WACHUSETT RESERVOIR WATERSHED
Land Management Plan: 2001 – 2010

Prepared by:

Metropolitan District Commission

Division of Watershed Management

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Wachusett Reservoir Watershed Land Management Plan: 2001-2010

Metropolitan District Commission / Division of Watershed Management

- Executive Summary -

10/22/01

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Wachusett Reservoir Land Management Plan: 2001 ? 2010
Executive Summary

The Metropolitan District Commission's Division of Watershed Management (MDC/DWM) has developed a 10-year Wachusett Watershed Land Management Plan that sets out principles, goals, and objectives for managing MDC owned land with the express purpose of protecting the public water supply. In addition, the plan describes MDC's land acquisition program within the Wachusett Watershed to increase the protection of the reservoir, as well as objectives for managing wildlife and protecting cultural resources. Note that this plan is distinct from other MDC/DWM plans, such as the Public Access Plan (recreation) and the Watershed Protection Plan (private and public land source water protection).

The following is a summary of the seven sections of the plan including background information, policies and program descriptions.

I. Introduction, Mandates and Statement of Mission

Contents: This section presents the legislative mandates, agency mission statements, and other foundations for MDC's land management program, as well as a general overview of the plan.

Key Points: Chapter 372 (Acts of 1984) provides the primary legislative mandate for MDC's land management activity. Chapter 372 established the Division of Watershed Management and directed it to "…utilize and conserve…water and other natural resources in order to protect, preserve and enhance the environment of the Commonwealth and to assure the availability of pure water for future generations." This statute sets forth clear authority for the active management of the watershed and its natural resources. Chapter 372 directs the MDC/DWM to periodically prepare watershed management plans for "…forestry, water yield enhancement and recreational activities."

The plan calls for the maintenance of a diverse, multi-layered forest cover on much of the watershed. The plan primarily focuses on management over the next ten years, but it also projects the forest cover and watershed conditions 60 years into the future. This plan should be viewed as an "adaptive watershed management plan" to be applied but updated and modified as new properties are added and new information comes to light.

A significant difference between the Quabbin Watershed and the Wachusett Watershed is the more common interface between MDC lands and private properties in the Wachusett Watershed.

II. Description of Wachusett Watershed Resources

Contents: This section gives an overview of the natural and cultural resources contained within MDC/DWM watershed lands surrounding Wachusett Reservoir.

Key Points: The MDC controls approximately 26% of the 71,000 acres in the Wachusett watershed system including land and water. Privately owned forestland comprises 37.3 % (26, 392 acres) of the watershed. Of the land controlled by the MDC, approximately 12,500 acres are forested, while 1640 acres are wetland areas and about 1000 acres are non-forested open space.

Wachusett soils are of glacial origin, range from poorly to excessively well drained, and generally have low to moderate erosion potential.

Quabbin Reservoir transfers account for over 50% of the average annual Wachusett inflow. Inflows from the Wachusett's main tributaries, the Stillwater and Quinapoxet Rivers account for another 30% of the average annual inflow.

Forested land accounted for about 43% of the initial acreage taken (1,475 of 3,380 acres) at the time the reservoir was being built. The idea of forests as a source of high quality water was becoming ever more accepted at this time and approximately 1,000 acres of tree plantations were established, with conifers comprising about 78% of all trees planted. The top five species (listed by basal area) on MDC lands are white pine, red maple, red oak, black oak, and white oak. Within the Wachusett forest, oak cover types make up 49 % of the forest.

Overall, Wachusett supports a variety and abundance of wildlife species. MDC forests provide habitat for a diversity of birds and mammals including white-tailed deer, turkey, grouse, beaver, raccoons, and fisher. The Wachusett Reservoir supports many water-based species including common loons, spotted sandpipers and bald eagles. The watershed harbors a variety of rare wildlife species and habitats. A total of 11 vertebrate state listed wildlife species are known to occur on the watershed, and most occurrences have been on MDC land.

Cultural resources on the Wachusett include both historic and prehistoric sites. Currently there are a total of twenty-seven recorded prehistoric Native American sites within, or in close proximity to the Wachusett watershed. MDC has excellent records of historic cultural resources, and a complete inventory of these sites, similar to that which has been completed at Quabbin, is a long term objective for Wachusett properties. A number of existing properties have been designated or declared eligible for the National Register of Historic Places.

III. Research based Principles Guiding Watershed Management

Contents: The purpose of this section is to identify various principles of watershed management that form the basis for the specific goals and implementation objectives for management of the Wachusett watershed lands during the period covered by the plan. These principles were distilled from the comprehensive literature review included in the Supporting Appendices for this plan, which summarizes the findings from approximately 350 watershed, forestry, and wildlife management papers that were reviewed by MDC/DWM staff.

Key Points: The central principle of watershed protection is the importance of maintaining forested, undeveloped cover across most of the watershed. Control of human activities, maintenance of roads (to prevent erosion while allowing access), and careful attention to riparian zones and wetlands follow as important watershed protection principles.

While some components of water yields are not controllable (e.g., precipitation, soil characteristics, topography), changes in vegetative cover, through management or natural disturbance, can have significant effects. Generally, as forest cover increases, water yields decrease.

Watershed forests can be managed in a way that provides significant benefits to long-term water quality protection, while minimizing adverse impacts during management operations. Forest management can deliberately restructure the forest so that it is better able to resist, and recover from, the impacts of severe natural disturbances. By maintaining a component of young forest throughout the watershed, this restructuring can provide both rapid recovery from disturbance and aggressive uptake of nutrients.

Among the principles described under the topic of Air Pollution is that forests function as "sinks" for airborne pollutants, mitigating their impacts. While this may benefit water quality protection, tree survival is affected by air pollution damage. Maintaining diverse and vigorous forests may mitigate this damage. Nitrogen saturation (in which nitrogen inputs from air pollutants exceed the assimilative capacity of the system) is of increasing concern in watershed forests, since it can lead to nitrate losses to streams. Again, forests that are actively accumulating biomass can mitigate these effects through increased assimilation.

Wildlife populations can have significant impacts on both habitat and water quality conditions. Land management practices that change habitat conditions will result in changes in the wildlife community.

IV. Watershed Management Goals

Contents: Based upon the principles distilled from the literature and local research, the experiences of MDC/DWM staff in managing watersheds, and the mandates from the laws and regulations that govern MDC land management, this section details MDC goals for overall Watershed Management, Water Quality and Yields, Land Protection, Forest Management, Wildlife Management, and Cultural Resource Protection.

Key Points: The primary goal of the MDC/DWM is to maintain high quality source water for present and future generations. The MDC/DWM strives to continually meet the Massachusetts Surface Water Quality Standards for Class A waters and regulations for source water quality resulting from the US EPA safe drinking water act. Secondary water quality goals include reducing/controlling nutrient inputs to the reservoirs, reducing the risk of a hazardous material spill and controlling general pollutant transport into the reservoir.

While water yield has been a concern in past years, the MWRA has devoted considerable efforts to Demand Management, and consequently the overall system demand has significantly decreased, therefore, water quality rather than water yield considerations are currently driving management decisions.

Land protection goals on MDC/DWM lands include working to limit land uses on the watershed to those that do not threaten water quality and to provide control over non-forest land use (e.g. roads), the effects of natural events (e.g. fire), and human activities that threaten water or other natural resources. Land protection goals for non-MDC lands include active encouragement of private landowners to be responsible stewards, work with other land protection entities to ensure watershed protection, and the purchase of conservation restrictions on lands that meet the criteria for protection.

Forest management goals include providing a vigorous uneven-aged diverse forest cover across the vast majority of MDC lands, maintaining forest cover that balances active growth and nutrient assimilation, dense filtration, temperature regulation and active reproduction, and retaining this forest cover by maintaining adequate forest regeneration across MDC lands. Additionally, the MDC/DWM will conduct any forest management activity such that the resulting benefits outweigh any potential negative impacts.

Non-forest management goals include providing a certain amount of non-forested habitat while insuring that the maintenance of these habitats has no negative impact on water quality.

The primary focus of the wildlife program on the Wachusett watershed is to minimize or eliminate adverse wildlife impacts on the drinking water supply, while protecting uncommon, rare or otherwise significant wildlife and their habitats.

The cultural resource protection goals include identifying significant cultural resources on MDC lands and preventing degradation of those resources.

V. 2001-2010 Management Plan Objectives and Methods

Contents: This section details the management objectives developed by the MDC to meet the goals specified in the previous section, and provides detail on the methods chosen to accomplish these objectives, in the area of Land Protection, Forest Management, Wildlife Management, and Protection of Cultural Resources.

Land Protection Activities

Land Acquisition

Contents: MDC has had an active land acquisition program at Wachusett since 1983. In the past decade, the MDC has acquired 10,446 acres on the Wachusett watershed (as of 6/01). This section outlines why and where MDC will continue to acquire private watershed lands.

Key points: The MDC Watershed Land Acquisition program has been funded from three bonds and a fiscal year budget allocation. The MDC is required by law to continue to purchase priority land, with an 8 million dollar per year allocation, on the active watersheds until the remaining funds in the bond are spent. These funds will have been spent by 2007. The relative sensitivity of Wachusett watershed lands has been determined by an in-depth analysis of the importance of various land criteria with respect to protecting the water quality of the Wachusett Reservoir.

Payments in-lieu of taxes (PILOT)

Contents: After land is acquired for watershed protection, the MDC/DWM is required by law to make Payments In-Lieu of Taxes (PILOT) on these properties.

Key Points: The PILOT program provides a significant benefit to the Wachusett communities. They receive the same revenue from permanently protected open space that they would have received from developed land, without the associated municipal costs of police, schools and fire services.

Land Disposition Policy

Contents: As the largest landowner within the Wachusett watershed, MDC receives requests for disposition of agency lands, often for purposes inconsistent with water supply protection.

Key Points: The MDC/DWM will consider land disposition only under exceptional circumstances. The MDC/DWM and EOEA both have land disposition policies that provide a framework to properly dispose of land provided the land is not deemed of critical importance to water supply protection.

Technical Assistance to Private Forest Landowners

Contents: This section outlines proposed plans to continue to encourage private forestland owners on the watershed to maintain their land in forest cover. This section also describes the use of conservation restriction purchases to prevent development while leaving land ownership in the current hands.

Key Points: Nearly 30,000 acres within the Wachusett watershed are "unprotected", privately owned forest. The MDC/DWM has expended funds to help private forestland owners on the watershed to complete forest management plans that, in turn, qualify them for federal cost-share assistance to conduct management activities that are desirable from a watershed protection standpoint.

Boundaries

Contents: This section outlines the maintenance approach regarding boundaries and encroachments.

Key Points: With the active land acquisition program ongoing, boundary marking is a challenge, especially when boundaries are continually being redrawn. It is extremely important for the MDC/DWM to maintain a good relationship with abutters to MDC 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 MDC land.

Public Education

Contents: This section describes the role of the MDC Watershed Rangers and the Division's general approach to interpreting land protection.

Key Points: Watershed Rangers provide a visual presence and proactively patrol to help prevent activities that would degrade water quality. When situations occur that require law enforcement personnel, rangers communicate with the State Police and other enforcement agencies. The MDC/DWM staff engages in both formal and informal education programs to enlighten the public about the Division's land management and land protection efforts.

Fire Protection

Contents: This section includes the history of fire occurrences on the watershed and the division's capability to deal with them.

Key Points: Forest fire is a potential threat to water quality, forest health, and public safety. Legal responsibility for suppression of wildfires resides with the local fire department. MDC assists in a supporting role under the direction of the town. The improvement and maintenance of the internal road system on MDC property is key in the ability to suppress wildfires. The MDC fire policy of 1994 specifies steps necessary for the suppression of wildfires on MDC lands.

Access Roads

Contents: This section outlines the importance of an internal forest road network to provide access for watershed activities such as forest management, fire protection, water quality sampling, patrolling and policing, and emergency access. This section also discusses the state of the road system and the future challenges for access on newly acquired properties.

Key Points: There are currently nearly 60 miles of roads on MDC property in the Wachusett watershed. Only about 12 miles of these roads can be utilized throughout most of the year. With the roughly 10, 000 acres of property purchased after 1985, new roads are required to provide access. Access maintenance is controversial. Access for watershed management activities can also be access for unwelcome activities that can pose a threat to water quality. The threat of fire may increase with improved access, but fire detection and suppression activities are enhanced.
The proper maintenance of forest roads is important to insure reliable access and to minimize erosion and the resulting sedimentation of tributaries. Maintenance is variable from year to year depending largely on weather and management activities. Based on the existing staff levels and their workload and the ongoing necessity for road maintenance, a crew whose primary responsibilities will be to construct and repair forest roads should be created.

Areas with Special Management Restrictions

Contents: MDC/DWM lands at Wachusett include areas where forest management will not occur, due to potentially negative impacts on water quality or other impacts.

Key points: Areas where special management restrictions are deemed necessary fall into two general categories. These are areas where regular forest management is either impractical or may result in unacceptable impacts and areas with uncommon, rare or potentially rare resources. The MDC has identified approximately 2,000 acres of land in the Wachusett watershed that will be classified as “Areas with Special Management Restrictions”.

Management of Forested Lands

Description of Forest Management Approach for Ten Years

Contents: This section details forest management objectives for the Wachusett watershed. It reviews the influence of natural disturbance, soils/species suitability, and the current condition of regeneration. It then outlines silvicultural activities that will first provide for the establishment of regeneration and that will create, over a 60-year period, the stable multi-layered watershed protection forest that is the ultimate goal of MDC's watershed forest management operations.

Key Points: The primary goal of management of the Wachusett forest is the creation of a forest that best serves the function of the land as a producer of high quality drinking water. The forest must be vigorous and diverse in species and ages, be actively accumulating biomass, and actively regenerating. The conversion of the present even-aged forest to a forest comprised of at least three age classes necessitates that one-third of any forest stand be regenerated to a new age class followed by the creation of another age class in 20 to 30 years, a sufficient span of time to allow the various age classes to grow and become well-differentiated from each other.

Over the next 30 years, one third, or 4,000 acres of the Wachusett forest will be converted to a new age-class. In order that this age class be evenly distributed throughout MDC land and evenly spaced through time, 130 acres must be regenerated each year. Therefore, approximately 400 acres will be treated annually (a third of which is regenerated).

The management of the Wachusett forest is planned to mitigate any negative impact resulting from natural disturbances, both large and small scale. The structure of an uneven-aged forest with three age classes well distributed across the landscape, is well designed to both resist and recover from the impacts of wind, ice, and heavy snow storms. Insects and disease are a major problem only when their impacts conflict with the MDC/DWM's objective of creating and maintaining a watershed protection forest. This means that only large-scale outbreaks that threaten to alter tree species diversity or forest structure fall into this category. It is a primary goal of forest management in the Wachusett forest to encourage the development of stands of trees comprised of species well suited to the site on which they are growing.

In deciding whether regeneration is adequate for Division purposes, species composition and site suitability, the number of seedlings/saplings per acre, and the spatial distribution of regeneration across the forest will be considered. Adequate regeneration is defined as the establishment of at least 2,000 stems per acre of seedlings/saplings greater than 4.5 feet in height of a diverse species composition.

On sites where the level of regeneration is inadequate, preparatory cuttings will be prescribed. These are designed to open the canopy sufficiently to allow increased light and heat levels at the forest floor thereby stimulating seed germination and seedling development. Once adequate regeneration is in place, it will be released systematically to give it light and space to grow. This is accomplished by harvesting a portion of the overstory from designated stands. Trees will be removed either singly or more often in groups and patches ranging from ¼ acre to two acres in size, with an average of about one acre. Occasionally there is a need to make larger removals over two acres because of species poorly suited to the site or unstable stands of damaged low-vigor trees.

Conservation Management Practices for Watershed Forest Management

Contents: The key to low impact silviculture is in on-the-ground supervision and planning. MDC has drafted detailed policies and procedures covering these activities.

Key Points: "Conservation Management Practices" refer to efforts to create resource-protecting standards for management activities. The MDC CMPs match or exceed the BMPs included in the state's Forest Cutting Practices and Wetlands Protection laws. The CMPs specify equipment, harvesting systems, and limitations around sensitive sites. Detailed timber harvesting specifications that protect the water and natural and cultural resources are outlined. MDC natural resources, environmental quality, and archaeological staff will review all silvicultural and roadwork plans as outlined in internal review policies.

Management of Non-forested MDC Lands

Contents: A percentage of MDC owned land is currently non-forested. This includes hay fields, reservoir shoreline, administrative areas, historic sites, early succession non-forested habitat, and gravel pits.

Key Points: A management plan will be written for each field the MDC/DWM intends to maintain as a field, which will address the specific goals of management, cutting/mowing schedules and procedures, control of invasive plants, filter strips width and maintenance, and other maintenance practices. The reservoir shoreline is cut on a rotational basis in order to encourage the herbaceous and shrub species to dominate the shoreline. Administrative area maintenance includes mowing of grass and the periodic maintenance of shrubbery. Historic sites will be maintained with an eye towards public interpretation of their past uses.

Management of Biodiversity

Contents: The MDC/DWM's goals for biodiversity focus on either maintaining or enhancing natural ecosystems across the watershed. The MDC/DWM 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.

Key Points: The MDC/DWM's principal goals for maintaining biodiversity are to retain most of these lands in forested condition, to identify and provide habitat for the protection of uncommon and rare flora and fauna, eliminate and prevent the spread of non-native invasive species, and provide the range of seral stages from early successional habitat through unmanaged mature forest.

Wildlife Management

Assessment of Impacts of Planned Watershed Management Activities on Wildlife

Contents: Land management activities that alter vegetation and other habitat conditions having corresponding impacts on the wildlife community in that area. Most impacts on the wildlife community will be the result of habitat changes or modifications.

Key Points: The MDC/DWM's primary long-term forest management goal is to establish and/or maintain a forest cover of diverse native tree species of many different age classes on a majority of its land holdings. Meeting this primary objective will mean wildlife communities on MDC land will be dominated by species adapted to forest conditions. Open and early successional habitat will be maintained on a relatively small percentage of the Division's land.

Conservation Management Practices for Wildlife Management

Contents: Given that the forest management program described in this plan can result in substantial changes in wildlife habitat, one of the key elements of the wildlife management program is recommending CMP's and specific actions to minimize the negative impacts and maximize the benefits of MDC's silvicultural operations, on wildlife.

Key Points: MDC will maximize benefits and minimize negative impacts on a variety of wildlife species by: observing buffer zones around rare species habitats, maintaining and encouraging a variety of mast-producing plants, providing a continuing supply of good to excellent snag and den trees and maintaining a range of sizes and types of downed woody material.

Population or Impact Control Plans

Contents: Due to their potential negative impacts on water quality, forest conditions, or infrastructure integrity, certain wildlife species require direct management attention. In this section, specific management recommendations are described for beaver, gulls, geese and muskrat.

Key Points: Beaver management issues within the Wachusett watershed can be broken down into two categories: water quality protection and damage to structures or resources. There is a consensus in the scientific community that beaver and muskrat can play an important role in the transmission of harmful pathogens to humans through water supplies. Beaver and muskrat are intensively managed by the Division when colonies are located within the defined Wachusett Pathogen Control Zone, which is a protection zone around the reservoir close to the intake. Beaver are managed outside this protection control zone on a case by case basis where water quality may be threatened. Outside of water quality issues the Division will restrict management of beavers to activities that threaten water supply infrastructure, roads or rare and uncommon plant communities. A program of harassment of gulls and geese using non-lethal means will be carried out with the goals of moving congregations of these birds away from the northern portion of the reservoir.

Active Management for Selected Wildlife Species

Contents: Most active management is focussed on providing habitat or conditions for rare or endangered species, in areas that do not affect water quality.

Key Points: Statewide, there is widespread concern about losses of habitat for species that utilize early successional habitat and closed canopy mature forest. While large-scale even-aged forest management may run counter to watershed protection objectives, there may be limited opportunities for the Division to actively manage for these habitats.

Cultural Resource Management Plan

Contents: The importance of policy with regard to cultural resources is emphasized.

Key Points: Without appropriate controls, forest management programs can be detrimental to archaeological resources. The MDC's Cultural Resource Management Program is a reviewing process that assesses the impacts that timber harvesting could have on archaeological resources should they exist on any given operation. A need for a comprehensive historic site inventory within the Wachusett watershed is identified.

VI. Research, Inventory and Monitoring Needs

Contents: Research needs are identified in the general areas of forests, forestry, wildlife and cultural resources.

Key Points: A variety of research topics are identified to aid the Division in its efforts to better manage the Wachusett watershed.

VII. Public Involvement

Contents: Public input is an important component in the effective management of MDC/DWM properties. A strategy for public involvement is outlined.

Key Points: Progress on implementation of the Wachusett land management plan will be presented as a component of an annual Wachusett public meeting. It is the intention of the agency that land management on MDC watershed properties will be an adaptive management activity.

Summary

The Wachusett Land Management Plan, outlined above, represents a comprehensive approach to the effective management of Wachusett watershed lands for the next ten years. This plan incorporates a large body of research, literature and staff expertise on a focused goal of protecting and enhancing the natural filtration capabilities of the 16,000 acres of MDC watershed land surrounding the Wachusett Reservoir. The MDC/DWM staff believe that this plan has been well researched and constructed to serve as a model for other New England water supply and conservation land managers.

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1 Introduction, Mandates, and Statement of Mission

1.1 Introduction: Wachusett, Unique Among MDC Watersheds

The Wachusett Reservoir was created in 1906 to augment supplies of clean drinking water for the ever-growing population in metropolitan Boston (Figure 1). It has been a source of drinking water continuously since 1907. Damming the south branch of the Nashua River in Clinton created the reservoir. With a 65 billion-gallon capacity, the Wachusett Reservoir was the largest reservoir in the world at the time that it was built (Massachusetts Board of Health 1895:129). The Reservoir has a surface area of approximately 6.5 square miles and is supplied by a 110-square mile watershed encompassing portions of 12 towns. In 1946, the Wachusett Reservoir was supplemented by the Quabbin Reservoir, due to ever-increasing demands for water from the continued growth of metropolitan Boston. Water travels from the Quabbin Reservoir via an aqueduct to the Wachusett Reservoir, continuing through the Cosgrove intake and on towards metropolitan Boston. In the three decades that separate the construction of the Wachusett and Quabbin Reservoir systems, the likelihood of development pressures around the reservoirs made it clear that long-term protection would require the purchase of a significant portion of the watershed. Unlike the largely protected Quabbin Watershed, the Wachusett Watershed was constructed without this lasting buffer. Aggressive and largely successful efforts have been made in recent years to correct this flaw in the system, and currently more than 25% of the Wachusett watershed is protected from further development. Nonetheless, enormous developmental pressures and more intensive use on privately owned lands within the Wachusett watershed continue to pose greater external water quality threats than on other MDC watersheds. This document outlines a Land Management Plan for protecting and managing MDC owned lands within the Wachusett Reservoir Watershed in the context of these pressures.

1.2 Agency Mission and Mandates

The Metropolitan District Commission (MDC), Division of Watershed Management (DWM), and the Massachusetts Water Resources Authority (MWRA) supply drinking water to 40 communities in the metropolitan Boston area as well as to several communities adjacent to MDC/DWM reservoirs. MDC/DWM is responsible for collection and safe storage of water, protection of reservoir water quality, and management of the watersheds. MWRA is responsible for treatment and transmission of the water supply.

The MDC/DWM manages the Wachusett Reservoir and associated watershed properties. The MDC is a multi-faceted state agency within the Executive Office of Environmental Affairs, and is charged with coordinating the enhancement of the quality of living within the metropolitan Boston area. Chapter 372 of the Acts of 1984 established the DWM and provided its primary mandate. Among other things, this act directed the Division to "…utilize and conserve…water and other natural resources in order to protect, preserve and enhance the environment of the commonwealth and to assure availability of pure water for future generations." In addition, the DWM was directed to periodically prepare watershed management plans that shall provide for "…forestry, water yield enhancement and recreational activities."

In order to meet the above legislative mandates, the DWM has established programs in Environmental and Water Quality, Engineering and Construction, Infrastructure Maintenance, Public Education, and Natural Resource Management. The long-term goals of the DWM are to:

- assure availability of clean water for present and future generations,
- effectively manage, protect, conserve and enhance the natural and structural resources under the responsibility of the DWM to ensure public health and safety,
- prevent adverse environmental impacts that could degrade watershed resources,
- provide educational programs in order to protect watershed resources,
- manage or conduct research that guides and assists the effective management of watershed resources,
- formulate emergency contingency plans that address existing and potential threats to DWM resources.

1.3 Plan Overview

The Division of Watershed Management's primary purpose is the long term protection and maintenance of water quality. Bearing this goal in mind, the land management plan was laid out to outline management objectives to establish and maintain the most effective and practical watershed cover in order to maximize the natural filtering capability of the lands surrounding the Wachusett Reservoir. The plan also identifies the need to protect lands through acquisition that are considered most sensitive with respect to protecting drinking water quality in the watershed. Other important natural and cultural resource components are incorporated into the plan, including wildlife and non-forested MDC land management.

This plan primarily focuses on management over the next ten years, but it also projects the forest cover and watershed conditions 60 years into the future. The importance of this long range view is that it plans for the future integrity of the "land/forest filter" in the face of such events as hurricanes, floods, fires, insect and disease outbreaks, environmental pollution, and other impacts unknown to managers today. The plan is written as an MDC/DWM guidance document for land management activities, and also will serve as a tool for involving the public in the development of land management objectives and strategies.

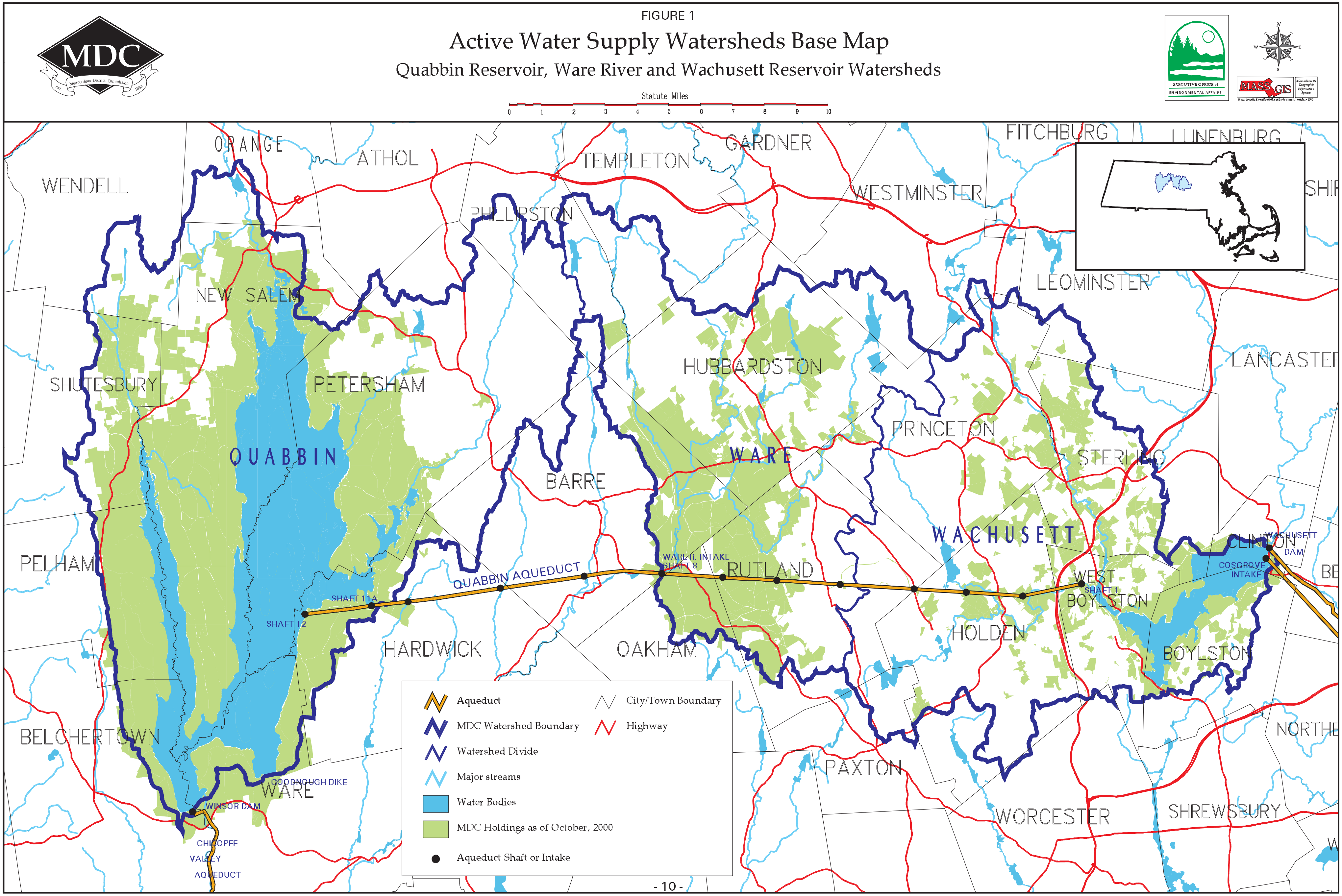
As with other Division land management plans, the Wachusett Plan calls for the maintenance of a species-diverse, multi-aged, multi-layered forest cover on much of the watershed. A significant difference between the Wachusett Reservoir watershed and the watersheds of the Quabbin Reservoir and Ware River is the regular interface that MDC lands have with private properties. Newly acquired properties must be managed not only from a water protection standpoint but also by taking into account such other factors as former property usage, wildlife considerations, and aesthetic and cultural resource values. This plan should be viewed as an "adaptive watershed management plan" to be applied but updated and modified as new properties are added and new information comes to light.

The plan itself includes sections on: 1) a Description of Wachusett Watershed Resources; 2) Research-based Principles Guiding Watershed Management; 3) a Statement of the Division's Watershed Management Goals; 4) Management Plan Objectives and Methods; 5) Research Needs; and 6) Public Involvement. The plan is written so that the management plan components are based on sections that precede them.

FIGURE 1

Active Water Supply Watersheds Base Map

Quabbin Reservoir, Ware River and Wachusett Reservoir Watersheds



2 Description of Wachusett Watershed Resources

2.1 Wachusett Watershed Ownership and Land Use

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

2.1.1 Current Land Uses

Land cover, land use and population density for the Wachusett, Quabbin, and Ware watersheds are shown on Table 1 and a land cover, land use map is presented in Figure 2. Although the watershed system is sparsely developed, the level of developed land is lowest in the Quabbin watershed and becomes more developed and populated eastward to the Wachusett watershed. No wastewater treatment plants or industrial discharges exist within any of the three watersheds.

TABLE 1. LAND COVER, LAND USE, AND POPULATION DENSITY OF MDC WATERSHEDS

Land Cover / Land Use by %, Excluding Reservoir Surface Areas				
	Quabbin Reservoir	**Ware River**	**Wachusett Reservoir**	**Combined**
Forest	87	75	67	77
Wetland	6	11	8	8
Agriculture	3	5	8	5
Residential	1	3	9	4
Commercial/ Industrial	0.1	0.2	0.6	0.3
Open Water	0.3	3	2	2
Other	3	4	7	4
Persons per sq.mi.	16	77	284	109

Source: MDC, MWRA, and CDM (1997)

TABLE 2. WACHUSETT RESERVOIR WATERSHED LAND OWNERSHIP AND LAND COVER / LAND USE

	MDC		**Other EOEA**		**Other Protected**		**Total Protected**		**Private**		**Total**	
	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%	Acres	%
Forest	12,458.3	17.6	3,111.0	4.4	5,213.3	7.4	20,782.6	29.4	26,392.7	37.3	47,175.3	66.7
Wetland	1,640.3	2.3	256.4	0.4	583.7	0.8	2,480.4	3.5	2,936.0	4.1	5,416.4	7.7
Agriculture	899.4	1.3	347.1	0.5	176.6	0.2	1,423.1	2.0	3,970.8	5.6	5,393.9	7.6
Residential	75.7	0.1	7.8	0.0	24.2	0.0	107.7	0.2	6,081.7	8.6	6,189.4	8.7
Com/Ind	24.9	0.0	1.3	0.0	13.3	0.0	39.5	0.1	746.6	1.1	786.1	1.1
Open Water	351.1	0.5	83.7	0.1	1,012.7	1.4	1,447.5	2.0	162.5	0.2	1,610.0	2.3
Other	1,042.7	1.5	44.4	0.1	634.3	0.9	1,721.4	2.4	2,474.5	3.5	4,195.9	5.9
Total	16,492.4	23.3	3,851.7	5.4	7,658.1	10.8	28,002.2	39.6	42,764.8	60.4	70,767.0	100.0

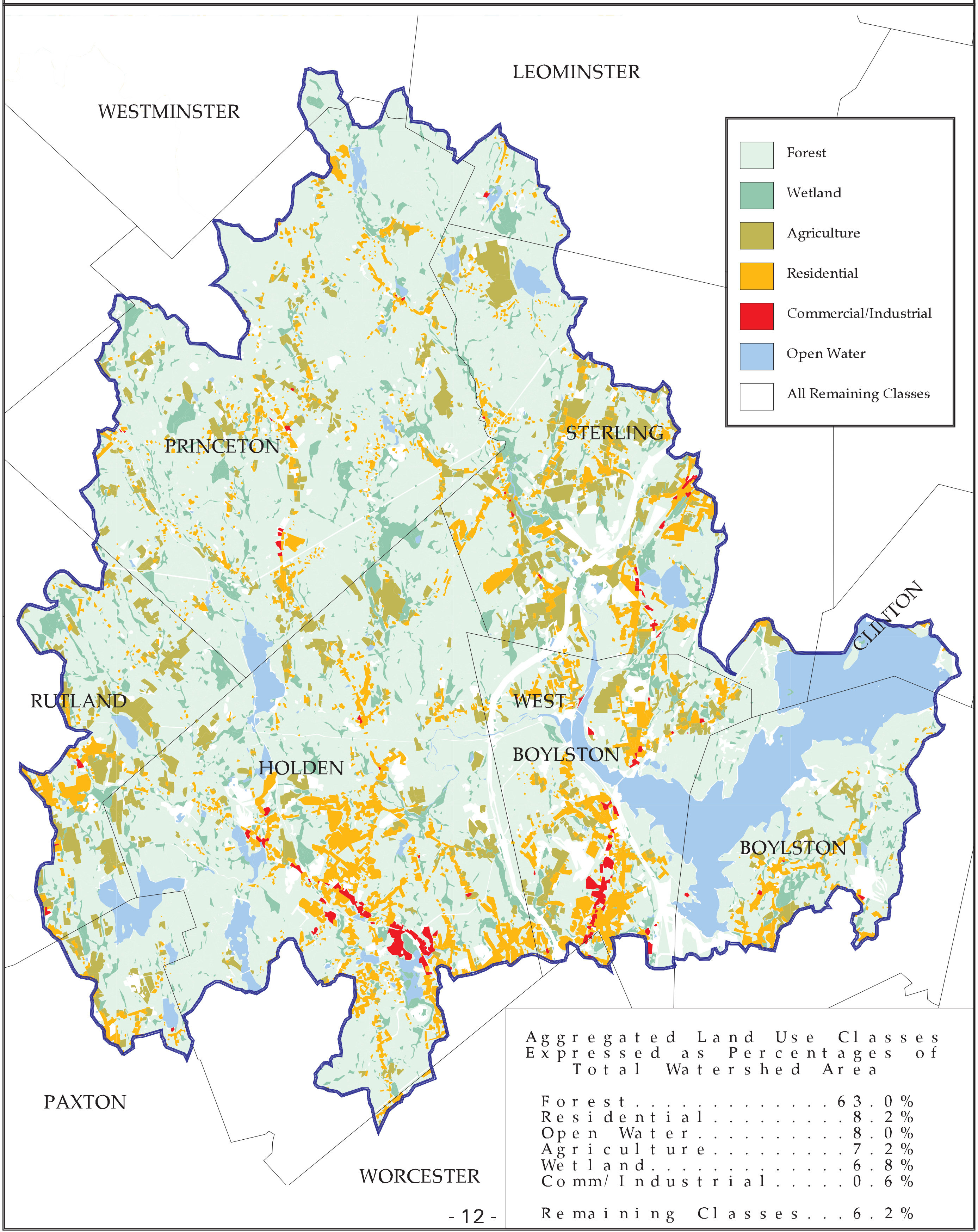
FIGURE 2

Aggregated Land Use Classifications

Wachusett Reservoir Watershed

Statute Miles

0 1 2 3 4 5



Aggregated Land Use Classes Expressed as Percentages of Total Watershed Area

Forest	63.0%
Residential	8.2%
Open Water	8.0%
Agriculture	7.2%
Wetland	6.8%
Comm/Industrial	0.6%
Remaining Classes	6.2%

The main land cover in all watersheds are forests and wetlands, totaling 75% in Wachusett, 93% in Quabbin, and 86% in Ware. The largest land uses are residential and agriculture. Residential land use is mostly low density and is most extensive in the Wachusett 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. In the Wachusett watershed, the subbasins most developed are Scarlett, West Boylston, and Gates. These subbasins are located in the southeastern part of the watershed, along Gates Brook and West Boylston Brook.

In 1997, Comprehensive Environmental inventoried agricultural sites for DWM. These sites include dairy/ livestock farms (varying from several medium-size dairy farms to sites with two to ten animals), grazed land (pastures where livestock roam), and a variety of crop farms (orchards, truck crops, field crops, nurseries, Christmas tree farms). Collectively, most of the dairy/livestock farms in the watersheds are small, with many hobby farms and residential properties with horses.

2.1.2 Protected Lands

Overall, the MDC owns and/or directly controls about 42% of the entire watershed system, exclusive of the reservoirs themselves. MDC owns approximately 57% of the Quabbin watershed, 37% of the Ware River watershed and 26% of the Wachusett watershed (Table 3). Other state agencies, non-profit land conservation organizations and municipalities own and protect another 21% of the combined watersheds. Figure 3 shows the MDC-owned and other protected lands in the watersheds.

TABLE 3. MDC AND OTHER PROTECTED OPEN SPACE

	Open Space as % of Watershed*		
Watershed	MDC-Owned	Other Protected**	Total Protected
Quabbin Reservoir	57	18	75
Ware River	37	20	57
Wachusett Reservoir	26	26	52
Combined	42	21	63

***** Watershed area excluding reservoir surface.
****** Includes lands owned by other state agencies, local government, and private entities.

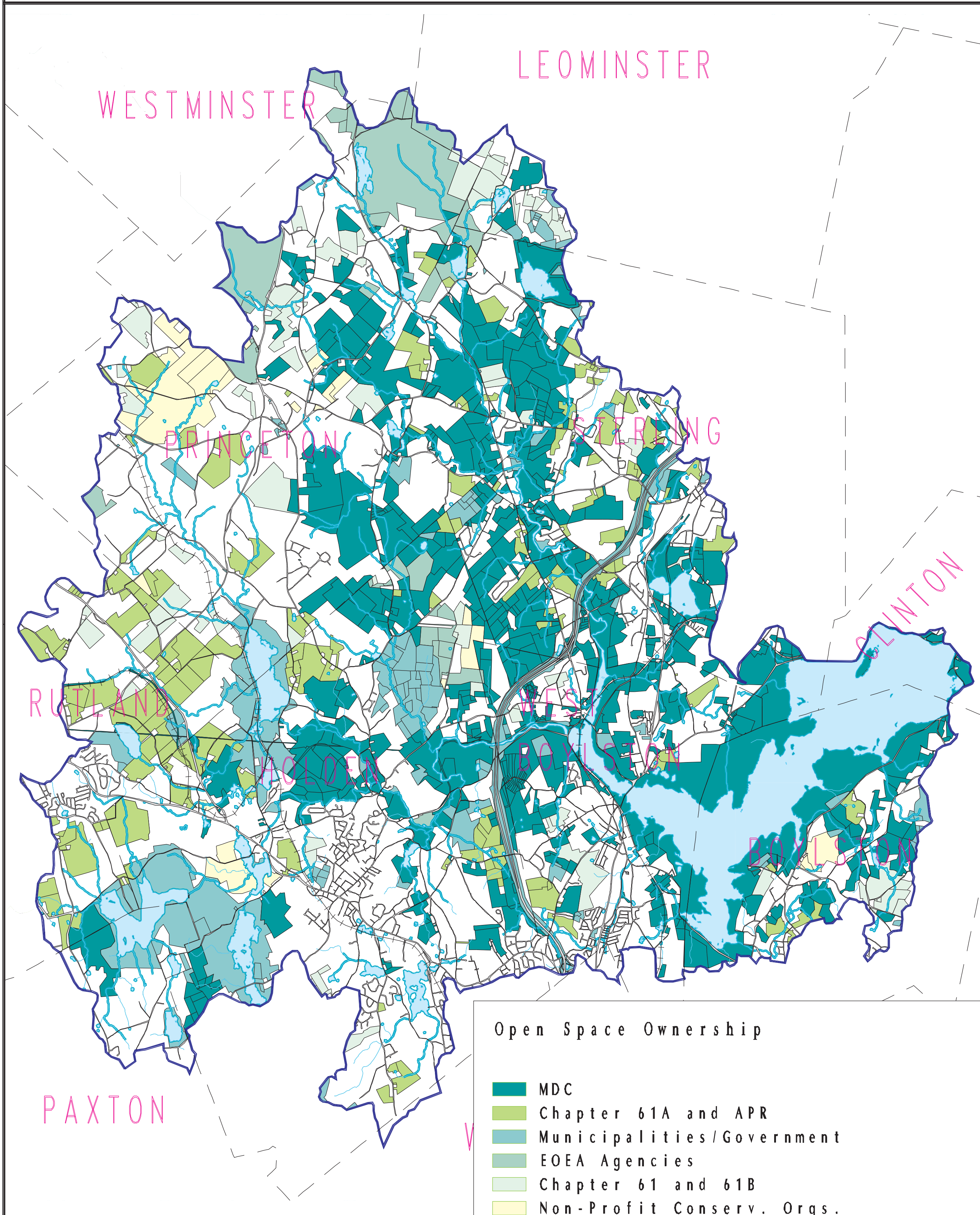
FIGURE 3

Protected Open Space Ownership

Reflecting MDC Acquisitions Through October, 2000

Statute Miles

0 1 2 3 4 5



2.2 Physical Characteristics of Wachusett Lands Under MDC Control

2.2.1 Geology

2.2.1.1 Regional Context and Bedrock Geology

A 1992 MWRA report by Geologist David Ashenden states: "Massachusetts is a part of the northern Appalachians which consist of a variety of rock types ranging from slightly deformed sedimentary rocks to those that have been severely deformed and metamorphosed. Numerous igneous intrusions are also included. The rocks range from Late Precambrian to Early Mesozoic in age. The area is the product of several orogenies involving plate accretion during the Paleozoic. Since that time prolonged erosion has removed literally thousands of feet of rock exposing the roots of old mountains. Locally younger and less deformed rocks are present primarily in the Connecticut valley and along the coastal plains."

At least three major geological blocks, delineated by fault lines, intersect the watershed: the Nashoba block or terrane, the Merrimack block or trough, and the Kearsarge-Central Maine synclinorium. The farthest east of these is the Nashoba block, consisting of volcaniclastic rocks and granitoid intrusions. The Cosgrove Aqueduct falls almost entirely within the Nashoba block. Heading west, the Nashoba is separated from the Merrimack block by the Clinton-Newbury fault. The Merrimack block (also known as the Merrimack trough) consists primarily of quartz-rich metamorphic rocks, and includes the Ayer Granite intrusions of the Oakdale Formation. The Ayer Granite has been aged at approximately 433 million years old, placing the Oakdale Formation as not younger than the Early Silurian period of the Paleozoic era. The next block to the west appears to be the Kearsarge-Central Maine synclinorium, although the contact between this block and the Merrimack has not been well defined, and may be obscured by the granites of the Fitchburg Plutonic Complex. These granites intruded between these two blocks at least 30 million years after the formation of the Ayer Granite.

Within the Merrimack block, there are three formations of note in the Wachusett Reservoir area: the Tower Hill, Oakdale, and Worcester Formations. The Tower Hill Formation consists of fine-grained quartzite and phyllite. The majority of the Oakdale Formation is finely laminated interbedded siltstones, but also includes quartzite, calcareous quartzite, siltstone, calcareous siltstone, and schist. The Worcester Formation is comprised of pelitic and aluminous phyllite, granulite, and schist. Of these formations, the Oakdale is the most extensive rock unit.

2.2.1.2 Surficial Geology

The Wachusett Reservoir watershed has been subjected to repeated glaciation, which has resulted in the creation and mixing of till deposits formed by the tremendous erosional power of glacial ice. The Ashenden report describes the presence of at least two layers of glacial tills on the watershed, the lower till, also referred to as drumlin till, and the upper till, which is ground moraine. The drumlin till is the core of true drumlins and some of the local hills near Wachusett Reservoir, and is considered to have occurred before the most recent (Woodfordian) glacial advance. The retreat of the Woodfordian glaciers occurred about 10-11,000 years ago, and left an upper till of ground moraine. Where the Woodfordian glaciers eroded the edges of the drumlin till, there was also mixing of the lower and upper tills. In the uplands, the thickness of the tills ranges from zero where bedrock is exposed to many feet in thickness.

In the valleys, these tills are covered by outwash sands and gravels, which have altered the drainage characteristics of these areas and have direct effects on vegetation types.

2.2.2 Soils

In the Wachusett watershed, the predominant soils found are Hinkley-Merrimack-Windsor, Paxton-Woodbridge-Canton and Chatfield-Hollis. Additional soil types are found in the upper watershed, including soils in the Peru, Marlow, Montauk, Ridgebury, and Whitman series, as well as Bucksport and Wonsqueak mucks. Many of these soils are well drained to excessively well drained, including the Hinkley-Merrimack-Windsor soils on outwash plains, and the Canton and Chatfield-Hollis soils on uplands. These soils occur on gently sloping to moderately steep areas and are very deep, except for Chatfield-Hollis soils, which typically have a depth to bedrock of only a few feet. Other soils are poorly drained, including the Paxton-Woodbridge, Peru, Marlow, Montauk, Ridgebury and Whitman soils, as well as the Bucksport and Wonsqueak mucks. The permeability of most of these soils is limited by a substratum present a few feet below the surface, except for Bucksport and Wonsqueak mucks, which are organic soils. Some of these soils occur in depressions and low flat areas in uplands and frequently contain water, including the Ridgebury, Whitman, Bucksport, and Wonsqueak soils. Others occur in gentle to strongly sloping areas throughout the watershed, including the Paxton-Woodbridge, Peru, Marlow, and Montauk soils.

The soils in the Wachusett, Quabbin, and Ware watersheds appear to have a low to moderate erosion potential. The predominant soils in the Wachusett watershed, for instance, have K factors ranging from 0.10 to 0.32 out of a possible range of 0.03 to 0.69, where higher values indicate higher erosion potential. Thus, soil erosion is only likely to be a problem in areas where slopes are greater than 15% or where vegetation has been disturbed. Because the great majority of the watersheds is forested and has slopes less than 15% (82% of the total watershed and 86% of the Wachusett Reservoir watershed), the extent of erosion prone areas is limited.

In the Wachusett watershed, areas with higher erosion potential are located near much of the Stillwater River; on Rowley, Ross, and Justice Hills in Sterling; and on much of the land south of Route 110 near the reservoir. Erosion has only been significant in a few of these locations: the area affected by the 1989 tornado, where vegetation was severely disturbed, and the steep bluffs on the east shore of the reservoir, where steep slopes coincide with thin vegetation and strong winds. (Revegetation and slope protection techniques have been used in these locations to reduce erosion.) No significant problems have occurred on erosion-prone areas that border tributaries.

According to the USDA Natural Resource Conservation Service, most soils in the Wachusett, Quabbin and Ware watersheds are not well suited for the disposal of wastewater through septic systems. Many soils that are well drained to excessively well drained tend to drain effluent too quickly to effectively filter it. On the other hand, soils that are poorly drained are not well suited for leach fields because they have slow permeability and water is usually present near the surface.

2.2.3 Hydrology

The hydrology of a watershed plays an important role in defining the water quality characteristics of its streams and lakes/reservoirs. The following sections describe the morphology of the reservoirs; the precipitation, evaporation, and streamflow patterns in the reservoirs watersheds; and the inflows and outflows and hydrodynamic characteristics of the reservoirs.

Figure 1 shows the watersheds of the Quabbin and Wachusett Reservoirs and the Ware River. The Sudbury Reservoir, located further east on the distribution system, is maintained as a backup emergency supply. The Quabbin and Wachusett Reservoirs receive the natural inflows of direct precipitation onto the reservoir surface, tributary rivers and streams (including baseflow, shallow subsurface flow, and saturated overland flow) and of overland flow from storm or snowmelt events. The Ware River may be diverted on a seasonal basis to Quabbin Reservoir through the Quabbin Aqueduct. Wachusett Reservoir, the terminal water supply reservoir, receives substantial transfers on an intermittent basis from Quabbin Reservoir.

