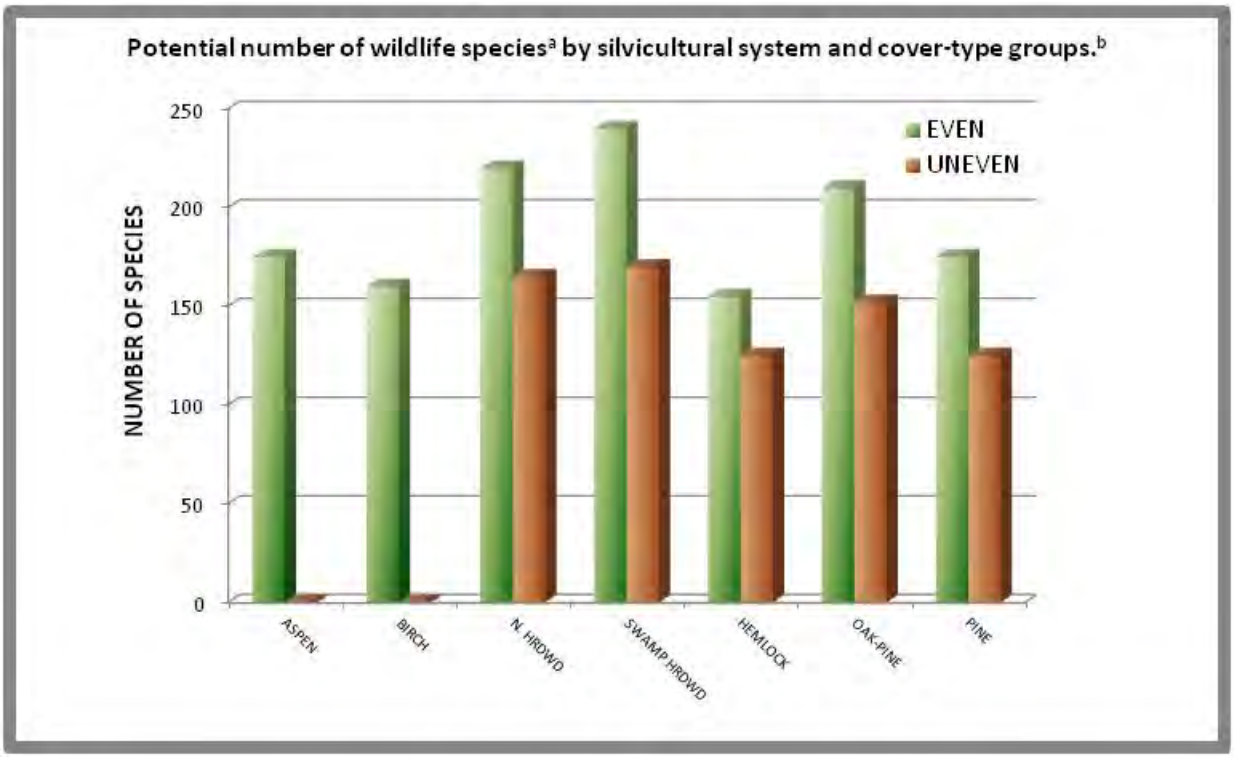
Early Successional Habitat Requirements

Providing habitat for early successional species involves considerations in both space and time. Early successional habitats are temporary and only support wildlife that depends on these habitats for 8-15 years. Therefore, either habitats need to be maintained (set back on a regular basis) or new areas of early successional habitat need to be created. Because maintaining early-successional forested habitat can be expensive, DWSP will instead create locally concentrated shifting mosaics of large patches of young, medium-aged and older stands using even-aged forest management techniques. This type of silviculture provides the opportunity to regenerate important shade-intolerant species such as aspen, cherry, and gray and paper birch (Figure 4-6). A rotational even-aged management approach (cut one large patch and allow it to regenerate, then shift to an

adjacent patch) provides the maximum amount of beneficial habitat at the landscape-scale (DeGraaf, 2006). The resulting habitat provides distinct foraging and shelter opportunities preferred by up to 26% more species than uneven-aged management in similar cover types (DeGraaf et al., 1992; Payne and Bryant 1994).

Thus, fully eliminating the use of even-aged management techniques within the watersheds could result in lower species richness and diversity. The majority of DWSP's forested acreage is regenerated by creating patch sizes which are too small to meet the needs of some declining species. Adding to the dilemma, private ownership accounts for about 70% of forested lands in Massachusetts, and tree harvesting on these lands tends to be relatively light, widely dispersed, and generally does not provide substantial early-successional habitat. Most private forested parcels in the state are less than 12 acres in size, so it is often not practical for private landowners to establish large areas of early successional habitat for wildlife. For the most part, adequate areas of early successional forested habitat needed by wildlife species of conservation concern can only be created on public lands. In the end, utilizing a range or combination of silvicultural treatments, rather than strict adherence to one, will eventually result in increased use by a wider variety of wildlife species (DeGraaf et al., 1992). Therefore, DWSP will create more of this habitat through even-aged silviculture.

FIGURE 4-6. POTENTIAL NUMBER OF WILDLIFE SPECIES BY SILVICULTURAL SYSTEM AND COVER-TYPE GROUPS



[a]Total number of amphibians, reptiles, birds and mammals using each cover type; [b] Taken from DeGraaf et. al 1992.; Even-aged: forests containing regeneration, sapling-pole, sawtimber, and large sawtimber stands in distance units of 5 Acres or larger. Uneven-aged: essentially continuous forest canopies and intermixed size and age classes produced by single-tree or small group selection.

Mimicking Natural Disturbances

DWSP recognizes the regional importance of these open habitats to the diversity of wildlife within the state. Unfortunately, land managers can't rely on natural disturbances to reliably provide adequate amounts of this type of habitat due to human alteration of the landscape over the past few centuries. The large amount of land that has been lost to development, coupled with the loss of species, suppression of fire, beaver control, and abundance of exotic, invasive species have all combined to alter natural processes. The maintenance of early successional habitats on today's landscape requires active management. Although DWSP will continue to manage a majority of its property as a multi-aged, multi-species forest, on particular areas where open habitat exists or could exist, DWSP will manage to maintain or enhance early successional communities.

Large-scale disturbances are required to create optimal early-successional forested habitats. Silviculturally, even-aged management techniques can mimic these disturbances. In some situations, DWSP will retain 10-20% of the overstory in clusters of trees scattered across the harvested stand to mimic the patchy effect of some natural disturbances. Preserving clumps of trees allows the DWSP to selectively save valuable mast, den, and nest trees. However, major catastrophic events sometimes leave larger areas without overstory trees. Thus, in some cases, even-aged management without retention may be used to mimic these largest disturbances.

Landscape Level Site Selection - Focus Areas and Management Methods

In order to create conditions favorable for early successional species, forest openings need to be large enough and placed appropriately to provide sufficient habitat to sustain viable animal populations over time. It would be counter-productive to create early successional habitat that was ecologically isolated or undersized. Such a site may actually serve as a sink habitat (when reproduction is insufficient to balance local mortality) causing populations to decline over time. Since water quality protection is DWSP's primary goal, site selection for these larger scale even-aged forest treatments will be based on topography, distance from the reservoir and associated tributaries, soils, and stand health/regeneration.

DWSP has identified young forest focus areas in each watershed that will create habitat in at least a 300+ acre section of forest (Figures 4-7, 4-8, and 4-9). Proposed future openings would occur one at a time over a period of many years. At Ware River, two young forest focus areas were chosen (Figure 4-7). At Quabbin, one focus area abuts the Federated Women's Forest, a second lies south of Route 122 adjacent to existing power lines, and the third is north or Route 122 near Spectacle pond (Figure 4-8). The Wachusett young forest focus area in Princeton is part of the Natural Resource Section's long-term wildlife monitoring program, and provides a good opportunity to further study forest management with regard to the short and long-term effects of even-aged management on wildlife populations (Figure 4-9).

FIGURE 4-7. PROPOSED YOUNG FOREST FOCUS AREAS FOR WARE RIVER WATERSHED

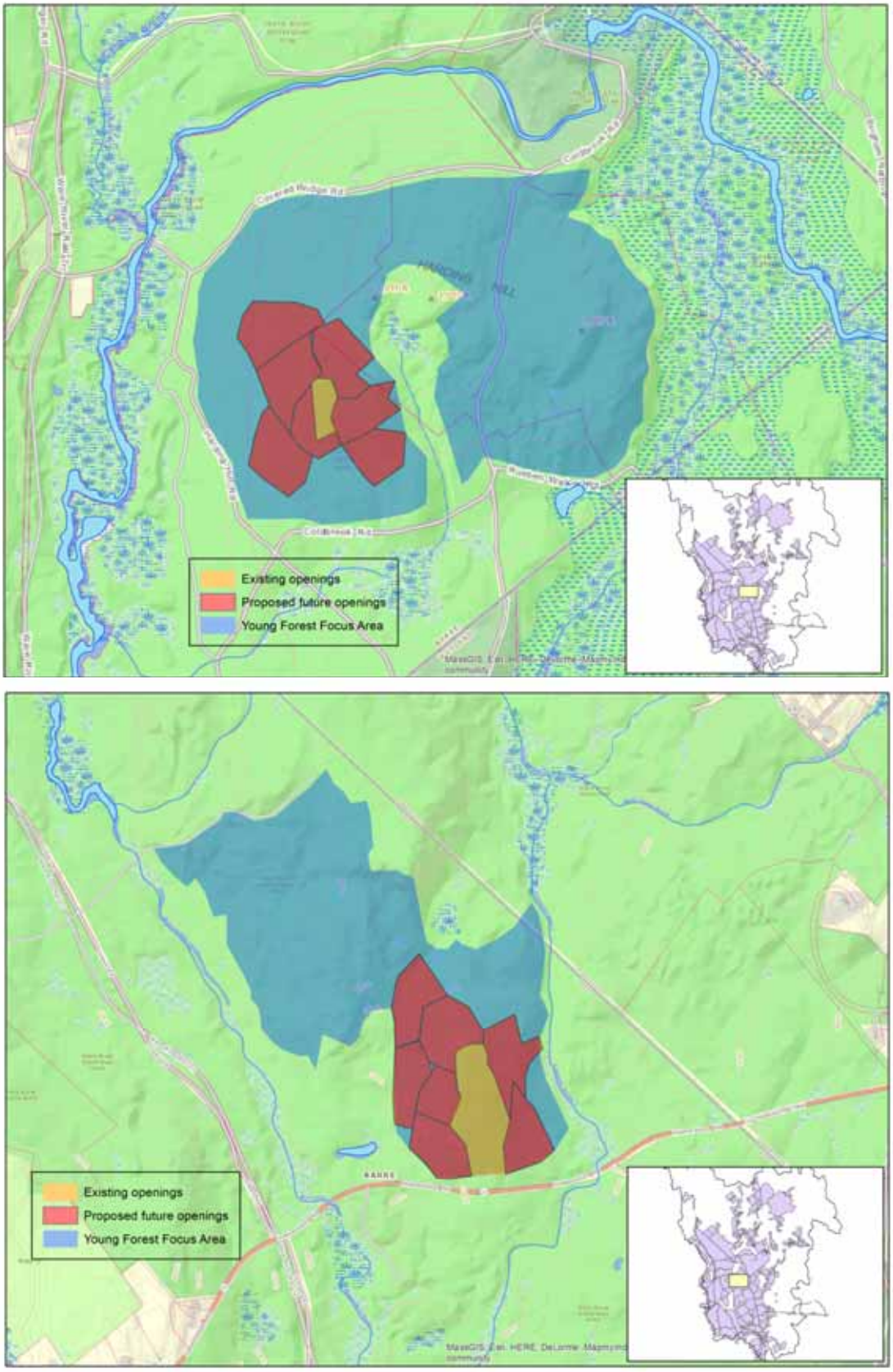
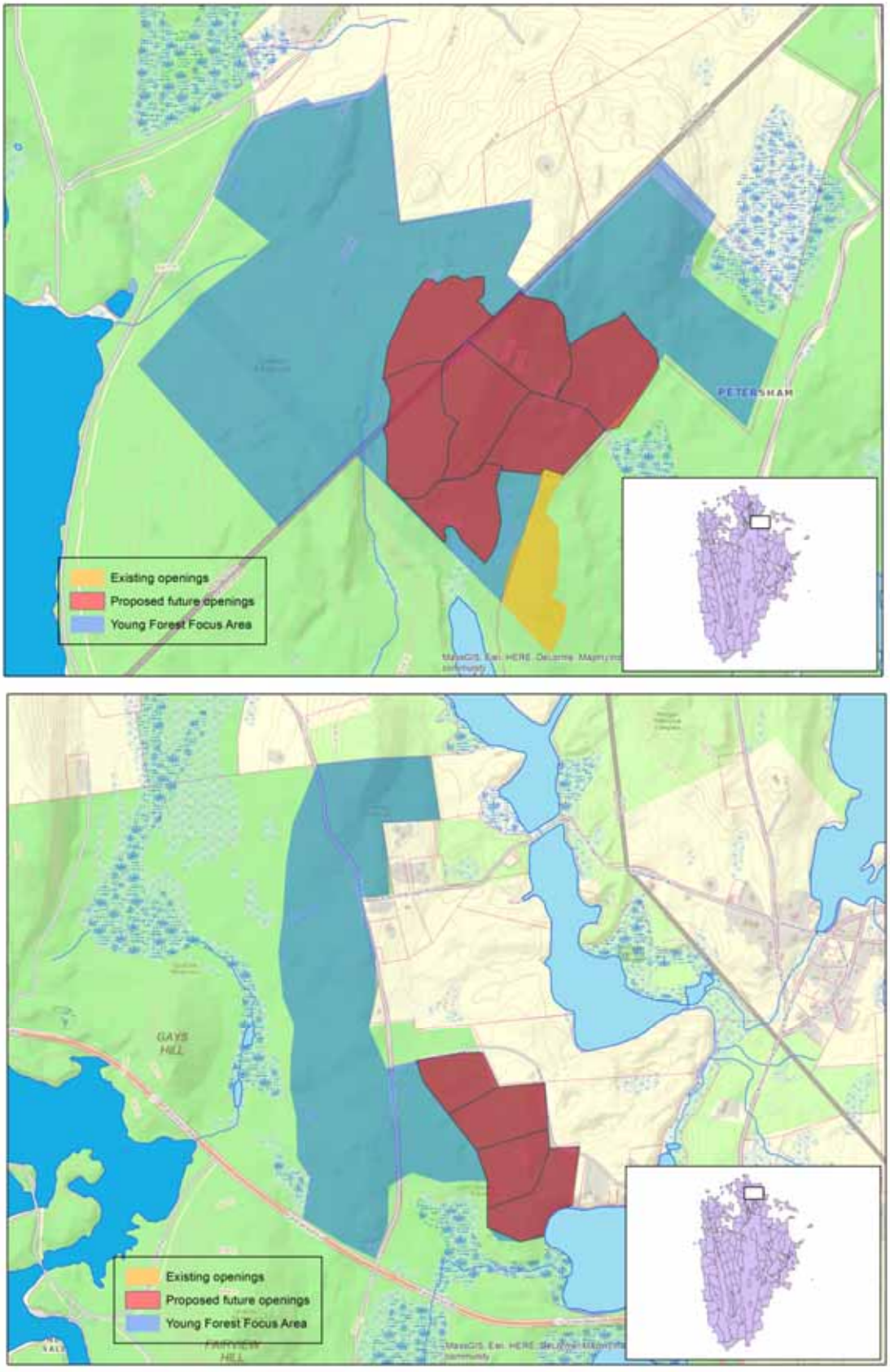


FIGURE 4-8. PROPOSED YOUNG FOREST FOCUS AREAS FOR QUABBIN WATERSHED



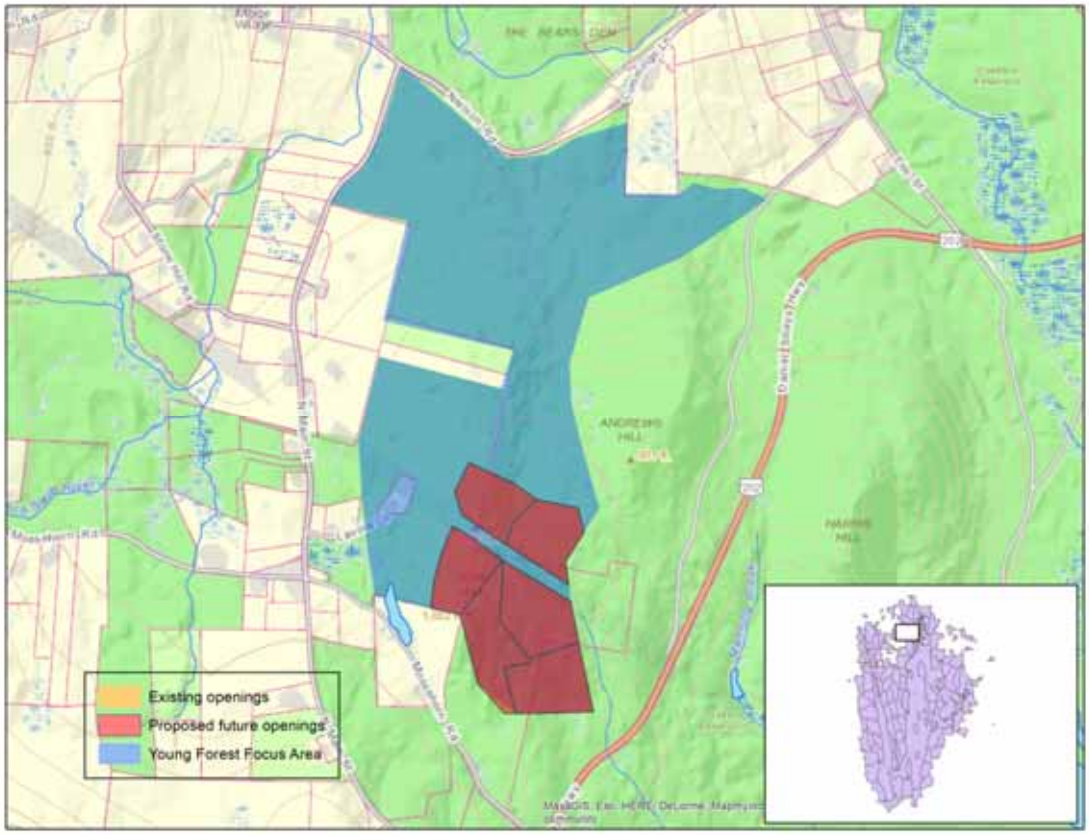
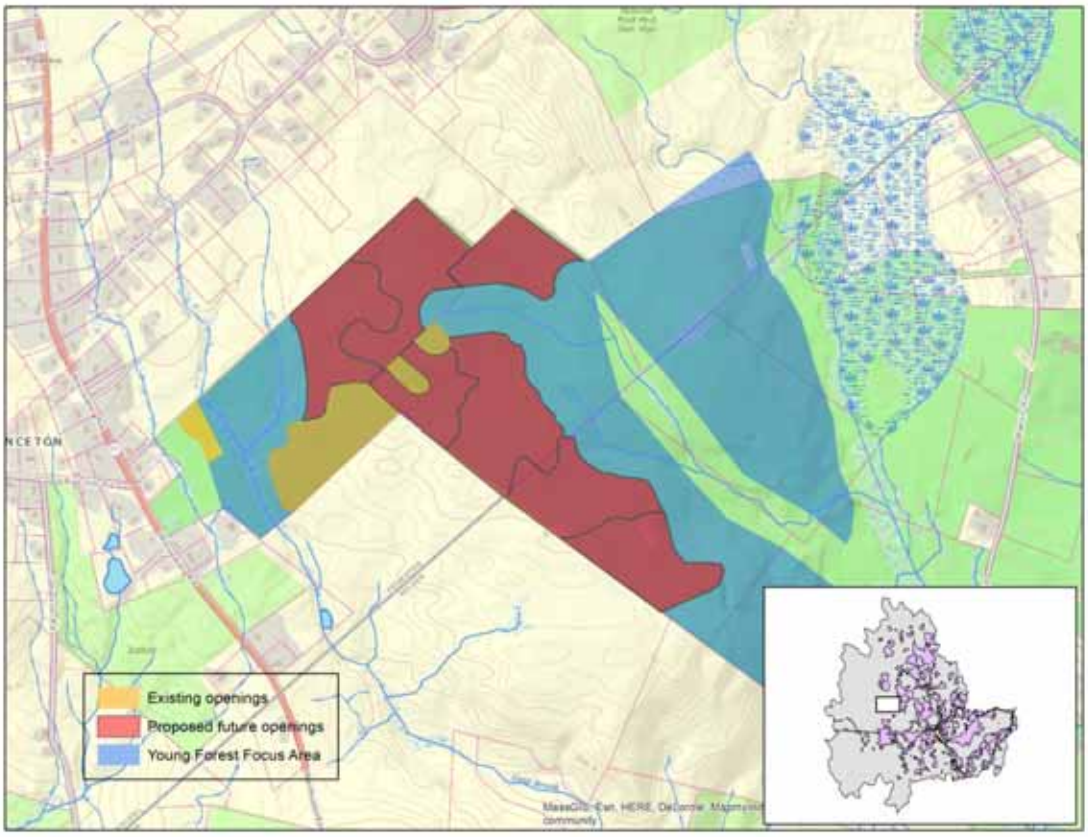


FIGURE 4-9. PROPOSED YOUNG FOREST FOCUS AREA FOR WACHUSETT WATERSHED



DWSP has also identified barren focus areas in the Quabbin and Ware River watersheds. In these focus areas, silviculture will likely be needed to restore habitat conditions, followed by other disturbance (primarily prescribed fire) to maintain these open habitats over the long term (Figures 4-10, 4-11, and 4-12).

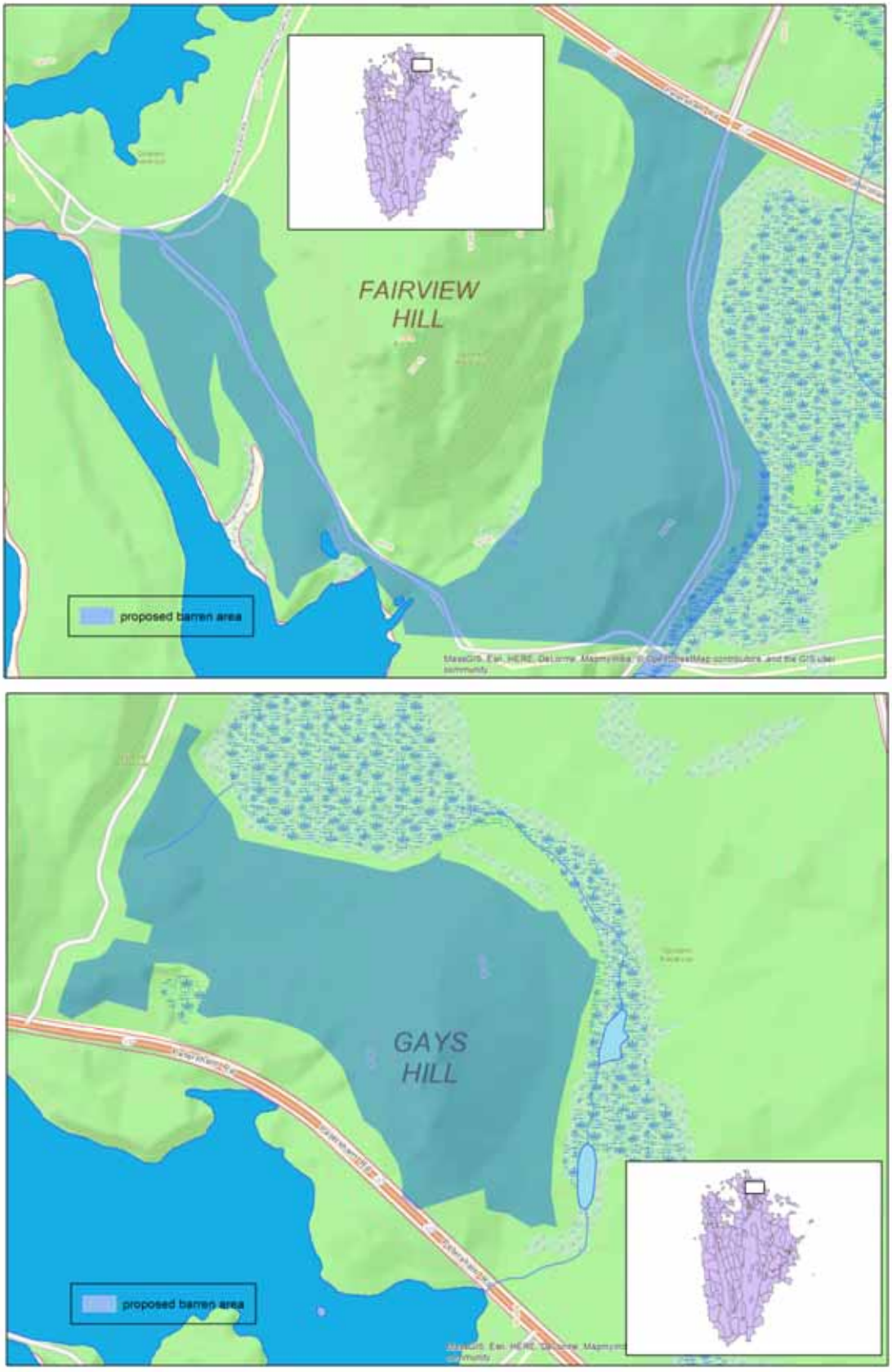
Finally, there may be situations outside the focus areas where larger openings are the most appropriate silviculture, and may provide additional incidental early successional habitat. These cases will be reviewed and addressed on an individual basis.

In each young forest focus area, one section (polygons in each map) will be cut every 3-5 years; sections are at least 10 acres in size, depending on stand composition and topography. The proposed openings build off existing openings (indicated on maps) created in the past and/or the proximity of other open habitat (i.e., open fields, wet meadows, power lines) within a half-mile. This type of management will create blocks of early successional habitat over the next 80-100 years. As with the restorative silvicultural harvests, these cuts:

- Must adhere to the 25% subwatershed removal limit.
- Will go through the normal lot proposal and review process.
- Require Commissioner approval for openings greater than 5 acres.
- Undergo public review and comment periods.

A restored pitch pine barren.

FIGURE 4-10. PROPOSED BARREN FOCUS AREAS FOR THE NORTH QUABBIN WATERSHED



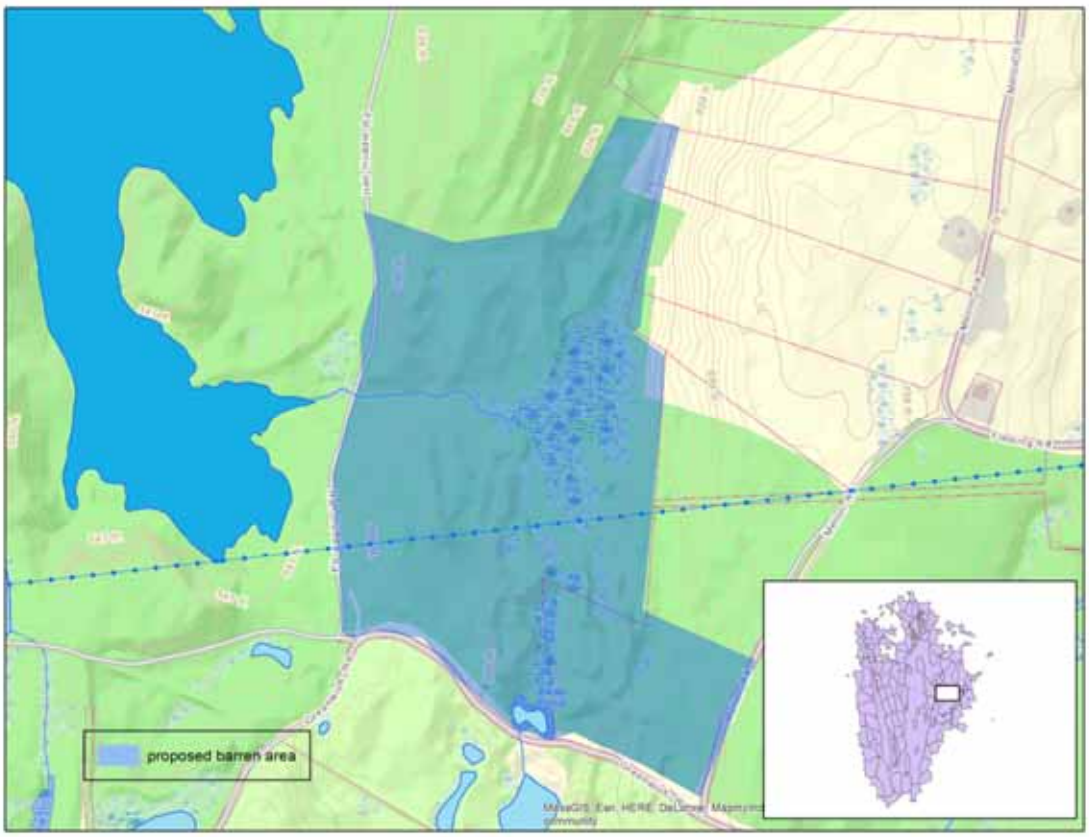
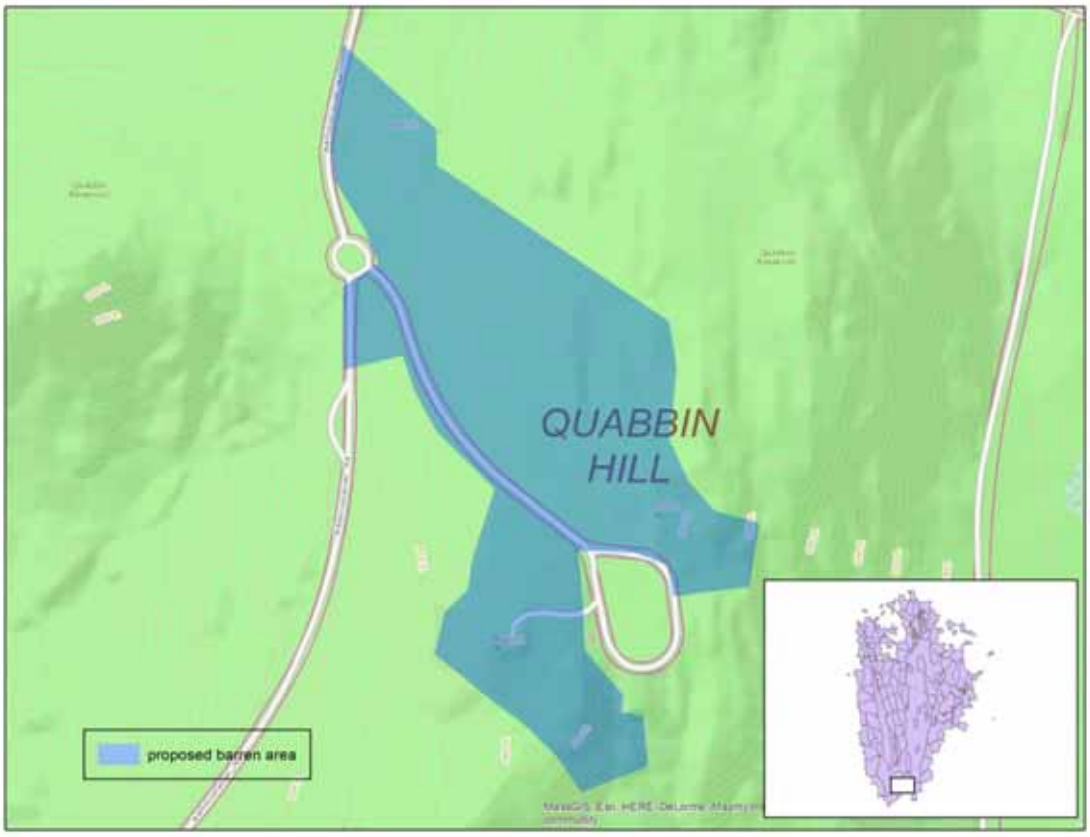


FIGURE 4-11. PROPOSED BARREN FOCUS AREAS FOR SOUTH QUABBIN WATERSHED



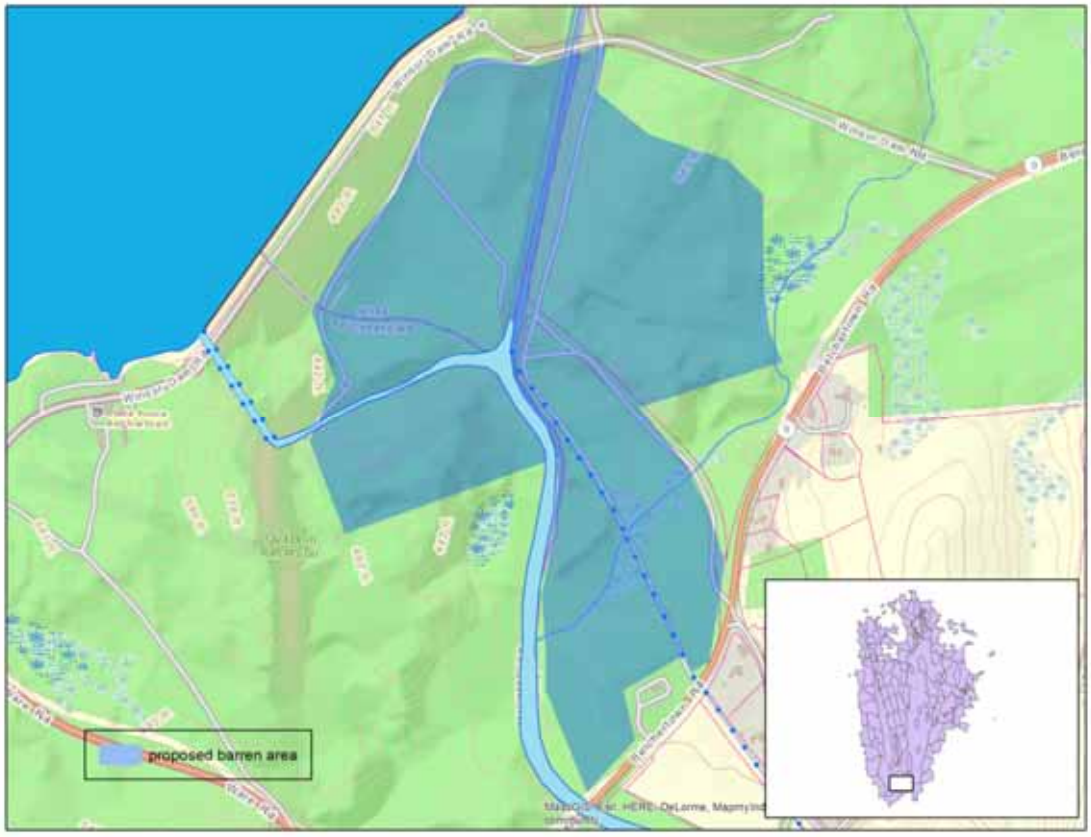
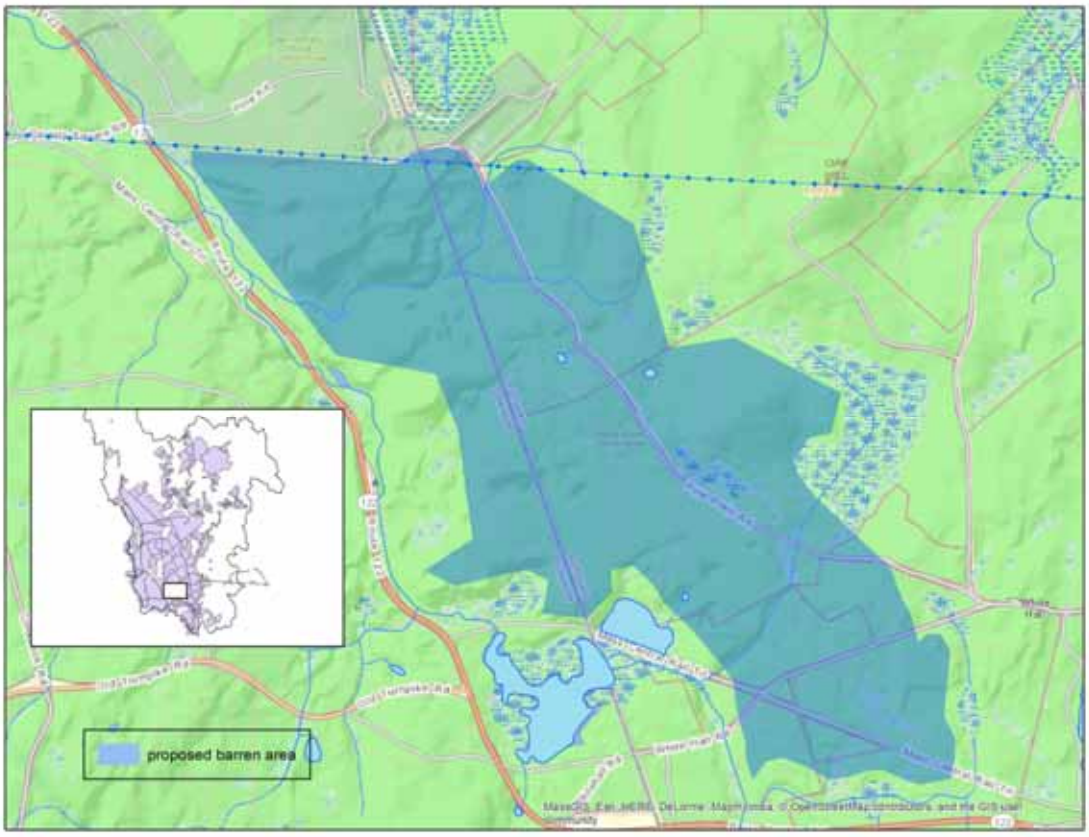


FIGURE 4-12. PROPOSED BARREN FOCUS AREAS FOR THE WARE RIVER WATERSHED.



Intermediate Treatments

Intermediate treatments are performed on stands prior to maturity. They are designated simply as "thinnings" when the objective is to remove trees of low vigor, thereby decreasing competition within the stand and increasing the vigor and growth rate of the residual trees. "Improvement" operations, which are also intermediate cuttings, are designed to adjust the species and quality composition of a stand. In practice, nearly all intermediate cuttings are a combination of both thinning and improvement. The defining objective of all intermediate operations is improving the growth and vigor of the residual overstory trees, rather than the establishment or release of regeneration. A secondary benefit is that the better formed and healthier trees that are left to grow tend to be more economically valuable, which may help reduce the costs of future management.

Preparatory cutting is an intermediate cutting practice designed to prepare some stands for entering the regeneration stage of management. Typical objectives for preparatory cuts are to adjust the species composition of the seed producing trees and/or increase the seed-bearing vigor of these trees. While referred to as preparatory cuts, the methods to accomplish these objectives are indistinguishable from intermediate thinning and/or improvement cutting.

Intermediate cuttings are not commonly performed as the sole objective of stand management on current DWSP forests at present because the majority of the watershed forests have grown beyond the dense, pole-sized stage, with the exception of some more recently acquired land.

Currently, most intermediate operations on DWSP lands are performed simultaneously with regeneration cuts in sections that are not being regenerated and can benefit from thinning or improvement. As stands move through the regeneration phase and new age classes become more common, a focus on tending these developing stands via intermediate cutting will return.

Management of Riparian Zone Filters

The riparian zone is defined as the areas that have the most direct influence on the water within streams. These include the channel itself, the bank area, areas subject to seasonal flooding outside the channel (the floodplain), and areas of the forest alongside the channel containing trees that provide shade and organic debris to the stream channel. The Wetlands Protection Act ("WPA": M.G.L. Chapter 131 §40) and its regulations (310 CMR 10.00) and the Forest Cutting Practices Act ("FCPA": M.G.L. Chapter 132 §40-46) and its regulations (304 CMR 11.00) both contain language that place limits on activities within riparian zones. The presumption behind these regulations is that manipulations of these zones may degrade the critical buffering capacity of these areas and may result in soil disturbances that can result in sediment transport to surface waters. These presumptions are supported by decades of research on nitrogen and sediment removals by forested stream buffers, which Sweeney and Newbold (2014) conclude point to a suitable minimum buffer width of ≥30 meters.

To meet regulatory requirements, a common riparian zone management strategy is simply to leave these areas unmanaged. However, DWSP recognizes these zones as the final and most critical opportunity to slow or capture nutrients and sediments released by a variety of natural and man-caused events on the watersheds and therefore does not categorically exclude them from management. The preferred vegetative structure of riparian zones in DWSP watersheds is an actively growing, diverse, disturbance-resistant forest cover. Maintaining this forest structure in these zones throughout the variety of disturbances that impact all New England forests may be best accomplished through carefully planned and implemented human intervention. To some degree, being located within the bottom of stream and river valleys shelters riparian forests from wind damage. However, as these forests mature, and especially where they are in the path of damaging storms, they become vulnerable. When damage occurs, it can result in soil and nutrient transport. Additional concerns include sudden changes in stream temperatures due to the loss of streamside forest cover and heavy accumulations of woody debris and sediments when trees fall directly into the stream channel or the streams are dammed.

Riparian zone

Conditioning the Riparian Understory

The most important resiliance to build into these riparian forests, as is true for the watershed forest in general, is the ability to quickly regenerate. Regeneration anchors soils following disturbances, resists damage from many disturbances (due to size and density), and shortens recovery times for reestablishing riparian forests following disturbances.

Through carefully implemented manipulations of the overstory and understory, DWSP foresters intend to establish a regeneration layer to help condition certain vulnerable riparian forests to be better able to fulfill their critical buffering functions throughout significant disturbances. DWSP's specific management strategies, and the types of riparian zones to which they will be applied, include:

- Standard silvicultural removals will occur within the managed portions of the riparian forest on moderate slopes with stable soils, within the restrictions of forest cutting practices regulations.

- In riparian areas too steep or wet to allow equipment, DWSP will provide light to the understory through non-extractive felling of trees individually and in small groups. In these cases, trees will be directionally felled along the contour and left lying in contact with the ground to meet slash law requirements, reduce fire danger, and trap overland movement of sediments and organic debris.

- Planting may occur in areas where advance regeneration or seed source is limited, where herbaceous competition is significant, where protective ground cover is currently lacking, or where aesthetics are a priority concern (e.g., near residences or high use areas).

Diversifying Age Structure in Riparian Filter Strips

The FCPA regulations require leaving forested filter strips along surface waters, in which at least 50% stocking must be retained in well distributed, healthy growing trees 5" DBH or larger (304 CMR 11.05 (1)(d)). The regulations state that "exceptions to this standard may be granted by the Director or the Director's agent, if it is shown in the forest cutting plan that a heavier cut is necessary to protect the stream, the bank or water quality." For "Outstanding Resource Waters", which include surface drinking water reservoirs and their tributaries, the width of filter strips varies, increasing with slope. The major impact of filter strip requirements to DWSP management is the need to regenerate these areas successfully using a series of single tree and small group selection removals. Patch cuts – even those that release advance regeneration – are not generally allowed in these areas. Partial cutting results in greater competition between developing regeneration and the residual overstory, and makes protecting desirable regeneration during successive cuts more challenging. Difficulties notwithstanding, DWSP will continue to actively manage to promote species and structural diversity in these crucial riparian forests.

The accuracy of current digitized mapping of streams, vernal pools, and slopes presents challenges to a realistic estimate of total area in filter strips, and staff will continue to refine the maps as changes are needed. On the ground, foresters apply the filters appropriately in all cases, regardless of the current level of accuracy of GIS.

Promoting Late Seral Forest Conditions

The decline in the amount of late seral stage habitat and the potential for protecting or restoring forest areas with the characteristics of 'old growth' have been widely discussed in the Commonwealth for many years. Late seral, old growth forest constitutes less than 0.1% of the New England region's forests, much less than occurred prior to European settlement. While there are no known late seral obligate wildlife species in Massachusetts, many species use this habitat, and scientific investigation is revealing ecological features unique to these areas, such as the presence of certain species of lichens and more complete development of mycorrhizal associations and functions. True old growth habitat has not been found on DWSP properties, but DWSP will promote late seral characteristics on managed land through the following management practices:

Active Management Techniques to Encourage Old-Growth Characteristics

- **Increase the diversity of tree sizes and ages**. Select some areas for harvest using single trees or small groups of trees, creating gaps up to 1/4 acre; repeat to create multi-aged stands.
- **Increase the number of snags**. Girdle (i.e., cut several rings of bark/cambium around the stem to deliberately kill the tree) some medium to large cull trees, where appropriate.
- **Increase the number and volume of downed logs**. Fell and leave on the ground medium- to large-sized cull trees to improve growth of residual trees.
- **Provide for future snags and downed logs**. Reserve permanent large diameter "legacy trees" within harvested areas.
- **Increase the number of large living trees**. Thin woods by removing competing, low-quality trees adjacent to the largest, most vigorous trees.

The STAC report briefly addresses this subject and suggests that a more deliberate effort to accelerate the development of old-growth characteristics using specialized thinning techniques could be considered where it is not in conflict with primary objectives for water supply protection. The techniques for implementing this practice are described on the MassWoods website (http://masswoods.net/information-on/restoring-old-growth-characteristics) and in the UMass Extension publication *Restoring Old-Growth Characteristics*.