2.2.3.1 Morphology

Wachusett Reservoir is a long and narrow reservoir. Morphometric characteristics (measurements of form and shape) of the Wachusett Reservoir are shown in Table 4.

TABLE 4. MORPHOMETRY OF WACHUSETT RESERVOIR

Attribute	Wachusett Reservoir
Volume Capacity	65 billion gallons
Surface Area	6.2 sq. mi.; 3,968 acres
Watershed Area	117 sq. mi.; 74,880 acres
Shoreline	37 miles
Length	8.5 miles
Maximum Width	1.1 miles
Mean Width	0.7 miles
Maximum Depth	128 feet
Mean Depth	49 feet
Normal Operation Range[1]	387-392 feet
Intake Depth	364 & 345 feet
Overflow Elevation	395 feet

[1]Datum used is Boston City Base (or 5.65 feet lower than USGS 1929 datum used for topographic mapping).

2.2.3.2 Precipitation and Evaporation

Annual precipitation is about 44 inches in the Wachusett watershed (MDC, MWRA, and Rizzo Associates, 1991b; MDC, MWRA, and Rizzo Associates, 1991a). 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 in lakes and reservoirs is usually lower. Annual evaporation in Wachusett Reservoir has been estimated as 22 inches (Brackley and Hansen, 1977), and more recently, as 24.5 inches (FTN, 1995). Monthly rainfall in the Wachusett watershed is nearly uniform, although it can vary significantly from year to year. Summer precipitation generally comes in high-intensity thunderstorms. Table 5 presents the ranges and averages in monthly precipitation for Wachusett Reservoir.

TABLE 5. MEAN MONTHLY PRECIPITATION AT WACHUSETT RESERVOIR

Month	Wachusett Reservoir (1897-1979)		
	Minimum (inches)	Maximum (inches)	Average (inches)
January	0.75	12.08	3.92
February	0.36	8.69	3.66
March	0.06	1.04	4.22
April	0.86	10.67	4.02
May	0.62	10.75	3.76
June	0.48	12.01	3.88
July	0.84	9.47	3.87
August	0.80	13.31	3.87
September	0.15	11.09	3.85
October	0.09	10.83	3.60
November	0.86	9.03	4.28
December	0.75	9.36	4.03

Source: MDC, MWRA, and Rizzo Associates (1991a, 1991b)

2.2.3.3 Streamflow

Streamflow in the Wachusett watershed, as in most of New England, has significant seasonal changes. 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.

In addition, streamflow also varies in response to rainfall events. According to the Wachusett Reservoir Water Quality: Interim Assessment (CDM, 1995b), stormwater flows in the Wachusett tributaries tend to be several times higher than baseflow and the magnitude of loading during stormwater conditions tends to dwarf that during baseflow conditions. Furthermore, time of travel from the upper reaches of the watershed to the reservoir tends accelerate during stormwater conditions. Time-of-travel maps for baseflow and stormwater conditions are currently being developed as part of the Wachusett

Watershed Stormwater Management Plan (CDM, 1998). Preliminary results show that baseflow stream velocities during the early summer (June) are about 0.3 ft/s, while in the spring (March-April) baseflow stream velocity ranges between 0.4 and 2 ft/s.

DWM is currently studying the influence of groundwater levels on streamflow in the watershed. Groundwater level data has been collected since 1996. Preliminary results show that high groundwater typically occurs for an extended period in the spring and in spikes during the fall, and that there is a strong relationship between high groundwater and increased baseflow in the tributaries. In areas to be sewered, these results will be used in conjunction with future monitoring to assess the impact that sewering will have on tributary baseflows.

2.2.3.4 Inflows and Outflows

Inflows and outflows to Wachusett Reservoir are listed in Tables 6 and 7. Tributaries to Wachusett Reservoir were not gauged until 1994. Since then, continuous recording gages have been installed in the Stillwater and Quinapoxet Rivers, and eight staff gages have been installed in other tributaries by the USGS for DWM. Because of the limited tributary flow data, streamflow records for the tributaries were synthesized using flows gauged in nearby rivers and streams and were transposed based on the flow per unit watershed area. FTN Associates (1995) describe the method. Average flows recorded since 1994 at the new gage locations agree well with those derived from the synthesized streamflow records.

MDC transfers from Quabbin Reservoir account for over 50% of the average annual Wachusett inflow. Transfers of up to 550 million gallons per day (mgd) are made as needed to maintain the Wachusett Reservoir surface levels and for water quality reasons. These transfers, which occur primarily in the summer and fall months, are not continuous and last for a period of several weeks at a time.

Inflows from Wachusett Reservoir's main tributaries, the Stillwater and Quinapoxet Rivers, account for another 30% of the average annual inflow. The remaining inflows originate in several small subwatersheds or flow directly into the reservoir from shoreline areas and groundwater inputs.

T. Kyker-Snowman

Tributary inflow

TABLE 6. INFLOWS TO WACHUSETT RESERVOIR

	Area (sq.mi.) [1]	Annual Flow (cfs)[2]	Annual Flow (mgd)[2]	% Annual Flow
Inflows:				
Quabbin Reservoir Transfers	149	235	152	51
Quinapoxet River	56	84 [3]	54 [3]	18
Stillwater River	32	65	42	14
Gates Brook	3	7	5	1.3
French Brook	2	4	3	0.9
Malagasco Brook	1.1	2	1	0.5
Malden Brook	1.3	3	2	0.6
Waushacum Brook	8	16	10	4
Direct Inflow	9	19	12	4
Direct Precipitation	6	22	14	5

TABLE 7. OUTFLOWS FROM WACHUSETT RESERVOIR

	Area (sq.mi.) [1]	Annual Flow (cfs)[2]	Annual Flow (mgd)[2]	% Annual Flow
Outflows:				
Cosgrove Aqueduct	NA	411	266	92
Spillway	NA	24	16	5
Evaporation	6	11	7	2
Other Outflows [4]	NA	9	6	2

[1] Areas obtained from MDC, MWRA, and Rizzo Associates (1991b).
[2] Inflows, outflows, and evaporation were estimated for 1987, 1990, 1992, and 1994 during the modeling study by FTN (1995). Values presented are averages for the years that were included in this study. Tributary inflows were estimated by gage transposition. MDC transfers from Quabbin Reservoir and outflows were obtained from MDC records. Evaporation was estimated using CE-QUAL-W2. Cosgrove Aqueduct outflows have declined, since this data set, to about 240 mgd.
[3] The Quinapoxet River contributes less flow than its drainage area would suggest, since water from 36% of its drainage area is diverted to the City of Worchester's reservoirs and is only released to the Quinapoxet River during periods of high flow.
[4] Other outflows include Clinton and Wachusett Aqueduct withdrawals and downstream releases.

The largest outflow from Wachusett Reservoir is the Cosgrove Intake withdrawal, which accounts for more than 90% of the water leaving the Reservoir. Other outflows from the Reservoir include flow through the Reservoir's spillway (which occur when the reservoir is full or almost full), evaporation and other minor outflows (Clinton withdrawals, Wachusett Aqueduct withdrawals at the dam, and downstream releases to the Nashua River).

2.2.3.5 Hydrodynamics

The basic hydrodynamic characteristics of Wachusett Reservoir include the following:

- Moderate to long residence times, defined as the reservoir volume divided by the annual inflows. Residence time at the Wachusett Reservoir is about 6 months, although this would double to about one year if Quabbin flows were not diverted into the reservoir.

- Wachusett Reservoir is a dimictic lake, turning over or mixing completely between fall overturn (usually in October) and the spring onset of stratification (usually in April).

- The Reservoir develops some ice cover, usually between January and March, but occurring as early as December or as late as April.

- Inflows tend to move into different depths at the reservoir depending on seasonal temperature differences between the tributaries and the reservoir. Tributary inflows will typically be warmer than the reservoirs in the spring and enter the reservoirs' epilimnion[1], and cooler than the reservoirs in the summer and fall and enter the reservoirs below the epilimnion. MDC transfers from Quabbin Reservoir into Wachusett Reservoir typically enter at the top of the hypolimnion.

- The hydrodynamics of Wachusett Reservoir were the subject of an extensive study by CDM and FTN Associates (CDM, 1995a; CDM, 1995b; FTN, 1995)[2]. This study made some important findings:

- Thomas Basin is an important feature of the reservoir, helping to preserve high water quality. The basin is separated from the main body of the reservoir by the Route 12 causeway, which constricts the width from approximately 1,000 feet to just over 50 feet. Most of the inflow to Wachusett Reservoir (about 90%) passes through Thomas Basin, including Quabbin transfers and Stillwater and Quinapoxet River inflows. Under normal tributary flow conditions (non-storm and Quabbin not transferring), the residence time in the basin can be on the order of several weeks. Even when Quabbin is transferring, the residence time in Thomas Basin is about 4 days, a sufficient period of time to allow the settling of solids present from the tributaries. Thus, Thomas Basin is an effective sedimentation basin for inflowing solids and their adsorbed contaminant load (*e.g.*, nutrients, bacteria, and possibly pathogens). While the turbidity of the inflowing streams is already low, the reduction of solids load (estimated to be about 85 to 90% of entering solids) certainly contributes to the high quality of water in the main body of the reservoir.

- Large inflows, including Quabbin transfers and storm flows from the main tributaries, can travel through the reservoir more quickly than would be expected from its residence time (about 6 months).

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[1] Stratified lakes are described as having three zones: the upper epilimnion, the metalimnion, forming a boundary between waters of different temperature; and the bottom hypolimnion.

[2] These studies were conducted as part of the MEPA process for the MWRA► s Walnut Hill Water Treatment Plant and underwent substantial public and citizen advisory committee review.

The hydrodynamic model for Wachusett Reservoir was used to estimate travel times to the intake during the stratified period for Quabbin transfers and Stillwater River stormflows with and without wind-induced transport. Quabbin transfers were estimated to reach the intake in 10 to 15 days. With winds in the prevailing direction, storm flows from the Stillwater River, when residing on the reservoir's surface waters, were estimated to reach the intake in 10 to 15 days, and in 28 to 30 days without wind. Tributary storm flows are more likely to reside in the reservoir's surface waters in the spring, when their water is warmer than the reservoir. Wind tends to accelerate the transport of these flows because the prevailing wind direction is down the long axis of the reservoir.

- Small inflows into the main body of the reservoir, including storm flows from smaller tributaries (such as Gates, French, Malagasco and Malden Brooks) tend to mix with the reservoir's water and not reach the intake as defined flows because they have insufficient volume and momentum to move through the reservoir.

- Quabbin transfers during the stratified period undergo limited mixing as they move through the reservoir and retain a distinct signature centered at elevations 355 and 360 feet Boston City Base (BCB) at the Cosgrove Intake. Because the intakes are located at 340 and 360 feet BCB, much of the water withdrawn when transfers are occurring is diluted Quabbin water.

- Withdrawn water at Wachusett Reservoir appears to originate from the epilimnion/metaliminion rather than the metalimnion/hypolimnion due to the presence of a submerged cofferdam. Wachusett Reservoir has intakes at two different depths, 360 feet BCB and 340 feet BCB. While the lower intake at 340 feet BCB is the only one currently operated, measured outflow temperatures are warmer than those predicted by the hydrodynamic model at this depth, matching those predicted by the model at elevation 360 feet BCB. This difference appears to be caused by the presence of a submerged cofferdam, used during construction of the intake building but not removed. The cofferdam appears to function as a weir, causing water drawn by the intake to be effectively drawn from higher in the water

2.2.3.6 The Quabbin "Interflow" in Wachusett Reservoir

The transfer of water from Quabbin to Wachusett Reservoir via the Quabbin Aqueduct has a profound influence on the water budget, water column profile characteristics, and hydrodynamics of the Wachusett Reservoir. During the years 1995 through 1999, the amount of water transferred annually from Quabbin to Wachusett ranged from a volume equivalent to 44 percent of the Wachusett basin up to 90 percent. The period of peak transfer rates generally occurs from June through November. However, at any time of the year, approximately half of the water in the Wachusett basin is derived from Quabbin Reservoir.

The peak transfer period overlaps the period of thermal stratification in Wachusett and Quabbin Reservoirs. Water entering the Quabbin Aqueduct at Shaft 12 is withdrawn from depths of 13 to 23 meters in Quabbin Reservoir. These depths are within the hypolimnion of Quabbin Reservoir where water temperatures range from only 9 to 13 degrees C in the period June through October. This deep withdrawal from Quabbin is colder and denser relative to epilimnetic waters in Wachusett Reservoir. However, due to a slight gain in heat from mixing as it passes through Quinapoxet Basin and Thomas Basin, the transfer water is not as cold and dense as the hypolimnion of Wachusett. Therefore, Quabbin water transferred during the period of thermal stratification flows conformably into the metalimnion of Wachusett where water temperatures and densities coincide.

The term interflow describes this metalimnetic flow path for the Quabbin transfer that generally forms between depths of 7 to 15 meters in the Wachusett water column. The interflow penetrates through the main basin of Wachusett Reservoir (from the Route 12 Bridge to Cosgrove Intake) in about 3 to 4 weeks depending on the timing and intensity of transfer from Quabbin. During the summer stratification period, the Quabbin interflow is conspicuous in profile measurements as a metalimnetic stratum of low conductivity. The interflow essentially connects Quabbin inflow to Cosgrove Intake in a "short circuit" undergoing minimal mixing with ambient Wachusett Reservoir water.

2.2.4 Topography

Mainly hilly, the topography of the Wachusett watershed encompasses flatter wetlands and flood plains, as well as mountainous terrain with exposed bedrock. The Wachusett watershed includes broader valleys and more wetlands than the watersheds further west. Elevations vary from 395 feet above sea level at Wachusett Reservoir to about 2,000 feet at Wachusett Mountain. 14% of Wachusett watershed, in widely scattered areas, contains slopes greater than 15%.

2.2.5 Developed/developable Areas

Excluding the reservoir, 75% (53,250 ac) of the Wachusett watershed is under forest or wetland cover, and 8% (5,680 ac) is under agricultural land uses. 52% of the watershed (excluding the reservoir surface) is currently protected, either through direct ownership by the MDC (26%) or other state/town agencies, or through protected status provided by private entities or regulations (e.g., Watershed Protection Act).

48% of the Wachusett watershed (excluding the reservoir) is "unprotected," i.e. available for development. Most of the undeveloped land is currently zoned for low density residential uses (1-2 acre minimum lot size). Commercial and industrial zoned lands represent a very small proportion of the watershed, and tend to be located near the town centers and major roads. No major development in the watershed is expected to occur in categories such as waste disposal, recreation, or major highways. Thus, future development in the watershed is expected to involve the gradual conversion of forested land into low-density residential land.

The cumulative amount of development that is expected in the watersheds is much lower than the current amount of available unprotected land. The rate of development depends on many social and economic factors, including development pressure, the need or willingness of current owners to sell their land, and population growth. For example, looking at the next 20-year period, projected population increases in the main towns within the Wachusett watershed (Boylston, West Boylston, Holden, Princeton, and Sterling) range from 5 to 26%.

Through its land acquisition program, MDC has purchased both undeveloped and developed lands in the Wachusett Reservoir watershed. Some types of developed properties that have been purchased include houses, a former gas station on Route 12 in West Boylston, gravel pits, and the Stillwater Farm located on Route 140 in Sterling. In addition, the former Metropolitan District Commission Police Station on route 70 in Clinton was kept by the agency after the police force was disbanded. There are numerous facilities and structures, along with other developed areas on the 16,000 acres that make up the MDC lands on the Wachusett Watershed. Some of these facilities are currently in use (e.g., the old stone church in West Boylston, as an interpretive site), while others are slated for removal (e.g., the concrete bathhouse in Clinton).

2.2.6 Other Open Lands

2.2.6.1 Recreational Fields

The town of West Boylston is permitted to utilize 10.3 acres of MDC land for recreational purposes. Located on either side of Thomas St. in West Boylston, the area is comprised of a softball field, a tennis court, a small basketball court and an open grass area used for a variety of purposes including youth soccer.

2.2.6.2 Fields/Non-forest

MDC owns approximately 953 acres of open upland scattered throughout the Wachusett Reservoir watershed and an additional 40 acres of fields outside of the watershed. There are approximately 270 acres of open wetland on MDC land in the watershed.

2.3 Wachusett Forest and Wildlife Conditions

2.3.1 Forest History

The landscape that confronted the Metropolitan Water Board in 1897, when work began on the construction of the Wachusett Reservoir, was very different from the Wachusett landscape today. Photographs from this time show wide open expanses of field and pasture with widely spaced pockets of forest visible from one end of the reservoir to the other. Farms and mills dominated the industry in the area. Forested land accounted for about 43% of the initial acreage (1,475 of 3,380 acres) taken by the MDC to construct the Wachusett Reservoir. Much of this land was occupied by young forest that originated with farm abandonment following the Civil War. The idea that forests are the source of high quality water was becoming ever more accepted during this time. New York set a precedent when it began in 1883 setting aside 1.25 million acres in the Adirondacks for the "preservation of the headwaters of the chief rivers of the state."

Once the decision was made that the newly acquired land, above the level to which the waters would rise behind the dam, should be covered in trees, the next decision would regard the character of this new forest. The fourth annual report of the Forestry Division of the United States Department of Agriculture stated in 1880:

> It is clear…that the influence of the forest, if any, will be due mainly to its action as a cover, protecting the soil and air against insolation and winds. That the nature of a cover, its density, thickness, and its proper position has everything to do with the amount of protection it affords, everybody will admit. A mosquito-net is a cover, so is a linen sheet or a woolen blanket, yet the protection they afford is different in degree and may become practically none…Just so with the influence of the forest; it makes all the difference whether we have to do with a deciduous or coniferous, a dense or open, a young low or an old high growth, and what position it occupies with reference to other elements, especially to prevailing winds and water surfaces.

Given that the forestry profession was in its relative infancy in this country, it was perhaps inevitable that the vision that the early managers had of a proper, organized forest would be based more on the European model of plantations rather than modeled on the far more complex character of the indigenous mixed-species forest. A Forestal Plan was developed that called for the creation of a road network, fire guard lanes and planting schemes. Plans were drafted as early as 1897 for "The Suggested Arrangement of Trees for Re-Foresting the Margins of the Wachusett Reservoir." Record Plans were created at a scale of 1"=300' that were ideal for recording tree planting. Two nurseries were established in 1898 to supply planting stock. Planting began in 1902. In the end, four and one-half million trees were planted from 1902 to 1946 (see species composition in Table 8). To the credit of the planners during this time, a remarkably wide variety of species were planted.

TABLE 8. PLANTING BY MDC, BY SPECIES, 1902-1946

Species	Percent of Total Planted	Species	Percent of Total Planted
White Pine	58%	Spruces	7%
Sugar Maple	14%	Arborvitae	5%
Red Pine	13%	All others	3%

78% (nearly 3.5 million) of all trees planted were conifers that were used to establish plantations (the vast majority of the arborvitae was planted as part of the shoreline hedge). The planting of nearly 650,000 sugar maples (all of which were natural seedlings "pulled" from the wilds of western Massachusetts) has resulted in an unusually high component of this species. In addition, red oak, American chestnut, ash, tamarack, hemlock and other species were planted. In 1906, 22,845 Douglas-fir seedlings were set out. Few are alive today although one is officially recognized as the largest in Massachusetts. Even giant sequoias (Sequoiadendron giganteum) were grown in the nursery for seven years until they died during the winter of 1918 with none ever planted out. Along with the seedlings, bushels of acorns and hickory nuts were heeled-in.

The records are, unfortunately, rather sparse regarding forest management during the first half of the 20th Century. The earliest annual reports refer to "improvement" operations typically described as, "The work of cutting out fruit and dead and undesirable trees." It is unknown if a professional forester was involved. The 1907 annual report mentions that all forestry related activities have been reclassified from construction to maintenance. In Fernow's 1903, Economics of Forestry, an improvement thinning is discussed as follows:

> The forester, instead of culling out the best kinds first, as the lumberman does, would take out undesirable ones first, and thus improve the composition of his crop. The material that results from these so-called "improvement cuttings" may sometimes not directly pay for the labor spent on them, but they are cultural operations, designed to put the property in more useful condition for the future, and hence they are at least indirectly profitable.

The term "improvement" seems to have been used rather loosely in the Annual Reports suggesting that a forester was not involved or at least not involved in writing the forestry section of the annual reports. In addition to describing proper improvement thinnings, "improvement" was most commonly used to describe work in preparing an already forested site for planting. It was also used when describing the cutting of young hardwoods or brush that interfered with the newly planted pines and the cutting of all understory vegetation within 100 feet of the highways (the "100 foot margins"). Regardless, a great deal of attention was paid to the forest around the Wachusett Reservoir for the first forty years of the last century and all of it with the intention of creating as ideal a forest cover for the production of high quality water as possible.

Unfortunately, there followed a period from about 1940 through the 1970's when little attention was paid the forest other than salvage work and planting immediately following the hurricane of 1938. This is precisely when the 1,045 acres of plantations that were established at a six-by-six foot spacing should have been receiving their initial thinning. Instead, what faced the first foresters in 1979 (the year of the first professionally administered timber harvest) were plantations then 40 to 70 years old that were severally overstocked, comprised of trees with short constricted crowns and sparse understories. Stands of this nature are highly susceptible to windthrow and disease and therefore were rather poor protectors of the water resource. The result could have been what one can see at the North Dike plantation, which was unique in having been first thinned in 1959 by the first Quabbin forester, Fred Hunt, and subsequently treated several times. The trees are well spaced, windfirm with deep crowns and excellent regeneration beneath.

From fiscal year 1980 through 2000, 3,306 acres of MDC forest at Wachusett have received silvicultural treatment (Table 9).

TABLE 9. FORESTED ACRES TREATED BY FISCAL YEAR

Year	Acres Treated	Year	Acres Treated
1979	292	1991	76
1980	124	1992	138
1981	146	1993	65
1982	279	1994	152
1983	222	1995	224
1984	251	1996	84
1985	141	1997	237
1986	67	1998	300
1987	41	1999	252
1989	82	2000	58
1990	75	**Total**	**3,306**

An additional 442 acres have received salvage treatment, the majority following Hurricane Gloria in 1985 and 1986 and a severe thunderstorm in 1989.

TABLE 10. ACRES SALVAGED BY YEAR

Year	1983	1985	1986	1989	1990	1992	2000	TOTAL
Acres	7	94	47	285	5	2	2	442

TABLE 11. ACRES TREATED BY SUB-BASIN

Sub-basin	Name	Acres
1	Res. Shoreline North (Gates 36 - Rt. 12)	547
2	Res. Shoreline South (Rt. 12 - Malag. Bk.)	207
3	Res. Shoreline East (Malag. Bk. - Gate 40)	615
4	Thomas, Quinapoxet and Stillwater Basins	271
5	French Brook	34
7	Malagasco Brook	13
8	Muddy Brook	4
9	Gates Brook	140
11	Malden Brook	45
12	Chaffins Brook	35
13	Asnebumskit Brook	2
14	Quinapoxet River	551
15	Trout Brook	73
16	Waushacum Brook	219
17	South Stillwater River	66
18	Middle Stillwater/Rocky Bk./Wilder Bk.	75
19	North Stillwater/ Justice Brook	27
20	Wachusett Brook	47
21	Off-Watershed Lands	335

2.3.2 Forest Types, Ages, and Conditions

2.3.2.1 Forest Types

The Wachusett forest is comprised of hundreds of individual stands. Each is defined as "a contiguous group of trees sufficiently uniform in species composition, arrangement of age-classes, and condition to be a distinguishable unit." Many of the differences between stands can be attributed to past land-use histories and stand origination. An easy prediction is that the stand type will change on the other side of the stone wall. These often abrupt stand boundaries will tend to blur as management and time allow the underlying ecological pattern to emerge.

Forest cover type maps have been created and updated by MDC foresters since the early 1980's. Table 12 shows the acres in these various forest types. Currently, these maps are made and updated by hand. However, within the next year, all of these maps will be converted to a digital format allowing for analysis using GIS technology.

TABLE 12. ACREAGE OF MDC-OWNED FOREST AT WACHUSETT BY TYPE

Forest Type	Acres	Percent
Mixed Oak	1909	16.9
White Pine-Oak	1725	15.3
Mixed Hardwoods	1516	13.4
White Pine-Hardwoods	1507	13.3
Red Maple	1147	10.1
White Pine	997	8.8
Oak-Hardwoods	992	8.8
Red Oak	947	8.4
Red Pine	146	1.3
Mixed Pine-Hardwoods	143	1.3
Northern Hardwoods	124	1.1
Hemlock-Hardwoods	122	1.1
Spruce	32	0.3
Total	***11,307***	***100***

2.3.2.2 Species Distribution

Species distribution is based on forest inventory completed by MDC foresters in 1998. Although over 40 species of trees were identified, five species account for 82% of the trees per acre and basal area per acre. These top five species are (listed in order by basal area): white pine, red maple, red oak, black oak and white oak. Other common species include white ash, red pine, hickory, black birch and eastern hemlock.

2.3.2.3 Size Distribution

The following charts illustrate the structural diversity of the Wachusett forest. However, none of these give a true indication of the age structure of the forest. Tree diameter is poorly correlated to age. Forest type map analysis gives some clue; trees of less than 40 feet in height occupy approximately 7.4%

of the forested acreage. The vast majority of these stands is the direct result of forest management operations, storm damage and field succession during the last 20-30 years. Taking into account the additional acres of small-scale unmapped young age-class areas throughout the forest, it can be conservatively estimated that not more than 10% of the forested acreage is in these young age-classes.

CHART 1. BASAL AREA BY SPECIES ON MDC LANDS ON WACHUSETT RESERVOIR WATERSHED

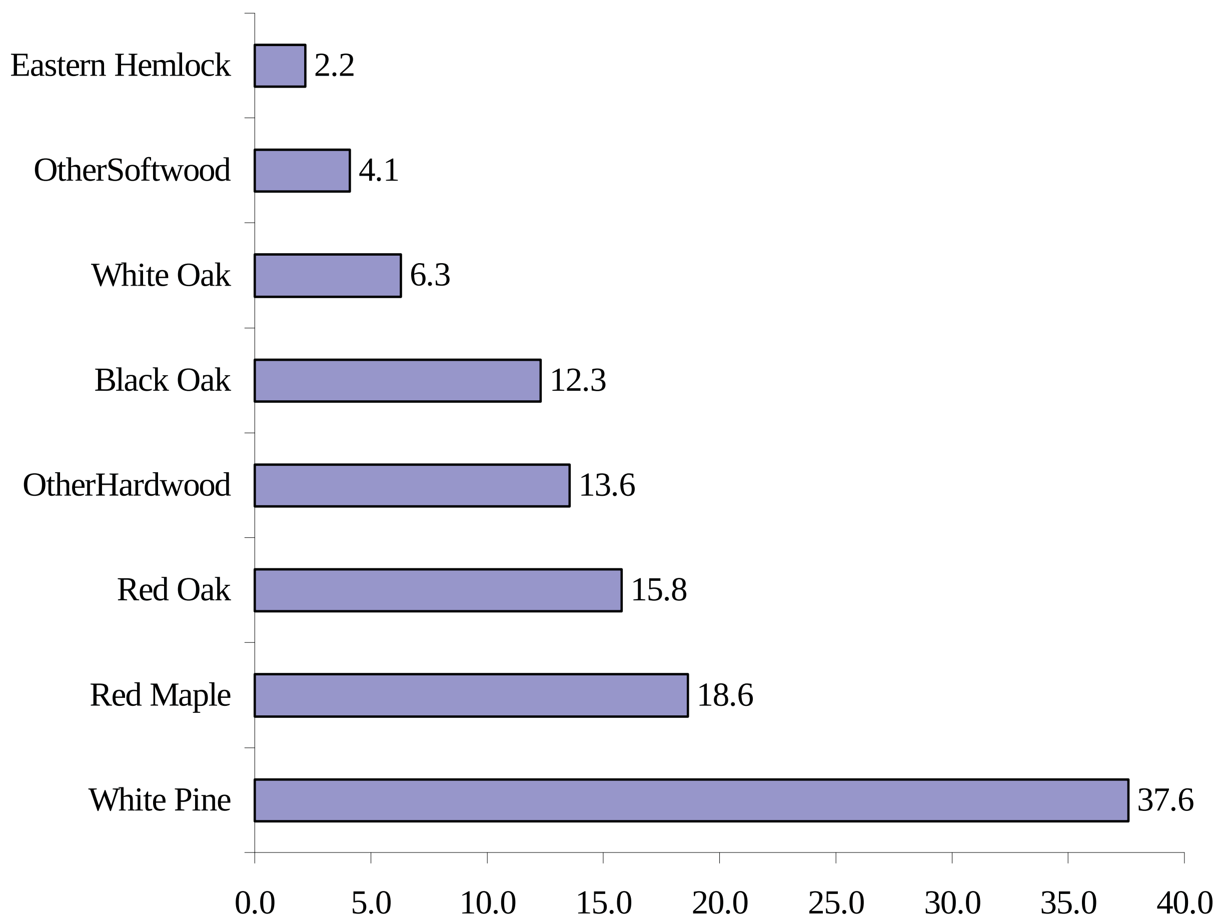


CHART 2. TREES/ACRE BY SPECIES, MDC LANDS ON WACHUSETT RESERVOIR WATERSHED

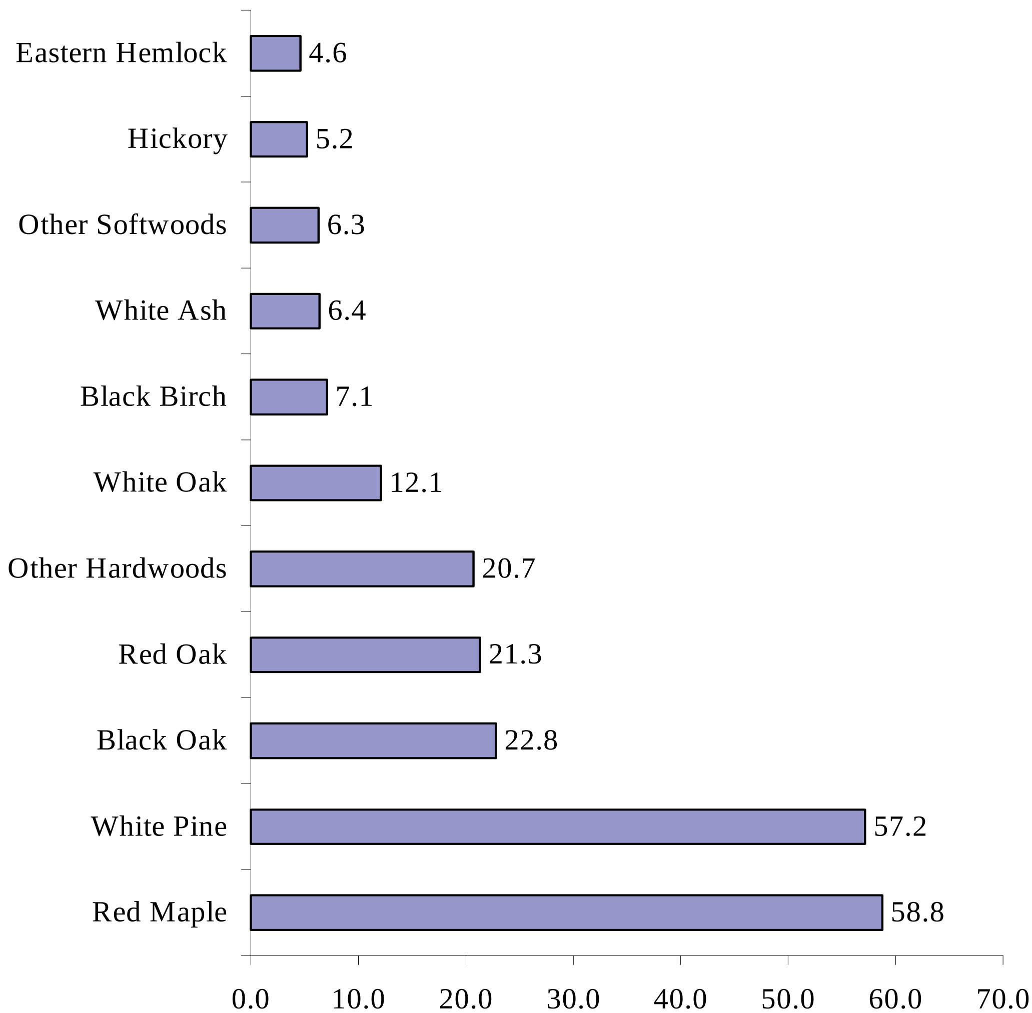
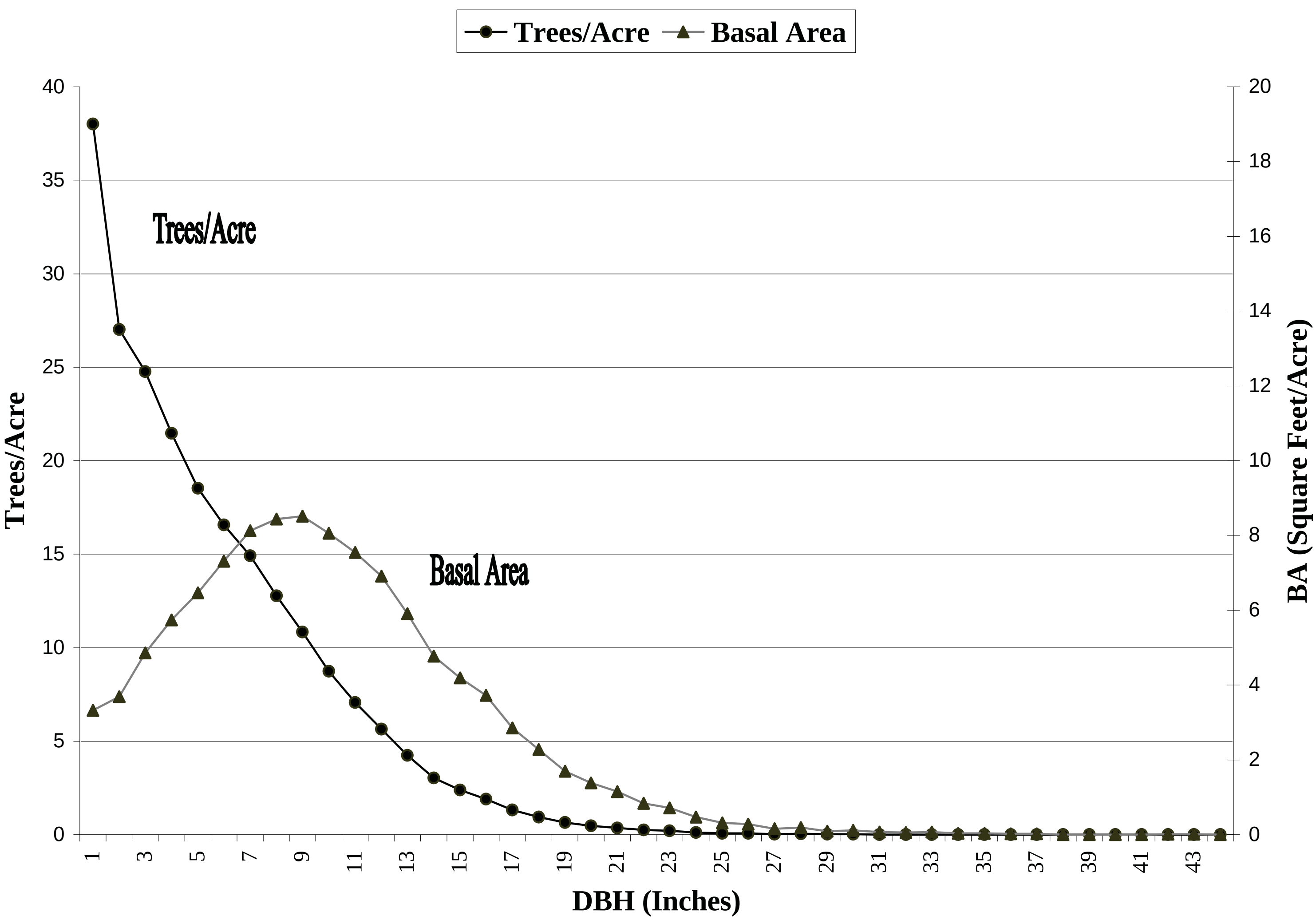


CHART 3. BASAL AREA AND TREES/ACRE BY DBH,

MDC LANDS ON WACHUSETT RESERVOIR WATERSHED



T. Kyker-Snowman

Polygala paucifolia,
Fringed polygala

2.3.3 Wachusett Flora, Common and Uncommon

During 1995 and 1996, MDC 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 flora, a list of all species encountered. The list of species encountered at Wachusett is included below:

TABLE 13. PLANT SPECIES OCCURRING ON CHECKED LOTS AT WACHUSETT

Field List – Flora
1996 Survey of Proposed Harvesting Lots
Karen Searcy - U Mass Herbarium
rare species underlined and bold;
*invasive species

Dicots	
Acer pensylvanicum	Striped maple
Acer rubrum	Red maple
Acer saccharinum	Silver maple
Acer saccharum	Sugar maple
Actaea pachypoda	Doll's eyes
Actaea sp.	Baneberry
Amelanchier sp.	Shadbush
Amphicarpaea bracteata	Hog peanut
Anemone quinquefolia	Wood anemone
Apios americana	Groundnut
Apocynum androsaemifolium	Spreading dogbane
Apocynum sp.	Dogbane
Aralia nudicaulis	Wild sarsaparilla
Aronia arbutifolia	Cherry
Aronia melanocarpa	Choke cherry
Aster acuminatus	Whorled aster
Aster divaricatus	White wood aster
Aster linariifolius	Stiff leaf aster
Baptisia tinctorea	False indigo
**Berberis sp.*	Barberry
**Berberis thunbergii*	Japanese barberry
Betula alleghaniensis	Yellow birch
Betula lenta	Black birch
Betula papyrifera	White birch
Betula populifolia	Gray birch
Boehmeria cylindrica	False nettle
Carpinus caroliniana	Iron wood
Carya ovata	Shagbark hickory
Carya sp.	Hickory
Castanea dentata	Chestnut
Ceanothus americanus	New Jersey tea
**Celastrus orbiculatus*	Japanese bittersweet
Celastrus sp.	Bittersweet
Chelidonium majus	Celandine
Chimaphila maculata	Spotted wintergreen
Circaea lutetiana var. canadensis	Canadian en. night.
Comandra umbellata	Umbellate toadflax
Comptonia peregrina	Sweet fern
Coptis trifolia	Goldthread
Cornus alternifolia	Alternate-leaf dogwood
Cornus canadensis	Bunch berry
Cornus florida	Flowering dogwood
Cornus sp.	Dogwood
Corylus americana	American hazelnut
Corylus cornuta	Beaked hazelnut
Crataegus sp.	Hawthorn
Diervilla lonicera	Bush honeysuckle
Epigaea repens	Trailing arbutus
Euonymus alatus	Winged spindle-tree
Fagus grandifolia	Beech
Fraxinus americana	White ash
Fraxinus pennsylvanica	Green ash
Fraxinus sp.	Ash
Galium sp.	Bedstraw
Gaultheria procumbens	Wintergreen
Gaylussacia baccata	Black huckleberry
Gaylussacia sp.	Huckleberry
Geranium maculatum	Wild geranium
Hamamelis virginiana	Witch hazel
Helianthemum sp.	Rockrose
Hieracium pratense	King devil (hawkweed)
Ilex verticillata	Winterberry
Impatiens capensis	Jewelweed
Kalmia angustifolia	Sheep laurel
Kalmia latifolia	Mountain laurel
Lespedeza sp.	Bush-clover
Ligustrum vulgare	Privet
**Lonicera sp.*	Honeysuckle

Lyonia ligustrina	Maleberry
Lysimachia quadrifolia	Whorled loosestrife
Lysimachia terrestris	Swamp candles
Melampyrum lineare	Cow wheat
Mitchella repens	Partridge berry
Monotropa uniflora	Indian-pipe
Myrica gale	Sweet gale, meadow-fern
Nyssa sylvatica	Black gum
Ostrya virginiana	American hop-hornbeam
Oxalis sp.	Wood sorrel
Parthenocissus quinquefolia	Virginia creeper
Parthenocissus sp.	Virginia creeper
Polygala paucifolia	Fringed polygala
Populus tremuloides	Quaking aspen
Potentilla canadensis	Canadian cinquefoil
Potentilla simplex	Old-field cinquefoil
Prenanthes trifoliolata	Gall-of-the-earth
Prunus serotina	Black cherry
Prunus sp.	Cherry
Pyrola elliptica	Shinleaf
Pyrola rotundifolia	Round-leafed pyrola
Quercus alba	White oak
Quercus coccinea	Scarlet oak
Quercus rubra	Red oak
Quercus velutina	Black oak
Ranunculus acris	Common buttercup
Rhamnus frangula	Alder-buckthorn
**Rhamnus sp.*	Buckthorn
Toxicodendron radicans	Poison ivy
Ribes cynosbati	Prickly gooseberry
Ribes sp.	Currant
Robinia pseudo-acacia	Black locust,false acacia
Rosa sp.	Rose
Rubus allegheniensis	Black raspberry
Rubus flagellaris	Dewberry
Rubus hispidus	Swamp dewberry
Rubus sp.	Blackberry
Sassafras albidum	Sassafras
Sedum purpureum	Garden orpine
Solanum dulcamara	Nightshade
Solidago sp.	Goldenrod
Spiraea alba var. latifolia	Meadowsweet
Taraxacum officinale	Common dandelion
Taraxacum sp.	Dandelion
Thalictrum sp.	Meadow rue
Tilia americana	Basswood
Trientalis borealis	Starflower
Ulmus americana	American elm
Ulmus rubra	Slippery elm
Ulmus sp.	Elm
Vaccinium angustifolium	Low-bush blueberry
Vaccinium corymbosum	High-bush blueberry
Vaccinium pallens	Early sweet blueberry
Veronica officinalis	Common speedwell
Viburnum acerifolium	Maple-leafed viburnum
Viburnum cassinoides	Witherod
Viburnum dentatum var. lucidum	Southern arrow wood
Viola sp.	Violet
Vitis sp.	Grape

Monocots

Agrostis sp.	Bentgrass
Andropogon scoparius	Bluestem
Arisaema sp.	Jack-in-the-pulpit
Arisaema triphyllum	Small jack-in-the-pulpit
Brachyelytrum erectum	Awned woodgrass
Carex debilis	Weak sedge
Carex pen/communis	Colonial sedge
Carex pensylvanica	Penn. Sedge
Carex platyphylla?	Broad-leaved sedge
Carex sp.	Sedge
Carex (stellulatae group)	
Carex stricta	Erect sedge
Carex swanii	Swan sedge
Carex sylvatica	Sedge-of-the-woods
Carex vulpinoidea	Foxtail-flowered sedge
Clintonia borealis	Yellow clintonia
Cypripedium acaule	Pink lady's slipper
Danthonia spicata	Junegrass
Epipactis helleborine	Helleborine
Glyceria sp.	Manna-grass
Glyceria striata	Fowl-meadow grass
Goodyera pubescens	Rattlesnake plantain
Goodyera sp.	Plantain
Iris versicolor	Blue flag
Isotria verticillata	Large whorled pogonia
Juncus tenuis	Slender rush
Maianthemum canadense	Canada mayflower
Medeola virginiana	Indian cucumber root
Orchid sp.	Orchid
Oryzopsis sp.	Rice grass
Panicum sp.	Panic grass
Poa sp.	Grass
Polygonatum pubescens	Hairy Solomon's seal
Polygonatum sp.	Solomon's seal
Saggitaria sp.	Arrowhead
Smilacina racemosa	False solomon's seal

Smilax herbacea	Jacob's ladder
Smilax rotundifolia	Common greenbrier
Smilax sp.	Greenbrier
Symplocarpus foetidus	Skunk cabbage
Trillium sp.	Trillium
Uvularia sessilifolia	Wild oats

Fern Allies

Equisetum sp.	Horsetail
Diphasiastrum digitatum	Trailing evergreen
Diphasiastrum tristachyum	Ground pine
Lycopodium clavatum	Common clubmoss
Lycopodium hickeyi	Hickey's clubmoss
Lycopodium obscurum	Tree clubmoss

Ferns

Athyrium filix-femina	Lady fern
Athyrium thelypteroides	Silvery spleen
Dennstaedtia punctilobula	Hay-scented fern
Dryopteris cristata	Crested wood fern
Dryopteris intermedia	Spinulose wood fern
Dryopteris marginalis	Marginal shield fern
Dryopteris spinulosa	Spinulose wood fern
Onoclea sensibilis	Sensitive fern
Osmunda cinnamomea	Cinnamon fern
Osmunda claytoniana	Interrupted fern
Osmunda regalis	Royal fern
Polypodium virginianum	Rock polypody
Polystichum acrostichoides	Christmas fern
Pteridium aquilinium	Bracken fern
Thelypteris noveboracensis	New York fern

Gymnosperms

Juniperus communis	Common juniper
Picea abies	Norway spruce
Picea sp.	Spruce
Pinus resinosa	Red pine
Pinus strobus	White pine
Pinus sylvestris	Scotch pine
Taxus canadensis	American yew
Thuja occidentalis	Arbor vitae
Tsuga canadensis	Hemlock

This list is not meant to be comprehensive for the entire watershed, but serves as a starting point for assessing the diversity of species present at Wachusett. In addition to the rare or uncommon species highlighted above (bold, underlined), there are uncommon species that have some likelihood of being found at Wachusett, were a comprehensive search initiated. These are listed in the table below, and are based on historic records from the herbarium and other sources.

TABLE 14. UNCOMMON PLANTS POTENTIALLY OCCURRING ON MDC 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

Family	**Species**	**Common Name**	**Status**	**Flowering**
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	*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

NOTE: For Status, E = endangered, T = threatened, SC = special concern, WL = watch list

MDC Foresters have located the following state-listed species during independent surveys of Wachusett properties:

Lupinus perennis	Wild lupine	WL
Isotria verticillata	Large whorled pogonia	WL
Arceuthobium pusillum	Eastern dwarf mistletoe	SC
Juglans cinerea	Butternut	WL
Orontium aquaticum	Golden club	T

Based on *The Vascular Plants of Massachusetts: A County Checklist*, 1999, by B. A. Sorrie and P. Somers, the following table summarizes species on state lists that have been found in Worcester County.

TABLE 15. NUMBERS OF WORCESTER COUNTY SPECIES ON STATE LISTS

	Endangered	Threatened	Special Concern	Watch List	Historical
Native	24	20	11	62	9
Introduced	3	1	0	4	1
Uncertain	1	1	2	3	0

Working with the U Mass herbarium, MDC has identified the following habitat/rare species relationships:

TABLE 16. HABITATS IN WHICH RARE SPECIES ARE LIKELY TO BE FOUND

***Forested Areas**:*

Rich Mesic Woods (less acid - rich herbaceous layer. Indicators: *Acer saccharum*, *Fraxinus americana*, *Adiantum pedatum*, *Asarum canadense*)

Species	Common name	Comments
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

Species	Common Name	Comments
Goodyera repens	Dwarf Rattlesnake Plantain	pine woods
Moneses uniflora	One-Flowered Pyrola	moist rich woods

Hemlock-Northern Hardwoods

Species	Common Name	Comments
Isotria medeoloides	Small whorled pogonia	vernally moist areas
Platanthera macrophylla	Large leaved Orchis	moist ravines, limey
Rhododendron maximum	Rhododendron	hemlock island in swamp
Triphora trianthophora	Nodding Pogonia	depressions under beech
Viola renifolia	Kidney Leaved Violet	damp rich woods

General Habitat:

Boulder/Talus Slope/Ledges

Species	Common name	Comments
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

Species	Common name	Comments
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.
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 Weed	
Sparganium fluctuans	Bur-Reed	
Utricularia minor	Lesser bladderwort	Seepy stream sides
Utricularia resupinata	Bladderwort	Swamps, swales, shores

Seeps / Seepage Areas

Species	Common name	Comments
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

Species	Common name	Comments
Arceuthobium pusillum	Dwarf mistletoe	On Black Spruce
Arethusa bulbosa	Arethusa	
Aster radula	Rough aster	beaver meadows/swamp borders
Gentiana linearis	Narrow-leaved Gentian	boggy meadows
Scheuchzeria palustris	Pod Grass	
Smilacina trifolia	Three-leaved Solomon	boggy woods

Species	**Common name**	**Comments**
Viola nephrophylla	Northern Bog Violet	
Xyris montana	Northern Yellow-eyed grass	

2.3.4 Wildlife

2.3.4.1 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. The Wachusett Watershed is a mosaic of habitat types and conditions. MDC owned land within the watershed is primarily forested, while privately owned lands are comprised of small farms, woodlots, and residential areas. This patchwork of habitats is both a benefit and detriment to wildlife species. A greater diversity of species may exist because of the diversity of habitats. However, the fragmented nature of the watershed 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 populations.

T. Kyker-Snowman

Wild turkey hen

Overall, Wachusett supports a variety and abundance of wildlife species. Wachusett Reservoir supports many water-based species (common loons, spotted sandpipers, bald eagles), and the many streams, lakes, and beaver ponds within the watershed host a variety of birds, amphibians, and reptiles. MDC forests provide habitat for a diversity of birds and mammals including white-tailed deer, turkey, grouse, raccoons, and fisher. In addition, neotropical songbirds, including black and white warblers, black-throated green warblers, and scarlet tanagers utilize MDC forests for breeding and migratory rest stops. Although a majority of MDC owned land in the Wachusett watershed is forested, several large tracts of early successional habitat do exist. These large open, grassy areas provide critical habitat for a variety of species dependent on open lands, including various insects, eastern meadowlarks, bobolinks, and a variety of sparrows.

Probably the most important feature of MDC owned land in the Wachusett watershed is that it is protected from development. As the Boston metropolis expands westward, there remain fewer and fewer acres of open space. The protection MDC lands provide to wildlife species is critical to their long-term survival.

In the last few years, the Division has conducted a variety of surveys to monitor various species of wildlife in the watershed. A yearly bald eagle survey is done each winter. In addition, annual surveys of common loons, Canada geese, and beaver are done at the Reservoir. Other state agencies occasionally conduct wildlife surveys on the watershed, including sampling for fish, waterfowl, and some mammals. In addition, recent surveys to document and sample vernal pools have been conducted. Some of these pools are monitored on a yearly basis.

While a great deal of information exists about certain wildlife taxa (i.e. birds, mammals) through information collected from surveys and observations, very little is known about other Wachusett wildlife. A complete species list for the watershed does not exist, and there is a paucity of information about insects, butterflies, dragonflies, and other more secretive species. It is possible that MDC lands in the Wachusett harbor state listed species that have yet to be documented.

P. Rezendes

Common loon

2.3.4.2 Rare Species and Habitats

Wachusett watershed harbors a variety of rare wildlife species and habitats. A total of 11 vertebrate state listed wildlife species are known to occur on the watershed, and most of those occurrences have been on MDC land. Table 17 indicates those species with their last known observation date.

Although a majority of MDC owned land in Wachusett watershed is forested, there are several unique areas that support rare or unusual habitat. 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. The Division owns a large number of vernal pools. Although not rare on MDC owned land, these unique breeding areas are becoming increasingly rare on a regional level.

TABLE 17. STATE-LISTED ANIMALS KNOWN TO OCCUR IN THE WACHUSETT WATERSHED

Common Name	Scientific Name	Status		Date Last Observed
Mammals:		State	Federal	
Water Shrew	*Sorex palustris*	SC[1]		1990
Birds:				
Common Loon	*Gavia immer*	SC		2001
Bald Eagle	*Haliaeetus leucocephalus*	E[2]	T[3]	2001
Short-eared Owl	*Asio flammeus*	E		1998
American Bittern	*Botaurus lentiginosus*	E		1992
Northern Harrier	*Circus cyaneus*	T		1997
Reptiles/Amphibians:				
Spring Salamander	*Gyrinophilus porphyriticus*	SC		1993
Wood Turtle	*Clemmys insculpta*	SC		1999
Blanding's Turtle	*Emydoidea blandingii*	T		1999
Spotted Turtle	*Clemmys guttata*	SC		1999
Four-Toed Salamander	*Hemidactylium scutatum*	SC		1990
Marbled Salamander	*Ambystoma opacum*	T		2000

[1] Special Concern: species documented to have suffered a decline that could threaten the species if allowed to continue unchecked.
[2] Endangered: species in danger of extinction throughout all or a significant portion of its range.
[3] Threatened: species likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

2.4 Cultural Resources at Wachusett

2.4.1 Prehistoric Overview

The Nashua River Basin is one of a number of significant tributary systems of the Merrimack River Basin. Prior to damming the Upper reaches of the South Branch of the Nashua River in 1908 to form the Wachusett Reservoir, the region's numerous lakes, ponds, wetlands, and streams supported abundant and readily available biotic resources.

The Wachusett Watershed is located near the eastern edge of the Worcester Plateau, which delineates the Central Uplands to the west from the Coastal Plain to the east. The terrain and topography of the region is very diverse as it was influenced by a combination of the bedrock formations and by later glaciation.

The composition of the bedrock, together with glacial and postglacial deposition and erosion, has created a mosaic of landforms, sediments and soils. This complexity, combined with a diverse flora and fauna base, have contributed to the many forms of land use practiced throughout the 12,000 years that humans have occupied the region.

Currently there are a total of twenty-seven recorded prehistoric Native American sites within, or in close proximity to, the Wachusett Watershed (Table 18). Within the greater Nashua River Basin, of which Wachusett is a part, at least another thirty-five sites have been recorded. This quantity is known to be low as it represents only those recorded at the Massachusetts Historical Commission, and does not take into account the many more that are known to collectors but are not recorded. Combined, the recorded and unrecorded sites clearly attest to the viability of this region's habitat for human habitation for thousands of years, and establishes the archaeological sensitivity of the region.

The existing archaeological evidence, flawed as it is, suggests that ***Paleo Indian*** hunters and gatherers may have reached the Nashua River Basin by 9,500 to 12,000 years ago. An unconfirmed find of an Eastern Fluted Point, the diagnostic artifact of the Paleo Period, from south Lancaster, adjacent to South Meadow Pond, is the only hint of human activity in the Nashua Basin itself. However, within the broader context of the Merrimack River Basin, of which the Nashua is a tributary, isolated fluted points have been recovered in Andover and Boxford, on the lower Merrimack, as well as on the middle reaches of the river in New Hampshire. The confluence of the Concord, Assabet and Sudbury rivers may also have been occupied at this time.

By about 9,500 years ago the warming climate had created an environment in southern New England that supported a mixed pine-hardwood forest. Although there are no recorded ***Early Archaic*** sites (ca. 9,500 to 8,000 years ago) in the Nashua River Basin, three sites have yielded the diagnostic Early Archaic Bifurcate Based Point within the lower Merrimack Valley. Low frequencies of Early Archaic materials have also been reported from two sites in New Hampshire. Analysis of private artifact collections also suggests the presence Early Archaic activity on the lower Assabet River ca. 9,500 - 8,000 years ago.

During the ***Middle Archaic period*** (ca. 8,000 - 6,000 years ago) climatic and biotic changes continued, and the mixed deciduous forests of southern New England were becoming established. Significantly, it is believed that the present migratory patterns of many fish and birds became established at this time. During the spring those rivers, streams and ponds utilized by anadromous fish for spawning would have been particularly important for fishing. Groups are likely to have traveled considerable distances to camp adjacent to falls and rapids where they could easily trap and spear the salmon, herring, shad, and alewives. This subsistence strategy persisted throughout prehistory.

Two sites known to be on MDC land were occupied during this time. The Muddy Brook Site, located at South Bay in West Boylston, has yielded at least one Middle Archaic artifact to an astute fisherman. When it was occupied the site was a short distance from the brook's confluence with the Nashua River. The second site is a large multi-component site between East and West Waushacum ponds (see below).

More sites in the Nashua Basin have yielded diagnostic ***Late Archaic period*** materials than the preceding periods. The marked increase in site frequencies and densities is consistent with findings throughout most of southern New England, and may document a population increase ca. 6,000 to 3,000 years ago. At least six sites within the watershed appear to have been occupied during the Late Archaic Period: two sites on Waushacum Pond, two on Eagle Pond, one on Chaffin Pond, and the South Bay Quartzite Quarry.

During the ***Early, Middle*** and ***Late Woodland*** periods (3,000 - 450 before present (B.P.)) Native Americans continued to occupy the Nashua River Basin. Evidence comes from five sites from each period. Regionally, horticulture was introduced during the Early Woodland and small gardens may have been planted in clearings located on the fertile alluvial terraces next to the Nashua River and its larger tributaries.

Because of the manner in which sites were discovered or collected it is impossible to distinguish with certainty the nature of Native American occupation here during the various Woodland Periods. Five sites hint at Early Woodland activities based on the presence of Small Stemmed Points, which are also used to identify Late Archaic affiliations. Two may have been Late Woodland sites. Currently, it is difficult to conclusively identify Middle Woodland sites from the existing artifact descriptions. One can only speculate that Native American presence continued here between 1,200 to 900 years ago, and that the area was not abandoned for some unknown reason.

TABLE 18. PREHISTORIC SITE INVENTORY

Town	Site	Type
Boylston	19-WR-220 Indian Rock	Unknown
Holden	19-WR-21 Quinapoxet Pond	Unknown
	19-WR-29 Eagle Lake (E)	Late Archaic/Early Woodland unknown
	19-WR-30 Eagle Lake (SE)	Late Archaic/Late Woodland
	19-WR-31 Eagle Lake (SW)	Unknown
	19-WR-33 Maple Spring Pond (E)	Unknown
	19-WR-34 Maple Spring Pond (W)	Unknown
	19-WR-181 Chaffin Pond	Unknown
	19-WR-182 Chaffin Pond	Late Archaic/Late Woodland
	19-WR-183 Chaffin Pond	
	19-WR-184 Rockshelter	Unknown
	19-WR-253 Quabbin Aqueduct	
Lancaster	19-WR-259 South Meadow Pond	Paleo
Sterling	19-WR-12 East Waushacum Pond	Unknown
	19-WR-13 Wattaquadock	Historic NA burial
	19-WR-14 unnamed	Historic NA burial
	19-WR-15 West Waushacum Pond	Historic NA burial
	19-WR-16 Selma-Wheaton	Middle & Late Archaic/Early Woodland
	19-WR-17 Quay Pond	Historic NA burial
	19-WR-18 Unnamed	Historic NA burial
	19-WR-19 Sterling Campground	Unknown
	19-WR-493 E. Waushacum ROW	Late Archaic/Early Woodland
	19-WR-593 110 Landfill	Unknown
	19-WR-540 South Meadow I	Woodland (Ceramic)
	19-WR-541 Chase Hill	Unknown/possible burial
West Boylston	19-WR-185 South Bay Quartzite Quarry	Late Archaic/Early Woodland
	19-WR-274 Muddy Brook	Middle Archaic

2.4.2 Interpretation of the Archaeological Record

In reviewing the archaeological record of the Wachusett Watershed, indeed that of the entire Nashua River Basin, there are more questions than answers. The record is uneven at best, and is the result of amateur archaeological and collecting activities, rather than professional research. Indeed, as resource managers, we are in the tenuous position of establishing management guidelines, and evaluating project impacts, based on limited, rather than reliable, data. Nevertheless, the following generalized statements can be gleaned from the overall archaeological record of southern New England, as opposed to being specific to Wachusett.

The existing archaeological record documents a pattern of multiple, recurrent occupation of individual sites within most of Southern New England. Few sites have yielded artifacts from a single cultural/temporal period. Instead, artifacts from several periods have typically been recovered from sites. This suggests that some particularly well-sited locations were occupied, or otherwise utilized, more than once. Recurrent, though intermittent, occupation of a single site, sometimes over a period of several thousand years, appears to have been the prevalent pattern of prehistoric site development in this region.

Small groups, probably based on kinship, would have found the uplands most attractive for short-term occupation. Settlement is likely to have occurred on virtually any elevated, level and well drained surface that was located immediately adjacent to sources of fresh water, including the headwaters of ephemeral streams, springs, and small wetlands and ponds. Rockshelters and other natural overhangs, and locations with southerly exposures would also have been utilized.

It was common for groups to occupy large ponds such as East and West Waushacum, and other bodies of water such as Eagle Lake, Chaffin Pond, Maple Spring Pond and Quinipoxet Pond. Though some of these were altered during historic times, Native Americans may have utilized them, and archaeological survivals are possible. The site inventory for Wachusett also includes stream and brookside locations, and an incalculable number of sites would have been located along the main trunk of the Nashua River, and at its confluence with tributary streams. Even a rockshelter is represented among the types of locations occupied by local Native American peoples.

The analysis of sites throughout New England, and the statistical calculation of the information outlined above, has allowed archaeologists to define what they call ***Site Location Criteria***. It is these criteria that are the foundation of the Silviculture review discussed below.

2.4.3 Historic Resources

2.4.3.1 Archaeological

Significantly, there may be as many as six historic period Native American burials recorded within the Town of Holden: this is an unusually high number for a single community. Early historic accounts place the Nashaway sachem Nashawhonan's camp somewhere around the two Waushacum ponds, and during King Philip's War (1675 - 1676) the Waushacum ponds were an important gathering ground for the Nipmucks. A skirmish between the local Nashaways and colonial forces also reputedly occurred here. In 1974 members of the Massachusetts Historical Society's (MHC) Ekblaw Chapter, looking specifically for Nashawhonan's camp, undertook excavations (with MDC permission) on the bridge of land between East and West Waushacum. While they did in fact find a large site here, nothing recovered suggests Contact or Early Historic period associations. Rather, diagnostic artifacts from the

Middle Archaic, Late Archaic and possibly Early Woodland suggest occupation here from as early as 8,000 years ago to about 1,200 years ago.

To date an Inventory of Historic Archaeological Resources, similar to that completed at Quabbin, and has begun at the Ware Watershed, has not been undertaken for Wachusett. Therefore, other than identifying a few of the more obvious sites, a discussion of historic archaeological resources within the Wachusett Watershed is premature. Suffice it to say, when completed, such an Inventory will probably be similar to Quabbin's in terms of the range and type of sites that exist in the watershed, except undoubtedly the numbers will be considerably less at Wachusett. One would expect to find numerous farmsteads with former house and barn foundations, as well as the remains of other out buildings, schools, commercial and industrial sites. Indeed, along the Quinipoxet River alone, no fewer than thirteen mill sites can be identified on the 1870's Beers Atlas alone. Other Atlases, such as the 1840 and 1890's series will reveal additional sites. Whole villages, such as Harrisville, that were once bustling commercial and industrial centers, were removed from the landscape with the construction of the reservoir.

To date, the research needed to determine if anything has survived at these locations has yet to be performed. An informal, one day walkover in the fall of 1999 (Ranger Kovich and Archaeologist Mahlstedt) identified a number of interesting archaeological sites. These included the remains of an unnamed saw mill, G.R. Henry's Shoddy Mill, the Glen Woolen Mills complex, and several probable tenement houses for the Glen Woolen Mills, as well as the Hamlet Woolen Mills near Harrisville. The success of this one-day reconnaissance clearly attests to the potential survival of many interesting and significant archaeological sites that bear mute evidence of the rich historic legacy of the region.

It is presumed that at Wachusett, like Quabbin and Ware, there was differential treatment to existing buildings and structures during the construction of the reservoir. In some cases the superstructures were carefully razed and relocated to unthreatened locations. These actions often left well defined and well preserved cellar holes, mill raceways, barn foundations, etc. In other instances, buildings were knocked down and pushed in, and graded over, leaving no evidence except an occasional ornamental planting that seems curiously out of context.

A good example of differential treatment is the case of the Old Stone Church. The Old Stone Church is the only structure of the old center of West Boylston remaining on its original site. Originally the church overlooked a section of West Boylston that was inundated by the construction of the reservoir. Other nearby buildings and structures were razed or relocated. Today, the church stands alone, silently looking out over the waters of the Wachusett.

2.4.3.2 Buildings & Structures on the National Register of Historic Places

Development of a public water supply system for Metropolitan Boston began as early as 1825. With expanding populations and increased commercial and industrial demand for water, the Metropolitan Water Supply System constantly had to be upgraded and enlarged. The fourth stage of this growth came with the creation of the Metropolitan Water District (1895-1926), and after an exhaustive search, the South Branch of the Nashua River, just above the city of Clinton, was selected as the site of a new reservoir.

When the construction of the Wachusett Reservoir began in 1895, it was the largest project of its kind in the United States. Today, the many aqueducts, dams, dikes, reservoirs, shafts and pumping stations that were built to create Wachusett Reservoir and convey its water to Sudbury Reservoir #5, and then onto Boston are recognized as historically significant at both the local and national levels. Accordingly, in 1989, these engineering features, and many more, were listed on the National Register of

Historic Places as the ***Water Supply System of Metropolitan Boston Thematic Resource Area***. The listing includes the 91 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 fifteen buildings and structures, and the ***Wachusett Dam Historic District***, which contains six individual buildings and structures (Tables 19, 20).

TABLE 19. WACHUSETT AQUEDUCT LINEAR DISTRICT

Property Name	Date(s)	Town(s)	Owner	Care/Control
Wachusett Aqueduct	1896-98	Clinton, Berlin, Marlborough, Northborough, Southborough	MDC	MWRA
Shaft #4 Chamber	1896	Berlin	MDC	MWRA
Metering Chamber	1897	Berlin	MDC	MWRA
Crane Meadow Road Arch	1897	Northborough	MDC	MWRA
Terminal Chamber	1897	Marlborough	MDC	MWRA
Northborough Rd Arch#1	1897	Southborough	MDC	MWRA
Northborough Rd Arch#2	1897	Southborough	MDC	MWRA
Assabet River Bridge	1897	Northborough	MDC	MWRA
Wachusett Lower Dam Open Channel	1896-97	Southborough	MDC	MWRA
Wachusett Upper Dam Open Channel	1896-97	Southborough	MDC	MWRA
Lynbrook Road Arch	1897	Southborough	MDC	MWRA
Flagg Road Arch	1897	Southborough	MDC	MWRA
Chestnut Hill Road Arch	1897	Southborough	MDC	MWRA
Hultman Aqueduct Shaft #1 Headhouse	1940	Southborough	MDC	MWRA
Hultman Aqueduct Diversion Dam	1940	Marlborough	MDC	MWRA

TABLE 20. WACHUSETT DAM HISTORIC DISTRICT

Property Name	Date	Town	Owner	Care/Control
Wachusett Dam	1900-06	Clinton	MDC	MWRA
Central Mass RR Bridge	1905	Clinton	MDC	MDC
Grove St. Bridge	1904	Clinton	MDC	MDC
Lower Gate Chamber and Powerhouse	1904	Clinton	MDC	MWRA
Lightening Arrestor Chamber	1911	Clinton	MDC	MWRA
Maintenance Building	1920	Clinton	MDC	MDC

2.4.3.3 Individual Listings and Properties Declared Eligible for Listing

2.4.3.3.1 Old Stone Church, West Boylston

The Old Stone Church, built by the Baptists in 1891, was barely completed when construction of the Reservoir began in 1895. Local granite from a quarry at Malden Hill was used to construct the English Country style building. Details of its ashlar construction are provided in the National Register

Nomination that was prepared in 1972. Abandoned, and unused, the church had fallen into a state of severe deterioration. A program of stabilization was undertaken years ago, and while it has largely arrested the principal problem, close inspection of its walls and joints reveals that it was not performed to particularly high standards.

2.4.3.3.2 Stillwater Farm, Sterling

Stillwater Farm dates to sometime in the 1790's, when Zebedee Reeding moved from Grafton. Like most New England farms, over the years it went through a succession of owners, and had grown appreciably: from the initial 50 acre Reeding purchase, to 153 acres when Samuel Howe purchased it in 1856. Sometime in the 1870's, Charles Chandler took possession of the farm. Several generations of Chandlers increased the holdings to 243 acres, moved the farm into commercial dairy and poultry, built numerous outbuildings such as hen houses, a corn crib, ice house, and 2 barns, and took over the adjacent Smith house.

Several intervening owners held title before Joseph A. Wronski, a Polish immigrant, assumed full ownership in 1925. Wronski and his five sons ran a typical New England farm, raising chickens, hogs, cows, and horses. They harvested gooseberries, and harvested timber and cordwood from a back lot. By 1971, with the sons employed in industrial jobs in Worcester, Wronski began to sell off some of his holdings, and in 1990, the MDC purchased the farm as part of its Wachusett Watershed protection program. This farm has been declared "eligible for listing" on the National Register, but is not yet listed.

2.4.3.4 Implications for Management for National Register Properties

The buildings and structures represented in the Wachusett National Register Listing represent an ensemble of significant technical, engineering, and architectural features, buildings and structures. Additionally, the Old Stone Church and Stillwater Farm, while more parochial in nature, nevertheless embrace the historic character of a past gone by. The designation of these properties to the National Register (or Declared Eligible for it) automatically places them on the State Register, thereby affording them a degree of protection from ill advised or uninformed development or alteration. Several statues have been passed that provide the Massachusetts Historical Commission, of the Secretary of State Office, with review jurisdiction of proposed projects on State and National Register Properties. MGL Ch. 9 s. 26-27c and Ch.254 of the Acts of 1988 establishes the authority of the MHC, outlines the review process, and clarifies who/what is covered under it.

The review process that the statutes establish is not meant to be tedious or obstructionist: to the contrary. Submission of a **Project Notification Form** (PNF) in a timely manner, and filled out entirely, with respect to detail, will result in a timely, and usually favorable response, provided that standard preservation guidelines are adhered to. Specifically, in considering any alterations to the historic fabric and/or grounds of a National Register, or State Register property, the ***Secretary of the Interior's Standards and Guidelines for Historic Preservation Projects*** must be followed. Failure to use the Standards in a good faith effort, and lack of detail and description in the PNF, will result in unwanted and unnecessary delays.

In its role as the "keeper" of the Register, the MHC can be of invaluable assistance to the MDC, as their trained staff of professional Historical Architects and Preservation Planners essentially become "in house" staff or "pro bono" consultants. They become part of the team, with both parties working toward a mutual goal. Their role is to see that a project has minimum adverse impacts to the registered property, and when accomplished, all parties benefit. Again, timely and thorough communication is the key to smooth and successful implementation.

3 Research-based Principles Guiding Watershed Management

The purpose of this section is to identify various principles of watershed management that form the basis for the specific goals and implementation objectives for management of the Wachusett watershed lands during the period covered by the plan. These principles were distilled from a comprehensive collection of approximately 350 watershed, forestry, and wildlife management papers that were reviewed by Division staff.

3.1 Watershed Management Principles

Watershed Protection

- Forested watersheds generally yield higher quality water than non-forested cover types. Most urban, suburban and agricultural land uses contribute in some way to lowered water quality.

- Uncontrolled human activities on water supply watersheds represent a major source of potential contamination. Efficient and effective water quality protection on both filtered and unfiltered water supplies requires control over human activities.

- Watershed cover conditions differ in their regulation of certain nutrients (e.g., nitrates); within the variety of watershed land cover types, the best regulation of nutrients is provided by maintaining vigorously growing forest across the vast majority of watershed sites.

- Fire protection, watershed ranger and police surveillance, water sampling, and other watershed management activities, including forest management, all depend upon an adequate, well-maintained watershed road system.

- The proper management and protection of wetland and riparian zones is a critical component of watershed protection.

Water Yields

- Water yields are influenced by precipitation amounts, site conditions (such as slope, aspect, and soils) and the intensity and type of watershed cover management.

- Water yields are affected directly by evapotranspiration rates of the watershed cover. Therefore, management activities that result in decreased evapotranspiration also result in increased water yield.

- Intensive, even-aged management of forested watersheds provides consistently greater water yields than either uneven-aged management or the absence of active management.

- Water yields decrease as young forests grow. As forests become more open, water yields increase.

Watershed Forest Management: General

- Watershed forests can be managed in a way that provides significant benefits to long-term water quality protection, while minimizing adverse impacts during management operations.

- With proper road location and maintenance, and proper planning and supervision of silvicultural activities, potential negative tributary water quality impacts (including turbidity, nutrients, organics, and streamwater temperature) from forest management can be minimized or eliminated.

- Stands developed through uneven-aged methods will continually include some younger, shorter trees. Older trees in these stands develop stronger, more tapered stems than those grown in dense, even-aged stands. Strongly tapered trees sustain less damage from wind. The younger component in uneven-aged stands enables them to recover from disturbance more quickly than maturing even-aged stands, thus improving their relative long-term water quality protection.

Watershed Forest Management: Disturbance Impacts

- Overstory blowdown can temporarily increase erosion and nutrient leaching, by disturbing soils, increasing decomposition rates, and causing a setback in biomass accumulation rates.

- Severe forest fire can significantly reduce soil infiltration, thereby increasing overland flow of water, sediments, organic materials, and nutrients.

- A forest that is diverse in age structure and species composition limits the impacts of age- and species-specific disturbances.

- Forests with advance regeneration in the understory will recover more quickly from disturbances to the forest overstory than will forests with poor understory development.

- Younger, shorter trees will sustain less damage from severe windstorms than taller, older trees, due both to their lower tendency to "catch" the wind, and to stem flexibility.

- While tightly grown, "aerodynamically smooth" *stands* may deflect wind better than those that are "aerodynamically rough," *individual trees* that have been grown in more open stands will develop strongly tapered stems that resist wind better than the non-tapered stems of trees grown in tight stands.

- Saturated overland flow from infrequent, large storms with associated intense rains and floodwaters account for much of the annual particulate, sediment, and dissolved nutrient outputs from watersheds.

Air Pollution Impacts

- Forests serve as "sinks" for various environmental pollutants, retaining them and slowing their movement into water supplies. A tall, dense, and layered forest serves this function more effectively than a short, sparse forest.

- Environmental pollution has been linked to general forest decline, which increases the susceptibility of those forests to insects, diseases and other impacts.

- Actively growing forests with a diversity of species and sizes may help buffer the impacts of acid precipitation on water supplies.

- Air pollution contributes to nitrogen saturation of forest ecosystems. Nitrogen saturation can cause elevated nitrate, aluminum, and hydrogen levels in streams and losses of cation bases from soils. These impacts can be compounded by acid precipitation and ozone pollution, and ameliorated by the accumulation of biomass and nutrients in an actively growing forest.

Wildlife Impacts

- Some wildlife populations can have significant impacts on both habitat and water quality conditions.

- The composition of wildlife communities is dictated by various factors, including habitat conditions, landscape characteristics, and mortality factors among many others.

- Land management practices that change habitat conditions will result in changes in the wildlife community.

3.2 Review of Principles of Watershed Forest Management Systems

3.2.1 Naturally-managed Forests

3.2.1.1 Water Yields

Tree growth and naturally occurring forest disturbances (fires, wind, disease, and insects) heavily influence the water yields from naturally-managed forests. Eschner and Satterlund (1965) studied a 491 square-mile watershed in the Adirondack Mountains of New York from 1912-1962. This study is particularly relevant to an examination of the impact of naturally-managed forests upon water yields. The land use on the watershed up to 1910 included land clearings, extensive fires, and heavy forest cuttings (chiefly logging of softwoods) that involved almost the entire watershed. In the late 1800's, the state of New York began purchasing lands in the watershed for the Adirondack Forest Preserve. From 1890 to 1910 the percentage of state-owned Forest Preserve in the watershed increased from 16% to 73%. The management policies of the Forest Preserve included laws against any cutting of trees and an active program of forest fire suppression.

The average forest density (in basal area) of the watershed increased from 65 square feet per acre in 1912 to 107 square feet per acre in 1952, due to forest growth and restrictions on cutting. Average basal area decreased to 97 square feet per acre in 1963 due in part to mortality from a windstorm in 1950. Another impact upon the watershed was a large increase in the beaver population during the study period. Throughout the Adirondacks, the number of beaver increased from an estimated 10 individuals in 1895 to an estimated 20,000 individuals by 1914, due to a prohibition on trapping introduced in 1895 and the introduction of 25 Canadian beaver and 14 Yellowstone Park beaver between 1901 and 1907. In 1965, most perennial drainages in the watershed had resident beaver.

The combined effects of unregulated forest growth and the increased number of beaver dams reduced the annual water yield of the watershed by 7.72 area-inches or 23% from 1912 to 1950. The authors postulated that forest growth reduced water yields through changes in evapotranspiration and snowmelt and beaver reduced yields through losses due to evaporation from beaver ponds. Although the net effect from beaver was a reduction in water yield, they tended to increase dormant season flow due to reduced interception and evapotranspiration following the killing of trees in flooded areas. Conversely, increased forest growth delays peak discharge and reduces yield. The effect of unregulated forest growth in lowering water yields was offset by increased in water yields resulting from the paving, straightening, and widening of 75 miles of roads within the watershed during the study period.

The trend of decreased water yields from 1912-1950 was reversed due to the large number of trees that were killed by the storm and the continued increase in mortality during the 13 years after the storm. The authors summarized the impact of the 1950 windstorm:

> The storm of November 1950, disrupted the associated patterns of forest stand development and streamflow change, returning both to a point nearer their 1912 levels.

In another study, Eschner (1978) analyzed four small watersheds in the Adirondack Mountains of New York. Logging, farming, and fires up to the early 1900's heavily impacted the East Branch of the Ausable River. Of the four watersheds, only the East Branch of the Ausable River was unaffected by the windstorm of 1950. Thus, this watershed offers a good example of a 42 year, stream-gauged period of uninterrupted forest re-growth. During this period, streamflow decreased by 4.2 area inches. Eschner concluded that this decrease was probably due to the natural regrowth of vegetation.

3.2.1.2 Water Quality

There have been few long-term studies of the impact of naturally-managed forests upon water quality. Several studies were cited above with regard to the impacts of old forests upon nutrient releases and the processes that are apparently involved. Other areas where naturally-managed forests may differ from actively-managed forests include response to natural disturbances, and nutrient/sediment interactions in stream channels.

The impact of disturbance is perhaps the key difference between a naturally-managed and actively-managed forest. In the actively-managed forest, silvicultural management is in effect a deliberate and regulated form of disturbance. In the naturally-managed forest, most disturbances are the result of unregulated natural events (e.g., wind, fire, disease, insects, or ice). While both actively-managed and naturally-managed forests will be exposed to certain recurring natural disturbances (e.g., hurricanes), the two systems may respond to these disturbances very differently.

In recent years, even forests isolated from developed areas are being increasingly impacted by human factors (air pollution, introduced insect/disease complexes, wildlife browsing). Eschner and Mader (1975) note:

> When extensive areas of relatively stable vegetation are set aside for wilderness, man's activities are sharply restricted. However, changes in the vegetation continue, and in some cases the possibility of catastrophic change increases...Treatment of large areas of watershed as wilderness, currently advocated by several interest groups, may not be consonant with management for maximum yields or protection of areas. On land long undisturbed, use of water by vegetation may be maximized and water yield reduced, while hazards of windthrow, insect, disease, or fire damage may increase.

Hewlett and Nutter (1969), in defining pollution, mention the potential impact of natural disturbances upon water quality:

> Because natural waters already carry materials that can degrade water for certain uses, we have some difficulty specifying just what "pollution" is. Natural water quality over the centuries has evolved the stream ecosystem under conditions that we might, rather pointlessly, refer to as "natural pollution." For our purposes, however, we shall regard pollution as man-caused and think of polluted waters as those degraded below the natural level by some activity of man. In this sense, therefore, unabused forests and wildlands do not produce polluted waters, although they may at times produce water of impaired quality.

Parsons et al. (1994), in a study of the impact of gap size on extractable soil nitrate stated:

> Large-scale mortality events leading to macroscale gap formation, which involves the simultaneous death of many adjacent trees over thousands or tens of thousands of square meters, are known to increase mineralization and nitrification rates in temperate forest ecosystems.

Tamm (1991), in reviewing the role of nitrogen in terrestrial ecosystems, noted:

> Natural agents such as storms, insect defoliations, and, above all, fire may destroy the existing vegetation and stimulate both nitrogen mineralization and nitrification, leading to temporary losses of nitrate.

Corbett and Spencer (1975) report that Hurricane Agnes and the 14 inches of rain that accompanied it caused significant erosional impacts to the Baltimore Municipal Watershed, chiefly due to streambank cutting and channel slumping. The authors note that these types of impacts are more related to channel depth than condition of forest cover. Hurricane Hugo caused extensive damage to coastal South Carolina. The U.S.D.A. Southeast Forest Experiment Station monitored stream waters within the Frances Marion National Forest before and after the hurricane, with a gap in monitoring for several months after the hurricane, due to access problems (McKee 1993, pers. comm.). The forest before the storm was mature pine-hardwoods and much of it was windthrown or snapped by the storm. Preliminary results show increased nitrogen in streams compared with levels found in regular monitoring done before the storm (Swank, Harms, Neary, Benston, McKee, and Hanson 1990, 1991, pers. comm.).

Researchers in South Carolina are also concerned about the threat of a large forest fire due to the amount of downed material that has increased from 8 tons/acre before the storm to 100 tons/acre after the storm. After a 1.6 acre simulated hurricane "pulldown" at the Harvard Forest, Carlson (1994) reported that downed woody debris increased from 4.1 tons/hectare in a control area to 33.5 tons/hectare. He suggests that the potential threat of fire will increase in the next several years as pulled-over trees die.

Numerous studies show that impacts from forest blowdown or a combination of blowdown and forest fire can increase tributary nitrate and phosphorus exports by several times background levels (Verry 1986 and Packer 1967 as cited in Ottenheimer 1992; McColl and Grigal 1975: Wright 1976; Schindler et al. 1979). Soil disturbance from blowdown of large numbers of trees may also result in significant erosion (Patric 1984, White et al. 1980, and Swanson 1982, all cited in Ottenheimer, 1992). Water quality changes associated with extensive windthrow and fire confirm that dissolved nutrients and in some cases, sediment, acidity, and total organic carbon can be elevated for several years (Patric 1984 and Swanson 1982 as cited in Ottenheimer 1992; Verry 1986; Schindler et al. 1980; Wright 1976; Corbett and Spencer 1975; McColl and Grigal 1975; Dobson et al. 1990; Dyrness 1965 and McKee 1993 pers. comm.). For example, nitrates increased by up to nine times and phosphorus by more than three times after extensive windthrow followed the next year by a wildfire in a monitored watershed in Ontario (Schindler et al. 1980).

Dobson et al. (1990), in reviewing data from hundreds of lakes in New York, New Hampshire and Sweden, found strong spatial and temporal associations between percentage of watersheds affected by large blowdown events and long-term lowered pH in basin lakes. They concluded that extensive blowdown alters hydrologic pathways by channeling flow through large macropores created by rotting roots so that water is less buffered by subsurface soils and bedrock. One lake adjacent to heavy blowdown that was extensively salvaged did not acidify, leading the authors to speculate that salvage may partially counter the impacts of blowdown on acidification.

The value of advance regeneration (regeneration established before overstory removal) in reducing the impacts of natural disturbances may be the critical factor distinguishing actively managed and naturally managed watersheds. After disturbance, areas that are quickly occupied with dense, fast-growing seedling/sapling growth will minimize transitional losses of nutrients, and particulate and erosional losses. MDC foresters Buzzell (1991 MDC) and Kyker-Snowman (1989) compared actively managed and naturally managed forests with regard to the presence and abundance of advance regeneration. Their findings definitively show that areas that have been actively managed have a much greater amount and density of regeneration and young forest growth. Arbogast (1957) also notes that a key consideration when implementing uneven-aged silviculture on previously unmanaged and undisturbed stands is to enhance age-class balance by encouraging development of sapling and pole-sized trees.

The impact of actively managed and naturally managed forests adjacent to stream channels is discussed thoroughly in Maser et al. (1988). Although this study is focused on forests of the Pacific Northwest, some principles are applicable to the northeast. The authors documented that streams flowing through young forests and those recently harvested contain only 5-20% of the large woody material found in streams flowing through naturally managed forests. The stability and length of wood pieces is also increased in naturally managed forests. While the authors document a clear difference in the fish habitat of the two streams, they also note that the increased debris in streams bounded by naturally managed forests may impact the stability of streams.

While it may seem that large amounts of woody debris would increase the amount of decomposed material in streams, wood in direct contact with water decomposes very slowly. The authors note that only 5-10% of a stream's nitrogen supply is derived from rotting instream debris. On the positive side, debris serves to create hundreds of dams that slow the flow of particulate material down the stream. The authors speculate that stream stabilization after floods is accelerated by large woody debris, noting that "large stable tree stems lying along contours reduce erosion by forming a barrier to downhill soil movement."

While the conditions in the Pacific Northwest are very different from those in the northeast (for example soils are less stable, forest types are totally different, and forest management systems consist generally of even-aged management using clear-cutting), some of the above material is applicable to the northeast and to MDC watersheds. Bormann et al (1969) in a study of a small watershed in the White Mountains of New Hampshire noted that 1.4% of the watershed was included in the actual stream channel and that debris pools occurred every 1-3 meters. They speculated that these pools served to slow the movement of suspended material from the watershed and reduce the erodibility of the system. Bormann et al. (1974) note that in mature forests the export of particulate material is derived from material stored in the stream bed. However, they note that most of this material moves very little, and approximately 90% decomposes slowly in place.

The above discussion highlights the need for careful consideration of lands adjacent to tributaries. In developing management plans for these areas, consideration should be given to the need for stability of the cover type and forest structure, given the potential occurrence of major disturbances. However, the benefits of the slow addition of natural wood-fall to these areas, and the erosion impediments and the stream pools created by this material, should also be analyzed. In assessing the management of stream buffers, Stone (1973) recommends careful thinning of buffer strips as often preferable to complete non-disturbance, as such thinning will limit the amount of debris falling directly into streams. Vellidis (1994) found that forested riparian strips next to agricultural lands took up and removed nutrients in soil and vegetation, preventing agricultural outputs from reaching streams. The author recommends that these forested strips be harvested periodically to ensure a net active uptake of nutrients, if they are to serve as an effective nutrient buffer.

3.2.2 Even-Aged Silviculture

3.2.2.1 Water Yields

Beginning at Wagon Wheel Gap in Colorado in 1911, experiments relating forest removals to water yield increases have been conducted at a number of small watershed locations throughout the U.S. Since 1940, three U.S. Forest Service Experimental Forests have supplied the bulk of the data for eastern U.S. applications. These forests are Hubbard Brook, NH; Fernow, WV; and Coweeta, NC. Experiments have included a wide variety of approaches ranging from clearing of small watersheds to patch, partial, and riparian cuts. Most experiments are paired watershed studies, where two small, adjacent or similar watersheds are studied; one watershed is treated silviculturally while the other is left intact, as a control.

Experimental findings show several general trends. However, variation due to site conditions such as slope, aspect, soils, geology, cover type, and additional factors make exact prediction of water yield increases difficult for a given site. Douglas (1983) notes that yield increases can be predicted within 14% of actual values. Federer and Lash (1978) developed a small watershed computer model aimed specifically at predicting water yield increases from forest management of small watersheds in the northeast, using input variables of precipitation, temperature, latitude, slope, aspect, cover type, and soils. This model was applied with a reasonable degree of accuracy to the Cadwell Creek watershed at Quabbin (O'Connor 1982b).

The following general trends emerge from the many watershed experiments that have been reviewed for the Quabbin Land Management Plan:

- Water yields increase as the percentage of forest cover removed increases - complete removal of hardwood cover on small watersheds can result in first-year yield increases of 4-14 area-inches (total average annual streamflow in the Northeast is approximately 20-25 area-inches or about 50% of total precipitation).

- Water yields decrease with reforestation of open watersheds and growth of younger forests, with a linear relationship between percentage of watershed reforested and water yield decrease; yield decreases are significant, in the range of 6-7 area-inches lost through significant forest regrowth and forest growth.

- Water yield increases are greatest the first year after cutting and decline thereafter, usually returning to pre-cutting levels by the 4th to 8th year; most clearing experiments returning to pre-cut levels within 10 years.

- Water yield increases are generally larger on north versus south facing slopes, with yields up to two and one half times greater for clearings on north facing slopes. One study also showed that west-facing forests used more water than those did on east-facing slopes.

- Differences between cut and uncut watershed yields increase exponentially as annual rainfall increases.

- Water yield increases from cutting in the many studies in the northeast occurred chiefly during the growing season, with areas of higher snowfall, deep soils, or conifer cover showing larger dormant season increases.

- Removal of conifer forests will yield more water than hardwood forests, as conifers use more water and snow evaporation is greater in conifers.

- Conversion of hardwoods to conifers will result in significant losses in water yields - one watershed in North Carolina had a 25% yield loss after conversion of hardwoods to white pines.

- Greatest yields are usually achieved through removal of riparian vegetation or lower elevation watershed vegetation.

- Much of the increased flow generated from cutting is seen as increases in low flow periods. Increases in peak flows do occur, but are not believed to cause increased flood risk where cutting is implemented on limited areas and moderate increases are generally yielded.

- Watersheds with deep soils generate longer lasting flow increases after cutting, and yields are more balanced between growing and dormant seasons; watersheds with shallow soils generate yield increases focused within the growing season.

- Certain early successional hardwoods use measurably more water than late successional hardwoods, and changes in water yield due to shifts in species composition may last in excess of a decade.

- Yield increases are lower in deep soils and in areas with fast regrowth of regeneration.

(Douglass and Swank 1972, 1975; Douglass 1983; Hibbert 1967; Federer and Lash 1978; Hornbeck and Federer 1975; Hornbeck et al. 1993; Lull and Reinhart 1967; Mader et al. 1972; More and Soper 1990; Mrazik et al. 1980; Storey and Reigner 1970; Trimble et al. 1974.)

Douglass (1983) and Storey and Reigner (1970) emphasize the significance of the above findings as a way to help meet present and future water supply needs in the eastern United States. Given the above summary, the types of management that will yield the most water are those consistent with even-aged management, especially involving large clear cuts.

While clear cutting of entire reservoir watersheds is not feasible for water quality reasons (see next section on water quality), judicious rotation of clear cuts may provide significant flow increases, especially during the growing season when they are most needed by water supply managers. Douglas and Swank (1972) summarize the value of forestry for water supply managers:

> We can conclude from the experimental watershed evidence in the Appalachian Highlands that cutting forest vegetation has a favorable impact on the water resource by supplementing man's supply of fresh water when consumptive demands are most critical. And, the amount of extra water produced can be predicted with a degree of accuracy that

is sufficient for many purposes. Although heavy forest cuttings will usually increase some stormflow characteristics on that portion of the watershed cut over, regulated cutting on upstream forest land will not produce serious flood problems downstream.

3.2.2.2 Water Quality

In describing the impacts of even-aged and uneven-aged management upon water quality, most studies reviewed involved either clear cutting (of whole watersheds or in limited blocks or strips - all of which fall under even-aged management) or partial cutting (where part of or most of the overstory is retained). It should be noted that while partial cutting falls under uneven-aged management, variations of the shelterwood cutting system (a form of even-aged management involving removal of the forest overstory in stages) involve only partial cuttings.

The impacts of even-aged management systems upon water quality vary with intensity and location of management; intensity, layout and maintenance of road systems; and planning and supervision of logging and woods roads operations (Lull and Reinhart 1967; Kochenderfer and Aubertin 1975; Hornbeck and Federer 1975). The water quality parameters principally affected by these activities are turbidity, nutrient levels, and stream temperature.

3.2.2.2.1 Turbidity

Turbidity is affected by soil exposed in poorly planned, located, and maintained road systems and log landings (Kochenderfer and Aubertin 1975). For example, gravel access roads may have an infiltration capacity of .5 inches per hour, while forests have capacities of 50 inches per hour (Patric 1977, 1978). Haphazardly built road systems may utilize 20% of a watershed, while well planned road systems may utilize 10% (Lull and Reinhart 1967). In addition to access and skid roads, the total compacted area of a typical logging area including landings may approach 40% (Lull and Reinhart 1972). In 1986, MDC/DWM conducted a study of pine thinning on the Wachusett Reservoir watershed completed by MDC watershed crewmembers and two private loggers under MDC supervision. For this study, the total area impacted by logging - including access roads, skid roads, and landings - ranged from 14.8% (MDC crew) to 19.6% (private loggers) (Kyker-Snowman 1989b). Stone (1973) reported soil disturbances covering 15.5% of the logged area for selection cutting, versus 29.4% for clear cutting in eastern Washington. Sediment export was directly proportional to the percentage of a watershed in roads and reducing this percentage was seen as critical for reducing sediment in streams in the Pacific Northwest (Dyrness 1965).

Hornbeck et al. (1986) report that increases in soil disturbance means greater erosion. Martin (1988) recommends setting predetermined travel routes for equipment and doing winter logging and using tracked vehicles rather than wheeled vehicles in sensitive areas. Hewlett (1978) recommends avoiding road locations near perennial and intermittent stream channels in order to eliminate impacts.

A study of erosion on New York City's water supply watersheds highlights the importance of protecting road and stream banks from the effects of erosion. This study of the erosion sources at the Schoharie Reservoir estimated that while road banks made up only .22% of the watershed, they were the source of 11% of all erosion. Streambanks, which made up only .44% of the watershed, were the source of 21% of all erosion (S.U.N.Y. 1981).

Construction of new access roads carries the greatest risk of erosion. Massie and Bubenzer (1974 as cited in O'Connor 1982a) found that 36% of all road erosion in the study area was produced by roads two years old or less, although this category of roads made up significantly less than 36% of all roads. Stone (1973) notes that some turbidity is inevitable with construction and initial use of new roads, but that almost all continuing damage from roads is avoidable by using recommended woods roads maintenance techniques.

A comparison study of graveled and ungraveled forest access roads in West Virginia showed that the application of even 3 inches of gravel reduced sediment losses eight-fold, even though the gravel road carried two times the traffic of the ungraveled road (Kochenderfer and Helvey 1974).

Lynch et al. (1975) traced increased turbidity on watersheds in Pennsylvania to scarified log landing areas. However, Kochenderfer and Aubertin (1975) report that:

> Bare soil exposed by road building, and to a much lesser extent by log landings, has long been recognized as the major source of stream sediment associated with logging operations.

Turbidity in a West Virginia watershed that was clearcut was traced to both road erosion and channel scour from heavier overland flow (Patric 1976). Channel scour is an impact that is unique to large-scale clearcuts or disturbances where peak flows may increase.

Mechanical compaction of soil reduces soil infiltration and reduces tree seedling survival (Martin 1988). Erosion problems result when mineral soil is exposed to rain, especially on areas with long, steep slopes. However, even compacted, exposed soils have high infiltration capacities. The most significant erosion occurs when soil is bared to the "B" horizon, beneath the organic and leached horizons (Patric 1977).

MDC measured soil bulk density (a parameter which shows soil compaction) on transects through a pine thinning at Wachusett Reservoir with three types of conventional logging equipment. Average soil bulk densities did not change significantly when measured before and after logging done by MDC's crew with a conventional small skidder and a forwarder. Average bulk density before logging was 6.18 grams/cubic centimeter (gms/cm) and 6.21 after logging; 13 gms/cm is considered the level where root penetration is inhibited. Stone (1973) reported that soil compaction varies enormously with soil type, moisture content, frequency of traffic, and type of "packing" impact. He concluded that the key to avoiding erosion from logging is to ensure that protection steps will handle extreme rain events on the most sensitive sites. The careful planning of skid roads is essential.

Cuttings where soils are not disturbed by roads or skidding do not discernibly increase turbidity (Kochenderfer and Aubertin 1975; Dyrness 1965; Bormann et al. 1974). In Connecticut, 80 logging locations were checked for compaction, erosion, and stream sedimentation. All such problems were found to be related to the transportation aspects of logging (O'Haryre 1980, as cited in More and Soper 1990). Other studies trace turbidity to erosion from heavily used logging roads, particularly after heavy rainstorms and from increased streamflow that caused channel erosion (Patric 1976; Pierce et al. 1970 as cited in More and Soper 1990).

Turbidity measurements were compared on watersheds in the Fernow Experimental Forest, West Virginia; treatments included a commercial clearcut, a silvicultural clearcut, and one watershed with no cutting. Turbidity (in Jackson Turbidity Units - JTU) during logging was 490, 6, and 2 units respectively. One year after cutting, turbidity was 38, 5, and 2 units respectively (Kochenderfer and Aubertin 1975). Douglass and Swank (1975) concluded that well-planned, well-maintained road systems do not damage water resources. In a comparison of logging with planned and unplanned skid trails, the planned logging had turbidity of 25 JTU while the unplanned logging had 56,000 JTU (Reinhart and Eschner 1962, as cited in Brown 1976). A comparison of regulated and unregulated logging in 1947-8 found that unregulated logging increased turbidity 10-20 times background levels while regulated logging increased turbidity only slightly (Douglass and Swank 1975).