Over 17,000 forested acres across the DWSP watershed system receive limited management (Table 4-9) and may be developing old growth characteristics where they have escaped catastrophic natural disturbances for a century or more. In addition, DWSP foresters have traditionally preserved unusual features within regular management areas, some of which include

old growth characteristics. These features range in size and type from individual "legacy trees" discovered and retained within a managed stand to small stands or sections of the landscape that have developed exceptionally old or large specimens of common or uncommon species. Where such areas can be efficiently and effectively treated to enhance old growth characteristics, this practice may be applied.

TABLE 4-9. LIMITED MANAGEMENT FORESTED AREAS ON DWSP LANDS

Type of area	Quabbin	Ware River	Wachusett	Sudbury	TOTAL
Wet, steep, otherwise inaccessible (estimates, subject to mapping limitations)	4,406	3,665	2,109	555	10,735
Islands	3,674	0	58	116	3,848
Designated natural areas and reserves	2,241	0	232	0	2,473
TOTAL	10,321	3,665	2,399	671	17,056

While some of these features can be preserved or enhanced for many years, DWSP recognizes the dynamic nature of the forest and the certainty that every legacy tree will eventually die and that storms or pests will eventually alter preserved features or entire stands, sometimes dramatically. This does not make such features less important to try to preserve; ongoing change is part of the nature of old growth, and thus the identification and enhancement of unusual features does not guarantee their long-term preservation.

4.2.6 Implementation of the Forest Management Approach

Each watershed has taken a slightly different approach over the last 15 years to determining the spatial and temporal arrangement of forest management practices. In the 2007 Quabbin Land Management Plan, DWSP implemented a hydrologic zoning system based on distances from streams, the reservoir, and the intakes using the Watershed Protection Act Primary Zone and the Pathogen Control Zone as models. Opening sizes were limited based on distances to surface water resources. In the 2003 Ware River Land Management Plan, DWSP implemented a strategy system; three strategy areas were defined based on where forest management could occur or would be restricted by regulations or access. Wachusett and Sudbury have used a less formal system that contained some parts of both the Quabbin and Ware River approaches. Foresters have tended to locate the largest openings furthest from critical water resources and accounted for various unmanageable lands.

This LMP will implement for all four watersheds a general approach to the location and application of silvicultural options incorporating recommendations by STAC and outlined in *From Here Forward*. The approach continues to be sensitive to water resources by incorporating or exceeding all regulatory BMP requirements, imposing subwatershed harvesting limits, and recognizing the management limitations of various land and habitat types.

Decision Criteria for Locating Proposed Silvicultural Activities

DWSP's working hypothesis is that sufficient diversity in structure and species composition will provide a level of redundancy and thus enhance the value of the watershed protection forest. All silvicultural decisions and assessments will reflect measured levels of structure and species diversity in the forest at any given point in time. DWSP can directly control age structure through the extent and rate of the creation of new age classes, and to some extent control species diversity in those new age classes by releasing existing advance regeneration and by deliberately patterning openings to promote species not yet present.

The systems used to guide foresters' decisions about where to plan and conduct silviculture each year differ between watersheds as a result of available information and individual approaches to organization and planning.

Wachusett and Sudbury Watersheds

Wachusett and Sudbury foresters decided in the mid-2000s to accurately determine the existing age structure of the forest. The foresters visited all mapped stands and used site disturbance evidence, stump ring counts, sapling whorl counts, and increment core ring counts to determine a 'year of origin.' Every acre of forested land, both managed and unmanageable, was aged in this manner. The age class distribution at the working unit, subwatershed, or watershed levels was determined for each mapped stand.

The following steps are followed using this data to locate proposed silvicultural activities. First, age diversity is analyzed for each subwatershed, and priority rankings for silvicultural need are given. Higher priority is assigned to subwatersheds with smaller percentages of younger forest; however, an effort is made to spread the work around the watershed rather than concentrate activities in one or two subwatersheds. Additionally, a check is made against the 25% subwatershed stocking removal limit. At both the watershed and subwatershed levels, diversity of age classes is the main factor determining where treatment is needed. Other factors are also considered at smaller scales.

Working units are then analyzed and ranked within suitable subwatersheds. A working unit is the equivalent of a pre-determined timber sale area, averaging about 50 acres, with identifiable, non-overlapping boundaries with other units. Each of the 320-plus units have been assigned a 'year to visit', when conditions in those units are likely to be appropriate for potential management activities. Those where work has previously occurred are given an appropriate return interval, and all others are initially given zeroes. When a unit gets treated, the 'year to visit' field is updated: if only prep cuts were done, then the return might be in 5 to 10 years; if enough acres were released in openings, then the return might be in 20 to 25 years. Each year foresters only consider units where the 'visit' year is the current year or less, which may include many more units than are ultimately proposed for treatment.

Higher priority may be given to units with the least percentage of young age classes, but many other factors are considered. For instance, the need to capture an existing crop of advance regeneration before it fails may place a unit higher on the list, pushing down a similar unit with no regeneration. Soil types are also considered, so not all of the lots sold in one year occur on soils with potential seasonal restrictions. Foresters must also be aware of wood markets, and potentially adapt their proposals accordingly, since markets for species can fluctuate rapidly. Finally, attempts are made within a given watershed to limit the proportion of operations each year where NHESP restrictions would limit logging to winter months.

At a rate of about ten proposals per year, all the working units at Wachusett will be treated once in the next 32 years. The watershed wide goal of 1% per year will be achieved if about a third of the acreage is regenerated in each unit.

Quabbin and Ware River Watersheds

Due to many factors, the method for locating proposed silvicultural activities at Quabbin and Ware River is slightly different than the steps used at Wachusett and Sudbury. Each of the five Quabbin blocks (Pelham, New Salem, Petersham, Prescott, and Hardwick) is divided into 10 - 20 compartments, ranging in size from 50 - 1000 acres. Compartments are numbered and grouped such that 10% are visited annually, and every compartment in the entire forest is visited once per decade. Some compartments are further divided into working units. Departures from this pattern may occur when there is a need to address pest or weather disturbances. The system is essentially the same for Ware River, except that there is no subdivision of the watershed into blocks. There are 50 compartments at Ware River averaging about 500 acres each.

Each working unit/compartment and all stands within those working units/compartments are visited on ten-year intervals. These visits are used to prioritize areas for silvicultural treatment in the following year, based on forest conditions observed, as follows:

- High risk of stand not surviving another 10 years (e.g., insect, fungus, or disease problems)
- Low vigor/low-quality trees occupying the growing space
- Undesirable non-native species (plantation)
- Stands with advance regeneration in place requiring release
- Stands with rapidly declining overstory trees.
- Lack of species and/or structural diversity (i.e., plantations or native single-species stands)

Summary of Planned Silvicultural Activities

The differences in the approach to identifying where silvicultural operations will take place each year around each watershed are the legacy of the Chief Foresters who developed the strategies. Each system allows for stand conditions to guide silvicultural options, and each will result in

every acre of the entire manageable forest receiving some kind of attention or inspection multiple times, and typically though not necessarily, receiving some level of treatment at least once, over the course of the next hundred years.

Foresters, and ultimately each Chief Forester, are responsible for tracking forest changes caused by silvicultural operations. Carefully written descriptions of stand conditions and silvicultural prescriptions are essential to understanding both the rationale and the effects of a particular treatment. Careful and consistent mapping of regeneration openings and other treated, untreated, reserved, and unmanageable areas will ensure consistency with plan acreage objectives, provide good age-structure information, and allow future foresters to more easily plan for subsequent management. Careful mapping of partial cuttings, whether for intermediate or regenerative purposes, can allow for some level of prediction regarding the 'conditioning' of the forest for natural disturbance recovery. All DWSP foresters use GIS software to create and edit maps, digitize forest types and other natural and cultural features, and plan silvicultural operations.

Table 4-10 indicates the types of silvicultural activities planned to occur yearly during this management period and the relative proportions of the affected acreages for each watershed.

Areas with Special Management Guidelines, Restrictions or Regulations

In addition to the actively managed areas of the four watersheds, there are substantial areas where special management guidelines, restrictions, or regulations are applied (Table 4-11). These fall into two general categories:

- Areas with uncommon, rare, or potentially rare resources.
- Areas with common but fragile resources or where standard forest management is impractical.

The first category includes areas such as uncommon forest communities, habitats containing rare, endangered, or threatened plant or animal species, and historic/pre-Contact sites. Examples of these areas include pitch pine/scrub oak communities; NHESP Priority Habitats; areas designated as Nature Preserves, Reserves, Natural Areas, or Parks; cellar holes; and Native American encampments and work sites. The delineation of each area may also require designating an appropriate buffer zone around the resource.

The second category includes commonly occurring but fragile areas such as bogs, forested wetlands, marshes, wet meadows, and vernal pools, or areas that are impractical to manage, such as slopes greater than 30% and islands. There may be rare plants, animals, or communities within these sites as well, and overlap of the two categories is not uncommon. For example, steep talus slopes are generally impractical to operate with timber harvesting equipment and often harbor rare or uncommon plants.

TABLE 4-10. SUMMARY OF PLANNED SILVICULTURAL ACTIVITIES BY WATERSHED

Watershed	Partial Cutting		Overstory Opening Cutting			
	Intermediate Harvests (thinnings)	Regeneration Establishment Treatments	Typical Openings [1]	Restorative Silviculture Openings [1]	Early Successional Habitat (ESH) Openings[2]	Green Retention Standards[3]
Quabbin	Variable based on stand conditions	Variable based on stand conditions	≥ 90% of regenerated acreage created through a range of opening sizes, averaging ~ 1 acre	≤ 10% of regenerated acreage in larger openings	Three focus areas, ~300 acres each, split into cutting blocks averaging ≥10 acres	Typically 5 - 10 ft² BA (but < 20 ft²) of pole and large trees retained singly or in small groups in most ≥ ½ acre openings
		Up to 450 acres/year				
Ware River	Variable based on stand conditions	Variable based on stand conditions	≥ 60% of regenerated acreage created through a range of opening sizes, averaging ~ 1 acre	≤ 40% of regenerated acreage in larger openings	Two focus areas, each one ~300 acres split into cutting blocks averaging ≥10 acres each	Same as above
		Up to 150 acres/year				
Wachusett	Variable based on stand conditions	Variable based on stand conditions	≥ 90% of regenerated acreage created through a range of opening sizes, averaging ~ 1 acre	≤ 10% of regenerated acreage in larger openings	One focus area of ~200 acres, split into cutting blocks averaging ≥10 acres each	Same as above
		Up to 150 acres/year				

Watershed	Partial Cutting		Overstory Opening Cutting			
	Intermediate Harvests (thinnings)	Regeneration Establishment Treatments	Typical Openings [1]	Restorative Silviculture Openings [1]	Early Successional Habitat (ESH) Openings[2]	Green Retention Standards[3]
Sudbury	Variable based on stand conditions	Variable based on stand conditions	≥ 90% of regenerated acreage created through a range of opening sizes, averaging ~ 1 acre	≤ 10% of regenerated acreage in larger openings	None planned	Same as above
		Up to 20 acres/year				

[1] Regeneration openings to occur on up to 1% of manageable forest in each watershed each year.
[2] Each focus area treated at least once every 5 to 7 years; focus areas are removed from regular manageable forested acreage calculations.
[3] Applicable to all Typical and Restorative openings > ½ acre; optional for Early Successional Habitat (ESH) openings.

TABLE 4-11. AREAS WITH SPECIAL MANAGEMENT GUIDELINES, RESTRICTIONS OR REGULATIONS

Area	Restrictions/Practices	Quabbin Acres	Ware River Acres	Wachusett Acres	Sudbury Acres
Islands	Public Access prohibited. Limited management.	3,674	NA	58	116
Steep slopes	Skidding limitations; limited non-extractive silviculture	1,712	TBD	106	0
Wetlands	No management except limited beaver control (see beaver policy, Section 4.4.2).	2,694	3,281	1,764	514
Rare and endangered species habitats	Subject to restrictions by MassWildlife/Natural Heritage and Endangered Species Program (see Section 4.2.7)	9,521	3,837	3,543	0
Riparian zones adjacent to tributaries and reservoir shores; vernal pools	Regulated by the FCPA (Ch.132) with additional DWSP restrictions; generally limited to 50% basal area removal	Application of variable filter strips along streams, water bodies, and vernal pools determined on ground as needed.			
Areas where access is precluded by physical, legal (ownership), or regulatory barriers; not wetlands	Limited management; may control herbivores, invasive species, and fire	TBD[1]	TBD	440	41
Areas of historic or cultural significance	Varies from no management to selective restoration and maintenance (see Section 4.5.2).	Application varies by site.			
Quabbin Park (western portions)	Limited management including tree planting, non-extractive regeneration cuts, and salvage or conversion cutting in plantations.	1,058	NA	NA	NA
Pottapaug Natural Area	Restricted by DWSP policy designation as a Natural Area, in 1991, no active forest management except recent conversion of pine plantations to natural stands. Control of herbivores, invasive species, and fire may occur.	1,183	NA	NA	NA

Area	Restrictions/Practices	Quabbin Acres	Ware River Acres	Wachusett Acres	Sudbury Acres
Poutwater Pond Nature Preserve	Designated a Nature Preserve under M.G.L. ch. 131, Managed according to the 1997 MDC Protection Plan for the Preserve. No active forest management. (see Section 3.6.3)	NA	NA	232	NA
Roads/Scenic roads	Regulated by the FCPA (Ch.132). (see Section 4.1.10)	50% basal area removal limit within 50 feet of all roads, 100 feet of Scenic Roads. Applied as required.			

[1] "TBD" items are undetermined as of printing, but will be updated as mapping is completed for all watersheds.

DWSP has been gradually mapping areas that are impractical for active management for a combination of reasons. For example, some potentially manageable land is enclosed by wetlands or adjacent rare species habitat in such a way that the land is difficult to access. These lands will be identified as limited access areas and will likely be excluded from the total acreage considered to be under active forest management. It is expected that once the mapping process has been completed for all watersheds, the acreage that is identified as limited access will be even more substantial than that listed in Table 4-11. DWSP may manage invasive species, herbivore populations, and fire on these properties, but commercial silviculture treatments are not planned for these areas. Besides providing protection for rare or fragile resources, the areas that have been set aside offer opportunities to gather data for comparison to areas that are being more actively managed.

4.2.7 Threats to the Forest: Insects, Diseases, Invasive Exotic Plants, and Climate Change

Insects and Diseases

Insects and Diseases: Issues and Approaches

- Damaging insects and disease causing organisms are a normal part of the forest ecosystem, but stability is threatened by introduced non-native pests.
- Problems arise for DWSP when impacts conflict with the objective of creating and maintaining a watershed protection forest.
- Approach to managing infestation varies by species.

Damaging insects and disease causing organisms are a normal part of the forest ecosystem. These native agents are vital components of biological diversity and also play key roles in

numerous ecological functions including nutrient cycling, decomposition, and predator-prey relationships. However, the presence of certain non-native organisms introduced to our forests, without their co-evolved complement of predators and parasites, can threaten the forest ecosystem. Native species generally remain in balance with their predators except when cultural effects (past land use or deliberate forest management) create unusual conditions, such as the deliberate creation of single-species stands (i.e., plantations), especially when they are established on unsuitable growing sites.

Insects and disease are seen as a major problem in DWSP's forests when their impacts conflict with the objective of creating and maintaining a watershed protection forest. Apart from the public safety issues of dying trees along roads and trails, generally only large-scale outbreaks that threaten to alter tree species diversity or forest structure generate concern. Chestnut blight, Dutch elm disease, and the gypsy moth had substantial impacts in the past and are still actively affecting watershed forests. There are many other significant current (and potential future) insect and disease threats to DWSP forests. DWSP's approach to managing the effects and outcomes of infestation varies by species. Refer to the Salvage Policy in Section 4.2.7 for general discussion of review and implementation of salvage cutting.

Current Pests Affecting DWSP Forests

Hemlock Woolly Adelgid (Aldeges tsugae)

The hemlock woolly adelgid (HWA) is a small aphid-like insect native to Japan. It arrived in North America in the 1920s and was first recognized on the east coast of the US in 1951 and in Connecticut in 1985. It is spreading across the range of eastern hemlock (*Tsuga canadensis*) and is a serious pest on both eastern hemlock and Carolina hemlock (*Tsuga caroliniana Engelm*).

Hemlock woolly adelgid, *Adelges tsugae*

Eastern hemlock grows throughout DWSP watersheds, but significant amounts are grouped into three forest types: relatively pure hemlock stands; mixed stands where white pine dominates; and in mixed stands where hardwoods dominate. At Quabbin about 1,642 acres (~3%) contain pure hemlock stands, and an additional 5,434 acres (~9%) contain stands with a significant component of hemlock mixed with other softwood and hardwood species. Despite the presence of HWA, Quabbin CFI data shows that between 2000 and 2010 hemlock mortality and harvest rates were fairly low, growth rates were surprisingly strong, and BA increased by 23%. On DWSP properties on the Ware River watershed, about 7% of the overall stocking is in hemlock, the vast majority of which is in mixed white pine/hemlock stands, which total approximately 4,325 acres. Hemlock volume at Ware River is estimated to be in excess of 10 million board

feet. Hemlock is less than 2% of the stocking, on just over 120 acres of hemlock/hardwood type on the Wachusett Reservoir watershed. A significant portion of the overall hemlock stocking is located on wet soils, on steep slopes, or in riparian zones, some of which are steep-sided ravines. A much smaller portion grows on drier and flatter terrain.

A thorough discussion regarding HWA biology and research is available in *the Quabbin Land Management Plan 2007-2017*. In summary:

- The insect is without natural enemies in the northeastern US. Scientists throughout the range of *Tsuga canadensis* are working to find and release safe predators shown to be effective in controlling HWA, including a wide variety of predatory coccinelid beetles and fungi.

- The HWA is susceptible to extreme cold, but high fecundity rates lead to rapid population recovery.

- Trees that are infected may die within 4-5 years, although some are persisting for much longer in a weakened condition. The insect attacks all ages of trees, though it prefers younger foliage. Trees on poorer, drier, ridge top sites may die more rapidly than those on well-watered sites, but trees located on the full range of sites have become infected and ultimately died.

- Loss of this overstory where hemlock dominates the riparian zone may present short-term water quality threats by raising stream temperatures and allowing nutrient transport.

- All approaches to management, including simply allowing HWA mortality to occur without intervention, result in changes to the forest floor that include increased mineralization and nitrification rates that produce more mobile inorganic nitrogen. To the extent that regeneration occurs in pace with or in advance of mortality, available inorganic nitrogen is recaptured and immobilized by biomass accumulation. Consequently, it should be expected that the highest accumulation of inorganic nitrogen will occur in soils where heavy cutting occurs with little or no regeneration on the ground, while the more gradual conversion associated with either partial, preparatory cutting designed to stimulate advance regeneration or letting the stand die and regenerate without intervention should reduce both the volume and the duration of soil accumulations of inorganic nitrogen. The significance of these differences in soil nutrient accumulations to quality changes in adjacent surface waters is uncertain.

- As is true with other removals of overstory trees, the loss of hemlock due either to salvage logging or defoliation and mortality results in an increase in soil moisture and subsurface flow, which also increase the likelihood of transporting both organic and inorganic nutrients to streams.

- There remains some uncertainty about the fate of individual hemlock stands. While there is no clear evidence of resistance, and trees eventually succumb once infected, the distribution of infection has been moderated at least by the variability in distribution vectors. Selected stands within large forests that have escaped infestation and remain healthy may be worth protecting, even at high cost. There is the possibility that they can persist beyond the infestation and provide landscape points from which hemlock might eventually recover, especially if natural and introduced controls eventually strengthen (Orwig and Kittredge, 2005; USDA Forest Service, 2005).

DWSP Policy for Hemlock Management in Response to HWA

DWSP Hemlock Management Policy

- Monitor high hemlock density stands (greater than 50% stocking in hemlock) for presence of HWA.
- Conduct sanitation/salvage cuts only in infested stands, defined as high hemlock density stands in which the majority of the hemlock trees are infected.
- Design salvage cuts to stimulate regeneration of multiple species of varying tolerance to shade. Retain scattered healthy hemlock individuals and attempt to leave sufficient stocking of other species to meet forest structural goals.
- Leave the variable-width filter strip (as defined in Chapter 132) uncut in hemlock salvage operations, except when hemlock occupies less than 30% of that filter strip, in which case the hemlock will be left and up to 20% of the filter strip stocking may be cut from the non-hemlock species.
- Avoid hemlock salvage in seasonally flooded wetlands and keep equipment off of hydric soils in hemlock stands except when they are dry enough or frozen enough to support logging equipment.

The DWSP Hemlock Management Policy was implemented in the 2007 Quabbin LMP and is extended to all DWSP watershed lands. It is a conservative approach to the HWA problem and considers a variety of factors including water quality protection, biological diversity, and market demand.

1. Because of the uncertainty associated with hemlock mortality and the possibility of natural or introduced biological controls, DWSP will not conduct pre-emptive harvests of healthy hemlock. High hemlock density stands containing greater than 50% stocking of

hemlock will be monitored for the presence of HWA. When the majority (greater than 50%) of the hemlock trees in an operable high hemlock density stand are infested with HWA, the stand will be considered for a harvest/salvage operation. Exceptions include operable, infested stands within areas such as the Pottapaug Natural Area on the Quabbin Reservoir, where harvesting is generally excluded unless managers determine that it is needed to prevent the spread of an insect or disease to other parts of the watershed, or to protect public safety.

2. Due to water quality protection concerns and the likelihood of increased inorganic nutrient availability, the hemlock management policy in uplands will differ from management in wetlands and riparian zones.

In upland areas, DWSP will harvest operable, infested hemlock stands to salvage wood and to reduce potential fire and recreational hazards associated with large volumes of standing and falling dead wood, while working to meet management goals for diverse forest structure. Where possible, scattered healthy overstory hemlock trees will be retained. These salvage operations will be designed to provide enough light to stimulate a diversity of shade intolerant species to compete with the common black birch regeneration response. Enrichment planting may be used in these upland areas to strengthen the diversity of the regeneration response.

DWSP will not cut infested hemlock stands located in seasonally flooded wetlands and will avoid running equipment in hemlock stands growing on hydric soils, except when these soils are dry or frozen enough to carry logging equipment without damage. In riparian areas, FCPA regulations limit cutting to 50% of the basal area, thus limiting the opportunity to stimulate shade intolerant regeneration except by increasing cutting adjacent to the filter strip. Harvesting stimulates mineralization and nitrification, leading to higher inorganic nitrogen pools. Black birch is competitively enhanced by high nitrogen levels and moderate light levels. Therefore, partial harvesting in riparian areas may favor black birch rather than diverse regeneration, the opposite of the desired effects. DWSP has experimented with planting in conjunction with partial cutting in riparian zones, and is working to document examples in which these trees have successfully competed with natural black birch regeneration. Allowing riparian are hemlocks to gradually die may reduce the risk of nutrient transport to adjacent streams.

In light of all the above, DWSP will not cut within the variable width filter strip defined by FCPA regulations during salvage operations in hemlock stands infested with HWA, unless hemlock occupies less than 30% of this filter strip, in which case the hemlock will be left alone and up to 20% of the filter strip stocking may be cut from the non-hemlock species, to stimulate new seed production and improve structural diversity. This policy will be in effect until evidence from stream and soil water sampling and/or regeneration research recommends modifications.

Asian Longhorned Beetle (Anaplophora glabripennis)

AP-Christine Peterson

Asian longhorned beetle

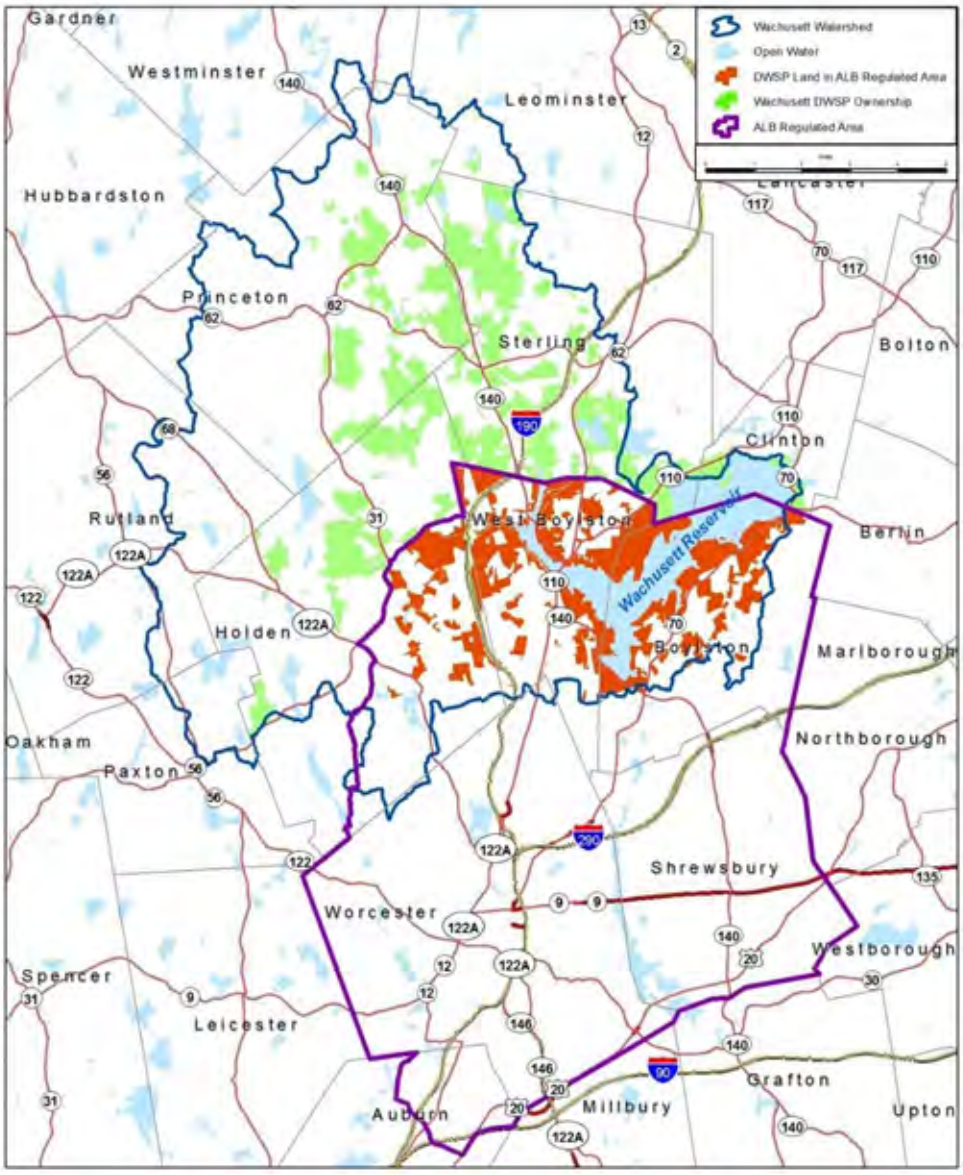
The most recent significant pest to threaten the Wachusett forest is the Asian longhorned beetle. It was first identified in Worcester, MA in August of 2008, but experts suspect it had been present there for at least 15 years. This large black and white-spotted beetle infests a wide range of hardwood species including all species of the genera Acer (maple), Betula (birch), Salix (willow) and Ulmus (elm). Upon the discovery of the beetle in Worcester, the USDA Animal Plant Health Inspection Service (APHIS) set up an eradication effort in cooperation with DCR. By the end of 2014, the program had removed more than 24,000 infested host trees in Worcester, Holden, Shrewsbury, West Boylston and Boylston. To date this pest has not been found in the Sudbury, Ware River, or Quabbin watersheds.

A 110 square-mile regulated area exists in an attempt to prevent the movement of potentially infested materials out of the already infested area. Approximately 9,740 acres of DWSP property lie within this regulated area (Figure 4-13). To date, complete host species removal operations have been conducted on 255 acres of DWSP property in Boylston, West Boylston and Holden. Given that these host species comprise nearly 40% of the Wachusett forest, this insect and the efforts to eradicate it have the potential to greatly alter forest structure and processes. Until ALB is declared eradicated, DWSP will only treat working units in the regulated area where host species constitute a very minor component of the overstory.

Red pine Scale (Matsucoccus resinosae)

Introduced on exotic pines planted for the 1939 New York World's Fair, this insect was found and identified on red pines in southern Connecticut in 1946. This insect is now spreading to red pine plantations throughout Massachusetts and has already swept through stands at Quabbin. It has been detected in several counties in New Hampshire and at one location in Maine. There are no natural controls, and mortality is rapid. DWSP is making a special effort to harvest remaining red pine plantations prior to infestation.

FIGURE 4-13. ALB REGULATED AREA AT WACHUSETT WATERSHED



Elongate Hemlock Scale (Fiorinia externa)

First discovered in New York City in 1908, this introduced pest of hemlock (and other native conifer species) feeds on the undersides of individual needles. In heavy infestations it can affect growth rates and cause foliage loss and eventually mortality. Outbreaks often follow HWA infestations, drought, or other stressors, and the compounded effects can hasten hemlock decline and mortality. This species is extending its range northward, and may threaten spruce and fir which tend to be even more susceptible than hemlock.

Gypsy Moth (Lymantria dispar dispar)

This pest was discussed in the previous Quabbin Land Management Plan section 2.4.1.2.6, and infestations were noted as occurring in 1889, 1964, 1981, and 2000. Several Quabbin islands, portions of the Prescott Peninsula, and extensive areas along the western side of the reservoir were once more seeing significant gypsy moth defoliation in 2015 and 2016, and even more extensive and severe impacts occurred across the watershed (and statewide) in 2017. Some mortality of oaks resulting from these repeated defolations coincident with recent drought conditions is expected, but the extent remains to be seen. Ware River, Wachusett, and Sudbury have suffered less severe defoliation so far, but the outbreak is likely to continue in 2018 despite significant gypsy moth mortality this year in some areas of the state. The long-term cycling of these outbreaks likely depends on a combination of environmental factors along with the biological and genetic features of gypsy moths and their predators, parasites, and pathogens.

Winter Moth (Operophtera brumata)

Known to feed on oaks, maples, basswood, ash, and apples, winter moth is potentially a serious problem for watershed forests. In Nova Scotia, it has been responsible for mortality of 40% of oak stands. Control efforts on the east and west coasts of the US and Canada have included both biological controls and insecticidal chemicals. The species has recently reached outbreak levels in coastal areas of Massachusetts and its presence continues to expand. It is causing significant but patchy defoliation on DWSP lands at Sudbury Reservoir and is known to occur in Worcester. (www.umassgreeninfo.org/fact_sheets/defoliators/winter_moth.pdf) Presently, DWSP has no mitigation plans for this pest.

Beech Bark Disease

This disease is caused by a fungal attack of bark that has been damaged by infestation by the beech scale (*Cryptococcus fagisuga*), which was introduced to North America in the 1890s. The fungi involved are primarily *Nectria Coccinea* var. *faginata*, and *Nectria galligena*. The effects of the disease range from injury and defects in the bark and wood, to mortality and resprouting; the young resprouting stems are often heavily infected and damaged. Diseased beech trees are often cut in cordwood thinnings, but vigorous resprouting from stumps and the entire root system promotes genetic clones that are themselves equally susceptible to the disease and can dominate overall regeneration diversity. The disease is widespread in all DWSP watersheds. Research efforts have looked at developing resistance from native beech stock; scale-feeding ladybird beetles; and fungal parasites of the *Nectria* fungus.

Emerging Threats

White Pine Blister Rust (Cronartium ribicola)

This fungus was introduced to North America around 1900 and causes branch dieback, topkill, and mortality in white pine. It requires an alternate host to complete its life cycle – wild or

cultivated currants and gooseberries. Massive efforts to control this rust by eliminating these hosts from the Massachusetts forest were undertaken in the early to mid-20th century. Recently, these host plants have begun to reappear in DWSP forests. Worse, a more virulent strain of the fungus has developed that infects supposedly rust-resistant cultivars of currants, which had been sold and planted extensively in New England. Given the importance of Eastern white pine in DWSP forests, staff will monitor for signs of this disease and consider options for mitigation.

Emerald Ash Borer (Agrilus planipennis)

This introduced beetle was first identified near Detroit, MI in 2002. It has since spread to fourteen states and has killed tens of millions of ash trees. To date it has been detected in Berkshire, Essex, Hampden, Worcester, and Suffolk Counties. The entire Commonwealth is now under a quarantine to prevent additional spread of this insect. To date there are no known infestations in DWSP forests, but the likelihood of future spread is high. Ash makes up a very small portion of the forest stocking on DWSP lands; it is generally sparse but can be abundant in certain habitats. Salvage or pre-salvage harvesting will be considered on a case-by-case basis.

Sudden Oak Death (Phytophthora ramorum)

A microorganism of unknown origin, sudden oak death infects a very wide range of conifer and hardwoods species. In Massachusetts, the greatest concern is the threat to northern red oak (*Quercus rubra*) and northern pin oak (*Quercus palustris*) trees. Laboratory tests show these species to be highly susceptible, and significant mortality is possible should this organism appear in the forests of Massachusetts.

Sirex Woodwasp (Sirex noctilio)

An introduced insect that threatens conifers, especially pines, it causes tree mortality through the introduction of a white rot fungus and toxic mucus that accompanies egg laying. Unlike the native woodwasp species, which only utilize dead and dying conifers, this species attacks live trees. The presence of this insect has been confirmed in many counties throughout New York and Pennsylvania.

Southern Pine Beetle (Dendroctonus frontalis)

A severe pest in southeastern US forests, this beetle affects all pines, including red pine and our native pitch and white pine. In severe outbreaks it may also infect hemlock and spruce. Warmer winter temperatures may allow this beetle to continue its recent northward expansion; in 2014 it was found extensively on Long Island, and in two locations in southern New York state. In 2015, it was discovered in Massachusetts, though to date it has not been observed in DWSP forests. Beetle larvae feed and tunnel extensively under the bark, and heavy infestations can kill a tree in months. Although there are some natural predators that exert some control, they are ineffective in stemming outbreaks. Southern forest managers utilize salvage harvest to remove infested trees and thinnings to lower stand density to lessen outbreak impacts. DWSP will likely consider similar treatments, especially in the more vulnerable pitch pine barrens focus areas.

Invasive Exotic Plants: Management Strategy

Definitions

Invasion by Japanese barberry

"Invasive" plants can be grouped into two categories – native or non-native species. Most of the difficulties associated with invasive plants involve plants that are non-native. This is true in part because these non-native "aliens" have been transported out of the ecosystem in which they evolved, and may have escaped specific population-controlling insects and diseases in the process. It is important to point out that not all non-native plants are invasive. Most have been intentionally introduced into agricultural or horticultural environments, and many are unable to reproduce outside of these intensively managed environments. There are, unfortunately, hundreds of others that were introduced either deliberately or accidentally to natural settings and that have managed to aggressively force out native plants, raising serious biodiversity issues, and potential threats to water quality protection (Table 4-12).

Some of the invasive plant problems on DWSP properties are the result of deliberate plantings of species that effectively addressed other concerns (for instance, planting autumn olive to improve wildlife habitat), but later revealed their invasive behavior. Other invasive species populations are escapees from landscaping predating DWSP's acquisition of some watershed properties, (e.g., Japanese barberry, Japanese knotweed, the buckthorns, and purple loosestrife). Many invasives are spreading from roadsides and backyards into DWSP lands and are helped along by soil disturbance. In all cases, a plant's "invasiveness" is composed of several defining qualities:

- The plant grows and matures rapidly on a wide range of sites and conditions.
- It is capable of producing vast quantities of seed that is easily dispersed by animals, and often can also reproduce vegetatively.
- There are no diseases or pests effectively controlling its reproduction and spread.
- Within the sites where it grows, the plant tolerates a wide range of annual microclimatic variation.

TABLE 4-12. INVASIVE PLANTS KNOWN TO BE PRESENT ON DWSP LANDS

Common name	Latin name	Habitat
Black locust	*Robinia pseudoacacia*	Edge of forest/field
Norway maple	*Acer plantanoides*	Forest
Oriental bittersweet	*Celastrus orbiculata*	Forest
Japanese barberry	*Berberis thunbergii*	Forest
Black swallow-wort	*Cynanchum louiseae*	Open areas and edges
Glossy buckthorn	*Frangula alnus*	Forest
Common buckthorn	*Rhamnus cathartica*	Forest
Honeysuckles	*Lonicera sp.*	Open areas, forest
Autumn olive	*Elaeagnus umbellata*	Open areas
Russian olive	*Elaeagnus augustifolia*	Open areas
Multiflora rose	*Rosa multiflora*	Open areas and edges, forest
Goutweed	*Aegopodium podagraria*	Floodplains, riparian areas
Japanese knotweed	*Polygonum cuspidatum*	Riverbanks, wet edges, roadsides
Purple loosestrife	*Lythrum salicaria*	Wetlands
Garlic mustard	*Alliaria petiolata*	Floodplains, disturbed woodlands, roadsides
Common reed	*Phragmites australis*	Wetlands
Burning bush	*Euonymus alata*	Open woods, fields, edge
Tree-of-Heaven	*Ailanthus altissima*	Disturbed edges and gaps, urban areas
Japanese stiltgrass	*Microstegium vimineum*	Forest, floodplain, fields, disturbed edges
Amur cork tree	*Phellodendron amurense*	Uplands, open or shaded areas
Castor-aralia	*Kalopanax septemlobus*	Forest
Linden viburnum	*Viburnum dilatatum*	Disturbed forest, wetlands
Border Privet	*Ligustrum obtusifolium*	Fields, forests, edges; sun or shade
Gray willow	*Salix cineria*	Wetlands, shorelines
Sycamore maple	*Acer pseudoplatanus*	Coastal, also disturbed open areas
Amur maple	*Acer ginnala*	Open areas and woods
Mile-a-minute vine	*Persicaria perfoliata*	Fields, edges, banks, wetlands, roadsides

DWSP Control Efforts During the Current Management Period

Summary of Invasive Plant Management Strategy

Treatment of invasive plants to control or reverse their spread will progress as time and budgets allow according to the DWSP's Terrestrial Invasive Plant Management Strategy, with priority being placed on the following:

- Areas where tree regeneration is most critical and is being prevented by one or more invasive plant species. This may include riparian zones and other critical water supply protection areas such as near intake shafts.
- Areas of invasive plants that are presenting a direct threat to existing rare or endangered plant populations or habitats. Control will be focused within proximal buffer areas and methods that do not put the rare or endangered species at further risk.
- Areas of recently established invasive plant populations limited in extent, so that local eradication is a reasonable expectation. Current examples include garlic mustard, Ailanthus, Mile-a-minue vine, and Japanese stiltgrass.

DWSP completed a Terrestrial Invasive Plant Strategy in 2012. For a complete summary of the current problem and the proposed solutions, please see: *Terrestrial Invasive Plants: Problem Statement and Management Strategies* (www.mass.gov/eea/docs/dcr/watersupply/watershed/dcrwatershedterrestrialinvasivesstrategy.pdf).

DWSP intends to use an integrated vegetation management plan (i.e. mechanical, cultural, biological, and/or chemical control methods) for the management of terrestrial invasive plants and will monitor and evaluate the results of these efforts for their effectiveness and cost. In some situations, the judicious use of herbicides is the preferred approach. An example might be a rare plant population, sensitive to the disturbance associated with mechanical control methods, where professional botanists specifically recommend herbicide treatments, such as cut stump application, as the most protective and least threatening approach to removing the threat to the rare plant population. In these situations, a detailed site-specific management approach will be written that will include the justification for herbicides, the specific protocol that will be followed, and the precautionary measures that will be taken to ensure all resources are protected. When using herbicides, DWSP will utilize conservative set-backs from wetland resources and will only apply those herbicides on the Department of Agriculture's list of herbicides approved for use in sensitive areas. Where herbicide use to control invasive plants is planned along internal roadsides or other right-of-way corridors, DWSP will develop and submit a Vegetation Management Plan (VMP) in accordance with 333 CMR 11.00.

Climate Change: Adaptation Strategies

Shifting climate patterns may have potentially large impacts on DWSP forests and natural resources. The average annual temperature in Massachusetts has warmed by nearly 3 ºF during the last century, and equal or greater amounts of warming are expected to occur through the end of this century (NOAA 2017). Climate change projections for Massachusetts suggest that many observed trends will continue, leading to warmer conditions, shorter winters, and more frequent and extreme precipitation events (Kunkel et al. 2013, Horton et al. 2014, NOAA 2017). These climatic changes are expected to have a variety of impacts, including a longer growing season (average, multi-model mean scenario predicts 23-25 more growing days by the end of the century), a shorter winter with more precipitation but less snowfall, the potential for summer drought with associated moisture stresses on plants and increased fire risk, and introduction or range expansion of pests, diseases, and invasive species (Dukes et al., 2009). It appears virtually certain that suitable habitat for many common native tree species will be shifted northward by the end of this century (Iverson et al. 2016, Janowiak et al, in press). Although forests are expected to undergo a variety of changes over the next century, local factors such as site conditions, past management, current species composition, forest stressors (e.g., insect pests, diseases, and disturbance), and the ability of tree species to establish and compete in new locations will all have a tremendous influence on the composition and health of the future forest (Rustad et al., 2012, Janowiak et al. in press).

Climate change challenges forest managers to make decisions in the face of added levels of uncertainty. To deal with this uncertainty, land managers can consider a variety of management actions to help forests adapt to climate change, including actions that resist impacts from climate change, actions that build ecosystem resilience, and actions that actively facilitate changes that make systems better adapted to future conditions (Swanston et al., 2016). Fortunately, many of the actions suggested by climate change experts are already regularly implemented by DWSP. For example, simply maintaining and promoting a diverse mix of coniferous and deciduous tree species may minimize changes in water yield as precipitation patterns and hydrology respond to increasing surface air temperatures (Creed et al., 2014). Some strategies are more complex and speculative and should be undertaken with some caution, such as experimenting with 'assisted migration' and the creation of 'designer forests' by planting novel mixtures of species adapted to predicted future climate (Park et al., 2009, Swanston et al., 2016). Table 4-13 gives an overview of possible forest adaptation strategies (Swanston and Janowiak, 2012). Many of the actions already being implemented by DWSP have important benefits for climate change adaptation because they help to increase the resilience of the forests to a variety of stressors, including those that are exacerbated by climate change. There are also several adaptation strategies DWSP will continue to research prior to integrating into land management planning. A climate change vulnerability assessment for New England has been prepared (http://forestadaptation.org/ne-assessment), and will be helpful in developing or modifying strategies related to DWSP's specific suite of species.

TABLE 4-13. CLIMATE CHANGE ADAPTATION STRATEGY

Strategy	Examples of Activities Currently Being Implemented	Examples of Activities under consideration based on additional research and stakeholder input
Sustain fundamental ecological functions	Maintain riparian areas	
	Maintain hydrology (protect wetlands, streams)	
	Maintain soil quality and nutrient cycling using harvesting BMPs, timing, and CWD	
Reduce the impact of existing biological stressors	Manage herbivores to protect regeneration	
	Prevent and control invasive plants	
	Make forests more resistant to pests (remove infestations; diversify plantations; thin to enhance vigor)	
Protect forests from severe fire and wind disturbance	Alter forest structure to reduce severity or extent of wind and ice damage	
	Maintain road network for fire access	
Maintain or create refugia	Prioritize and protect existing populations on unique sites	
	Protect sensitive or at-risk species or communities	
Maintain and enhance species and structural diversity	Promote diverse age classes	
	Maintain & restore diversity of native trees	
	Establish reserves	
Increase ecosystem redundancy across the landscape	Manage habitats over a range of sites and conditions	
	Establish multiple reserve locations	
Promote landscape connectivity	Protect land through ownership and CRs to reduce the effects of fragmentation	
	Partnerships to promote mutual conservation goals & create protected habitat corridors	
Enhance genetic diversity		Favor existing genotypes that are better adapted to anticipated future habitats
		Use seeds, germplasm, and other genetic material from across a geographic range
Facilitate community adjustments through species transitions	Allow/encourage range expansion of southern native species	Manage for species and genotypes with wide moisture and temperature tolerances
		Establish or encourage new mixes of native species
Plan for and respond to disturbance		Expect more frequent storms, and plan response options, e.g., salvage, replanting vs. natural regeneration, invasives control

adapted from Swanston and Janowiak, 2012

4.2.8 Best Management Practices in DWSP Watershed Forest Management

Harvesting systems carry some risk of short-term water quality impacts. DWSP prevents measurable negative impacts to water quality through the use of Best Management Practices (BMPs). The success of BMPs will continue to be measured by comparison of water quality upstream and downstream from a selection of logging projects. DWSP meets or exceeds the requirements of the Forest Cutting Practices Act ("FCPA": M.G.L. Chapter 132 §40-46) and Regulations (304 CMR 11.00), which in turn ensures compliance with the Wetlands Protection Act ("WPA": M.G.L. Chapter 131 §40) and Regulations (310 CMR 10.00). Whenever these regulations are revised, DWSP management practices will meet or exceed the revised standards.

Strict adherence to DWSP's BMPs ensures that forest management is conducted in a manner that does not impair water resources or other natural/cultural resources on the watersheds. Silvicultural practices can impact the forest and soils essential to protecting water quality if not carefully implemented. One of the primary concerns is the placement of forwarder and skid roads and log landings, where logging work is concentrated and potential soil disturbance is greatest. Proper location of these in relation to streams, rivers, reservoirs, ponds, vernal pools, and bordering vegetated wetlands is important so that soils do not move from these areas into water or wetland resources. In addition, DWSP uses forestry BMPs to diminish the negative impact of silvicultural operations on the residual vegetation, to minimize soil compaction during these operations, and to keep potential pollutants out of the water resource. Where harvesting equipment could pose a threat to sensitive cultural resources, there may be some restrictions placed on timing and equipment choice (see section 4.5).

Planning and Practices: Equipment, Silvicultural Planning, and Workmanship

There are many variables to consider when planning and conducting a logging operation. Variables such as weather, soil moisture, soil depth, topography, and existing vegetation are beyond human control. These natural constraints must be factored into planning, and logging schedules and expectations adjusted accordingly. Variables such as equipment, silvicultural planning, and operator workmanship can be controlled and matched to the constraints of a given site.

Logging Equipment

Logging equipment has changed dramatically in the last 50 years. The primary logging machine was once the 50-70 horsepower (hp) crawler tractor-sled combination. These tracked machines were 5-6' wide and weighed 5-7 tons. Today, most logging is done with 4-wheel drive articulated skidders or 4-8 wheel drive articulated forwarders with 70-260 hp motors, widths of 7-10', and weights of 6-24 tons (empty) or more. Skidders drag logs using a rear-mounted cable and winch or a hydraulic grapple, while forwarders carry logs on integrated log bunks. Cable skidders have become considerably less common, as have the smaller skidders in general. Small skidders are useful for logging in tight stands and on sensitive soils, whereas larger 100-230 hp models, which

weigh from 8-18 tons and are 8-10' wide, may be too large and heavy for stand and soil conditions.

Cable skidder.

Other types of logging equipment include wheeled and tracked feller-bunchers and feller-processors. Feller-bunchers cut trees and put them in piles, usually for removal by a grapple skidder. Three- or four-wheeled feller-bunchers must drive up to each tree for felling, whereas tracked models can reach out and fell a tree 10-20 feet from the machine. A feller-processor grips the tree, cuts it, places it on the ground, de-limbs it, and cuts it into logs, which are retrieved by a forwarder. These machines are sometimes referred to as "cut-to-length", or CTL, systems. Combinations of small, maneuverable feller-bunchers and forwarders, small skidders and forwarders, and small tracked or rubber-tired feller-processors and forwarders have all worked successfully on DWSP watersheds.

Rubber-tired skidder

DWSP specifies equipment types as well as ground pressure and width restrictions appropriate to specific soils and within specific forest types, where needed, in timber harvesting permits. Widths are either from direct measurement or from manufacturer's specifications; ground pressures are based upon a formula that combines machine weight and weight of an average load of logs with an estimated footprint for the tire size specified, at an average tire inflation pressure. Some examples from this rating system for a variety of older skidders and forwarders are shown in Tables 4-14 and 4-15.

TABLE 4-14. SAMPLE SKIDDER SIZES AND GROUND PRESSURE

Machine Model	Tire Size (inches)	Width (inches)	Ground Pressure (lbs/sq in.)
Cable skidders			
TimberJack 208	23.1 x 26	102	4.9
JohnDeere 440C	23.1 x 26	102	5.0
Franklin 105XL	23.1 x 26	110	5.3
TreeFarmer C4	18.4 x 26	93	6.5
JohnDeere 540	23.1 x 26	105	6.6
CAT 508GR	23.1 x 26	106	7.1
Clark 665	23.1 x 26	114	7.9
Clark 665	18.4 x 24	104	9.5
TreeFarmer C6	18.4 x 34	97	10.1
CAT 518	18.4 x 34	99	11.2
Grapple skidders			
Franklin Q80	30.5 x 32	131	7.9
Prentice 490	24.5 x 32	118	10.0
Tigercat 610	24.5 x 32	115	9.7
John Deere 648G	24.5 x 32	123	8.2
Caterpillar 525C	30.5 x 32	133	8.2

TABLE 4-15. SAMPLE FORWARDER SIZES AND GROUND PRESSURES

4 Axle Forwarders	Tire size (mms x inches)	Width (inches)	Ground pressure (lbs / sq. inch) *Unloaded*	*Loaded*	*Loaded, with Eco Tracks*
Rottne/Solid F12	700 x 26.5	112	5.6	10.1	6.8
John Deere 1110	600 x 26.6	107	5.3	14.5	12.4
Timberpro 815	700 x 26.5	113	3.4	14.5	10.3
Valmet 860	600 x 22.5	110	5.5	17.4	9.9
Caterpillar 574	700 x 26.5	111	5.6	15.7	9.3

(Sources: Caterpillar Inc, Forest Products Forwarders Ground Pressure Table: Forestry Research Institute of Sweden (Skogforsk) & Forest Engineering Research Institute of Canada (FERIC)

Rubber-tired Feller/ CTL Processor.

Matching the equipment with the site conditions to minimize any damage is critical to the success of watershed silvicultural activities. Each site has unique conditions that require the experienced judgment of the forester to predict impacts and set appropriate specifications. Some of the locally available logging equipment may be too large or heavy to meet DWSP requirements in certain vegetation or soil conditions, while some may be limited by terrain. However, experienced - and above all, conscientious - operators can often provide excellent results with careful use of even very large equipment, in some situations.

An example of a "preferred logging system" that accomplishes DWSP goals under difficult conditions is a small CTL processor and forwarder combination, used for thinning dense pine plantations on a variety of soil conditions. Both machines are able to work in these conditions with minimal root, stem, crown, or soil damage. In addition, these machines can successfully work around walls and foundations and sometimes do not require a landing, as logs can be stacked on the roadside. This combination can also work in previously thinned stands that have an understory of young trees, with minimal damage to the young growth. Generally, when trying to save and promote growth of advance regeneration, fixed-head processors are preferred. Dangle-heads are allowed when damage to advance regeneration is not a concern, due to its scarcity or poor condition.

Forwarder with tracks.

While smaller tracked feller-processors are inherently limited to stable ground conditions (few rocks and gentle slopes) and trees less than 16" DBH, current models can fell trees up to 30" DBH and come equipped with self-leveling cabs that allow work on slopes up to 30% and rubber tires that allow work on rocky ground. In old stands where the trees are generally large, hand felling is necessary. Multi-aged stands generally have many more stems/acre than the present even-aged stands and consequently are more difficult to work in without damaging residual trees. A combination of a winching machine and forwarder works addresses the problem well in multi-aged stands.

Silvicultural Planning

A well-planned harvest

Foresters and loggers are likely to have different expectations when a particular harvest operation is planned and conducted. Foresters need to carefully communicate their planned silvicultural goals and expected results for each lot. Silvicultural plans have to address present cutting practices, landscape aesthetics, cultural resources, wildlife resources, wetlands, and rare or endangered species. While the protection of non-tree resources is of particular concern, the most difficult aspect of planning concerns the maintenance of multi-age stands of trees. These stands have a diversity of seedlings, saplings, and poles that are easily damaged. The positioning of temporary and permanent logging roads, landings, and small and large group cuts is crucial to successful long-term development of the stand. Logging operation success and optimal protection of water resources are dependent upon careful advance planning. See Figure 4-14 for an example of silvicultural planning.

Operator Workmanship

Operator workmanship is one of the most crucial and variable factors in forest management because good planning and preparation must be reinforced by professional workmanship by operators. DWSP maintains tight control over loggers working on the watersheds and reserves the right to suspend operations or remove operators who fail to adhere to permit standards. Furthermore, every harvesting operation receives a written post-harvest inspection and evaluation report that is filed for future determination of the operator's commitment to good workmanship. Ideally, operators feel a shared commitment to the sustainable stewardship of the watershed land. Some examples of professional workmanship by loggers include:

- ***Protection of Residual Vegetation***. Skilled tree felling, skidding, forwarding and the development of skid/forwarder roads, coupled with patience and careful operation, prevents damage to the roots, stems, and crowns of understory and overstory vegetation.

- ***Cultural Resource Protection***. The protection of cultural resources results from both good planning and good workmanship. For example, small versatile equipment can reduce soil compaction and work around walls and foundations without damage. Boom fellers can cut and lift trees out of sensitive sites, and forwarders can be used to stack logs roadside when landing sites are limited due to cultural sites or poor soil conditions. See Section 4.5 for a more detailed discussion on this subject.

FIGURE 4-14. SILVICULTURAL PLANNING EXAMPLE

Silvicultural Planning Example

Area Description, Silviculture History and Stand Description

This approximately 48 acre area is comprised of parts of two properties DCR acquired in 1995 and 2000. This lot is on both sides of a hilltop, bounded by an intermittent stream, stone walls, and a powerline. Once pastureland, the oak forest north of the internal wall that divides this unit originated in the 1920s, and was logged in the early 1990s before DCR acquisition. The white pine stand south of the stone wall is an uncut stand with high stem density, which originated from pasture abandonment in the 1930s. The present age structure of this working unit is as follows: 1% 0-20 years old, 0% 21-40 years, 0% 41-60 years, 79% 61-80 years, 20% 81-100 years, 0% > 100 years old. Forest types include white pine (WP), white pine/oak (WO), oak/hardwood (OH), and mixed oak (MO). There are some excellent quality red oaks, especially on the northeast slope north of the internal stone wall. The advance regeneration present (sometimes in adequate numbers) is made up of small, suppressed, "umbrella" oaks with some white pine. There is the occasional pocket of better developed advance regeneration north of the stone wall.

Silviculture and Equipment

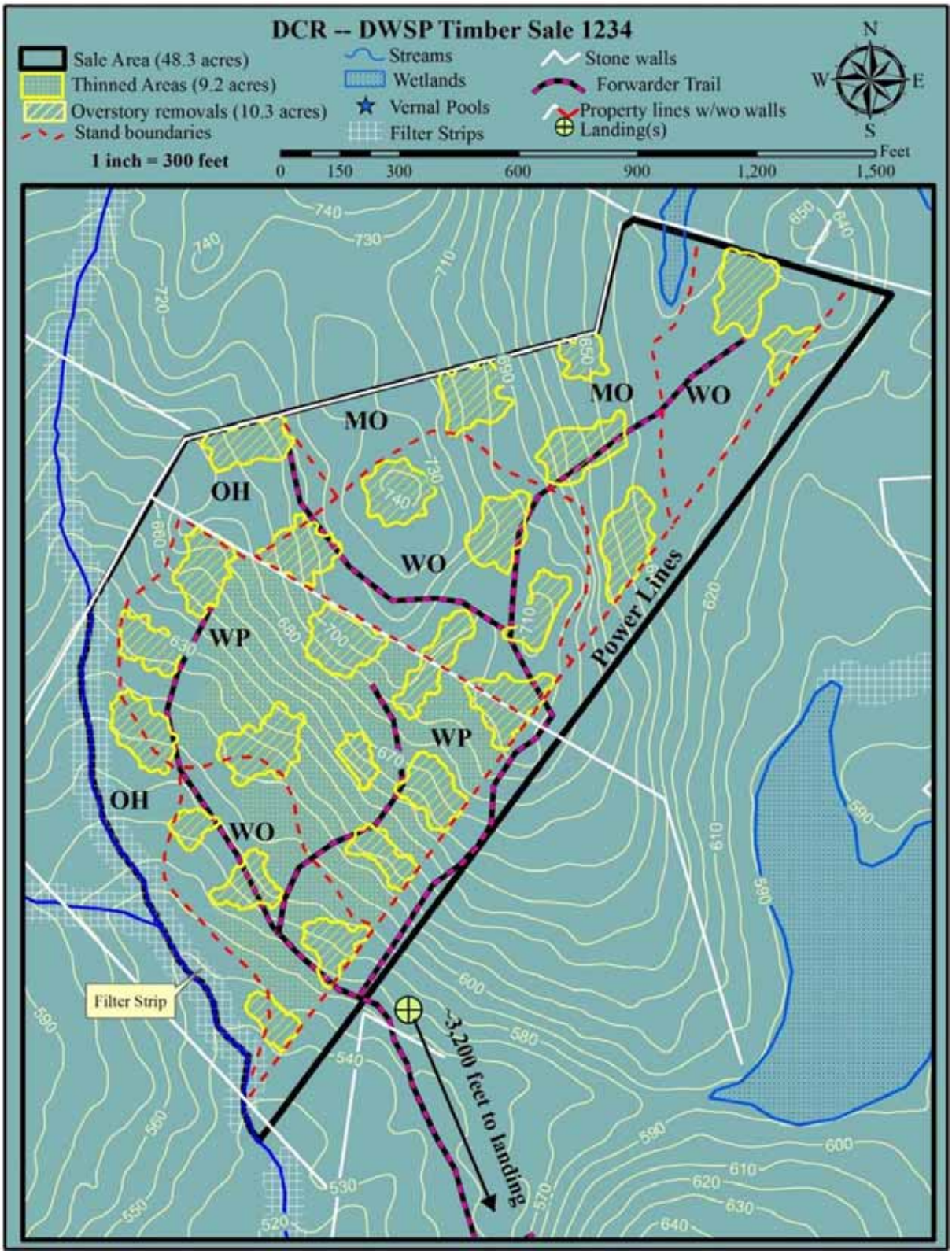
Overstory removal patches averaging about 0.4 acres have been placed to release advance regeneration. Patches have been shaped to fit the landscape, are variably shaped and sized, are designed to minimize long straight edges, and contain occasional large retained trees. The combination of mechanized felling and forwarding is the best option to protect as much of the advance regeneration and residual standing tree cover as possible. Thinning south of the wall will remove low vigor pines and maples, improve growing space for better quality trees, and foster regeneration.

BMPs

Primary access from the lot starts with a southeasterly connection to an old logging trail that ends at a previously used landing on the public road south of the area. Although longer than heading to the road to the north, this trail avoids installing a bridged stream crossing on a significant stream just north of the harvest area. Trails have been laid out to avoid any new stone wall crossings, but otherwise there are no known cultural resource sites in this area requiring protection.

All required filters and buffers have been flagged, and work within these areas is restricted. No work will be done on wetland soils. Parts of the filter strip will receive selective cutting and will only be worked when frozen or dry. On the hill, the slopes are challenging in places but workable with care. Forwarder roads throughout the harvest will be protected with water bars and mulching where necessary. A potential vernal pool is located at the northern boundary of the sale area, and no work is proposed adjacent to this pool at this time. Den trees, standing snags, and stick nests have been avoided during the marking of the lot, and the logger is expected to protect them when operating.

FIGURE 4-14 (CONTINUED). SILVICULTURAL PLANNING EXAMPLE



- ***Aesthetics***. DWSP watershed land is public property; the general public regularly passes through DWSP lands either via adjacent public roads or on interior roads. Attention to aesthetics is important everywhere, but most important along traveled ways. Trash is cleaned up. All slash and debris from fallen trees is kept back from the road's edge following regulatory requirements. Landings are cleaned of unmerchantable tree debris. Care is taken to maintain large roadside trees and to promote replacement trees. While every harvest changes the look of the forest, attention to aesthetics reflects how loggers feel about their work and the land, and affects how the public reacts to forest management.

BMPs to Prevent Soil Movement and Sedimentation

Summary of BMPs To Prevent Sedimentation

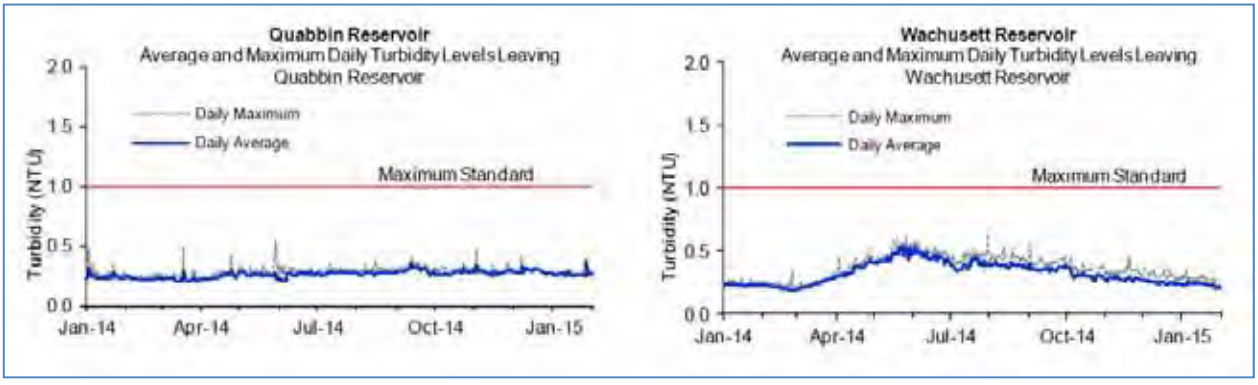
- ***Landings***
  - Locate appropriately and stabilize.
  - Utilize erosion controls, as needed.
- ***Skid and Forwarder Roads***
  - Place limits on steeper grades.
  - Stabilize with woody debris and water bars as needed to prevent erosion during lot suspensions and upon completion.
- ***Stream Crossings***
  - Avoid when possible; design and locate appropriately when necessary.
  - Always bridge both perennial and intermittent streams when flowing.
  - Mitigate unstable approaches; allow non-bridged crossings with mitigation, as needed, when stream is dry or frozen.
- ***Filter Strips***
  - Limit cutting to 50% of basal area.
  - Apply variable width filters to all streams.
  - Do not allow equipment within 50 feet of a stream bank, except to cross.
  - Do not allow primary skid or forwarder roads within variable width filter.

A primary purpose of BMPs is to prevent or minimize the movement of soil to the water resource. During a harvesting operation, this is most likely to occur on a landing or skid/forwarder road. In these areas, the humus layer is sometimes lost and the soils may be temporarily compacted and channelized so that water will flow over the surface instead of passing through the soil. If the road is unwisely placed on a continuous slope, rainwater will

increase in volume and velocity as it travels down-slope, scouring the path, removing soil, and creating a gully. If the road connects with a stream, the suspended soil may be carried much further. The result of careless logging practices can be erosion, increased stream turbidity levels, and deposition of the eroded materials downstream. As a water provider, DWSP implements BMPs that provide simple and effective means to minimize all of these impacts while continuing to manage for long-term watershed protection.

The US EPA Surface Water Treatment Rule (SWTR) requires filtration by every surface water supplier unless strict source water quality criteria and watershed protection goals can be met. Source water quality criteria rely on a surrogate parameter, turbidity, and an indicator organism, fecal coliform bacteria, to provide a relative measure of the sanitary quality of the water. For turbidity, the US EPA SWTR standard is 5.0 Nephelometric Turbidity Units (NTU), while the Massachusetts Department of Environmental Protection (DEP) has adopted a more stringent performance standard of 1.0 NTU. MWRA monitors turbidity of Quabbin Reservoir water continuously at the William A. Brutsch Water Treatment Facility prior to chlorination, and turbidity of Wachusett Reservoir water at the Carroll Water Treatment Plant before ozonation. Both reservoirs have demonstrated consistently low turbidity levels (Figure 4-15), and DWSP will continue to implement BMPs to minimize any risk to stream and reservoir water quality.

FIGURE 4-15. TURBIDITY LEVELS AT QUABBIN AND WACHUSETT RESERVOIRS



(Source: MWRA Data)

Landings

Landings are permanent sites that should be located on well-drained ground and soils that will support the logging equipment. When located on moderately drained soils, landings are constructed with natural and/or man-made materials that prevent rutting and maintain a workable surface. This generally includes the use of crushed gravel, which allows water infiltration and supports heavy equipment, and may also include the use of "geo-textiles," woven road construction fabrics that prevent mixing of gravel with the soils below. The FCPA regulations only require that landings be located in 'upland areas,' but since neither principal skid roads nor cutting more than 50% of the basal area are allowed in variable filter strips, landings are precluded there as well.

A well-organized log landing

DWSP has additionally adopted several of the BMP Manual (Catanzaro et al., 2013) guidelines regarding landings. All operators will have oil absorbent materials at the landing and in all equipment, as well as information regarding responses to hazardous spills. Skidder or forwarder roads upslope of the landing are designed to direct storm and meltwater away from the landing. Where necessary, an erosion control barrier is maintained between the landing and access road (road ditch, hay bales, etc.), and landings are required to be smoothed, and seeded if necessary, after use. Landings will be located at least 100 feet from any water/wetland resource areas in most cases; in the rare cases where the landing must be located within 100 feet of a resource, effective erosion/sediment control barriers will be installed, and petroleum products will be stored away from the water resource. Upon completion, the sensitive areas will be promptly re-vegetated.

Skid Roads

Skid roads are designed to be re-used and are therefore located on soils that can support the skidder, such as well-drained gravel or well-to-moderately-drained stony till soils. Some soils, regardless of their drainage capacity, are wet in the spring, early summer and late fall; in these areas harvesting must be scheduled for dry or frozen conditions. Skid road establishment usually requires cutting some trees (selected in advance by DWSP foresters), and woody debris is often placed in the road to assist in supporting equipment to help protect the soil. Skid roads are relatively straight to avoid damaging roadside tree stems and roots, and continuous grades are deliberately interrupted to divert rainwater off the road. Most skid road grades are less than 10%, but in some cases, climbing grades may reach a maximum of 20%. These steeper climbing

grades are limited to 200 continuous feet. Downhill skidding grades are allowed up to 30% but for no more than 200 feet on grades greater than 20%. Skidding grades greater than 20%, if not protected by frozen ground or snow cover, are "armored" with tree branches and other erosion-control measures as necessary.

Skidding distances are minimized to prevent excessive wear to roads unless longer skid distances will better protect resources. Skidder width and weight requirements are tailored to site conditions. Skidding is stopped when rains or thaws make the soils temporarily unable to support skidders.

At the end of the logging operation or when work is suspended, all temporary roads are stabilized through seeding, mulching, and/or the construction of water bars to prevent erosion. Water bars are designed and placed frequently enough to prevent the buildup of erosional energy from water flowing downhill along trails with exposed soil. It is sometimes difficult to regularly space water bars due to rocky conditions and lack of places to discharge water, so spacing may vary. Water bars are designed with the following parameters:

- Angle across and down the road to create a 3-5% pitch.
- Discharge water to an appropriate area that drains away from the road.
- Prevent sediment deposition into any water resources.

A skidder can usually be used to construct water bars unless the soils are very rocky or ledgy. In rocky soils, they may have to be built by hand. Nearby logs and brush are often used for reinforcement. If closely spaced, water bars do not have to be more than 6-8 inches deep, including the height of the berm. Deeper water bars with higher berms are more effective for a longer time, and may also provide a disincentive for unauthorized uses. After completion of logging, water bars may be seeded during the growing season.

Forwarder Roads

Forwarder roads are located on soils that can support these machines. The layout of forwarder roads is more flexible than for skid roads because forwarders do not require straight roads, and can maneuver around residual vegetation. Forwarders are generally more limited than skidders on steeper slopes and wetter soils, although newer machines with tracks can accommodate steeper conditions for longer stretches, adding flexibility to the forester's options for management in those areas. Forwarder roads sometimes require rough preliminary grading to remove stumps and rocks.

Forwarders were originally designed to stay on the road and pick up logs brought to the road by a skidder, but their role in forestry has grown. In operations that combine skidders and forwarders, skidders operate the sloping and rough ground, while forwarders operate on the more level terrain, around areas of more sensitive soil, vegetation, or cultural features, and handle long

hauling distances. Water bar and other stabilization requirements for forwarder roads are the same as for skid roads.

Stream Crossings

Given the existing infrastructure of public roads and interior forest roads, stream crossings are often necessary to access significant portions of DWSP watershed lands. Frozen conditions are favored whenever possible to protect the actual crossing and the approaches, and to limit the amount of soil carried in machine tires or on skidded logs. However, frozen stream conditions are ephemeral and never guaranteed from year to year.

Portable bridging is required by FCPA regulation for crossing all streams within 1,000 feet of the high water marks of the reservoirs, and on DWSP lands is also used for crossing any perennial or intermittent tributary stream when flowing. This bridging, generally provided by the logger, consists of either pre-fabricated sections transported to the site, or site-constructed bridging. Past studies (Thompson and Kyker-Snowman, 1989) have shown that machine placement and removal of crossing mitigation can move substantial sediments into the stream, especially where banks are steep or unstable. Therefore, it may be preferable in some conditions to construct mitigation on-site and without machinery. In either case, the bridging will be designed and constructed so as to minimize degradation of stream water downstream of the logging activity during and after that activity.

Correct location of crossings is important in order to avoid soft soils that the machine may carry onto the bridge and into the water. FCPA regulations require that all crossings be marked with paint or flagging and accurately mapped on the cutting plan. All crossings are made at right angles to the streamflow. If frozen conditions are not available, then banks and adjacent soils are protected with tops of trees, poles, or other suitable material. In all crossings, any bridging is designed and installed to accommodate the 25-year stormflow for the upgradient drainage. Most temporary crossing construction will be removed at the completion of the operation, and the site stabilized. DWSP foresters supervise the design, construction, and placement of bridging or other mitigation, and the proper protection of approaches, in advance of equipment travel over the structure. They also monitor their effectiveness as BMPs during use, and their removal upon completion of the operation.

Skidder on a temporary bridge

Small, intermittent streams may be crossed without bridging when they are dry or frozen. Dry crossings may be poled to protect the stream bottom. DWSP foresters will frequently monitor all unbridged crossings, and will require discontinuing, further mitigation, or bridging as conditions dictate. No stream crossing is allowed

to result in rutting, disruption of stream bank integrity, or measurable downstream water quality degradation. Table 4-16 outlines the various stream-crossing situations encountered on DWSP watersheds and level of protection these crossings are given.

TABLE 4-16. PROTECTION MEASURES APPLIED TO VARIOUS STREAM CROSSING SITUATIONS

Types of Crossing Situations	Minimum Level of Protection	
	BMPs + Mitigate	BMPs + Bridge
Intermittent stream, above the highest wetland in the drainage.	Always	When flowing
Intermittent stream, downstream of highest wetland, crossing further than 1,000 feet from reservoir high water mark.	Always	When flowing
Any intermittent stream with unstable banks/approach.	Always	When flowing
Intermittent stream, downstream of highest wetland, crossing within 1,000 feet of reservoir high water mark; regardless of flow conditions.		Always
Continuously flowing stream.		Always

"Wetland" refers to bogs, swamps, wet meadows, and marshes. "Mitigate" includes use of poles, brush, or slabs placed in or beside a small stream when necessary to minimize equipment impacts on bank or streambed integrity. "Bridge" includes installed or site-built structures that are above the stream profile and capable of keeping all equipment and harvested products out of the profile. "BMPs" refers to right-angle crossing, protecting and stabilizing banks and approaches, appropriately installing water bars on upgradient skid roads, and any additional techniques to prevent sediment reaching streams.

Filter Strips

Filter strips are vegetated borders along streams, rivers, or water bodies (including vernal pools) and represent the final opportunity to prevent transport of sediment, nutrients, and pollutants into streams or reservoirs from nearby roads or landings. When roads and landings are near water resources, filter strips are given special attention. FCPA regulations requires a minimum 50-foot filter strip along all regulated streams (including perennial and certain intermittent streams; see page 13 in DCR's Best Management Practices Manual (Catanzaro et al., 2013)), in which 50% of the basal area must be retained in healthy, growing trees. For Outstanding Resource Waters, which include all surface water drinking supplies and their tributaries, FCPA regulations require increasing the filter strip width based on slope. Machinery is not allowed in the first 50 feet of any filter strip except at approved stream crossings, on pre-existing logging roads, and where necessary to reduce environmental damage. Primary skid roads are not allowed within variable filter strips.

DWSP expands on these requirements by applying filter strips to unregulated intermittent streams, and by increasing the filter strips beyond "variable width" requirements for certain slope/soil combinations. For example, on poorly drained and somewhat poorly drained soils the filter strip is increased 40 feet for each 10% increment of slope angle above 10%. On well-

drained and moderately well-drained soils the filter strip is increased 40 feet for each 10% increase in slope angle above 20%.

BMPs for Point-Source Pollutant Control

Petroleum Products

Typical petroleum products present on logging operations include gasoline and diesel fuels, hydraulic fluid, lubricants, and bar and chain oil. All machines are inspected by DWSP foresters for leaks prior to arrival and for the duration of their stay on the watershed. Checks are made of all hydraulic components, fuel tanks and lines, engine, transmission and axles. All petroleum products that are not in machine storage are stored in safe durable containers and removed from the watershed at the completion of each day. Petroleum storage is only allowed in tanks designed, manufactured, inspected, and certified for commercial use. No re-fueling or servicing is allowed within the 50 foot filter strip along water bodies or within 25 feet of any wetland. Permittees are required to follow a Spill Response Protocol (see below).

Human Waste

Deposition of human solid waste is not allowed on DWSP property. Permit specifications require the use of a portable bathroom facility (a "portable, self-contained, leak-proof unit of three gallons or more"). The only exception to this policy will be the use of existing sanitary facilities on the watershed, which include those installed for recreational access.

Rubbish

All waste material, including parts, packaging, lubricants, garbage, sandwich wrappers, and other litter must be stored in appropriate containers and removed daily from DWSP property.

Spill Response Planning for Silvicultural Operations

Spill Response Protocol Summary

- All loggers are required to carry spill pads in each piece of logging equipment.
- All spills must be reported immediately to the Forester and/or DCR staff.
- A Spill Response Plan which includes a map showing resource areas and emergency phone numbers is provided with the Permit.

All logging permittees who work on DWSP properties are licensed Massachusetts Timber Harvesters, with basic training, experience, and a good understanding of the potential water quality threat represented by the size and weight of their equipment and by the volumes of petroleum products carried on this equipment. Log trucks and tractor-trailers typically carry up to 200 gallons of diesel fuel. Larger mechanized harvesting equipment can carry as much as 150 gallons of hydraulic fluid, as well as diesel fuel. In some situations, DWSP allows fuel trucks

with much larger capacities to be brought into staging areas to refuel equipment. On operations using hand felling or chainsaw bucking at the landing, chainsaw gas and bar and chain oil will also be on site, though generally in amounts of less than ten gallons. Some processors use bar and chain cut-off saws, so will also carry bar and chain oil.

The most common type of spill that occurs at harvesting operations is the failure of a hydraulic line on harvesting equipment. These machines are designed to prevent high-volume spills by including automatic shutdown of hydraulic pumps or automatic pump reversal to pull fluid back into the reservoir in response to a sudden drop in pressure. Because of these safeguards, most spills involve less than ten gallons of fluid.

As mentioned above, all Timber Harvesting Permits on DWSP properties require that each piece of logging equipment carry on-board, at all times, sufficient oil-absorbent cloth to catch a ten-gallon spill, providing an immediate response to a leak or a hose failure. In addition, DWSP assesses the area prior to harvesting and develops a Spill Response Plan (SRP). Where the lot can be accessed from more than one road, or from both directions on the same road, it is assumed that a spill response could be mobilized quickly. In situations with more problematic access, DWSP may maintain additional spill response materials on site. Finally, the Spill Response Plan is included in the permit for the timber sale, which includes:

- Locations of all wetlands, streams, culverts, and other water features within the lot.
- A map showing access to and from the nearest public road, with the location of all wetlands, streams, culverts, intersecting roads and areas of critical habitat identified.
- Any limitations placed on the quantity and type of fueling permitted within the lot.
- The requirement for a pre-harvesting meeting between DWSP foresters and the logging contractor to review spill response procedures.
- Locations of permanent and temporary access roads and all staging areas.
- A list of phone numbers to call and procedures to follow in the event of a spill.

BMPs to Protect Wetlands, Vernal Pools, and Rare Species

Wetlands

DWSP has identified and mapped 8,253 acres of DWSP-owned wetland within the four watersheds. Although timber harvesting is allowed by law in wetlands in Massachusetts, DWSP limits harvesting in these areas. When DWSP's forest management operations necessitate harvesting in or crossing a bordering vegetated or freshwater wetland, DWSP complies with all the requirements of the WPA regulations and the FCPA regulations for cutting in wetlands (defined in the most current revisions of these regulations). The regulations allow for harvesting in wetland areas provided the following conditions are met: a Forest Cutting Plan is filed, no more than 50% of the basal area is cut, the residual forest is well distributed, there is a minimum

of five years between successive harvests, and machinery is only allowed within wetland areas when the ground will support that machinery (i.e., when it is frozen or dry). In addition, DWSP does not allow machinery within low, flat wetland forest with deep muck soils that are seasonally flooded. These muck soil wetlands account for the majority of identified wetlands on DWSP watershed lands.

DWSP conducts a limited amount of non-harvesting forestry work in wetland resource areas, including planting, pruning, thinning, and maintenance of boundaries and fire breaks. Since a Forest Cutting Plan would not be filed for these activities, they are required to be done in accordance with WPA regulations.

Vernal Pools

Vernal pools provide critical habitat for a number of amphibians and invertebrates, some of which breed only in these unique ecosystems, and/or may be rare, threatened or endangered species. Although vernal pools may only hold water for a period in the spring, the most important protective measure is learning to recognize these pool locations, even in the dry season. Foresters can then incorporate the guidelines below in their plans to ensure that these habitats thrive. More stringent guidelines are followed when MESA-listed mole salamanders are present (see: www.mass.gov/eea/docs/dfg/nhesp/regulatory-review/mole-salamander-cmp.pdf.)

For the purposes of protection during forest management operations, DWSP chooses to treat all vernal pools (verified by DWSP wildlife biologists to be functioning as vernal pool habitat) as if they are Certified, and follows all FCPA regulations for Certified pools. Beyond that, DWSP includes a 15-foot no-cut buffer around the pool edge, a 100-foot shade zone, a 200-foot low ground disturbance zone, and adheres to the additional recommended guidelines in the BMP Manual for protection of vernal pools (see Figure 4-16 and Section 4.4.5).

Rare and Endangered Flora and Fauna

Primary regulatory and programmatic responsibility for the protection of endangered, threatened, or special concern species in Massachusetts rests with the Natural Heritage and Endangered Species Program (NHESP) of MassWildlife. The 1990 Massachusetts Endangered Species Act protects 256 rare plant species. DWSP's Natural Resources Section keeps records of listed plant and animal species on DWSP land that were discovered by in-house personnel or passed along by other professionals or the public, monitors known populations of listed plant species, and updates NHESP with new occurrences. NHESP maintains a more complete database, and in order to ensure that land management activities do not disrupt or destroy listed species or their habitats, NHESP reviews DWSP harvesting that is planned within a mapped Priority Habitat or Estimated Habitat for rare species (NHESP, 2008), and sets restrictions on the harvesting activity if necessary to protect the species of concern.

Several organizations, including NHESP and the New England Wild Flower Society, are working to develop specific management recommendations for the perpetuation of uncommon plant species. Much remains to be learned about the specific light, moisture, and regeneration requirements for the species of concern. Some species will persist best if given a wide berth, while others rely on periodic disturbance. DWSP will coordinate closely with NHESP and will apply recommendations as they are developed to guide management practices towards protecting and benefitting known rare plant populations (see Section 4.4.3).

Additional Regulatory Requirements: Fire Prevention, Roadside Buffers

Fire Prevention

Fire prevention concerns both the forest and machinery. M.G.L. Chapter 48, §16, the "Slash Law," adequately deals with the disposal of slash along boundaries, water bodies, wetlands, highways, roads and utility right-of-ways. Slash is not allowed within 25' of any stream, river, pond or reservoir. This law is summarized in the BMP Manual (Catanzaro et al., 2013), and is also the DWSP standard.

Machine fires can spread to uncontrolled forest fires and cause water and soil pollution. Keeping a leak-free, well-maintained machine and having the proper fire extinguishers on the machine can prevent damaging machine fires. All machines are inspected for proper fire extinguisher and spark arresters by a DWSP forester before entering the site.

FIGURE 4-16. PROTECTION OF VERNAL POOLS

Vernal Pool and Depression and No-cut Area ..... 15-foot buffer around pool

Objective 1: Maintain the physical integrity of the pool depression and its ability to hold seasonal water.

1. Keep heavy equipment out of the pool depression at all times of the year. Rutting here could cause the water to drain too early, stranding amphibian eggs before they hatch. Compaction could alter water flow and harm eggs and/or larvae buried in leaf litter at the bottom of the depression.
2. Prevent sedimentation from nearby areas of disturbed soil, so as not to disrupt the pool's breeding environment.
3. Keep tops and slash out of the pool depression. Although amphibians often use twigs up to an inch in diameter to attach their eggs, branches should not be added, nor existing branches removed. If an occasional top lands in the pool depression leave it only if it falls in during the breeding season and its removal would disturb newly laid eggs or hatched salamanders.
4. Cut no vegetation within 15 feet of the high-water mark of the pool depression. Silvicultural manipulations are limited to girdling (for instance, to enhance vigor of uncommon swamp white oak trees).

Shade Zone..... 100-foot buffer around pool edge

Objective 2: Keep a shaded condition in this 100-ft.-wide buffer around the pool depression. Amphibians require that the temperature and relativity humidity at the soil surface be cool and moist.

1. No equipment is allowed to operate within 50 feet of the pool edge.
2. Light, partial cuts that can maintain this microclimate are acceptable; clear cuts are not. Understory vegetation such as mountain laurel, hemlock, advance regeneration or vigorous hardwood sprouts after a harvest will help to maintain this condition. Avoid leaving only trees with small or damaged tops, or dead and dying trees.

Objective 3: Minimize disturbance of the forest floor.

1. Operate in this area when the ground is frozen and covered with snow, whenever possible. Keep equipment 50 feet away from the pool depression and winch out logs or wood cut in this first 50 feet.
2. Avoid operating during muddy conditions that would create ruts deeper than 6 inches. Ruts can be an impediment to migrating salamanders, some of which are known to use the same vernal pools and migratory routes for 15 to 20 years.
3. Minimize disturbance of the leaf litter and mineral soil that insulate the ground and create proper moisture and temperature conditions for amphibian migrations.

Low Ground Disturbance Zone..... 100-200 feet from pool edge

Objective 4: As above, minimize disturbance of the forest floor in this area.

1. Operate equipment in this area when the ground is frozen or covered with snow, whenever possible.
2. Follow 2 and 3 from objective 3 above.
3. Avoid locating landings and heavily used skid roads in this area. Be sure any water diversion structures associated with skid trails and roads do not connect to or cause sedimentation in the shaded zone or the vernal pool itself.
4. Standard silvicultural treatment options allowed.

Roadside Buffer Strips

FCPA regulations require the maintenance of aesthetic buffer strips along the edges of highways and public roads. Within this buffer, no more than 50% of the basal area can be cut at any one time and no additional trees can be cut for five years. Buffer strips are 50 feet wide except along designated scenic roads, where they must be widened to 100 feet. The buffer is generally measured from the existing roadside tree line, but the placement ("Buffer strips shall extend 50 feet back from the outer edge of the highway...") is subject to interpretation by service foresters. The intent is to retain a 50- or 100-foot belt of trees with at least 50% stocking to act as a visual screen. To assure compliance with this regulation, DWSP conservatively measures from the edge of the right-of-way layout, not the tree line (which may begin well within the road right-of-way layout). DWSP has occasionally been granted permission to exceed the 50% limit on road buffers, where partial cutting within rapidly deteriorating stands (mainly overstocked and failing white pine and red pine plantations) was very likely to create even more hazardous conditions on public roads. In these cases, written permission from the local or state entity with authority over the road is required, along with consultation and permission from the service forester.

4.2.9 Internal Review of Proposed Forest Management Operations

The key to the proper protection and management of the resources under the care and control of DWSP is the care and expertise of the staff. As the on-the ground implementers of DWSP's forest management plans and policies, the DWSP foresters' knowledge of and sensitivity to the various aspects of the watershed land management plan have a direct bearing on the ultimate success of the program. It is impossible, however, for any one individual to assimilate all aspects of the diversity of knowledge in the evolving fields of natural and cultural resource management. A secondary key to implementing sensitive management, therefore, is review by specialists in various disciplines of study in natural and cultural resources, and effective communication between these specialists and the forest managers.

These supporting disciplines within DWSP include water quality and environmental engineering, forest planning, wildlife biology, civil engineering and road maintenance. Experts routinely consulted outside DWSP include rare species botanists and zoologists (Massachusetts Natural Heritage and Endangered Species Program (NHESP)) and cultural resources specialists (DCR Office of Cultural Resources). DWSP also has available a wide variety of experts conducting academic research on the watersheds at any given time, in part because of the research value of the resources under DWSP's care and control. These professionals and interested non-professionals who spend time studying and exploring the watersheds contribute invaluable observations that complement DWSP's understanding of its watershed resources.

To efficiently and effectively coordinate and focus this collective knowledge towards the improved protection of the drinking water supply and other natural and cultural resources, DWSP has developed the following procedure for the annual review of all proposed DWSP forest management activities on DWSP watersheds. These reviews help to assure consideration

and implementation of the general guidelines for cultural and wildlife resource protection discussed elsewhere in this plan.

Lot Proposal Development

Each year in the fall/winter, DWSP foresters compile a set of forest management proposals for the upcoming fiscal year (beginning in July). Each lot (*note: the term 'lot' is commonly used by foresters to refer to any forest management operation*) proposal describes:

- Overstory tree species composition and condition
- Size/age class distribution
- Regeneration abundance, diversity, and distribution
- Terrestrial invasive plant species presence and distribution
- Presence of disease with significant implications for forest health
- Significant insect infestation
- Significant storm damage
- Relevant past land use and forest management
- Soils
- Water resources, including streams, wetlands, and vernal pools
- Proposed silvicultural treatment with accompanied rationale, harvesting equipment preferences, and expected outcome
- Subwatershed analysis results (see below)
- Known cultural resources
- Unique or unusual wildlife or wildlife habitats
- Known rare or endangered species or protected habitats
- Access issues and required improvements to roads and/or landings.

Lot proposals are complemented by maps of the planned operations, which include: the proposed lot boundary, landings, and primary skid roads; the location of streams, proposed stream crossings, wetlands, vernal pools, subwatershed boundaries, known cultural features, and known wildlife features and NHESP protected habitat.

NHESP digital maps are checked using GIS. If the project overlaps rare species habitat, the DWSP forester consults with the DWSP wildlife biologist to find out what species of flora or fauna of concern are present so that the project can be designed accordingly. Additionally, the DWSP forester may request a site visit by NHESP staff for guidance on project implementation and mitigation strategies.

Subwatershed Analysis

The forester conducts a preliminary subwatershed analysis for each proposed lot. Each subwatershed that overlaps the lot is reviewed for harvests in the prior decade in order to ensure that new harvesting will not exceed the cumulative limit of removing not more than 25% of

forest stocking in any subwatershed within any 10-year time period. See section 4.2.4 for more detail.

Review of Lot Proposals

In late winter the completed maps and lot proposals are compiled by DWSP Natural Resources (NR) staff and distributed to the review team (DWSP Regional Directors, wildlife biologists, and Environmental Quality (EQ) staff, as well as the DCR Archaeologist). Site visits are scheduled in April and May so that the reviewers may observe and note any relevant information not included with the proposals, discuss the proposal with the forester, assess the overall consistency of the proposals with management plan silvicultural and resource protection objectives, and assess and/or confirm the status/existence of vernal pools.

Silvicultural Review

NR resource specialists review the proposal summaries for consistency with Land Management Plan silvicultural objectives, including overall prescription, opening sizes and acreage, and subwatershed harvesting limits. During the field visits, overstory and regeneration conditions are observed, landing and road layouts are checked for consistency with regulatory constraints and LMP policies and standards, and interesting or unusual features or vegetation are noted, including terrestrial invasive plant populations.

Water Quality Protection Review

EQ staff review the planned forest management and, where necessary, conduct site examinations. Chemical, biological and physical risk factors to water quality are considered. The truck transportation routes from the DWSP gates to the farthest point on each lot, as well as the cutting operations, are reviewed. BMP types, location and expected maintenance schedules are reviewed. Water quality sampling locations are identified to monitor BMPs, road culverts, and other areas where higher turbidities might occur (see Section 4.2.11 for more details). EQ staff may give site-specific guidelines regarding special precautions designed to increase the protection of site water quality.

Cultural Resource Protection Review

When forest management is planned in areas containing or likely to contain cultural resources, the DCR Archaeologist identifies types of activities that could damage these resources, such as soil compaction or disruption of existing structures like walls or foundations. The Archaeologist identifies areas of high, moderate, or low probability of containing pre-Contact occupation sites, and may also make recommendations (either in a memo or in a more formal Site Avoidance and Protection Plan (SAPP)) for removing trees that threaten existing historic structures. With these concerns identified, the foresters modify timber-harvesting approaches as needed to protect these resources. At Quabbin, DWSP staff also consult closely with the Swift River Valley Historical Society to ensure that all historical resources that may exist on the proposed lots have been properly identified and provisions made for their protection.

Wildlife Review

Each spring, DWSP wildlife biologists review the planned forest management operations. Local knowledge of state rare, endangered, and threatened species is referenced, as well as the location of any critical or important habitat features in the wildlife biologists' files. The status of known and potential vernal pools is assessed. After completion of fieldwork by the wildlife biologists, the foresters are alerted to any potential conflicts between the proposed work and important habitat features. Specific recommended practices for wildlife habitat conservation are outlined in Section 4.4.5.