In a study at Hubbard Brook, New Hampshire, a watershed was logged with a strip cut even-aged method. In the two years during and after logging, 6 of 147 streamwater samples exceeded 10 turbidity units (Hornbeck and Federer 1975). A study of different stream crossing techniques in the MDC Ware River watershed found that temporary bridge crossings caused less impact than ford crossings or crossing on poles. Increases in turbidity caused by temporary bridge crossings were not measurable beyond 100 feet downstream from the bridge (Thompson and Kyker-Snowman 1989).

Clearing of riparian areas has been associated with increased turbidity (Corbett and Spencer 1975). Lynch et al. (1975) compared middle slope clear cuts with lower slope clear cuts and found turbidities of 4 part per million (ppm) on middle slope cutting, 196 ppm on lower slopes, and 2 ppm on an uncut control watershed.

While useful predictive models exist to estimate soil loss from agricultural practices, few soil loss predictive models exist for silvicultural operations. Burns and Hewlett (1983) developed a model that evaluated clearcut, disking, and planting operations in the southeastern U.S. This model is based on the percentage of bare soil after logging practices and the location of bare soil areas with regard to perennial stream channels. The authors recommend keeping any exposed soil areas away from wet and dry stream channels, in order to minimize erosion. Currier et al. (1979) developed a procedure for analyzing water quality impacts from forest management. Larson et al. (1979) began assembling existing data into a system of computer models. Li et al. (1979) developed a sediment yield model based on the Universal Soil Loss Equation and tested in Colorado.

3.2.2.2.2 Nutrients

Logging impacts on nutrient levels can vary by the amount of cover removed, type of cover removed, watershed slope, location within the watershed (lower areas cause faster nutrient input, but higher areas cause more nutrient loss), and the timing of the regeneration response. Soil type and depth also control impacts (e.g., deep, poorly-drained, fine-textured soils tended to bind free nutrients before they reached the streams) (Bormann et al. 1968; Brown 1976; Carlton 1990; Martin and Pierce 1980; Martin et al. 1984). While turbidity increases are caused by soil disturbance, increases in nutrient levels can result solely from cover removal. For example, at Hubbard Brook, New Hampshire all trees on a catchment were cut and left on the ground and herbicides applied to prevent regrowth. As a result, stream concentrations of several ions increased significantly (Douglass and Swank 1972). In this study, nitrates increased more than forty times background amounts (Bormann et al. 1968). Cuttings associated with significant nutrient increases typically involve clearing of large percentages of watersheds. However, even clearing of entire watersheds at Fernow Experimental Forest, WV and Pennsylvania State Experimental Watersheds did not appreciably increase nitrates (Kochenderfer and Aubertin 1975; Lynch et al. 1975).

Nutrient increases from cleared areas are derived both from the increases of nutrients released as the decomposition process increases in sunlight and by the reduction in uptake due to the loss of plant cover (Vitousek 1985). At Hubbard Brook, New Hampshire, strip clear-cutting of one third of a watershed caused nitrate increases of nearly two times an undisturbed watershed and one third that caused by a watershed that was completely clear-cut (Hornbeck et al. 1975). The coarse-textured soils of New England that have a lower nutrient-holding ability may be more susceptible to nutrient losses, particularly in areas without plant cover (Hornbeck and Federer 1975). Soils that are shallow to bedrock, thin unincorporated humus on infertile soil, and coarse skeletal soil on steep slopes are all also susceptible to nutrient loss (Williams and Mace 1974). In areas where soils may be sensitive to nutrient loss, limiting cutting to light partial cuts may be necessary to prevent nutrient loss (Brown 1976).

Aber et al. (1978) modeled changes in forest floor biomass and nitrogen cycling using various regimes of clear-cutting. A projected rotation that clear-cuts a forest each 30 years versus one on a 90 year cycle will accumulate less floor biomass and release more nitrogen to streams. Williams and Mace (1974) state that, in general, the more drastic the manipulation of the forest, the larger the corresponding release of nutrients, with minor manipulations causing little or no nutrient release. In their study of jack pine clear-cutting in Minnesota, summer logging involving whole tree removal was found to cause significantly more nutrient leaching than winter logging with only stem removal.

3.2.2.2.3 Temperature

Stream temperature is important in protecting aquatic life and because of its impact on dissolved oxygen and nutrients (Brown 1976). Stream temperatures vary depending on the presence of forested buffer strips adjacent to stream channels (Hornbeck et al. 1986). Douglass and Swank (1975) concluded, “stream temperatures are not increased by forest cuttings if a buffer strip is retained to shade the stream.”

Kochenderfer and Aubertin (1975) found that clear-cuts on upper watershed areas did not increase stream temperature, as few stream channels occur in these areas. In lower watershed cuttings where trees were left adjacent to the stream channel, cuttings had no influence on stream temperature.

3.2.2.2.4 Summary

Studies indicate that erodibility of a watershed impacted by either natural disturbances or logging will remain low “as long as destruction does not involve severe and widespread disruption of the forest floor” (Bormann et al. 1974). The relevant components of logging operations are skidding, log landing, and access road construction, where mineral soil may be exposed.

While increases in streamwater nutrients vary by type of cutting and watershed characteristics, the two key aspects of cutting that influence nutrient release are the location and amount of clearing and the response of forest regeneration. Even where openings are revegetated within four years by rapidly growing early successional species, nutrient losses can still occur (Bormann et al. 1974).

Studies have demonstrated the methods that will hold water temperature and turbidity increases within tolerable limits (Swank 1972). Patric (1978) states there is overwhelming evidence that neither the productivity of soils nor the quality of water is substantially lessened during or after responsibly managed harvests. Stone et al. (1979) report that if proper precautions are taken, water quality impacts from logging are essentially non-existent. Regarding timber harvesting, Stone (1973) concludes that “adverse impacts can be greatly reduced or entirely avoided by skilled planning and sufficient care.”

3.2.3 Uneven-Aged Silviculture

3.2.3.1 Water Yields

While most of the trends summarized in the even-aged management water yields section above also hold true for uneven-aged management, the effects upon water yield vary. For example, uneven-aged management on north-facing slopes, removing conifers and involving significant percentages of basal area, will probably result in higher water yields than less intensive cuts removing hardwoods on south-facing slopes. However, either approach to uneven-aged management will likely result in smaller water yields than a comparable even-aged management approach. This is due to less dramatic changes in soil moisture and evapotranspiration caused by the partial cuttings and smaller openings used in uneven-aged management. Adjacent vegetation and advance regeneration more quickly fill these smaller gaps. In addition, adjacent trees utilize part of the additional soil moisture created by cutting. Hunt and Mader (1970) found that when two white pine forest plots at Quabbin Reservoir were thinned by 30% and 80%, soil moisture increased slightly to moderately and growth increased by 70% and 230% respectively. Hornbeck et al. (1993) reported that when 24% of a basin was cut in one clearing it yielded twice the water of a similar basin where 33% of the forest was removed in scattered openings.

Douglass (1983) found that "partial cuttings were not as efficient for augmenting water yield as were complete cuttings." Storey and Reigner (1970) note:

> There are several ways we can manipulate vegetation to effect water savings. The obvious one is by heavy cutting of trees, thereby removing rainfall intercepting surfaces and removing the transpiring agent. According to considerable evidence our people have collected, single tree selection cutting saves little or no water. The cutover area need not be large; cutting in blocks or strips or even group selection of trees to be removed will save water.

While it is clear that silvicultural systems employing partial cuttings yield less water than complete cuttings, partial cutting studies do show increased yields (Mrazik et al. 1980). For example, of the 10 selection cut or thinning watershed experiments in the U.S. listed by More and Soper (1990), 8 resulted in significant yields. The average annual significant yields for each of the first five years after cutting ranged from .4 to 2.3 area-inches. When the ten experiments are averaged, selection/thinning resulted in a yield of 1 area-inch per year for the first five years after cutting. Hibbert (1967) reported results of seven selective cuttings in North Carolina and West Virginia with all watersheds except one having a southerly exposure. The average annual yield for years measured after cutting was 1.13 area-inches. The lightest cuttings necessary to produce significant yields remove approximately 20% of the forest basal area (Kochenderfer and Aubertin 1975, as cited in More and Soper 1990; Trimble et al. 1974). Douglass and Swank (1972) assembled a model that predicts a first year water yield increase based on reduction in forest basal area. This model predicts that a 30% reduction in basal area will increase yields approximately 2-3 annual area-inches.

In predicting the significance of water yields to be derived from uneven-aged management, specific site characteristics of watersheds must be examined. For example, cuttings on north facing watersheds with deep soils will result in relatively larger yields. Using regression lines from Hibbert (1967), a one-third reduction in forest cover on a north-facing watershed is estimated to yield three times the streamflow of a similar cut on a south-facing watershed.

Yields from uneven-aged management should also be viewed in comparison to the two above alternatives: even-aged management and natural management. When compared with these two options, uneven-aged management falls between the two. For example, partial clearing of watersheds with even-aged management may yield 5 or more area-inches per year (approximately 25% increase in yield) for the first few years after cutting (estimated from Hibbert 1967). However, aging forests or naturally-managed watersheds with new forest growth will have reduced water yields over periods without disturbance. For example, Hibbert (1967) reports on three small watersheds (all less than 2,000 acres) in New York where an average of 47% of the watersheds was planted to conifers. After 25 years, the three watersheds averaged 5.3 area-inches less streamflow. Another medium sized watershed (over 300,000 acres) that was passively managed for 38 years and on which average basal area doubled, showed a decrease in yield of 7.7 area-inches - equivalent to a 25% reduction.

Thus, existing data show potential water yield increases of approximately 25% for even-aged management and potential decreases on unmanaged forests of up to 25%. Uneven-aged management falls in between these two approaches, but averages small yield increases (on the order of approximately 5% for the first few years after cutting). The above approximate range would be reduced in actual magnitude depending upon the percentage of the watershed cut and the frequency of the rotation of cuttings. However, the relative comparison of the three alternatives should generally hold true. At Quabbin watershed, the mature forest cover would probably produce fairly consistent yields under a naturally-managed approach, and small to moderate increases under either an uneven-aged or even-aged approach.

3.2.3.2 Water Quality

Many of the principles underlying the potential for water quality impacts as a result of logging operations apply equally to even-aged and uneven-aged management. In order to avoid repetition, only the potential water quality impacts unique to uneven-aged systems will be reviewed in this section. As with even-aged management, the impacts upon water quality vary with intensity and location of management; intensity, layout, and maintenance of road systems; and planning and supervision of logging and woods roads operations (Lull and Reinhart 1967; Kochenderfer and Aubertin 1975; Hornbeck and Federer 1975).

Uneven-aged systems remove single trees and small groups of trees. In a temperate-region forest study of gap-size impacts on nitrates, Parsons et al. (1994) measured extractable nitrate in soil plots. Within a lodgepole pine forest in Wyoming, gaps were created by removing 1, 5, 15, or 30 trees. The authors found that, compared with adjacent undisturbed forest, gaps created by removing 1 or 5 trees had no increase in nitrate. The 15-tree gaps had higher nitrate levels, and 30-tree gaps had nitrate levels 2-3 times higher than the 15-tree gaps. This same stand was previously thinned with no increase in nitrates, and clear-cut with soil nitrate increases of 10-40 times adjacent undisturbed forest. The authors recommend selective harvesting if nitrogen availability is of concern on a site. Stone (1973) notes:

> Any management practices that reduce vigor of the residual vegetation or delay regrowth and regeneration - such as scarification, excessive herbicide application, or maintenance of excessive deer herds - could increase loss rates [nitrate leaching] above those observed on the harvest clearcuts. On the other hand, greater surface soil shading, as by partial cutting methods, narrow stripcuts, increased cover density on clearcuts, or any means of hastening regrowth, would reduce losses [nitrate leaching] even more.

Trimble et al. (1974), in comparing management systems, state that water quality is ordinarily maximized on forest land by maintaining an unbroken tree and litter cover. The city of Baltimore's forest management utilizes the selection system because "although this [the selection system] is not the most economical system of cutting to use, it leaves sufficient cover to protect the watershed..."(Hartley 1975).

The literature clearly reports that where stream shading is unaffected, stream temperature will not change (Douglass and Swank 1975; Hornbeck et al. 1986; Kochenderfer and Aubertin 1975). With little significant impact upon temperature and nutrient streamwater parameters, the chief potential impact of uneven-aged management systems is turbidity. However, increased turbidity appears to be less of a concern with uneven-aged management, due to the lighter cutting practices and the amount of forest cover. For example, a comparison study of two watersheds at the Fernow Experimental Forest in West Virginia showed only slight elevations of particulates after three selection cuts during the 1950's and 1960's (cuts included 13%, 8%, and 6% of basal area) as compared to an adjacent undisturbed watershed. In a separate study, Corbett and Spencer (1975) reported no turbidity increases from a thinning operation.

One area of potential concern regarding traditional uneven-aged systems is that cutting cycles are often more frequent, meaning more frequent forest entry and more miles of access roads in use at any given time (Stone et al. 1979). However, the actual impacts will depend upon the uneven-aged method adopted. For example, in uneven-aged forests managed for water supply purposes, trees can be grown on longer rotations and longer cutting cycles. Rhey Solomon, water resource manager for the U.S. Forest Service notes "...the way to keep the water flowing and safeguard the forest is to rotate management throughout the watershed" (American Forest Council 1986).

3.3 Impacts of Air Pollution on the Forested Watersheds of the Northeastern U.S.

The intent of this section is to look at the impact of air pollution on present and future forests of the southern New England region. For water supply purposes, managers must consider both the forest as an ecosystem and its function as a watershed. The focus must include both the direct impacts of air pollution upon watershed forests and the impacts of resulting ecosystem degradation upon water quality.

While the following discussion outlines specific impacts of air pollution upon forests, it is extremely difficult to isolate these impacts from the many other processes and stresses occurring in forest ecosystems (climatic stresses, insects, diseases, fire, ice, wind, etc.). It is also difficult to isolate the impact of one specific pollutant, e.g., ozone or nitric acid, from the composite of impacts affecting a forest. Klein and Perkins (1988) state:

> It is now recognized that no single causal factor is responsible, but that there are a variety of anthropogenic causal factor complexes interacting with natural events and processes that, together, induce stresses in forests that culminate in declines of individual plants and of ecosystems.

3.3.1 Acid Deposition

Carlton (1990) contains an excellent overview of the impact of acid deposition upon watersheds. In Massachusetts, data indicate that the average pH of precipitation is 4.2, which is six times more acidic than uncontaminated precipitation (Godfrey 1988, as cited in Carlton 1990). In New England, approximately 60-70% of the acid falls as sulfuric acid and 30-40% as nitric acid (Murdoch and Stoddard 1992; Rechcigl and Sparks 1985, as cited in Carlton 1990). Murdoch and Stoddard (1992) note a study in Maine that showed the sulfuric acid component decreasing in recent years, while the nitric acid component is increasing, leaving the pH of precipitation fairly constant. For example, Stoddard (1991) reported that sulfate deposition had decreased by 1.8% from 1970 to 1984 in the Catskill Mountains of

New York. However, the acidity remained the same due to equal increases in the nitric acid component. In Massachusetts, depositions amount to .3 to .7 pounds of hydrogen ion, 16.2 to 27.5 pounds of sulfate, and 8 to 22 pounds of nitrate per acre per year (Petersen and Smith 1989).

Sulfuric and nitric acids tend to accelerate replacement of aluminum, calcium, magnesium, and other base cations in the soil with hydrogen ions (Hovland et al. 1980, as cited in Carlton 1990). In this way, acid deposition will increase soil acidity and directly impact biological activity, soil fertility, and cation-exchange capacity (Carlton 1990). Acid precipitation can also leach aluminum directly into streams causing potential negative water supply and aquatic and fish impacts (McAvoy 1989). Key factors in determining the susceptibility of watersheds to acid inputs include: the supply of base cations in soils; the percentage of base-rich groundwater flow versus storm flow; the relative importance of snowmelt events; the average storm rainfall intensity, volume, and duration; and the soil depth, texture, pH, and cation exchange capacity (McAvoy 1989; Peters and Murdoch 1985; Veneman 1984). Records at Hubbard Brook, New Hampshire show that while sulfate inputs have declined, base cation inputs from precipitation have also declined (145 micro eq/liter in 1963 to 104 micro eq/liter 1989) causing sensitivity to acidification to actually increase (Driscoll et al. 1989). The authors attribute the decrease in base cations to a large reduction in suspended particulates since 1970 due to reduction of coal and open burning emissions.

Some researchers have questioned the extent of the impact of acid precipitation. For example, Krug and Frink (1983) feel that most aluminum in streamwater is due to acid soils (caused by natural humic acids) not acid rain. Krug and Frink (1983) and Veneman (1984) note that streamwater can become more acidic as the acid humus layer increases with forest age and because thick humus layers may reduce the amount of water percolating into the subsoil and increase saturated overland flow. Studies in Connecticut and the Berkshires of Massachusetts show that soil acidity increases with forest age (Art and Dethier 1986; Krug and Frink 1983). In Connecticut, litter pH changed from 5.5 to 3.9 from 1927 to 1980 and the mineral soil pH from 5.1 to 4.6 during this period. A study in Norway also concluded that changing land use and consequent vegetational succession was largely responsible for acidification of soils and water Krug and Frink (1983).

Reuss and Johnson (1986) identified the key difference between natural and anthropogenic acid inputs as the ability of the stronger nitric and sulfuric acids to leach through to stream waters, whereas the weaker natural organic acids will leach from upper to lower soil horizons, acidifying soils but not stream waters. Therefore, a key factor in identifying systems acidified by pollution is whether pH is attributed to organic acids or sulfates and nitrates.

Driscoll et al. (1988) noted that the "acid rain" and "acid soil" argument is largely due to the lack of long-term data on basin soil and water quality. To help resolve this controversy, the authors compared two similar basins, one in New Hampshire (NH) where acid deposition is significant (pH 4.1) and one in British Columbia (BC) where acid deposition is insignificant (pH 5.0). The basins have similar bedrock, glacial history, and soils but differed in vegetation type and precipitation amounts. Both headwater streams were acidic. The key difference was that the BC stream was dominated by weak organic acids, had low aluminum concentrations, and low sulfate loading, while the NH stream was dominated by strong acids (nitric and sulfuric), had high aluminum concentrations, and high sulfate loading.

Two streams in the Quabbin watershed, the West Branch of the Swift River and the East Branch of Fever Brook, received similar analysis to those in NH and BC (Rittmaster and Shanley 1990). The concentrations of sulfate and hydrogen ions in precipitation were significantly higher at Quabbin than at the New Hampshire site. While both Quabbin streams had high aluminum concentrations during high flow periods, Fever Brook aluminum was in an organic form that is not toxic to fish. Fever Brook also had one half the net export of sulfate of the Swift River, a result of sulfate reduction in the extensive beaver flowage at Fever Brook.

Veneman (1984) rated the ability of the soils of Massachusetts to buffer acid inputs using many of the criteria outlined above. Of the 25 soil types that make up almost all of the MDC lands at Quabbin, only four (all wetland soil types) were classified as “acid precipitation will have no negative impact on water quality,” whereas sixteen types are listed as “acid precipitation will have a moderate or significant impact on water quality.” Baker (1984) re-measured soil parameters at eight sites at Quabbin that had been measured in 1962. He found that soils had increased in acidity and exchangeable aluminum and were now releasing sulfate, whereas they were adsorbing sulfate in 1962. These changes have reduced the neutralization capacity of the soils.

3.3.2 Interaction Between Air Pollution and Forests

Reuss and Johnson (1986) use the term “canopy leaching” for the process where hydrogen ions replace base cations in the forest canopy. Krug and Frink (1983) report that 90% of the hydrogen ions in acid rain at Hubbard Brook, NH are neutralized in the northern hardwood canopy during the growing season (rain pH of 4.1 changed to 5.0 in throughfall). In studies in the west-central Adirondack Mountain region of New York, Peters and Murdoch (1985) noted that throughfall in deciduous forests was less acid than rain, while thoughfall in coniferous forests was more acid than rain.

As the forest flora exist in several layers above and below the ground surface, the accumulation/neutralization that occurs at these various layers tells a great deal about how the forest processes incoming acid deposition. Yoshida and Ichikuni (1989) studied the chemical changes to precipitation as it passed through the canopies of three different types of Japanese forests. They reported that from 49-74% of the total incoming acid deposition was neutralized by the forest canopies, with deciduous oak forests neutralizing the least and cedar forests neutralizing the most. Virtually all of the cations and anions studied, with the exception of the hydrogen ion, increased as precipitation fell through the canopy (the authors studied Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, NH_{4+}, H^{+}, Cl^{-}, NO_{3-}, SO_{42-}, and Al). This indicates the process of “canopy leaching” is evident in these forests. The authors note that similar occurrences have been documented in New England by other authors.

Laboratory studies indicate acid precipitation increases leaching of calcium and potassium from vegetative foliage (Smith 1981). In order for the forest canopy to replace the cations and anions lost, similar amounts of these substances must be taken up from the soil. In some cases, acid conditions cause these nutrients to be leached below the root zone where they become unavailable to plants (Klein and Perkins 1988). The net effect of the above processes is to acidify the soils and damage forest ecosystems (Yoshida and Ichikuni 1989).

Increasing acidity of soil water causes leaching of aluminum, an element of increasing concern to water supply managers. Aluminum also damages fine tree roots and inhibits the uptake of calcium, a nutrient vital to plant growth. This situation leads to further imbalance in nutrients and increases susceptibility to drought stress, decline in growth, and increased mortality (Johnson and Siccama 1983, as cited in Art and Dethier 1986; Petersen and Smith 1989; Smith 1981). For example, soil acidity is a potential contributor to increased nitrate leaching from forests (Vitousek 1977). Klein and Perkins (1988) report that temperature, moisture, light, nutrients, and soil factors all contribute to susceptibility to disease. This type of pollution may also affect recovery from winter injury.

According to Klein and Perkins (1988), trees undergoing nutrient stresses may be predisposed to decline when natural and pollution-caused stresses are added. Forests that are damaged by decline go through a process of "reorganization" during which time increased nutrients are leached from the system into tributaries. This increased loss of nutrients may in turn perpetuate the forest decline.

Soil acidity will vary relative to air pollution levels, as well as other factors including soil type and horizon, underlying geology, and successional stage of forest cover (Art and Dethier 1986). In general, the soils of the New England region have a low acid neutralizing capacity or "ANC" (Godfrey 1988, as cited in Carlton 1990). Art and Dethier (1986) studied the relationship of land use and vegetation to the chemistry of soils in the Berkshires. Acidity of the upper-most soil layer was positively correlated to species composition and stand age, with stands less than 140 years averaging pH 4.21 and those over 140 years averaging pH 3.92. Several studies verify an increase in soil acidification with successional sequences following agricultural abandonment (Robertson and Vitousek 1981, Thorne and Hamburg 1985, Krug and Frink 1983, all as cited in Art and Dethier 1986). Acidity varied with land use history, with previously pastured lands having significantly lower pH in the upper horizons than previously cultivated lands. The conclusion is that past land use has a significant impact on species composition and overall soil acidity (Art and Dethier 1986). These studies are useful in considering overall differences in chemical processing in various types and ages of forests and in assessing the potential susceptibility of various forests to impacts of acid deposition.

Soil water pH generally decreases deeper into the soil profile. For example, in a study of eight forest soils in central Massachusetts, mean pH in the A and C horizons were 4.39 and 3.58 respectively; an increase in acidity of eight times. Exchangeable aluminum in the A horizons was nearly four times as high as in the C horizons (Baker 1985, as cited in Carlton 1990).

High levels of ozone cause injury to leaf surfaces of sensitive tree species such as white pine, black cherry, and white ash, especially during summer months. Ozone also reduces photosynthetic rates and the supply of carbohydrates to the roots (Petersen and Smith 1989; Reich and Amundson 1985; Smith 1981). High levels of ground level ozone occur at Quabbin Reservoir, with readings recorded at Quabbin Hill sometimes exceeding other state recording stations including those in Boston.

C. Read

Local sources of air pollution

The combined effects of acid deposition and ozone pollution may be contributing to a measurable decline in Massachusetts forests. A statewide study of the Massachusetts forests identified 24,000 acres that show signs of decline, including yellowing leaves, dead branches, and standing dead trees. This represents a 10% increase in forest decline over twenty years ago (Parker 1988). In addition, the growth rate on one third of the red and white pines studied has dropped 20-50% since the 1960's (Freeman 1987). The overall impact of air pollution predisposes trees to insect and disease outbreaks. For example, research shows that air pollution predisposes pine trees to bark beetle infestations and makes several tree species more susceptible to root rotting fungus (Smith 1981).

In Massachusetts, the decline of red spruce and sugar maple has been examined most closely. Studies of red spruce on Mt. Greylock found that this decline involved a combination of factors, including pathogens, insects, and ice, snow, and wind. However, the decline studied was attributable only in small part to these factors. The high acidity of rain and fog, the high soil acidity, and the low soil nutrient content (including low calcium) at these sites point towards air pollution as a chief cause of the decline of red spruce. The study of sugar maple decline also concludes that many trees are in a weakened condition, which magnifies the impact of other detrimental factors (Petersen and Smith 1989).

In addition to acid deposition and ozone pollution, current air pollution contains metals, polychlorinated biphenyls (PCBs), alkanes, and various polycyclic hydrocarbons and organic acids (Rechcigl and Sparks 1985, as cited in Carlton 1990). Soil and vegetation surfaces are the major “sinks” for pollutants in terrestrial ecosystems (Smith 1981, as cited in Carlton, 1990). For example, the leaves and twigs of an average sugar maple tree 12 inches in diameter will remove the following elements from the air in one growing season: 60 mg of cadmium, 140 mg of chromium, 5800 mg of lead, and 820 mg of nickel (Smith 1981). Klein and Perkins (1988) report that the accumulation of metals affects nitrogen transformations in hardwood forests.

Forest soils serve as sinks for lead, manganese, zinc, cadmium, nickel, vanadium, copper, and chromium; tree trunks also serve as sinks for large amounts of trace metals including nickel, lead, chromium, cadmium, and manganese (Smith 1981; Driscoll et al. 1988, as cited in Carlton 1990). The U.S. Environmental Protection Agency designed a 40-acre “model forest” containing several hardwood species and white pine (Smith 1981, as cited in Carlton 1990). The model predicts that, within five years of planting, this hypothetical forest and its soils would annually remove the following pollutants:

96,000.00 tons/year of ozone
748.00 tons/year of sulfur dioxide
2.20 tons/year of carbon monoxide
0.38 tons/year of nitrogen oxides
0.17 tons/year of peroxyacetylnitrate

The net effect of air pollution on a forest ecosystem is a combination of decreased photosynthesis, decreased growth, increased respiration, reduced biomass, and possible reductions in reproduction. These impacts produce a range of symptoms that together are termed “forest decline.” The severity of the decline depends on the amount of pollutants, and the species and site conditions involved. An additional impact of air pollution is alteration of forest ecosystem composition and structure, through selectivity of impact. More severe air pollution, and air pollution on naturally stressed sites, serves to simplify the overall make up of the ecosystem and make it less diverse and less stable (Klein and Perkins 1988; Smith 1981). Smith (1981) defines three classes of air pollution impacts:

- Class I: low dosage, where ecosystem serves as a sink for pollutants;
- Class II: intermediate dosage causing nutrient stress, reduced photosynthesis and reproductive rate and increased predisposition to insects and diseases;
- Class III: high dosage where mortality is widespread and gross simplification of the ecosystem alters hydrology, nutrient cycling, erosion, microclimates, and overall ecosystem stability.

Klein and Perkins (1988) reviewed more than 400 studies relating to forest decline and concluded:

> There are interactions between primary causal complexes and their direct effects and secondary causes and consequences of forest decline discussed here, so that the web of interactions becomes formidable. Nevertheless, a start must be made on these analyses, not

only to understand forest decline holistically, but also because of the pressing need to develop concepts and strategies to ameliorate or reverse the imminent collapse of forested ecosystems. Recognizing that species sensitivities to causal factor complexes varies greatly, inevitable simplification of ecosystems will drastically affect their ultimate stability.

3.3.3 Nitrogen Saturation

3.3.3.1 Overview

The potential problem of nitrogen saturation, defined as the declining ability of an ecosystem to retain added nitrogen, was only identified in 1981 (Aber 1992). Researchers are concerned that acid deposition may also be adding significant amounts of nitrogen, originating chiefly from nitrogen oxides in air pollution. The effects of nitrogen saturation include elevated nitrate, aluminum and hydrogen ion concentrations in stream water (Van Miegroet and Johnson 1993). Monitoring of nitrates is required for drinking water (standard=10 ppm) because of health effects upon infants and potential formation of carcinogenic byproducts (Skeffington and Wilson 1988). Nitrates can also cause algal blooms in lakes and reservoirs. Excess nitrogen deposition may also effect forest composition and productivity (Aber 1992).

Bormann and Likens (1979b) report a doubling in nitrate concentration in precipitation since 1955. Schindler (1988) reports that deposition of nitrogen oxides have increased much more rapidly than sulfates in recent decades. Ollinger et al. (1994) report that there is a more than twofold increase of wet nitrate deposition from east to west between eastern Maine and western New York State. The authors mapped broad-scale wet and dry nitrogen deposition across the Northeast, with the Catskill region in the highest category (10.34-12.66 kg N/ha/yr.) and the Quabbin region in the 7.99-9.16 kg N/ha/yr. category.

3.3.3.2 Processes Involved

The processes related to nitrogen saturation are more complex than those related to precipitation inputs of sulfates, mainly because nitrogen can be both an acid and plant nutrient component and because of the complex interactions between soils and plants and the various compounds of nitrogen. In the ammonium form, nitrogen is a nutrient for the plant/soil biota complex. In the nitrate form, nitrogen can be a nutrient for biota but can also be a very mobile and dominant anion involved in base cation depletion and mobilization of aluminum through the soil and into stream water.

A key reaction in this process is nitrification, the conversion of ammonium to nitrate. Others are denitrification (in which atmospheric nitrogen is released from nitrates) and nitrogen mineralization (the process by which ammonium is formed from organic nitrogen in soils). Mineralization is an important process, as the storehouse of nitrogen in soils far exceeds that in the plant system (75-97.5% of nitrogen is in inorganic form in soils) but the nitrogen can be more mobile in the plant system. As long as the soil system delivers an amount of nitrogen less than or equal to the capacity of the plant system, nitrogen is held within the system. Thus, nitrogen saturation requires both the soil and plant systems to be saturated.

The interaction of these three processes - nitrification, denitrification, and nitrogen mineralization - is dependent upon various bacteria, pH levels, season and climate, as well as variations in plant/soil composition. An added complication is the process of nitrogen fixing, by which plants transform nitrogen gas (the most prevalent component of the atmosphere) to nitrogen in a usable form in the soil/biota system. The relative importance of nitrogen fixation is dependent on the composition of nitrogen-fixing plants in the system. Bormann and Likens (1979b) estimate that 70% of the nitrogen store at Hubbard Brook, NH is derived from fixation and the remainder from deposition. In general, predictions of the timing of the onset of nitrogen saturation are limited by the lack of understanding of soil properties and the complex processes at work there (Schofield et al. 1985; Agren and Bosatta 1988; Nadelhoffer et al. 1984; Aber 1992,1993).

Disturbance of the plant/soil system by natural or anthropogenic events tends to increase mineralization of nitrogen and consequent nitrification in the system. Vitousek et al. (1979) analyzed processes that keep nitrate leaching in balance. These include the accumulation of ammonium in soil solution on cation exchange sites in the soil, and lack of soil water for nitrate leaching. A delay in nitrate movement after disturbance is critical as this allows vegetation to develop and take up much of the available nitrate before it can leach into stream waters.

Van Miegroet and Johnson (1993) summarize the complexity of the nitrogen saturation process:

> This soil condition is the integrated result of vegetation type, age and vigor, past N accumulation history, climatic conditions, and current and past N input regime and soil characteristics.

Aber et al. (1989) have developed equations based on field work that can help model the nitrogen cycle using soil litter analysis.

3.3.3.3 Symptoms and Site Susceptibility

Aber (1992) describes the characteristics - including annual stream water nitrate trends - of nitrogen-limited, nitrogen-transition, and nitrogen-saturated systems. In general, nitrogen-limited systems have low nitrate loss during snowmelt, high carbon:nitrogen ratios in soil litter, and high soil dissolved organic carbon concentrations. Nitrogen-saturated systems exhibit the reverse conditions for these three criteria. The identification of elevated nitrates in storm events, especially during snowmelt, may be a first indication that system inputs are exceeding capacity, at least temporarily. For example, researchers at the New York City water supply watersheds in the Catskills are concerned about peaks of nitrates in the spring (up to 128 micro eq/l) combined with elevated summer levels (Murdoch and Stoddard 1992). Rittmaster and Shanley (1990) in studying two tributaries at the Quabbin reported that nitrate concentrations were generally low, but nitrate peaks of 20 and >35 micro eq/l were reported in the two streams during the snowmelt period. The authors attributed these peaks to short soil contact time during storms. There are no other records of nitrate peaks at Quabbin, but limited storm sampling has been done.

Brown et al. (1988) recommend consideration of vegetation type and age, site history, carbon: nitrogen ratios in soil organic matter, external inputs, and nitrogen turnover rates to thoroughly evaluate the condition of a system with regard to nitrogen saturation. The authors note that because natural plant communities change, nitrogen saturation is a “moving target.” Van Miegroet and Johnson (1993) reported that forests with small soil nitrogen pools, due to either limited accumulation history or frequent disturbance such as fire, generally have low nitrification potential and insignificant nitrate leaching, irrespective of age or vigor of the forest. Sites that have high soil nitrogen content coupled with a low carbon:nitrogen ratio have a high nitrification potential, and under these conditions the annual leaching of nitrates is strongly dependent on atmospheric inputs, forest age and tree nitrogen uptake rates.

3.3.3.4 Impacts of Forest Succession and Disturbance

Stand age is an important factor in determining nitrogen uptake and annual nitrogen accumulation rates in tree biomass. A declining trend in nitrogen immobilization as a stand matures may explain why nitrate leaching losses are typically larger in mature versus vigorously growing forests. Long periods without disturbance may allow high nitrogen accumulation and low carbon:nitrogen ratios and increased nitrification potentials (Van Miegroet and Johnson 1993). Hemond and Eshleman (1984) note that both higher plant uptake and microbial immobilization contribute to limiting nitrate losses from Temperate Zone mid-successional forests.

Murdoch and Stoddard (1992) state:

> In watersheds where forests are accumulating biomass, biological demand for nitrogen is often sufficient to retain virtually all atmospherically deposited and mineralized nitrogen during the growing season and reduces net nitrate release to stream water.

In their analysis of elevated summer nitrate levels in Catskill Mountain streams, Murdoch and Stoddard hypothesize that the older forests in the Catskill Preserve may have a low demand for nitrogen and may therefore be unable to retain all of the atmospheric nitrogen entering the watersheds. The authors are currently engaged in a study of nitrogen cycling in New York City water supply lands in the Catskills, investigating nitrogen input/output in different landscape types and documenting streamwater chemistry changes over short distances (Murdoch, 1993 pers. comm.).

Aber et al. (1991) note that changes in species compositions may effect the ability of a forest to absorb nitrogen. For example, due to longer needle retention, pine takes up less nitrogen than oak or maple. The authors also modeled the timing of nitrogen saturation of a hypothetical forest under different scenarios. For example, forest harvesting (removal of nitrogen) slowed the onset of saturation; ozone pollution reduced net primary productivity and moved the onset of saturation up from 300 years in the future (without ozone pollution) to 50 years into the future (with ozone pollution); and alteration of forest species from low nitrogen-demanding to high nitrogen-demanding species delayed the onset of saturation. This modeling exercise did not examine the impact of forest succession.

4 Watershed Management Goals

4.1 Drinking Water Protection Goals

4.1.1 Water Quality

The enabling legislation that created the Division of Watershed Management directs the DWM "*… to assure the availability of pure water for future generations*"

Water quality in the Wachusett Reservoir depends on many watershed features, including natural characteristics, land use, and hydrology. A major tenet of watershed management is protection through ownership of watershed lands. Owning and managing forest lands surrounding a water supply source is recognized as the most direct and proven method of protecting the sources of long-term water quality. Purchase of land or buffers protects land from development, which is generally accepted as detrimental to water quality. However, there still remain numerous questions and options about managing protected lands in order to produce the best water quality.

The Division of Watershed Management must continually assess the quality of the water, and develop management strategies that assure the availability of clean water. The DWM's overarching Planning Document for Wachusett Reservoir is the Watershed Protection Plan Update for Metropolitan Boston Water System, Wachusett Reservoir 1998. In this plan, DWM defined water quality goals for the system as follows:

Primary Goals for Water Quality

- PREVENT WATERBORNE DISEASE.
- MEET THE SOURCE WATER COLIFORM CRITERION.
- MAINTAIN A HIGH QUALITY SOURCE WATER.

Secondary Goals for Water Quality

- REDUCE/CONTROL NUTRIENT INPUTS TO THE RESERVOIRS.
- REDUCE RISK OF A CHEMICAL OR HAZARDOUS MATERIAL SPILL.
- CONTROL GENERAL POLLUTANT TRANSPORT INTO THE RESERVOIR.

These goals are used to make and evaluate all management decisions. The Division's Environmental Quality Section collects samples from thirty-five stations on twenty-five tributary streams and from five reservoir stations. The water quality data are reviewed as part of the decision making process. Additionally, MWRA has a detailed water quality sampling program beginning at the Cosgrove Intake and throughout the water transmission and distribution systems. These data are used with the Environmental Quality Section's data to continually monitor the reservoir and watershed systems.

4.1.2 Water Yield

In past years, water yield was a concern for the system, and much effort was devoted to developing land management strategies that would increase water yield. The MWRA has devoted considerable efforts to Demand Management, and consequently the overall system demand has significantly decreased since 1988. The MWRA states that demand is projected to remain well below safe yield of the system. Therefore, water quality considerations will drive management decisions, and yield need not be considered at this time.

4.2 Land Protection Goals

4.2.1 Goals for MDC Land Protection

- WORK TO LIMIT LAND USES ON THE WATERSHED TO THOSE THAT DO NOT THREATEN WATER QUALITY.

- PROVIDE CONTROL OVER NON-FOREST LAND USE (E.G., ROADS), THE EFFECTS OF NATURAL EVENTS (E.G., FIRE), AND HUMAN ACTIVITIES THAT THREATEN WATER OR OTHER NATURAL RESOURCES.

Control over harmful activities on the Wachusett watershed is best achieved when the Commonwealth has actual ownership, or other direct control over allowable activities on the land. Thus, MDC has an active land acquisition program geared towards acquiring ownership of, or other rights on, key parcels on the watershed - primarily those near the reservoir and its 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. In some cases, this may involve converting open land to forested cover.

The location, marking, and maintenance of the boundaries of MDC watershed lands are important land protection activities, since clear boundaries allow for better control over illegal activities that could threaten watershed integrity. Effective resolution of boundary encroachments is also an integral part of boundary maintenance.

The control of potentially harmful activities on watershed lands requires a human presence on those lands, both to identify and locate those activities, and to provide effective enforcement of rules and regulations. This presence is provided by MDC personnel, and is a principal responsibility of the MDC Rangers. This presence allows for the timely discovery and resolution of potentially harmful human activities (e.g., illegal dumping) and natural events (e.g., fires) on the watershed.

Effective monitoring and control also depends on a good road system that allows quick access to all parts of the watershed lands. However, since gravel roads also constitute a source of sedimentation caused by erosion into streams and water bodies, watershed road maintenance must be done in ways that minimize these potential adverse impacts.

Finally, land protection goals can sometimes be best served through the designation of “Areas of Special Management Restrictions,” on which management and other human activities are restricted. Such designations are especially appropriate on sites where the topography, hydrology, vegetation or other characteristics limit the potential benefits of active management.

4.2.2 Goals for Management of Non-MDC Lands

- ACTIVELY ENCOURAGE PRIVATE LANDOWNERS TO BE PROPER STEWARDS OF THEIR PROPERTIES.
- SET UP COOPERATIVE AGREEMENTS WITH OTHER LAND PROTECTION ENTITIES TO ENSURE WATERSHED PROTECTION.
- CONTINUE TO PURCHASE CONSERVATION RESTRICTIONS WHEN POSSIBLE ON LAND THAT MEETS THE APPROPRIATE CRITERIA FOR PROTECTION.

When sensitive land cannot be purchased in fee, efforts must be made to utilize other means to protect those properties. Educating the public on proper management strategies to protect the lands within the watershed is a Division priority for non-MDC properties. Through M.G.L Ch. 61 (Forestland Tax Law) and the Massachusetts Stewardship Program, the Division has encouraged private landowners to become active stewards by providing resources and assistance in managing their forests and wildlife and by helping them to understand their role in watershed protection.

In 1998, the MDC entered into a Memorandum of Agreement with the Department of Environmental Management concerning the care and protection of lands within the water supply watersheds of the MDC Watershed System. This agreement addresses DEM lands that fall within the MDC watersheds and the cooperative approach to coordinate the management of adjacent lands in order to enhance the protection of water resources. The MDC/DWM will continue to work with other state, municipal and non-profit environmental landowners on agreements to protect land within the watershed.

Conservation Restriction purchases are an alternative to land acquisition by fee. Purchasing a conservation restriction prevents development while allowing the current landowner to retain ownership and use of the land. Conservation Restrictions require annual monitoring to assure compliance with the restriction specifics and with general watershed protection standards.

4.3 Land Management Goals

4.3.1 Wachusett Watershed Forest Management Goals

- PROVIDE A VIGOROUS FOREST COVER, DIVERSE IN SPECIES COMPOSITION AND TREE SIZES AND AGES, ACROSS THE VAST MAJORITY OF THE MDC LANDS.
- MAINTAIN FOREST COVER THAT BALANCES ACTIVE GROWTH AND NUTRIENT ASSIMILATION, DENSE FILTRATION, TEMPERATURE REGULATION, AND ACTIVE REPRODUCTION.
- RETAIN THIS FOREST COVER BY ENCOURAGING AND MAINTAINING ADEQUATE FOREST REGENERATION ACROSS MDC LANDS.
- ENHANCE AND MAINTAIN THE ABILITY OF THE WATERSHED FOREST TO BOTH RESIST AND RECOVER FROM DISTURBANCE.
- PREVENT EROSION OF SEDIMENTS AND NUTRIENTS FROM THE WATERSHED FOREST, AND PROVIDE FOR ACTIVE ASSIMILATION OF AVAILABLE NUTRIENTS.

- LIMIT THE EFFECTS OF HUMAN-CAUSED AIR POLLUTION BY PROVIDING COVER THAT FILTERS AND/OR BUFFERS POLLUTANTS.
- DEVELOP A LOW-MAINTENANCE WATERSHED FOREST, WHICH PROVIDES LONG-TERM WATER QUALITY PROTECTION WITH MINIMAL INTERVENTION.
- CONDUCT ANY FOREST MANAGEMENT ACTIVITY SUCH THAT THE RESULTING BENEFITS OUTWEIGH ANY POTENTIAL NEGATIVE IMPACTS; COMPLY WITH OR EXCEED ALL ENVIRONMENTAL REGULATIONS GOVERNING FOREST MANAGEMENT ACTIVITIES IN MASSACHUSETTS.
- SALVAGE DEAD AND DOWNED MATERIAL IN AREAS WHERE THIS SALVAGE WILL REDUCE THE THREATS OF FIRE OR NUTRIENT TRANSPORT, AND LIMIT THE NEED FOR SALVAGE, THROUGH DELIBERATE MANAGEMENT PRACTICES AIMED AT REDUCING THE LIKELIHOOD OF DAMAGE.

The Division has determined that a diverse, vigorous forest cover should be maintained on the vast majority of its holdings, due to the unequaled water quality protection this cover provides. The chief value of this tree cover is to act as a filter for purifying the water that passes through it. The tall crowns of the forest overstory add depth to this filter and provide temperature regulation of surface, ground, and stream waters. Those portions of the forest that are actively growing and assimilating available nutrients limit the export of these nutrients to the reservoir. The forest understory provides uninterrupted recovery from overstory losses. The forest overstory canopy, the forest understory, the vegetative ground cover, and the thick organic mat of decomposing matter on the forest floor, as well as root systems interspersed within the mineral soil below, all work in concert to produce water of high quality.

In order to retain forest cover through the variety of disturbances that affect that cover, it is a Division goal to expediently establish and retain adequate forest regeneration across the watershed. While the specifics of "adequate regeneration" are addressed later in the plan, the Division believes it is a prudent goal to steadily maintain well-distributed reproduction, so that the forest is capable of quickly recovering from disturbance. In simple terms, the understory represents a "reserve forest," a back-up to cover the eventuality of overstory losses.

A primary goal of Wachusett forest management is to develop a diversity of age-classes, including well-distributed regeneration, in order to reduce the susceptibility of the forest to catastrophic wind damage. While hurricanes are potentially the most disruptive disturbance facing the Wachusett watershed forest, the more frequent occurrence of less dramatic disturbances is also of concern to managers. These include the effects of air pollution, insects and diseases, and changes brought about by smaller scale weather events such as localized windstorms and heavy snow or ice storms. A forest that is diverse in species composition and multi-aged will resist natural impacts and human-caused pollution because these impacts tend to be species and/or size/age specific. Thus, the Division's forest management will "condition" the forest to be able to recover quickly from both localized, endemic disturbances and widespread, catastrophic events, in part by maintaining diversity.

Producing and retaining a diverse forest cover addresses the Division goal to protect the tributaries from undesirable chemical, nutrient, and sediment inputs in a variety of ways. First, this cover reduces the erosion potential of precipitation and minimizes damaging overland flow. It also serves to buffer chemical impacts to water quality by maximizing water contact time with vegetation and soil components. Through the process of evapotranspiration, forests act as water yield "regulators," moderating the potential water yields of watersheds and thereby regulating the loss of nutrients, minerals, and natural elements from the watersheds to the water supply below. Forests that are growing actively accumulate nutrients from the soil, reducing their export to tributaries. Finally, forests likely play an important role in reducing the effects of human-caused pollution such as acid precipitation, heavy metals, and other environmental pollutants by both buffering impacts and by acting as "sinks" for certain pollutants such as lead.

The Division has concluded that the diversity of species appropriate for watershed management purposes should reflect the basic variation in the landscape and natural site conditions (e.g., soils, topography, water, aspect, slope) found at Wachusett. While a range of tree species may be adequately suited to a given site, the management of species that are unsuited to the site (for example, upland species on wetland sites) does not provide optimal watershed protection. Trees growing off of the sites to which they are physiologically most suited are more susceptible to disease, wind, and other environmental impacts (demonstrated by the declining vigor of many red pine plantations on wet soils). In general, species that are well suited to their sites will grow vigorously over long periods of time, reducing the frequency of mortality and salvage operations. This principle is inherent in the goal of the Division to create a watershed protection forest that requires a minimum of maintenance to achieve its function.

It is a Division goal that any forest management activities on the watershed be conducted in such a way that even if no natural disturbances affect an area, the overall benefits to the resource from the activity still outweigh the potential impacts resulting from the activity itself. All activities have both long- and short-term consequences. In assessing the net costs or benefits of forest management activities, the Division considers both immediate and future impacts. For example, activities such as the cutting and/or removal of trees to deliberately regenerate an area must be controlled such that any short term negative water quality impacts from harvesting will be less than the long term benefits derived from diversifying the forest cover.

When major losses of forest trees occur naturally, it is a goal of the Division to salvage dead and downed materials when such salvage will reduce nutrient export and will decrease the risk of catastrophic fires. Further, by reducing the likelihood of damage requiring salvage, and by maintaining good access to forest areas susceptible to damage, forest management should reduce the difficulty and potential water quality threat of these salvage operations.

4.3.2 Non-Forest Management Goals

- INSURE THAT THE MAINTENANCE OF NON-FORESTED HABITATS HAS NO NEGATIVE IMPACT ON WATER QUALITY, THROUGH THE USE OF STRICT CONSERVATION MANAGEMENT PRACTICES.
- PROTECT AND ENHANCE THIS DIMINISHING HABITAT FOR MANY SPECIES OF WILDLIFE THAT ARE CONSIDERED UNCOMMON, RARE OR UNIQUE ON A REGIONAL OR STATEWIDE BASIS.
- MAINTAIN AN IMPORTANT COMPONENT OF THE AESTHETIC DIVERSITY OF THE LOCAL LANDSCAPE.
- PRESERVE IMPORTANT HISTORICAL AND CULTURAL RESOURCES.

The Division has determined that, although it is imperative to maintain forest cover on the vast majority of its holdings, there is significant and widely diverse value in the presence of non-forested habitats. Through the use of Conservation Management Practices 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.

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. The Division recognizes that as the largest owner of land in the Wachusett watershed, it has a responsibility to consider the effects of its land management decisions. The Division has concluded that maintaining a small percentage of its holdings in a non-forested condition has a greater net benefit for rare and uncommon wildlife than the marginal benefit these relatively few acres may provide for water quality protection if converted to forest cover.
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 watershed have been in existence since the 1700's and are an important part of the natural heritage of the watershed.

4.4 Wildlife Management Goals

- MITIGATE ADVERSE IMPACTS OF WILDLIFE ON WATER QUALITY, INFRASTRUCTURE, AND OTHER WATERSHED RESOURCES.

- PROTECT UNCOMMON, RARE, AND OTHERWISE SIGNIFICANT WILDLIFE SPECIES AND HABITATS WHEREVER THEY EXIST ON MDC LANDS.

- ASSESS AND MITIGATE IMPACTS OF WATERSHED MANAGEMENT ACTIVITIES ON WILDLIFE THROUGH A PROCESS OF NOTIFICATION, SITE VISITS, REVIEW OF RECORDS AND LITERATURE, AND RECOMMENDATIONS TO APPROPRIATE MANAGEMENT STAFF.

- ACTIVELY MANAGE FOR SELECTED WILDLIFE SPECIES THAT ARE CONSIDERED TO BE UNCOMMON, RARE, OR UNIQUE ON A REGIONAL OR STATEWIDE BASIS.

Wachusett Reservoir's role as a water supply reservoir must be given top priority. Mitigating the potential impacts of roosting birds, aquatic wildlife, and burrowing animals is critical.

Although active wildlife management is not a large part of this plan, the Division recognizes that its management activities may impact certain wildlife species or habitats. It is the Division's goal to avoid adversely impacting significant wildlife species or their habitats. This will be 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 be a priority, the Division recognizes that its management activities have the potential to impact more common wildlife. MDC will assess the impacts of these land management activities on the wildlife communities at Wachusett, and thereby minimize any adverse impacts. This will be accomplished through long-term monitoring programs and an in-house review process for all planned management activities.

On certain portions of the watershed it may be feasible and desirable to proactively manage the habitat for the benefit of wildlife. This level of land management is a step beyond habitat protection and is focussed on either habitats or wildlife species that are rare or of special concern on a regional or statewide basis. Some activities might include prescribed burns to enhance a field or meadow, selective removal of exotic plants, erecting nesting platforms for certain species of birds, or creating brush piles or rock piles in suitable habitat.

4.5 Cultural Resource Protection Goals

- IDENTIFY SIGNIFICANT CULTURAL RESOURCES ON WATERSHED LANDS.
- PREVENT DEGRADATION OF CULTURAL SITES AND RESOURCES.

Cultural resources are fragile and non-renewable. Once destroyed they are gone forever; they cannot be regrown, rebuilt, or repaired. Similar to endangered and threatened species of flora and fauna, the fragility of these resources places a value on them that is difficult to calculate.

Preservation legislation, as well as MDC's Cultural Resource Management program, are designed to ensure that future generations will have the opportunity to understand, appreciate, and learn about the past. The Division is concerned with locating and assessing the condition of both historic and prehistoric cultural resources, and generating plans for protecting those resources that are considered unique or are otherwise significant.

The Division's Cultural Resource Management Program at Wachusett is adapted from a broader plan that was developed for the agency as a whole in 1990. The original plan was articulated in draft form in an MDC document entitled *Cultural Resource Management Plan: Volume One Management Policies, Operating Procedures & Organization*, by Chief MDC Archaeologist Thomas F. Mahlstedt, 1990. The agency plan has been modified to address the specific requirements and nature of the resources contained on the Division's watershed lands.

T. Kyker-Snowman

Well-built stone wall, a cultural resource

4.6 Biodiversity Goals

- MAINTAIN AN UNDEVELOPED, FORESTED CONDITION ON MOST OF THE DIVISION'S LAND HOLDINGS.
- WORK TO IDENTIFY ALL UNCOMMON OR RARE SPECIES PRESENT ON DIVISION LANDS, AND PROVIDE HABITAT CONDITIONS AND LEVELS OF PROTECTION RECOMMENDED FOR PERPETUATING THESE SPECIES.
- WHERE FEASIBLE AND APPLICABLE, AND ON LIMITED ACREAGE, MAINTAIN EARLY SUCCESSIONAL FORESTED AND NON-FORESTED HABITATS ON DIVISION LANDS.
- WORK TO IDENTIFY AND ELIMINATE INVASIVE SPECIES FROM DIVISION PROPERTIES.
- MAINTAIN FOREST RESERVES ON A PORTION OF THE DIVISION'S HOLDINGS.

The Division's greatest single contribution to regional biodiversity is the maintenance and management of large areas of undeveloped, forested habitat. Forests can contribute to soil and water conservation, and provide habitat for a range of indigenous plants and animals, aesthetic values, and recreational opportunities (Norton, 1999). The protection from development that results from MDC/DWM ownership contributes significantly to the long-term viability of a variety of organisms and natural communities.

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 occur continually on Division 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.

The Division owns several hundred acres of non-forested habitat including abandoned agricultural fields, active and inactive hay fields, and scrub/shrub meadows. A majority of these habitats will be maintained in an early successional stage through mowing and/or the use of fire in order to provide habitat for an array of organisms that depend on non-forested areas. As discussed previously, in order to ensure biological representation of indigenous species, a range of habitat conditions must be present. Early successional forested habitat has been clearly identified as a rare habitat type within the state (MassWildlife, pers. comm., 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. When possible, even-aged management techniques will be used to create and/or maintain this habitat in selected portions of MDC/DWM holdings.

G. Buzzell

Field Habitat at Wachusett

Invasive species are commonly recognized as a major threat to native flora and fauna and biodiversity. In extreme cases, invading exotics can out-compete and exclude native vegetation, resulting in a monoculture of the invasive plant. The result is a tremendous loss of native plant and associated animal diversity. The Division will strive to identify, control and eliminate invasive species from Division lands, within the limits imposed by water quality protection or limitations of resources and personnel.

The primary reason for incorporating forest reserves into land management planning is to ensure representative examples of biodiversity indigenous to an area are protected (Norton 1999). Forest reserves are important because they contribute to the full range of biodiversity and are important to a wide spectrum of species requiring undisturbed habitat. 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. The Division has set aside a 213-acre reserve (Poutwater Pond) and will assess the feasibility of creating additional reserves around the watershed.

5 Management Plan Objectives and Methods: 2001 – 2010

5.1 Land Protection

5.1.1 Land Acquisition: Summary Objectives

5.1.1.1 1985-2000 Land Acquisition Program Objectives and Accomplishments

5.1.1.1.1 Program History

A major tenet of watershed management is protection through ownership and control of watershed lands. Owning and managing undeveloped lands (particularly forested land) surrounding a water supply source is recognized as the most direct and proven method of protecting the source's long-term quality.

When the Wachusett Reservoir was completed in 1905, the commonwealth had purchased 4,170 acres of land to be flooded, and 5,608 acres of watershed land, or 7.9% of the total watershed. The next 80 years saw only limited and sporadic land acquisition on the Wachusett Reservoir watershed, usually triggered by impending development on critical parcels near the reservoir. In several cases, original watershed holdings were sold out of state ownership for various municipal and private interests.

5.1.1.1.2 Program Goals and Accomplishments

Over the past 15 years, the MDC has conducted a watershed land acquisition program "*to protect sensitive watershed land from urbanization and to restore and maintain stable forest cover on 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 caused by bacteria, pathogens, nutrients, sediments, heavy metals, and other pollutants associated with increased stormwater discharge caused by impervious surfaces.

The MDC Watershed Land Acquisition Program has been funded from three bonds and a fiscal year budget allocation. These include Commonwealth open space bonds established in 1983 and 1987 of $3 million and $30 million, a $135 million bond established by the Watershed Protection Act of 1992, and a fiscal year budget allocation of $16 million in FY 1997.

To determine the most effective watershed protection outcome for these land acquisition funds, MDC created the Land Acquisition Policy Panel (LAPP), consisting of MDC and MWRA staff members representing all facets of watershed management expertise. LAPP developed a unique and comprehensive GIS computer model for the Wachusett watershed that scores the sensitivity (watershed index) of all land using twelve weighted criteria and three basin multipliers. The watershed index, calculated by the computer model, indicates areas that are rich in water resources and sensitive to degradation caused by human activity. The criteria include proximity to the reservoir and tributaries, slopes, zoning, aquifers, wildlife habitat protection, and threat from development.

From the beginning of the program (1985) through June 2001, MDC increased the percentage of agency land at the Wachusett watershed from 7.9% to 24.7% with the purchase of 280 properties. This represents the acquisition of 10,446 acres in fee, and 1,501 acres in watershed conservation restrictions. The total MDC acreage at Wachusett now stands at 17,547. With the reservoir included, the total area of MDC controlled area is 21,717 acres, or 30.6% of the watershed.

In August of 1998, the MDC and the Department of Environmental Management signed a *Memorandum of Agreement Concerning Care and Protection of the Water Supply Watersheds of the MDC Watershed System, Including the Wachusett and Quabbin Reservoirs and the Ware River*. 2,100 of the 6,100 acres delineated in this agreement are within the Wachusett watershed. With this Care and Control agreement added to the Wachusett MDC holdings, the total MDC protected acreage becomes 19,647, or 27.7% not including the reservoir. Including the reservoir places that figure at 23,817 acres, or 33.5% of the watershed.

Land acquisition goals and parcel selection criteria, originally outlined in a 1987 MDC report, were further refined in the 1991 Wachusett Reservoir Watershed Protection Plan (WPP). The WPP called for the acquisition of 10,500 additional acres on the Wachusett, bringing the total MDC ownership level on the watershed to 25% (not including the reservoir). The WPP Executive Summary (1992) stated that this goal would be reached over the next 15 years, or in 2007. [Correspondence from EPA has called for 25% ownership, not including the reservoir, by August 1998.]

Since FY91, the MDC has acquired 11,947 acres on the Wachusett watershed (as of 7/01). Land acquisition progress at Wachusett is ahead of the schedule set in the WPP Executive Summary. In 9.5 years of the 15 year schedule (63% of the time frame), MDC has completed the acquisition of 99% of the recommended high risk acreage called for in the 1991 WPP.

5.1.1.2 Land Acquisition Goals for 2001 and Beyond

MDC is required, by law, to continue to purchase priority land, with an $8 million per year allocation, on the active watersheds until the remaining funds in the bond are spent. This will occur in 2007. The majority of the remaining $48 million in acquisition resources will be spent on the Wachusett watershed. Land acquisition goals for the Ware River and Quabbin watersheds will be implemented based on Wachusett and Ware River computer model analysis and staff expertise.

The present combined total of MDC and Other Protected Open space on the Wachusett watershed stands at 39,417 acres (21,870 acres including the WsPA Primary Zone, and 17,547 acres of MDC non-reservoir land), or 55.5% of the watershed. Approximately 10% of the watershed is developed for residential and commercial/industrial uses. The remaining privately owned undeveloped land (about 33% of the watershed) will be the focus of a revised and updated land acquisition modeling effort to best prioritize parcel selections based on watershed sensitivity indices and remaining available funds.

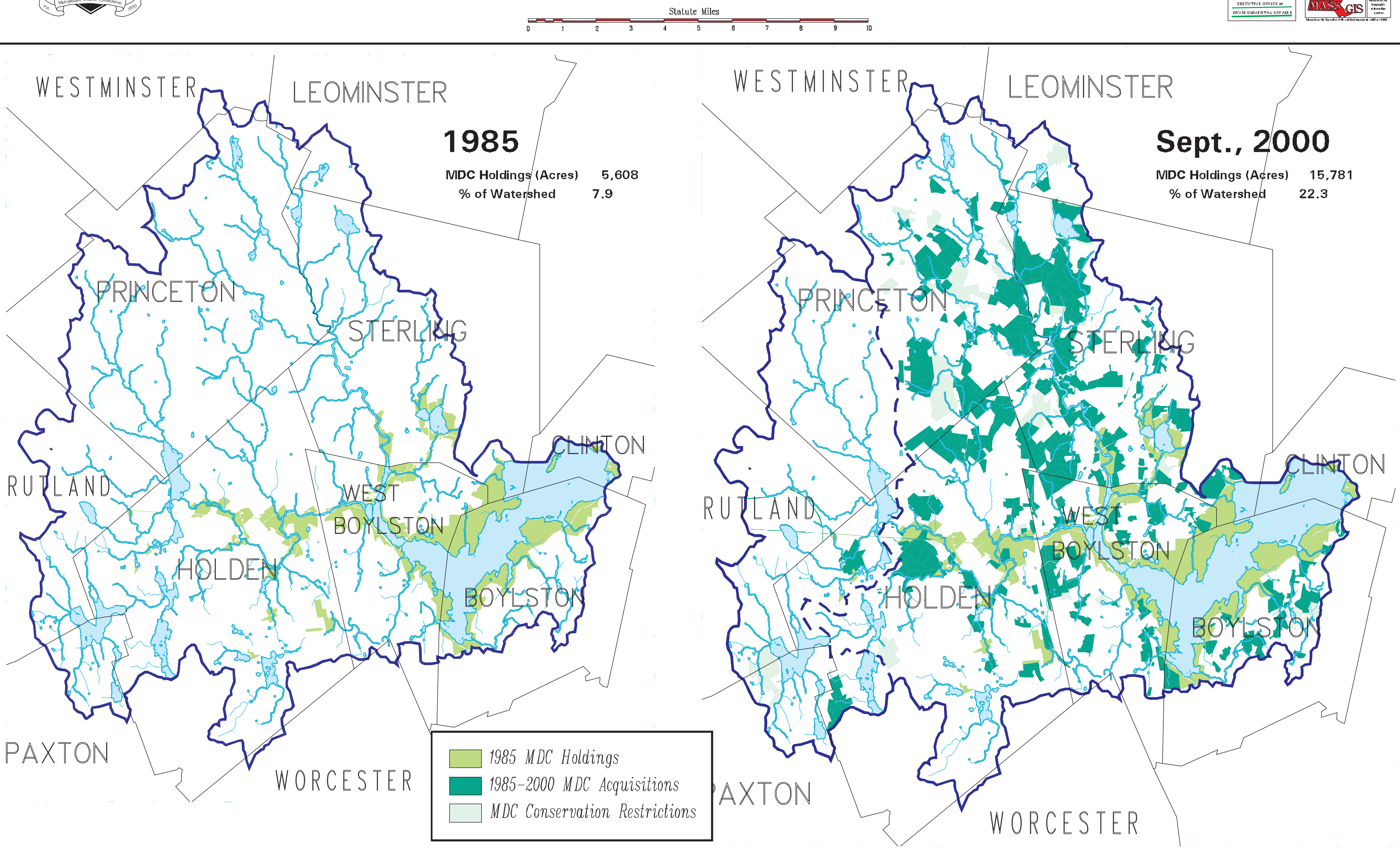
Using the analysis from the GIS computer models and staff expertise, MDC will allocate the remaining $48 million of land acquisition funds among the Quabbin Reservoir, Ware River, and Wachusett Reservoir watersheds. The highest priority will remain the Wachusett watershed, the closest reservoir to consumers and with the least percentage of sensitive watershed land protected.

The relative sensitivity of Wachusett watershed lands has been determined by an in-depth analysis of the importance of various land criteria with respect to protecting the water quality of the

FIGURE 4

Wachusett Reservoir Watershed Land Acquisition Program

Comparison of MDC Holdings in 1985 and 2000



Wachusett Reservoir (MDC Land Acquisition Plan, April 1998). Overlapping weighted criteria multiplied by one of three overlay basins in which they fall results in a Land Sensitivity Index. As all land in the watershed is assigned a discrete sensitivity index, the number of acres of land with the same index was multiplied by the index value in order to implement the Land Sensitivity Index at Wachusett. For example, if 125 acres have an index of 45, these two figures will be multiplied. This process was completed for all land in the watershed to calculate a total figure for the entire watershed.

The present MDC owned land, totaling 24.7% of the watershed area, represents a total Land Sensitivity Index of 32+%. 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, allowing DWM staff to better estimate the amount of high priority acreage that can be purchased with remaining land acquisition funds.

P. Morrone

View of Mt. Wachusett from Tower Hill

5.1.1.3 Payments In-Lieu of Taxes (PILOT)

After land is acquired for watershed protection, the MDC/DWM is required by MGL Ch. 59, §5G to make Payments In-Lieu of Taxes (PILOT) on these properties. This law took effect for Wachusett Reservoir watershed lands in 1987. The PILOT amount is calculated by multiplying the local commercial tax rate by the land valuation as determined by the Department of Revenue (DOR). While the program is administered by the MDC/DWM, the PILOT funds come from the MWRA. The DOR is required to value the land at its “highest and best” use; this means that property that is under Article 97 open space protection is still valued as developable parcels. A key provision of this statute is that the PILOT amount can never be less than the previous year’s amount, even if the tax rate or valuation diminishes. In

FY2000, $1.06 million was distributed to Wachusett Reservoir watershed communities through the PILOT program.

Revaluation of state property occurs, by law, only once every five years. Unfortunately for the communities, this means that any property acquired within this cycle will not be included in determining PILOT amounts. However, MDC does pay the remainder of the existing year's taxes at the time of acquisition, and if the sale occurs in the second half of the fiscal year, it is obligated to pay the following year's taxes as well. Furthermore, if a property is being purchased out of Chapter 61 or 61A (the Forestland Taxation program), the agency is required to pay "rollback" taxes to the town, rebating the previous four years' tax abatements.

The state lands revaluation by the Department of Revenue that concluded in June of 2000 placed the value of MDC property in Wachusett Reservoir watershed communities at $107,300,400, which is more than 100% greater than the 1995 valuation. This increase, which took effect with the FY2001 PILOT, reflects both the additions in MDC land ownership (particularly of valuable "prime lots" that could have been developed) and the rise in property values throughout the watershed. It is estimated that starting in FY2001, the PILOT program will distribute approximately $2 million to the Wachusett Reservoir watershed communities.

The PILOT program provides a significant benefit to the Wachusett communities. They receive the same revenue from permanently protected open space that they would have received from developed land, without the associated municipal costs of police, school and fire services. MDC/DWM will continue to implement the PILOT statute, work with the MWRA to ensure proper payments, and assist the DOR in its revaluation efforts.

5.1.1.4 Land Disposition Policy

The Division of Watershed Management 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 areas of land ownership throughout the water supply system that may not be deemed of critical importance to water supply protection, these areas require careful and consistent scrutiny prior to disposition. The MDC/DWM will consider land disposition only under exceptional circumstances.

The MDC/DWM Land Disposition Policy, approve 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 Watershed Land Disposition Policy is to provide additional watershed-specific instructions to the Executive Office of Environmental Affairs on disposition of Article 97 lands.

5.1.2 Technical Assistance to Private Forest Landowners

As described in Section 2.1, almost 30,000 acres within the Wachusett watershed are "unprotected," privately owned forestland. This figure does not include forestlands protected by various private organizations in the Wachusett watershed. The Division's plans for further acquisition of the most critical parcels of unprotected private land at Wachusett are outlined in Section 5.1.1. above. Activities on the remaining unprotected lands are of major concern from an overall watershed protection standpoint. The current Watershed Protection Plan for Wachusett Watershed outlines the threats associated with conversions from forestland to developed land. Thus, a program of land protection through technical assistance to encourage the maintenance of these lands in forest cover seems well justified.

The Watershed Protection Plans have rated the threat from logging on private watershed lands to be moderate to high. In addition to keeping lands in forest, this program will also strive to reduce impacts to the watershed from forest cutting on private lands, as there is a substantial amount of forest cutting occurring on these lands.

In 1998-99, as part of a landowner education program, the Division established the "Stillwater Farm Interpretive Trail." This project was completed in conjunction with the Friends of the Wachusett Reservoir and the Massachusetts Forest Stewardship Program. The Forest Stewardship Program encourages landowners with many different objectives to become active stewards and to strengthen their desire to keep land in forest cover. The Stillwater Farm Interpretive Trail provides a self-guided tour through the land use history and management practices on this typical farm woodlot.

In 1995, the Division started a program of direct technical assistance to forest landowners at the Wachusett Reservoir watershed, where nearly 50,000 acres of unprotected forest lands existed. The Division hired a Private Lands Forester, with funding provided jointly by MDC and the U.S.D.A. Forest Service (in conjunction with the Department of Environmental Management). The need for a Private Lands Forester had been noted in the past two Quabbin land management plans. This forester assisted DEM foresters in administering MGL Ch.132 (the Forest Cutting Practices Act) on the Wachusett watershed. In addition, duties included outreach to private landowners to encourage land protection through programs such as MGL Ch. 61 (Forest Tax Law) and the Massachusetts Stewardship Program. The Division also encouraged general use of its Conservation Management Practices for forestry operations on watersheds, as is recommended in the 1991 Watershed Protection Plan for both the Quabbin and Wachusett watersheds. The Private Lands Forester worked to encourage private landowners to manage their forests and wildlife to meet watershed-wide goals, looking beyond their individual property boundaries and designing management strategies that address the issues of the larger ecosystem.

In order to increase landowner participation in Chapter 61 and the Stewardship programs, the Division contracted to hire private consultant foresters to complete forest management plans for landowners wishing to gain entry into these programs. In FY 95, $40,000 was dedicated to completing plans for approximately 2,000 acres of private forestland and to cost-share practices that benefit the watershed, such as tree planting and erosion control on roads.

The Private Lands Forester worked closely with the Land Acquisition Coordinator so that lands that should be added to acquisition lists (due to imminent development, etc.) could be more easily identified. The Land Acquisition Coordinator also directed landowners with a strong aversion to selling their land to the MDC to the Private Lands Forester, so that intermediate protection measures (Chapter 61 or Stewardship) could be utilized.

A related alternative to the purchase of land is the utilization of Conservation Restriction purchases to prevent development while leaving land ownership in the current hands. For example, MDC/DWM currently holds conservation restrictions on 19 properties totaling more than 1,273 acres in the Wachusett Reservoir watershed, and additional properties are under consideration. The private lands assistance program works directly with the Land Acquisition Coordinator to identify opportunities for CRs. It is important to note, however, that Division experience with CRs has shown that CR acquisition costs are often nearly the same as fee simple acquisition, and somewhat less desirable in that they require regular monitoring to assure compliance with the restriction specifics and with general watershed protection standards.

At the conclusion of the contract for a full-time Private Lands Forester, the Division shifted responsibilities for maintaining the private lands stewardship program to the staff in the Natural Resources Section. The program has continued, and as of the end of 1999, approximately 4,000 acres of private properties had been accepted for the program, while 10-year forest management plans were completed for approximately 2,600 acres. The average cost to the Division to provide this level of protection is approximately $13 per acre.

5.1.3 Boundaries

5.1.3.1 Maintenance

Given the generally suburban nature of the Wachusett watershed, the proper marking of MDC boundaries is perhaps even more important than it would be in a more rural setting. The primary purpose of marking property boundaries is the avoidance of encroachment. A well maintained, obvious boundary is far less likely to be illegally crossed.

When the reservoir was built, all MDC boundaries were fenced and a forty-foot wide firebreak constructed that was mowed annually. These boundaries made it clear that one was entering MDC/DWM land. During the latter half of this century, dwindling labor resources have made the maintenance of the fence and firebreaks unfeasible. The firebreaks long ago lost their effectiveness as obstacles to wildfire, as field and pasture have been replaced by forest. In addition, much of the new boundary associated with recent acquisitions has never been well marked.

For the last twenty years or so, marking the MDC/DWM boundaries has been a responsibility of the Forestry staff. Recently, the Ranger staff has volunteered to assist. The goal of marking all boundaries on a ten-year cycle has not been met due primarily to the continued acquisition of new lands, which results in redrawn property lines. Regular boundary marking will continue to be an important goal. Careful planning is required to ensure that boundary marking efforts are not wasted (e.g., blazing along a stone wall only to have that wall become an internal feature following a predictable acquisition).

5.1.3.2 Encroachment

The following is a list of the types of encroachments that have been discovered on MDC 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

The Natural Resources Section is currently resolving encroachments. Since 1989, 19 encroachments have been discovered and resolved. Most resolutions occur through a series of letters following field investigation. Rarely has court action been required.

In order to reduce the number of encroachments, it is recommended that all new land purchases be surveyed prior to purchase unless recently recorded survey plans for the land exist. Currently, only parcels that are to be subdivided and a portion of those with poor deed descriptions or unclear boundaries are surveyed prior to purchase. However, at an average cost of $10,000 per survey, the Division needs to dedicate increased resources to surveying as part of its land acquisition program.

5.1.3.3 Cooperation with Abutters

DWM staff work hard to educate abutters about the agency's objectives for watershed protection. As the largest landowner within the Wachusett Watershed, it is extremely important for the Division to maintain a good relationship with abutters to MDC 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 would report unauthorized uses or encroachment problems that may occur on MDC land.

5.1.3.4 Rights-of-way

Although 52 % of the Wachusett watershed is protected (through direct ownership by MDC, other public or private conservation groups, or through regulatory control) much of the watershed is considered urbanized. Urbanization necessarily includes public utilities to meet residential, commercial/industrial, and transportation needs within the watershed.

When the Wachusett reservoir was constructed during the early 1900's, railroads, secondary roadways, power lines, and other public utility facilities existed throughout the watershed. Many of these facilities were relocated or discontinued due to the construction of the reservoir. Rights-of-way (ROW) were granted to the various entities to relocate, maintain, repair, upgrade, and replace utilities, which now pass through Division property.

During 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 Division 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 the Division before the ROW is approved and any construction is permitted to proceed.

Maintenance of certain rights-of-way follows procedures for resource identification and notification established in the document dated January 2, 1997, entitled: *Memorandum of Understanding between the Massachusetts Department of Food and Agriculture, Pesticide Bureau and the Metropolitan District Commission, Division of Watershed Management, on: Identification of Water Features within the Quabbin, Ware and Wachusett Watersheds, which are subject to protection under DFA Pesticide Regulations 333 CMR 11.00.*

5.1.4 Public Education

5.1.4.1 Role of MDC Watershed Rangers in Land Protection

The MDC directly manages about 40% of a 257,000-acre watershed and reservoir system, which provides drinking water for over 2.4 million people, but also provides access for both appropriate and inappropriate uses by the visiting public. For several decades prior to 1992, the Metropolitan Police, who had jurisdiction in any town that contained MDC property, patrolled the system. In 1992, the MDC police force was consolidated with the State Police and other police departments. A Memorandum of Understanding was established with the MA State Police to provide the same services to the MDC watersheds that were carried out by the former Metropolitan Police. Following the consolidation, the MDC as an agency and the Division of Watershed Management felt it would be prudent to create a limited ranger program to complement the efforts of the police. The Watershed Protection Plan of 1998 specifically recognized a need to hire additional Watershed Rangers, seven of which were identified for the Wachusett Watershed. MGL Ch. 92, s. 34b specifies the authority of these rangers, as follows:

" *The Metropolitan District Commission is hereby authorized to establish a park ranger program within the department to preserve, maintain and protect the parks, reservation, historic sites and open space and to ensure the environmental integrity of properties under the care, custody and control of the commission*."

Watershed Rangers provide a visual presence and proactively patrol to help solve problems, such as vandalism, inappropriate recreation uses, illegal dumping and accidents within the watershed that may degrade water, forest, wildlife and cultural resources. The rangers rely on rules education rather than enforcement to seek compliance. Rangers do not have law enforcement powers. When situations occur that require law enforcement personnel, Watershed Rangers communicate these to the State Police and other enforcement agencies.

Watershed Rangers are "good will ambassadors" and not only show a positive presence but also speak on behalf of the agency and the DWM about proper watershed stewardship and drinking water protection to community or organization gatherings, children, school groups, service organizations, senior groups, etc. The primary goals of the Metropolitan District Commission's watershed rangers are to educate the public on the importance of watershed protection and help protect the drinking water supply. Through their positive interaction with visitors, rangers protect these open spaces and encourage all people to do the same by obeying all watershed rules and regulations for specific MDC reservoirs and the system as a whole.

Watershed Rangers provide security for MDC facilities and other designated buildings, and regularly monitor potential trouble spots on the watershed. Special use and group permits may be checked by rangers to ensure that permittees are in compliance with their permit. Through the course of patrolling, the rangers keep a daily log of their activities. Incidents are documented and are referred to the appropriate individual. Rangers also aid in placement of regulatory signage throughout the watershed.

5.1.4.2 Interpreting Land Protection/Management Priorities

The MDC/DWM staff engages in both formal and informal education programs to enlighten the public about the Division's land management and land protection efforts. The staff tries to explain to interested parties what management and protection activities we undertake and the reasons behind these efforts. We work to clarify for the public that our activities in fulfilling the Division's mission are based on scientific fact and mandated by law.

The Division is charged with protecting the MWRA drinking water supply. Past experience and present scientific information have determined that the highest quality water comes from a forested landscape. The legislature has approved and mandated that the Division engages in an active land-purchasing program to preserve the present character of the watersheds and stop activities that are deemed harmful to water quality. The Division gears interpretive efforts towards explaining to the public why so much land is being purchased, how the agency buys the land, and the ways in which this activity impacts town tax bases (generally very positively; see 5.1.1.3, Payments In Lieu of Taxes)

The Division actively manages it land to ensure high quality drinking water. Many of the activities the division pursues (forestry, wildlife management, public access controls, limits on recreation opportunities and limits on growth and development) are controversial in nature. The Division supports a professional staff making decisions based on research, study, standard practice in the field, years of experience, and careful deliberation, including the active solicitation of public input. The educational effort seeks to build a sense of partnership and stewardship between the area town governments, local population, and the MDC/DWM.

5.1.5 Fire Protection

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 peoples lives. Fortunately, these types of fires are very rare occurrences in the forest types in this part of the country. The vast majority of wildfires are low intensity, relatively cool, low flame height fires that burn little more than a portion of the leaf litter and kill little of the understory or groundcover vegetation. However, any fire is a potential threat to the visiting public and private property and therefore it is in the public interest to control all wildfires on MDC property. This is especially true in the relatively highly developed Wachusett watershed where the MDC's landholdings are often highly interspersed with private land.

The records of past forest fires at Wachusett are, unfortunately, incomplete. During the past six years, seven fires have burned about 60 acres. The Metropolitan Water and Sewer Board (predecessor of the MDC) kept account of fires from 1909 to 1920 in the annual reports. During this time period, forty fires burned 700 acres of woodland and young plantation. Most occurred in spring when low humidity combines with dry fuels. Sparks from passing coal-powered steam locomotives were the typical cause.

However, the landscape of the Wachusett watershed was vastly different 90 years ago than today. The primarily agricultural terrain resulted in drier soils, finer fuels and generally windier conditions at ground level; all prime conditions for easily set wildfire. Today, the mature even-aged forest is far less susceptible to fire due to its high, closed canopy, more humid microclimate and generally moist forest floor. However, during times of drought, during most any summer on the drier hilltops or adjacent to the remaining fields and pastures, fire still poses a threat that must not be ignored.

Other than the rare wildfire started by sparks from a passing train, the visiting public causes nearly all other fires. The risk of these types of fires can be minimized by the strict enforcement of the regulations against the setting of campfires (many fires are the result of escaped campfires built by fishermen), increased patrolling during times of increased fire risk, and the elimination of all public access during times of extreme fire danger. MDC property was closed to public access in October of 1984 during a period of extreme fire danger conditions. The addition of the MDC Ranger staff has made a significant difference in the ability to detect violations and enforce restrictions.

The legal responsibility for the suppression of all wildfires, even on MDC property, resides with the local fire departments. All suppression activities performed by MDC staff is in a supporting role under the direction of the town Fire Chief. Typically, the initial suppression is performed by the local fire department with the responsibility for mop-up, at least in part, turned over to the MDC.

The internal road system on MDC property is the link that allows fire-fighting equipment to get to the fire. Therefore, the improvement and maintenance of these roads is key to the ability to suppress wildfires. Of concern is the vast acreage acquired since 1989 and the often insufficient access into these lands (see the next section for a discussion of this issue).

The ability of the MDC to effectively respond to wildfires has been markedly improved over the past several years and this trend needs to continue. Two 100-gallon slip-on tanks have been acquired and are installed on vehicles throughout the fire season along with fire-fighting hand-tools. Communication has been greatly improved by the addition of a radio system comprised of base, vehicular and hand-held units. Most lacking is the proper training of MDC personnel in wildfire control techniques. The certification of all willing employees in the U.S. Department of the Interior, National Park Service, Wildfire Control Training program will be a goal for the immediate future.

The MDC has a Forest Fire Policy that is periodically updated. This policy specifies the steps necessary for the suppression of wildfires on MDC lands, including involvement with other state and municipal agencies. The complete, current policy is available upon request.

5.1.6 Access Roads

5.1.6.1 Road Maintenance: Priorities and Objectives

The internal forest road network at Wachusett provides access for important watershed management activities such as forest management, fire protection, water quality sampling, patrolling and policing and emergency access. The purpose of this section will be to discuss the current state of the road network and maintenance needs and to examine the adequacy of the existing network regarding both condition and coverage.

There are currently 70.5 miles of roads on MDC property in the Wachusett watershed. The condition of these roads varies widely from paved (less than 3%) to solid well drained roads that are usable most of the year (about 17%) to lower quality roads that are often compact loam with few if any drainage features (about 80%). The lower quality roads are unusable for a significant portion of the year. These 70.5 miles of road occupy about 237 acres, or 1.5% of the watershed. The best quality roads usually originated as well engineered and built town roads (as least well engineered for the time, considering that Wachusett construction was coincident with the invention of the "horse-less carriage"). Many of the lower quality roads originally provided access to fields, pastures and woodlots and were improved to various degrees by the MDC following reservoir construction.

The density and the access provided by the road network varies widely throughout MDC property. Averaged over all 15,338 acres of state ownership, there is approximately 20 feet of road per acre of land (this is almost exactly the same as at the Quabbin Reservoir). However, this number ranges from 67 feet/acre in the Gate 26 to 35 Sub-basins to 0 feet/acre in the Malagasco Brook Sub-basin. It is clear that the highest density of roads is in the 5,608 acres of land that pre-date the latest acquisitions that began in 1985. In the six Sub-basins that cover this "original" ownership, road density averages 44 feet/acre with 78% of the total road network. On the 9,730 acres of land recently acquired, road density averages 7 feet/acre with 22% of the total.

These numbers indicate that there is wide disparity in the current level of accessibility between newly acquired lands and land owned before 1985. In order to improve access into these 9,730 acres of land, road construction is required. A conservative estimate is that 15 miles of new road are required. This number will only increase with future acquisitions. The decision where to build a new road requires the careful consideration and balancing of many factors. It is not as simple a formula as "every property needs a road." Some properties are small enough that frontage along an existing town road provides all the access required. However, these small disjointed parcels are relatively few and will become increasingly so with future acquisitions.

Access for watershed management activities can also be access for unwelcome activities that can pose a threat to water quality. Such threats include simply the increased attractiveness that a road creates, thereby encouraging the increased use of an area by the general public, and the greater potential for dumping. Conversely, better access allows for better patrolling and monitoring by MDC Ranger staff, which can minimize these threats. The threat of fire, accidental or intentional, is also increased with improved access, but fire detection and suppression activities are enhanced. All road construction decisions must be made on a case-by-case basis while keeping the overall objectives of watershed management in mind.

The proper maintenance of forest roads is important to both ensure reliable access and to minimize erosion and the resulting sedimentation of tributaries. A properly crowned road surface comprised of well-packed material with adequate drainage features should be the goal for all of the primary access roads on MDC property. The secondary roads have less stringent requirements with the stability of the surface material being the minimum standard. This is often met merely by the maintenance of a healthy grass cover.

The amount of maintenance the road network requires is highly variable from year to year depending largely on weather and management activities. The minimum that has been provided in the past is annual mowing and the removal of downed woody material following storm events. Re-grading, the addition of gravel and the replacement or repair of drainage structures has occurred to a limited degree (on approximately six miles of road in the last ten years) and appeared to be adequate to maintain the roads. However, the addition of 9,730 acres of land since 1985 has added over 13 miles of forest roads. In addition to the continuing use of access for forest management activities and shoreline maintenance work, there is greatly increased year-round use of the entire road system by the Ranger staff (added in 1995), and by employees participating in the Bird Control Program (started in 1993). The result is that the overall quality of the road network has been declining.

MDC staff has identified approximately 15 miles of road that require improvement beyond ordinary maintenance. This work is required to upgrade existing roads on newly acquired lands that have no other access or roads for which use is too seasonally restrictive. The addition of bank-run gravel, topcoating with processed gravel, grading and the construction and installation of storm water structures are required and will consume an estimated 30,000 cubic yards of material. The construction of the estimated 10 miles of new road would consume an additional 25,000 – 35,000 cubic yards of material. All new road construction will be submitted to an internal review process that will include review by Environmental Quality staff, the Division wildlife biologist, and the MDC archaeologist. After satisfying review by these staffs, final approval must be given by the Wachusett Reservoir Superintendent before construction can begin.

To date, virtually all of the gravel used to maintain the road system has come from MDC owned pits. There are presently three active gravel pits from which material is being extracted for use. They are:

- South Meadow Rd., Clinton (off watershed)
- Lily Pond pit, inside Gate 28, West Boylston
- Sundin pit, north of Asnebumskit Brook, Holden

There is an estimated combined total of approximately 50,000 cubic yards remaining in these pits.

The South Meadow Road and Lily Pond pits are the two primary sources of material and significant deposits remain. The Sundin pit has been recently used but may be "played out" with primarily sandy deposits remaining. Its location makes it potentially useful for future roadwork in the immediate area therefore further investigation will be made before abandoning this pit. (See Section 5.3.7.3 for a discussion of gravel pit reclamation.)

Over the last 9 years, the existing Maintenance Equipment Operator (MEO) crew at Wachusett has averaged 0.6 miles of road constructed, repaired and maintained (beyond annual mowing) per year. With 25 miles of road needing repair and construction, it is clear that the current MEO crew, given all of the other tasks that they are required to perform, is insufficient to meet the needs of the future. A crew whose primary responsibilities will be to construct and repair forest roads where needed should be created. This crew should consist of an appropriate combination of MEO I's and II's, supervised by someone with significant road construction and civil engineering expertise and provided with all of the necessary equipment.

5.1.6.2 Conservation Management Practices for Road Maintenance

The objectives of forest road maintenance on the watershed are to provide for vehicle access to support key watershed management activities, and to minimize adverse water quality impacts associated with this road system. Activities that are dependent upon a good access road system include fire protection, forest management, water sampling, research, and police patrols. These activities require stable, properly shaped and ditched road surfaces with adequate structures to manage stormwater. Division staff and equipment accomplish the vast majority of road maintenance on MDC properties.

To accomplish these objectives Division crews use various mitigating procedures to protect stream water quality during routine maintenance activities. These procedures are outlined below. It should be noted that specific sites might require special systems not described here, such as the use of geotextile, erosion control blankets, subsurface drainage, and riprap materials. In addition, wildlife conservation practices will be considered when constructing new roads (see section 5.5.2.2.2).

- *Shaping Road Surface*: The basic component of a stable road is the proper crowning and ditching of the road to allow stormwater to flow off the travel surface and be collected in the roadside ditch.

- *Relief Ditches, Relief Culverts, and Waterbars*: The frequent removal of storm water from the roadside ditch is important to limit the amount of soil and gravel that is washed from an area during an event. 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 stormwater not less than 50 feet from streams or wetlands.

- *Detention and Retention Basins:* These basins will be installed where needed during road reconstruction activities to reduce the velocity of stormwater and increase infiltration.

- *Dry Season Work*: Except for emergency repair work, some major bridge work (which may extend beyond dry periods), and emergency culvert replacement, road work will generally be accomplished during dry periods (primarily summer), when low water flow and stable soil conditions will help mitigate impacts from soil disruption.

- *Use of Silt Fence/Hay Bales*: Whenever road maintenance work requires disturbance near wetlands, the wetland will be protected by properly installed hay bales or industry standard silt fence.

- *Seeding of Disturbed Areas*: Upon completion of road maintenance projects areas of disturbed soil will be graded and seeded with quick growing grass species. The Division has purchased a "hydro-seeder" for this purpose.

- *Special Road Surfaces*: Because of the huge variation of historical forest road construction and use, alternative road surface materials may be appropriate in limiting loss of material through erosion. Forest roads that are rarely used may be shaped and seeded with grass. Yearly mowing and culvert cleaning would then maintain these roads. Depending on location and use, these roads may also be blocked by use of barways to keep out all but essential traffic.

Two additional road surface materials will be examined in this management period: 1) paving (which is currently prohibited by legislation) to stabilize steep road sections and 2) calcium chloride applications to control dust (a form of erosion) and consolidate fine surface materials in high traffic areas. The benefits of utilizing these materials will be carefully weighed against any potential threats to water quality, and there are no plans for wide application of either without thorough investigation of their effects and proper authorization.

It is the Division's intention to limit washouts by replacing under-sized culverts with structures that will meet standards for a 50-year flood (defined as flood levels with a 2% chance of occurrence in any given year). Both culverts and ditches will be kept open and clear of all restrictions in order to prevent the back up of stormwater and the resulting washout. Beaver control structures in use on the watershed will be designed to accommodate the full, specified flow of water through the culvert. In addition, the Division will continue installation of overflow spill areas (reinforced, low areas on a road adjacent to major streams) capable of spilling the flow from a 100 year flood (1% chance of occurrence in any given year) on major tributaries.

Other general road maintenance occurring on a regular basis includes grading, removal of hazardous roadside trees, roadside mowing (which facilitates drainage and keeps roads open), and the processing and spreading of gravel as needed.

As part of its land acquisition program, MDC/DWM acquires access roads or the land abutting these roads. It is the Division's policy to install gates to limit access to all newly acquired roads in order to minimize erosion and illegal dumping along these roads. Division Forestry staff maintains records of road areas where gates are proposed, and more specific and complete descriptions of the current road maintenance plan (including standard operating procedures for road work and road standards for different uses).

5.1.7 Areas with Special Management Restrictions

The recognition of a category of land that requires "special" management was first proposed in the 1972 Quabbin Reservoir Watershed Management Plan. That plan recognized those areas as "Protection Areas" where management would not be allowed due to potentially negative water quality or other impacts. Sites falling into this category included islands, rock quarries, mill sites and exceptional forests among others. This idea was further refined in subsequent Quabbin plans and that tradition and concept is carried forward into this first Wachusett Reservoir Watershed Land Management Plan.

Areas where special management restrictions are deemed necessary fall into two general categories:

- Areas where regular forest management are either impractical or may result in unacceptable impacts.
- Areas with uncommon, rare or potentially rare resources.

The first category includes areas that are commonly occurring but are also fragile, sensitive or impractical such as forested wetlands, marshes, bogs, vernal pools or steep slopes greater than 30%.

The second category includes areas such as uncommon forest types, locations of rare, endangered or threatened species of plant or animal, and historic or prehistoric sites. A new addition to this category is areas known as "Primitive Woodlands." Henry David Thoreau discussed the concept of primitive woodlands as part of an overall forest classification system. He adapted this system from a land classification system put forth by the English landscape architect William Gilpin. Thoreau defined primitive woodlands as those that have always been forested, even thought they may have been cut one or more times in the past. The critical characteristic is that these woodlots were never used for agricultural purposes and that they therefore have always had a forest floor. (Foster, D.R. 1999) Many questions need to be answered before specific management recommendations can be made. What ecological value do primitive woodlands have? Does the presence of these areas add to the biological diversity of the area? How many acres and where are the primitive woodlands on MDC/DWM lands? Initial investigations looking at 1830 survey plans of each town indicate that there is the potential for a significant acreage of primitive woodlands. These plans show the areas within each town that were still forested at the peak of agricultural clearing. However, how many of these areas that were forested in 1830 were subsequently cleared? The Division hopes to further investigate this intriguing concept.

The MDC/DWM has identified approximately 2,000 acres of land in the Wachusett watershed that will be classified as "Areas with Special Management Restrictions."

TABLE 21. AREAS WITH SPECIAL MANAGEMENT RESTRICTIONS

Area Description	Restrictions
Islands 58 acres	No management
Steep Slopes	No management
Wetlands 1,630 acres	No management except limited beaver control (see beaver policy)
Rare and endangered species habitats 3,164 acres (includes reservoir surface)	Subject to restrictions by MassWildlife/NHESP
Riparian zones adjacent to tributaries and the Reservoir shore 576 acres	Subject to restrictions of FCPA (Ch. 132); limited non-harvest silviculture
Poutwater Pond Nature Preserve 213 acres	Restricted according to The 1997 MDC Protection Plan for Poutwater Pond Nature Preserve
Disturbance-sheltered areas	Relatively low intensity management
Areas of Historic, Cultural or Natural Significance	Varies from no management to selective restoration and management
Primitive Woodlands	Yet to be determined

5.2 Management of Forested Lands

5.2.1 Description of Forest Management Approach for 2001 – 2010

5.2.1.1 Objectives of Wachusett Forest Management

The primary goal of management of the Wachusett forest is the creation of a forest that best supports the production of high quality drinking water from the land. This watershed protection forest is vigorous, diverse in species and ages, actively accumulating biomass, and actively regenerating.

The first forest management plan for any DWM property, written in 1960 for the Quabbin forest, proposed that a predominantly uneven-aged forest provides the best protection for a high quality water supply. Every Quabbin plan since then has agreed with this statement including the latest 1995 – 2004 plan. This first Wachusett Plan continues this tradition with a conviction based on the most up-to-date information, the latest review of relevant information and literature, and the experience of the professional staff in the management of the Wachusett forest.

The conversion of the present even-aged forest to a forest comprised of at least three age classes has already begun, although at a slower pace than is now required, given the significant increase in acreage resulting from the land acquisition program. When the forestry program began in 1979, the MDC owned approximately 5,600 acres in the watershed compared to the 16,822 acres owned as of the writing of this plan. The creation of three well-defined age classes in any section of the forest necessitates that one-third of the forest be regenerated to a new age class followed by the creation of another age class some appropriate length of time later. This length of time will be about 20 to 30 years, a sufficient span

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A silvicultural system is defined as, "…a planned program of silvicultural treatments during the whole life of the stand." (Smith 1986) The name of the system is commonly derived from the name of the reproduction method that is used to regenerate the stand. The silvicultural system that will be employed throughout the vast majority of the Wachusett forest in order to create three distinct age classes, is a variation of an uneven-aged system. The silvicultural method that perhaps best describes the regeneration plan for the Wachusett forest is group-selection or uneven-aged with patch cutting as suggested by Marquis (1991). However, the tendency to pigeonhole a complicated and highly variable process into a pre-defined term can unnecessarily restrict the wide variety of techniques available to forest managers. "Formulation of a silvicultural system should start with analysis of the natural and socioeconomic factors of the situation. A solution is then devised…When the important act of inventing the solution has proceeded far enough the less important step of attaching a name to it can be taken." (Smith 1996)

Over the next 30 years, one-third, or 4,000 acres of the managed forest at Wachusett will be converted to a new age-class. For this age class to be evenly distributed throughout MDC land and evenly spaced through time, 130 acres must be regenerated each year. Therefore, approximately 400 acres will be treated annually (one third of which is regenerated).

5.2.1.2 The Role of Natural Disturbances at Wachusett

Natural disturbances occur at virtually all scales of time and area. The infestation of a single tree by carpenter ants, the perpetual browsing of deer, and a forest fire are all natural disturbances. These disturbances, though "natural," can compromise the ability of our forest to protect water quality. It is the goal of DWM to insure the supply of high quality drinking water for both the short and long term. The management of the Wachusett forest must be planned to mitigate any negative impact resulting from natural disturbances, both large and small scale. The most significant disturbance that effects the forests of Massachusetts is hurricanes.

> From meteorological records and forest reconstruction it has been estimated that hurricanes strike southern and central New England every 20-40 years, while catastrophic storms like those of 1635, 1788, 1815 and 1938 occur approximately every 100-150 years. (Foster 1988)

Catastrophic hurricanes have the ability to disturb a significant portion of the forest, changing species composition and age distributions suddenly. However, there are variables that effect the extent to which a forest is impacted by various windstorms and some of these are under the forester's control. A study of the Hurricane of 1938 at Harvard Forest in Petersham, MA (Foster and Boose, 1992) shows that conifers are more susceptible to windthrow than hardwoods and tall trees are more susceptible than short trees. These two factors in combination with the slope and aspect of any given site are significant determinants of wind damage. In the Harvard study, conifers greater than 34 feet tall and hardwoods greater than 74 feet tall on nearly level sites (<5 degrees) or windward oriented slopes (S,SE,E) were severely damaged (>75% of all trees were damaged); there was intermediate damage (50-75% of all trees were damaged) on mild leeward slopes (5-10 degrees, N,NW,W) or intermediate orientation (NE,SW, >5 degrees). Hardwoods greater than 64 feet tall on these same exposures were damaged 51-75% and 25-50% respectively.