Rare and Endangered Plants

During the past several decades, DWSP staff have worked with professional botanists to identify and protect populations of state or federally listed rare or endangered plant populations (Tables 3-11, 3-12, 3-13, and 3-14). A spatial database is maintained and regularly updated so that the locations of these populations can be readily identified when they exist within the boundaries of a proposed harvesting area. While there remains significant uncertainty about management practices that would harm versus enhance the survival of these populations, the general approach is to avoid them during the operation, unless NHESP advises otherwise. Foresters identify known populations as part of the proposal narrative, and NR staff check for unidentified populations during the field review.

Comment Integration

Comments from all reviewers are compiled by NR staff and distributed internally. Where the review process identifies undesirable potential impacts and modifications are required prior to approval, the foresters consult with the reviewers to design a practical solution. Significant modifications to the area to be harvested and/or the proposed practices may require further internal review prior to final approval. For the projects that involve regeneration openings exceeding five acres in size, direct approval of the Commissioner is required – a change resulting from the STAC process and DWSP's *From Here Forward*.

Public Review

The final review stage is a public process. Each June, maps and summaries of the approved proposals are posted on DWSP's Watershed Forest Management Projects web page, and are presented by the Chief Foresters at advertised public meetings for each watershed. At Quabbin and Ware River, these are the regular June Quabbin Watershed Advisory Committee (QWAC) and Ware River Watershed Advisory Committee (WRWAC) meetings, while at Wachusett/Sudbury a special public meeting is scheduled generally around the same time. Comments and questions are addressed at the meetings, and written comments are accepted through the DCR website during a 30-day period following the public meetings. The proposals are modified, if appropriate, according to public comments.

Internal Review Policy for Salvage Operations

A salvage harvest involves the removal of trees that are dead, dying, toppled or damaged as a result of an extensive disturbance such as a disease or insect infestation, windstorm, ice storm, fire, etc. Removing dead or dying trees from a damaged forest can encourage regeneration, reduce fire hazard, allow the capture of timber value, and strengthen the resistance of surviving trees. Where roads have been blocked, restoring access for fire control and emergency response is a priority. Review and permit procedures may be streamlined when a salvage harvest is indicated and conditions warrant rapid action.

Salvage logging is not guaranteed to happen in every circumstance, but will be considered on DWSP property subject to the following criteria:

- physical damage from wind, ice, snow, or fire has impacted a majority of the tree cover over a significant area, or biological pests or pathogens have caused or are causing significant and/or rapid decline and mortality to a majority of the canopy trees over a significant area,
  and
- failure to salvage is expected to result in significant water quality or public safety threats, and/or unreasonable economic sacrifice.

There is consultation and agreement among foresters, Regional Directors, and Natural Resources staff regarding the significance of potential threats and the appropriate use of salvaging for each individual situation.

Salvage harvesting is conducted subject to the following requirements:

- The timeline for the internal Lot Review process is condensed as necessary to accommodate immediate time sensitive requirements or constraints; the appropriate Citizens Advisory Group(s) is notified and consulted.
- Foresters seek bids from at least three qualified loggers and award a salvage permit that best meets the interests of the DWSP.
- Salvage operations are held to the same standards for water quality, soil, residual stand, downed woody material, and rare and endangered species protections as regular forest management operations.

4.2.10 Post-Review: Planning, Marking, and Final External Review/Approval

Once lots complete the internal and public review, the foresters lay out and mark the approved harvesting lots, and map the regeneration opening locations. The Regional Director or Assistant Regional Director conducts a final review and approval of each marked lot.

As each lot is prepared, a Forest Cutting Plan is also prepared which the logger is required to follow. The Cutting Plan shows the area to be harvested, location of skid roads, landings, wetland resource areas and stream crossings. It also specifies the measures to protect water, soils, wetlands, and rare species. The Forest Cutting Plan is submitted to the DCR Bureau of Forestry Service Forester for review and approval, and copied to the local Conservation Commission. DCR Service Foresters check all cutting plans against the Natural Heritage maps of rare and endangered species habitats and, if they overlap, submit these plans to NHESP for review and comment. The DCR Service Forester has 10 days to act on the Cutting Plan. If wetland resources are involved, FCPA regulations require the DCR Service Forester to conduct a site visit prior to the start of the operation.

Once the Cutting Plan is approved, the lot is advertised, and through a competitive bidding process, the right to harvest wood products from the lot is sold to a private timber harvester who is then issued the Permit to Harvest Forest Products.

4.2.11 Control of Harvest Operations: Permit to Harvest Forest Products

DWSP policies are designed to protect watershed resources such as water quality, wetlands, soils, residual trees, and cultural resources when conducting silvicultural operations that require the removal of forest products from the forest. Both the Permit to Harvest Forest Products, discussed below, and the BMPs, discussed in Section 4.2.8, address these concerns.

The permit consists of written specifications detailing the forest products offered for sale, maps delineating the sale area, and a proposal where a bid for the forest products is entered and signed. Maps include a locus map, a larger-scale detailed sale map, and a Spill Response Plan map specific to the permit area. Specifications are grouped into ten sections:

1. **General Conditions.** These include responsibilities and liabilities accepted by the Permittee, including dates for completion, options for extension, equipment inspections, pre-work meeting, and written release for entry by the forester.

2. **Water Quality Specifications.** These are primarily concerned with petroleum leaks and spills (proper secure storage of products, adequate equipment for quick containment and cleanup), and control of human waste (portable toilet requirements).

3. **Harvesting Specifications.** These are concerned primarily with the process of cutting trees and removing forest products from the forest. Included are provisions for the protection of residual trees and soils, treatment of slash, restoration of roads and landings, and weather related suspension of operations.

4. **Insurance Requirements.** The Permittee is required to carry specified minimum amounts of commercial general liability insurance and vehicle liability insurance.

5. **Utilization Standards.** To provide an acceptable appearance, meaningful utilization of wood products, and reduced fire hazard, the standards specify the maximum diameter of softwood and hardwood tops to be left in the woods. To provide adequate nutrient retention and wildlife habitat conditions, they also set minimum amounts of coarse woody debris (generally 200 cubic feet per acre) to be retained following whole-tree removal operations.

6. **Silvicultural Specifications.** These specifications detail specific treatments the harvester must complete in order to meet silvicultural objectives, and may include pruning, girdling, non-commercial improvement cutting, or scarification to aid germination.

7. **Harvesting Systems.** These specifications allow or limit the type and size of fellers, forwarders, and skidders and other equipment to minimize soil compaction and rutting, physical damage to residual trees, and impact on cultural resources.

8. **Supplemental Provisions.** Occasionally a forester knows of specific limitations that may affect the operability of a particular lot. Known rare species populations or habitats, cultural or archeological features, or other situations that must be avoided are likely to be noted in this section of the permit. Road and landing work responsibilities may also be clarified here.

9. **Bidding, Payment, and Bonding Specifications.** This section of the permit details sealed bid and deposit requirements, and the payment schedule for the balance of the winning bid amount. It also specifies requirements for a Performance Bond, which is a sum of money, varying with the size of the lot and the potential for damage, held by DCR until all specifications of the permit are met, and kept by the agency if these conditions are not met.

10. **Plan of Operation.** The Plan of Operation, at a minimum, lists the names and license numbers of the licensed timber harvesters who will operate the job, the permittee's representative, if applicable, and the specific equipment that will be used. Depending on the size and complexity of the timber sale operation, the Permittee may also be required to set forth planned periods for, methods of, and amounts of road construction, timber harvesting, completion of slash disposal, erosion control measures and other requirements of the Permit, and the planned route for hauling timber. This plan must be approved in writing by the DWSP forester prior to the commencement of operations.

4.2.12 Supervision of Timber Harvesting Operations and BMP Implementation

A Bureau of Forestry Service Forester visits the site before approving the Cutting Plan and may visit the site during the harvest. However, throughout the active operation, it is the responsibility of the licensed DWSP forester in charge to continuously monitor the licensed harvester's compliance with all provisions of the Permit to Harvest Forest Products and the Cutting Plan. Particular attention is paid to the BMPs (see Sections 4.2.8, 4.4.5, and 4.5.2). As explained above, BMPs are designed to protect water resources from erosion and sedimentation, and to minimize soil compaction in wetlands.

The DWSP forester meets with the logger on site before the work begins to review the BMPs and other standards that have been specified in the Cutting Plan and the Permit to Harvest Forest Products. The forester will have marked and flagged the locations of main skid trails, stream crossings, wildlife features and cultural resources, etc.

The DWSP forester typically checks on active harvests at least once or twice a week, sometimes as often as daily for complex operations with high volume production, or as weather conditions change. The DWSP forester uses a detailed checklist to verify and document that the expected standards have been implemented including:

1. Erosion control at skidder trails, forwarder roads, and landings.

2. Stream crossing stability during and following completion of the harvest.

3. Proper handling and storage of petroleum products, and records of the presence of and response to any spills, if any, of petroleum products.

4. Containment and removal of human waste and trash.

On sites that involve stream crossings, EQ staff sample turbidity levels regularly during the harvest. While the operation is in progress, the forester, NR, EQ and Watershed Maintenance (WM) staff communicate as needed to assess activity on the lot, BMP status and water quality sample results. During the operation, DWSP reserves the right to suspend the harvesting activity if warranted by weather, soil, or wildlife conditions.

Upon completion of silvicultural operations, DWSP forestry staff review and report on the operator's protection of the residual forest, soils, wetlands, and identified special habitats or plant populations, as well as post-harvest treatment of access roads (repairing and seeding if necessary, and the installation/rebuilding of water bars to divert water on steep sections), stream crossings (removal of temporary bridging materials, repairing and/or protecting approaches), and landings (removal of unutilized materials, smoothing, blocking off, seeding if necessary). EQ staff may maintain records on conditions at stream crossings and/or landings, as needed. The DWSP forester also notifies the DCR Service Forester that the job is complete, and requests a final

inspection. If conditions are stable, there are no threats to water quality, and there is full compliance with the timber harvest permit, the operator's performance bond is released.

4.2.13 Strengthened Monitoring of Harvesting Operation Impacts and Outcomes

The STAC report, highlighting the distinction between *compliance* monitoring (to meet regulatory standards) and *performance* monitoring (to test the short-term effects of management practices on water quality in tributary streams), included recommendations regarding monitoring and increased transparency and reporting of the effects of timber harvesting. These recommendations included: implement a regional BMP monitoring protocol developed by the USDA Forest Service for the Northeastern Area (www.na.fs.fed.us/watershed/bmp.shtm#FieldGuide); establish camera posts and aiming markers on harvest sites to capture a chronological documentation of the regeneration of the forest following these harvests; and increase sampling of associated tributary water quality above and below and/or before and after timber harvests.

A temporary bridge allows machinery to cross water resources and minimize potential impacts.

Monitoring BMP Effectiveness

In order to more systematically assess not only the application of BMPs but also their effectiveness in preventing problems, DWSP IS using an adaptation of the US Forest Service (USFS) Northeastern Area protocol recommended in the STAC report for monitoring the effectiveness of BMPs. The USFS protocol uses objective measures of outcomes (e.g., estimated volumes of sediment delivered to a bank-full channel or water body) rather than documentation of the use of individual prescriptive methods or practices, thus complementing the supervision and record keeping provided by the DWSP forester and Bureau of Forestry Service Forester. DWSP has adapted the protocol to the extent possible to match both agency needs and current technology. BMP monitoring protocol is conducted by NR, Forestry, and EQ staff.

Monitoring Streamflow and Water Quality

As mentioned above, the STAC final report included a strong recommendation to increase and enhance water quality monitoring. Specifically, STAC recommended that the short-term effects of active forest management on water quality be tested (STAC, 2012).

Short-term Tributary Monitoring

DWSP and MWRA perform water quality compliance monitoring in the Quabbin and Wachusett Reservoirs, the Ware River, and associated tributaries via tests for a wide range of potential pollutants. Permanent sampling stations are located on major tributaries, in the reservoir, and at aqueduct intakes. Annual reports are online at: www.mass.gov/eea/agencies/dcr/water-res-protection/water-quality-monitoring.

DWSP EQ staff monitor construction activities on private lands in the watersheds to ensure that BMPs for resource protection are working. DWSP monitors turbidity regularly to assess stream impacts of problematic land development projects. Likewise, to improve performance verification for the controls over the effects of timber harvesting on associated tributaries, DWSP performs turbidity monitoring at forestry operations, in particular at stream crossings and during storm events.

Each proposed timber harvest is inspected by EQ to determine and confirm where water resources are present and if sampling opportunities exist to test for impacts from the forestry operation. A subset of stream crossings are then monitored above and below and before and after harvest operations for differences in turbidity using the following protocol:

- Turbidity samples are collected monthly at proposed stream crossing sites during both dry and wet weather prior to the start of any activity to establish baseline conditions.
- The forester oversees the installation and removal of all temporary crossing structures. EQ may collect turbidity samples at these times above and below each monitored stream crossing (when necessary and if streams are flowing).
- Turbidity samples are collected periodically above and below each monitored stream crossing during dry weather and during or following storm events throughout active logging operations. If elevated turbidity is obvious in the field at a downstream site, additional downstream samples are collected to determine the extent of the impact.
- Turbidity samples may be collected monthly or periodically above and below monitored stream crossing sites for one year following the completion of all crossing activity.

Water quality impacts can occur at areas other than stream crossings, especially if riparian buffers, filter strips, or areas with steep slopes are disturbed. The sampling protocol described above is focused on lots that include stream crossings but may also be applied where timber harvesting is taking place within fifty feet of a stream or steep slopes are present. DWSP recognizes that the most significant potential impacts will occur during or immediately following intense rain or snowmelt events. If the number of active sites and available staff precludes more frequent sampling at all locations, monitoring will focus on wet weather events and less frequent dry weather sampling. If sampling identifies water quality problems, that site's monitoring effort is increased to clarify the source of the problem.

Long-term Tributary Monitoring

NR and EQ staff are implementing long-term water quality monitoring studies on both the Quabbin and Wachusett watersheds to test the hypothesis, supported by previous research findings at other North American sites, that DWSP BMPs and harvesting policies are effective in preventing measurable impacts on stream water quality from timber harvesting operations.

NR staff designed a long-term study on the Quabbin watershed in the late 1990s with assistance from researchers at the University of Massachusetts. First order tributaries located on Prescott Peninsula were chosen as focus areas, in part due to the desirability of completely controlled and fully forested sub-watersheds. The Middle Branch of Dickey Brook (MBDB) was chosen to serve as the reference watershed, on which only minimal management had occurred during the decades prior to this study. The East Branch of Underhill Brook (EBUB) was chosen as the treatment site on which to eventually apply typical DWSP forest management. Weirs were installed on both streams to enable accurate discharge measurements, thus allowing nutrient loading calculations as well as snapshots of nutrient concentrations.

Water samples and measurements have been taken for many years at these sites, providing data sufficient to show seasonal patterns, value ranges, and to calculate reasonable mean values for the parameters monitored. Hydrolab auto-samplers recorded continuous temperature, dissolved oxygen, specific conductance, turbidity and pH at MBDB from 2000-2005, and at EBUB from 1999-2005. Monthly grab samples and discharge measurements have been collected at those sites for total suspended solids, nitrate, nitrite, total Kjeldahl nitrogen and total phosphorus continuously since April 2002. UV_{254} was added in July of 2013, and ammonia, dissolved organic carbon and total organic carbon were added in January of 2014. Several storm events have been monitored to document changes in flow rates and water quality parameters as these streams respond to precipitation, and this effort is planned to continue at least three times annually.

Now that a very robust quantity of baseline data has been collected, NR, Forestry, and EQ staff will implement the silvicultural treatment within the forest on the East Branch of Underhill Brook watershed. Sampling will continue throughout the active logging and will be maintained following the completion of all activity for at least five years to fully document any effects.

A similar paired sub-watershed study got underway at Wachusett in 2013. Monthly dry weather grab sampling and quarterly storm event monitoring using automatic samplers is being conducted in order to establish base line conditions at each site prior to the harvest on the experimental site. Parameters include pH, temperature, dissolved oxygen, turbidity, total suspended solids, total organic carbon, ammonia, nitrate, nitrite, total phosphorus, and UV_{254}. Tributary flow and of precipitation amounts and intensity are documented regularly. Sampling will continue throughout the active harvesting and will be maintained following the completion of all activity for at least five years, just as at Quabbin.

When feasible, DWSP Aquatic Biologists utilize macroinvertebrate sampling to supplement water quality sampling data, and to biomonitor streams in both harvested and control sub-watersheds. Samples are collected in the late spring (May-June) before and following logging activities. Although most macroinvertebrate sampling is done in perennial streams, biomonitoring in ephemeral streams has been proven to provide useful information.

Monitoring and Documentation of Regeneration Response

In addition to post-harvest monitoring of operator compliance, harvest operations are also monitored for successful accomplishment of silvicultural objectives. Periodic regeneration surveys are designed to document the regeneration response following a range of silvicultural harvest activities. Information is collected on species diversity, numbers and size of tree seedlings and saplings, as well as the presence and possible competition presented by both native and alien invasive plants. These results, along with periodic browse surveys, are also used to help assess the success of the Quabbin Deer Control program. If rare plant populations or uncommon habitats are known to be present in the area, these are monitored both before and following the harvest to determine positive or negative effects.

Finally, DWSP has implemented the STAC recommendation to utilize photographs taken at known, recorded locations and directions in order to document the conditions of the overstory and understory prior to and following a representative selection of regeneration harvests. DWSP Forestry offices have been equipped with good-quality digital cameras so that this task can become a component of the forester's visits before, during, and immediately after a lot is harvested, as well as over the years that follow. The agency has used this technique to follow changes in regeneration responses (Figure 4-17) in the past and to document gradual declines from pests such as the hemlock woolly adelgid.

FIGURE 4-17. HALF-ACRE OPENING, PRESCOTT PENINSULA, 1996-2008

4.3 Non-Forested Areas

4.3.1 Goals

- *Ensure that the maintenance of non-forested upland habitats protects has no negative impact on water quality, through the use of strict BMPs, including the maintenance of forested buffers along adjacent water resources.*
- *Where feasible and applicable, maintain early successional non-forested habitats on DWSP lands for species of wildlife that are considered uncommon, rare or unique on a regional or statewide basis.*
- *Maintain the aesthetic diversity of the local landscape, where appropriate and not in conflict with water resource protection.*
- *Work to identify new invasive species and prevent their spread and identify areas where existing invasives may be reduced or eliminated.*
- *Preserve important historical and cultural resources within these areas.*

The continuing loss of early successional habitats is of great concern to wildlife managers in Massachusetts. A wide variety of species of plants and animals depend for at least a portion of their lifecycles on various types of non-forested habitats. DWSP recognizes that as one of the largest landowners in each watershed, it has a responsibility to consider the effects of its land management decisions. Through the use of BMPs applied on a field-by-field basis, any potential negative impacts to water quality will be avoided in the maintenance of these non-forested areas.

In addition, these acres of land have significant, if difficult to define, value as an integral component of the aesthetic diversity of the area. They also have value as cultural and historical resources. Many of the fields in the watersheds have been in existence since the 1700s and are an important part of the natural and cultural heritage of the watershed.

4.3.2 Management of Non-Forested DWSP Lands

In addition to land purchased and maintained expressly for water quality protection, DWSP owns and manages fields and other non-forested lands in the watersheds. Presently, DWSP has identified four broad categories of non-forested areas: 1) fields; 2) lands along or adjacent to the

reservoirs' shorelines; 3) areas within administration areas; 4) areas that serve as historic, recreational, or aesthetic places.

Broad changes in land use have dramatically impacted the number, type, and extent of open lands within the watershed. Although there is some controversy over whether extensive native grasslands existed prior to European colonization of the Northeast, available evidence suggests that some large grasslands and heathlands occurred in the region (Askins, 1999). This suggests that grasslands and grassland birds have been a component of avian diversity in New England for a long time (Dettmers and Rosenberg, 2000). Beaver activity, wildfires, windstorms, and fires set by Native Americans generated some early successional habitat. This likely created small pockets of grassland and patches of habitat for early successional species.

During the 1800s, agricultural land dominated the landscape, and grasslands were more abundant in the Northeast than they have ever been before or since. As a result, the number of grassland species increased significantly. In the mid-1800s, agricultural land use shifted far westward to the less-rocky, more fertile soils in the Midwest. Since then, the amount of grasslands and open fields has decreased dramatically in the Northeast, causing a similar decrease in many types of vegetation and species of animals that depend on open habitat. As farms were abandoned, the open fields and meadows were left unmaintained. Without frequent disturbance such as mowing, burning, or grazing, the grasslands gradually reverted back to forest. Some grassland species, such as the loggerhead shrike and regal fritillary butterfly, were extirpated from Massachusetts. At least one obligate grassland subspecies is already extinct in the Northeast; the endemic Heath Hen (*Tympanuchus cupido cupido*) was extirpated from Martha's Vineyard, Massachusetts in 1932 due to habitat loss (Askins, 2000).

Recent population trends for grassland dependent species show disturbing declines. Analysis of the North American Breeding Bird Survey indicates that of 28 species of grassland-dependent breeding birds detected throughout North America, 68% (19 species) show a significant negative trend from 1966-2003 (Sauer, et al., 2003). In the Northeast, of all bird groups, grassland and shrubland dependent birds are exhibiting the most pervasive and steady declines in abundance (Witham and Hunter, 1992; Askins, 1993, 2000). Bobolinks and grasshopper sparrows have declined 38 and 69 percent, respectively, in the last 35 years. Partners in Flight, a national conservation organization, has identified neotropical migratory bird species of concern in Massachusetts. These species have a high perceived vulnerability (they may or may not be state or federally listed) and are critical to maintaining avifauna diversity in the state. Priority species include Henslow's sparrows, upland sandpipers, grasshopper sparrows, and bobolinks. These species are all associated with grassland habitat.

As farmland continues to be abandoned or converted to house lots, the amount of viable open land continues to shrink. The remaining grasslands, particularly large (> 100 acres) or clustered fields, are increasingly vital to a variety of wildlife. Eastern meadowlarks, savanna sparrows,

eastern bluebirds, and bobolinks use hayfields, meadows, or pastures to forage and raise young. During the fall and winter, fields provide food for migrating sparrows, warblers, larks, and snow buntings. Raptors such as northern harriers, short-eared owls, and American kestrels hunt in fields for small mammals (meadow voles, meadow jumping mice) and insects. White-tailed deer often graze in fields, and foxes will hunt fields for small mammals or rabbits. Finally, native invertebrates like bees and butterflies feed on nectar of grassland wildflowers.

DWSP recognizes the regional importance of these open lands to the diversity of wildlife within the state. DWSP owned lands within the watersheds are predominately forested and only a small percentage (< 10%) are non-forested uplands. The Massachusetts Office of Geographic Information (MassGIS) 2005 land use data identifies only about 9,000 acres (3%) of non-forested open land (brush land, agriculture, pasture) within the four watersheds. DWSP does own a variety of fields, distributed across the Quabbin, Ware River, and Wachusett watersheds, and these fields range in size from < 1 acre to ~90 acres. Although DWSP will continue to manage the majority of its property as a multi-aged, multi-species forest, on particular areas where ecologically significant open habitat exists, these important communities will also be managed, maintained and/or enhanced.

4.3.3 Early Successional Non-Forested Habitat Management Practices

Field Prioritization

DWSP currently owns approximately 650, 170, and 180 acres of fields in the Wachusett, Quabbin, and Ware River watersheds, respectively. In all cases, these are either open lands DWSP recently acquired through its land acquisition program, or land DWSP has traditionally managed in an open condition. DWSP currently does not actively convert forested land to non-forested open lands, but, where appropriate, will continue to manage and prioritize lands that are currently non-forested.

Fields are prioritized based on their size, distance to flowing water, relative isolation, and juxtaposition with other open fields. In general, very small (< 2 acres), isolated fields are abandoned and allowed to naturally regenerate to forest cover. In addition, those fields (or portions of fields) that border reservoir tributaries are also abandoned and forest allowed to regenerate to provides an adequate buffer along flowing streams. Larger fields (> 5 acres) that are isolated will be maintained in open condition through various management practices. Large (> 20 acres) fields situated near (< 1 mile) or next to other fields will be given top management priority, because these areas offer the most potential for wildlife diversity. Large clusters of open habitat may actually act as one unit, providing habitat for species (northern harrier, upland sandpiper) that require large (> 100 acres) tracts of open land. These areas are maintained or enhanced using a variety of management techniques in order to optimize the available habitat. Individual management plans and/or permits and maps have been created for each maintained field.

The quality of DWSP fields is variable. Encroaching exotic invasive plants are invading some – perhaps most – DWSP-owned fields. The list includes multiflora rose, autumn olive, honeysuckle, bittersweet, buckthorn, and others. These plants typically crowd out native species and degrade the quality of the existing habitat. Most invasive plants are extremely vigorous and hardy and can be difficult to control. Removal and control of these species is critical to the maintenance of this grassland habitat.

Fields Managed by DWSP

Land Management Practices on DWSP Managed Fields

- No cutting during the active growing season (May 1 – August 15).
- Cut fields at least once every three years, but preferably every other year. This will still inhibit woody vegetation and allow late-blooming wildflowers to develop.
- Set mower height, when mowing, at a minimum of 8-10 inches off the ground to provide habitat for small mammals.
- Record a cutting plan and maintenance record for each field that shows date(s) cut and any setbacks.
- Maintain field edges so the forest does not encroach.
- Accommodate uncommon species (e.g., fringed gentians) found in certain fields through adjusted mowing patterns (i.e., rotational mowing, contiguous fields).
- Follow DWSP Terrestrial Invasive Plant Strategy for terrestrial invasive control.

DWSP staff manages about 550 acres of fields (125 in Wachusett, 60 in Ware River, and 167 in Quabbin) that are not leased for hay production. These fields require active management in order to maintain them in an open condition. However, because they are managed internally, there are more opportunities to apply various non-harvest management techniques to enhance the existing habitat, such as prescribed fire and delayed mowing.

Some fields may be better suited to maintenance by fire rather than mowing. Prescribed fire can reduce buildup of dead vegetation, prevent the spread of woody vegetation, release nutrients into the soil, and rejuvenate plant growth. However, burning an area can eliminate some butterflies and moths, and the newly burned area may be avoided by some bird species. Hayfields can develop a thick layer of thatch that deters some nesting grassland birds and fire is an effective way of removing this layer. When feasible and practical, prescribed fire management can be a

benefit to early successional bird populations and other wildlife usually within a year or two of the burn. DWSP conducts fire management according to the following guidelines:

- Conduct burns during appropriate times to avoid impacting wildlife (e.g., in early spring after snowmelt but before bird nesting). Consider appropriate weather conditions.

- Burn fields once every 3-4 years; if possible have an unburned, adjacent field available for nesting birds during the burn year.

- Burn, if possible, only a portion of the area on larger fields in any given year. Staggering burns allows for the development and availability of a variety of habitat conditions. Do not more burn more than 30% of habitat during any year.

Given the purpose of maintaining open habitat for rare species, it is important to understand the potential for management practices to have negative impacts to the very species being promoted. Routine maintenance (mowing, brush cutting) or watershed maintenance activities (road repair) do not require NHESP notification. In these situations, it is possible to unknowingly and negatively impact rare or endangered species, but DWSP works to prevent this from happening through cooperation with NHESP to identify and map areas of concern that may be impacted. DWSP works with NHESP to improve staff awareness of rare species presence in order to prevent unintended impacts.

Fields Managed Through Permits

DWSP started working cooperatively with the Department of Agricultural Resources (DAR) in 1987 to permit the use of certain parcels of DWSP land by local farmers. The intent was to find a low-cost means of maintaining these areas in an open condition. This management decision recognized the value of fields for wildlife diversity, maintenance of the rural landscape, and their contribution to the local agricultural economy. Low impact haying can be an effective method of maintaining such fields and the values they support. DWSP's current haying permit program is no longer run through DAR but is administered internally. Permits are issued through a competitive process and valid for 5 years.

There are presently 325 and 122 acres of DWSP property mowed under the haying permit program or through deeded rights granted at the time of acquisition in the Wachusett and Ware River watersheds, respectively. Most of the Wachusett land – 235 acres – is administered through five year permits, while 90 acres is maintained through a lifetime deeded right. All the Ware River fields are maintained through five year permits.

When haying permits are renewed, DWSP presents the following mowing options to farmers:

1. No mowing until after August 1, or

2. A first mowing may take place before June 1 and a late cut after August 1. No cutting in June or July, or

3. If fields are part of a multiple field complex then one field per year must either have a delayed cut (after August 1) or not be cut at all.

DWSP recognizes that some (or all) of these options may present substantial challenges to farmers trying to produce hay. If DWSP is unable to locate a farmer who will hay under these options then the following restrictions are implemented to the extent possible:

- Fields, when feasible, are cut only once as late as possible, preferably after August 1. At a minimum, delay mowing until mid-July. Cut before the first frost.

- Maintain the mower blade at least 6 inches off the ground.

- Birds are faithful to nesting fields so consistency is important. Do not mow fields early one year that have been consistently mowed late for several years prior.

- If cutting must be done prior to mid-July, then farmers are encouraged to cut in one of the following manners:

    - Set aside 50% of the field from cutting until mid-July. The unrestricted half can be cut anytime. Second cuttings can occur on either area at the farmer's discretion.

    - Cut the whole field leaving uncut strips of 1 tractor width between cut areas.

    - On small fields, the whole field may be cut in a series of parallel lines from the inside out leaving an uncut patch in the middle of the field.

The following activities are allowed on permitted hay fields:

1. Farmers may cut branches up to 5" in diameter (or larger with permission from DWSP) on the perimeter of fields to maintain field edges.

2. Application of commercial fertilizers in accordance with soil test results or up to 50 pounds/acre, whichever is less.

3. Application of ground limestone in accordance with soil test results.

4. Reseeding with no-till methods.

5. Till seeding with written prior approval from DWSP.

The following activities <u>are not</u> allowed on permitted hay fields:

1. Application of pesticides or herbicides.
2. Application of wood ash.
3. Application of manure.
4. Mowing within buffer strips, which will be a minimum of 50' wide along surface waters or tributaries, and possibly wider depending on slope, soils, and quality of buffer vegetation (determined case-by-case in the development of each individual field's management plan).

4.3.4 Wachusett Reservoir Shoreline

Shoreline Hedge

A feature unique to the Wachusett Reservoir, and perhaps its most notable aesthetic feature, is the arborvitae hedge that parallels the shoreline. Originally planted along 34.3 miles of the 40-mile shore (including islands), it was designed to screen out leaf litter that could potentially discolor the reservoir water. "All the deciduous trees on the shore of the lake will be removed," states a Worcester Telegram article in May of 1900, "as the leaves falling and blowing into the water will tend to discolor and make impure the drinking water of the Metropolitan district and cause decaying vegetable matter to gather in the hollows of the bed of the lake." Seedlings of arborvitae (*Thuja occidentalis*), also known as Northern white-cedar, were planted three feet apart in two parallel rows set two feet apart beginning twenty-five feet from the high water flow line. Behind this, at least two rows of white pine were planted. The result is a full height screen with the ten to thirty foot tall, shade tolerant arborvitae providing the bottom of the screen and the eighty-foot tall white pines towering over, providing the top.

Arborvitae hedge along Prescott Cove on the Wachusett Reservoir. (Pictometry)

A report written by DCR Forestry staff (French and Buzzell, 1992) assessed the state of the hedge. At that time, approximately 6.4 miles of hedge had been lost due to a variety of factors. The primary instrument of destruction has been soil erosion, particularly on the outwash bluffs that dominate the shoreline in Boylston. To a lesser degree, fire and blow-down have made smaller scale deductions though many of the smallest of these gaps have repaired themselves with time. Arborvitae has shown itself to be a tenacious survivor, able to grow on a wide variety

of soil types and able to reproduce both by seed and vegetatively. Even so, a 2014 assessment of the hedge found that only 21.2 miles remain of the originally established 32.0 miles of shoreline (not including islands).

Since the planting of the shoreline hedge, an annual regimen of vegetation control in front of the hedge has occurred. In every year until the late 1980s, all of the vegetation growing from the water's edge up to the hedge was cut around the entire reservoir. This was necessary to both insure the survival of the arborvitae, into which much time, money and effort had been invested, and to eliminate any source of leaf material from in front of the leaf screen. During the late 1980s and early 1990s, it became clear that shrinking labor crews could no longer achieve the goal of complete yearly cutting. Also, the necessity of cutting all of the vegetation for protection of water quality, whether tree, shrub, or herbaceous, came into question. The decision was made that portions of the shoreline be cut on a rotational basis with the entire shoreline being cut on approximately a three year rotation. Only tree species would be removed. It is the trees that pose a threat to the arborvitae through shading and the trees that, if allowed to grow to full size, generate far more leaf litter than shrubs. In time, as the mountain laurel, alder, blueberry, dogwoods, witch-hazel and other shrub species come to dominate the shoreline, the interval of time before any section of shoreline requires cutting should increase.

This has proven to be true over the last cycle of cutting. However, this program will have to remain flexible and adaptive, as all of the sections of the shoreline will not respond identically. It is certain that some sections will take longer to develop this inhibiting shrub layer so these will continue to require more frequent maintenance.

The maintenance of the Wachusett Reservoir shoreline vegetation is not solely related to the issue of the arborvitae hedge and the minimizing of organic matter entering the reservoir. The stability of the shoreline is a concern for a variety of reasons related to water quality. A 2014 internal report written by Wachusett Environmental Quality staff looking at the issue of falling trees and low bluff erosion along the specific sections of the shoreline detailed the following implications to water quality:

- Eroded soils transported to the reservoir deliver nutrients (mostly phosphorous), which is undesirable because it will promote algae and plant growth.
- Eroded soils deposited along the shoreline could increase the area of shallow substrate for rooted aquatic plants, which could potentially provide ideal habitat for unwanted invasives such as *Phragmites* and *Glossostigma* (mudmat). This would be an even greater concern if eroded soils were to accrete in coves or near tributaries.
- Eroded soils deposited on land also provide an opportunity for terrestrial invasive species to take hold.
- Large trees falling into the reservoir have several negative consequences:

- When large trees fall the upended root system loosens large volumes of soil which can easily be transported to the reservoir by wind and rain. The loss of these roots also increases soil exposure and reduces slope stability, promoting slope failure and erosion into the future.
- Tree limbs in the water can trap leaf litter and sediment and may promote the development of shallow substrate for rooted aquatic plants.
- The submerged trees and limbs, if not removed, will slowly decompose, releasing more unwanted nutrients into the water.

This report goes on to list a wide range of options in dealing with these specific conditions followed by a set of recommendations, some of which have been incorporated into the following general procedures for the maintenance of the Wachusett Reservoir shoreline:

- GIS maps have been produced, clearly indicating which sections of the shoreline will continue to be managed. The 21.2 miles of shoreline which will continue to be managed have been divided into six sections, each of roughly equal length.
- The maintenance of these sections will occur on a 3-year return interval, meaning that about 7 miles of shoreline will be cut each year.
- In these sections, only trees species will be cut. All shrubs will be left. Any arborvitae trees which may be present out in front of the hedge will be left.
- Where the shoreline is characterized by the presence of rip-rap (along Rt. 140 in South Bay, for example), all vegetation whether tree or shrub will be cut.
- All of the downed material resulting from this cutting will be chipped if possible. Otherwise, the material will be dragged from the shoreline and deposited in the forest behind the hedge.
- There are some sections of the shoreline where an eroding condition has arisen. In some cases, the arborvitae hedge has been lost. Mature trees that were once in the forest behind the hedge, have their root systems undercut by the continuing erosion and periodically topple into the reservoir. These specific sections are not included in the 21.2 miles of normally managed shoreline. There are other sections (included in the 21.2 miles) where the same conditions exist except that the hedge is still in place simply because the erosion hasn't yet advanced far enough away from the reservoir. The following procedures will take place in these eroding sections:

    - Only tree species are cut. However, instead of chipping or dragging the material behind the hedge, the material will be dragged and piled along the base of eroding slope to act as a wind break. It is wind action on these sections of shoreline that is the prime cause of soil erosion.
    - Any trees that fall into the reservoir will be removed. This material will also be secured along the toe of these low bluffs.

- A long-term goal will be the establishment of a young, conifer-dominated condition at the edge of the forest either where the hedge is missing or behind existing hedge where it remains. The width of this young forest will likely vary greatly depending on site conditions (e.g., slope, aspect, character of the existing forest).
- In order to determine the rate at which these sections of shoreline are eroding and retreating into the neighboring forest, 14 reference markers on both low and high bluffs have been installed.
- More aggressive erosion control efforts will be considered in the future following an assessment of the effectiveness of the above mentioned procedures and with the new knowledge of the rate of erosion.

Erosion of the shoreline and loss of the arborvitae hedge has also been an ongoing problem on what are referred to as the high bluffs. Sawyer Bluffs and Scar Hill Bluffs in Boylston are the primary examples of this condition. Wind action seems to be the primary driver of this erosion along with perhaps some water table/phreatic zone interaction with the face of the bluff. Some efforts have gone into trying to stabilize the face of these bluffs with plantings, hydroseeding, and erosion-control fabric with mixed success. However, natural succession has had a notable impact in at least the establishment of tree cover on much of these bluffs in the past decade or two. Gray birch is the most common species to take hold along with a fair diversity of other species such as white pine, black and white oak, and red maple. None of these sections of high bluff are included in the 25.5 miles of regularly managed shoreline and no work is planned in the immediate future. Further study and observation is needed.

Wildlife Considerations

The shorelines along Quabbin and Wachusett reservoirs and their islands provides breeding habitat (common loons, mallard ducks, Canada geese) and food resources (beaver, spotted sandpiper) for various wildlife species. In most cases, the narrow width and characteristics of the shorelines minimize their habitat significance for most wildlife species. However, the habitat it does provide is critical to some animals and attracts other animals that could impact water quality. To address these concerns, shoreline management considers three issues: maintenance of grassy versus woody shoreline vegetation, maintenance of critical shoreline habitat, and removal of undesirable vegetation.

Maintenance of Grassy and Woody Shoreline Vegetation

Several areas of the each reservoir's shoreline are maintained in open grassy conditions (e.g., North/South dike, Old Stone Church, emergency spillway). Wachusett's North and South Dikes and Quabbin's Goodnough Dike and Winsor Dam are required by state and federal dam regulations to be maintained free of woody vegetation in order to preserve the structural integrity of these earthen structures. These areas are mowed several times annually to maintain a good grass condition.

The downstream slopes of Wachusett's North and South dikes historically contained some trees (and even some agriculture) in addition to grass. Recent changes to federal and state Dam Safety regulations and policies now require that these downstream slopes be maintained completely in a grassy condition. All the trees from these dikes were removed in 2012 and converted to grass cover. Beginning in 2014, DWSP developed a North and South Dike mowing plan that maintains the area in a grassy condition, but accommodates nesting grassland birds. There are portions of Winsor Dam and Goodnough Dike that are also mowed less frequently and allowed to develop a more complex herbaceous cover. In addition, the reservoir side of these dikes is comprised of large rip-rap. Vegetation growing on this side is occasionally removed by hand.

Besides the dikes, there are grassy areas located adjacent to reservoir shorelines that do not need to be maintained for structural reasons (Stone Church, Rt. 12 power lines, fishing areas) but have been kept in open conditions for aesthetic or public access concerns. The area immediately around the Old Stone Church will be maintained in lawn to provide public access. The remaining open areas on both sides of the Rt. 12 causeway will be periodically maintained, and the area around the detention basins will be routinely maintained. This will allow a wider diversity of vegetation to grow, but will still maintain the area in open condition. Conditions at each of the three Quabbin fishing areas will be maintained to allow easy access.

Removal of Undesirable Vegetation

DWSP closely monitors beaver activity within each reservoir and removes and discourages active beaver colonies in certain portions. While most of the reservoirs' shoreline provides marginal to poor beaver habitat because of shoreline structure (riprap, rock), exposure to wind and waves, and lack of food resources, there are areas with sufficient resources to support beaver. Typically these areas are located in mainland coves or on islands that provide protection and have an adequate supply of woody vegetation along the shore. In order to discourage dispersing beaver from occupying these sites, selective cutting is used to remove preferred woody vegetation, ideally, at least every 5 years. These areas are prioritized when planning shoreline maintenance activities. In addition, to date no selective cutting has occurred on any of the reservoirs' islands, even though some of these islands represent marginally sufficient habitat in which cutting could discourage beaver. Islands within DWSP's control zones that routinely attract beaver colonies are assessed to determine if removing vegetation may discourage repeated colonization.

Maintenance of Critical Shoreline Habitat

The islands within Wachusett and Quabbin Reservoirs can provide nesting habitat for Common loons, a state listed species of special concern. Loons nest almost exclusively on islands (or floating rafts), and it is doubtful that the reservoirs' main shoreline would attract nesting pairs. Loons typically nest on small islands with sparse or low-lying vegetation. Some loons will locate their nest in dense vegetation, although many nests are in the open and exposed. There are several islands within each reservoir that either provide nesting habitat or could potentially attract breeding pairs of loons. Most of these islands contain low-lying vegetation, although

some pioneer tree species (birch, poplar) are invading. In the future, it may be necessary to assess the conditions of preferred breeding islands to determine if breeding habitat has changed.

4.3.5 Administrative Areas and Facilities

Administrative Areas and Facilities include the Wachusett Maintenance Headquarters on Wilson Street, Ranger Headquarters on Wilson Street, West Boylston Maintenance headquarters on Lancaster Street, Oakdale Power Station, John Augustus Hall, the main Quabbin Administration Building, and a number of satellite offices in Belchertown, New Salem, and Oakham. Some of these sites are in residential areas and are viewed and/or accessed by the public. Few of these sites are within close proximity to the Reservoirs or a tributary with the exception of the Oakdale Power Station, the Quabbin Administration Building, and nearby offices along Blue Meadow Road. Maintenance of these sites includes mowing grass to maintain appearance and access and the periodic maintenance of shrubbery, both of which occur on an as needed basis to maintain the appearance of these facilities. The use of soil additives, such as limestone, to maintain the integrity of the lawns in these areas is considered only after soil tests are made. Herbicides and pesticides are used only as a last resort and any use is in compliance with all applicable laws and regulations.

4.3.6 Historic and Aesthetic Management

Stillwater Farm

Stillwater Farm.

The Stillwater Farm Interpretive Site in Sterling is used by DWSP as a watershed and land use history educational facility. This locally significant historic property was purchased by DWSP in 1990 as part of the ongoing system-wide land acquisition program. A self-guided Forestry and Land Use History Interpretive Trail loops through the wooded hillside above the farm. One square acre is delineated in a meadow behind the barn. Viewable across Route 140, the meadow adjacent to the Stillwater River provides an opportunity to witness early field succession following agricultural abandonment. The house is used for displays and exhibits pertaining to watershed dynamics, land-use history, and natural resource protection. Stillwater Farm provides a unique opportunity to demonstrate the delicate relationships between land use and water quality through targeted programming on a property currently moving from an agricultural past to its new role in watershed protection. Overall, public use of the Stillwater Farm is low-impact in nature.

Old Stone Church

Old Stone Church at Wachusett Reservoir.

The Old Stone Church is a historic and picturesque site located on the northwest shore of Wachusett reservoir in the town of West Boylston. The original Baptist church was built in 1892; the Metropolitan Water and Sewerage Board purchased the church in 1902 as part of Wachusett Reservoir construction and it was left standing to commemorate the town. In 1973 the Old Stone Church was listed in the National Register of Historic Places. By 1975, the structure had fallen into a dire state of disrepair and the Town petitioned the state legislature to appropriate funds to rebuild the church. The exterior structure of the church was completely rebuilt in 1983 by DCR with assistance of the West Boylston Historical Commission. Today, the church serves as a landmark for the Town and has become a well-known tourist attraction. DWSP staff regularly maintain the grounds and area around the Church and recently reconstructed the slope surrounding the Church to address human-caused erosion.

Dana Common

Dana Common.

Dana Common has been listed on the National Register of Historic Places. Located about 1 ½ miles in from Gate 40 in Petersham, this former town center is a favorite destination for walkers and for history lovers, who may stop to read the various markers and interpretive signs. It also serves as a meeting place for annual gatherings of former residents (and their descendents) of the 'lost' Quabbin towns. Staff maintain about 14 acres of grassy areas here through periodic or annual mowing.

4.3.7 Viewsheds

A viewshed is an area of land, water, or combined landscape that is visible from a fixed vantage point. The term is used widely in urban planning, archaeology, and military science. In DWSP's land management context, viewsheds are vantage points of particular scenic or historic value in the watersheds that are deemed worthy of preservation. The preservation and creation of viewsheds is a minor goal in DWSP's land management decisions and requires both forest harvesting decisions (to maintain the view) and the designation and maintenance of open space areas.

Enfield Lookout.

Examples of DWSP viewsheds within the Quabbin Reservoir watershed system include:

- **Pelham Lookout**. Includes a magnificent view of the west arm of the reservoir and Prescott Peninsula.
- **New Salem Lookout.** Provides a panorama of the north end of the reservoir and forested lands.
- **Enfield Lookout**. Vantage point offers a beautiful perspective of the reservoir's west and east arms.
- **Quabbin Hill Lookout Tower.** On a clear day, visitors can see Mount Greylock and New Hampshire to the north and west.
- **Frank E. Winsor Memorial Lookout**. Offers a direct view of the Winsor Dam.