The structure of an uneven-aged forest, with three age classes well distributed across the landscape, is well designed to both resist and recover from the impacts of windstorms. Resistance is improved when much of the forest is shorter than the critical height categories according to the Harvard model and resilience is improved when there are enough young trees in place to reoccupy the site should the overstory be destroyed. This structure should translate to less risk to water quality in the event of a major windstorm. Fewer trees blown over means fewer trees needing to be salvaged and reduced fire hazard, and therefore a lower risk of subsequent nutrient losses to tributaries and the reservoir.

5.2.1.3 Forest Insects and Diseases

Damaging insects and disease causing organisms are as normal and natural a part of the forest ecosystem as are the trees themselves. To view these organisms as nothing more than destructive agents whose absence would only benefit forest health is to misunderstand their ecological role. They not only are vital components of biological diversity but play key roles in numerous ecological functions including nutrient cycling, decomposition and predator-prey relationships. The impact of an infestation or disease outbreak can only be viewed from within the context of management objectives. A homeowner, whose front-yard specimen birch tree is infested by the bronze birch borer, is justified in viewing the situation as serious and worthy of immediate action. The death of this tree would conflict with the objective of having a healthy attractive birch in the yard. A single infested tree in the middle of the forest is not a concern where the objective is to have a healthy, functioning forest ecosystem. In fact, having trees dying in the forest is a necessary aspect of a healthy forest.

In the Wachusett forest, insects and disease are a major problem only when their impacts conflict with the Division's objective of creating and maintaining a watershed protection forest. For the most part, this means that only large-scale outbreaks that threaten to alter tree species diversity or forest structure fall into this category. Chestnut blight was such a disease. It was first discovered in the Wachusett forest in 1911 and had already spread to chestnut trees in all towns of the watershed. Salvage of the dead and dying trees began immediately in the hope of protecting the yet uninfected chestnuts. Before the blight, chestnut was one of the dominant trees in the forest. Today, it is essentially a minor shrub. Occasionally, an individual may grow to the status of a small tree before again being infected, dying back to the ground and perhaps putting out new sprouts.

The gypsy moth is another example of a serious pest. It was first found in the Wachusett forest in 1910. A great deal of effort was spent in trying to control the inexorable spread of this insect. Every winter, all egg masses that could be found were painted with creosote. The Annual Report for 1916 states, "At the close of the year about 2,000 acres of land had been covered and 143,100 egg clusters had been found and painted at a cost of $818." This work continued at least until 1947 when the last Annual Report was written. Epidemics of this insect can result in significant mortality of a wide range of tree species both in the overstory and understory resulting in alterations to forest structure, composition and health.

MDC archive

Gypsy moth caterpillar

Both the fungus that causes chestnut blight (*Cryphonectria parasitica*) and the gypsy moth (*Lymantria dispar*) are introduced organisms that came to the Wachusett forest without their co-evolved complement of predators and parasites; a recipe for the development of an unhealthy ecological condition. Other examples that have in the past or currently effected the Wachusett forest include Dutch elm disease, beech bark disease, and white pine blister rust. Native species generally remain in balance with their predators except when cultural effects (past land use or deliberate forest management) create unusual conditions. Some examples are establishing species that are unsuited to the site, deliberately creating single species stands (i.e. plantations), and growing forests on soils that are nutrient depleted from a long history of farming practices.

The next significant threat to the Wachusett forest is the hemlock woolly adelgid (*Aldeges tsugae*), a small aphid like insect native to Asia, first seen in the eastern U.S. in Virginia in 1955. Since then it has been moving up the East Coast and was first found on the Wachusett watershed in 1998 in Boylston. It feeds on hemlock at the base of the needles, removing nutrients and secreting a toxic substance in its saliva. The most recent research and observations indicate that the amount of hemlock in the forests of Massachusetts may be significantly reduced over the next decade or more. While hemlock comprises just 2% of the stocking of the Wachusett forest, a significant proportion of it occurs in riparian zones and on steep slopes above riparian areas. This makes the loss of these hemlocks potentially more critical from a water quality point of view and the commercial salvage of these areas more problematic. No extraordinary measures will be taken to salvage infested hemlock on upland sites. However, sites deemed more critical to water quality will be considered for salvage operations either through commercial or non-harvest means.


T. Kyker-Snowman

Egg casings of hemlock woolly adelgid

5.2.1.4 Species/Site Suitability

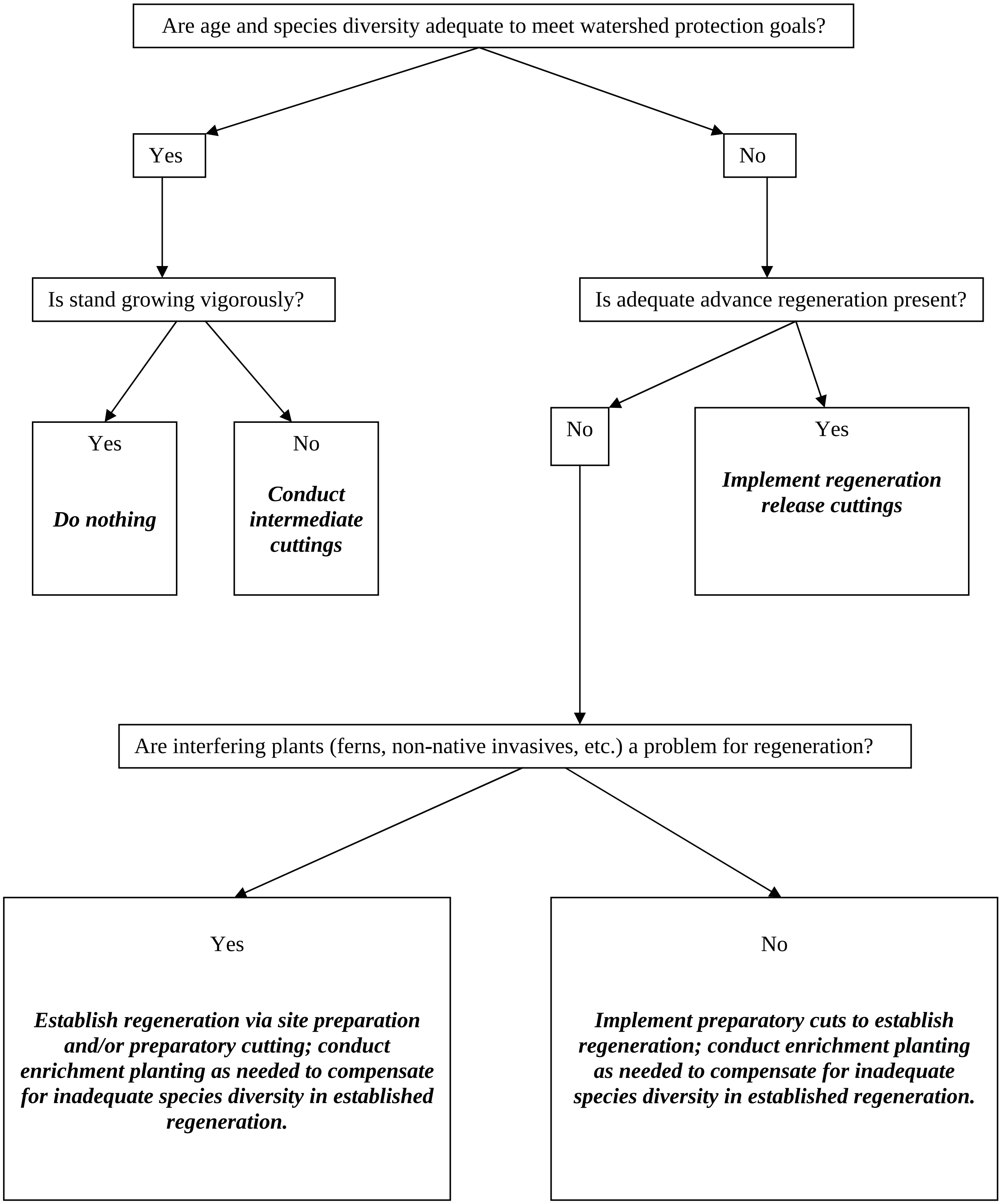
Every species of tree has a preferred range of environmental variables that best suits its long-term health and reproduction. These variables include the amount of light received, heat (i.e., minimum and maximum seasonal temperature) and soil nutrients and moisture. Much of the Wachusett forest owes its composition to three factors: succession following past land use practices (especially pastures and agriculture), succession following the Hurricane of 1938, and the deliberate planting of both conifer and hardwood species. None of these three modes of stand initiation guarantees that the species that occupy the site are those that are best suited to that site or that the diversity of species is adequate. Many white pine plantations were established on moderately well drained soils that are far better suited to the long-term growth of a variety of hardwood species such as red oak and sugar maple. Conversely, past land use practices and fire history have resulted in stands of white, black and scarlet oaks on excessively drained sites where white pine is well suited and should be a major component. It is a primary goal of forest management in the Wachusett forest to encourage the development of stands of trees comprised of species well suited to the site. This is a critical factor in our larger goal of creating a healthy, stable, low maintenance forest.

5.2.1.5 Silvicultural Practices

Figure 5 outlines the general decision-making process Division Foresters follow to determine the appropriate silviculture for any area. At its most basic, the process can be simplified to the following:

- Where regeneration is lacking, we will establish it.
- Where regeneration is adequate, we will release it.
- We will encourage species appropriate to the site.
- Most importantly, we will cut the poorest quality trees first and leave the best.

FIGURE 5. SILVICULTURAL DECISION-MAKING PROCESS



5.2.1.5.1 Establishment of Regeneration: Preparatory Cutting and Planting

There is no hard and fast rule for determining whether or not an existing level of regeneration is adequate. There are three factors to consider when making such a determination: the species composition/site suitability, the number of seedlings/saplings, and the spatial arrangement. A high number of seedlings well distributed but of a species poorly suited to the site is considered inadequate. Conversely, a patchy distribution of a variety of species well suited to the site may be adequate if it occupies enough of the area to warrant release as a new age class. In the MDC's 1991 Quabbin Reservation Deer Impact Management Plan (MDC, 1991), an exhaustive literature review and a survey of regeneration in "off-Reservation" lands at the Quabbin were performed in order to determine what "success" meant regarding the level of regeneration 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 of a diverse species distribution. Spatial arrangement, the distribution of regeneration across the forest, is an additional objective of regeneration adequacy.

On sites where the level of regeneration is considered inadequate, preparatory cuttings will be prescribed. These are designed to open the canopy sufficiently to allow increased light and heat levels at the forest floor thereby stimulating 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, disturbing the leaf litter can enhance the seedbed, and competing vegetation can be reduced.

In situations where a desired species is absent from the overstory and therefore a seed source is unavailable, planting will be considered. The most common examples of this situation are dry site mixed oak stands with no white pine component in the overstory. The only practical method to establish white pine in these stands is through planting.

5.2.1.5.2 Release of Regeneration

Once adequate regeneration is in place, it will be released systematically to give it light and space to grow. This is accomplished by harvesting a portion of the overstory from designated stands. The cutting cycle (the period between harvests) for any given area will average 20 to as long as 30 years, depending on the site. Most areas will be treated using a variation of the selection method as previously described. Trees will be removed either singly or more often in groups and patches ranging from ¼ acre to two acres in size, with an average of about 1 acre. This range in opening size allows for the successful regeneration of a wide diversity of species due to varying tolerances of shade. It is anticipated that openings larger than one acre will become increasingly rare as the forest is brought into a more balanced distribution of ages, sizes, and species than currently exists.

T. Kyker-Snowman

Regeneration release opening

Occasionally, there is the need to take a more wholesale approach to the conversion of stands comprised of species poorly suited to the site or unstable stands of damaged, low-vigor trees. Overstory removals larger than 2 acres are an option under the following situations:

- *Plantations.* The most common examples are the plantations (most comprised of red or white pine and Norway or white spruce). Some of these plantations were never thinned and consequently the trees are tightly spaced with short, narrow crowns. These stands are poor candidates for small openings or partial overstory removal due the poor form and inadequate wind-firmness of the residual trees. The most practical method for regenerating these stands is the removal of larger blocks of overstory trees following the establishment of regeneration. Regeneration may be established in these stands either through the very careful application of a preparatory operation (the creation of strips within the plantation or overstory removal immediately adjacent to the plantation) or through planting.

- *Degraded stands.* Also common are stands of very low quality and vigor. These stands typically result from high-grading (the highest value trees removed, leaving only poor quality trees) and/or poor harvesting (excessive damage to residual trees, incomplete removal of poorly-formed or diseased trees) by previous landowners. Regardless of the cause, the result is high-risk stands of low quality, low vigor, and often physically damaged trees. An overstory comprised of such trees is not a viable long-term protection forest. These stands often have diverse advanced regeneration that is ready to be released. Removal of large blocks of overstory trees is the most desirable method for restoring these stands.

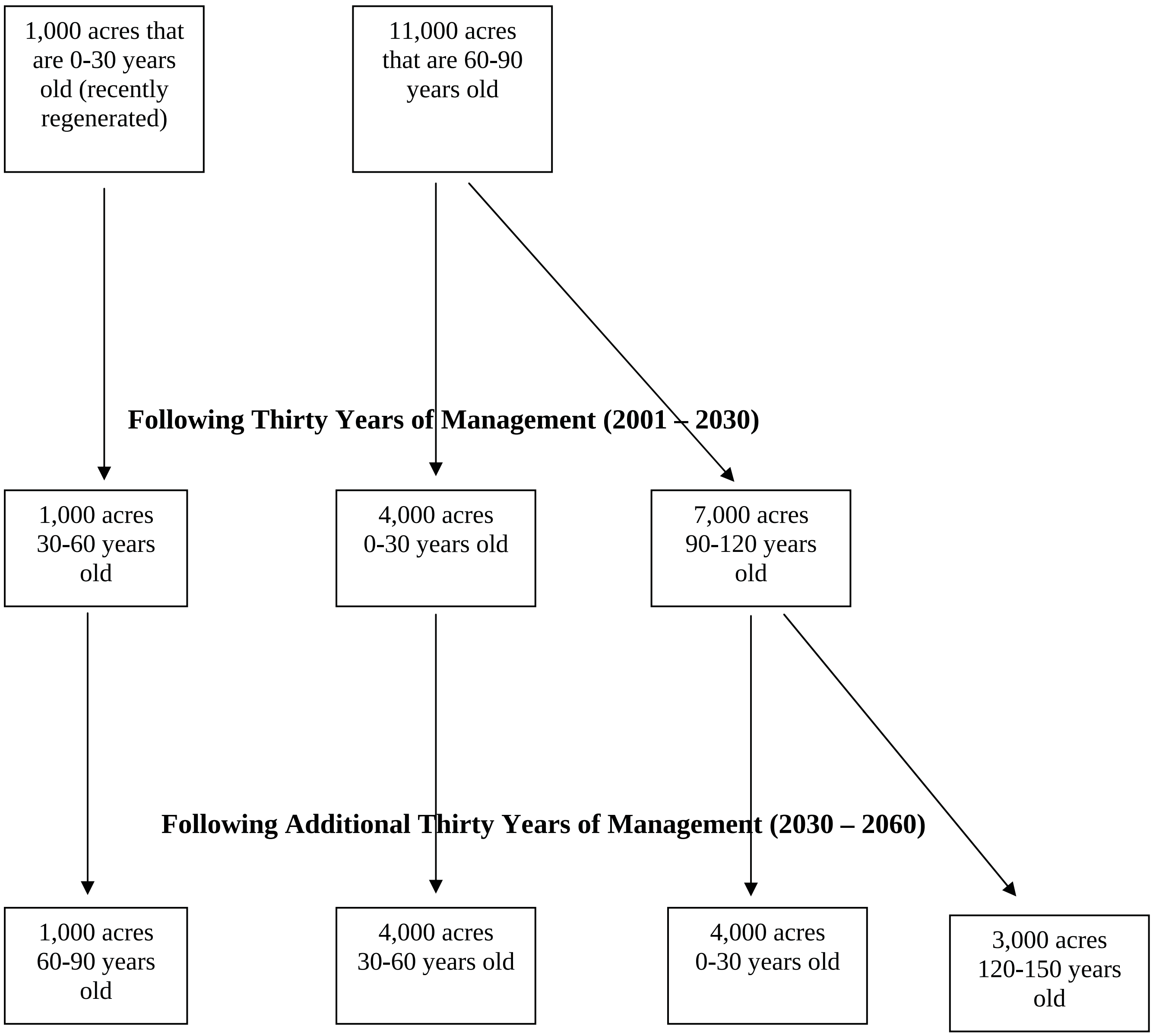
In order that an adequate accounting be kept and to insure that each regeneration cut leads to the desired result, the acreage of the area that is released to a new age class for each silvicultural operation will be recorded. In this way, the long-term impacts of management will be assessed as well as the immediate impact on the distribution of age classes within the stand, sub-basin and forest. The Division will contract a photographic fly-over of MDC property mid-way through each ten-year management plan period. This will greatly enhance the ability to document and monitor the progress of this gradual conversion of the forest. Figure 6 depicts the generalized, long-term silvicultural strategy for converting the current even-aged forest to one composed of balanced distributions of three age classes.

T. Kyker-Snowman

Feller-processor in spruce plantation

FIGURE 6. CHANGES IN WACHUSETT FOREST AGE STRUCTURE VIA SILVICULTURE: 2001-2060

Current Structure of the Managed Forest (2001):



5.2.1.5.3 Intermediate Cuttings

Intermediate cuttings are performed on stands prior to maturity. They are designated 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 remaining trees. "Improvement" operations are designed to adjust the species and quality composition of stand. In fact, virtually all intermediate cuttings are a combination of both thinning and improvement. The defining characteristic of all intermediate operations is that there is no intention regarding the establishment or encouragement of regeneration.

In the Wachusett forest, intermediate cuttings are rarely performed as the sole objective. This is due to the relative lack of purely pole-sized stands on MDC property, although this is changing as land is acquired that has a different forest management history than the bulk of the MDC-owned forest. Most intermediate operations are performed simultaneously with preparatory and regeneration cuts as many stands are being treated for the first time without the benefit of prior management. During the next ten years, intermediate cuttings are planned for 100 acres.

5.2.1.5.4 Non-Harvest Silviculture on Sensitive Sites

There are areas across the watershed where adding new age-classes in order to improve resilience is a high priority but conditions do not allow commercial operations. Examples include steep slopes and areas where soils will not support conventional machinery. On a limited area of less than 100 acres, overstory manipulations will be conducted in some of these areas without removing forest products. MDC will select only those sensitive areas where there is a clear threat of loss of overstory and where this event would have a significant effect on a tributary or shoreline area. Examples include pine plantations with restricted access, high hurricane exposure and shore frontage.

The technique would remove the minimum amount of overstory to allow understory development of either native regeneration or planted trees. Efforts would be made to fell trees across the slope, and to lop the branches to reduce fire danger. This method has the advantage over natural disturbance of methodically selecting both the timing and the placement of openings, which then fill with younger age classes and "anchor" the area in the event of a major overstory disturbance. As the trees will not be removed, there will be negligible risks of soil disturbance or erosion in these areas.

5.2.1.5.5 Riparian Zone Management

The most common riparian zone management strategy land managers take in a variety of plans and Conservation Management Practices is simply to leave these areas alone. In fact, this strategy has the force of law in many states, as a component of wetland protection or timber harvesting regulations. MGL Ch. 131 (Wetlands Protection Act) and Ch. 132 (Forest Cutting Practices Act) both contain language that restricts activities within riparian zones. The assumption behind these regulations is that manipulations of these zones will degrade the critical buffering capacity of these areas and may result in soil disturbances that are more likely to result in sediment transport into streams. However, studies show that it is the activity of removing trees that is associated with these impacts. The MDC/DWM recognizes these zones as the final, and therefore most critical opportunity to slow or capture nutrients and sediments released by a variety of natural and man-caused events on the watersheds.

Section 3.2 includes a review of literature regarding the benefits of establishing forested buffers along streams in urbanized watersheds. While urbanization increases flood flows and the concentration of a number of pollutants in stormwater, forested buffers help to filter these pollutants before they reach streams. Depending upon the size of the forested area, these buffers may reduce flood flows (Anacostia Restoration Team 1992, Neville pers comm. 1996, Lowrance 1994, Schueler 1987, USDA Forest Service 1991, and U.S. EPA 1993). Forested buffers also have the benefit of discouraging geese from grazing and loafing on the reservoir shoreline and have been recommended by the recently completed Watershed Protection Plan for Sudbury watershed as an effective practice for this reason (Comprehensive Environmental 1997).


C. Read

Riparian zone

Section 3.2 recommends that MDC become more active in assisting private landowners in establishing a forested buffer along streams. While most MDC riparian lands are already forested, additional protection can be gained by enhancing the structure and composition of riparian forests and by reducing shoreline and streamside mowing practices.

The preferred vegetative structure of riparian zones is an actively growing, diverse, self-perpetuating, and disturbance-resistant forest cover. While this is the objective for the majority of MDC watershed land, it is more critical at Wachusett and is therefore a very high management priority. Maintaining this forest structure throughout the variety of disturbances that impact all New England forests, including riparian zones, 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 prevailing storms, they become vulnerable to sudden and dramatic damage. When this damage occurs, it is of great concern to watershed managers because it can result in substantial amounts of soil and nutrient transport. Addition concerns include sudden changes in stream temperatures due to the loss of forest cover and heavy accumulations of woody debris when trees fall directly into the stream channel.

As is true for maintaining the watershed forest in general, the most important resistance to build into these forests is the establishment of regeneration. This regeneration serves to anchor soils following disturbances, resists damage from many disturbances (due to size and density), and shortens recovery times for reestablishing riparian forests following disturbances.

Riparian forests that are simply left alone will establish regeneration as the overstory begins to age and decline in vigor. However, where full crown closure is maintained for long periods of time, understory development will be limited by low understory light and thus there will be delays in recovery following major disturbances. Through carefully implemented manipulations of the overstory and understory, MDC managers intend to systematically "condition" certain vulnerable riparian forests to be better able to fulfill their critical buffering functions throughout significant disturbances. Specific management strategies, and the types of riparian zones to which they will be applied:

- Standard silvicultural removals will occur within the managed forest where soils and cutting practices allow (Section 5.2 and Figure 5.)

- Directional felling of small groups and individual trees, without removal, will be done to bring light to the understory where soils prevent equipment of any size. Trees will be felled perpendicular to prevailing slopes and cut into sections so that the trunk comes in contact with the ground to enhance the sediment trapping capabilities of the riparian zone. Felling will not be done into streams. It is felt that natural fall due to individual tree death (as opposed to catastrophic events) will add sufficient material in streams to create beneficial debris dams.

- Planting will occur in areas where seed source is limited, where herbaceous competition is significant, where protective ground cover is currently lacking (e.g., under dense plantations), and where aesthetics is a concern (e.g., near residences or high use areas). This practice may include planting with "tree tubes" sufficiently tall to bring seedlings above herbaceous cover. It will also include non-harvest fellings in order to maintain light levels sufficient to support understory growth.

As this is a new approach to watershed management, it will consist chiefly of directional fellings and tree plantings. The areas chosen are:

- Areas where an important buffer or riparian area is involved.
- An area that is exposed to significant disturbance, such as from future hurricanes.
- An area that would benefit from planting and tubing to help establish regeneration.

5.2.1.5.6 Salvage Policy

The advancing average age of the Wachusett watershed forest and the steady arrival of new insect pests have lead to an increase in salvage cuttings in recent decades, in response to natural disturbances. In addition to (or shortly following) insect and disease damage, these disturbances include windthrow, especially of trees with weakened root structures, and ice and snow damage. Salvage activities are not planned, but are important components of watershed maintenance when the disturbance damages large areas of forest, or greatly increases the threat of additional damage. Removals of dead or dying trees from damaged forests can lower fire hazard (e.g., in hemlock defoliated by looper or woolly adelgid), allow the salvaging of timber value, and strengthen the resistance of surviving trees (e.g., by removing trees weakened by gypsy moth to improve survival of adjacent trees). The Division is aware of the importance of the steady addition of large woody debris to the forest ecosystem. However, the volume of dead and dying wood that is eventually salvaged is a small fraction of the total mortality in any given period of time. Therefore, ecosystem functions will continue to be met while other short-term concerns are addressed.

Where large areas are involved, salvage activities may preempt planned activities described in this plan. Following the microburst tornado that struck the watershed in 1989 (and damaged 300 acres of MDC forest in less than 20 minutes), there was strong public pressure to "clean up the mess." The close proximity of these watershed forests to residential developments may increase the priority for salvage following disturbances, to improve aesthetics and reduce both perceived and actual fire danger. In addition to public pressure for a rapid response, there are often other time pressures driving salvage operations. For example, when white pine is damaged during the warm months of the year, its wood loses value rapidly due to fungal invasions that cause discoloration ("blue-stain"). Wood-boring insects also invade damaged timber rapidly during warmer months and can greatly reduce value. Where roads are blocked by disturbances in adjacent forests, there is also an obvious need to conduct salvage rapidly in order to restore access, which is critical for fire control and emergency response. In situations that involve these time pressures, review and timber harvest permit procedures may be streamlined when an operation is deemed to be salvage and conditions warrant rapid action.

5.2.1.6 Summary of Planned Silvicultural Activities

To summarize the above sections describing the activities that are planned to meet forest management goals, the Division plans to complete the following silvicultural activities during the period from 2001-2010:

TABLE 22. PLANNED SILVICULTURAL ACTIVITY, 2001-2010

Operation	Estimated Amount
Pine Plantation Intermediate and Regeneration Cuttings	650 acres
Non-Plantation Intermediate Cuttings	100 acres
Non-Plantation Preparatory and Regeneration Cuttings	3,250 acres
Areas of Non-Harvest Silviculture	100 acres
Tree Planting	30,000 trees on 300 acres

As the land acquisition program has vastly increased MDC landholdings throughout the watershed during the past decade, it became necessary to reorganize the basis upon which forest management activities are organized and tracked. In the past, Compartments were the basic level of organization. Roads and streams arbitrarily defined compartments and an attempt was made to make them all roughly the same size. In an effort to more closely tie management priorities to the basic hydrologic sub-unit of the watershed, all forest management activities are currently organized at the sub-basin level. This gives management decisions a stronger basis from a hydrologic point of view and allows better coordination between watershed protection priorities and forest management priorities.

5.2.1.7 Silviculture by Major Forest Type

The major forest types are described below with a summary explanation of the silviculture that is planned for each type.

5.2.1.7.1 Oak Type

The oak type is best divided into two sub-types based on site characteristics.

5.2.1.7.1.1 Dry Site Oak Type

Scarlet, black, and white oak are the primary species along with red and chestnut oak, white pine and red maple. This type occupies approximately 1,910 acres, typically on excessively drained outwash soils and thin-to-bedrock till soils. Most of these forests owe their composition to a combination of past heavy cutting practices, fire history and the loss of American chestnut. These stands are typically of low vigor with slow growth rates, lacking in adequate regeneration and are the stereotypical “hotspot” where gypsy moth infestations arise.

The primary goal of management in these stands is the introduction of white pine as a component. White pine is far better suited to these sites. It is capable of superior growth than the oaks and regenerates well. There are stands where white pine exists as a scattered co-dominant, and sometimes dominant member of the overstory. These trees are highly valued as a seed source for future pine regeneration and their ability to function in this role is enhanced by removing competing trees from around them while creating a desirable seed bed throughout the stand by partial overstory removal. Where white pine does not exist as a seed source, planting is a commonly used option and has shown good results. Pitch pine will be considered for introduction (it presently exists but sporadically and in very low numbers) into the very driest site where it is especially well adapted.

5.2.1.7.1.2 Mesic Site Oak Type

These stands, which occupy approximately 1,940 acres, are comprised of red, black and white oak with the hickories, red maple, black birch, and white pine as the most common secondary components. They are similar in origin to the dry site oak type but differ due to their occurrence on more mesic, moderately-drained sites. These stands will be converted to a greater diversity of species especially white pine and the longer-lived hardwoods such as hickory. The oaks, which are prime examples of the long-lived, low maintenance species that are sought for the watershed forest, will be maintained as a significant component.

5.2.1.7.2 White Pine Type

This type will be broken into sub-types based on stand origins. Those stands will only be considered plantations that are still predominantly composed of pine. Many stands that originated as plantations now have a significant component of hardwoods and will be included in the discussion of natural white pine stands.

5.2.1.7.2.1 Plantations

The only definitive character of the sites occupied by white pine plantations is that there is no pattern. Plantations were established on 1,045 acres on virtually every soil type from xeric outwash soils to poorly drained tills. Unfortunately, the one common factor is that until the 1980's, these stands did not receive the thinning operations that planting at a six by six foot spacing necessitates. The result is that there are now 380 acres of white pine plantation whose makeup is incongruous with those of a proper protection forest.

The goal of management for all of the plantations regardless of soil type is the conversion to an appropriate diversity of species. On the moister sites, this will lead to white pine being resigned to a minor component in the long-term. On the drier sites, white pine will be maintained as a significant component.

5.2.1.7.2.2 Natural White Pine Type

Natural stands that are composed primarily of white pine most commonly originate in abandoned fields and pastures. There is currently 620 acres of this type. The pine's relatively heavy seed is capable of falling through thick grass, unlike the lighter-seeded hardwoods. The result is stands of nearly pure white pine typically surrounded by stonewall. Pine that develops under these conditions are commonly attacked by the white pine weevil resulting in crooked, multiple leader stems. Such trees are more susceptible to wind and snow damage. Also, such stands are often heavily stocked with very limited understory development. Therefore, the goal of management is to diversify the species composition, introduce new age classes and remove the individuals of poorest growth form.

5.2.1.7.3 Red Pine Type

All of the red pine in the Wachusett forest was established by planting during the last century. Today, there are approximately 146 acres of red pine plantation. As was the case with white pine plantation, red pine was planted on a wide variety of soil types, many that are not well suited to the long-term development and regeneration of red pine. Red pine will grow very well on the moister, more fertile sites. However, it is also highly prone to root damage and subsequent disease problems and windthrow on these sites. Red pine is well suited to growth and development on drier soils and it is on these sites that a component of red pine will be maintained while encouraging an increased diversity of appropriate species. On the more mesic sites, red pine will gradually be eliminated as a component of the stands.

5.2.1.7.4 Mixed Hardwoods

There are approximately 1,320 acres of forest comprised of a variety of hardwood species. Red maple, white ash, hickory and red oak are the dominant species along with a component of white pine. This type is most common on mesic soils in mid- to low-slope situations and tends to grade into the red maple type as soil moisture increases. These sites are ideally suited to the growth of highly diverse stands. The focus of management will be the maintenance of this diversity, along with the establishment of new age classes.

5.2.1.7.5 Red Maple

Stands dominated by red maple occupy approximately 1,150 acres. Common secondary species include white pine, white ash, hemlock, red oak and black cherry. While most red maple stands occupy poorly drained, wetland sites, approximately 350 acres occur on non-wetland soils on low-slope sites that do support logging equipment given the use of adequate CMPs. Many of these stands are similar to mixed-hardwood stands except for the predominance of red maple, which often tends to be of poor form and vigor. Therefore, the goal of management will be the diversification of these stands at both the species and age class level. A greater component of species such as red oak, white ash, black cherry, yellow birch and bitternut hickory will be sought.

5.2.2 Conservation Management Practices for Watershed Forest Management

NOTE: MDC/DWM has begun to use the Canadian term "Conservation Management Practices" to replace the older term "Best Management Practices." Both terms refer to efforts to create resource-protecting standards for management activities.

Forest management at Wachusett is done to improve watershed protection. As a minimum Conservation Management Practice, the Division will uphold the standard that no measurable negative impact on the quality of water, as measured at locations downstream from a logging project, will occur. Division staff will measure water quality periodically upstream and downstream from logging projects to assure compliance with this standard. Described below are the specific practices designed to accomplish this compliance. It should be noted that the Division meets or exceeds the requirements of both the Forest

Cutting Practices Act and the Wetlands Protection Act (MGL Ch. 132 and 131). Whenever these regulations are revised, Divisions management practices will meet or exceed the revised standards.

5.2.2.1 Introduction

Strict adherence to MDC/DWM's Conservation Management Practices (CMPs) 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, as described in the management plan, are employed to bring about specific forest conditions. These practices require the cutting and removal of overstory trees to diversify structural and species compositions and to maintain the vigor of the residual overstory. The forest is treated, on an average, every 25-30 years and at that time, 1/3 or more of a stand may be removed to establish and release forest regeneration. The process of removing trees can impact the forest and soils essential to water quality if not carefully regulated.

Among the areas of greatest concern are the placement of forwarder and skid roads and log landings, where logging work is concentrated. 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. Beyond this principal concern, Conservation Management Practices are designed 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.

5.2.2.2 Variables

There are many variables to consider when planning and conducting a logging operation, including equipment limitations, weather, soil depth, soil moisture, topography, silvicultural practices, vegetation, and operator workmanship. Variables such as weather, soil moisture, soil depth, topography, and existing vegetation are beyond human control. The constraints they place on logging must be factored into planning, and logging schedules and expectations adjusted accordingly. Variables such as equipment, silvicultural planning, and operator workmanship can be modified, for instance by matching allowable logging equipment with the constraints of a given site.

5.2.2.3 Logging Equipment

Logging equipment has changed dramatically in the 30 years that forest management has been active on MDC watersheds,. 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 a 4-wheel drive articulated skidders or forwarders with 70-100 hp, widths of 7-8', and weights of 6-8 tons. Skidders drag logs attached to a rear-mounted cable and winch, while forwarders carry logs on an integrated trailer.

Other types of logging equipment include grapple skidders, wheeled and tracked feller-bunchers, and feller-processors. A grapple is an add-on feature that replaces the winch and cable with hydraulically operated grapple arms. Feller-bunchers cut trees and put them in piles, usually for removal by a grapple skidder. There are 3 or 4 wheel feller-bunchers that must drive up to each tree for felling, whereas tracked models can fell a tree 10-20 feet from the machine. A feller-processor (usually on tracks) fells, de-limbs, and cuts trees, leaving piles of logs or cordwood, which are retrieved by forwarders.

Small skidders are useful for logging on watersheds whereas larger 100-130 hp models, that weigh between 8-11 tons and are 8-9' wide, are usually too large and heavy for stand and soil conditions. Combinations of small, maneuverable feller-bunchers and forwarders, small skidders and forwarders, and small tracked feller-processors and forwarders have all worked successfully on MDC watersheds. Table 23 shows typical combinations of equipment that work on various types of harvesting operations on MDC watersheds.

TABLE 23. HARVESTING METHODS/EQUIPMENT USED ON MDC WATERSHED LANDS, LISTED BY MOST FREQUENTLY HARVESTED PRODUCTS

Method/Equipment	4-8' Cordwood or pulpwood	8-20' Sawlogs, fuelwood, pulpwood	Whole-tree
1. Chainsaw felling with 4WD pickup truck	√		
2. Chainsaw felling with cable skidding	√	√	
3. Chainsaw felling with forwarding	√	√	
4. Rubber-tired, four-wheeled feller/buncher with grapple skidding		√	√
5. Rubber-tired, four-wheeled feller/buncher with chainsaw limbing and forwarding		√	√
6. Rubber-tired, three-wheeled feller/buncher with grapple skidding			√
7. Tracked feller/buncher with grapple skidding		√	√
8. Tracked feller/processor with forwarding	√	√	

In an effort to specify equipment that is appropriate on specific soils and within specific forest types, the Division has determined ground pressure and width measurements for most of the equipment common to the area, and specifies restrictions, where needed, in timber harvesting contracts. 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. Examples from this rating system are listed in Table 24.


T. Kyker-Snowman

Forwarder with tracks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Rubber-tired skidder

TABLE 24. SAMPLE EQUIPMENT SIZE/GROUND PRESSURE RATINGS

Machine Model	Tires	Width	Ground Pressure
TimberJack 208	23.1 x 26	102”	4.9lbs/sq in
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 “

Some of the logging equipment available is too large or heavy to meet MDC requirements in certain vegetation or soil conditions, and some is limited by terrain. Matching the equipment with the site conditions so that minimal damage occurs is critical to the success of watershed silvicultural activities. MDC specifies equipment requirements for each site in its contract bidding. This includes machine width and ground pressure limits, as well as specific equipment requirements (e.g., forwarders). While each site has unique conditions that require the experienced judgement of the forester to predict impacts, ground pressures are generally limited to 8 pounds per square inch or less on soils that are less well-drained (Types 4 and 5 - see Section 2.2.2). Machine widths are limited in intermediate cuttings of dense, unthinned stands with moderate topography, most typically to around 8.5 feet (102”).


T. Kyker-Snowman

Mechanical feller

An example of a “preferred logging system,” that accomplishes MDC goals under difficult conditions is a small feller-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 do not require a landing, as logs are stacked on the roadside. This combination can also work in previously thinned stands that have an understory of young pines, with minimal damage to the young growth.

The feller-processor is limited to stable ground conditions (few rocks and gentle slopes) and trees less than 16” DBH. In older multi-aged stands where the trees are much larger, hand felling is necessary.

Multi-aged stands will always 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 well in multi-aged stands. This logging system addresses the problem of damage to the residual trees associated with long skid roads.

Table 25 summarizes some of the Division's effort to match equipment and logging systems with site conditions. The methods listed in Table 25 are taken from Table 23.

TABLE 25. HARVESTING METHODS/EQUIPMENT USED IN VARIOUS SOIL/TERRAIN COMBINATIONS

	Excessively drained soils	Well-drained thin soils	Well-drained thick soils	Moderately well-drained soils	Poorly to very poorly drained soils
Level to 10% grade	Methods 1-8	Methods 1-8	Methods 1-8	Methods 1-8 with frozen or dry soils only; ground pressure < 8 lbs/sq. in	Generally not worked with ma-chines
11-20% grades	Methods 2-6	Methods 2-6	Methods 2-6	Methods 2-6 with frozen or dry soils only; ground pressure < 8 lbs/sq. in	NA
Slopes greater than 20%	Method 2	Method 2	Method 2	NA	NA

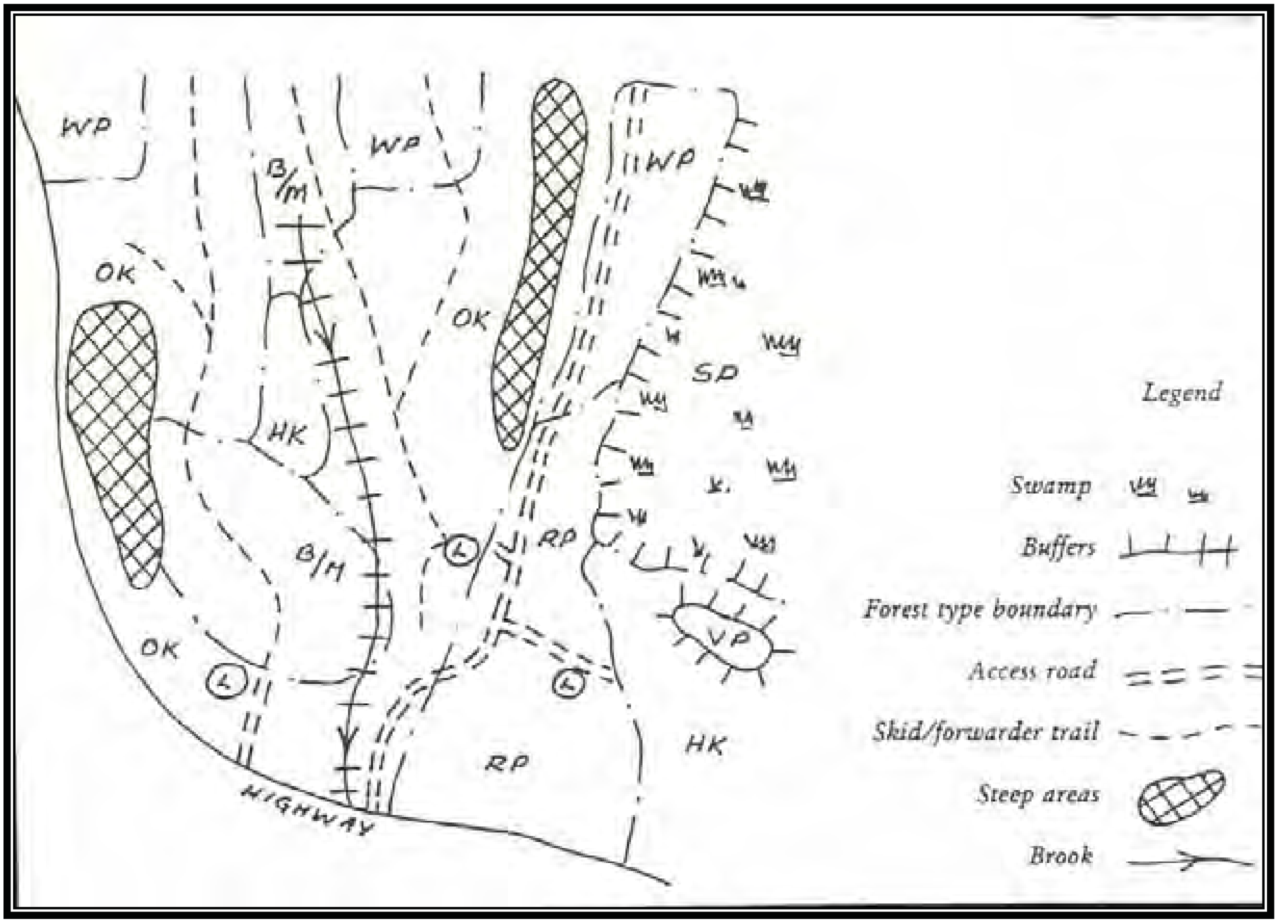
5.2.2.4 Silvicultural Planning

Silvicultural plans have to address present and future 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 great numbers of trees, especially seedlings, saplings, and poles that are more easily damaged than larger trees. The positioning of permanent logging roads, landings, and small and large group cuts is crucial to the long-term success of silviculture. Logging operation success is dependent upon careful advance planning (see Figure 7 for an example of silvicultural planning).

T. Kyker-Snowman

Well-planned harvest

FIGURE 7. HYPOTHETICAL EXAMPLE OF SILVICULTURAL PLANNING



This approximately 200 acre area of MDC forest contains separate stands of white pine (WP), hemlock (HK), birch/maple (B/M), oak (OK), spruce (SP), and planted red pine (RP). A fire in 1957 severely burned the lower 1/3 of the area, and the red pine was planted shortly after this fire. The topography and hydrography of the area include large areas of well-drained sandy soils, but also several small steep areas, a year-round brook, a swamp, and a vernal pool (VP). These areas are delineated with buffers where required. Work within these areas is restricted; steep areas and muck soils are not worked, and buffers are only worked on frozen or dry ground. Fairy shrimp and mole salamander eggs have been found in the vernal pool, verifying its importance to wildlife. No work is proposed adjacent to this pool.

Except for the steep and wet areas, all the stands have received preparatory cuttings within the past 25 years, and the understory has developed in response. Additional work in this area will release advance regeneration by removing patches of overstory trees averaging 1 acre in size. Where understory species diversity is limited, further preparatory cuttings will occur, as well as enrichment plantings of appropriate species. Primary access is across the permanent road shown by a double dashed line. Single dashed lines are skidder and forwarder roads that have been used in the past and seeded and drained to prevent erosion. Landings are designated by a circled L, and represent areas used in the past and maintained as wildlife openings between operations. These roads and landings will be used again in current operations, and then returned to grass. There is evidence that the landings have been used between operations by wild turkey.

5.2.2.5 Operator Workmanship

Operator workmanship is one of the most crucial and variable factors in forestry operations because good planning and preparation can be negated if operators perform poorly. Most loggers are paid on a piecework basis. Their paycheck does not always relate to how hard or how carefully they worked, but on the amount of wood that gets to the mill. However, the Division maintains tight control over loggers working on the watersheds, and exercises its right to remove operators who fail to adhere to contract standards. It is important that foresters and loggers develop mutual respect that is based upon a shared commitment to the sustainable stewardship of the land.

5.2.2.6 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 or nutrients into streams or reservoirs from nearby roads or landings. When roads and landings are near water resources, filter strips are given special attention. Chapter 132 (Forest Cutting Practices regulations) requires a 50 foot filter strip, in which cutting is limited to 50% of the basal area and machinery is generally not allowed (exceptions include stream crossings).

Chapter 132 regulations require increasing the filter strip based upon slope conditions and along Outstanding Resource Waters (protected public water supplies) and their tributaries (excluding Vernal Pools and bordering vegetated wetlands), streams that are 25 feet or more from bank to bank, ponds of 10 acres or greater, and designated scenic rivers. The Division meets these requirements and also increases the filter strip, based on both slopes and soils, for other areas not included in the definitions above. For example, on moderately and poorly drained soils the filter strip is increased 40 feet for each 10% increment of slope angle above 10%. On well-drained outwash and till soils the filter strip is increased 40 feet for each 10% increase in slope angle above 20%. Equipment may enter the filter strip in limited cases where streams must be crossed (see Section 5.2.4.1.4).

5.2.2.7 Buffer Strip

Buffer strips are retained and managed for aesthetic purposes along the edges of highways and public roads. Chapter 132 requires that within this strip, no more than 50% of the basal area can be cut at any one time and that no additional trees can be cut for five years. Buffer strips will be 50 feet except along designated scenic roads, where Chapter 132 requires them to be 100 feet in width.

5.2.2.8 Wetlands

The Division's forest management operations will comply with all the requirements of the Wetlands Protection Act, MGL Ch. 131 s 40, and the Forest Cutting Practices Act MGL Ch. 132 s 40-50 for cutting in wetlands (including bordering vegetated wetlands and freshwater wetlands as defined in the most current revision of Ch. 131 and 310 CMR 10.00, and as these are revised). Generally, activities that are not conducted under a Ch. 132 Forest Cutting Plan but will alter wetland resource areas (which include a 100 foot "buffer zone" beyond the water or the bordering vegetated wetland), are subject to approval through the filing of a Notice of Intent with the local conservation commission.

T. Kyker-Snowman

Vernal pool

All of the Division's silvicultural activities that involve wetland resources are conducted under a Chapter 132 cutting plan, and therefore are exempt from Chapter 131 procedures, with the exception of limited amounts of work that does not include harvesting, including planting, pruning, and pre-commercial thinning and maintenance of boundaries and fire breaks. All of these latter activities are defined as "normal maintenance of land in agricultural use" by Chapter 131, and are therefore exempt from its filing procedures.

Chapter 132 requires a 50 foot filter strip along all water bodies and Certified Vernal Pools (see section 5.2.2.6. above and 5.2.2.9 below), but allows harvesting in wetland areas provided that no more than 50% of the basal area is cut and the ground is only traveled by machinery when it will support that machinery (when it is frozen or dry). In addition, the Division does not allow machinery within low, flat wetland forest with deep muck soils that are seasonally flooded, even though statewide regulations allow work in some of these areas during frozen or dry conditions. Most of the muck soils on Division lands at Wachusett are included within the designated wetlands on the watershed. The Division has identified and mapped approximately 1,630 acres of wetlands within the Wachusett property, which are avoided when lot boundaries are drawn for proposed annual silvicultural operations. The Division also adheres to the statewide recommended practices for protection of vernal pools, including a 50 foot shade zone and a 200 foot buffer (see Figure 8).

5.2.2.9 Logging Practices

A primary purpose of CMPs is to prevent or minimize the movement of soil to the water resource. During a logging 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.

Logging practices and the human behavior necessary to avoid environmental degradation during logging are discussed in the following sections. A cutting plan still relies upon the judgement and common sense of the logger and forester to make the right decisions in order to protect the land and associated resources.

T. Kyker-Snowman

A well-organized log landing

FIGURE 8. TIMBER HARVESTING GUIDELINES NEAR VERNAL POOLS.

Adapted from guidelines that were cooperatively developed by foresters and wildlife biologists in Massachusetts.

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.

Vernal Pool and Depression — *No activity*

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.

Shade Zone — *50 foot buffer around pool edge*

Objective 2: Keep a shaded condition in this 50-ft. wide buffer around the pool depression. Amphibians require that the temperature and relativity humidity at the soil surface be cool and moist.

1. Light, partial cuts that can maintain this microclimate are acceptable; clear cuts are not.
2. 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. When operations must be scheduled in dry seasons, keep equipment 50 feet away from the pool depression and winch out logs.
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 — *50-200 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. Locate landings and heavily used skid roads outside of 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.

5.2.2.9.1 Landings

When determining placement and layout of landings, their size and number are minimized and they are located on soils that will support the logging equipment. Landings are permanent sites and are placed on level and well-drained ground whenever possible. Frozen soils are desirable because they support heavy trucks, but these conditions cannot be assumed to occur for more than a month or two each year. 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. Landings will not be accessed by skidder or forwarder roads that direct water into the landing. An effective barrier is maintained between the landing and access road (road ditch, hay bales, etc.) and landings are required to be smoothed and seeded after use.