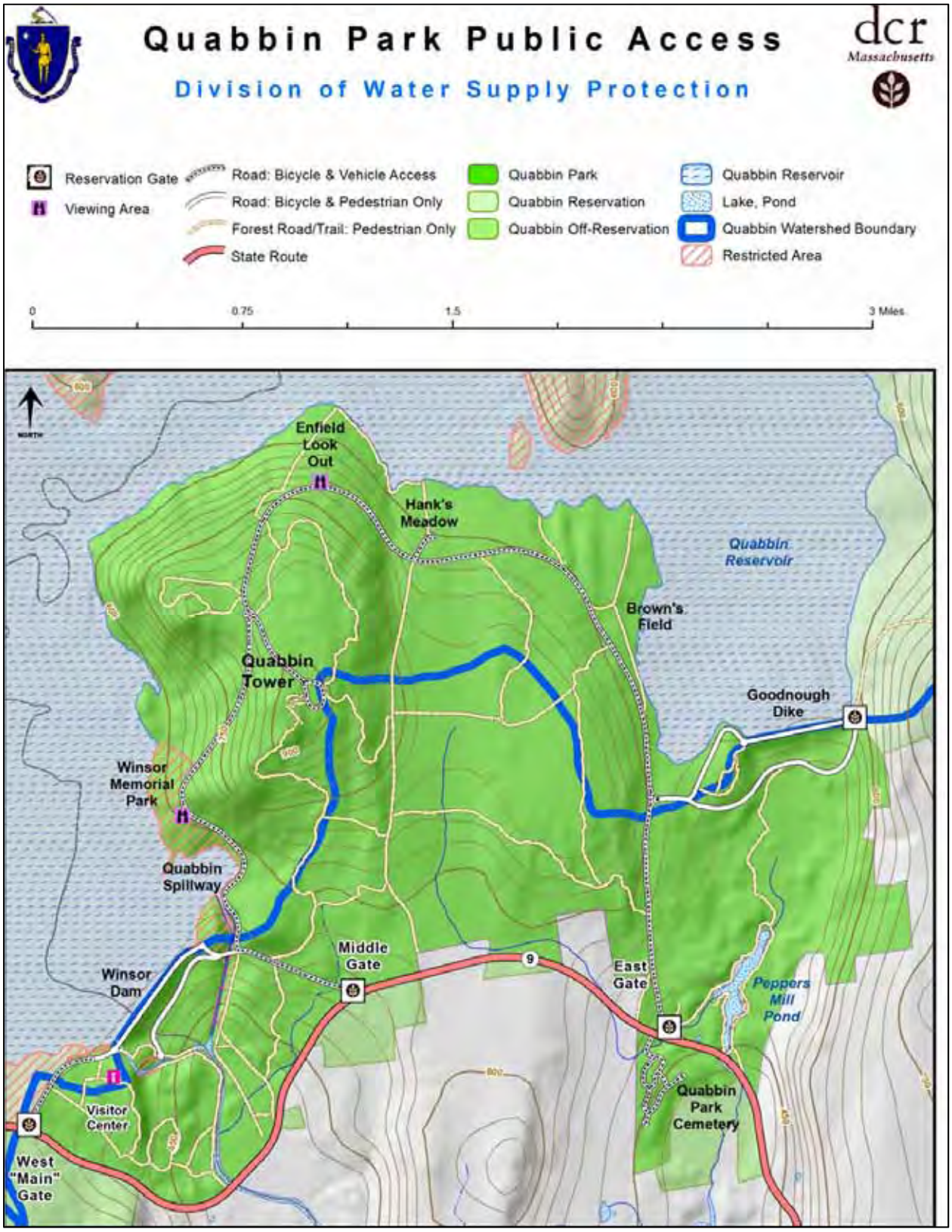
There are no designated viewsheds within the Ware River, Wachusett Reservoir, or Sudbury Reservoir watersheds.

4.3.8 Recreational and High Use Public Areas

Quabbin Park

Quabbin Park (Figure 4-18; which includes the 82 acre Quabbin Cemetery) is approximately 3,000 acres in size. The entire Park represents only about 5% of the DWSP owned land at Quabbin, but estimates suggest that over 80% of the recreational use in the system occurs in the Park. The *Quabbin Park Management Plan* provides specific policies and procedures for maintaining this well-visited resource. Approximately half of the Park area, including the cemetery, is located outside the Quabbin watershed.

FIGURE 4-18. QUABBIN PARK



There are many areas within Quabbin Park used by the public for passive and active recreation access, including:

- Quabbin Visitors Center (restrooms) located in the Administration Building.
- Winsor Dam located near the Administration building used for walking and biking. (The Winsor Dam has been closed to general vehicle access since September 11, 2001.)
- Y-Pool (seasonal portable toilet) located off-watershed used for fly-fishing.
- Winsor Memorial used for bird watching, sightseeing, and picnicking.
- Quabbin Hill Lookout Tower (restrooms and portable toilets) used for sightseeing, bird watching, and picnicking.
- Enfield Lookout (portable toilet) used for birding, walking, and picnicking.
- Hank's Meadow/Picnic area (seasonal portable toilet) used for bird watching, walking, and picnicking.
- Goodnough Dike/Picnic area (seasonal portable toilet) used for walking, biking, bird watching, and picnicking.
- Quabbin Park Cemetery, located off the Quabbin watershed, is approximately 82 acres in size. It contains over 6,000 graves that were relocated from the towns of Greenwich, Prescott, Dana, and Enfield due to the construction of the reservoir.

Boat Launch Areas

Boat Launch Area 3.

Boat Launch Areas 1, 2, and 3 are high use recreational areas in the Quabbin Reservoir watershed. DWSP staff record the number of visitors to these areas; Table 4-17 shows the results for the 2015 fishing season, when the areas were open seven days per week. DWSP manages these areas to reduce the risks from sanitation facilities, gas and oil, aquatic plants, non-point source pollution (from vehicle parking and boat launching), and hazardous material storage (e.g., fuel for boats). Monitoring and rule enforcement is conducted by Watershed Rangers and the fishing area attendants with support from the Massachusetts State Police and Massachusetts Environmental Police Officers. DWSP staff use the Watershed Protection Regulations, 350 CMR 11.00 as well as the *Quabbin Reservoir Watershed System Public Access Management Plan* to guide specific management decisions in these areas.

TABLE 4-17. BOAT LAUNCH AREAS RECORDED VISITORS DURING 2015 SEASON

Visitor Type	Area 1 (Gate 8)	Area 2 (Gate 31)	Area 3 (Gate 43)	Total
Parking[1]	1,734	1,584	1,080	4,398
Private Boats	3,091	4,858	6,449	14,398
DCR Rental Boats	3,621	3,607	4,748	11,976
Seasonal Passes Sold				655

[1] Parking includes people fishing from shore, but also general access to the fishing area

Ware River

There are some non-forested high-use public areas in the Ware watershed as well. Approximately 550 acres were transferred in the mid-1950s to the Army Corps of Engineers at Barre Falls for flood control purposes. The transfer consisted of two nearly equal parcels, one containing the main dam and the other containing the dike area. The vast open acreage attracts visitors for walking, biking, picnicking, birding, and disc golf. In 1961, 1,300 acres were leased to the Department of Environmental Management (now DCR MassParks) to develop a recreation facility at Whitehall and Long Ponds, which became Rutland State Park. The lease expired in 1986 and was renewed for 230 acres adjacent to the bathing area.

Wachusett and Sudbury

Areas extensively used in the Wachusett watershed include: the Old Stone Church; the area on Route 140 adjacent to the Route 12 crossing of Thomas Basin; areas around the Wachusett dam; River Road; the powerhouse and fountain area below the dam; and the North Dike area. These areas experience significant public use, are very visible and historically have been maintained in mowed lawn areas for public access. Most of these areas are in close proximity to the reservoir and therefore maintenance plans must consider potential water quality impacts. Most of these areas are mowed with similar frequency to the Administrative Areas.

Passive recreation makes up the majority of public use in the Sudbury watershed, mainly walking and shoreline fishing in the areas open for those activities. The only intensive public use area is the "9/11" soccer field on Acre Bridge Road situated on land leased to the Town of Southborough.

4.3.9 Site Restoration

Unused/Abandoned Buildings

Most of the unused or abandoned buildings within the watershed system were acquired during the land acquisition program dating back to 1986. DWSP has performed environmental cleanup of these sites and completed building demolition/removal and site restoration. The environmental site and building assessments required for all unused/abandoned structures include sampling and testing for asbestos-containing materials (ACM) and lead-based paints (LBP). Depending on the history of the site and field observations for evidence of hazardous

materials, a Licensed Site Professional may be needed to assess for any possible regulatory issues, particularly M.G.L. ch. 21E. Following the site assessments, DWSP contracts must be written for removal of all ACM, excessive levels of LBP, and removal of hazardous materials. Upon resolution of environmental issues, a demolition and removal contract can be written and advertised. If new acquisitions include buildings or structures, these are evaluated for condition, historic value and use to DWSP. Those that are of no use and/or beyond repair are removed.

Compromised Sites

There are currently no known compromised sites on DCR watershed property. If any such sites are found in the future, environmental assessments and proper clean-up will occur. Following the site cleanup, any site restoration necessary will be completed to the extent required by all related federal or state laws and regulation, such as M.G.L. ch. 21E.

4.3.10 Rail Trails and Other Trails

The Massachusetts Central Railroad (MCRR) was a 104-mile rail line that was chartered in 1869 to carry freight and passengers between Boston and Northampton. The MCRR ceased passenger service west of Clinton in 1932 and freight service west of Oakdale in 1938. The line between Rutland and Oakdale was abandoned in 1939. Several miles of line that have been upgraded as a rail trail are currently open on DWSP property, including the Sterling spur and the section from Oakdale to Holden and from Rutland into Oakham. The rail trail enjoys tremendous popularity and support from the general public.

Ownership of the old rail lines is split among DWSP, other State agencies, local towns, and several private parties. Wachusett Greenways, Inc., a local non-profit has a Memorandum of Agreement with DWSP for the initial development and on-going maintenance of this trail on DWSP property. DWSP involvement is critical to the eventual linkage of the various sections. This rail trail provides a safe, enjoyable recreational opportunity to the general public. The trail acts to channel recreation to a narrow well-defined corridor, thus controlling recreational impacts. Trailheads act as excellent points of contact for information exchange and rules education. DWSP also allows walking and bicycling on many miles of existing forest roads in the Ware River and Quabbin Reservoir watersheds; the Public Access Plans have additional information on these recreational activities.

There are a few designated pedestrian use only trails that partially traverse DWSP property. The Bay Circuit Trail runs down the east side of Sudbury Reservoir, and the Sudbury Reservoir Trail runs mainly on the west. The Midstate Trail runs through the heart of the Ware River watershed, and the New England Scenic Trail runs along forest roads on the west side of Quabbin Reservoir west of Route 202. The Public Access Plans have additional information on these recreational activities.

4.4 Wildlife Management

4.4.1 Goals

- ***Mitigate adverse impacts of wildlife on water quality, infrastructure, and other watershed resources.***
- ***Maintain or enhance ecosystem biodiversity.***
  - ***Identify and protect all uncommon or rare species present on DWSP lands.***
  - ***Actively manage for selected wildlife species or suites of species that are considered to be uncommon, rare, or unique on a regional or statewide basis.***
  - ***Incorporate practices that generally benefit wildlife.***
- ***Assess and mitigate impacts of watershed management activities on common wildlife through site visits, long-term monitoring, review of records and literature, and recommendations to appropriate management staff.***

The primary focus of the wildlife program on the watersheds is to protect the water supply from potential adverse impacts caused directly or indirectly by wildlife while also protecting wildlife diversity and habitats. In certain circumstances, where applicable, active management to enhance wildlife habitat will occur.

The DWSP reservoirs' primary function as a public water supply is given top priority in any management decisions. Mitigating the negative impacts of roosting birds, aquatic wildlife, and burrowing animals on that water supply is a critical component of management. In addition, broad scale, active wildlife management, especially to manage the deer populations at Quabbin, is conducted as part of this plan for the protection of the drinking water supply.

While such active wildlife management to protect water supply is a major component of this plan, it is also DWSP's goal to avoid adversely impacting rare or uncommon wildlife species or their habitats during land management activities. This is accomplished primarily through inventory and survey work to locate rare species and habitats, proper coordination with MassWildlife's Endangered Species and Natural Heritage Program, and proper precautions using management guidelines and Conservation Management Practices (CMPs).

While directly protecting rare or endangered wildlife will also be a priority, DWSP recognizes that its management activities have the potential to impact more common wildlife. Another goal, therefore, is to assess the impacts of these land management activities on the general wildlife communities on DWSP lands. This assessment can be used to help minimize adverse impacts. This is accomplished through long-term monitoring programs and an in-house review process for all planned management activities.

When possible, and where appropriate, DWSP will also proactively manage habitat for the benefit of wildlife on the watershed. This type of land management concentrates on habitats or wildlife species that are rare or of special concern on a regional or statewide basis. Some treatments could include prescribed burns to enhance a field or meadow, reclaiming old fields/orchards, barrens restoration, creating early-successional forest, selective removal of exotic/invasive plants, erecting nesting structures for certain species of birds, or creating cover (brush piles or rock piles) in suitable habitat.

4.4.2 Population or Impact Control Plans

DWSP's primary responsibility is the long-term protection of the quantity and quality of drinking water. DWSP has identified certain wildlife species as posing a real and persistent threat to water quality. As a result, DWSP has been working to address these wildlife concerns. It is DWSP's general policy not to interfere with or actively manage native wildlife. However, when wildlife activities threaten to impact the water quality of the reservoirs, the structure or function of the watershed forest, or the integrity of watershed structures, then DWSP takes an active role in mitigating these problems. Current species of concern and their associated risks are discussed below.

Beaver

General Comments

Beaver are a species that can dramatically alter the surrounding habitat, which in turn can affect other wildlife species and human activities and resources. Beaver have been linked to water-borne pathogens and are potential carriers of both *Giardia spp.* and *Cryptosporidium spp.* In addition, beaver can cause localized damage to roads, culverts, and trees. In general, the habitat they create is seen as beneficial to a variety of wildlife species. Whether any one colony is seen as a benefit or a detriment depends on a variety of factors. DWSP policy regarding beavers requires a detailed assessment of the situation and then applies the solution that offers the best long-term remediation.

Beaver in the partially frozen Quabbin Reservoir at Boat Area 3.

Beaver populations within the watersheds increased following a trapping ban in 1996, but then declined. As beaver continue to colonize riparian areas, it is important to recognize their role in hydrologic and ecological processes. A careful review of the literature would indicate that it is not the presence of beaver dams themselves but their persistence through time that has the biggest potential impact on water quality.

Maret et al. (1987) felt that it was really the downstream channel that had the largest impact on water quality, as they state, "Our data illustrate the importance of location of beaver ponds along a stream in improving water quality. If water quality is to be maintained downstream from ponds and if nutrient export to a lake or reservoir is to be reduced, then the channel downstream from the pond complex must be stable or the pond complex must be located close to the lake or reservoir." Most streams within the DWSP watersheds are low-order (first to third), and beaver dams constructed across these streams have the strong potential for long-term stability and persistence. On those sites with historically unstable beaver dams or on particularly "flashy" streams, then beaver control will be addressed as described below.

There is no evidence to suggest a decline in water quality (outside pathogen protection) associated with stable, long-term beaver dams and beaver activity. Most evidence would suggest that beaver ponds (like most wetlands) have either no negative effect on water quality or have a filtering effect that improves water quality by decreasing erosion, trapping sediments, particulates, and nutrients. Changes to vegetation along the banks of beaver ponds results in a species shift away from species preferred by beaver or economically valuable deciduous trees to a larger proportion of woody shrubs and unpalatable or undesirable (by beaver) canopy trees. The more open canopy that results from beaver activity stimulates regeneration and increases habitat diversity.

Overall, there appear to be either no effects or positive effects on both faunal species richness and diversity when comparing ponds to unaltered riparian wetlands. There are still site-specific situations where beaver will need to be controlled as detailed in the next section. Outside these specific situations where damage is occurring, there does not appear to be a need to focus beaver control efforts on a watershed basis.

Beaver Management Policy

Beaver management issues on DWSP lands can be broken down into two categories: Water Quality Protection and Damage to Structures or Resources.

Beaver and Water Quality Protection

There is consensus in the scientific community that beaver can play an important role in the transmission or amplification of harmful pathogens to humans through water supplies. DWSP completed a report that summarizes these concerns and addresses management recommendations for beaver at both the Wachusett and Quabbin watershed reservoirs. For more detailed information regarding this see the report titled, *Quabbin and Wachusett Reservoirs Watersheds Aquatic Wildlife Pathogen Control Zones* (MDC 1999)**.** This report clearly defines a zone around each reservoir where beaver are excluded and eliminated on a continual basis for water quality protection. The report does not address beaver management for water quality protection outside this protection zone.

In addition to identifying and controlling beaver within the defined Control Zone, beaver colonies located within the main reservoir will also be identified as time and resources allow. If possible, these colonies are removed during the regular trapping season in order to limit the local population of beaver and proactively target colonies closest to the control zone.

Damage to Structures or Resources

Outside the water quality protection zone, it is the DWSP's general policy to allow unrestricted beaver occupation. However, the following situations are examples where beaver activity may be discouraged, mitigated, or modified:

- Beaver activity that threatens rare or uncommon plant or animal communities.
- Beaver activity that precludes the use of necessary access roads needed for watershed maintenance, management, or protection.
- Beaver activity that threatens the proper functioning or structure of dams, culverts, and other parts of the water supply infrastructure.
- Beaver dams on unstable or flashy streams with a history of, or potential for, regular washouts.

The following procedure is used to mitigate the damage when there is a conflict with a beaver colony. DWSP personnel encountering problem beaver sites contact the Natural Resource Section with detailed information about the problem. Upon review, the Natural Resource Section will decide the most appropriate control activity for each site. Options available include: water level control devices, dam stabilization, culvert protection, or lethal removal. Site-specific control options are chosen based on site conditions, history of the site, and type of damage occurring. The goal is to provide the most effective control possible that mitigates the problem within appropriate laws and guidelines.

When lethal measures are determined to be the best alternative to alleviate the problem, there are specific guidelines that are followed. Lethal removal will only be used if all of the following criteria for the site are met:

- Beaver are causing documented (observation, photographs, etc.) damage to DCR infrastructure (roads, culverts, bridges).
- Other, non-lethal means (water level control devices, fencing, etc.) would not be able to mitigate the problem because of limitations in access, maintenance, or effectiveness.
- DCR property being damaged is essential and cannot be temporarily abandoned.
- Lethal measures can be implemented within appropriate laws and guidelines and without threat to the safety of the public, domestic animals or other wildlife.

Beavers Affecting Adjacent Landowners

DWSP recognizes the beaver as a part of the natural environment and their contribution to the quality and diversity of natural habitat. Where they are not in danger of creating water quality concerns, beaver are allowed to remain. However, DWSP also recognizes that beaver activity on DWSP land can impact municipal areas, public health and safety, as well as private property, or other public infrastructure. DWSP's policy on beaver occupying DWSP land that negatively impacts adjacent landowners includes:

- Offer technical assistance on solutions (lethal and non-lethal) to the problem.
- Grant permission to access DWSP property to alleviate the problem within appropriate laws and guidelines.

Muskrat

In the past, most of the attention regarding water quality and wildlife has focused on beaver and their role in pathogen transmission. DWSP has identified muskrat as another key species in their pathogen prevention program. The muskrat impact control program in this plan is focused on water quality protection within the reservoir. A detailed description of the program can be found in *Quabbin and Wachusett Reservoirs Watersheds Aquatic Wildlife Pathogen Control Zones* **(**MDC, 1999). In addition, muskrat have the potential to cause damage to watershed infrastructure. In situations where muskrat are causing damage to these structures (i.e., dikes, dams), appropriate measures will be used to mitigate the damage. Measures may include lethal removal of the individuals, followed by habitat manipulation to discourage reoccupation.

Gulls

Wachusett and Quabbin Reservoirs provide a daytime loafing area and night-time roosting site for a variable number of gulls. Three species of gulls (ring-billed, herring, great black-backed) are the most common. Gull numbers generally begin to increase in late summer and early fall and reach a maximum during the winter months (particularly when other water bodies freeze). By spring and early summer, most gulls have left the area to migrate to their summer breeding habitat. Although gulls are present at the reservoir all day, most gulls will leave the nighttime roost soon after sunrise. The gulls disperse to spend the day at feeding sites, including parking lots and waste water treatment plants. By late afternoon, most gulls are returning to the reservoir to spend the night. As a result, harassment efforts are focused during the late afternoon to early evening.

DWSP has been monitoring bird populations at Wachusett and Quabbin Reservoirs since the late 1980s. Early studies provided evidence that a high number of gulls in the certain portions of the reservoirs correlated with high fecal coliform counts at the Cosgrove and Chicopee Valley Intakes. In response to these studies, DWSP initiated a bird harassment program in 1993. Since 1993, DWSP has conducted a yearly harassment program to scare birds out of the Bird Harassment "Gull-Free" Zones (Figures 4-19 and 4-20).

FIGURE 4-19. WACHUSETT RESERVOIR GULL CONTROL ZONE

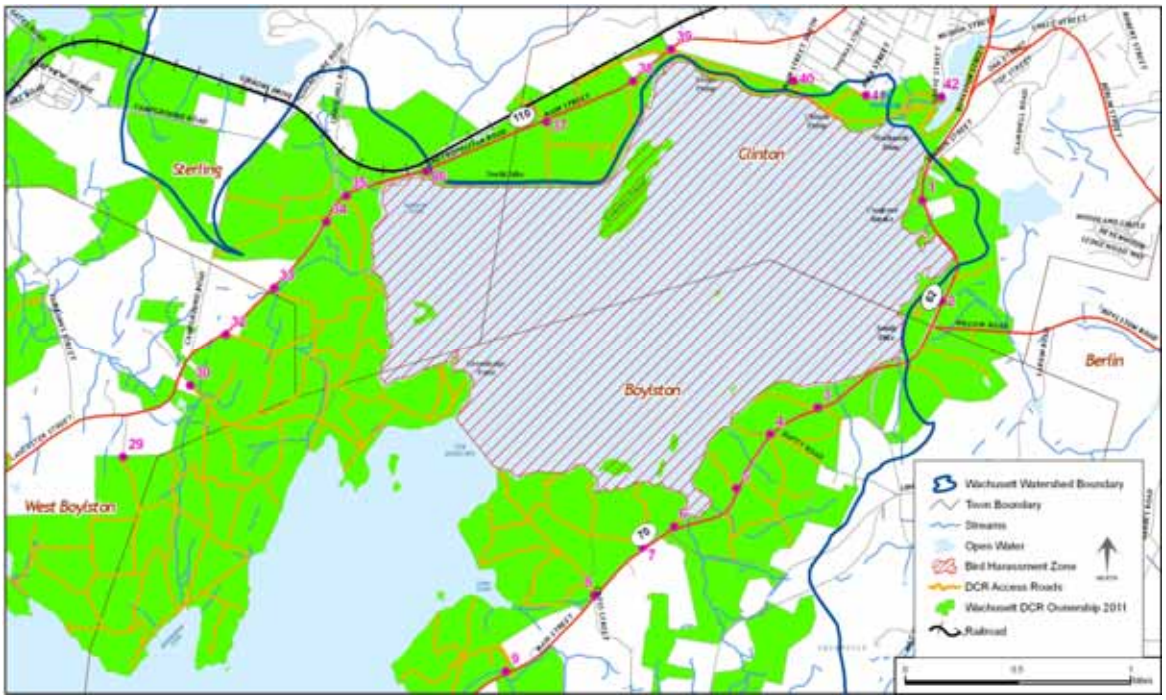


FIGURE 4-20. QUABBIN RESERVOIR GULL CONTROL ZONE

The harassment program is a year-round effort, although active harassment activities usually occur from September until the reservoirs freeze. Daily harassment activities are supervised and/or carried out primarily by DWSP Environmental Quality personnel. In addition, DWSP maintenance personnel conduct harassment from boats when necessary. Natural Resource staff are responsible for program monitoring, passive harassment techniques, and program development. Active harassment is done using pyrotechnics, lasers, a human presence, and boats. Birds are either scared from shore using "Shell-crackers," and/or lasers, or a boat is used to scare and herd the birds towards the southern end of the Wachusett Reservoir or the northern end of the Quabbin Reservoir.

Control efforts during the active harassment period of the program are conducted up to seven days per week until the reservoirs freeze. During icy conditions when boat use is impossible, DWSP uses an airboat to harass the birds. Over the years, DWSP has used several passive techniques in conjunction with the active harassment program. These techniques include using netting to exclude birds from critical areas, erecting structures that support "scary-eye" balloons, using remote activated sound deterrent stations, and habitat manipulation to discourage bird use. Coupled with the harassment activities at the reservoir, DWSP has worked with other EOEEA agencies to develop regulations to control state solid waste landfills. In the fall of 1998, DEP instituted regulations that required all municipal solid waste landfills to harass and discourage gulls from feeding and loafing at their sites. In addition, new landfills must submit a written gull harassment program prior to receiving their operating permit. To date, the new regulations have been successful in reducing the number of gulls at area landfills. However, more diligent monitoring and enforcement is needed to ensure continued compliance.

Since 1993, the bird harassment program has been very successful in reducing the number of birds located in close proximity to intake structures. As a result, fecal coliform counts for that time period have been extremely low as well. DWSP will continue the harassment program indefinitely and continue to make modifications and adjustments to ensure its long-term success.

In 2008, DWSP initiated an intensive field study to examine the winter ecology of gulls in central Massachusetts. Over 1,500 gulls were captured and fitted with satellite transmitters or wing-tags. Results from the study highlighted the importance of anthropogenic sources (hand-outs, waste water treatment plants) of food for wintering gulls. The study also documented how often DWSP's reservoirs were used and how site faithful gulls were to central Massachusetts. Results from this study were published in a variety of scientific journals and have helped direct DWSP into activities that could potentially reduce the local population of gulls during the winter, including preventing people from feeding gulls and controlling agricultural sources of food (Clark et al., 2013, 2014, 2015, 2016a, 2016b).

Geese

Canada geese are present year round at Quabbin, Wachusett, and Sudbury Reservoirs. There are approximately 40 resident geese on Sudbury Reservoir, 35 on Wachusett and less than 20 on Quabbin that only leave the area when the reservoirs freeze. In addition, during the fall and winter, several hundred more geese utilize the reservoirs during migration. From a water quality perspective, geese are a lower priority species than gulls because of their feeding behavior and population levels. However, DWSP still considers geese to be a high priority species, and geese are actively harassed during the bird harassment program. Although less responsive to harassment efforts, all of the active and passive harassment techniques are geared toward scaring geese as well as gulls.

A goose nesting on an island at Sudbury Reservoir.

In addition to actively harassing geese at the reservoirs, there has been a strong effort to reduce the local resident goose population through an intense population reduction program. Since 1995, attempts have been made to identify all Canada goose nests on the reservoirs. Once identified, the eggs in each nest are treated to prevent hatching. The goal of this program is the gradual long-term reduction in the resident adult goose population. This program will continue in the future.

Other Waterfowl

Other than Canada geese, the reservoirs harbor a variety of waterfowl. During the spring and summer, there is a relatively small number of resident mallard ducks. During the fall and winter, the number of waterfowl can increase substantially, and on some occasions there may be several hundred ducks (e.g., ring-necked, mergansers, mallards) at the reservoirs. Fortunately, most ducks continue their migration south or north within a few weeks. During the time they are located on the reservoir, these species of ducks are included in the harassment efforts if they are located within the bird harassment zone.

Two other species of potential concern are the mute swan and the double-crested cormorant. A seasonal resident at the reservoirs, cormorants typically begin to show up in mid-late summer after the breeding season has ended. They are present through late fall and non-breeding individuals return again in the spring. Although relatively scarce (< 50 individuals) when compared to gulls and geese, these birds are extremely difficult to harass. While other bird species tend to fly when scared, cormorants often dive and swim beyond the limit of harassment. The cormorant is included as a target species in the bird harassment program, and research will

continue to develop new and better harassment techniques. In addition, no cormorants will be allowed to nest on either reservoir. Mute swans, a large non-native bird, are becoming increasingly common and have been documented nesting on the Sudbury Reservoir. Efforts are made to monitor their populations and prevent them from nesting on DWSP reservoirs.

Burrowing Animals

The burrowing activity of certain wildlife species such as woodchucks, foxes, moles, and voles can cause damage to the integrity of earthen dams, dikes, and other watershed structures. Routine animal burrow surveys are conducted of all dams and dikes. Active burrows are treated with lethal measures to remove resident animals. Burrows are then filled in to prevent further damage and to aid future surveys in distinguishing active and inactive sites.

White-Tailed Deer

White-tailed deer populations are increasing in most of the northeast. There is continuing concern about these increasing populations and their impact on natural resources (deCalesta, 1994; VerCauteren et al., 2011; Healy, 1997a; Alverson and Waller, 1997; McShea and Rappole, 1997). Deer populations within Massachusetts are increasing in the central and eastern part of the state (D. Stainbrook, MassWildlife, pers. comm.). White-tailed deer can thrive in suburban environments where there is abundant food, few predators, and enough wooded areas to provide cover. Coupled with expanding deer populations is increased fragmentation of the landscape that can isolate these wooded reserves and in many cases prevent people from effectively hunting white-tailed deer populations. Even in areas where hunting is feasible, there is growing concern that both hunter interest and hunter recruitment is declining. In many situations, these circumstances can lead to overabundant deer densities.

White-tailed Deer on Quabbin Reservoir Watershed

Overabundant deer populations can influence and affect the abundance of woody species (Waller and Alverson, 1997). In addition, intensive deer browse may cause problems in regenerating particular species such as oak. When deer populations are protected for many years and sustained at high densities, forest structure may be altered completely, resulting in park-like stands with grass or ferns dominating the understory (Waller and Alverson, 1997). Situations like this were documented on the Quabbin Reservation and in the Alleghany National Forest in northwest Pennsylvania (Waller and Alverson, 1997). In response to growing concerns about the lack of forest regeneration and the absence of an understory layer within large portions of Quabbin Reservation, the area was opened to limited, controlled public deer hunting in 1991. Hunting has been conducted on sections of the reservation each year since.

The controlled hunts constituted only one component of a comprehensive 1991 White-tailed Deer Impact Management Plan for the reservation that also included the use of electrified fencing (now discontinued) and various changes in DWSP's land management program. That plan called for six years of controlled hunting, followed by a major review and re-evaluation of

the program. That review was conducted in the spring of 1997 when two reports (*Quabbin Regeneration: Summary Report 1988-97* and *Quabbin Reservation White-tailed Deer Impact Management Program: Results and Evaluation 1991-1996*) were issued by the DWSP. Also at that time, recommendations for the next phase of the program were issued in the document *Quabbin Reservation White-tailed Deer Impact Management Program: Summary Report and Proposal 1997*. Those recommendations called for a continuation of the controlled hunting program with several changes proposed to make the program more efficient.

The driving force behind the deer reduction program at Quabbin has always been to reduce the impacts of deer browsing to a level that allows and promotes the development of a healthy, resilient, diverse forest that can adequately and continuously protect water quality. Major components of the deer population reduction program were to: 1) reduce population densities; and 2) maintain those densities at a level that allows for the continued growth and regeneration of forest tree species. After several years of controlled hunts, substantial reductions in deer population densities were achieved in all hunt areas, and DWSP has been in the maintenance phase of its program since that time.

The maintenance phase of the program is essential for preserving relatively stable deer population levels and eliminating potentially large swings in deer densities that could occur if hunting were stopped for an extended period of time. In the absence of regular hunting mortality, deer populations at lower densities that have little natural mortality and an increasing food supply would expand and could jeopardize the forest regeneration progress made to date. In 2000 and 2004, five-year plans were developed that outlined proposed activities for each five year period (Clark, 2004). Since 2009, an annual report has been written that follows the same general 5-year plan laid out in previous plans. When necessary, changes can be made to the program to make it more efficient or effective.

Since 1991, Quabbin deer populations have been lowered substantially through the annual managed hunts, and the forest has responded tremendously. Regeneration surveys conducted during 2004 indicate that the number of tree stems/acre has increased from 910 in 1989 to 4,532 in 2004 (a 400% increase). Tree species diversity also continues to increase, and although white pine and black birch dominate the understory, more maple, oak, and hemlock trees are present.

Deer hunting on Quabbin Reservation is limited to a four day managed hunt, with access strictly controlled through a check-in/check-out procedure. Participating hunters are required to attend an orientation session every seven years and follow specific rules and regulations to ensure hunter safety and protect water quality. Since 1991, over 5,000 deer have been harvested from Quabbin Reservation by approximately 30,000 hunters (Table 4-18). Since 1991, several administrative changes have been made to the hunt including allowing vehicle scouting prior to the hunt, instituting a five block rotation, and defining antlerless deer killed at Quabbin as "bonus" (not counting towards the state-wide bag limits).

TABLE 4-18. RESULTS OF THE QUABBIN CONTROLLED DEER HUNT, 1991-2016

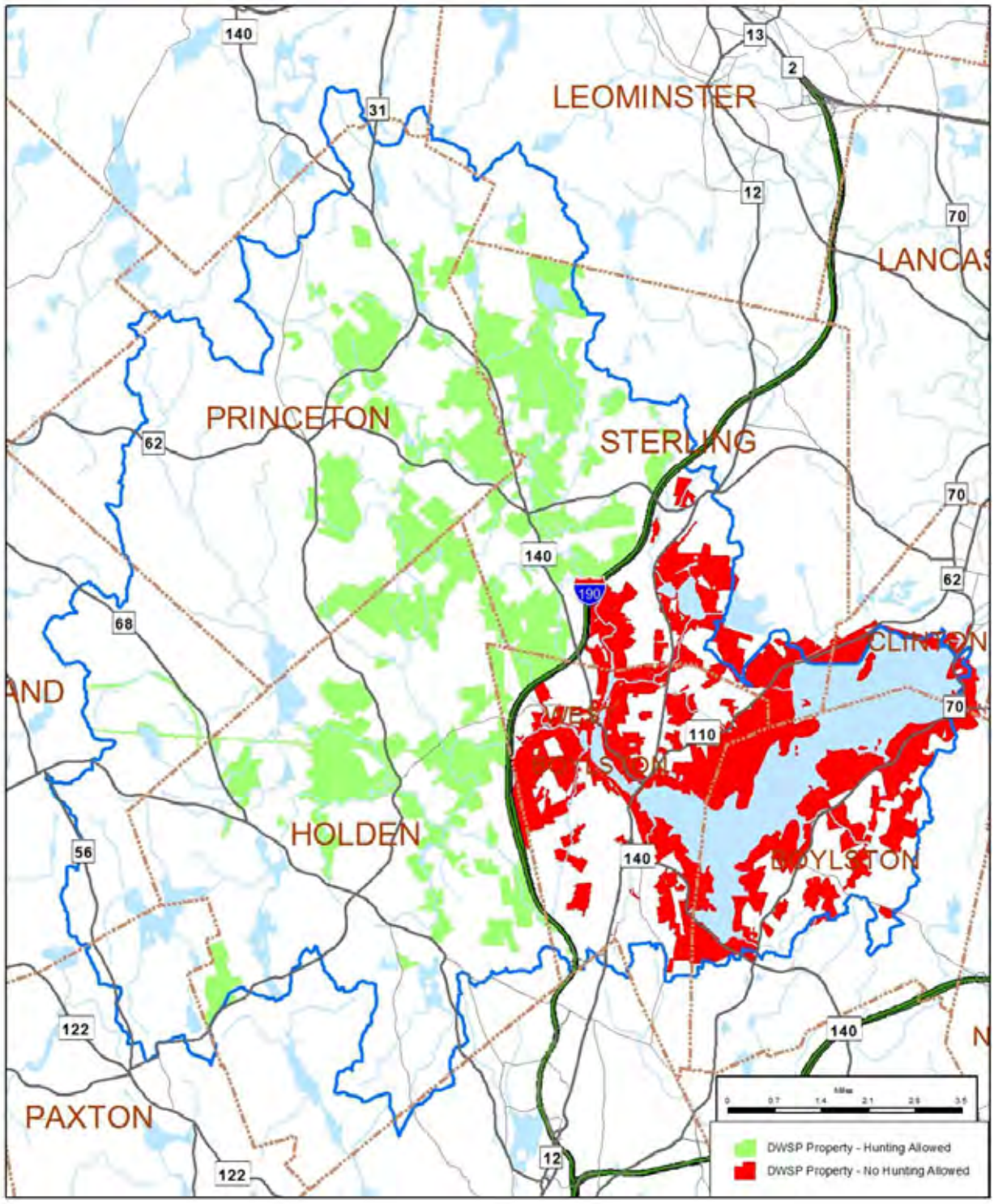
Year	Total Deer	% Female	% Male	% A/L[1]	Deer/Mi^2 (killed)	# Hunters	Hunter Success[2]	Mi^2 Hunted
1991	575	60.3	39.7	71.8	40.9	855	67.3%	14.1
1992	724	54	46	60.5	21.7	1,971	36.7%	33.4
1993	474	62	38	67.1	9.5	2,168	21.9%	49.7
1994	673	59.9	40.1	68.9	10.7	2,118	31.8%	63.1
1995	284	64.8	35.2	74.3	4.7	1,508	18.8%	60.9
1996	129	58.1	41.9	67.4	2	1,213	10.6%	63.1
1997	293	62.1	37.9	73.4	4.8	1,207	24.3%	63.1
1998	123	57.7	42.3	65.9	2.3	1,099	11.2%	55.8
1999	112	39.3	60.7	51.8	1.8	1,192	9.4%	63.1
2000	106	47.2	52.8	55.7	1.7	818	13.0%	49.1
2001	101	51.5	48.5	58.4	1.9	855	11.8%	52
2002	153	48.4	51.6	64.1	3	967	15.8%	50.2
2003	306	69	31	83.7	6.9	938	32.6%	44.2
2004	167	47.9	52.1	58.7	3	1,259	13.3%	55.8
2005	117	53	47	65	1.8	1,071	10.9%	49.1
2006	117	38.5	61.5	42.7	1.8	1,165	10.0%	52
2007	147	44.9	55.1	56.5	2.3	1,086	13.5%	50.2
2008	80	43.8	56.2	55.0	1.8	1,103	7.3%	43.7
2009	200	57.5	42.5	67.0	3.6	1,225	16.3%	55.4
2010	116	41.4	58.6	61.2	2.4	1,043	11.1%	49.2
2011	73	37.0	63.0	49.3	1.4	1,186	6.2%	53.7
2012	84	45.2	54.8	59.5	1.6	931	9.0%	51.6
2013	122	58.2	41.8	69.7	2.8	782	15.6%	43.7
2014	105	49.5	50.5	53.3	2.0	950	11.1%	51.7
2015	48	43.8	56.2	60.4	1.0	865	5.5%	49.2
2016	53	24.5	75.5	30.2	1.0	874	6.0%	53.7
Total	**5482**	**50.8**	**49.3**	**61.2**	**5.3**	**30,449**	**17.0%**	**50.8**

[1] Antlerless deer: female deer and young males with antlers less than three inches long.
[2] Hunter success: number of deer taken per 100 hunters. Some hunters may harvest more than one deer, so these numbers slightly overestimate the proportion of successful hunters.

White-tailed Deer on Wachusett Reservoir Watershed

Hunting (including deer) was prohibited on DWSP lands in the Wachusett watershed for a majority of the last century. In 1996, the MDC initiated a 2-year pilot program that allowed hunting on most MDC lands in the watershed west of interstate I-190. Within the next two years, the MDC formalized its hunting program and hunting has been allowed west of I-190 ever since (Figure 4-21). Deer populations within the Wachusett watershed were recently estimated using pellet count surveys. Density estimates in the hunted areas west of I-190 were approximately 9 deer per mi^2. However, deer densities east of Interstate I-190 where hunting is prohibited ranged from 25-82 deer per mi^2. Deer densities above 20 per mi^2 can have an impact on tree regeneration and growth. In addition, anecdotal observations (i.e., browse lines, poor tree regeneration) within the unhunted lands suggest deer densities may be well above the 20 deer per mi^2 threshold.

FIGURE 4-21. WACHUSETT RESERVOIR WATERSHED LANDS CURRENTLY OPEN TO HUNTING



The Wachusett Reservoir watershed differs from both the Quabbin and Ware River and is characterized by smaller parcels scattered around the watershed. Many of these parcels have been acquired recently by DWSP and were traditionally hunted; however if the newly acquired

lands are within the current no hunting zone, then hunting activity is prohibited. There are approximately 7,000 acres of DWSP land in this no hunting zone. Given the high degree of fragmentation within the watershed, DWSP recognizes the potential for some of its lands within the no-hunting zone to serve as refuges for an increasing deer population.

Given the lessons learned at the Quabbin Reservation, Wachusett staff is primarily concerned with the potential impact high deer densities may have on tree regeneration and growth within the no-hunting zone. DWSP scientifically monitors forest regeneration of recent harvests (< 10 years old) within the Wachusett watershed. Additionally, Wachusett foresters routinely walk and inspect a variety of forest stands and sites within the watershed and make anecdotal observations about regeneration. Recent inspections in the no hunting zone have raised concerns about the forest's ability to regenerate. Given the trend of rising deer populations, shrinking hunting opportunities, and a declining hunter base, DWSP recognizes the potential for some of its no-hunting lands to experience overabundant deer populations.

Although primarily focused on the impacts of overabundant deer on tree regeneration, DWSP also recognizes that other social issues related to overabundant deer may become more prevalent. These include increased deer/vehicle collisions and personal property damage and potential exposure to Lyme disease via deer ticks.

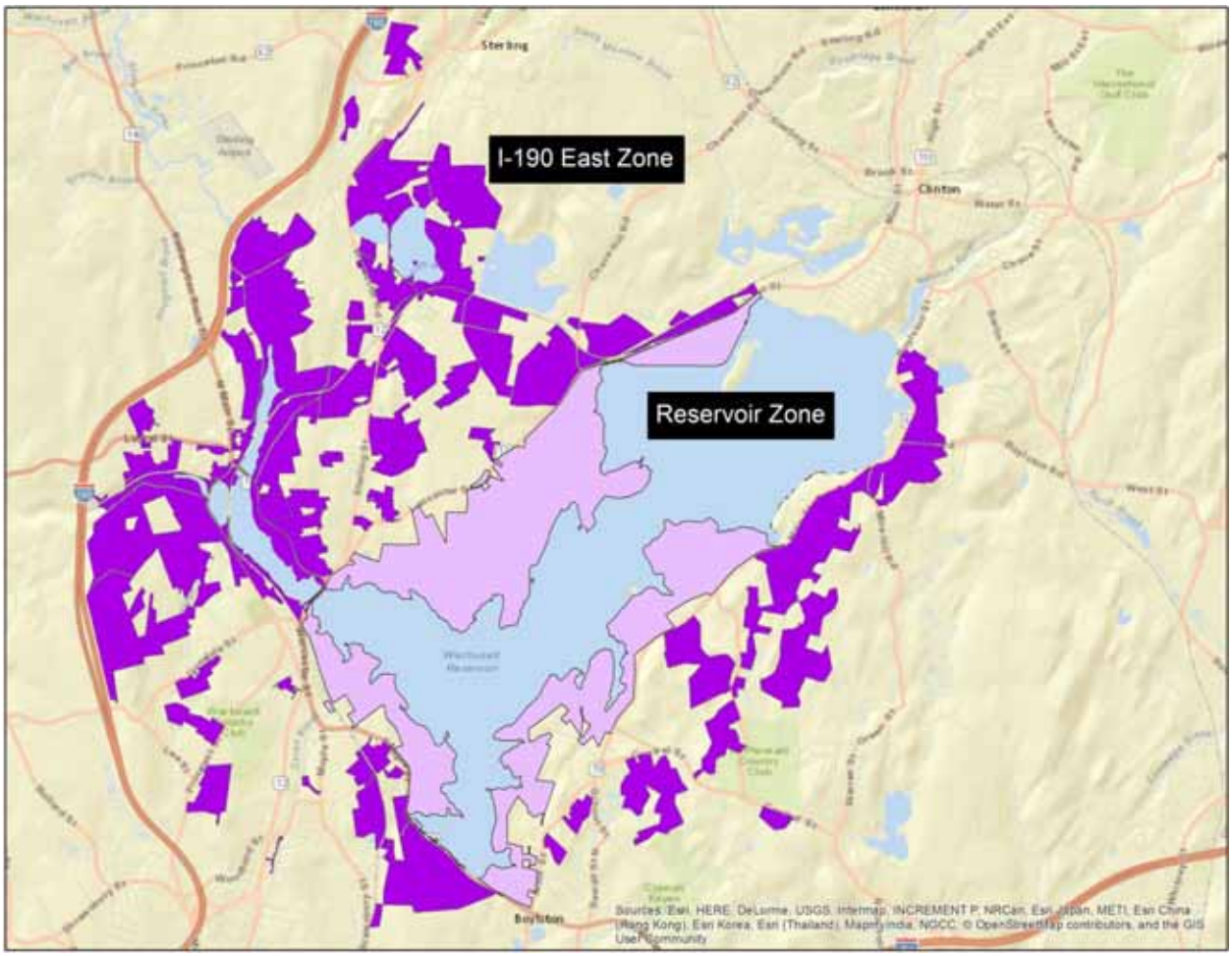
As a result, DWSP has initiated some long-term monitoring efforts, including the installation of three deer exclosures and population monitoring using pellet surveys. Early evidence suggests that deer densities in the current no-hunting portion of DWSP land in the Wachusett watershed are higher than similar DWSP lands in the huntable zone. Given the lessons learned in other areas, it is DWSP's responsibility to maintain deer densities at levels compatible with cultural and natural carrying capacities. Therefore, following a public review and comment period, DWSP plans to open up additional lands to hunting in 2018 to reduce deer densities to a level more compatible with resource management goals. In addition, while this initial approach is designed to lower deer densities in the current no-hunting zone, as deer densities decline, modifications to the proposed approach may be warranted. Regular reviews will be conducted and changes made when appropriate.