5.2.2.9.2 Skid Roads

Skid roads are designed to be reused 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 and harvesting must be scheduled for dry or frozen conditions. Skid roads are cut out before use and limbs left in the road to protect the soil. Skid roads are relatively straight to avoid damaging roadside tree stems and roots, but they are not allowed to carry water for more than 100 feet. 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%. On skidding grades greater than 20%, which are not protected by frozen ground or snow cover, tree branches will be put on the road and other erosion-control measures taken as necessary.

Skidding distances are minimized to prevent excessive wear to roads unless frozen ground, snow, or rocks protect them. Skidder width and weight requirements are tailored to site conditions. The Division has rated many commercially available skidders by taking into account their horse power, weight, load capacity, tire size, and width to determine their suitability for logging on water supply watersheds (see Table 24 for examples). Skidder width ranges from 85-114 inches and loaded ground pressures range from 5-11 lbs/sq. inch. Typically, machines with loaded ground pressures of 8 lbs/sq. inch or less and widths of 102" or less are allowed on MDC watersheds. Skidding is stopped when rains or thaws make the soils unable to support skidders.

At the end of the logging operation or when work is suspended, skid roads are stabilized to prevent erosion. The construction of water bars accomplishes this task. On slopes greater than 10%, water bars are spaced every 50 feet and on slopes less than 10%, they are spaced every 100 feet. 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 to meet two criteria:

- They must angle across and down the road to create a 3-5% pitch.
- They must discharge water to an area that drains away from the road.

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 dug by hand. They do not have to be more than 6-8 inches deep, including the berm, unless they have to deflect more than the overland flow off skid roads (in which case depths are doubled). After completion of logging, water bars on skid roads are seeded during the growing season.

5.2.2.9.3 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. Forwarder roads can pass through the forest avoiding soft soils, trees, and sloping ground. Forwarder roads usually have less than a 5% slope with an occasional grade up to 10% for a maximum of 100 feet. 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 they also replace skidders when soil and/or vegetation conditions and cultural features cannot accommodate skid roads and skidder landings. In operations that combine skidders and forwarders, skidders operate the sloping and rough ground for distances of less than 1,000 feet, while forwarders operate on the more level terrain and handle long hauling distances. Water bar requirements for forwarder roads are the same as for skid roads.

5.2.2.9.4 Stream Crossings

Stream crossings are usually avoidable on MDC watershed properties. When streams must be crossed, frozen conditions are favored whenever possible. These conditions not only protect the actual crossing, but also protect the approach and limit the amount of soil carried in machine tires or on skidded logs.

Portable bridging is used to cross all streams with a continuous flow. This bridging consists of either pre-fabricated sections transported to the site (the Division has constructed portable bridge sections for use by private contractors), 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 prevent degradation of stream water measured downstream of the logging activity before, during, and after that activity.

Correct siting of crossing locations is important in order to avoid soft soils that the machine may carry onto the bridge and into the water. Chapter 132 requires that all crossings be marked with paint or flagging and carefully mapped prior to filing of a 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 mitigation that involves structures that obstruct streamflow is designed and installed to accommodate the 25-year stormflow for the upgrade drainage. All temporary crossing construction is removed at the completion of the operation, and the site stabilized. Division foresters supervise the design, construction, placement, and removal of bridging or other mitigation and the proper protection of approaches, prior to the commencement of logging on the site.

Crossings of small, intermittent streams subject to MGL Ch. 131/132 protection (those portions downstream from the highest bog, swamp, wet meadow, or marsh in the drainage) are mitigated to prevent measurable downstream water quality degradation when these streams are flowing. These streams are only crossed without mitigation during frozen or dry conditions (when they are not flowing). No intermittent stream crossing will be allowed that would result in rutting or disruption of stream bank integrity. Chapter 132 further requires that all streams, including intermittent streams downstream of the highest wetland, within 1000 feet of the reservoir high water mark must be crossed with portable bridging. Division foresters will monitor all unbridged crossings frequently, and discontinue or mitigate them if conditions deteriorate and downstream water quality is threatened.

In the past MDC has crossed streams on a very limited basis. For example, from 1978 to 1990, the Division conducted 130 logging operations on the Quabbin and Ware River watersheds that involved 12 stream crossings (7 were across existing culverts, two were mitigated with DEM-approved techniques, and three were crossings of intermittent streams in dry or frozen conditions).

Table 26 outlines the various stream-crossing situations encountered on Division watersheds and level of protection these crossings are given.

C. Read

Skidder on a temporary bridge

TABLE 26. PROTECTION MEASURES APPLIED TO VARIOUS STREAM CROSSING SITUATIONS

	Level of Protection		
Type of Crossing Situation	CMPs Only	Mitigate	Bridge
Intermittent stream, above the highest wetland in the drainage.	√		
Intermittent stream, downstream of highest wetland, when not flowing; crossing further than 1,000 feet from reservoir high water mark.	√		
Intermittent stream, downstream of highest wetland; crossing further than 1,000 feet from reservoir high water mark; when flowing.		√	
Any intermittent stream with unstable banks/approach; regardless of flow conditions.		√	
Intermittent stream, downstream of highest wetland, crossing within 1,000 feet of reservoir high water mark; regardless of flow conditions.			√
Continuously flowing stream.			√

“Wetland” for the chart above refers to bogs, swamps, wet meadows, and marshes. “Mitigate” includes use of poles, brush, or slabs placed in or beside a small stream 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.

5.2.2.10 Pollution Control

This section describes methods for control of petroleum product spills, human waste, and the disposal of rubbish generated by loggers and logging machinery maintenance.

Petroleum products: All machines are inspected by Division 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. Trucks, forwarders, skidders and other equipment that carry petroleum products must have a minimum of 6 petroleum-absorbent pads (3'x 3') on the machine. Immediate action to contain and stop any petroleum spills followed by prompt notification of the forester is required. The forester in turn contacts MDC Environmental Quality personnel.

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.

Human waste: Deposition of human solid waste is not allowed on the watershed. Contract specifications require the use of a portable bathroom facility (a minimum of a “Coleman” chemical toilet). 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 the watershed.

5.2.2.11 Fire Prevention

Fire prevention concerns both the forest and machinery. MGL Ch. 48, s. 16, a.k.a. 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 also the Division standard.

Machine fires can spread to 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 Division forester before entering the site.

5.2.2.12 Residual Vegetation

Avoiding damage to roots, stems, and crowns of understory and overstory vegetation is essential in maintaining a protection forest. Damage can occur from unskilled tree felling, skidding, forwarding and the development of skid/forwarder roads. Skilled loggers and foresters can prevent most damage if the proper logging system is used. Division contracts include the right to suspend operations due to operator inexperience or negligence.

5.2.2.13 Cultural Resource Protection

The protection of cultural resources fits well with watershed management because they both require low-impact logging systems. For example, small versatile equipment can reduce soil compaction and work around walls and foundations without damage. In many locations, there are no places for a landing due to cultural sites or poor soil conditions. Forwarders mitigate this problem by stacking logs on the roadside. The "preferred logging system" in these situations is a combination of cutting, lifting, or winching trees out, and forwarding them to an appropriate landing to meet cultural resource protection objectives (see Section 5.6.1.3 for a more detailed discussion on this subject).

5.2.2.14 Aesthetics

Aesthetics can be affected by all of the practices described in the above sections, and are the demonstration of workmanship quality. The maintenance of aesthetics reflects how the logger feels about his work and about the land on which he is working. This perspective cannot be forced, but it can be encouraged and learned. When work is done correctly it is not conspicuous, but when it is done carelessly, it is obvious to all. These are public lands and the public regularly passes through them either along public roads or on roads within the watersheds. Attention to aesthetics is important everywhere, but most important along traveled ways. All slash and debris from fallen trees is kept 20' back from the road's edge or on the backside of a bordering stone wall. Landings are cleaned of unmerchantable tree debris. Care is taken to maintain large roadside trees and to promote replacement trees.

5.2.3 Control of Harvest Operations Through Timber Sale Permit

5.2.3.1 Introduction

In conducting silvicultural operations that require the removal of forest products from the forest, Division policy is to protect watershed resources such as water quality, soils, residual trees, and cultural resources. Both the timber sale contract, discussed below, and the Conservation Management Practices presented in the preceding section address these concerns. In general, the timber sale contract specifies the performance standards, whereas the CMPs explain how these contract specifications are met.

The Contract consists of written specifications, pages detailing the forest products offered for sale, maps delineating the sale area, and a proposal page where a bid for the timber is entered and signed. The written specifications deal most directly with protecting watershed resources. Specifications consist of five parts: a.) Contractual Specifications, b.) Water Quality Specifications, c.) Logging Specifications, d.) Equipment Specifications and e.) Bidding and Bond Specifications. Parts b., c., and d. pertain to protecting watershed resources.

5.2.3.2 Water Quality Specifications

These specifications are primarily concerned with petroleum leaks and spills and control of human waste. Petroleum products are required to be kept in suitable containers and removed from the work site each day, unless stored in tanks designed for fuel, such as those on the logging equipment. Oil absorbent pads and blankets are required on site and with all equipment, in order to intercept and immediately control a petroleum spill. All associated refuse from maintenance and repair is required to be stored in appropriate containers and removed from Commission lands as soon as possible. Human waste is required to be deposited in Division toilets or toilets supplied by the operator.

5.2.3.3 Logging Specifications

Logging specifications are concerned primarily with the process of cutting trees and removing forest products from the forest. MDC timber harvesting contracts specify conditions for lopping slash to enhance decomposition and reduce fire hazards. Specifications are described for keeping slash out of streams and back from access roads. The penalty for cutting unmarked trees is set at three times the value of the tree. Utilization standards (maximum stem diameters to be left unharvested) are specified in each contract in order to limit slash. There are also specifications to limit damage to residual trees and soils, especially in the felling and removal of forest products. Locations for logging roads and landings are determined by the forester; the contract specifies the condition in which these areas must be left at the completion of the operation. The contract makes it clear that the logging operation may be suspended due to wet or extremely dry conditions, at the forester’s discretion.

5.2.3.4 Equipment Specifications

These specifications limit the size of skidders and other equipment to minimize soil compaction and rutting and to minimize physical damage to residual trees and cultural resources. These specifications may require specific equipment due to the conditions of the lot. For instance, where it is difficult to place straight skid trails, or where dense regeneration is present, the forester may specify that a forwarder must be used and that skidders are not allowed. Where hauling distances to a truck landing are long, but the lot itself requires skidding, the forester may require that both pieces of equipment must be used. The Division also may require a tracked feller-buncher-processor on lots that have sensitive cultural resources requiring specialized tree removal, on soils that cannot support heavy equipment, or in stands with heavy forest stocking that cannot be thinned properly with standard equipment.

5.2.4 Internal Review and Monitoring of Forest Management Operations

The key to the proper protection and management of the resources under the care and control of the Division is its staff, and the care and expertise they bring to their work. Because the foresters walk each acre of land on which forest management occurs, the management controls enforced by this staff are of paramount importance. As the on-the ground implementers of the Division’s land management plans and policies, the foresters’ knowledge of, and sensitivity to the various aspects of the watershed management plan have a direct bearing on the ultimate success of the program. However, it is impossible for any one individual to assimilate all aspects of the diversity of knowledge in the evolving fields of natural and cultural resource management. Therefore, the second key to implementing sensitive management is in-house review by specialists in the various key disciplines of study in natural and cultural resources, and effective communication between these specialists and the forest managers.

Within the Division, these supporting disciplines include wildlife biology, forest planning, water quality and environmental engineering, civil engineering, and cultural resource protection. Experts available outside MDC include rare species botanists and zoologists (Massachusetts Natural Heritage and Endangered Species Program) and cultural resources specialists (Massachusetts Historic Commission). The Division 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 the Division's care and control. These professionals, and interested non-professionals who spend time studying and exploring the watersheds, contribute invaluable observations that complement the Division's understanding of its watershed resources.

To efficiently and effectively coordinate and focus this collective knowledge towards the improved protection of the water supply and other natural and cultural resources, the Division has developed the following procedure for the annual review of all MDC forest management activities on the Wachusett Reservoir watershed. These reviews are in addition to the general guidelines for cultural and wildlife resource protection.

- Each December, the Division's foresters compile a plan of all proposed forest management that could occur during the next fiscal year (July-June). The only operations not included are emergency salvage after natural events. Each January, the foresters carefully map and describe the boundaries of each planned operation so that they are readily distinguishable on the ground (where boundaries are not easy to describe, they are marked with flagging). These outer boundaries may include internal areas where logging is restricted (vernal pools, stream filter strips, etc).

- After mapping the areas where forest management is proposed, the foresters submit site maps and complete forms describing the proposed silviculture in detail to the Division Natural Resource Section. Natural Resources staff digitize the maps of the planned operations, which include proximal wetlands and previously identified critical cultural and wildlife sites, prepare area summaries of these operations, and check the overall consistency of the operations with management plan silvicultural and resource protection objectives. After reviewing the proposed operations, Natural Resources then forwards copies to the watershed Superintendent, the MDC Chief Archaeologist, and the Division's wildlife biologist.

- In 1986, 1990, and 1994 consultants compiled cultural resource maps for MDC/DWM watershed properties. These maps denote known and likely historic sites. This identification process has not yet occurred for the Wachusett Reservoir watershed, although a proposal is being drafted at the time this plan was written. Once these resources are identified, and where forest management is planned for areas containing or likely to contain cultural resources, the Chief Archaeologist will identify types of activity that could damage these resources, such as soil compaction or disruption of existing structures such as walls or foundations. The Chief Archaeologist may also make recommendations for removing trees that threaten existing historic structures, and identifies areas of high, moderate, or low probability of containing prehistoric occupation sites. With these concerns in hand, the foresters modify timber-harvesting approaches as needed to protect these resources.

- Each spring, the Division's wildlife biologist reviews the planned forest management operations. Where necessary, the wildlife specialist conducts site examinations. Landscape level wildlife changes over long time spans will also be tracked using an evolving set of techniques. 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 biologist's files. After completion of fieldwork by the wildlife specialist, the foresters are alerted to any potential conflicts between the proposed work and important habitat features, keyed to flagging on the ground where necessary. Specific wildlife Conservation Management Practices are outlined in Section 5.5.2 of this plan.

- In 1995 and 1996, the Division contracted with a professional botanist to review all proposed Division lots for the presence of rare or endangered plant species. The bulk of this plant inventory occurred during May and June, although the botanist made preliminary recommendations pending an additional survey for late flowering species, conducted in August, for a limited number of these operations. See section 2.3.3 for a detailed description of this study. In her final reports, the botanist made specific conservation management recommendations to protect these plant populations.

- Where the review process identifies undesirable potential impacts, the foresters consult with the reviewers to design a practical solution. Once the review process is complete, the foresters lay out and mark the harvesting lots. At this time a Forest Cutting Practices Act (MGL Ch. 132) Cutting Plan is prepared (outlining skid roads and specific site impacts). The Forest Cutting Plan is submitted to the Department of Environmental Management (DEM) and copied to the local Conservation Commission. After the lot has been advertised and awarded to a private contractor, Chapter 132 requires DEM staff to conduct a site visit prior to the start of the operation if wetland resources are involved. These regulations also require that Department of Environmental Management 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 Natural Heritage for review and comment.

Throughout the active operation, it is the responsibility of the forester in charge to continuously monitor compliance with water quality protection measures. In particular, these include stream crossings and work near wetlands, conditions of skidder and forwarder roads as well as main access roads, equipment maintenance, and the treatment and placement of slash. The Division "Permit to Harvest Forest Products" includes detailed specifications for each harvesting operation. During the operation, the Division reserves the right to suspend the harvesting activity if warrented by weather, soil, or wildlife conditions. Upon completion of silvicultural operations, it is the responsibility of the foresters to check for full compliance with all timber harvest permit specifications prior to the release of the performance bond and filing of final reports.

5.3 Management of Non-Forested MDC Lands

5.3.1 Management Practices for Non-Forested Management

In 1999, Division forestry and wildlife staff performed an intensive survey of all non-forested, non-wetland habitats on MDC land at Wachusett. The following data were collected or calculated for each area:

- Habitat type (Forb dominated, Grass dominated, Shrub dominated,
- Hay field, Gravel pit, Administrative)
- Primary Cover (Forb, Grass, Shrub)
- Secondary Cover (Forb, Grass, Shrub)
- Primary Soil Class (Xeric, Mesic, Hydric)
- Secondary Soil Class (same)
- Slope (<1%, 1-5%, 6-10%, >10%)
- Aspect
- Invasives Present (Yes/No, including a list of species)
- Sub-Basin
- Acres
- General Comments (including the presence of birds that require non-forested habitats)

There are currently 162 uniquely identifiable non-forested management areas totaling 964 acres on MDC lands in the Wachusett watershed (an additional 5 areas totaling 39.6 acres exist on off-watershed MDC lands). This represents 6.3% of the total 15,307 acres of MDC land in the watershed. In comparison, the MassGIS 1992 land use datalayer indicates that on non-MDC land in the watershed, non-forested non-wetland habitat types cover nearly 14% of the land area. Residential areas (generally non-forested) cover an additional 12% of the non-MDC land area.

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TABLE 27. ACREAGE OF NON-FORESTED HABITATS BY SUB-BASIN

Sub-basin	Sub-basin Name	Acres of Non-Forest	Percent of MDC
1	Res. Shoreline North (Gates 36 - Rt. 12)	59.5	4.0
2	Res. Shoreline South (Rt. 12 – Malag. Bk.)	17.4	3.0
3	Res. Shoreline East (Malag. Bk. - Gate 40)	7.1	0.6
4	Thomas, Quinapoxet and Stillwater Basins	127.7	18.6
5	French Brook	1.7	0.6
8	Muddy Brook	8.6	7.3
9	Gates Brook	2.3	0.8
11	Malden Brook	41.8	10.0
13	Asnebumskit Brook	18.0	12.4
14	Quinapoxet River	84.9	3.2
15	Trout Brook	156.8	12.1
16	Waushacum Brook	88.6	8.3
17	South Stillwater River	266.5	24.0
18	Middle Stillwater/Rocky Bk./Wilder Bk.	30.0	2.5
19	North Stillwater/ Justice Brook	5.4	1.1
20	Wachusett Brook	49.0	2.8
21	Off-Watershed lands	39.6	N/A

TABLE 28. ACREAGE OF NON-FORESTED HABITAT TYPES

Habitat Type	Acres	Percent of Non-Forest Land
Hay	308.9	33
Grass	201.4	21
Shrub	186.3	20
Forb	151.3	16
Administrative	77.5	8
Savannah	14.3	1
Gravel Pit	13.1	1
Total	*952.8*	*100*

A management plan will be written for each field the Division intends to maintain as a field, which will address: the specific goal(s) of management; cutting/mowing schedules and procedures; control of invasive plants; filter strips width and maintenance; and other maintenance practices.

5.3.2 Reservoir Shoreline Maintenance

5.3.2.1 Shoreline Hedge

One of the most notable aesthetic features of the Wachusett Reservoir 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". Arborvitae (*Thuja occidentalis,* also known as Northern white-cedar) seedlings 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.

A report written by MDC forestry staff (French and Buzzell, 1992) found that as of 1992, 27.9 miles of the original 34.3 miles survived. The 6.4 miles of loss are 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 over time though many 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.

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 1980's, all of the vegetation growing from the water's edge up to the hedge was cut. 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 1980's and early 1990's, it became clear that the shrinking labor crews could no longer achieve the goal of complete yearly cutting. Also, the necessity of removing all of the vegetation was questioned based on protection of water quality. What marginal benefit, if any, is gained by cutting all vegetation rather than a portion and is it worth the effort?

Today, the shoreline is cut on a rotational basis and only tree species are removed. The goal is to encourage the herbaceous and shrub species to dominate the shoreline thereby discouraging tree growth. 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. Given the current condition of the vegetation, a rotation whereby the entire shoreline is cut every five years seems optimal (the current rate of cutting will have to be increased to meet this goal). This will result in about seven miles being cut annually. In time, as the mountain laurel, blueberry, dogwoods, witch-hazel and others come to dominate the shoreline, the interval of time that any section of shoreline will require cutting will increase. 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 require more frequent maintenance.

5.3.2.2 Wildlife Considerations

The shoreline along the reservoir and its 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 shoreline precludes the use of 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 should consider three issues: conversion of grassy shoreline to woody vegetation, maintenance of critical shoreline habitat, and removal of undesirable vegetation.

5.3.2.2.1 Conversion of Grassy Shoreline to Woody Vegetation

Several areas of the reservoir's shoreline are maintained in open grassy conditions (North/South dike, Old Stone church). The north and south dike must be maintained free of woody vegetation in order to preserve the structural integrity of these earthen dikes. However, woody vegetation takes several years to invade and become established. Therefore, the dikes will only be fully cut every other year. In off years, several feet on either side of existing roads will be cut to allow pedestrians clear access. Cutting the dikes every other year would provide better wildlife habitat, while still maintaining herbaceous cover.

In other shoreline areas, grassy fields exist (Old Stone Church, Rt. 12 powerlines, Gate 1) that are not related to structural resources. One of these grassy areas is located in an undesirable area in close proximity to critical watershed resources (Gate 1). In this area, there is no engineering reason to maintain herbaceous cover. The grassy habitat attracts feeding Canada geese, which may impact water quality. This area will not be cut or maintained in herbaceous cover and low-growing woody vegetation may be planted to replace existing grass.

There are grassy areas located outside critical watershed areas that do not need to be maintained for structural reasons (Stone Church, Rt. 12 powerlines) 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 completely cut every other year. This will allow a wider diversity of vegetation to grow, but will still maintain the area in open condition.

5.3.2.2.2 Removal of Undesirable Vegetation

The Division closely monitors beaver activity within the reservoir and removes and discourages any active beaver colonies. While most of the reservoir's 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 that represent moderate beaver habitat. Typically these areas are located in coves 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 to remove preferred woody vegetation should occur at least every 5 years. When planning shoreline maintenance activities, these areas should be given priority. In addition, to date no selective cutting has occurred on most of the reservoir's islands. Some of these islands also represent moderate habitat, and cutting will be conducted there as well.

5.3.2.2.3 Maintenance of Critical Shoreline Habitat

The islands within Wachusett Reservoir 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 Reservoir's 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 the 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 remove or disturb vegetation on these islands in order to provide optimum breeding habitat for loons.

5.3.3 Agricultural Land Under MDC Control

In 1987, the MDC entered into a cooperative agreement with the Department of Food and Agriculture to permit the use of certain parcels of MDC land by local farmers. The intent was to find a low cost means of maintaining these areas in an open condition many of which (particularly at the Ware River and Quabbin Reservoir) were created by clearing poor quality pine plantations with the goal of increasing water yields. Since then, many of the parcels that have been acquired (particularly in the Wachusett watershed) have included agricultural fields. While water yield is currently less of a concern, and the vast majority of the MDC's holdings will be maintained in forest cover, a small percentage will be maintained in an open state. This management decision recognizes the value of fields for wildlife diversity, maintenance of the rural landscape, and their contribution to the local agricultural economy. Low impact agriculture is an effective method of maintaining such fields.

The presence of agricultural fields is a significant component in the overall scenic character of the Wachusett watershed. The wholesale conversion of these fields to a forested condition would represent a significant change in this character. The rate that this change would occur must be acknowledged along with the overall change in this scenic quality. The MDC recognizes the impacts that its land management decisions can have on the scenic resources of the watershed.

Forestry and wildlife staff conducted a complete inventory of all non-forested areas on MDC lands in 1999. This work concluded that there are 309 acres of hay field on MDC property. This represents 2.0% of MDC land. These are 29 fields that have either been hayed under MDC/DFA special permits or were hayed in the recent past prior to MDC purchase. In 1999, 19 fields totaling 201.7 acres were hayed under permits administrated by DFA. An additional 86.1 acres are hayed or mowed annually according to deeded rights granted to the prior owner.

The following criteria will be used when deciding which MDC fields will be maintained as fields through the agricultural permitting system and which will either be converted to forest cover (either naturally or with help by planting) or maintained as non-agricultural open space:

- Only fields that have traditionally been used for agricultural purposes will be considered (no new fields will be created).
- No fields will be maintained on hydric soils.
- No fields will be allowed within 50 feet of any Surface Water or Tributary as defined in 350 CMR 11.00 (The Watershed Protection Act).
- No field will be maintained on slopes that average greater than 15%.

Once all fields are screened through the above criteria, Division personnel will make the final decision on a field by field basis. The criteria used will include the proximity of the field to tributaries and wetlands, slope, soil type, the adequacy of existing buffers or berms and the potential benefits to wildlife diversity. In fields where the buffers are considered inadequate, the Division will decide whether to assist natural succession by the planting of appropriate species of trees and shrubs or to allow natural development to occur. Hay will be the only crop that may be grown on MDC lands.

MDC personnel will then create a management plan for every field that has been chosen for continued agricultural use. This plan will include a map showing all required buffers, specifications for allowable fertilizers and soil testing and restrictions on timing of the cutting or number of cuts allowed and restrictions on the type and frequency of reseeding. Constraints and conditions will be applied according to three general levels of sensitivity:

Maximum Restrictions:

These will be applied to fields that are nearest to tributaries or through a combination of slope, soil, quality of buffer and proximity to a tributary are deemed more sensitive than proximity alone might indicate. Restrictions and stipulations are:

- The use of all pesticides and herbicides is prohibited.
- The use of manure, uncomposted or composted, is prohibited.
- Only slow release fertilizers* may be used in accordance with soil test results.
- Ground limestone may be used in accordance with soil test results.
- Reseeding may only be done using no-till methods.
- A detailed review will be conducted for these fields, to determine whether buffer widths need to be larger than 50 feet.

* As defined in the Association of American Plant Food Control Officials Publication No. 48

Minimum Restrictions:

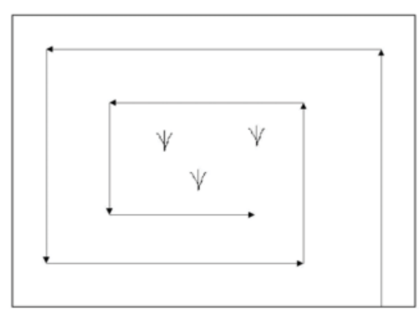
It is difficult to determine the precise hydrological connections between fields and tributaries. However, these minimum restrictions will be applied to fields that are considered the least sensitive due to distance from tributaries or other resources or when a combination of slope, soil, quality of buffer and distance to a tributary are deemed less sensitive than proximity alone might indicate. For instance, a field may be simply too far from any wetland regardless of soil or slope to be considered sensitive. On the other hand, a field may be nearer to a tributary but level terrain with a well-vegetated buffer may render it less sensitive. Restrictions and stipulations are:

- The use of all herbicides and pesticides is prohibited.
- Fertilizer (slow release or otherwise) may be used in accordance with soil test results.
- No compost or manure may be used.
- Ground limestone may be used in accordance with soil test results.
- Reseeding may be done using till or no-till methods.

Moderate restrictions will be applied to all fields that fall between the two extremes of sensitivity. They will consist of an appropriate adjustment of the already stated restrictions and stipulations.

In order to maximize their wildlife value, leased fields may be subject to certain additional restrictions when deemed necessary in order to conserve grassland nesting birds and other wildlife.

- When feasible, cut the fields only once as late as possible, preferably after August 1, but at a minimum mowing should be delayed until late June. Cutting should be done before the first frost.
- If cutting must be done prior to late June, then cutting should occur in one of the following manners:
  - Set aside 50% of the field from cutting until June. 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 at least 1 tractor width between cut areas.
  - On small fields, the whole field may be cut and it should be done in a series of parallel lines from the inside out leaving an uncut patch in the middle of the field as shown here:



Recommended Cutting Method

5.3.4 Administration Areas

In addition to lands purchased and maintained expressly for water quality protection, MDC owns lands that are used for administrative or other purposes. These areas fall into several categories based upon their maintenance needs and aesthetic interest.

Administrative Facilities: These areas include The Wachusett Administrative Office and Maintenance Headquarters on Wilson Street, Ranger Headquarters and adjacent House on Wilson Street, West Boylston Maintenance headquarters on Lancaster Street, Oakdale Power Station, and John Augustus Hall (although not actually owned by MDC, the grounds of the facility are maintained by MDC). These sites are generally in residential areas and are viewed and/or accessed by the public. None of these sites are within close proximity to the Reservoir or a tributary with the exception of the Oakdale Power Station. Therefore maintenance includes mowing of 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 will be 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.

Public Areas: Other areas used extensively include: the Old Stone Church; the area on Route 140 adjacent to the Route 12 crossing of Thomas Basin (near Bob's Hot Dog stand); the top of the Dam on both sides; 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 will be mowed with similar frequency to the Administrative Areas, with several noted exceptions:

- The steep slopes on either side of the dam and along River Road are currently mowed. MDC is researching alternative types of ground cover to eliminate the need to mow some of these areas, while maintaining an acceptable appearance.
- The North Dike area will be mowed only as often as needed to limit the growth of woody vegetation, which may impact the stability of the dike. The area will be monitored and more regular mowing of the top of the dike employed if public access becomes limited by tall grass.

Work needs to be done to restore eroded and unstable areas along the Dike. These areas will be graded, seeded and mulched. Herbicides and pesticides will be used only as a last resort and then will be used in compliance with all applicable laws and regulations. Woody vegetation in these areas will be removed or trimmed only as needed to provide access and for public safety along walkways and pathways.

Open Areas with Limited Public Use or No Public Access: These areas include: the field under the power lines at Gate 25; the small field area at Gate 26; the small area between the West Boylston Rail Trail, the gravel parking area along Thomas Street and the Quinapoxet River basin; the field at Shaft 2 on Manning Street; and the South Dike. The South Dike will be mowed only as needed to keep woody vegetation from growing on the dike. The same is true in fields at Gate 25 and 26. The area adjacent to the gravel parking area on Thomas Street should be left to grow naturally except for a maintained roadway along the River. The Gate at this road will be relocated closer to Thomas Street to discourage vehicle access in this area.

Old Stone Church and Stillwater Farm: Management at the Old Stone Church and at Stillwater Farm are discussed in more detailed in the following section.

5.3.5 Historic/Aesthetic Management

5.3.5.1 Stillwater Farm

The Stillwater Farm Interpretive Site in Sterling is a collaborative venture between the MDC/ DWM and the Friends of the Wachusett Watershed. This locally significant historic property was purchased by DWM in 1990 as part of the ongoing system-wide land acquisition program. The eighteenth century farmhouse and nineteenth century barn are being restored and fitted for use by DWM interpretive staff and the Friends. The long-range goal is to use the farm as a watershed and land use history educational facility. In 1997, the MDC/DWM and the Friends signed a joint Memorandum of Agreement outlining collaborative efforts in preserving Stillwater Farm. A self guided Forest Stewardship Interpretive Trail loops through the wooded hillside above the Farm. One square acre is delineated in a meadow behind the barn. Mowed trails in the meadow adjacent to the Stillwater River and attendant wetlands will provide close hand viewing of early field succession following agricultural abandonment. The barn and house will be 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 a its new role in watershed protection. Overall, public use of the Stillwater Farm will be of a low-impact nature.

5.3.5.2 Rail Trails

The Wachusett watershed has two proposed rail trails within its boundaries, including the old Massachusetts Central Railroad (MCRR) bed and the Sterling spur. The Wachusett Greenways group is championing both trails. The 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. The only section of either trail currently open to the public is a 1.2-mile section in West Boylston. The West Boylston section enjoys tremendous popularity and support from the general public. Ownership of the old rail lines is split among the MDC, local towns, and several private parties. The Wachusett Greenways group is coordinating interested parties and spearheading efforts to bring the rail trail to reality in abutting towns. MDC involvement is critical to the eventual linkage of the various sections.

Rail trails provide a safe, enjoyable recreational opportunity to the general public. The trails act 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. The higher the use of the trails the less likely illegal and unwanted activities will take place there, e.g., horse riding, consumption of alcohol, or motor vehicle use. High use also means a higher degree of safety from medical problems and crimes against people. The public is very enthusiastic about the section that is now open and seems appreciative of the efforts MDC has made to develop the trails. Where the rail corridors cross water, MDC/DWM is working to help install bridges that should ameliorate negative impacts. The spirit of cooperation and coordination with many local residents that has developed around rail trails should help the MDC/DWM accomplish its mission of safeguarding the Wachusett watershed to ensure the safety of the MWRA's water supply.

5.3.5.3 Old Stone Church

The Old Stone Church is a historic and picturesque site located on the northwest shore of the reservoir in the town of West Boylston. The original Baptist church was built in 1892 and the Metropolitan Water and Sewerage Board purchased the church in 1902 as part of Wachusett reservoir construction and was left standing to commemorate the town. In 1973 the Old Stone Church was listed in the National register as a historic site. 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 by the MDC with assistance of the West Boylston Historical Commission by 1983. Today, the church serves as a landmark for the town and has become a well-known tourist attraction. MDC/DWM staff regularly maintain the grounds and area around the Church.

5.3.6 Site Restoration

5.3.6.1 Unused/Abandoned Buildings

Most of the unused or abandoned buildings within the Wachusett watershed were acquired during the land acquisition program dating back to 1986. Several new land acquisitions contain structures that may be of use to the Division, and the cost-effectiveness of retaining these is being considered. Buildings that are not needed because of location or condition will be scheduled for demolition and removal. There are presently 13 properties that have abandoned structures scheduled for demolition and removal. The structures include houses, garages, barns, sheds, cabins, and one service station. Environmental assessments for these 13 sites have been completed and they are in the process of being cleaned up through a Division contract. Once environmental cleanup is complete, an additional Division contract will accomplish building demolition/removal and site restoration.

For all unused/abandoned structures, the environmental site and building assessments required 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 (LSP) may be needed to assess for any possible 21-E (hazardous materials) issues. Following the site assessments, Division 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. Complete site restoration, including loaming, grading, and hydroseeding of the demolition sites, is part of this contract.

5.3.6.2 Compromised Sites (solid waste/21E)

There are several dumpsites (consisting of solid waste only) on MDC property within the Wachusett watershed. These areas of waste include building materials, scrap metal, furniture, appliances, and other miscellaneous debris. These sites are included in the proposed demolition and removal contract. One area of building material debris has ACM (roofing shingles) that will be disposed of as hazardous materials. Any other evidence of possible hazardous materials at dumpsites will require additional environmental assessments for testing by a LSP and proper disposal as recommended. Following the site cleanup, any site restoration necessary will be completed.

5.3.6.3 Exhausted Gravel Pits or Stripped Land

There are presently 2 gravel pits on MDC property in the watershed that are either exhausted of usable material or are not used for other reasons. These pits were established prior to MDC acquisition. In addition, there are several areas that have been stripped of topsoil for a variety of reasons. Together, these areas account for a total of approximately 82 acres of land. These lands are not functioning as a suitable producer of high quality water due to the lack of forest cover. Therefore, it will be the goal of the Division to "put to bed" all of these pits and reclaim the stripped land during the next ten years. The procedure for this will be as follows:

- A pit must first be declared abandoned by the Superintendent after consulting with forestry, civil engineering, natural resources and environmental quality staff.
- The stability of the pit (angle of faces, etc.) and the actual erosion threat in the pit should be determined. If the pit is determined to be stable, then a wildlife habitat evaluation should be conducted to determine if the pit should be left in its abandoned state with no additional reclamation (see section 5.4.3.2).
- For sites determined to be in need of reclamation, a plan for the reclamation (pit or stripped land) will be created jointly by representatives from the forestry, civil engineering, natural resources, and environmental quality staffs.

A typical plan will include specifications, procedures and schedules for:

- Knocking down the pit banks to a stable slope.
- Adding loam to a desired depth.
- Determining the origin of the loam.
- Revegetating the site in both the short and long term.
- Determining erosion mitigation needs (i.e. hay bales or silt fence).
- Scheduling consultation with the local Conservation Commission when necessary.

5.3.7 Recreation Management

5.3.7.1 Requests for Additional Town Recreation Land

On occasion, the Division of Watershed Management has received requests from towns to use, lease or obtain land that is under control of MDC. Many of these requests include the use of lands for athletic fields. The DWM has an approved Policy Statement entitled "Criteria, Requirements and Procedures Related to Request for Disposition of Metropolitan District Commission Division of Watershed Management Lands" dated April 30, 1998. The requirements and procedures set forth in this policy are followed by the DWM when local towns approach the agency for land swaps and/or leases.

As stated in this policy "The Metropolitan District Commission DWM will consider an Article 97 land disposition only under exceptional circumstances. The determination of what constitutes 'exceptional circumstances' rests with the Metropolitan District Commission and EOEA." In addition, it states, "The Metropolitan District Commission DWM shall not promote the use of watershed lands for purposes that are inconsistent with water quality goals."

5.3.7.2 Principles from Wachusett Access Plan

The Wachusett Public Access Plan was developed to guide future MDC policy regarding public access and recreational use of its 16,000 acres of land and water resources. The access plan was completed in 1996 after more than two years of cooperative input from staff and local communities, recreationists and other open space advocates. The goal of the plan was to reduce the existing level of threats to water quality from public use of MDC Watershed lands and to provide management programs that afford long term protection of Wachusett Reservoir. Recommendations made in this plan have been developed to address specific concerns of the U.S. Environmental Protection Agency (EPA) and Massachusetts Department of Environmental Protection (DEP) that focus on the threat of *Giardia* and *Cryptosporidium* pathogens that can be introduced from human sources and the presence of domestic animals at Wachusett Reservoir. Key management recommendations included:

- Improve protection of aqueduct intakes
- Provide greater enforcement of regulations
- Provide sanitary facilities
- Improve signage
- Expand educational programs
- Foster community participation
- Improve site maintenance

5.4 Management of Biodiversity

5.4.1 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 us 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 even a larger regional perspective. Current Division management activities incorporate a multitude of specific activities that maintain or enhance biodiversity at the micro or stand level (i.e., saving wildlife trees, buffering vernal pools, etc.). However, current Division management activities often lack the large-scale perspective that is so important to maintaining biodiversity. Hunter (1999) describes only two real goals when planning for biodiversity. They are: 1) Maintain the biodiversity of ecosystems that are in a reasonably natural condition, and 2) Restore the biodiversity of ecosystems that have been degraded.

The Division's goals for biodiversity focus on either maintaining or enhancing natural ecosystems across the watershed. The Division 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. The Division's primary management activity on these lands is creating small openings in the forest to stimulate regeneration and diversify species. These activities maintain forest cover while mimicking small-scale disturbances that occur naturally all the time. When possible and feasible, the Division will

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5.4.2 Mandate

In 1973, Congress passed the Endangered Species Act to provide federal protection for 292 declining species, and began to legally define the national commitment to maintaining biodiversity in the process. The ESA specifically protected 27 plant and animal species in Massachusetts, and provided both the impetus and funding to restore popular species such as the Peregrine Falcon and the Bald Eagle in the state. Subsequent to the passage of the ESA, Massachusetts has added additional statewide legal protection for biodiversity. Both Chapter 131 (the Wetlands Protection Act) and Chapter 132 (the Forest Cutting Practices Act) require regulatory bodies to consider impacts on habitat and species during proposed development or management activities. In 1990, Massachusetts passed its own Endangered Species Act, providing protection currently for 424 plant and animal species. This act provides regulatory protection for significant habitats of the listed species, as well as direct protection for the species.

In recent years, the protection of biodiversity has become a high priority for state agencies in Massachusetts. Massachusetts is a diverse environment that currently supports at least 15,000 visible (i.e. macroscopic) native species of plants and animals (including about 12,000 insects). MassWildlife (previously the Division of Fisheries and Wildlife) currently maintains the Natural Heritage and Endangered Species Program, the goal of which is to protect the state’s native biological diversity. MassWildlife also recently launched the “Biodiversity Initiative,” in order to coordinate two new programs that were created by the 1996 Open Space Bond Bill (Chapter 15, Acts of 1996). These programs include the Ecological Restoration Program and the Upland Habitat Management Program. The Ecological Restoration Program’s major goal is to “focus future restoration action on the fundamental problems threatening biodiversity, including the restoration of natural processes and native community composition.” To achieve this goal, the Ecological Restoration Program intends to follow the following strategies:

- Conserve species before they become rare by protecting their habitat.
- Restore natural processes that sustain biodiversity at key sites.
- Limit invasion by exotic or invasive species.
- Replicate natural processes, where they cannot be maintained or restored, at appropriate times, places, and in justifiable quantities.
- Consider species reintroduction only when species’ requirements and causes of extirpation are sufficiently understood, and carefully consider the costs and benefits.

The Natural Heritage Program, in conjunction with the Massachusetts Chapter of The Nature Conservancy published “Our Irreplaceable Heritage: Protecting Biodiversity in Massachusetts” in 1998. This document outlines a Biodiversity Protection Strategy that includes the following:

- Encourage all conservation agencies, land trusts, municipalities, and not-for-profit conservation organizations to increase the importance given to and financial support for the conservation of uncommon and underprotected components of biodiversity.

- Educate landowners about maintaining and restoring certain natural processes and minimizing disturbance.
- Aid land managers in implementing land management techniques that mimic natural processes where they cannot be maintained or restored.
- Strive to achieve an equitable distribution of biologically viable conservation lands at all topographic elevations and across all ecoregions.
- Take action to conserve natural communities and species that have experienced tremendous loss or are under considerable threat.
- Focus attention on natural communities and species, common or rare that are underprotected.

The April 2000 "The State of Our Environment" from the Executive Office of Environmental Affairs (EOEA), acknowledges the link between human needs and healthy, thriving natural communities. EOEA identifies loss of habitat through development and invasive species as the two most distinct threats to maintaining natural diversity in Massachusetts, and further commits to preserving biodiversity through the identification and protection of critical habitats and the creation of bioreserves that will include central cores of public land. Specific to public forestland, EOEA has completed a Forest Vision Project that sets priorities for a biodiversity-based management approach (unpublished as of the drafting of this Plan).

MDC Division of Watershed Management mandates, stated in MGL Ch. 92, and Special Acts in the Legislature including c.372 of 1984, and c.737 of 1972, are directed at the production and protection of drinking water for metropolitan Boston. However, these laws also set forth a broad commitment to the protection of natural resources and species diversity. Chapter 737 addresses the management of Quabbin and Ware River Watersheds, and includes the following broad mandates:

Section 2: "The natural ecology of the district shall be maintained and it shall be conserved in the present degree of wilderness character...[it] shall be protected in its flora and fauna in all reasonable ways…no act shall be undertaken which will adversely affect the balance of nature…"

Section 8: "Lumbering or logging operations shall be permitted…to the extent and for the purpose of maintaining and conserving its forests in a healthful state of natural ecological balance consistent with reservoir and watershed purposes…"

As stated in Section 4.6 above, the Division's principal goals for maintaining biodiversity on its Wachusett holdings are to retain most of these lands in a forested condition, to identify and provide habitat for the protection of uncommon and rare flora and fauna, to eliminate and prevent the spread of non-native invasive species, and to provide the range of seral stages from early successional habitat through unmanaged mature forest.

5.4.3 Rare and Endangered Species

5.4.3.1 Flora

Refer to Section 2.3.3 for a description of both common and rare plant species and their habitats on the Wachusett watershed. *Isotria verticillata*, the large-whorled pogonia was the only rare plant species discovered during the 1996 survey of proposed timber-harvesting lots at Wachusett for rare species (conducted by the staff of the University of Massachusetts herbarium). MDC Foresters have also located the following state-listed species during independent surveys of Wachusett properties:

Lupinus perennis	Wild lupine	WL
Arceuthobium pusillum	Eastern dwarf mistletoe	SC
Juglans cinerea	Butternut	WL
Orontium aquaticum	Golden club	T

Although there is no current record of their presence, the species below have been predicted to occur on MDC watershed properties at Wachusett, based on past records and suitable habitats/range:

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
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
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	*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

NOTE: For Status, E = endangered, T = threatened, SC = special concern, WL = watch list

Primary responsibility in Massachusetts for the protection of endangered, threatened, or special concern plant species rests with the Natural Heritage and Endangered Species Program of MassWildlife. NHESP has identified 257 species of plants in these categories across the state, and is working continually to design protection strategies. Regulatory support for these efforts exists at both the federal and the state level. The Federal Endangered Species Act of 1973 protects 292 species of national significance, which includes the small-whorled pogonia (*Isotria medeoloides*) that is found in Massachusetts. Additional protection was provided by the 1990 Massachusetts Endangered Species Act, which protects a


P. Somers

Isotria medeoloides
Small-whorled pogonia

total of 424 species, of which 250 are plants. The small-whorled pogonia (*Isotria medeoloides*) is perhaps the most significant rare plant that might be found at Wachusett (no current record), as it is considered endangered in Massachusetts and is also threatened nationally.

Plants are considered rare for a variety of reasons. In some cases, it is simply that Massachusetts is 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. Bruce Sorrie, former Massachusetts state botanist, estimated that a surprising 72% of the species extirpated from the state had been lost due simply to the loss of early successional or recently disturbed habitat (Sorrie, 1989). Karen Searcy, current curator of the University of Massachusetts herbarium, reported in 1995 that 13% of the rare species likely to occur on Division 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. Invasive, non-native plants have also been implicated in the decline of some uncommon native species (see section 5.4.5 below).

Management recommendations for protecting rare plant populations begin with efforts to identify current populations. The Division is committed to working to locate these populations and adding them to GIS databases so that they will appear on maps even at times when they are difficult to locate in the field. Several organizations, including the NHESP in Massachusetts and the Southern New England Forest Consortium, 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. The Division will rely on recommendations being developed to guide management practices around known and discovered rare plant populations. For instance, the Southern New England Forest Consortium has recently published "Rare and Endangered Species: Field Guide for Southern New England," which includes management recommendations. This guide recommends that managers looking to support one-flowered pyrola should "maintain a residual overstory or high basal area in forests where populations have been found" and "thin out understory vegetation." Roundleaf shadbush requires managers to "prevent woody vegetation from overtaking the site" because "this species does not like a closed forest canopy." The Division will continue to work to identify rare plant populations and to research and apply management recommendations for their protection.

5.4.3.2 Fauna

MDC property within the Wachusett watershed is home to a number of state-listed vertebrate species (Table 29). However, because the Division's land holdings are protected from development, it is possible that past rare animal surveys bypassed MDC land. It is likely that there are undiscovered populations of rare and endangered species on Division property. Although land protection is one of the most critical factors for survival, it would be very helpful to know where these species are located. The Division actively manages its landholdings, and therefore there is the potential for these activities to impact listed species. In addition, some species may require additional management in order to enhance or modify existing habitat to benefit their survival.

In order to ensure that land management activities do not disrupt or destroy listed species or their habitats, an accurate and current species occurrence database must be available and expanded. The Division biologist keeps records of listed species on MDC land that were discovered by in-house personnel or passed along by the public. The state's Natural Heritage and Endangered Species program (NHESP) has a much more complete and detailed databases of listed species. In some cases, land management activities carried out by the Division (forest cutting plan) are reviewed by NHESP. However, in other situations, routine maintenance (mowing, brush cutting) or watershed maintenance activities (road building/repair) are conducted without informing NHESP. In these situations, it is possible to unknowingly and negatively impact rare or endangered species. It would be helpful for the Division to have access to NHESP's records for planning management activities. More importantly, additional rare species surveys need to be conducted (see Section 6.3), particularly on recently acquired parcels where little is known about the land.

In many cases, rare and endangered species become rare because of loss of habitat. One of the greatest benefits of MDC land to wildlife is that it will remain in a natural state and not be developed. However, as mentioned, most of this potential land will be covered by mature forest. This is a benefit to rare or endangered species requiring forested habitat (sharp-shinned hawk, cooper's hawk, timber rattlesnake), but will not help other species that require different habitat such as fields (upland sandpiper) or early successional forest (golden-winged warbler). Approximately half the species listed in Table 29 are either dependent on wetlands or utilize them during some portion of their lives. Protecting and maintaining functioning wetland systems is a priority for the Division, which should benefit wetland species. In addition, vernal pools on Division land receive particular attention (see section 5.5.2) and protection. Further, current state CMPs for vernal pools are being studied to determine their effectiveness in protecting vernal pool dependent species.

Non-forested upland habitat is much rarer on Division property and is limited to abandoned farms and maintained open spaces. There are several species on Table 29 that require open fields or meadows. Although the Division will not create field habitat, it does recognize the importance of this habitat in the landscape. Therefore, where feasible, the Division will maintain and enhance this habitat on select portions of its land (see Section5.5.4).