DWSP's proposal divides lands east of Interstate I-190 into two zones: Reservoir and I-190 East (Table 4-19, Figures 4-22 to 4-24). Proposed access, hunting methods, and restrictions would be different for each zone. DWSP property currently within the existing hunting zone (west of I-190) will continue to be hunted following existing rules and regulations.

TABLE 4-19. CHARACTERISTICS OF PROPOSED AND EXISTING DWSP LANDS OPEN TO HUNTING AT WACHUSETT

Zone	Acres	Comments	Estimated Deer Density (deer/mi^2)
I-190 East	4,700	Land east of Route I-190, excluding Reservoir	25-39
Reservoir	2,839	Interior Gates	82
I-190 West	9,652	Land currently hunted; west of Route I-190	9

FIGURE 4-22. PROPOSED NEW HUNTING ZONES ON DWSP LANDS IN THE WACHUSETT WATERSHED



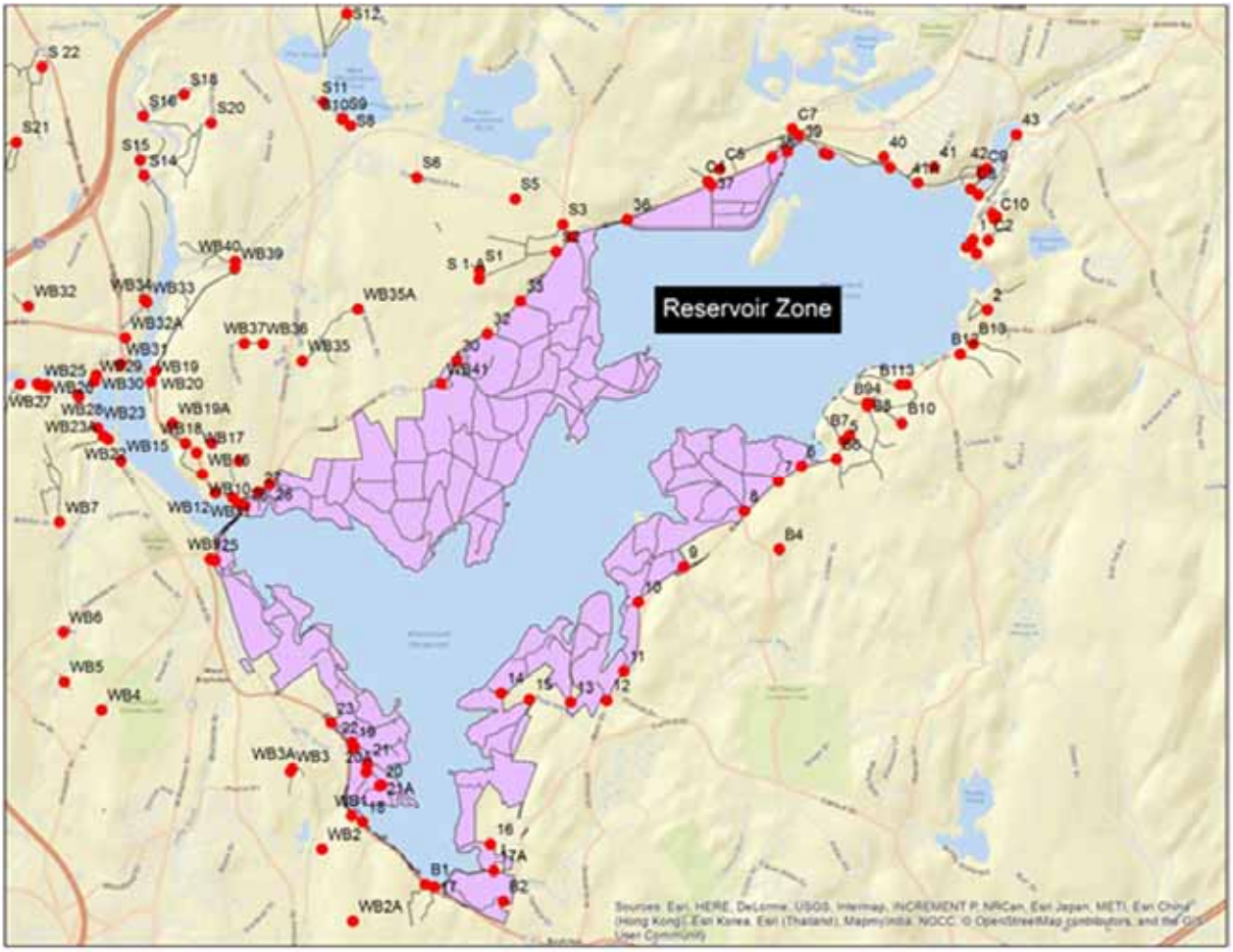
Reservoir Zone

The primary concern in this zone is overabundant deer impacting tree regeneration and growth. An additional concern is this zone's proximity to the Reservoir (Figure 4-23) and its use for shoreline fishing and passive recreation. Therefore, the proposed hunting plan in this zone would be restricted to white-tailed deer only and would occur after the fishing season closes. Hunting for other game animals will not be permitted. Hunting would be allowed during the 2-

week shotgun season (primitive arms may also be used during this season) and the primitive arms season that follows.

Hunters would apply for each season (shotgun and primitive arms), and a random drawing for each season will be conducted to select a specific number of hunters. Selected hunters would be given an access permit that must be with them while hunting. Hunters will be required to walk into this zone from one of the existing gate locations. In addition, hunters harvesting a deer in this zone must check the deer in at MassWildlife's Central District office in West Boylston. Tree stands will be allowed in this zone, but may only be put up a month before the season opens and must be taken down within a month after the season ends. Further, all tree stands must be labeled, and permanent trees stands or screw-in steps are not allowed.

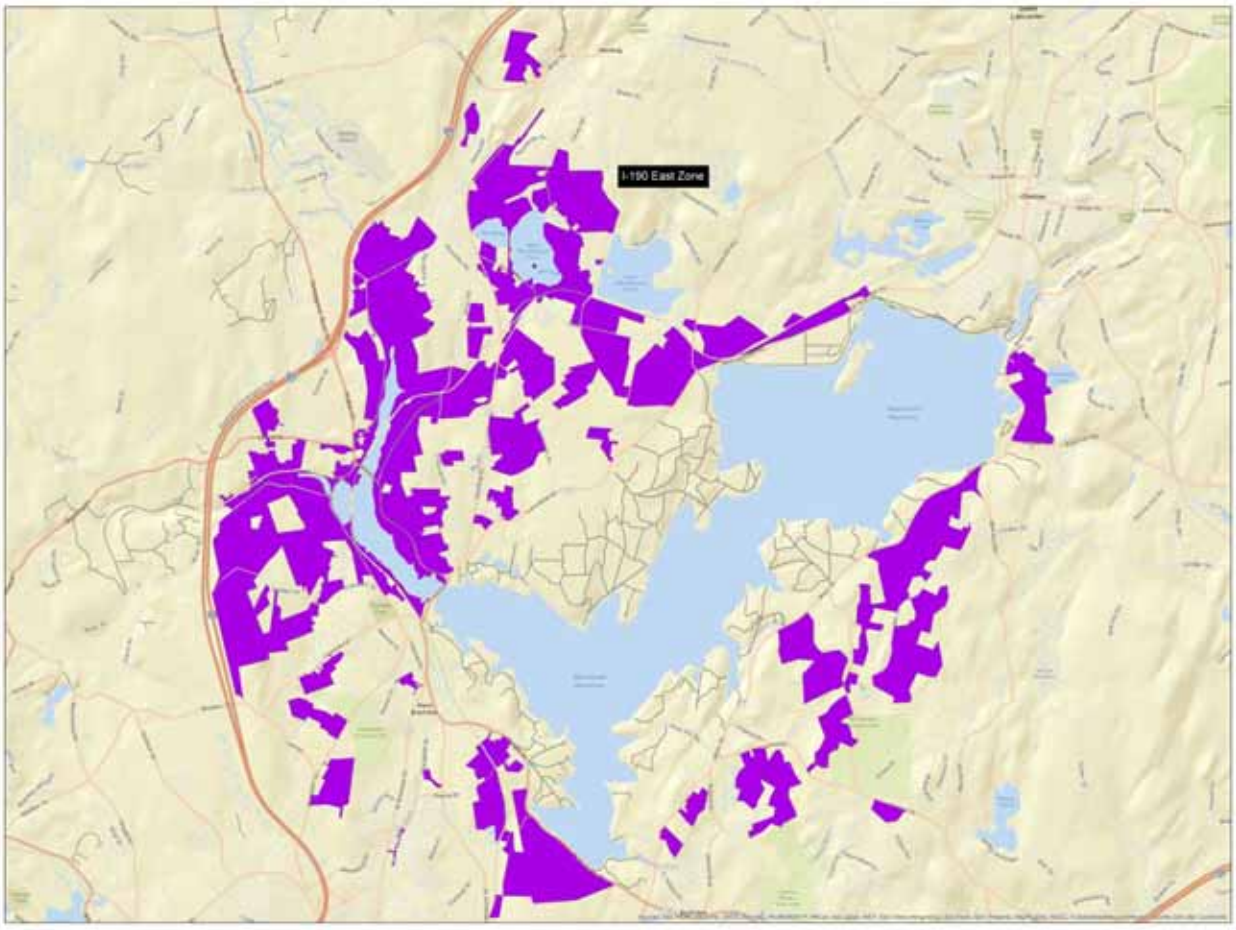
FIGURE 4-23. PROPOSED NEW RESERVOIR HUNTING ZONE ON DWSP LANDS IN THE WACHUSETT WATERSHED



I-190 East Zone

Overabundant white-tailed deer populations are the primary concern in this zone as well, but given its location from the reservoir, the proposal would allow all types of hunting during any hunting season, except ***no dogs*** may be used for hunting in this zone (Figure 4-24). Deer hunting would be allowed following all state-wide Fish and Wildlife laws and regulations (i.e., archery, shotgun, and primitive) and all safety regulations. All access would be by foot. Tree stands would be allowed in this zone, but they can only be put up a month before deer season opens and must be taken down within a month of deer season ending. In addition, no permanent tree stands or screw-in steps are allowed, and all stands must be properly labelled with the owner's name and address. In the future, if DWSP purchases land within this zone, it will become (or remain) huntable following the zone's restrictions.

FIGURE 4-24. PROPOSED NEW I-190 EAST HUNTING ZONE ON DWSP LANDS IN THE WACHUSETT WATERSHED



Permitting

DWSP currently requires all hunters to send in a paper application to receive a free hunting permit before they can hunt on DWSP properties west of I-190. DWSP will continue this permitting system, but will transition to an online application. Hunters wanting to hunt outside the Reservoir zone (i.e., I-190 West or I-190 East) would be required to fill out a free online application and receive their permit electronically or in the mail. Hunters are required to keep this permit with them while hunting, and the permit will be valid for five years. Hunters choosing to participate in the Reservoir zone hunting period would be required to fill out a specific online application for either the shotgun or primitive portion of the Reservoir zone hunt. If selected, these hunters will receive their season-specific permit electronically or in the mail. This permit is only valid for one year, and hunters must apply for the random selection each year they want to participate.

Moose

Moose are North America's largest terrestrial wild animal. An average adult moose weighs around 1,000 pounds and stands six feet at the shoulder. Moose and their ancestors originated in Siberia and made their way to North America across the Bering land bridge. At the time of European settlement, moose were distributed from Alaska, across Canada into the northern United States from North Dakota east to Pennsylvania and all of New England, including Massachusetts. Moose also extended down the Rocky Mountains in the West. Temperature was probably the limiting factor in the southern distribution of moose in North America. Winter stress typically occurs when temperatures exceed 23°F and summer stress when temperatures are > 59°F (Franzmann and Schwartz, 1997).

Moose were extirpated from Massachusetts by the early to mid-1800s (Peek and Morris, 1998; Veccillio et al., 1993). A small number of moose escaped from a game preserve in Berskshire County around 1911 and may have persisted for several years (Veccillio et al., 1993). Most sightings during the next 50 years were probably northern vagrants. Since the late 1980s, the number of moose sightings has increased greatly (Peek and Morris, 1998). In 1998, the state's moose population was estimated as at least 75 animals including cows with calves (Peek and Morris, 1998). Current estimates of moose populations in Massachusetts are around 1,000 animals (MassWildlife, pers. comm.). Possible reasons for the increase in moose populations include the absence of predators, reversion of farms to forested areas, legal protection, increased wetlands from expanding beaver populations, and larger forest openings (Franzmann and Schwartz, 1997).

Moose populations continue to persist in Massachusetts. DWSP lands within the Quabbin and Ware River watersheds probably function as a core habitat for moose populations given their large size and diversity of habitats. Moose populations in the state suffer relatively little natural or human caused mortality. Black bears and coyotes are the only potential predators of moose and are primarily limited to killing young calves (Benson and Patterson 2013). There are approximately 2,000 black bears in Massachusetts, and most of them are located west of the Connecticut River. As a result, current bear populations are not capable of limiting moose populations. The main source of moose mortality is most likely from interactions with people. In 1997, 12 moose were killed on roads, four nuisance animals were destroyed, and four were immobilized and relocated (Peek and Morris, 1998). It is likely that moose/vehicle collisions will continue to rise as moose populations expand. Because moose/car collisions are extremely dangerous for both humans and moose it has been suggested that moose are incompatible with an urbanized state such as Massachusetts, and the public's tolerance of moose is limited (Peek and Morris, 1998; Veccillio et al., 1993).

A GPS-collared moose at Quabbin Reservoir.

Moose and Vegetation

Moose are primarily browsers and feed on the leaves, buds, and twigs of a variety of tree and shrub species. An adult moose can consume 40-60 pounds (10 times more than a deer) of browse daily (Snyder, 2001). During the summer, moose spend time in lakes and ponds feeding on aquatic plants. A good deal of work has been done assessing the impact of moose on boreal forest ecosystems (Danell et al., 1991; Edenius, 1994; Angelstam et al., 2000; Connor et al., 2000; McLaren et al., 2000; Brandner et al., 1990; McInnes et al., 1992). There exists little if any information on the impact of moose in the southern portion of their range. While boreal ecosystems are relatively simple in terms of species diversity and structure, forests in Massachusetts are much more complex in both composition and processes. While information regarding moose in boreal ecosystems is important and insightful, it does not necessarily represent moose in mixed hardwood/softwood forests.

In Europe, moose were shown to have negative impacts on the quantity and quality of Scots pine (Angelstam et al., 2000). Moose density was found to be the contributing factor affecting the

amount of moose related damage (Angelstam et al., 2000). A study in a Newfoundland park suggested that moose have changed species composition and influenced forest succession (Conner et al., 2000). Hunting has been prohibited in the park since 1974, and natural predation by black bears has not had an impact on the moose population (Conner et al., 2000). Several studies have examined the interaction of moose and Balsam fir, a preferred winter food of moose. In order to successfully regenerate Balsam fir in Newfoundland, McLaren et al., (2000) had to maintain high hunter harvest until trees were > 3m in height. McLaren et al. (2000) concluded that since wolves were extirpated from Newfoundland, hunting has been the only option to reduce moose populations. McInnes et al., (1992) concluded that moose in the boreal forests of Michigan prevented saplings of preferred species from growing into the canopy. Further, it appeared that browsing by moose influenced the long-term structure and dynamics of the boreal forest ecosystem (McInnes et al., 1992).

Compared to the relatively simple ecosystem of the boreal forest, Massachusetts's forests are comprised of a diversity of hardwood and softwood species. There is substantial evidence linking overabundant deer populations in hardwood forests with negative environmental impacts (McShea et al., 1997). Recent research suggests the combined effect of deer and moose browsing delayed tree recruitment by three years (Faison, 2015). In addition, combined browsing reduced the abundance of herbs and shrubs (Faison, 2015). If moose populations continue to expand, the potential exists for moose to impact forest ecosystem structure and function. Localized browsing damage has already anecdotally been noted, particularly during winter weather when moose mobility becomes hampered and browse pressure becomes locally intense.

Monitoring Moose Populations

Because moose populations continue to persist in Massachusetts and relatively little is known about the potential impacts of moose on forest ecosystems, it is important to monitor moose populations over time to gather as much information as possible. DWSP has taken an active role in a variety of moose research or moose related topics, including:

1. DWSP has conducted a moose monitoring program since 2002 on the Ware River watershed. Permanent plots are visited each spring to try and locate moose sign. The presence or absence of recent moose sign provides an estimate or relative abundance of moose in the Ware River Watershed.
2. DWSP helped fund a cooperative study of moose in Massachusetts. The study, being conducted by UMass and the USGS Massachusetts Cooperative Fish & Wildlife Research Unit, tagged several moose tagged with GPS collars to closely follow their movements. In addition, moose and deer exclosures were erected in 2010 to study the effects of herbivore (moose only vs. moose and deer) browsing on tree regeneration and growth.

3. An aerial infra-red survey of Quabbin Reservation was conducted during the spring of 2007 to identify deer and moose. The survey produced a known minimum number of animals during one point in time. While the technology seemed promising, time constraints prevented the contractor from adequately completing the survey.
4. DWSP staff have provided testimony at Senate sub-committee meetings discussing the potential impacts of moose on the landscape and encouraging legislators to modify existing laws to allow moose to become a regulated game species.
5. Hunters in the Quabbin deer hunt have been asked to document moose sightings since 2006. Hunters who see moose during the hunt fill out a survey card and report their sightings to DWSP biologists to record on a topographic map. Sightings are used to estimate minimum population estimates. Surveys will continue during future Quabbin hunts.
6. DWSP conducts annual moose pellet surveys to estimate moose (and deer) densities on various sections of each watershed.

4.4.3 Protection of and Management for Biodiversity

Introduction

Biodiversity can be defined as the diversity of life in all its forms and at all levels of organization (Hunter, 1999). This definition encourages one to look beyond simple species diversity and include genetic and ecosystem diversity as well. Setting management goals for maintaining biodiversity is inherently difficult for a variety of reasons. In most cases, natural resource managers are responsible for managing biodiversity without a complete understanding of all the elements of biodiversity that may exist. For example, approximately 1.7 million species have been described globally, although estimates of the total number of species range from 10-100 million (Hunter, 1999).

The most critical component to any attempt to incorporate biodiversity into management activities is the need for a large-scale perspective. Management decisions must be made with a landscape, watershed, or larger regional perspective. Current DWSP management activities incorporate a multitude of specific activities that maintain or enhance biodiversity at the micro or stand level (e.g., saving wildlife trees, buffering vernal pools, etc.). Taking the large-scale perspective, Hunter (1999) describes only two real goals when planning for biodiversity:

1. Maintain the biodiversity of ecosystems that are in a reasonably natural condition.

2. Restore the biodiversity of ecosystems that have been degraded.

DWSP's goals for biodiversity focus on either maintaining or enhancing natural ecosystems across the watershed. DWSP recognizes that its greatest contribution to regional biodiversity is

protecting large areas of land from development and maintaining most of those lands in forest cover. DWSP's primary management treatment on these lands is creating forest openings to stimulate regeneration and diversify species. These activities maintain forest cover while mimicking disturbances that occur naturally.

DWSP will also incorporate other management techniques to try and create or maintain a broader range of habitat conditions in order to provide habitat for a range of indigenous species, when possible and feasible. For example, creating or maintaining early successional forested and non-forested habitat is critical to a variety of species that require specific conditions that are only provided in these habitats. In addition, DWSP recognizes the importance of providing for the unique ecological relationships that can develop in areas of unharvested forest either as designated or de facto reserves. Finally, identifying and providing habitat for the protection of uncommon and rare flora and fauna and stemming the spread of non-native invasive species are also important aspects of DWSP's biodiversity protection strategy.

Protection of Rare and Endangered Species

In order to ensure that land management activities do not disrupt or destroy listed species or their habitats, it is a DWSP objective to develop a more complete and current species occurrence database. DWSP's Natural Resources Section keeps records of listed plant and animal species on DWSP land that were discovered by in-house personnel or passed along by other professionals or the public. The MA Natural Heritage and Endangered Species program (NHESP) maintains more complete and detailed databases of listed species. Timber harvesting carried out by DWSP is reviewed by a Service Forester, who passes the cutting plan to NHESP when the harvesting map intersects a mapped Priority Habitat or Estimated Habitat for rare species (NHESP, 2006). NHESP sets restrictions on the harvesting activity if necessary to protect the species of concern.

DWSP property is inhabited by a number of state-listed vertebrate species. Rare species surveys often (and logically) focus on lands that are most actively threatened by development, rather than on large protected public holdings. DWSP conducts general and some targeted surveys that discover new populations of listed species (plant and animal), but it is likely that there are undiscovered populations of rare and endangered species on DWSP property. Although land protection is the most critical factor for their survival, DWSP recognizes the value in knowing where these species are located, in order to set priorities for specific protection measures and to guide management activities in or near critical habitats.

4.4.4 Active Management to Enhance Habitat for Selected Wildlife Species

Examples of DWSP Active Habitat Enhancement for Wildlife

- Support habitat for bald eagle breeding.
- Construct and deploy floating cedar rafts for loon nesting.
- Provide nest boxes or structures for owls, eagles, or other birds of prey.
- Maintain open sunny conditions over known snake hibernacula.
- Erect summer roosting bat boxes.

Some species may be helped by adequate habitat protection, but still need additional assistance to successfully breed. In these cases, when personnel and resources allow, DWSP may provide the added breeding structures or conditions.

Bald Eagles

Quabbin Reservoir has played a critical role in the recovery and continued success of bald eagles in Massachusetts. From 1982 to 1988, 41 bald eagle chicks from Michigan and Canada were transported to Quabbin Reservoir and "hacked" or raised in artificial nesting platforms without human association. The efforts paid off in 1989 when two pairs at Quabbin successfully hatched chicks.

A bald eagle nesting on Wachusett Reservoir

Eagles have bred successfully at Quabbin Reservoir each year since, and anywhere from 9-12 pairs may breed annually. An additional pair has bred intermittently on Wachusett Reservoir since 2007. Quabbin and Wachusett also serve as important wintering areas for both resident and non-resident bald eagles. Because of their large size, Quabbin and Wachusett are often the last bodies of water in the state to freeze, providing open water habitat for eagles well into the winter. Annual mid-winter eagle counts were conducted in Massachusetts from 1986-2012 along two standardized routes (Quabbin Reservoir and Assawompsett Pond). Two additional routes (Connecticut River and Merrimack River) were

added in 1995. Over that period, Quabbin Reservoir has consistently attracted more wintering eagles than any other area in the state. In fact, the eagle count at Quabbin Reservoir has accounted for 41-97% of the total number of eagles seen in Massachusetts during the annual survey.

The bald eagle continues to recover on a national level. In 1995, the federal status of the bald eagle was changed from Endangered to Threatened. In June of 2007, the federal government removed the bald eagle from the endangered species list. It still has federal protection through the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. Its status in Massachusetts remains endangered. As a result, continued effort is made by DWSP to ensure its existence on the Reservoirs. In cooperation with MassWildlife, buoys are placed in the water near active eagle nests at Quabbin to exclude fishermen and boaters from approaching too close. Each spring active nests on DWSP reservoirs are visited and eagle chicks are leg-banded, blood is drawn, and overall health is recorded. Leg bands provide critical survival, dispersal, and breeding information.

Finally, special attention is given to shoreline nesting and roosting habitat. When forestry operations are conducted along the reservoir's shoreline, super-canopy trees are selectively saved because these are favored by nesting eagles. In addition, other high quality potential nest trees, particularly hardwood trees with 3-pronged forks or conifer trees with a "bowl" shape near the top are saved. Lastly, consideration is given to thinning around these quality trees to ensure continued growth and allow for easy flight paths in and out of the tree.

Common Loons

There is little evidence of nesting loons in Massachusetts during the first half of the 20th century. Between 1940 and 1970 there are sporadic reports of nesting at Quabbin Reservoir, including one report in 1943 and another in 1959. Loons have nested annually at Quabbin Reservoir since 1975, and have nested at Wachusett Reservoir since the early 1980s. Currently, Quabbin and Wachusett Reservoirs host the largest number of breeding pairs of any water bodies in the state. During the 2016 nesting season, 22 pairs were present on Quabbin and five pairs on Wachusett. In addition, a pair was observed on Hycrest Reservoir in Princeton. In total, Seventeen pairs successfully nested and hatched 17 chicks (12 survived to fledging).

A common loon constructing a nest on Quabbin Reservoir

Loons prefer to nest on islands with sandy shores, low lying vegetation, and a shallow approach that makes it easier to travel to and from the nest. Most loon territories on DWSP reservoirs have at least one potential nesting island. However, because Quabbin and Wachusett Reservoirs are water supply reservoirs, water levels can fluctuate greatly depending on precipitation and consumer use. While loons can tolerate some fluctuation in water levels, increases of more than 6 inches or drops of more than 12 inches typically mean nest flooding or abandonment, respectively. Reservoir water levels cannot be specifically controlled during the loon nesting season. Therefore, in order to overcome potential water level problems, DWSP utilizes artificial nesting rafts.

These loon rafts are constructed of dried cedar logs, wire mesh, and a camouflage canopy. Rafts are loaded with vegetation and anchored in the loon's territory each spring. During late summer, rafts are towed to shore, propped up, and stored for the winter. There are currently 10 rafts in 10 different loon territories at Quabbin Reservoir, while 8 rafts are deployed at Wachusett Reservoir. Rafts allow nesting loons to escape fluctuating water levels. While rafts can increase loon productivity, they do not always succeed in attracting the nesting pair. There are several loon pairs that have a raft in their territory that still chose to nest on a natural island.

Nest Boxes for Land Birds

Some bird species may lack suitable nesting sites needed for successful breeding. While nest boxes are not a substitute for proper habitat management that provides natural snags and cavity trees, they can provide rare or uncommon species an opportunity to increase its local or regional population. As many as 50 species of North American birds are known to use nest boxes (Payne and Bryant, 1994). In particular, bluebirds, kestrels, and a variety of owls respond well to the presence of nest boxes.

There are approximately 50 nest boxes located in early successional non-forested habitat on DWSP lands. The boxes were originally erected to attract breeding bluebirds to the open habitats. While some boxes are maintained by volunteers, many boxes need repair or to be replaced. Because of limitations in staffing and time, little effort is made to adequately remove old nesting material, inspect the boxes during nesting season to remove unwanted species, or checked for insect infestations. A nest box for kestrels was recently erected on Wachusett Reservoir's North Dike and other nesting boxes may be erected to attract more kestrels and/or owls.

Snake Hibernacula

There are only a few known snake hibernaculum on DWSP lands. One is located in Hardwick in an old spoil pile that was created during the digging of a Quabbin Aqueduct vertical shaft. The spoil pile is essentially a huge mound of rocks and stones that provides small cavities and crevices where snakes can spend the winter. Snakes make their way through the crevices to areas below the frost line. Ideally, hibernacula face south to allow adequate sun exposure. Over time, this spoil pile grew vegetation, including large trees. The vegetation, particularly large conifer trees, can create too much shade and degrade the quality of the site.

DCR and MassWildlife staff removing vegetation from the Hardwick snake hibernaculum.

In order to restore the full potential of the hibernaculum in Hardwick, DWSP removed all vegetation from the spoil pile in 2014 to allow full sunlight to reach the ground. This vegetation removal is conducted periodically to maintain the habitat. In addition, vegetation on the spoil pile at Shaft 3 in Holden was removed recently as part of a timber sale. The conditions at Shaft 3 are similar to the Hardwick site and may be used by overwintering snakes.

Bats

A summer bat house on DWSP lands at Wachusett Reservoir.

There is growing national concern about the future of some bat species in North America. White-nose syndrome (WNS) is a disease that affects hibernating bats. Since its discovery in 2006, WNS has killed an estimated 6 million bats, and in some hibernacula, 90-100 percent of the bats have died. WNS can affect a number of different bat species found in Massachusetts, including Big brown bats, Eastern small-footed bats, Indiana bats, little brown bats, and Northern long-eared bats. Long-term research conducted at Quabbin Reservoir suggests that some of the once common species have experienced dramatic declines in population (Brooks, 2011). In response to these concerns, DWSP has built and deployed five summer bat boxes around the Wachusett Reservoir watershed, and two bat boxes at Quabbin Reservoir. These boxes are placed in open fields away from high public use areas and are used during the summer by both females rearing young and males.

Additionally, bats are surveyed during the maternal roosting season (June 1st-July 15th) using ultrasonic detectors. These acoustic surveys are based on the national survey developed by the US Army Engineer Research and Development Center. These surveys record and identify the echolocation calls of bats along 20-30 mile transects within the Wachusett, Ware and Quabbin watersheds. These surveys provide relative abundance, spatial distribution, and species presence/absence information for the bats found in Massachusetts.

In order to protect the listed Northern long-eared bat from potential impacts during timber harvests, DWSP biologists routinely consult with NHESP's database of bat hibernacula and maternity roost tree locations. If proposed operations overlap with these designated habitats, appropriate restrictions are implemented.

4.4.5 Recommended Forestry Practices for Conservation of Wildlife Habitat Features

DWSP foresters are concerned primarily about maintaining water quality standards and improving forest health and vigor. Monetary gain from forest resources is a minor consideration when planning management activities. A direct result of this flexibility is that it allows DWSP foresters to incorporate sound and beneficial wildlife management components into their forest cutting plans. High quality mast trees, active and potential den and nest trees, and critical habitat features have been, and continue to be, conserved and encouraged on DWSP property.

These following practices for wildlife habitat conservation are generally complementary to water quality protection standards. DWSP foresters incorporate these practices into the design of their forest management projects.

Vernal Pools

Vernal Pool Management Objectives: *DWSP will locate and verify vernal pools on its properties and maintain vernal pool depressions in an undisturbed state.*

***Recommended Practices*:**

- Seek additional input from NHESP when management activities are going to occur around a pool that contains state-listed species.
- Incorporate the latest vernal pool datalayer into land management activity plans.
- Continue to identify and confirm status of photo-interpreted vernal pools.

See Section 4.2.6 for DWSP management practices involving vernal pools.

Vernal pools are contained basin depressions with no permanent outlet that typically hold water for at least two to three months in the spring and summer. Vernal pools may or may not dry completely each year, but their periodic drying, shallow water, winter freezing, and low oxygen levels keep them free of fish populations.

Vernal pools provide unique habitat within the landscape in a variety of ways. Vernal pools represent specialized breeding habitat for species adapted to short hydro-periods and a fishless environment. Wood frogs, spotted salamanders, and fairy shrimp need vernal pools to sustain their populations. Vernal pools also serve as rare species habitat, particularly for the marbled and blue-spotted salamander. In addition to the pool itself, the upland area around the pool (above the spring high-water mark) is critical to support populations of amphibians that breed in vernal pools. This area provides important forest floor environment (shaded, moist, with abundant leaf litter and coarse woody debris cover) for amphibian dispersal, foraging, and hibernation during the time animals are not in the pool. As small wetlands interspersed within an upland landscape, vernal pools serve as biological links to other upland areas and stepping stones to larger wetlands (Calhoun and deMaynadier, 2004).

A classic vernal pool.

Because of their unique characteristics, vernal pools play a critical role in the life cycles of many amphibians, reptiles, and invertebrates. As a result, DWSP considers vernal pools to be important wildlife habitats. In fact, many state-listed species are associated with or dependent on vernal pools. Many vernal pools dry completely during the late summer and fall and can be difficult to identify. DWSP has made efforts to locate and identify vernal pools during the spring. Accurate and detailed records of located pools, including UTM coordinates and animal use, are stored in databases. In addition, the University of Massachusetts at Amherst identified hundreds of "potential" vernal pools on DWSP property through aerial photos. The potential pools have been digitized into GIS, and DWSP continues to ground-truth these pools in the field to ascertain their status for inclusion in land management planning.

Seeps

Seep Management Objectives: *DWSP will continue to protect seeps, springs, and surrounding soils.*

***Recommended Practices*:**

- Avoid leaving slash in woodland seeps or springs.
- Maintain mast-producing trees above and around seep.
- Remove conifer trees on south side of seep; retain conifers on north and west sides of seep.
- Schedule harvests to occur on frozen ground or during the driest conditions where seeps are present.
- Avoid running heavy equipment within 50 feet of the edge of a seep.
- Use seeps, when feasible, as the center for uncut patches to retain cavity trees, snags, and other wildlife features.
- Lay out skid trails and roads in stands to avoid seeps that are present and obvious.

Woodland seeps tend to be small (< ¼ acre) areas where ground water flows to the surface of the forest floor and saturates the soil. Seeps generally do not freeze during the winter and typically have little or no snow cover. Seeps often occur in natural depressions and may act as "seed traps" in which nuts, seeds, and fruits from surrounding trees and shrubs accumulate. This makes them important winter feeding sites for turkey, deer, and other wildlife.

Winter seep

Seeps also provide a seasonally important source of food and water for resident and migratory wildlife (Hobson et al., 1993). These areas tend to have early sources of green vegetation, such as skunk cabbage (*Symplocarpus foetidus*). This can be an important food source for black bears in the spring and early summer. Earthworms and insects at seeps attract early migrants such as robins and woodcock. Spring salamanders and hibernating frogs, which can attract skunks and raccoons, may also use seeps (DeGraaf et al., 2006).

Orchards

Orchard Management Objectives: DWSP will save scattered apple and other fruit trees when possible and increase their health and vigor when feasible.

***Recommended Practices*:**

- Continue to identify abandoned orchards and clusters of fruit trees.
- Save, if possible, all fruit trees when trees are being marked for harvest.
- Remove other trees and shrubs, when feasible, back to the drip line of the fruit tree.
- Remove large over-topping trees that are shading the fruit tree, on at least three sides, particularly to the south.
- Prune and fertilize fruit trees, when possible, at least every three years.

Several apple orchards, totaling approximately 20 acres, and a number of scattered fruit trees exist on DWSP property. One orchard (about 6.5 acres) in the Wachusett watershed is currently being maintained as an organic orchard through a long-term permit with local residents, while a second orchard (3.5 acres) has been abandoned for several years and is slowly being overwhelmed by poison ivy, shrubs and trees. Riis Hill in the Ware River watershed was recently reclaimed as an orchard and field.

A reclaimed apple orchard at Riis Hill, Ware River

Wild apple trees are one of the most valuable wildlife food species in the Northeast (Elliot, 1998; Tubbs et al., 1987; Hobson et al., 1993). Animals will utilize the bark, buds, leaves, fruit and twigs of an apple tree. Mice, voles, and rabbits will eat the bark while grouse and deer consume the buds. Deer and snowshoe hares eat the twigs and leaves and white-tailed deer, grouse, squirrels, fox, fisher, porcupine, and rabbits will eat apples or apple seeds (Oehler et al., 2006). Apple trees also provide nesting and perching habitat for bluebirds, flycatchers, robins, orioles, and sapsuckers (Elliot, 1998). Apple trees in abandoned orchards eventually become crowded by invading shrubs and over-topped by the encroaching forest. Prolonged crowding and shading will lead to decreased vigor and eventually death. Ensuring that the apple trees receive direct sunlight is critical to their productivity. Annual pruning is another way to boost health and encourage fruiting.

Wildlife Wintering Areas

Wildlife Wintering Area Management Objectives: *DWSP will maintain the functional value of wildlife wintering areas.*

***Recommended Practices*:**

- Identify and map all known or potential WWA using aerial photos, cover type maps, and field inspections.
- Schedule forest harvest operations, when feasible, during December-April within WWA so treetops are available for browse.
- Protect advanced conifer regeneration during timber harvesting.
- Cut stumps low to encourage vigorous sprouting.
- Conduct planned activities within WWA that ensure that at least 50% of the wintering area remains in closed canopy coniferous overstory to provide functional shelter.
- Avoid concentrating harvest in any one area of the WWA.
- Try to maintain travel corridors (unbroken, dense softwood cover 60-100 meters wide) that connect all areas of the WWA.

Winter deer yard

Wildlife wintering areas (WWA) provide shelter and food for animals during the winter months when cold temperatures, snow cover, and limited food resources create physiologically demanding conditions. One example of a WWA is the so-called "deer yard." These deer wintering areas (DWA) typically are in hemlock or pine stands where there is > 70 percent conifer crown closure. In more northern climates, winter deer yards may be comprised of dozens of deer. In Massachusetts, much smaller groups of deer may concentrate in these habitats. Deer typically move to these areas when snow depths are around 12". DWA provide reduced snow depths, higher nighttime temperatures, reduced wind, and greater relative humidity. These areas must not only provide adequate cover, but also a quality supply of deer food. Cedar, red and sugar maple, birch, and hemlock are preferred foods.

Another important wintering area is dense conifer cover (i.e., spruce stands) which provides increased thermal protection and wind cover for a variety of birds and mammals. For example, grouse will seek conifer stands for thermal protection when snow depths are < 8 inches.

The general guideline for wildlife wintering areas is to maintain as much overstory as possible, while providing for the establishment and continued growth of preferred browse and conifer tree species.

Mast

***Mast Management Objectives**: DWSP will continue to maintain and encourage a variety of mast-producing plants within the watershed*

***Recommended Practices*:**

- Continue to manage stands to contain multiple species of mast-producing trees and shrubs.
- Continue to retain productive beech, oak, and hickory trees when they occur as single or scattered trees in stands dominated by other species.
- Retain beech trees with smooth or blocky bark or raised lesions to promote resistance; remove standing trees with sunken cankers or dead patches to reduce sprouting of diseased individuals. Retain some large beech trees that have potential for good mast production, regardless of disease condition.
- Lay out skid trails and roads that avoid vigorous patches of understory shrubs.
- Save all hardwood mast trees, when practical, that occur in conifer plantations.

Mast is a critical component of quality wildlife habitat. Trees, shrubs, and vines produce fruits, nuts, and berries called mast. Mast can be hard (nuts, seeds) or soft (fruit, berries). Hard mast in particular contains more fat and protein than other plant foods and is actively sought by a variety of birds and mammals. Hard mast is particularly important in autumn as many animals prepare for winter. Bears, squirrels, raccoons, deer, and turkey will fatten up on acorns, beechnuts, and hickory nuts. Resident songbirds such as nuthatches, chickadees, and blue jays rely on mast during winter when other food is scarce. Migrating birds will often rely on fruits and berries during migratory stops to replenish energy.

Although all trees and shrubs are defined as mast producers, some species are more important to wildlife. The value of mast to wildlife differs with the size, palatability, accessibility, nutritional content, abundance, and production frequency. In general, oak, hickory, beech, walnut, butternut, cherry, ash, and conifers are the most important mast trees. In addition, birch, hazel, alder, and aspen are also important to some wildlife species.

Hard Mast

Red, white, and black oak and hickories are the most important source of mast on DWSP lands. Beech comprise a relatively small (< 3%) component of the overstory. Oaks are probably the most important wildlife mast trees in the northeast. Acorns are eaten by over 100 species of birds and mammals (Healy, 1997b). The frequency and characteristics of oak production varies from species to species. Red oaks produce a good crop of acorns every 2-5 years, black oaks every 2-3 years, and white oaks every 4-10 years. Red and black oak acorns take two years to develop, while white oaks take only one year. Peak acorn production begins at around 25 years for red oaks, 40 years for white oaks, and 40-75 years for black oaks (Flatebo, 1999). White oak acorns contain less tannin and may be more palatable to wildlife.

Beech and hickory trees comprise a smaller component of DWSP's forests. Hickories are scattered around the watersheds, usually interspersed with oaks. They have good seed crops every 1-3 years and begin producing quality crops at 40 years. Hickory nuts have one of the highest fat contents of any mast. Beech trees occur irregularly across the watershed. The prevalence of beech bark disease and low market demand has shifted attention away from this species. However, beechnuts can be an important source of food for a variety of wildlife. Wild turkeys prefer beechnuts to all other mast (Williamson, undated).

The seeds of maples, birches, ashes, and conifers provide food for many birds and small mammals. Red squirrels rely heavily on conifer seeds and their populations will fluctuate in response to annual crops. Birches are an important mast producer because most of the seed crop is retained on the tree above the snow. Birds, including pine siskins and grouse, count on birch seeds for their winter diet. White and red pines are the most widely distributed conifers on DWSP lands. Mice, voles, grosbeaks, and finches are a few of the animals that utilize conifer mast. Chickadees and goldfinches prefer hemlock seeds.

Soft Mast

Raspberry

Black cherry trees comprise a relatively small percentage of DWSP's forest canopy. However, bears, small mammals, and over 20 bird species eat cherries (Flatebo, 1999). Pin and chokecherries are short-lived, but provide valuable fruit to wildlife. A variety of understory shrubs and trees produce soft mast. Blueberries, serviceberries, dogwoods, and viburnums are abundant. In addition, herbaceous plants such as blackberry, raspberry, wild strawberry, and partridgeberry, are utilized by many species of wildlife.

Wildlife Trees

Wildlife trees are often divided into two categories: snags and den trees. Snags are standing dead or partially dead trees at least 6" dbh and 20 feet in height (DeGraaf and Shigo, 1985). Den trees are live trees possessing a cavity large enough to serve as shelter for birds and mammals or a site to give birth and raise young. In general, den trees must be 15" or greater in dbh and have a minimum cavity opening of 4" in diameter (Blodgett, 1985). Over 50 species of northeastern birds and mammals utilize snag and den trees during part of their lives (Blodgett, 1985). Some uses of snags and den trees include cavity nest sites, nesting platforms, food cache, dwellings or dens, nesting under bark, overwintering sites, hunting and hawking perches, sources of feeding substrate, and roosting (Payne and Bryant, 1994).

Forestry operations most likely have the greatest potential impact on the number, type, and location of snag and den trees on DWSP properties. Thinnings, salvage, firewood and sawtimber cutting, and post-harvest windthrow can result in inadvertent wildlife (snag and den) tree losses. However, DWSP's forest management practices (and practitioners) are generally sensitive to

snag management. Single-tree or group selection harvest practices will have only slight to moderate adverse impacts on snag production and retention. Although it would be ideal to retain all wildlife trees, practical field applications often make that unlikely. DWSP's objective is to maintain an optimal number of snags and dens across the watershed (Table 4-20).

TABLE 4-20. OPTIMUM NUMBER OF SNAGS AND/OR DEN TREES PER ACRE BY HABITAT TYPE

	Forest Interior		Semi-open/Open	Wooded Watercourse
Tree dbh (in)	Dens	Snags	Dens[1]	Dens[1]
> 19	1	0	3	2
10-19	4	4	4	14
< 10	2	2	3	9

[1] Animals here need den trees because creating snags by deadening is not recommended in these land-use patterns.
Source: Payne and Bryant, 1994

Snags

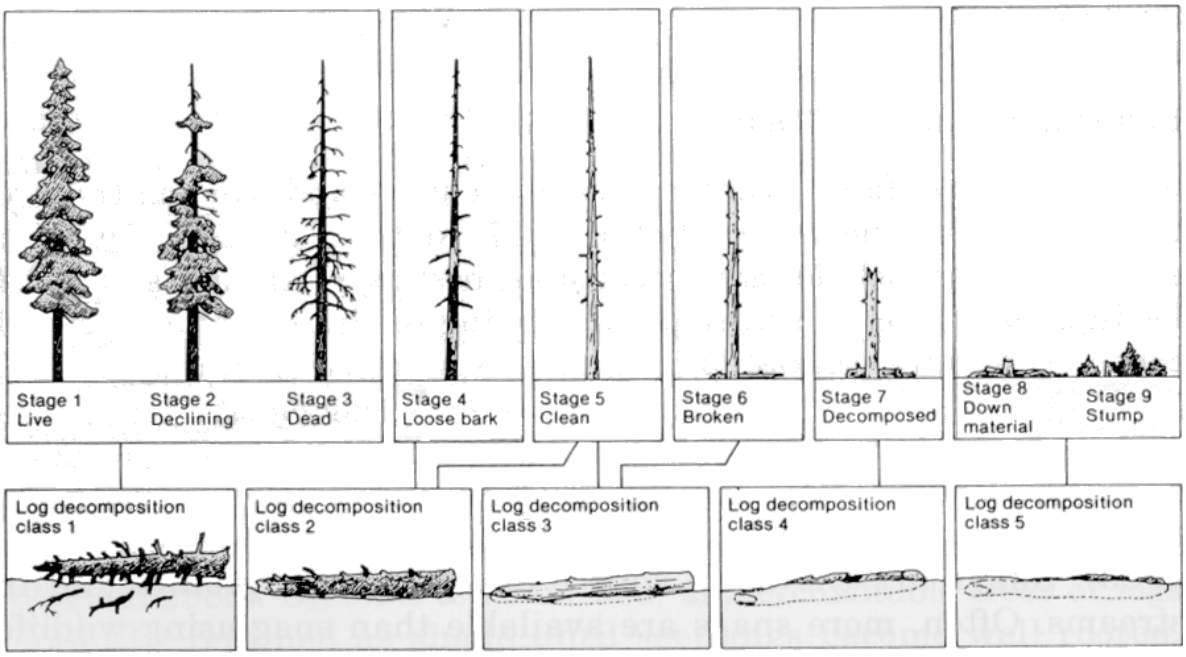
***Snag Management Objectives**: Forestry operations will continue to provide a supply of good to excellent quality snag trees, distributed over time and space in order to provide habitat to cavity dependent wildlife. In areas where good snag trees are lacking, retain poorer quality trees until better trees develop.*

***Recommended Practices*:**

- Leave all snags, when possible, within 100 feet of wetlands and riparian areas.
- Maintain a minimum of six snag trees per acre; four should be > 24" dbh and two < 24" dbh.
- Avoid disturbing snags from April to July to stay away from nesting birds and denning mammals.
- Leave snags in place as coarse woody debris instead of removing them if they are felled during management operations.
- Identify, when possible, current or potential snags through exterior signs such as fungal conks, butt rot, burls, cracks, wounds/scars from lightning, fire, or mechanical damage, woodpecker holes or cavities, or dead or broken limbs or tops so they can be retained.

As a tree dies, it progresses through several stages of decay (Figure 4-25) and is used by different wildlife at each stage (Payne and Bryant, 1994). Newly exposed bare branches provide excellent perches for woodland hawks (Cooper's, sharp-shinned), as well as flycatchers and phoebes. During the loose-bark stage, brown creepers and bats may nest or roost under the bark.

FIGURE 4-25. DECOMPOSITION STAGES OF SNAGS AND DOWNED LOGS



As a tree deteriorates, primary excavators (woodpeckers) begin to create cavities. Almost all northeastern woodpeckers excavate nest cavities in live or dead trees. Secondary nesters then use these cavities. Once trees have decayed to a point where there are no longer branches, it is classified as a snag (less than 20 feet tall it is a stub). Many insectivorous birds will use the snag for foraging. Finally the snag will either topple to the ground or wear to a stump. The fallen log provides habitat for carpenter ants. Amphibians and reptiles will live in and under the rotting wood; small mammals also utilize the downed logs. In addition to the stages of decay, other variables determine a particular snags value to specific wildlife species.

Snag tree.

Characteristics such as tree size, location, species, and how it was killed are important determinants of wildlife use (DeGraaf and Shigo, 1985). In general, when managing for wildlife trees, the rule is bigger is better. Large birds need large diameter trees to excavate nesting cavities. Smaller birds are able to find nest sites in large trees, but it does not work the other way. In addition, large snags usually stand longer than smaller ones. Emphasis is often placed on managing for viable woodpecker populations because their success will provide enough nesting sites for secondary cavity nesters. Table 4-21 provides the number of cavity trees necessary to sustain the hypothetical maximum populations of nine woodpecker species found in New England.

TABLE 4-21. NUMBER OF CAVITY TREES NEEDED TO SUSTAIN NEW ENGLAND WOODPECKERS

Species	Territory Size (Acres)	Average nest tree[1] DBH (in.)	Average nest tree[1] Height (ft.)	(A) Cavity trees used, minimum (N)	(B) Pairs/100 acres, maximum (N)	(C) Cavity trees needed per 100 acres[2] (A x B) (N)
Red-headed woodpecker	10	20	40	2	10	20
Red-bellied woodpecker	15	18	40	4	6.3	25
Yellow-bellied sapsucker	10	12	30	1	10	10
Downy woodpecker	10	8	20	4	10	40
Hairy woodpecker	20	12	30	4	5	20
Three-toed woodpecker	75	14	30	4	1.3	5
Black-backed woodpecker	75	15	30	4	1.3	5
Northern flicker	40	15	30	2	2.5	5
Pileated woodpecker	175	22	60	4	0.6	2.4

Source: DeGraaf and Shigo, 1985. [1] Larger trees may be substituted for smaller trees. [2] Number of cavity trees needed to sustain population at hypothetical maximum level.

Den Trees

***Den Tree Management Objectives**: DWSP will provide a continuing supply of good to excellent quality den trees, distributed over time and space in order to provide habitat to cavity dependent wildlife. In areas where good den trees are lacking, poorer quality trees will be retained until better trees develop.*

***Recommended Practices*:**

- Retain as many live trees with existing cavities and large unmarketable trees as possible.
- When possible, retain all trees > 29" dbh or at a minimum two or more trees > 29" dbh per 100 acres.
- Leave at least one tree 15-29" dbh per acre.
- Leave at least one tree per acre that shows potential for developing into a den tree (broken top, large broken limbs, fire scar); oaks, sugar maples, ash, and hemlock are good trees to select because they readily form natural cavities or are long-lived.
- Leave all dens trees within 100 feet of a wetland or riparian area.

Den trees are living, hollow trees used by a variety of mammals including mice, raccoons, squirrels, and bears. In general, there are usually fewer den trees available in an area than could be used by wildlife because large (> 15" dbh) rough or rotten trees are relatively rare. Unlike cavity trees, which have central columns of decay, den trees are hollow or have large hollow limbs, but are still alive and vigorous. Den trees usually have easily visible openings in the sound wood. Some heavily used den trees (e.g., by raccoons) are hardwoods with the top

Potential den tree

snapped off. Den trees usually have low commercial value, but their value to wildlife is extremely high and long lasting. It may take 100 years to develop large den trees, and once developed some trees (oaks, sugar maple) can live for several hundred years (DeGraaf and Shigo, 1985; Tubbs et al., 1987). Once den trees die and fall to the ground, the remnant hollow log may last 25 years, providing breeding habitat for redback salamanders and ringneck snakes.

Live cavity trees can often be identified and reserved during silvicultural operations. Key characteristics of valuable den trees include: a healthy crown with strong survival potential, a cavity entrance that is protected from rain, evidence of current use such as gnawing around the entrance or claw marks, and multiple benefits such as more than one den and mast production (Healy et al., 1989).

Downed Woody Material

Downed Woody Material Management Objectives: *DWSP will continue to maintain a range of sizes and types of downed woody material and retain or provide downed woody material in sites where it is lacking.*

***Recommended Practices*:**

- Leave snags in place if they must be felled during management operations.
- Avoid damaging existing downed woody material during harvesting, particularly large (> 16" dbh) hollow logs and stumps.
- Leave, when possible, at least four logs of decomposition class 1 or 2, per acre; at least two of these logs should be > 12" dbh and > 6 feet long. Hollow butt sections of felled trees can be used (see Figure 4-18)
- Retain as many logs as possible of classes 3, 4, and 5 (see Figure 4-18).
- On slopes, orient logs along contours and place against stumps when possible.
- In full overstory removal, leave slash on at least 10% of the site in scattered piles or rows.
- Do not add debris to streams and avoid disturbing woody material already in stream.

Downed woody material refers to slash, logs, large and small limbs, stumps, and upturned tree roots that accumulate on the ground either naturally or through forestry operations. Downed woody debris provides food, cover, and nursery habitat for a range of flora, fauna, and fungi. Downed woody material provides critical wildlife habitat and is used for nesting, shelter, drumming, sunning, as a source and place to store food, and as natural bridges (Elliot, 1988). The specific value of downed woody debris depends on the physical distribution, amount, size, degree of decay, and orientation of debris relative to slope and exposure (Flatebo et al., 1999). Decaying logs also serve as nurse-trees for seedlings and colonization sites for fungi. Too much or too little downed woody material can be detrimental to wildlife. In general, it is best to retain or produce downed woody material that is distributed similarly to what would occur naturally as course woody debris in any given stand type (often random and clumped rather than evenly distributed).

Surveying downed woody material

Logs are generally considered to be the most valuable downed woody material because of their slow decay and longer persistence. Long logs > 16" (diameter at small end) are especially important wildlife habitat features. As logs age and decay their role as wildlife habitat shifts. Logs supported by branches provide shelter, feeding, and display sites for a variety of birds and mammals. As the log settles to the ground and continues to decompose it may be used by small mammals, snakes, toad, and salamanders for shelter, food, and travel. Large logs with hollow portions may be used as den sites by larger mammals.

Woodland Raptor Nests

Woodland Raptor Nest Management Objectives**:** *DWSP will maintain suitable nesting sites for woodland raptors across the landscape over time and will avoid disturbing nesting pairs of raptors. State-wide forestry Conservation Management Practices (CMPs) for bald eagles will be followed when appropriate.*

Recommended Practices:

- Contact DWSP's wildlife biologist when planning forest management activities in the vicinity of a bald eagle nest.
- Inspect mature white pine and hardwood trees for large stick nests when cruising timber. When possible, do not cut trees containing large stick nests and hardwoods with 3-pronged forks.
- Maintain an uncut buffer of at least 66 feet around active raptor nest trees and retain 65-85 percent canopy closure within 165 feet of large active stick nests in closed-canopy forests.
- Maintain an uncut buffer of at least 66 feet around nest tree if an active raptor nest is located before or during a scheduled harvest operation; do not harvest within 330 feet of the nest during April-June.
- Harvesting schedules and buffer zones may be relaxed if an active raptor nest can be positively identified as belonging to a common or tolerant species (e.g., red-tailed or broad-winged hawk).
- Retain several supercanopy pines near the reservoir shoreline as potential future nest trees for bald eagles.
- Follow appropriate snag tree management guidelines.

Eagles, hawks, owls, falcons, and vultures are known as raptors. There are 19 species of raptors that breed in New England. Seventeen of the 19 species are known or potential breeders on DWSP lands (Table 4-22).

Most raptors are predators and feed upon birds, mammals, fish, amphibians, insects, and snakes. While most raptors will eat a variety of animals, some species like the osprey have much narrower food requirements. Compared to other birds, raptors require relatively large home range (60-> 900 acres) in order to meet their food and nesting requirements (Flatebo et al., 1999). Raptor nests are widely dispersed across the landscape in a variety of habitats and forest conditions.

TABLE 4-22. ACTUAL AND POTENTIAL BREEDING RAPTORS ON DWSP LANDS

Species	Breeding Status	Nest Site Selection
Turkey vulture	Breeder	Rocky outcrops, ledges, cavities
Osprey	Potential breeder[1]	Stick nests in trees, snags, poles
Bald eagle[2]	Breeder	Stick nests in living trees
Northern harrier[2]	Potential breeder	On ground, over water
Sharp-shinned hawk[2]	Potential breeder	Stick nest on tree limb-usually conifers
Cooper's hawk	Potential breeder	Stick nest (may use old crow nest) on horizontal branch in hardwood or conifer
Northern goshawk	Breeder	Stick nest (used or new) in hardwood
Red-shouldered hawk	Breeder	Stick nest (new) in tall tree
Broad-winged hawk	Breeder	Stick nest in tall tree
Red-tailed hawk	Breeder	Stick nest in oak/white pine
American kestrel	Breeder	Cavity, nest box
Barn owl[2]	Potential breeder	Cavities, buildings, artificial
Screech owl	Breeder	Cavities and woodpecker holes (Pileated/Flicker)
Great-horned owl	Breeder	Cavities, old crow, hawk, or heron nests
Barred owl	Breeder	Large natural cavities or old bird nests
Long-eared owl[2]	Potential breeder	Old crow/hawk nest or natural cavity
Saw-whet owl	Breeder	Natural cavity or woodpecker hole

[*] Source: Adapted from DeGraaf and Rudis 1986

[1] Potential breeders are raptors not known to be currently breeding on DWSP lands, but capable of breeding there, given the bird's range and habitat requirements.

[2] Listed with the Massachusetts Natural Heritage and Endangered Species Program as an endangered, threatened or special concern species.

Bald eagle nest at Quabbin Reservoir

Some raptors will build a new nest each year within their territory, while other raptors will use the same nest for a number of years or claim the nest built by another species. Raptor nest trees must be large and strong enough to support nests ranging from 18" in diameter (broad-winged hawk) to over 3 feet (bald eagle, northern goshawk) (Flatebo et al., 1999). Large diameter broken stubs, closely spaced branches halfway up large white pines, and 3-pronged main forks of mature hardwoods are most frequently used by stick nest building raptors. By maintaining existing nests and identify potentially good future nest trees, an area's raptor population can be maintained over a long period.

Many raptors nest early in the year. By February-March, most great-horned owls and some red-tailed hawks and barred owls are incubating eggs. Most other raptors are incubating by May. Nesting raptors can be vulnerable to human disturbance. There is a wide range of tolerance depending on the species. Some intolerant species (bald eagles, goshawks) may abandon the nest during the early weeks of incubation. Repeated flushing of the female from the nest may also subject the eggs to fatal chilling or the young to predation.

Identifying active nests is critical to ensuring their protection and establishing a buffer zone to minimize disturbance. The easiest, and unfortunately most infrequent, way to detect active nests is to see birds in or around the nest. However, active nests can be identified when no birds are visible by looking for the following indicators:

- Prior to egg laying, some raptors decorate the nest with fresh branches, usually from a conifer.
- After hatching, whitewash (excrement), regurgitated pellets, and prey remains may be found on the ground near the nest tree.
- Raptor nests can be distinguished from squirrel nests by their shape and lack of leaves (squirrel nests are saucer-shaped and made mostly of leaves).

4.4.6 Gravel Access Roads: Assessment of Impacts to Wildlife

An extensive network of access roads is used by DWSP to remove wood, control fires, maintain watershed structures, and aid in navigation (see Section 4.1.10). DWSP roads within the watersheds include gravel secondary roads, and narrow, grassy woods trails. While roads are necessary to DWSP, they can also act as barriers to animal movements and may fragment the forest. DWSP's active forest management program requires harvest operations to occur every 15-30 years on most watershed lands. In addition, roads are utilized by wildlife, environmental quality, and Ranger staff. Each road may access many different areas, so there is likely a significant vehicle presence every few years on any given road.

The effect of forest roads on wildlife and biodiversity depends on the size, type and location of the road. The frequency with which a road is used and its proximity to other travel routes will also determine its impact. Roads effectively create an edge habitat that benefits some species, but has negative effects on species sensitive to disturbance or predators. Roads are often used by some wildlife species as travel lanes, but they may impede the movements of other species that require continuous vegetative cover.

Maintained gravel forest roads on DWSP property constitute a long standing and relatively permanent feature in the habitat structure of the area. Because traffic on DWSP roads, particularly at night, is minimal, there is little concern about direct mortality of wildlife populations. The more general concern is that a strip of dirt or gravel under an open canopy can serve as a physical or psychological barrier to animal movements (DeMaynadier and Hunter,

2000). Studies have documented this barrier affect for small mammals and invertebrates (see DeMaynadier and Hunter, 2000). In addition, DeMaynadier and Hunter (2000) documented the barrier effect of forest roads on salamanders.

4.4.7 Planned Watershed Management Activities: Assessment of Impacts to Wildlife

The management activities described in this plan will have various impacts on the wildlife communities found on DWSP lands. Most are a result of habitat changes or modifications. The forest management approach described in this plan has landscape level effects, although individual changes at any given time are temporary, very localized, and small. While the management techniques used to reach the forest management goals will not be as dramatic as historic events (1938 hurricane, flooding of the reservoirs), it is important to understand how these plans will impact the habitat and wildlife communities on the watersheds.

The amount and types of habitat in Massachusetts has been significantly transformed twice since early colonial times. Once covered by primeval forest, a majority of the land in the watersheds was cleared for agriculture. This trend persisted for decades, until about 1840 when 70 percent of the upland was in pasture, farm crops, orchards, or buildings. The next 100 years was another period of change as most of the farmland was abandoned and grew back into forest. Dramatic changes in the wildlife community accompanied these broad landscape changes. Some species thrived and expanded their range, while others were temporarily extirpated or became extinct. When agriculture dominated the landscape, species such as black bears, wild turkeys, and white-tailed deer were gone from most of their former range. Bluebirds were abundant during the agricultural period, but are now less common breeders. Other open habitat species (e.g., bobolinks, vesper sparrows, and golden-winged warblers) are declining as available habitat shrinks. Today, most of the undeveloped land in the watershed system is forested.

These regional land use changes were the most significant factors shaping today's wildlife community. Other large-scale disturbances to the landscape, such as the flooding for the reservoirs, the 1938 hurricane, and periodic fires, have further shaped the wildlife community. The current trend of human population expansion in parts of the Wachusett Reservoir and Ware River watersheds has meant the loss of more and more open space to residential housing. This suburban/ex-urban type of environment generates its own unique wildlife community.

While DWSP's management activities will affect habitat and wildlife species composition on a small scale, they do not match the impacts from the landscape level activities described above. DWSP manages, for the most part, diverse forests in various age classes. Future management will focus on encouraging regeneration and improving the health and vigor of the forest.

General Impacts

The number of species that occupy a given forested habitat is in large part a function of both vertical and horizontal diversity across the watershed. Horizontal diversity provided by open and wetland habitats contributes greatly to the overall forest community because these areas contain species not associated with closed canopy forested conditions and provide food, water, and cover opportunities not available in only forested areas. Open and early successional habitat is maintained on a small percentage of DWSP's land, primarily focused on areas appropriate for even-age silviculture, fields managed for wildlife, administrative open areas associated with developed areas (e.g., facilities with extensive lawn, dikes), and old beaver impoundments. Wildlife communities associated with forests and forest edges should benefit the most from DWSP's management plan. Species requiring early successional or open habitat will benefit in those areas where that type of habitat exists.

Specific Impacts

Cutting to Establish Regeneration or Planting

As with most types of active management, this type of silviculture involves trade-offs. Thinning the canopy will stimulate the understory and increase vertical diversity within the stand. This should benefit species requiring a developed understory (e.g., Eastern towhee, snowshoe hare), but will negatively impact species requiring older, intact forest canopies (e.g., Northern goshawk, pileated woodpecker). Disturbing the forest floor could have a negative impact on those species living on the forest floor, or living in the leaf litter or shallow soil (e.g., ovenbird, red-backed voles, and spotted salamanders). However, this impact is temporary, and the resultant increase in density of ground cover is a benefit to these species. Overall, forest wildlife diversity within these stands should increase as vertical structure and tree diversity increases, although individual wildlife species may either benefit or decline from the alteration.

Planting desired species within a stand (e.g., conifers) can increase the species diversity of the area and provide understory cover more quickly than the pace of natural regeneration.

Release of Regeneration

Single-tree Selection

Single-tree selection essentially maintains an intact forest canopy and is well suited to regenerating shade-tolerant tree species. Those species requiring continuous forest canopy and large tracts of unbroken forest habitat are favored by single-tree selection because the structure of the habitat is only minimally altered with each cut. Many Neotropical migratory forest songbirds (forest warblers, wood thrush, and ovenbird) are edge sensitive species that require unbroken tracts of forest to successfully breed. When single trees are removed from the forest, no edge or transition habitat is created and the forest interior is maintained. While this will

benefit these edge sensitive species, those species (ruffed grouse, white-tailed deer, Eastern towhee, chestnut-sided warbler) that rely on edge habitats will be limited to areas where it exists.

Irregular Group Shelterwood and Patch Cuts

A good deal of attention has been focused on the potential problems of forest fragmentation in the northeast. Most of this effort has centered on Neotropical migrants and the continued decline of some species of forest interior birds. Area-sensitive songbirds do not reproduce well along edge habitats (Faaborg et al., 1993). In most cases, when trying to conserve edge-sensitive species, it is recommended that extensive areas of contiguous forest are maintained and the amount of edge habitat minimized.

There are several large blocks of contiguous forest in the watershed system that support interior forest conditions. These areas have been identified by The Massachusetts Division of Fisheries and Wildlife interior forest GIS dataset. This dataset identifies extensively forested portions (minimum 50 acres) of the Massachusetts landscape where forest cover is relatively un-fragmented by human development. DWSP controls approximately 84,120 acres (56,920 at Quabbin, 15,200 at Ware River, 7,900 at Wachusett, and 4,100 at Sudbury) of interior forest as identified by MassWildlife. These areas support edge-sensitive species that prefer interior forest (e.g., Black-throated Blue Warbler, Acadian Flycatcher, Northern Parula, and Blue-headed Vireo).

It is hard to speculate how much impact DWSP land management activities will have on edge-sensitive species because DWSP's lands represent a mosaic of habitat types within a fragmented landscape. A timber harvest on DWSP's forested land is not analogous to the fragmentation that would occur if the same land were developed for residential housing or agriculture. Harvested areas are temporary and still remain in the same land use (in this case forest); only the age class is changed. The area is allowed to regenerate into mature forest. However, since DWSP proposes to use irregular group shelterwood and patch harvesting to treat a majority of stands, it is prudent to consider the impact of this practice on wildlife communities. Any management decision will positively affect some species and adversely affect others (Hagan et al., 1997).

The most influential factor negatively associated with this type of silviculture would be the introduction of edge effects. Many studies have documented the reduced nesting success of songbirds near forest edges when compared to the interior (Wilcove, 1985, Paton, 1994). This reduced success is a result of nest predators (blue jays, chipmunks, raccoons, crows) and/or nest parasites (brown-headed cowbird). In addition, rates of cowbird parasitism increase near openings within large forest tracts (Wilcove, 1985, Paton, 1994).

Initially it might appear that edge effects would be limited to isolated woodlots surrounded by houses or barren land. Unfortunately, edge effects are applicable to forest ecosystems because small openings within forests create edges. Although most changes in vegetation caused by group selection extend only 30-100 feet into the surrounding forest, the increases in nest

predation and parasitism may extend as far as 1,000-2,000 feet into the forest. Therefore a small number of openings scattered in a larger block of forest could impact the amount of habitat considered interior forest. However, these edge effects are relatively short-lived as the young forest grows and matures. DWSP will continue to monitor the effects of its forest management activities using long-term wildlife monitoring plots.

Adding to the problem is the nature of some of DWSP's watersheds. Wachusett and Sudbury watersheds are largely fragmented. DWSP land often abuts residential/commercial land, other non-forested areas, or small woodlots where large numbers of nest predators potentially live and reproduce (these areas support domestic cats, raccoons, blue jays, etc.). Therefore, predation rates could very likely be higher in the adjacent forest openings.

Impacts of fragmentation on mammals are less well known. It is likely that species most sensitive to habitat fragmentation were extirpated long before they could be studied. Mountain lions, wolves, elk, and woodland bison have been gone from the watershed system for decades. As a result, those mammals left within the watersheds are the ones adapted to surviving in fragmented, human-altered landscapes. It is likely that the main limiting factor on mammal populations is human disturbance and not the impacts of managed forests.

Openings within forests do benefit certain wildlife species. Welsh and Healy (1993) found that bird diversity and overall abundance were higher in managed rather than unmanaged forests. Another study suggests that landscape disturbance had little or no negative impact on bird abundance, and that disturbance benefited many species, some of which are considered forest interior breeders (Thompson et al., 1992). Wild turkey, ruffed grouse, Eastern towhee, red-shouldered hawk, and white-tailed deer will benefit from the proposed openings. Forest openings will allow for denser ground cover, increased light, and a more open canopy.

Full Overstory Removals

Full overstory removals in plantations produce the greatest immediate change in habitat. Full overstory removal is a silvicultural technique associated usually with even-aged management, and can cause both positive and negative impacts to wildlife. In general, removing the overstory will provide early successional habitat that is utilized by a variety of species (see Section 4.3.3). Early successional species will particularly benefit from this management because the larger stand size will attract and sustain larger populations of those species. Those species requiring continuous forest canopy are impacted by these treatments. In addition, species utilizing conifer-dominated habitat (red squirrels, some Neotropical migrants, nesting raptors) may be displaced by the removal of conifer plantations.

Riparian Zone Management

As part of normal forest management operations, DWSP may undertake limited non-harvest cutting of trees within riparian filters and wetlands (where physical and regulatory restrictions preclude the use of heavy equipment) to increase light and stimulate regeneration. Cut trees

would be left in place within the riparian area, cut so as to lay along the ground surface generally parallel to the stream. This increase in the availability of course woody debris would provide additional cover and nutrients for forest floor wildlife. The additional light would allow for a greater diversity of understory trees and ground cover. This would benefit wildlife species that benefit from a denser understory layer of vegetation.

Removing a large number of deciduous trees along the riparian zone could have potential negative impacts on species requiring large expanses of continuous wooded streams. However, if single trees or small groups are removed, these impacts would likely be minimal. On streams where there is almost continuous conifer (e.g., hemlock) cover, the understory characteristically has little regeneration. This habitat type is uncommon on the watershed and provides unique habitat for a variety of wildlife. When cutting trees within the riparian area foresters will try to save cavity or potential cavity trees, which are extremely valuable to a range of wildlife species.

A final consideration regarding this management technique would be to recognize that stimulating regeneration and new growth along riparian wetlands might be beneficial to beaver populations (see Section 4.4.2). Availability of a winter food supply is an important factor affecting beaver distribution in areas where stable water levels are possible. While it is DWSP's objective to establish a diverse regeneration layer in the riparian forest to provide optimal protection for the water supply, this new growth may stimulate beaver populations, requiring more frequent beaver control efforts within the Pathogen Control Zone.

4.4.8 Considerations During Timber Marking, Harvesting, and Other Land Management Activities

Land management activities conducted at any time of the year have the potential to disrupt or impact common and rare wildlife species. While careful planning and preparation can mitigate some of the potentially negative impacts on wildlife resources, other specific impacts or events may not be discovered until operations begin in the field. Locations of active raptor nests, quality den and snag trees, and seeps might only be discovered when foresters begin marking individual trees in a lot. It is during these detailed lot inspections that some of the specific wildlife habitat management recommendations can be implemented. In addition, broader considerations such as timing of operations, harvesting techniques, record keeping, and other miscellaneous considerations can be addressed.

Natural Heritage and Endangered Species Program Massachusetts Forestry Conservation Management Practices (CMPs) for Listed Wildlife Species

The Natural Heritage & Endangered Species Program (NHESP), in collaboration with DCR's Division of Water Supply Protection, DCR's Bureau of Forestry, and the Massachusetts Division of Fisheries and Wildlife's Forestry Program, prepared wildlife conservation management practices (CMP) documents for certain rare species that are listed and protected by the Massachusetts Endangered Species Act (MESA). These CMP documents provide information on the rare species' life history and habitat requirements and make scientifically-based recommendations on how to minimize potential adverse impacts of forestry activities. The goal of these recommendations is to protect rare species populations and maintain rare species habitats for long-term viability while maintaining the opportunity for the sustainable management of the state's forests (www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/regulatory-review/forestry-rare-species-review/forestry-cmps-for-rare-species.html).

The NHESP uses these recommendations in its review of specific Forest Cutting Plans. The existence of the CMPs improves the speed and consistency of the NHESP's reviews of Forest Cutting Plans, makes the outcome of the Cutting Plan reviews more predictable to the forestry community, and allows DWSP foresters to anticipate various recommendations and incorporate those into operational planning and Cutting Plan preparation. These recommendations do not supersede any law, regulation, or official policy of this or any other agency. Rather, these guidelines are intended to complement existing regulatory review processes by providing up-to-date, scientifically-based management recommendations for forestry activities as they impact specific species.

Although the best available scientific information, researchers, and managers were consulted in preparing these documents, it is expected that new information will arise about the species' requirements and their response to habitat modifications. With the recognition that both forestry practices and rare species conservation require adaptive management it is acknowledged that the recommendations in these documents may need to be updated and revised in the future.

Timing of Operations

The timing of land management activities can have a dramatic impact on wildlife species. Activities that occur during the breeding season (late spring-summer) can impact the reproductive success or survival of many wildlife species. Some species (bald eagle, great-blue heron, and coyote) are extremely sensitive to human disturbance and may abandon or forgo breeding when repeatedly disturbed. Fortunately, some sensitive species can be easily identified or have known nesting sites. Great-blue herons nest in visible colonies, usually in dead snags over water. Bald eagles build large stick nests that are easily seen and may be used for many years. However, for most other species their nest, burrow, or den is well hidden and would not be discovered until an operation had already begun. When an uncommon or rare species is

discovered during forest management operations (either by the logger or forester), the following procedure is followed:

1. DWSP personnel will notify the Natural Resource Section when land management activities have clearly disrupted a species' breeding efforts.
2. The Natural Resource Section will assess/determine the nature of the nesting/denning activities, the conservation status of the species involved, stage of breeding (courtship, incubation, brooding), and initial response to the disturbance.
3. The Natural Resource Section will determine what options will be used to mitigate and avoid further disturbance during the remainder of the breeding season.

When land management activities can be conducted during less sensitive times, efforts are made to accommodate wildlife species. Maintenance (mowing, burning, etc.) of fields and open areas are done in early spring (March/April) or after August 1 to avoid destroying nesting birds and mammals. No activity occurs in or near seeps during winter. In some cases, activity during certain times of the year is preferred. Working around vernal pools is often best during winter when frozen/dry conditions minimize rutting and disrupting the forest floor. Further, logging during the fall and winter usually has minimal impact on most wildlife species and may actually benefit some animals by providing additional browse and cover.

Because impacts cannot be avoided everywhere, DWSP will:

- Continue to gather data on critical and sensitive wildlife and their habitats on the watershed.
- Assess the potential impacts of the timing and location of operations on a case-by-case basis to avoid impacting special concern species.
- Shift, when feasible, the timing or location of an operation to avoid these impacts.

Harvest Planning Considerations

Harvesting operations, with proper planning, can be conducted while still maintaining snags, den trees, and mast producing trees within the opening. In larger, mostly forested habitats it is important to mimic natural disturbances. Wherever possible, create an irregular border that follows natural landscape features. In small harvests close to other open land, approximately circular openings (low perimeter:area ratio) will minimize the amount of edge, possibly discouraging edge predators and nest parasites (Hunter, 1999).

Landings and Trails

Certain design features are incorporated to minimize wildlife impacts when forwarder roads, skid trails, and landings are being planned.

- Avoid, if possible, vigorous patches of native shrubs by forwarder roads and skid trails.
- Keep roads/trails as narrow as possible.
- Seed abandoned logging roads, skid trails, and landing sites, when possible, with a native grass-legume mixture.

Value of Malformed Trees and Species Mixes

DWSP's silvicultural practices include cutting trees with weak crown forms that are more susceptible to damage. Some of these trees have wildlife value, and DWSP foresters typically leave some of these trees uncut. For example, trees growing on an angle ("hurricane-tipped") serve as travel routes for arboreal mammals from the ground to the forest canopy. In addition, older trees with large stocky limbs often have protected crotches that are used by nesting birds and mammals. These trees also typically have a high potential for cavity formation. While it is not necessary to maintain all occurrences of these trees, DWSP foresters recognize the importance of retaining some during harvesting operations.

Particular combinations of trees species are also valuable to wildlife. Mature oak trees within hemlock or other conifer stands provide food resources during winter. Small pockets of hemlock within hardwood stands can serve as significant wildlife cover. Both of these habitat conditions should receive special treatment when feasible.

Communication and Record Keeping

DWSP foresters, Rangers, and other natural resource managers spend a large amount of time walking, observing, and assessing DWSP lands, and often observe significant wildlife or important wildlife habitats. Because of the size of the watershed, these anecdotal observations are a critical source of biological information, and may be key to avoiding or mitigating potential wildlife impacts of future land management activities. Good communication between field staff and the Wildlife Biologists in the Natural Resource Section ensure records are routinely maintained and updated.

4.5 Protection of Cultural Resources

4.5.1 Goals

- *Identify significant cultural resources on watershed lands.*
- *Prevent degradation of cultural sites and resources.*

A well-built stone wall is a cultural resource found on DWSP lands.

Cultural resources are part of our collective heritage and human experience, and are often fragile and non-renewable. Preservation legislation, as well as DCR's Office of Cultural Resource's programs, are designed to ensure that future generations will have the opportunity to understand, appreciate, and learn about the past. DWSP is concerned with locating and assessing the condition of both historic and pre-Contact cultural resources, and generating plans for protecting those resources that are considered unique or are otherwise significant. DWSP's Cultural Resource Management Program is adapted for watershed purposes from a broader plan that was developed for the agency as a whole. The original plan was articulated in 1990 in the *Cultural Resource Management Plan: Volume One Management Policies, Operating Procedures & Organization,* by then Chief Archaeologist Thomas F. Mahlstedt.

Each of the four watersheds is rich in both pre-Contact (before European colonization) and historic (post-European colonization) resources. Accordingly, safeguards have been built into DWSP's land management program to protect cultural sites and artifacts, both through the review of proposed silvicultural projects to identify and mitigate possible impacts of management activities on pre-Contact resources, and through a program of proactive vegetative management around significant historical sites.

4.5.2 Review of Proposed Silvicultural Projects

Forest management activities can be detrimental to archaeological resources without appropriate controls. Modern harvesting methods employ a wide range of heavy machinery, some of which, because of weight distribution and/or tire characteristics, can do irreparable damage to pre-Contact sites. Skidding logs can further disturb the soil and cultural resources that may lie within it. Forest management operations also entail clearing areas for landings, turn-arounds, and access roads. Those archaeological sites that lie closest to the surface can be obliterated by such activities. It is these same types of sites – those that are the youngest in time (i.e., the Early, Middle, and Late Woodland) – that were most susceptible to destruction by the plow of the local farmer, and thus represent a relatively scarce and precious piece of the archaeological record.

The DCR Archaeologist is one of several specialists who review proposed silvicultural operations during the annual internal review process. The Archaeologist specifically evaluates and assesses the impacts that harvesting could potentially have on historic resources that are evident or pre-Contact resources that may exist at any given site.

Lot Proposal Stage and Archeological Review

The DWSP forester submits a detailed lot proposal form and 1:12,000 (or other appropriate) scale map for in-house review well in advance of any silviculture operation on a site. The proposal describes the purpose for prescribed silvicultural treatment for an individual lot. It contains detailed site-specific information, including all cultural resources known to the forester: foundations, cellar holes, walls, wells, dams, and pre-Contact sites. See Section 4.2.7 for a more complete discussion of the lot proposal review process.

Lot proposals and the associated maps provide the basis for impact assessment by the DCR Archaeologist. Site visits are sometimes required in order to assess microenvironment and features not reflected on the maps of the lot. The primary analytical tool, developed by a DCR Archeologist, is an unpublished predictive model of pre-Contact site potential, based on the site location criteria described below.

Site Location Criteria for Pre-Contact Sites

Archaeologists have analyzed the environmental characteristics of thousands of sites throughout New England, and have identified a number of topographical variables that are consistently associated with pre-Contact sites:

- Relatively flat ground (i.e., slope 0-7%).
- The presence of well-drained soils.
- Proximity to fresh water (i.e., within a maximum of 1,000 feet, with areas within 250 feet of water having the highest potential) at the time of occupation

Other variables, such as aspect, availability of stone suitable for tool-making (e.g., rhyolite, quartz, quartzite, or steatite), and elevation above sea level and strategic vantage points, may also be important, as well as proximity of known sites from previous exploration. When several of the key criteria are met, the site of the proposed silviculture operation may have been an attractive location for Native American habitation or subsistence activities, and is thus classified as sensitive or potentially sensitive for pre-Contact resources.

Harvesting Restrictions and Limitations for Sensitive Pre-Contact Sites

Restrictions are recommended for silvicultural operations on sites that have been classified as "Sensitive" or "Potentially Sensitive" for Pre-Contact Resources that limit the potential for degrading those resources. By employing restrictions on harvesting operations that minimize ground disturbance, a compromise is achieved that allows the harvest to occur while affording some protection to whatever archaeological resources may lie buried below the ground, regardless of the uncertainty surrounding their exploration.

The following are types of restrictions that have been recommended for Sensitive areas:

- Harvest when soil conditions are frozen or dry enough to prevent soil compaction.
- Avoid soil disturbances due to inappropriate or oversized equipment.
  Encourage use of mechanized harvesting equipment with long reach and weight distributing tracks in order to minimize the extent and intensity of ground impact.

One or more of the above restrictions may be recommended for proposed operations in areas classified as Potentially Sensitive. Details of appropriate restrictions are fine-tuned through close interactions between DWSP foresters and the DCR Archaeologist, including analysis of past management sites for potential impacts.

In some cases, particularly with large acreage sales, portions of a lot may satisfy some, or all of the site location criteria, while other portions satisfy none. On those sites, some of the above harvesting restrictions may be recommended for the sensitive portion of the operation, but not apply in other portions. On rugged upland sites with complex microtopography or significant surface stone, or in previously disturbed areas that fail to meet the key criteria, restrictions are less likely to be placed on the operations.

4.5.3 Vegetation Management at Historic Sites

DWSP has developed a strategy for preserving its historic resource base taking into consideration current and likely future fiscal constraints. The strategy is modest in staff-hours and cost, but it can have a lasting effect on the survival of historic archaeological sites.

Vegetation, if left to grow unchecked in and around stone foundations and other historic structures like dams, raceways, etc., will ultimately alter these archaeological features. The

dislocation of foundation stones, and the spalling of cement caused by root activity are among the most immediate threats to some of these cultural resources. Should uncontrolled growth continue, in several cases the existing historical remains will be of little value and interest when the Commonwealth has the resources to undertake more lasting preservation.

The historic resource preservation strategy, when appropriate and/or recommended by the DCR Archaeologist, provides a limited and selective vegetation growth control management program in and around archaeological sites and historic buildings and structures. This same limited program has been employed on historic sites by other sections of DCR.

As a general site stabilization and preservation technique, vegetation management entails:

- Removal of most brush, saplings, and small to medium sized trees from on and within archaeological features (e.g., cellar holes and their foundation walls, channelized stream beds, mill dams, and historic buildings).
- Removal by cutting as close to the ground as feasible. Vegetation is not pulled, or otherwise dislodged in a manner that would affect root systems.
- While manual removal may often be the best technique, in some cases, where the terrain is sufficiently level and stable, mechanized harvesting equipment may be appropriate. Mechanical processors have a long reach that limits the need to bring equipment too close to the structure. These machines pick the tree up and swing it away from the site so there is no concern about the direction of the fall. Machines with tracks tend to distribute the machine's weight, thereby limiting compaction to buried deposits within the work area.

In most cases, DWSP staff perform the vegetation management around historic sites. Skilled private loggers/contractors who are well known to DWSP foresters can also be allowed to undertake the work. At sites that are imminently threatened, and that otherwise fall within a proposed silvicultural operation, it may be prudent to allow the private contractor to perform the selective cutting around historic sites. Contracts can include clauses that direct the logger to take extra care and precautions around cellar holes/foundations, etc. Vegetation management, in most cases, requires periodic and cyclical treatment depending on the nature of the growth, and the condition and significance of a specific site.

5 Research, Inventory, and Monitoring Needs

DWSP recognizes the importance of applied research and has supported a wide variety of watershed research through limited direct funding, granting outside researchers access to its properties, and internal research projects. While some of this research primarily benefited the researcher, the vast majority also informed DWSP managers and improved or supported watershed management practices. While DWSP's research budget has fluctuated, researchers who have their own funding continue to be attracted to DWSP lands because they are contiguous, undeveloped watershed lands generally behind secure gates or patrolled on a regular basis. In addition, watershed properties have provided an excellent backdrop for a wide range of graduate theses or dissertations.

Listed below are research, inventory, or monitoring needs in the general areas of forests and forestry, wildlife, and cultural resources. These are listed in part to direct DWSP's own efforts in the coming decade, but also as a specific reference for potential researchers who are looking for a project that would address a demonstrated need.

5.1 Forest Research

5.1.1 Regenerating Forests in Riparian Filter Strips

The objective of maintaining (and ultimately regenerating) a 'protection forest' that starts at the reservoirs' shorelines and the banks of tributaries may conflict with the regulatory restrictions prohibiting the use of patch cuts within stream filter strips. Current regulations dictate that only 50% of the basal area may be cut at one time, and the remaining trees must be "well-distributed." With an average cutting cycle of 30 years, DWSP's ability to successfully regenerate white pine and oak may be limited, and filter strips may become dominated by shorter-lived shade-tolerant red maple and black birch. It would be helpful to study the effects of patch-cutting within filter strips on various water quality parameters. Water quality sampling that established baseline stream conditions could be compared to parameters measured during and post-harvest to determine the impacts of patch cuts and partial cuts in close proximity to water resources. This could better inform regulatory restrictions where cutting cycles are very long.

5.1.2 Analysis of DWSP Forest Age Structure

One objective for managing the forest is to generate diversity in age structure. Thus, a careful analysis of the current distribution of age classes could be undertaken. Similar work was recently completed for DWSP properties on the Wachusett and Sudbury Reservoir watersheds, and could serve as a template for extending this to Quabbin and Ware River watersheds. Early descriptions, silvicultural records, plantation maps, and field sampling with increment borers can all be used to deduce a 'year of origin' for all stands as well as mapped harvest openings on

DWSP lands. Thus a complete picture of the age structure will be available for analysis and guidance of future silviculture. This work could be completed by students and DWSP foresters.

5.1.3 Evaluation of Forest Access Roads

Given that roads are a potential source of pollution and sedimentation on DWSP lands, a systematic evaluation of the road system would be valuable. This project would include a watershed-wide mapping of road conditions to identify trouble spots that could result in sediment transport during storm events. Part of this project would involve locating the most appropriate model for sizing culverts and utilizing GIS to routinely size culverts and design roads that will withstand 50-year storms. The road systems could also be evaluated for the capacity to accommodate the vehicles used by today's wood product transporters. The results of these evaluations could be utilized when planning road repair, improvements, and road construction on newly acquired property.

5.1.4 Rare Terrestrial Habitats Inventory

DWSP contracted with the University of Massachusetts Department of Natural Resources Conservation to classify and begin to identify rare and uncommon habitats on the Quabbin watershed (see Section 3.6.3). This report was completed and provided examples of these habitats. However, a more thorough effort is needed to identify these rare habitats on DWSP lands in order to protect their critical features during management activities. While some habitats are identified as part of the internal review process for proposed timber harvesting or road maintenance activities, most habitats need to be identified and mapped for all watersheds.

5.1.5 LIDAR Data Collection for DWSP

MassGIS has produced raster datasets containing very accurate ground elevation data based on LiDAR (Light Detection and Ranging) technology. This data covers mainly eastern Massachusetts, but does include Wachusett and Sudbury watersheds. The precision of this data has proven invaluable for more accurate mapping of landforms, stream flows, and even foundations and stone walls on those watersheds. DWSP has also obtained the full point cloud data set for Wachusett and Sudbury, which has been used to generate canopy heights and precisely locate small gaps. Procuring newer LIDAR data at a much higher resolution, covering all the watersheds, would allow DWSP to better map and understand the resources as well as track management activities results.

5.1.6 Continuous Forest Inventory Data Merging and Analysis

DWSP has maintained a fixed-plot, Continuous Forest Inventory system since 1960 on Quabbin and Ware River (see Section 3.4.1). The trees and other features of these plots have been remeasured at least every 10 years since their establishment. Given the large leaps in computer technology and data management each decade, there is a significant need to bring all past records, which were initially stored on paper and then punch cards, into a current, comprehensive and readily accessible modern database. Some of this laborious data entry and merging has

begun, and once accomplished it will be possible to mine this dataset for a very wide variety of information, including uncommon empirical evidence of growth and mortality rates, a comparison of these to known patterns of disturbance or climate change, comparisons of changes in forest structure and composition among disturbed and undisturbed sites, and quantification of carbon storage and cycling.

5.1.7 Continuation of Research Comparing Natural and Deliberate Disturbances

DWSP initiated, in partnership with academic researchers, a long-term paired watershed study comparing the effects of deliberate (timber harvesting) versus natural (insect defoliation) disturbances to the background conditions of unmanaged controls over the past ten years. This study included the installation of low-cost V-notch weirs to study water quantity, monthly grab sampling to document nutrient and sediment backgrounds, and automated water quality sampling to capture differences during storm and snowmelt events. Over 10 years of baseline data have been collected from these first-order tributaries, and it is time to move forward with the next phase of the research where harvests are conducted in the experimental sub-watershed. Results of this study may provide the agency with site-specific quantification of water supply effects of land management practices and natural disturbances.

5.2 Wildlife Research

5.2.1 Responses of Riparian Vegetation to Short-term and Long-term Beaver Occupation

Beaver are a high priority species. Since Question 1 passed in 1996, there has been effectively no trapping mortality on beaver in any of the watersheds. Even if Question 1 were repealed or modified, there are very few trappers left in the state. While beaver are intensely managed in certain portions of the watersheds for water quality reasons, most beaver colonies are not disturbed if they are located outside the control zone and not causing any property damage. However, because beaver occupy riparian zones and have the potential to alter local hydrology and impact riparian vegetation, it is important to understand these impacts. Studies that document both short-term and long-term effects of beaver occupancy on riparian vegetation would be helpful to determine beaver's impact on tree diversity, regeneration, and tree growth.

5.2.2 Biological Surveys and Inventories

In order to minimize or avoid negative impacts of land management activities on wildlife and critical habitats, all proposed activities are reviewed by DWSP's Wildlife Biologists. It is impossible to physically inspect the hundreds of proposed acres; DWSP must rely on records of known occurrences of critical habitat or species. Although new information is added as it becomes available, the database is far from complete. Biological surveys conducted by qualified persons can provide critical additional information that will aid DWSP efforts to protect these resources during land management activities. Information could also be incorporated into GIS data layers.

5.2.3 Microbial Source Tracking

A variety of animals, both domestic and wild, can contribute to water quality contamination. In many situations, raw water samples will contain high levels of contamination, but the source of the contamination is unknown. Technology now exists to identify contamination sources using genetic markers specific to a particular species or group of species. Research to identify problem sites and determine the source of contamination can help direct DWSP's efforts in mitigating these sources.

5.2.4 Landscape Level Management to Limit Gull Populations

A large-scale study of gull ecology was completed in 2012 (see Section 4.4.2). As a follow-up to that study, research is needed to determine if cumulative changes in food availability can influence the local population and presence of gulls in central Massachusetts. Specifically, can the amount of available food be controlled on a large enough scale to influence the movements and foraging ecology of gulls, and are there methods available to more effectively exclude remaining gulls from Wachusett and Quabbin Reservoirs. Further, results from this study suggest that human provided food may be a determining factor in how many gulls are present in central MA. Further work is needed to identify the motivations behind feeding gulls and which social marketing techniques may be useful in stopping the behavior.

5.2.5 Routine Monitoring Activities

Routine monitoring programs for selective species will continue during this management period, including surveys for beaver and muskrat within the reservoirs, monitoring Common loon nesting around the watersheds, Canada goose breeding surveys, bald eagle nesting activity, and bat and breeding bird surveys. In addition, the long-term wildlife monitoring program will continue to track populations of small mammals, reptiles, amphibians, and nesting songbirds and their responses to watershed management activities. Future efforts to monitor other species may be necessary, depending on population densities and management goals. Species such as cormorants, mute swans, and muskrat are present in the watersheds in relatively low numbers but may need to be monitored if populations increase.

5.2.6 Vernal Pool Surveys

Several years ago, DWSP completed a contract that mapped potential vernal pools on the watersheds using color infrared photos. Over 1,000 potential pools were identified. These pools are gradually being surveyed by DWSP to determine their status (i.e., functioning pool, not a pool) and their importance as habitat, as well as attempts to locate other unmapped pools. To improve protection for this resource, the survey and mapping effort could be increased. The mapping would be incorporated into GIS to facilitate land management planning.

5.2.7 Habitat Use and Population Dynamics of an Expanding Moose Population in the Southern Portion of Its Range

Moose have been present on DWSP lands since the 1990s. Watershed lands within Quabbin and Ware River most likely serves as corridors and core habitat for the species within the state. Little research has focused on moose populations in the southern extent of their range. Recent research by UMass and the USGS Cooperative Unit collared moose with GPS collars to track their movement patterns. In addition, moose and deer exclosures have been erected at Quabbin and the Ware River to examine regeneration pattern and browsing by these ungulates. DWSP has provided financial and technical support to this research effort since it began. DWSP will continue to support this research and potentially initiate other research projects. Research could focus on the habitat use and population dynamics of moose and the potential impact of resident moose populations on forest growth and regeneration. Further, DWSP could continue efforts to collect moose sighting data during the annual Quabbin controlled deer hunt to provide long-term information on the relative abundance of moose.

5.2.8 Use of Unmanned Aircraft Systems

Unmanned Aircraft Systems (UAS) refers to the complete package needed to fly unmanned aircraft. It includes both the aircraft and associated support equipment including a control station, data links, telemetry, communications, and navigation equipment. UAS provide a range of useful applications including: aerial surveys of nesting bald eagles, bird roost counts on each reservoir, and forest management/habitat assessment. High resolution video and/or still photos can be captured using UAS, and they can provide real-time information to personnel on the ground. Further, UAS can reduce risk to personnel by avoiding dangerous situations (i.e., tree climbing, boating during winter).

5.3 Cultural Resources Research

The principal research need for the continued protection of cultural resources on DWSP properties is to inventory, accurately map, and digitize all known historic cultural sites. This inventory would be modeled after the multi-phased historic site inventory that was completed for the Quabbin Reservoir watershed in 1995-96. Verified sites are mapped using locational GIS so that important sites can be identified and properly protected when management activities are proposed. In addition, a variety of other efforts could be initiated once this inventory was complete.

5.3.1 Historic Sites Inventory

Improve the inventory of historic sites by adding attributes such as site age, owner, activities, and buildings, to the database. These data will be used to prioritize vegetation management efforts and improve the review of silvicultural operations.

5.3.2 Effects of Historical Cultivation on Prehistoric Sites

Conduct archaeological sampling of red pine plantations, which were primarily planted on previously cultivated land, to determine the nature of sub-surface disturbance and survival factor for prehistoric sites.

5.3.3 University Field Schools

Encourage local universities to conduct archaeological field schools on watershed lands to further test and refine site location criteria.

Glossary of Terms

Listed in alphabetical order below are definitions for many terms found in this land management plan. Specific sources of definitions are shown in parenthesis where applicable. (SAF = Society of American Foresters Dictionary of Forestry, 2008; www.dictionaryofforestry.org)

age class: one of the intervals, commonly 10 years, into which the age range of tree crops (and sometimes other vegetation) is divided for classification or use. (from SAF)

advance regeneration: young trees (seedlings or saplings) that have become established naturally in a forest

area inch; acre inch: used to describe changes in water yield from a given area of land. For instance, if a change in vegetation results in an increase of one acre inch in water yield, this translates to 43,560 ft^2 per acre x 1/12 ft yield =3,630 cubic feet per acre; 3,630 cu ft / 7.5 gals per cu ft = 484 gallons additional yield per acre.

basin; watershed: the land area from which all water flows to a single, identified water source, such as a stream, a river, or a reservoir. Sub-basin or subwatershed is used to refer to the basin of a tributary or lower *order* stream (the higher the order, the greater the area drained) within a larger basin or watershed.

basal area (BA): the area in square feet of the cross section of a tree taken at 4.5 feet above the ground. BA = $0.005454(DBH^2)$. (See *DBH*)

basal area factor (BAF) : number of square feet of basal area (see BA) per acre represented by a tree counted using a device calibrated for measuring BA using variable radius point sampling. Common BAF used in New England is 10, so that each tree counted 'in' the plot represents 10 square feet of BA, regardless of its actual diameter.

Best Management Practices, BMPs: in natural resources management, a set of standards that have been designed for an activity, and often a region, to protect against degradation of resources during management operations.

biological diversity (or "biodiversity"): a measure, often difficult to quantify, of the variety and abundance of plant and animal species within a specified area, at the genetic, species, and landscape level of analysis. The 1992 UN Convention on Biological Diversity defined biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

biomass: the total quantity, at a given time, of living organisms of one or more species per unit area (species biomass) or of all the species in a community (community biomass) (from SAF).

carbon sequestration, carbon storage: the incorporation of carbon dioxide into permanent plant tissues (from SAF)

clearcut: an even-aged regeneration harvest method that removes essentially all trees in an entire stand or large area, and in which advance regeneration is either not present or not yet of a size or stocking level to warrant describing the cut as a removal cut of a shelterwood overstory. MA regulations define a patch cut as a clearcut between 1/4 and 1 acre in size, and set a maximum clearcut size of either 5 or 10 acres depending on the source of seed for regeneration.

conservation restriction; conservation easement; watershed preservation restriction (WPR): a legal agreement between a landowner and another party whereby the landowner deeds the rights to development of the property to the other party, but retains ownership of the land and other rights to its use. Specific agreement varies, but the general result is to protect land from conversion to new uses without requiring transfer of ownership. DWSP also limits or retains the right to approve certain agricultural and silvicultural practices in its WPRs.

Continuous Forest Inventory (CFI): an extensive method of forest inventory in which trees growing within permanently located sample plots are remeasured at periodic intervals to determine forest growth and condition. DWSP's CFI at Quabbin and Ware River is composed of 1/5 acre permanent plots located on watershed-wide 1/2 mile grids, which are remeasured every 10 years.

cutting cycle: the frequency with which silvicultural cuttings are conducted in any given area. Cutting cycle is a subunit of "rotation," which is determined either by the maximum life of the existing overstory, or by a predetermined maximum age imposed on the area.

cutting plan (Forest Cutting Plan**):** for any commercial timber cutting of wood products greater than 25,000 board feet or 50 cords on any parcel of land at any one time, the Forest Cutting Practices Act ("FCPA"), M.G.L. Chapter 132 §40-46, requires filing a Forest Cutting Plan with the Department of Conservation and Recreation and the local conservation commission. The Cutting Plan includes information such as: landowner name and address, property location, Best Management Practices used for stream and wetland crossings, harvesting in wetlands, type of cutting being proposed for the property, the volume of products to be harvested, a detailed site map, and a locus map.

Cryptosporidium: a coccidian protozoan parasite found in humans and various wild and domestic animals that can be transmitted via water and often causes serious intestinal illness. While the epidemiology and transmission of Cryptosporidium are similar to Giardia, its oocysts are smaller than the cysts of other protozoa, and thus may be more difficult to remove from water supplies.

DBH; diameter at breast height: the diameter of a tree, outside the bark, taken at 4.5' above the ground, generally in inches and fractions.

diverse/diversity: in this plan, the term is used to characterize *forest structure*, referring to mixing multiple size and age classes of trees together at a variety of scales either as distinct layers (understory, midstory, and overstory) or as a mosaic of intermixed groups, as well as to characterize *species composition*, with a general goal of avoiding monocultures and developing mixtures of long-lived native species, including hemlock, pine, oak, birch, and maple, throughout the forest. Diversity should help to provide resistance and resiliency in the event of major forest disturbances, and thus spread and minimize risk to water quality.

edge effect: traditionally, this term has been used to describe the increased richness of flora and fauna found where two habitat types or communities meet. More recently, and specifically in this plan, the term has been used to refer to the increased predation and brood parasitism that often occurs near these boundaries.

endogenous disturbance: disturbance that originates within the ecological community. For example, a single tree that succumbs to a root-rot fungus and falls to the ground, breaking off several other trees on the way, creates an endogenous disturbance. While the proximal cause of the treefall may be wind or accumulation of snow and ice, the primary cause is still considered endogenous in this instance (see also *exogenous disturbance*).

establishment cut: as part of the shelterwood regeneration method, a partial overstory harvest designed to prepare the seed bed and create a new age class of trees.

even-aged: an area of forest composed of trees having no, or relatively small, differences in age. By convention the maximum difference admissible is generally 10 to 20 years, or up to ±20% of the rotation. (from SAF)

exogenous disturbance: disturbance that originates from forces outside of the ecological community. For example, storms that carry high winds can cause large-scale treefall well in advance of normal senescence and decay. The cause of the disturbance is therefore considered exogenous. (see also *endogenous disturbance*)

feller-buncher; feller-processor: logging machine that grasps a tree to be cut or "felled," severs it at the stump with either a saw or hydraulic shears, and directionally drops it to the ground. Some machines can accumulate, or "bunch" several trees before releasing them, and many are capable of carrying the trees upright for a distance to a preferred drop location. The most complex machines (feller-processors) are also capable of delimbing (slicing off the branches) and bucking (sawing) trees into logs of predetermined lengths (termed 'processing', an essential component along with forwarding in a 'cut-to-length' logging operation system).

flow control pipe ("beaver pipe"): generally a length of culvert that is extended into a beaver pond and at or near the top of the beaver dam, in order to maintain the pond surface at a desired level; most often used to keep water from flooding and damaging infrastructure, especially roads.

forest canopy: the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth. Generally used in reference to tall or mature trees.

forest fragmentation: the separation of a previously contiguous forested area into discontinuous patches or "fragments" through conversion to non-forested cover. These fragments are less useful to wildlife species that require large contiguous habitats. Fragmentation by suburban development is likely to be detrimental to "deep woods" species, while the simple break imposed by an interior gravel access road is not often an impediment.

forwarder: a logging machine used to "forward" logs from the woods to a landing. Differs from a skidder in that the logs are hydraulically loaded onto the machine and carried, rather than dragged through the woods.

gap: any break or opening in a forest canopy. Although the term lacks a defined size limit, *gap* is commonly used to refer to very small, single tree or small multiple tree openings, often through natural mortality. See also *patch*.

GIS: Geographic Information System - a computer-based analysis and mapping system for spatially-linked data sets.

***Giardia*:** A flagellated protozoan parasite (*Giardia lamblia*) that colonizes and reproduces in the small intestines of humans and various wild and domestic animals, often causing giardiasis, a serious intestinal illness. It can be found in soil, food, or most commonly water that has been contaminated by feces from an infected host.

group selection: a regeneration method within an uneven-aged management system, trees are removed and new age classes are established in small groups. Variation in group size will create differing microenvironments that promote different tree species based on tolerance to shade from the surrounding uncut stand.

hurricane exposure ("exposed," "intermediate," "sheltered", "protected"): generally used in DWSP management plans to mean physical exposure of a site to catastrophic hurricane winds, those coming from the southeast. Research at the Harvard Forest in Petersham, MA provides a model of the impact of a New England hurricane like the one in 1938, which shows that actual damage depends on slope and aspect as well as the type and size of vegetation present.

intermediate cut: cutting of trees in a stand during the period between establishment and maturity. Objectives typically include the improvement of vigor by reducing competition and

the manipulation of species composition. Regeneration that may develop in the understory following intermediate cuts is incidental to these objectives, but nevertheless serves a temporary role as a forest in reserve.

irregular shelterwood: similar to the *shelterwood* silvicultural system except that the overstory is removed in an irregular pattern, typically partially cut in each of a series of cutting entries protracted over as long as half the rotation. The resulting new stand is quite uneven-aged (wide intervals between the oldest and youngest trees) and mimics the multi-storied effect of strictly uneven-aged systems.

log landing: a clearing of variable size to which logs, pulp, and/or firewood are skidded or forwarded from the woods during a logging operation, in order to facilitate their processing or further transport by truck.

mast: the fruit and seeds of trees and shrubs. Mast constitutes an important food source for many wildlife species.

mesic: in reference to soils, this term is used to characterize those mid-slope and lower slope areas where soil moisture is moderate; on the gradient between very dry upland or ridgetop conditions (xeric) and bottomland or wetland conditions (hydric)

milacre: one one-thousandth of an acre as in "milacre plots for regeneration inventory." A circular milacre plot has a radius of 3.72 feet.

mineral soil: any soil consisting primarily of minerals (sand, silt, and clay) material, rather than organic matter.

multi-storied or multi-layered forest: a forest containing a distinct understory, midstory, and overstory. From a watershed perspective, these layers provide, respectively, immediate response to disturbance, vigorous uptake of nutrients, and deep filtration of air-borne and precipitative pollutants.

overstory: The uppermost layer of tree and woody vegetative cover in a forest. See *forest canopy*.

patch; patch cut: the terms 'patch', 'group', 'gap', and 'opening' are essentially synonymous within this plan, each referring to a discrete portion of a stand from which all or nearly all trees are removed to establish or release a new age class. However, patches are defined within MA cutting practices regulations as *clearcuts* between 1/4 and 1 acre in size (see *clearcut* definition above). To confuse matters even more, the term 'patch' can itself be broadly defined as any homogeneous stand structure from small to large scale that is distinct from surrounding structures, and it may be either a cleared area, *a mature forest structure*, or some other structure, e.g., 'a patch of heathland' (O'Hara, 2014). See also *gap*.

preparatory cutting: removing trees near the end of a rotation so as to open the canopy and enlarge the crowns of seed bearers, with a view to improving conditions for seed production (from SAF).

protection forest: an area, wholly or partly covered with woody growth, managed primarily to regulate stream flow, maintain water quality, minimize erosion, stabilize drifting sand, conserve ecosystems, or provide other benefits via protection (from SAF).

regeneration: recently established tree growth, generally seedlings and saplings; also, the process of establishing this growth through either natural or artificial methods, as in "bring about the regeneration of a forest area."

regeneration cut: any removal of trees intended to create a new age class by assisting regeneration already present or creating conditions to make regeneration possible.

riparian: pertaining to the bank of a stream or other water body. Riparian vegetation refers to the plant community growing in close proximity to a watercourse, lake, swamp, or spring, which significantly influences and is influenced by the neighboring body of water (from SAF).

rotation: in conventional forestry, rotation is the planned number of years between the formation or regeneration of a crop or stand and its final cutting at a specified stage of maturity. In the selection system of uneven-aged management, however, the concept of a rotation is replaced with the average age of trees removed to initiate regeneration (from SAF).

salvage; salvage cutting: the removal of trees damaged by fire, wind, insects, disease, fungi, or other injurious agents to recover financial timber value or to reduce fuel loading and fire hazard. Sanitation cutting is related, but is a proactive removal of diseased or highly susceptible trees in order to slow or halt the spread of a disease or other destructive agent.

seep: a wet area, generally associated with groundwater saturation or surface breakout, which is important to wildlife because it remains unfrozen, and generally uncovered, during periods when the ground is otherwise snow-covered, which makes it an important seasonal source of food and water for wildlife.

sere (seral): the temporally sequential series of successional stages in an ecosystem, from the pioneer (early seral) stage through the climax (late seral) stage. See *succession*.

shelterwood: mostly even-aged silvicultural systems in which, in order to provide a source of seed, protection for regeneration, or a specific light regime, the overstory (the shelterwood) is removed in two or more successive partial cuttings. The first is ordinarily the seed or *establishment* cutting (though it may be preceded by a *preparatory* cutting) and the last is the final cutting, while any intervening cuttings are termed removal cuttings. Where adequate

regeneration is already present, the overstory may be removed in one cutting, resulting in a method referred to as a one-cut shelterwood (from SAF).

silviculture: generally, the science and art of cultivating (i.e., growing and tending) forest crops, based on a knowledge of silvics (the study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors affecting growth and change). More particularly, the theory and practice of controlling the establishment, composition, constitution, and growth of forests (from SAF).

site: in forestry, the combination of environmental factors that affect the ability of a species to grow and persist, including at least soil characteristics, aspect, altitude and latitude, and local climate. Sites are often nicknamed for the ability of specific trees to grow on them, e.g. "a good pine site."

site index (SI): a species-specific measure of actual or potential forest productivity, expressed in terms of the average height of dominant and co-dominant trees at a specified index or base age. Usually pertains to even-aged stands. In New England, foresters use 50 years as the standard index age, so for example a site at Quabbin with a red oak site index of 65 can grow red oak to an average of 65 feet in height in 50 years. (from SAF)

site preparation: in silviculture, any of a variety of treatments of a site that are intended to enhance regeneration success. A common goal of these treatments is *scarification*, i.e. disturbing enough of the accumulated organic layers above the mineral soil so as to expose that soil and enhance the ability of seeds that fall on it to germinate and grow. The simple skidding of logs is an incidental, and often sufficient, scarification or site preparation method.

site-suited: species that have evolved to take advantage of a particular type of site. Species growing 'off-site' may exhibit lower resistance to disturbance or disease. Red pine grows and persists well on deep, sandy soils, where root rots are less common, but may become excessively prone to wind and or root rotting diseases on the moist agricultural soils on which they were typically planted.

skidder: logging machine used to 'skid' (drag) logs from the stump to a landing or a forwarder road. Felled logs or trees are either winched by cable to the skidder (cable skidder), or lifted by the butt (stump) end with a hydraulic grapple (grapple skidder), and then dragged. Usually for efficiency several logs or trees are bunched together and skidded out as one group or 'hitch'.

stand: a contiguous group of trees sufficiently uniform in age-class distribution, composition, and structure, and growing on a site of sufficiently uniform quality, to be a distinguishable and manageable unit (from SAF)

stocking: in forestry, the extent to which a site is occupied by trees compared to a pre-established optimum or standard for a given stand age; a relative measure of stand density. Most commonly measured as basal area per acre, stocking is often related directly to crown closure, as a site is considered fully occupied when crown closure is complete (when each crown has grown to touch all adjacent ones). As crowns can be of very different sizes among species and tree ages within stands, average diameter (dbh) and total number of trees of a "fully stocked" site is variable.

stream order: a hierarchical classification system for streams based on degree of branching. Small unbranched streams arising in the outermost reaches of a watershed stream system are labeled "first-order"; two first-order streams join to form a "second-order" stream; two second-order streams join to form a "third-order" stream, etc.

succession: the gradual supplanting of one community of plants by another, the sequence of communities being termed a "sere" and each stage "seral." Succession is "primary" (by "pioneer species") on sites that have not previously borne vegetation, "secondary" after the whole or part of the original vegetation has been supplanted. "Early succession" generally refers to the pioneer stages and species that follow disturbance, while "late succession" refers to stages and species that occur as an area continues to develop undisturbed for long periods (from SAF).

thinning: an intermediate silvicultural treatment, generally with the goal of altering the forest composition and/or improving the growing conditions for the residual overstory trees, regardless of associated regeneration effects. Most thinnings remove poorer quality or lower value trees, leaving better quality stands still considered to be fully stocked, i.e., capable of fully occupying the site a short while after the thinning has been completed.

turbidity: a water quality measure that is most commonly derived by measuring the proportion of a given amount of light that is deflected by suspended/dissolved sediments in a water sample, giving an indirect measure of these sediments. A common unit is the Nephelometric Turbidity Unit, NTU, which measures the amount of white light (400-600 nanometer wavelengths) deflected 90 degrees to the incident beam.

uneven-aged: a stand composed of trees of three or more distinct age classes, either intimately mixed or in small groups. (from SAF).

vernal pool: a temporary body of fresh water that typically fills in the autumn or winter due to rainfall and rising groundwater. Annual or periodic summer drying prevents fish from establishing permanent populations, which is crucial to the reproductive success of several vertebrate and many invertebrate species of wildlife. (from NHESP)

water yield: the amount or volume of water that flows in a given period of time from a watershed. Yield is equal to the precipitation minus evaporation, transpiration, and change in groundwater storage.

watershed; subwatershed: see **basin**

wetland: generally refers in the DWSP land management plans to areas defined as "wetlands" by M.G.L. ch.131, §40 (the "Wetlands Protection Act") and 310 CMR 10.00 (the "Wetlands Protection Regulations"), updated as these are revised.

References

Alverson, W. S., and D. M. Waller. 1997. Deer populations and the widespread failure of hemlock regeneration in northern forests . *In*: The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press. 402 pp.

Angelstam, P., P. Wikberg, P. Danilov, W.E. Faber, and K. Nygren. 2000. Effects of moose density on timber quality and biodiversity restoration in Sweden, Finland, and Russian Karelia.Alces. 36: 133-145.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Pages 1-34 *in* D. M. Power, editor. Current Ornithology, Volume 11.

Askins, R. A. 1999. History of grassland birds in eastern North America. Studies in Avian Biology 19:60-71.

Askins, R. A. 200. Restoring North America's Birds: Lessons from Landscape Ecology. Yale University Press, New Haven, CT.

Blodgett, D. 1985. Snag and den tree management guidelines. Habitat Highlights. Vol. 5. No. 4. 2 pp.

Bormann, F.H. and G.E. Likens. 1979. Patterns and process in a forested ecosystem; disturbance, development and the steady state based on the Hubbard Brook Ecosystem Study. Springer-Verlag. New York, N.Y. 253 pp.

Brackley, R. A. and Bruce P. Hansen. 1977. "Water Resources of the Nashua and Souhegan River Basins, Massachusetts", Atlas HA-276, USGS.

Brandner, T.A., R.O. Peterson, and K.L. Risenhoover. 1990. Balsam fir on Isle Royale: effects of moose herbivory and population density. Ecology. 71(1): 155-164.

Brayton, D. Scott. 1984. The beaver and the stream. Journal of Soil Water Conservation. March/April: 108-109.

Brooks, R. T. 2011. Declines in summer bat activity in central New England 4 years following the initial detection of white-nose syndrome. Biodiversity Conservation 20:2537-2541.

Calhoun, A. J. K., and P. deMaynadier. 2004. Forestry habitat management guidelines for vernal pool wildlife. MCA Technical Paper No. 6, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York.

Camp Dresser and McKee Inc. and FTN Associates, Ltd. 1995. Task 2.3: Wachusett Reservoir Draft Modeling Report July 1995. Report submitted to Massachusetts Water Resources Authority.

Catanzaro, Paul; Jennifer Fish; David Kittredge. Massachusetts Forestry Best Management Practices Manual; 2nd edition. 2013. Pub. UMASS Extension and DCR, available online at www.masswoods.net

Clark, D. E., K. K. G. Koenen, K. G. MacKenzie, J. W. Pereira, and S. DeStefano. 2013. Stainless-steel wires exclude gulls from a wastewater treatment plant. Journal of the American Water Works Association 105-609-618.

Clark, D. E. 2014. Roosting, site fidelity, and food sources of urban gulls in Massachusetts: implications for protecting public water supplies. Dissertation, University of Massachusetts, Amherst, MA.

Clark, D. E. J. W. Pereria, K. G. MacKenzie, K. K. G. Koenen, and S. DeStefano. 2015. Assessing gull abundance and food availability in urban parking lots: can education reduce the amount of human-provisioned food? Human-Wildlife Interactions 9:180-190.

Clark, D. E., S. DeStefano, K G. MacKenzie, K. K. G. Koenen, and J. J. Whitney. 2016a. Roost site selection by ring-billed and herring gulls. Journal of Wildlife Management 80:708-719.

Clark, D. E., K. K. G. Koenen, J. J. Whitney, K G. MacKenzie, and S. DeStefano. 2016b. Fidelity and persistence of ring-billed (*Larus delawarensis*) and herring (*Larus argentatus*) gulls to wintering sites. Waterbirds 39(sp1):220-234.

Coumou, Dim and Stefan Rahmstorf. 2012. A decade of weather extremes. Nature Climate Change, Vol. 2, July 2012, 491-496.

Connor, K.J., W.B. Ballard, T. Dilworth, S. Mahoney, and D.Anions. 2000. Changes in structure of a boreal forest community following intense herbivory by moose. Alces. 36: 111-132.

Creed, Irena F., et al. 2014. Changing forest water yields in response to climate warming: results from long-term experimental watershed sites across North America. Global Change Biology, (2014) 20, 3191-3208.

Danell, K., L.Edenius, and P.Lundberg. 1991. Herbivory and tree stand composition: moose patch use in winter. Ecology. 72(4): 1350-1357.

deCalesta, D. S. 1994. Effects of white-tailed deer on songbirds within managed forests in Pennsylvania. The Journal of Wildlife Management 58:711-718.

DeGraaf, R.M., and A.L. Shigo. 1985. Managing cavity trees for wildlife in the Northeast. U.S. For. Serv. Gen. Tech. Rep. NE-101. 21 pp.

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and J.W. Lanier. 1992. New England wildlife: management of forested habitats. U.S. For. Serv. Gen.Tech. Rep. NE-144. 271 pp.

DeGraaf, R.M., M. Yamasaki, W.B. Leak, and A.M. Lester. 2006. Technical Guide to Forest Wildlife Habitat Management in New England. University of Vermont Press. Burlington, Vt. Published by University Press of New England. Hanover and London. 301 pp.

DeMaynadier, P. G., and M. L. Hunter, Jr. 2000. Road effects on amphibian movements in a forested landscape. Nat. Areas. J. 20:56-65.

Dettmers, R. and K. Rosenburg. 2000. Partners in flight landbird conservation plan: physiographic area 9: southern New England. Version 1.0. American Bird Conservancy. Website: http://www.blm.gov/wildlife/plan/pl_09_10.pdf

Dissmeyer, G.E., ed. 2000. Drinking water from forests and grasslands: a synthesis of the scientific literature. Gen. Tech. Rep. SRS-39. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 246 p.

Donkor, N.T., and J.M. Fryxell. 1999. Impact of beaver foraging on structure of lowland boreal forests of Algonquin Provincial Park, Ontario. For. Ecol. Manage. 118:83-92.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning, W.H. Freeman and Company, New York, NY, 818 pp.

Dukes et al., 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? Canadian Journal of Forest Research Vol. 39, 231-248.

Edenius, L. 1994. Foraging behavior by moose in forest stands subjected to severe browsing. Alces. 30: 37-40.

Elliot, C. A. 1988. A forester's guide to managing wildlife habitats in Maine. U. Maine Coop. Ext. 46 pp.

Faaborg, J. M., T. M. Donovan, and J. Blake. 1993. Habitat fragmentation in the temperate zone: a perspective for managers. Pages 331-338 *in* Status and Management of Neotropical Migratory Birds, D. M. Finch and P. W. Stangel, editors. U. S. Department of Agriculture, Forest Service General Technical Report RM-229.

Faison, E. K. 2015. Complex effects of ungulate browsing on tree recruitment and herbaceous layers in New England temperate forests. Dissertation, University of Massachusetts, Amherst.

Flatebo, G., C. R. Foss, and S. K. Pelletier. 1999. Biodiversity in the forests of Maine: guidelines for land management. Univ. Maine Coop. Ext. No.7147 167 pp.

Foster, D.R. and E.R. Boose. 1992. Patterns of forest damage resulting from catastrophic wind in central New England, U.S.A. Journal of Ecology 80:79-98.

Foster, D.R., J.D. Aber, J.M. Melillo, R.D. Bowden, and F.A. Bazzaz. 1997. Forest response to disturbance and anthropogenic stress. BioScience 47:7, p 437.

Franzmann, A.W., and C.C. Schwartz. 1997. Ecology and management of the North American moose. Smithsonian Institution Press and Wildlife Management Institute. 733 pp.

French, J.M. and G.S. Buzzell. 1992. Wachusett Reservoir Arborvitae Hedge Report. MDC.

Gustafson, E. J., and T. R. Crow. 1994. Modeling the effects of forest harvesting on landscape structure and the spatial distribution of cowbird brook parasitism. Landscape Ecology 9:237-248.

Hagan, J. M., P. S. McKinley, A. L. Meehan, and S. L. Grove. 1997. Diversity and abundance of landbirds in a Northeastern industrial forest. The Journal of Wildlife Management 61:718-735.

Hägglund, Å., and G. Sjöberg. 1999. Effects of beaver dams on the fish fauna of forest streams. For. Ecol. Manage. 115:259-266.

Hammerson, G.A. 1994. Beaver (Castor canadensis): Ecosystem alterations, management, and monitoring. Nat. Areas J. 14(1):44-57.

Harper, R.M. 1918. Changes in the forest area of New England in three centuries. Journal of Forestry. 16: 442-452.

Healy, W.M., R.T. Brooks and R.M. DeGraaf. 1989. Cavity trees in sawtimber-size oak stands in central Massachusetts. North. J. Appl. For. 6(2):61-65.

Healy, W.M. 1997a. Influence of deer on the structure and composition of oak forests in central Massachusetts. *In*: The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press. 402 pp.

Healy, W.M. 1997b. Thinning New England oak stands to enhance acorn production. N. Journ. Appl. For. 14(3):152-156.

Hobson, S.S., J.S. Barclay, and S.H. Broderick. 1993. Enhancing wildlife habitats: a practical guide for forest landowners. NE Reg. Agric. Engin. Serv. 172 pp.

Hewlett, J.D. and W.L. Nutter. 1969. An outline of forest hydrology. University of Georgia Press, Athens, GA, 137 pp.

Higgins, George R. 1968. Hydrological Studies in Massachusetts; a report for the Massachusetts Water Commission.

Hornbeck, J.W. and J.N. Kochenderfer. 2004. A century of lessons about water resources in Northeastern forests., Chapter 2 In A century of forest and wildland watershed lessons, G.G. Ice and J. D. Stednick, eds., Society of American Foresters, 287 p.

Hornbeck, J.W., M.B. Adams, E.S. Corbett, E.S.Verry, and J.A. Lynch. 1993. Long-term impacts of forest treatments on water yield: a summary for northeastern USA. Journal of Hydrology, 150:323-344.

Horton, R., G. Yohe, W. Easterling, R. Kates, M. Ruth, E. Sussman, A. Whelchel, D. Wolfe, F. Lipschultz. 2014. Chapter 16: Northeast. In: J.M. Melillo, T.C. Richmond, G.W. Yohe and (eds.), eds. Climate change impacts in the United States: the third National Climate Assessment: U.S. Global Change Research Program: 371-395. Available at http://nca2014.globalchange.gov/downloads

Hunter, M.L. Jr. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press. 698 pp.

Iverson, Louis R., Anantha M. Prasad, Stephen N. Matthews, and Matthew P. Peters. 2014. Climate as an agent of change in forest landscapes. Chapter 2 in Forest Landscapes and Global Change: Challenges for Research and Management, J. C. Azevedo et al. (eds.), p. 29-42.

Iverson, L., F. Thompson III, S. Matthews, M. Peters, A.M. Prasad, W. Dijak, J.S. Fraser, W.J. Wang, B.B. Hanberry, H. He, M.K. Janowiak, P.R. Butler, L.A. Brandt, C.W. Swanston. 2016. Multi-model comparison on the effects of climate change on tree species in the Eastern U.S.: results from an enhanced niche model and process-based ecosystem and landscape models. Landscape Ecology.

Janowiak, M.K., A.W. D'Amato, C. Swanston, L. Iverson, F. Thompson III, W. Dijak, S. Matthews, A. Prasad, M. Peters, J.S. Fraser, L. Brandt, P. Butler, S. Handler, P.D. Shannon, D. Burbank, J. Campbell, C. Cogbill, M. Duveneck, M. Emery, N. Fisichelli, J. Foster, J. Hushaw, L. Kenefic, A. Mahaffey, T.L. Morelli, N. Reo, P. Schaberg, K.R. Simmons, A. Weiskittel, S. Wilmot, D. Hollinger, E. Lane, L. Rustad, P. Templer. in press. New England and New York forest ecosystem vulnerability assessment and synthesis: a report from the New England Climate Change Response Framework Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station

Jensen, P. G., P. D. Curtis, and D. L. Hamelin. 1999. Managing nuisance beavers along roadsides: a guide for highway departments. Cornell University. 14 pp.

Johnston, C.A. and R.J. Naiman. 1990. Browse selection by beaver: effects on riparian forest composition. Can. J. For. 20:1036-1043.

Kelty, M.J., D.B. Kittredge, Jr., T. Kyker-Snowman, and A.D. Leighton. 2003. The conversion of even-aged stands to uneven-aged structure in Southern New England. Northern Journal of Applied Forestry 20(3), pp 109-116.

King, S.L., B.D. Keeland, and J.L. Moore. 1998. Beaver lodge distributions and damage assessments in a forested wetland ecosystem in the southern United States. For. Ecol. Manage. 108:1-7.

Klotz, R. L. 1998. Influence of beaver ponds on the phosphorus concentration of streamwater. Can. J. Fish. Aquat. Sci. 55:1228-1235.

Kunkel, K.E., L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, J. Rennells, A. DaGaetano, J.G. Dobson. 2013. Regional climate trends and scenarios for the U.S. National Climate Assessment. Part 1. Climate of the Northeast U.S. Washington, DC: US Department of Commerce, National Oceanic and Atmospheric Administration. 87 p. Available at

http://www.nesdis.noaa.gov/technical_reports/NOAA_NESDIS_Tech_Report_142-1-Climate_of_the_Northeast_U.S.pdf

Maret, T.J., M. Parker, and T.E. Fannin. 1987. The effect of beaver ponds on the nonpoint source water quality of a stream in southwestern Wyoming. Wat. Res. 21(3):263-268.

Massachusetts Division of Fisheries and Wildlife, Dept. of Fish and Game. 2015. Draft State Wildlife Action Plan. 458 pp.

McInnes, P.F., R.J. Naiman, J.Pastor, and Y.Cohen. 1992. Effects of moose browsing on vegetation and litter of the boreal forest, Isle Royale, Michigan, USA. Ecology. 73(6): 2059-2075.

McLaren, B.E., S.P. Mahoney, T.S. Porter, and S.M.Oosenbrug. 2000. Spatial and temporal patterns of use by moose of pre-commercially thinned, naturally-regenerating stands of balsam fir in central Newfoundland. Forest Ecology and Management. 113: 179-196.

McRae, G., and C. J. Edwards. 1994. Thermal characteristics of Wisconsin headwater streams occupied by beaver: implications for brook trout habitat. Trans. Am. Fish. Soc. 123:641-656.

McShea, W.J., and J.H. Rappole. 1997. Herbivores and the ecology of forest understory birds. *In*: The Science of Overabundance: deer ecology and population management. Smithsonian Institution Press. 402 pp.

McShea, W.J., H.B. Underwood, and J.H. Rappole. 1997. The science of overabundance: deer ecology and population management. Smithsonian Institution Press. 402 pp.

MDC, Division of Watershed Management. 1991. Quabbin Reservation white-tailed deer impact management plan. Unpublished MDC report.

MDC/MWRA. 1991. Watershed protection plan: Quabbin Reservoir and Ware River watersheds. Prepared by Rizzo Assoc. and CH2M Hill. February 28, 1991.

Naiman, R.J., C.A. Johnston and J.C. Kelly. 1988. Alteration of North American streams by beaver. BioScience 38(11):753-762.

Naiman, R.J., G. Pinay, C.A. Johnston, and J. Pastor. 1994. Beaver influences on the long-term biogeochemical characteristics of boreal forest drainage networks. Ecology 75(4):905-921.

NHESP (Massachusetts Natural Heritage and Endangered Species Program). 2008. Massachusetts natural heritage atlas, 13th edition. Printed and distributed by the Massachusetts Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program, Westborough, MA. http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/regulatory-review/regulatory-maps-priority-and-estimated-habitats/natural-heritage-atlas-book.html

NOAA National Centers for Environmental Information. (2017). State Climate Summaries: Massachusetts. State Summary 149-MA. https://statesummaries.ncics.org/ma PDF version (see figure 1) https://statesummaries.ncics.org/sites/default/files/downloads/MA-screen-hi.pdf

Novak, M. 1987. In: M. Novak, J.A. Baker, M.E. Obbard, and B. Malloch, eds. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Toronto. pp. 283-312

Norton, D.A. 1999. Chapter 16, Forest Reserves in M.L. Hunter, Jr. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press. 698 pp.

Oehler, J.D., D.F. Covell, S. Capel, and B. Long. 2006. Managing Grasslands, Shrublands, and Young Forest Habitats for Wildlife. A Guide for the Northeast. Northeast Upland Habitat Technical Committee, Massachusetts Division of Fisheries and Wildlife. 143 pp.

O'Hara, K.L. 4014. Multiaged silviculture- managing for complex forest stand structures. Oxford University Press, New York, NY. 213 pp.

Orwig, D.A. and D.B. Kittredge. 2005. Silvicultural options for managing hemlock forests threatened by hemlock woolly adelgid. IN: U.S.D.A. Forest Service, 2005. B. Onken and R. Reardon, Compilers. Third symposium on hemlock woolly adelgid in the eastern United States. Asheville, North Carolina. February 1-3, 2005. Online: http://www.na.fs.fed.us/fhp/hwa/pub/2005_proceedings/index.shtm

Park, Andrew, Klaus Puettmann, Edward Wilson, Christian Messier, Susanne Kames, and Amalesh Dhar. 2014. Can Boreal and Temperate Forest Management be Adapted to the Uncertainties of 21st Century Climate Change?, Critical Reviews in Plant Sciences, 33:4, 251-285.

Paton, P. W. C. 1994. The effect of edge on avian nest success: how strong is the evidence? Conservation Biology 8:17-26.

Payne, N.F. and F.C. Bryant. 1994. Techniques for wildlife habitat management of uplands. McGraw-Hill, Inc. 840 pp.

Peek, J.M., and K.I. Morris. 1998. Status of moose in the contiguous United States. Alces. 34(2): 423-434.

Raup, H. 1966. The view from John Sanderson's farm. Forest History 10:2-11.

Runkle, J. R. 1985. Disturbance regimes in temperate forests. In: The Ecology of Natural Disturbance and Patch Dynamics. S. T. A. Pickett and P. S. White (editors), Academic Press, Orlando, FL, pp. 17-33.

Russell, K.R., C.E. Moorman, J.K. Edwards, B.S. Metts, and D.C. Guynn, Jr. 1999. Amphibian and reptile communities associated with beaver (Castor canadensis) ponds and

unimpounded streams in the piedmont of South Carolina. J. Freshwater Ecol. 14(2):149-160.

Rustad, Lindsey, John Campbell, Jeffrey Dukes, Thomas Huntington, Kathy Fallon Lambert, Jacqueline Mohan, and Nicholas Rodenhouse. 2012. Changing Climate, Changing Forests: The Impacts of Climate Change on Forests of the Northeastern United States and Eastern Canada. Gen. Tech. Report NRS-99. Newtown Square, PA: U.S. Dept. of Agriculture, Forest Service, Northern Research Station. 48 p.

Satterlund, D.R. and P.W. Adams. 1992. Wildland watershed management. 2nd edition. John Wiley & Sons, Inc. New York, N.Y.

Sauer, J. R., J. E. Fallon, and R. Johnson. 2003. Use of North American breeding bird survey data to estimate population change for bird conservation regions. The Journal of Wildlife Management 67:372-389.

Schlosberg, S. and D. King. 2007. Ecology and Management of scrub-shrub birds in New England: A comprehensive review. USDA Natural Resources Conservation Service Resources Inventory and Assessment Division.

Searcy, K.B. 1996. 1996 rare plant survey: Quabbin,Ware River,Wachusett, and Sudbury watersheds. Final report to MDC.

Smith, M.E., C.T. Driscoll, B.J. Wyskowski, C.M. Brooks and C.C. Cosentini. 1991. Modification of stream ecosystem structure and function by beaver (Castor canadensis) in the Adirondack Mountains, New York. Can. J. Zool. 69:55-61.

Smith, D.M., B.C. Larson, M.J. Kelty, P.M.S.Ashton. 1997. The practice of silviculture: applied forest ecology. John Wiley and Sons, New York, NY. 560 pp.

Snodgrass, J.W. and G.K. Meffe. 1998. Influence of beavers on stream fish assemblages: effects of pond age and watershed position. Ecology. 79(3):928-942.

Snyder, E.J., and K. Bontaitis. 2001. Moose fact sheet. University of New Hampshire Cooperative Extension. 4 pp.

STAC (DWSP Science and Technical Advisory Committee). 2012. Review of the Massachusetts DWSP Watershed Forestry Program. 75 pp.

Swanston, C. and M. Janowiak. 2012. Forest Adaptation Resources: Climate Change Tools and Approaches for Land Managers. Gen. Tech. Rep. NRS-87. USDA Forest Service, Northern Research Station. 121 p.

Sweeney, Bernard W. and J. Denis Newbold, 2014. Streamside Forest Buffer Width Needed to Protect Stream Water Quality, Habitat, and Organisms: A Literature Review. Journal of the American Water Resources Association (JAWRA) 50(3): 560-584.

Thompson, C. H. and T.D. Kyker-Snowman. 1989. Evaluation of non-point source pollution problems from crossing streams with logging equipment and off-road vehicles in

Massachusetts: 1987-1988. Report produced as part of Generic Environmental Impact Report on Forest Management in Massachusetts. Massachusetts Department of Environmental Management.

Thompson, F. R., W. D. Dijak, T. G. Kulowiec, and D. A. Hamilton. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. The Journal of Wildlife Management 56:22-30.

Thornthwaite, C.W., J.R. Mather, and D.B. Carter. 1958. Three water balance maps of eastern North America. Resources for the Future, Inc. Washington, D.C.

Thornton, K.W., S.P. Holbrook, K.L. Stolte, and R.B. Landy. 2000. Effects of forest management practices on Mid-Atlantic streams. Environmental Monitoring and Assessment 63:31-41.

Trani, M.K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, and C.M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildl. Soc. Bull. 29(2).

Tubbs, C.H., R.M. DeGraaf, M. Yamasaki and W.M. Healy. 1987. Guide to wildlife tree management in New England northern hardwoods. USDA For. Serv. Gen. Tech. Rep. NE-118.

U.S.D.A. Forest Service, 2005. B. Onken and R. Reardon, Compilers. Third symposium on hemlock woolly adelgid in the eastern United States. Asheville, North Carolina. February 1-3, 2005. Online: http://www.na.fs.fed.us/fhp/hwa/pub/2005_proceedings/index.shtm

Vecellio, G.M., R.D. Deblinger, and J.E. Cardoza. 1993. Status and management of moose in Massachusetts. Alces. 29: 1-7.

VerCauteren, K.C., C.W. Anderson, T.R. van Deelen, D. Drake, W.D. Walter, S.M. Vantassel, and S.E. Hygnstrom. 2011. Regulated commercial harvest to manage overabundant white-tailed deer: an idea to consider? Wildlife Society Bulletin 35(3):185-194.

Verry, E.S. 1986. Forest harvesting and water: the Lakes States experience. Water Resources Bulletin. 22(6):1039-1047.

Vitousek, P.M. and W.A. Reiners. 1975. Ecosystem succession and nutrient retention: a hypothesis. Bioscience 25:376-381.

Waller, D. M., and W. S. Alverson. 1997. The white-tailed deer: a keystone herbivore. Wildlife Society Bulletin 25:217-226.

Welsh, C. J. E., and W. M. Healy. 1993. Effect of even-aged timber management on bird species diversity and composition in northern hardwoods of New Hamphsire. Wildlife Society Bulletin 21:143-154.

Wilcove, D. S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology 66:1211-1214.

Williamson, S. J. Undated. Forester's guide to wildlife habitat improvement. University of New Hampshire, Cooperative Extension.

Witman, G. G., and M. L. Hunter, Jr. 1992. Population trends of neotropical migrant landbirds in northern coastal New England *in* J. M. Hagan, III and D. W. Johnston, editors. Ecology and Conservation of Neotropical Migrant Landbirds. Smithsonian Institute Press, Washington, D.C.

Williamson, S. J. n.d.. Forester's guide to wildlife habitat improvement. Univ. New Hampshire, Coop. Ext. 41 pp.

Yeakley, J.A., D.C. Coleman, B.L. Haines, B.D. Kloeppel, J.L. Meyer, W.T. Swank, B.W. Argo, J.M. Deal, and S.F. Taylor. 2003. Hillslope nutrient dynamics following upland riparian vegetation disturbance. Ecosystems (2003) 6:154-167.