Areas with highly disturbed soils represent important habitat for several species listed in Table 29. On Division land there are several large active and inactive gravel and sand pits, areas of stream and shoreline erosion, and abandoned industrial/residential land. 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 (D.H. Small – pers.comm.). The Division recently documented wood turtles laying eggs in an abandoned Division sand pit. In many cases, however, these highly disturbed areas are scheduled for restoration (see Section 5.3.7.3). The Division recognizes the potential wildlife value some of these areas have, and in the future the Division 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 can be abandoned and left in its disturbed state.

Adequate habitat protection may assist some species listed in Table 29, but some still need additional assistance to successfully breed. In these cases, when personnel and resources allow, the Division may provide the added breeding structures or conditions. For example, the Division has constructed, deployed, and maintained floating cedar rafts in the reservoir, which are used by common loons for nesting. Although loons will and do nest on natural islands, the rafts provide protection from rising and falling water levels. When possible, the Division may also provide nesting boxes for Common barn and long-eared owls, and erect nesting structures for bald eagles.

TABLE 29. STATE-LISTED VERTEBRATE SPECIES WHOSE RANGES FALL WITHIN THE WACHUSETT WATERSHED, AND THEIR CURRENT STATUS ON MDC PROPERTY.

SPECIES	STATUS[1]	OCCURRENCE[2]
AMPHIBIANS		
Blue-Spotted Salamander	SC (Special Concern)	Probable
Marbled Salamander	T (Threatened)	Documented
Spring Salamander	SC	Documented
Four-Toed Salamander	SC	Probable
Eastern Spadefoot	T	Potential
REPTILES		
Spotted Turtle	SC	Documented
Wood Turtle	SC	Documented
Blanding's Turtle	T	Documented
Eastern Box Turtle	SC	Probable
Copperhead	E (Endangered)	Potential
Timber Rattlesnake	E	Potential
BIRDS[3]		
Common Loon	SC	Documented
Pied-Billed Grebe	E	Potential
American Bittern	E	Documented
Least Bittern	E	Potential
Bald Eagle	E	Probable
Northern Harrier	T	Potential
Sharp-Shinned Hawk	SC	Probable
Cooper's Hawk	SC	Probable
King Rail	T	Potential
Upland Sandpiper	E	Potential
Common Barn Owl	SC	Potential
Long-Eared Owl	SC	Probable
Short-Eared Owl	E	Potential
Sedge Wren	E	Potential
Golden-Winged Warbler	E	Potential
Vesper Sparrow	T	Probable
Grasshopper Sparrow	T	Probable
Henslow's Sparrow	E	Potential
MAMMALS		
Water Shrew	SC	Probable
Southern Bog Lemming	SC	Probable

[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 = species in danger of extinction throughout all or a significant portion of its range.

[2] Occurrence of species on MDC 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.

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

5.4.4 Rare Natural Communities

A natural community is a combination of physical and biotic conditions that form a functionally distinct area of the landscape (Garrett et al, 2000). An area's physical conditions (e.g., topography, hydrology, geology, etc.) will determine the vegetative composition, which in turn will dictate the type of animal community that lives there. Ideally, to adequately protect and enhance these communities, all features of the system must be properly protected and enhanced, not just individual parts.

Natural communities may be rare or uncommon globally, statewide, or at a local level. To ensure all rare communities receive adequate protection it is necessary to know where the communities are located on the landscape. Unfortunately, the Division has little information regarding rare or exemplary communities within the Wachusett watershed. Some communities (e.g., vernal pools, Poutwater Pond Nature Preserve) are known and documented. However, most communities considered rare or exemplary on a local or regional level have not been mapped. The Division's first step in managing rare natural communities should be to properly classify rare, unique, and exemplary communities that may occur within the watershed. When the classification system has been established, mapping can begin to locate communities. Field inspections of mapped communities should be done to verify mapped areas. Adequate management and protection of the rare community and surrounding area should be done to try to maintain the integrity of the area.

A project to map rare, unique, and exemplary natural communities is currently being conducted on the Quabbin watershed (Garrett et al., 2000). A classification system tailored to Quabbin communities was developed and preliminary field verifications were conducted. Community mapping and management recommendations were completed in September 2000. Some information from the Quabbin study can be utilized at Wachusett. 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 the Wachusett watershed. Because the Division is constantly acquiring new land within the Wachusett watershed, some parcels may contain rare or exemplary communities that haven't been discovered. A complete census of Division land needs to be done to accurately inventory community types. In addition, a project similar to the Quabbin study should be conducted at Wachusett to classify rare and exemplary communities.

5.4.5 Poutwater Pond Nature Preserve

The Poutwater Pond area (Figure 9) was designated officially as a Nature Preserve in 1998, the first such designation under the Nature Preserve Act. The Nature Preserves program was created by a 1990 amendment to MGL Ch. 131, Section 10. Under the act, state lands within the jurisdiction of the Executive Office of Environmental Affairs (EOEA) 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. MGL Ch. 131 states that any lands, waters, or shores under EOEA 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.

Poutwater Pond lies in northern Worcester County in an area that is lightly developed, but where urbanization impacts are increasing. Within the Wachusett Reservoir watershed, approximately 14% of the area is in developed (residential, urban, and commercial) land uses. The Poutwater Pond bog is in the center of an expanding area of protected open space, due to recent land acquisition activity centered on the protection of the Wachusett Reservoir. Although recent development has occurred in the vicinity of Poutwater Pond, the bog sits inside a block of several thousand acres of protected land.

The classification of Poutwater Pond as a National Natural Landmark in 1972 by the National Park Service is indicative of the important regional value of this natural resource. Only sites containing excellent examples of ecological or geological features that are representative of a particular natural region are considered for this designation. Beyond this designation, Poutwater Pond is considered by the state's Natural Heritage and Endangered Species Program to be one of a small number of bogs in the state that are in relatively undisturbed condition. Poutwater Pond is situated near the geographic center of the 75,000-acre Wachusett Reservoir watershed. Within this watershed area, there are only two other northern bogs. Poutwater is the best example of a mostly undisturbed bog within the watershed. The other two bogs, both along the Stillwater River, have been recently acquired by the MDC. Both have smaller bog environments, are less diverse, and have been impacted by past development activities.

Poutwater Pond is significant for the unique geologic, hydrologic, and botanical characteristics of the site. The area designated as a Nature Preserve has a diverse surficial geological make-up that includes a kettle hole depression, organic muck soils, upland glacial till soils, and an esker. 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. Poutwater Pond is classified as 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. Plant communities include two forested wetland communities dominated by 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.

The Poutwater Pond site had been in private ownership until 1994 when it was acquired for watershed protection purposes by the MDC, and had experienced relatively little impact from the visiting public. The main impacts to the site are from group visits to the bog (annual tours from local colleges and conservation organizations) and from a poorly conducted, private logging operation in the upland forest just outside of the Nature Preserve boundary. Group visits left a well-worn trail through a section of the floating mat (this trail has since been restored and upgraded). The recent logging operation caused road erosion and left logging debris in adjacent upland areas.

The Poutwater Pond Nature Preserve includes 213 acres under the care and control of MDC that encompasses the pond and the majority of its watershed, adjacent downstream wetland areas, and 11 acres under the control of DFW that encompasses an upland area that drains to the pond (Figure 9). MDC, the Mass. Division of Fisheries and Wildlife, and the Town of Holden collectively protect an extensive area surrounding the bog and wetland system (including the drainage area for the bog and pond).

Although the initial flora and fauna inventories of the Nature Preserve serve as a useful baseline, Poutwater Pond Nature Preserve has great potential for further botanical and faunal research, as well as examination of the peat deposits in the bog as part of paleobotany studies. If managed carefully, Poutwater Nature Preserve can be an excellent educational resource for local schools, ranging from elementary to the college level. Due to the significant natural resources and excellent research and educational potential, Poutwater Pond Bog represents an excellent site for designation as the state's first Nature Preserve.

The objectives for dedicating Poutwater Pond as a Nature Preserve are:

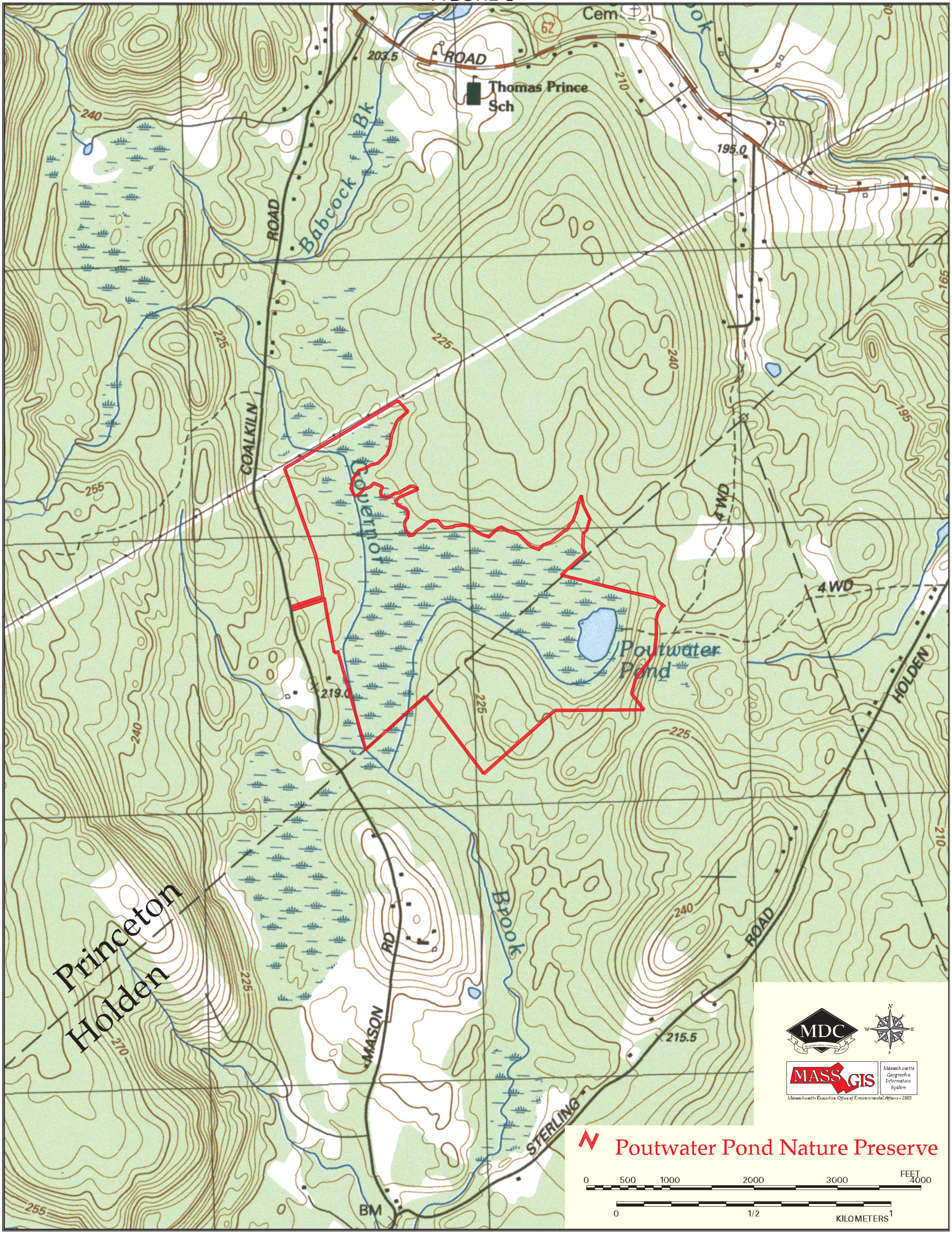
- To protect the unique natural features included in this area as a representative of a significant habitat and natural community within the Commonwealth.

- To study the unique natural features and ecology of this area.

- To educate the public regarding these unique features, in a manner which limits public impacts to the site, and encourages an increased awareness and stewardship for the site.

The 1997 MDC Protection Plan for Poutwater Pond Nature Preserve also 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.

FIGURE 9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5.4.6 Control of Invasive Plants

5.4.6.1 Definitions

"Invasive" plants fall into at least 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 have managed to aggressively force out native plants, raising serious biodiversity issues, and potential threats to water quality protection.

It has taken awhile for these issues to become apparent. Some of the invasive plant problems on MDC properties are the result of deliberate plantings of species that effectively addressed other concerns (for instance, planting autumn olive to improve wildlife habitat), but then became invasive. Other invasive species are escapees from landscaping that predates MDC's acquisition of reservoir properties, including Japanese barberry, Japanese knotweed, the buckthorns, and purple loosestrife. In all cases, a plant's "invasiveness" is composed of several defining qualities:

- The plant grows and matures rapidly in abundantly available habitats.
- 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 (which generally means there are no close relatives in the habitats it invades).
- The plant does not require intensive management to thrive.

T. Kyker-Snowman

Invasion by Japanese barberry

5.4.6.2 Problems Associated with Invasives

The EOEA report "The State of Our Environment" (April, 2000) states that "the two biggest threats to biodiversity in Massachusetts are the destruction and fragmentation of wildlife habitats and the introduction of invasive non-native species." The Nature Conservancy has reported that 42% of the declines of threatened or endangered species in the US are partly or wholly due to the effects of invasive species. Some of these threats are subtle. For instance, when the declining West Virginia White butterfly lays its eggs on the invasive garlic mustard instead of on the usual native mustards, its eggs fail to develop. Other threats are more obvious. For instance, purple loosestrife currently covers an estimated 500,000 acres in northern US and southern Canada, displacing native food sources and threatening to prevent successful nesting in 90% of the wetlands used by breeding waterfowl along the Atlantic and Mississippi flyways. Impacts from invasives on the soil and its faunal community have also been documented. There is evidence that a Chinese tallow tree is altering nutrient cycling where it invades, causing a decline in the native soil invertebrates as a consequence.

Beyond issues of biodiversity conservation, resilient plant communities are important to watershed management for controlling the erosion of soil and nutrients throughout the range of natural disturbances (e.g., droughts, insect outbreaks, fire, wind, heavy snow and ice). Resilience is dependent upon species and size diversity in the plant community, because disturbances are frequently species and/or size specific. When plants become aggressively invasive, replacing the diverse native flora with local monocultures, they increase the susceptibility of the plant community to disturbances. The prevention of forest regeneration by certain aggressive invasives has become a problem on some areas of the watersheds. Around the Quabbin Reservoir, Japanese barberry that was planted on historic homesites has taken advantage of high deer populations (which do not feed on barberry) to colonize and monopolize the understories of significant forest areas. At the Wachusett Reservoir, autumn olive has aggressively occupied open fields, delaying or precluding their return to forest cover. Invasives are often more effective than natives in colonizing disturbed areas, and may overrun young trees that do become established. Table 30 lists the invasive plants that are present at the Wachusett Reservoir.

TABLE 30. INVASIVE PLANTS PRESENT AT WACHUSETT RESERVOIR

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
Shining buckthorn	*Rhamnus frangula*	Forest
Common buckthorn	*Rhamnus cathartica*	Forest
Honeysuckles	*Lonicera sp.*	Open areas
Autumn olive	*Elaeagnus umbellata*	Open areas
Russian olive	*Elaeagnus augustifolia*	Open areas
Multiflora rose	*Rosa multiflora*	Open areas and edges
Goutweed	*Aegopodium podagraria*	Floodplains, riparian areas
Japanese knotweed	*Polygonum cuspidatum*	Riverbanks, wet edges
Purple loosestrife	*Lythrum salicaria*	Wetlands
Garlic mustard	*Alliaria petiolata*	Floodplains, disturbed woodlands, roadsides
Phragmites (common reed)	*Phragmites australis*	Wetlands
Winged euonymus	*Euonymus alata*	Open woods, fields, edge

5.4.6.3 Control and Management Options

In February of 1999, President Clinton signed an Executive Order, to “prevent the introduction o invasive species and provide for their control and to minimize the economic, ecological, and human health impacts that invasive species cause.” This order calls for a federal Invasive Species Council that “shall recommend plans and actions at local, tribal, State, regional, and ecosystem-based levels” to address prevention and control of invasives. The first edition of a National Invasive Species Managemei Plan from this Council was to be produced by the summer of 2000. This plan may provide both additional mandate and the budget to begin to gain control over invasives.

All of the features that make a plant invasive also frustrate efforts to control and reverse its expansion. Seed production is generally prolific, and many invasives also reproduce vegetatively.

General control requires the removal or killing of mature plants, but also requires that these removals be timed in such a way that they do not result in further reproduction and spread of the plant. Controls are either mechanical or chemical. Mechanical controls include hand-pulling, girdling or mowing, mulching, tilling, and the use of heat. Chemical control is often more efficient and effective, but carries stronger risks of collateral damage to non-target species, as well as risks of water and soil contamination. Controls need to be designed around the morphology, phenology, and reproductive strategies of specific plants. For instance, while prescribed fire will reduce invasions of conifers in native grasslands, it tends to stimulate growth and reproduction of many other invaders.

The primary invasive plants found on the Wachusett watershed are listed below with recommended controls from various sources in the literature:

TABLE 31. MAJOR INVASIVE PLANTS AT WACHUSETT, AND RECOMMENDED CONTROL

Invasive Species	Recommended Control [1]
Norway maple	Cut mature trees as close to base as possible; pull seedlings/saplings including as much of the root as possible.
Oriental bittersweet	Regular mowing of edges and open areas will exclude bittersweet; triclopyr herbicides are effective as foliar or basal applications.
Buckthorns	Seedlings are easily pulled. Larger stems can be pulled or cut, and may be killed by repeated fire. Freshly cut stumps should be treated with a 50% solution of glyphosphate to prevent resprouting. As buckthorns enter dormancy later than most species, treatments should be applied mid to late autumn to reduce risk to non-target species.
Honeysuckles	Hand-pulling is effective for isolated shrubs less than 3 years old. Most effective control of larger populations occurs through cutting and basal application of 20% glyphosphate. Seeds are not long-lived, so returning to remove seedlings by hand every two years or so should eliminate the population in time. Repeated burning is only effective for a short time, as the shrubs continue to resprout indefinitely following fire.
Olives	Repeated cutting of mature stems and sprouts and pulling of new seedlings may be effective. Best control is achieved by cutting followed by either burial or herbicide treatment of cut stump.
Multiflora rose	Regular mowing, where feasible, will remove this plant. Larger shrubs should be pulled or dug out. Where mowing is not practical, cutting followed by stump treatment with glyphosphate to prevent resprouting, is effective.

[1] Control measures are from current literature and are NOT MDC/DWM policy at this time.

5.4.6.4 MDC Control Efforts During This Management Period

Treatment of invasive plants to control or reverse their spread will progress as time and budget allow, from the highest to the lower priority areas, as follows:

- Areas of invasive plants that are presenting a direct threat to existing rare or endangered plant communities. Control will be focused on area of direct threat.
- Areas where tree regeneration is critical and is being prevented by one or more invasive plant species. This may include riparian zones and other critical protection areas.

- Areas where invasive plant populations are recently established and limited in extent, so that control is a reasonable expectation.

5.4.7 Maintenance of Early Successional Habitat for Landscape Diversity

5.4.7.1 Importance of Early Successional Non-Forested Habitat

Broad changes in land use have dramatically impacted the number, type, and extent of open lands within the watershed. Early successional habitat was a major component in the landscape prior to European settlement. Evidence suggests that grasslands existed in the Northeast before Europeans arrived, and grassland birds have been a component of avian diversity for a long time (Dettmers and Rosenberg 2000). Beaver activity, wildfires, windstorms, and fires set by Native Americans generated early successional habitat. By the 1800's grasslands were even more abundant in the northeast as agricultural land dominated the landscape. Since the mid-1800's, the amount of grasslands and open fields has decreased dramatically, causing a similar decrease in many species of plants and animals that depend on open habitat. As farms were abandoned, the open fields and meadows were left undisturbed. Without frequent disturbance such as mowing, burning, or grazing, grasslands will gradually revert back to forest. Some grassland species, such as the loggerhead shrike and regal fritillary butterfly, have been extirpated from Massachusetts (Vernegaard, et al. 1998).

Recent population trends for grassland dependent species show disturbing declines. Bobolinks and grasshopper sparrows have declined 38 and 69 percent, respectively in the last 25 years (Jones and Vickery. 1998). 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, butterflies like the monarch, tiger swallowtail, and various fritillaries feed on nectar of grassland wildflowers.

The Division recognizes the regional importance of these open lands to the diversity of wildlife within the state. Division owned land within the watershed is 92 percent forested and 6 percent non-forested upland. The non-forested uplands are comprised of approximately 952 acres and includes gravel pits, administrative areas, and both active (hay only) and abandoned agricultural fields. These fields range in size from <2 acres to ~90 acres, and are distributed across the watershed. Although the Division will continue to manage a majority of its property as a multi-aged, multi-species forest, on particular areas where open habitat exists, we will manage to maintain and/or enhance these grassland communities (see Section 5.3).

5.4.7.2 Early Successional Non-Forested Habitat Management Practices

5.4.7.2.1 Field Prioritization

The Division owns a variety of open lands. In all cases, these are either open lands the Division recently acquired through its land acquisition program or has traditionally managed in an open condition. The Division will not actively create non-forested open lands that are now forested and will only continue to manage or prioritize lands that are currently non-forested. Analysis of the distribution, size, and juxtaposition of open lands within the watershed highlights the need for prioritization. Fields will be prioritized based on their size, distance to flowing water, relative isolation, and juxtaposition with other open fields (J. Scanlon. pers. comm.). In general, very small (<2 acres), isolated fields will be abandoned and allowed to naturally regenerate to forest cover. In addition, those fields (or portions of fields) that border reservoir tributaries will also be abandoned and to allow trees to grow. This will provide an adequate forest buffer around 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 (Vernegaard, 1998; Sample and Mossman, 1997). These areas will be maintained or enhanced using a variety of management techniques in order to optimize the available habitat.

Following prioritization, those fields not abandoned will receive management to either maintain them in open habitat or to enhance the existing conditions. Division personnel, private farmers with lease agreements, and service contractors will complete required management activities. Grasslands used for hay will be managed differently than those fields were hay production is not occurring. In both cases, wildlife considerations will be incorporated into the proposed management activities. [See section 5.3.3. for a discussion of Agricultural Land under MDC Control]

5.4.7.2.2 Non-Agricultural Grasslands

Approximately 617 acres of MDC fields are not leased for hay production. On these fields, wildlife habitat management will be one priority. While they are not mowed yearly for hay, these fields still require active management in order to maintain them in a grassland condition. However, there are more opportunities to apply various management techniques to enhance the existing habitat. The following management guidelines for mowing on lands not used for hay production will be followed:

- Mowing should be limited to every one to three years. This will still inhibit woody vegetation and allow late-blooming wildflowers to develop.
- In years when fields are mowed, mowing should occur after August 1.
- When mowing, mower height should be a minimum of 8-10 inches off the ground to provide habitat for small mammals.
- Manage adjacent fields as one unit: Multiple contiguous fields should be managed through rotational mowing to provide a diversity of grassland types.

The Division owns several large contiguous grasslands that are potential candidates for other management activities. In addition, some smaller grasslands may also be suited to disturbances other than mowing. Burning grasslands can reduce buildup of dead vegetation, prevent the spread of woody vegetation, release nutrients into the soil, and rejuvenate plant growth (Jones and Vickery, 1998). 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. When feasible and practical, fire management can be a benefit to grassland bird populations and other wildlife usually within a year or two of the burn. If and when the Division conducts fire management, the following guidelines will be followed.

- Burns should be conducted in early spring (mid-March to the end of April) after snowmelt but before bird nesting. Appropriate weather conditions should be considered.
- Grasslands should be burned once every 3-4 years, and if possible an unburned, adjacent field should be available for nesting birds during the burn year.
- If possible, on larger grasslands only a portion of the area should be burned in any given year. Staggering burns allows for the development and availability of a variety of habitat conditions. Not more than 30% of habitat should be burned during any year.

The quality of Division grasslands is variable. Encroaching exotic invasive plants are invading some fields. 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. The Division feels it is necessary to actively try to remove and control the existence of these species in order to optimize available grassland habitat. Multiflora rose, autumn olive, honeysuckle, and buckthorns have all been found on Division grasslands. The inventory of all Division fields in 1999 found that 48% of all fields have invasive species present. [See section 5.4.6. for a discussion of the Control of Invasive Plants]

5.4.7.3 Importance of Early Successional Forested Habitat

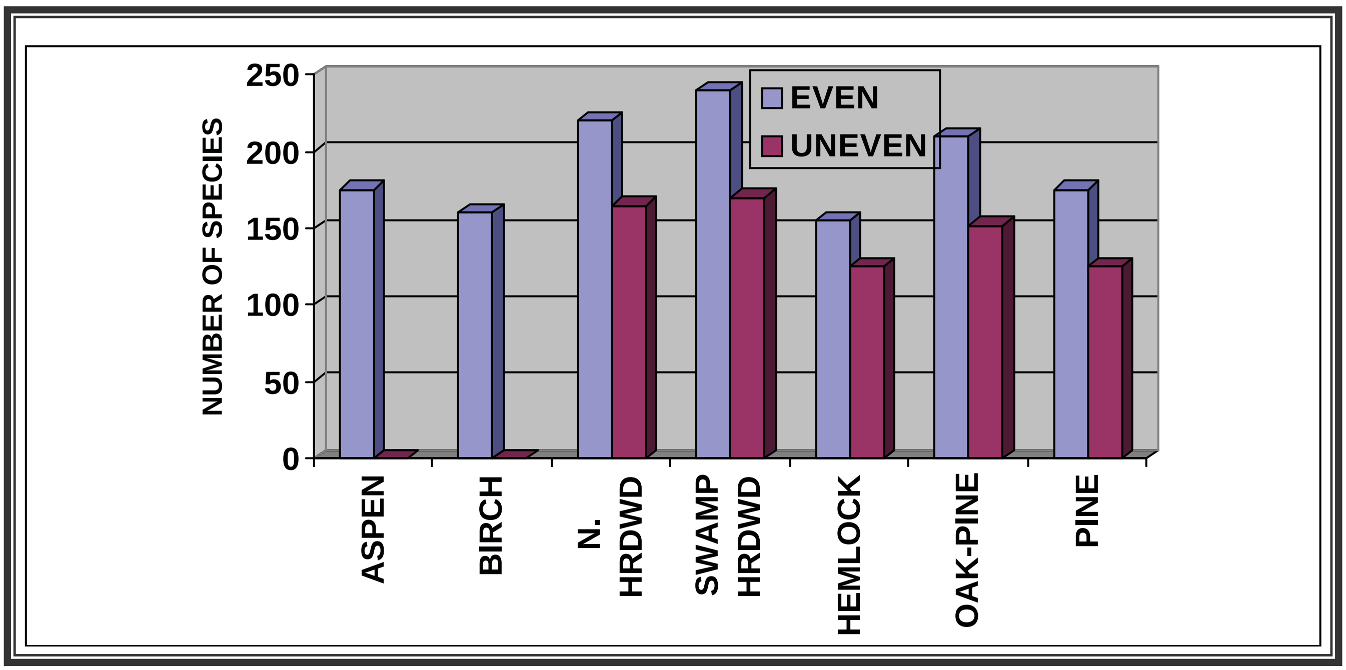
Evidence suggests that early successional forested habitat was present in sufficient amounts and distributed well enough across the landscape to support long-term populations of early successional birds in the Northeast prior to either European or Native American intervention (Dettmers and Rosenberg 2000). Fire, major weather events, or beaver activity maintained or generated these habitats across the landscape. European and Native American populations increased the amount of early successional habitat in the region. By the mid 1800's, forest cover in New England had dropped from >90% to <50% (Dettmers and Rosenberg 2000). As farms were abandoned during the late 1800's large amounts of early successional habitat became available. Over time these large areas of early successional habitat grew beyond the early seral stages used by early successional species.

Species dependent on these early successional habitats have been declining since the 1950's as the amount of available habitat continues to shrink (Scanlon 2000). Partners in Flight species of concern list highlights species associated with early successional forested habitat (i.e. blue-winged warbler, eastern towhee, and prairie warbler). Providing habitat for early successional species involves considerations in both space and time. Early successional habitats are temporal and only support wildlife for 8-15 years. Therefore, either habitats need to be set back on a regular basis or new areas of early successional habitat need to be created.

Even-aged forest management is the primary technique used to produce early successional forest stands. This type of silviculture provides the opportunity to regenerate shade-intolerant species such as aspen and birch. The resulting habitat provides distinct foraging and shelter opportunities for species that are not usually available when uneven-aged management is used (DeGraaf et al. 1992). Even-aged management provides habitat for up to 26% more species than uneven-aged management in similar cover types (DeGraaf et al. 1992) (Fig. 10). Failure to incorporate some even-aged management techniques within the watershed could result in fewer species. Payne and Bryant (1994) state that even-aged management tends to support more wildlife species than uneven-aged management does in northern hardwoods, hemlock, oak-pine, and pine forests of the northeast. Because the current level of tree harvesting within the state is relatively light, widely dispersed, and generally does not provide substantial early-seral habitat, the Division will try to incorporate management techniques geared towards creating this type of habitat. 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).

As mentioned previously, in order to provide the widest range of habitat conditions across the watershed, a variety of management techniques and applications may be needed to either create or sustain various habitat conditions. Although uneven-aged management techniques will be primarily applied across the watershed, it is important to recognize the role even-aged management plays in maintaining biodiversity. However, it is also important to realize that early successional habitat only needs to comprise a relatively small percentage of managed land in order to meet population objectives for early successional species. Limitations of resources and personnel preclude the Division from managing a large percentage of MDC land holdings in early successional stages. Therefore, for this management period, the Division's goal for early successional forested and non-forested habitat will be approximately 6-8% of MDC land. The current estimate of the amount of early successional habitat (primarily non-forested) on Division land is approximately 6%. Therefore, in order to meet management goals, some current early successional non-forested land may be abandoned, while other early successional forested areas are created.

FIGURE 10. POTENTIAL WILDLIFE SPECIES BY SILVICULTURAL SYSTEM AND COVER-TYPE GROUPS



Source: DeGraaf et al. 1992.

Even-aged: forests containing regeneration, sapling-pole, sawtimber, and large sawtimber stands in distinct units of 5 acres or more. **Unveven-aged**: essentially continuous forest canopies and intermixed size and age classes produced by single-tree selection cuttings.

5.4.7.4 Early Successional Forested Habitat Management Practices

Even-aged management is used to create early-seral forested habitats. Although "clear-cuts" are often associated with even-aged management, there are a variety of even-aged techniques that can be used to accomplish particular management goals. First, it is important to note that "clear-cut" implies that there is no regeneration in place prior to harvest. Even-aged techniques used on Division lands would always be done on stands where some regeneration was in place. Further, complete overstory removal will not be done. Typically 10-20% of the overstory will be retained in clusters of 5-10 trees scattered across the stand. An average of 2-3 clusters per acre will be retained. These occasional clumps of trees are an attempt to mimic natural disturbances. Major catastrophic events typically do not completely remove the overstory in a given area, but instead create a patchy effect on the landscape as some trees survive the event. In addition, preserving clumps of trees allows the Division to selectively save valuable mast, den, and nest trees.

In order to create conditions favorable for early successional species, forest openings need to be large enough and placed appropriately to provide enough habitat to sustain viable animal populations over time. It would be counter-productive to create early successional habitat that was too small and actually serve as a sink habitat for species. Therefore, given constraints on property size, land use, and watershed characteristics, openings on Division lands would not exceed 15 acres. Forest openings of various sizes would be carefully placed within the watershed to ensure adequate water quality protection concerns. Topography, distance to tributaries, soils, stand health, and distance to human interface would be considered when planning even-aged management. Further, when this type of management is introduced, it can provide the catalyst for further study of forest management to determine the short and long-term effects of even-aged management on nutrients and water quality parameters.

5.5 Wildlife Management

5.5.1 Assessment of Impacts of Planned Watershed Management Activities

The management activities described in this plan will have various impacts on the wildlife community at Wachusett. Most impacts on the wildlife community will be a result of habitat changes or modifications. The forest management approach described in this plan has landscape level affects, although individual changes at any given time will be very localized and small.

The amount and types of habitat at Wachusett has been dynamic since early colonial times. Once covered by primeval forest, a majority of the land in the Wachusett watershed was cleared for agriculture. This trend persisted for decades, until about 1840 when 75 percent of the arable land was in pasture or farm crops (DeGraaf et al., 1992). The next 100 years was another period of dramatic change as most of the farmland was abandoned and new forest invaded. Dramatic changes in the wildlife community accompanied these broad landscape changes. Some species thrived and expanded their range, while other 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 very rare breeders. Other open habitat species (bobolinks, vesper sparrows, and golden-winged warblers) are declining as well as available habitat shrinks. Today, most of the undeveloped land in the Wachusett watershed is forested. While the Division's management activities will alter habitat and wildlife species composition, probably the most significant impacts to the wildlife community have been these large regional changes in land use. In addition, recent human population expansion into the Wachusett watershed has meant the loss of more and more open space, which is converted to residential housing. Further, large-scale disturbances to the

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While the management techniques used to reach these goals will not be as dramatic as previous events, it is important to understand how these plans will affect the habitat and wildlife communities on the watershed.

5.5.1.1 General Impacts

The Division's primary long-term forest management goal is to establish and/or maintain a forest cover of diverse native tree species of many different age classes on a majority of its land holdings. This goal will primarily be accomplished through uneven-aged forest management. A 20-30 year cutting cycle will be used in most areas, and harvest will be primarily through selection of individual trees or groups (1/20-1/4 up to 2 acres). As a result, the wildlife community on MDC land will be dominated by species adapted to forest conditions. However, uneven-aged management is the best technique for preserving individual trees of high wildlife value (dens, nests, roost, mast producers) (Payne and Bryant 1994). In addition, uneven-aged management increases vertical diversity. The end result is an even distribution of a low but constant population of understory plants and associated wildlife (Payne and Bryant 1994).

Meeting this primary objective will mean wildlife communities on MDC land will be dominated by species adapted to forest conditions. Those species requiring early successional or open habitat will be rarer and isolated to those areas where that type of habitat exists. Open and early successional habitat will be maintained on a small percentage of the Division's land, primarily associated with fields on recently acquired farms, open areas associated with developed areas (Old Stone Church, dikes), and beaver impoundments. Forest wildlife communities should benefit most from the Division's management plan.

5.5.1.2 Specific Impacts

5.5.1.2.1 Preparatory Cutting and Planting

Preparatory cutting and planting is primarily practiced in stands that either lack adequate understory regeneration or regeneration is lacking species diversity. Prep cuts involve opening up the canopy and may also include disturbing the forest floor and planting selected species. 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 (eastern towhee, snowshoe hare), but will negatively impact species requiring older, intact forest canopies (northern goshawk, pileated woodpecker). Overall, wildlife diversity within these stands should increase as vertical and species diversity increases, although specific wildlife species may either benefit or decline from the alteration.

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 (ovenbird, red-backed voles, and spotted salamanders). However, this impact is temporary and the resultant increase in density of ground cover will be a benefit to these species. Planting desired species within a stand (e.g., conifers) will increase the species diversity of the area and provide a faster amount of understory cover.

5.5.1.2.2 Release of Regeneration

5.5.1.2.2.1 Single-tree Selection

Silvicultural methods proposed during this 10-year plan focus on group selection (~2 acres) removal of overstory trees to release regeneration. In addition, some single-tree selection may also be used. Group selection has a potentially larger impact on wildlife habitat and species than single-tree selection. As mentioned above, 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 integrity of the habitat is not altered. 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.

5.5.1.2.2.2 Group Selection

Much attention has been focussed recently on the potential problems of forest fragmentation in the northeast. Most of this effort has centered on Neotropical migrantory birds and the continued decline of some species. It has been shown that area-sensitive songbirds do not reproduce well along edge habitats (Sullivan and Brittingham, 1994). 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. Because the Wachusett watershed is a mosaic of habitat types and represents a fragmented landscape, it is hard to speculate how much impact MDC land management activities will have on edge-sensitive species. Alterations to MDC forested land are not analogous to what would occur if the same land were developed for residential housing or agriculture. However, since the MDC will use group selection (openings up to two acres in size) to treat the majority of Wachusett forest stands, it is prudent to consider the impact of this practice on wildlife communities.

The most influential factor 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 (see Wilcove, 1988). 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, 1988). Initially it might appear that edge effects would be limited to isolated woodlots surrounded by houses or barren land. On MDC land there is primarily a matrix of interconnected forest at different stages of succession. 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 forest, increases in nest predation and parasitism may extend as far as 1000-2000 feet into the forest. Therefore a small number of openings in the forest could impact a large area. Adding to the problem could be the nature of the Wachusett watershed. MDC land often abuts other non-forested areas or small woodlots where large numbers of nest predators potentially live and reproduce (residential areas support cats, raccoons, bluejays, 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 forest fragmentation were extirpated long before they could be studied. Mountain lions, wolves, elk, and woodland bison have been gone from the watershed for decades. As a result, those mammals left within the watershed 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 fragmentation.

Openings within forests benefit wildlife species that depend on herbaceous and early successional forest habitat. 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. This type of habitat favors certain species of wildlife.

5.5.1.2.2.3 Large OverstoryRemovals in Plantations

Full overstory removals in plantations produces the greatest immediate habitat change due to silviculture on MDC/DWM properties. Full overstory removal is essentially even-aged management and involves both positive and negative effects on wildlife. In general, removing the overstory will provide excellent early successional habitat that is utilized by a variety of species. Early successional species will particularly benefit from this management because the larger stand size will attract and sustain larger populations of those species. Species requiring continuous forest canopy will be 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.

5.5.1.2.2.4 Non-harvest Removals on Sensitive Sites

There are areas on the watersheds where a reduction of overstory trees is desireable in order to diversify age structure, but where conventional harvesting may be impossible or risky (e.g., a shoreline plantation or a hurricane exposed island). On a limited number of these sites, the Division proposes to cut trees but not remove them. This practice would enhance forest regeneration without negatively impacting the sensitive site. Non-harvest tree cuttings will also add course woody debris to an area, particularly large size log classes that are important to a variety of wildlife. In addition, removing some canopy trees will increase species diversity and enhance the ground and shrub layer of the area. This type of management is being proposed on less than 100 acres on the Wachusett watershed, so it will have little impact on wildlife species at the landscape level.

Cutting trees along the reservoir shoreline could impact the potential for bald eagle nesting. There are no bald eagle nests along Wachusett Reservoir to date. However, if large “supercanopy” trees are removed, it may impact the ability of eagles to nest in the future. Careful attention will be given to providing adequate nest trees along the shoreline.

5.5.1.2.2.5 Riparian Zone Management

The Division plans to conduct limited non-harvest removals of trees along riparian wetlands to increase light and stimulate regeneration. Cut trees will be left in place along the riparian area. This will add coarse woody debris, providing additional cover and nutrients for forest floor wildlife. The additional light will allow for a greater diversity of understory trees and ground cover, which will benefit wildlife species that rely on dense understory vegetation.

This management practice could have potential negative impacts on the wildlife community depending on where the harvesting was to occur and how many overstory trees were removed. Removing a large number of deciduous trees along the riparian zone could have negative effects 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 some streams there is almost continuous conifer (hemlock) cover, which characteristically has little understory regeneration. This habitat type is uncommon on the watershed and provides unique habitat for a variety of wildlife. Removing trees in these areas could alter the microclimate of the area and have potentially negative effects on the wildlife and stream communities. When harvesting trees along the riparian area it is important to save cavity or potential cavity trees. Cavity trees along riparian wetlands 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. Availability of a winter food supply is an important factor affecting beaver distribution in areas where stable water levels are possible.

5.5.2 Conservation Management Practices (CMPs) for Wildlife Management

Division 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 Division 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 has been and continues to be conserved and encouraged on Division property.

CMPs for wildlife management are generally complementary to water quality protection standards. The following wildlife CMPs highlight current management techniques already being practiced and elaborate on other management techniques that can be employed.

5.5.2.1 Habitat Features and Management Recommendations

5.5.2.1.1 Vernal Pools

D. Clark

Vernal pool

Vernal pools are contained basin depressions with no permanent outlet that typically hold water for at least 2-3 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 keeps them free of fish populations.

Because of their unique characteristics, vernal pools play a critical role in the life cycles of many amphibians, reptiles, and invertebrates. As a result, the MDC considers vernal pools to be a critical wildlife habitat. 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. In recent years, the MDC 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, Amherst recently identified over 300 “potential” vernal pools on the Wachusett watershed through aerial photos. These pools have been digitized, and in the future, these pools will be field checked to ascertain their status. Locations of known documented vernal pools will be transferred to a GIS datalayer for inclusion in land management planning documents.

Research is currently being conducted at Quabbin Reservation to test the effectiveness of Massachusetts Conservation Management Practices for vernal pools. While the state CMPs provide direct protection of the pool, there is concern that the wildlife species utilizing the pool may also rely on a larger area surrounding the pool for a majority of their life cycle. This research will test the effectiveness of the current CMPs.

5.5.2.1.2 Vernal Pool Management Objectives

MDC/DWM is working to locate and identify all vernal pools on MDC property 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.
- Digitize all aerially intrepreted vernal pools and provide datalayer to GIS personnel for inclusion in land management activity plans.
- Identify and confirm status of photo-intrepreted vernal pools.

Within Pool Depression:

- Continue to maintain physical integrity of pool depressions and their ability to seasonally hold water.
- Continue to keep depressions free of slash, treetops, and sediment from forestry operations. If slash does fall into pool during the breeding season do not remove it so breeding activity is not disturbed.

Edge of Pool:

- Keep shaded condition in 50-foot buffer zone around pool depression.
- Minimize disturbance of forest floor within 200 feet of pool edge.
- Avoid making ruts >6 inches deep within 200 feet of the pool.
- Conduct low-intensity harvests preferably when ground is frozen.

5.5.2.1.3 Seeps

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 surround trees and shrubs accumulate. This makes them important winter feeding sites for turkey, deer, and other wildlife.

Seeps 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. 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.

D. Clark

Winter seep

5.5.2.1.4 Seep Management Objectives

MDC/DWM 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.
- Where seeps are present, schedule harvests to occur on frozen ground or during the driest conditions.
- Avoid running heavy equipment within 50 feet of the edge of a seep.
- When feasible, use seeps as the center for uncut patches to retain cavity trees, snags, and other wildlife features.
- In stands where seeps are present, lay out skid trails and roads prior to the harvest when seeps are obvious.

5.5.2.1.5 Orchards

Abandoned apple orchards and scattered fruit trees exist on MDC watershed property. 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). White-tailed deer, grouse, squirrels, fox, fisher, porcupine, and rabbits will eat apples or apple seeds. 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.

5.5.2.1.6 Orchard Management Objectives

MDC/DWM will save 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.
- If possible, keep and enhance all fruit trees.
- When feasible, remove other trees and shrubs back to the drip line of the apple tree.
- If large over-topping trees shade the fruit tree, remove them on at least 3 sides, particularily to the south.
- When possible, prune and fertilize trees at least every 3 years.

5.5.2.1.7 Wildlife Wintering Areas


P. Rezendes

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. An important wintering area is often related to white-tailed deer use of concentration areas or "yards." These deer wintering areas (DWA) typically are in hemlock or pine stands where there is >70 percent conifer crown closure (Elliot 1998). Deer typically move to these areas when snow depths are around 12" (Flatebo et al. 1999). DWA provide reduced snow depths, higher nighttime temperatures, reduced wind, and greater relative humidity (Flatebo et al. 1999). 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) that provides increased thermal protection and wind cover for a variety of birds and mammals. For example, grouse will seek conifer stands when snow depths are <8 inches for thermal protection.

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.

5.5.2.1.8 Wildlife Wintering Area Management Objectives

MDC/DWM 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.
- When feasible, schedule forest harvest operations 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.
- Planned activities within WWA should be conducted to 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 60-100m wide) that connect all areas of the WWA.

5.5.2.1.9 Mast

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). It contains more fat and protein than other plant foods and is actively sought by a variety of birds and mammals. Mast is particularly important in autumn, as many animals will focus on eating mast in preparation for winter. Bears, squirrels, raccoons, deer, and turkey will fatten up on acorns, beechnuts, and hickory nuts. Resident songbirds such as nuthatches, chickadees, and bluejays 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 (Flatebo et al. 1999). 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.

5.5.2.1.9.1 Hard Mast

At Wachusett, red, white, and black oak, beech, and hickories are the most important sources of mast. Oaks are probably the most important wildlife mast trees in the northeast. Acorns are eaten by over 100 species of birds and mammals (Healy 1997). 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 2 years to develop, while white oaks take only 1 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 et al. 1999). White oak acorns contain less tannin and may be more palatable to wildlife.

Beech and hickory trees comprise a smaller component of Wachusett's forest. Hickories are scattered around the watershed, 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 important mast producers 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 pine are the most widely distributed conifers at Wachusett. Mice, voles, grosbeaks, and finches are a few of the animals that utilize conifer mast. Chickadees and goldfinches prefer hemlock seeds.

5.5.2.1.9.2 Soft Mast

T. Kyker-Snowman

Raspberry

Black cherry trees comprise a relatively small percentage of Wachusett's forest canopy. However, bears, small mammals, and over 20 bird species eat cherries (Flatebo et al. 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.

5.5.2.1.10 Mast Management Objectives

MDC/DWM 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.
- Foresters will 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.
- When possible, save all hardwood mast trees that occur in conifer plantations.

5.5.2.1.11 Wildlife Trees

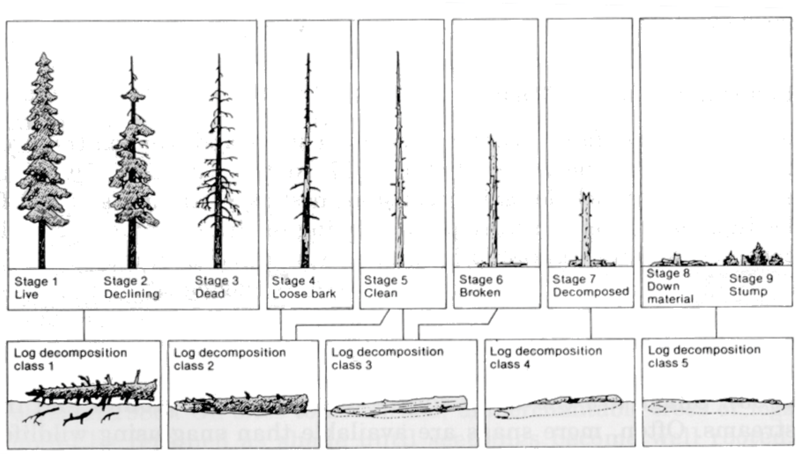
Wildlife trees are often divided into two categories: snags and den trees. Snags are standing dead or partially dead trees at least 6" dbh and 20 feet in height. Den trees are live trees possessing a cavity large enough to serve as shelter for birds and mammals or a site to give birth and raise young. 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.

Forestry operations most likely have the greatest potential impact on the number, type, and location of snag and den trees at Wachusett. Thinning, salvage, firewood cutting, and windthrow will result in wildlife tree loss. However, the Division's use of uneven-aged management is conducive 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 make that unlikely. It is possible to maintain an adequate number of snags and dens across the watershed to meet habitat requirements (Table 32).

TABLE 32. OPTIMUM NUMBER OF SNAGS AND/OR DEN TREES PER 100 ACRES BY THREE BROAD HABITAT TYPES.

Size	Forest Interior		Semi-open/Open	Wooded Watercourse
Tree dbh (in)	Dens	Snags	Dens[1]	Dens[1]
> 19	100	0	300	200
10-19	400	400	400	1,400
< 10	200	200	300	900

Source: Payne and Bryant, 1994
[1] Creating snags by deadening trees is not recommended in these habitats.



Source: Payne and Bryant 1994

FIGURE 11. DECOMPOSITION STAGES OF SNAGS AND DOWNED LOGS

5.5.2.1.11.1 Snags

As a tree dies, it progresses through several stages of decay (Fig. 11) and is used by different wildlife at each stage. 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.

As a tree deteriorates, primary excavators (woodpeckers) begin to create cavities. Most 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 (< 20 feet tall 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. In addition, 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 snag's value to specific wildlife species. 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 cavity trees, the rule bigger is better is ideal. 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 provides nesting sites for secondary cavity nesters (Table 33).

TABLE 33. NUMBER OF CAVITY TREES NEEDED TO SUSTAIN THE HYPOTHETICAL MAXIMUM POPULATIONS OF NINE SPECIES OF WOODPECKERS FOUND IN NEW ENGLAND

Species	Territory Size (Acres)	Avgerage nest tree[1]		(A) Cavity trees used, minimum	(B) Pairs/100 acres, maximum	Cavity trees needed per 100 acres[2] (A x B)
		DBH (in.)	Height (ft.)			
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.

5.5.2.1.11.2 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 maintain self-sustaining populations of all cavity dependent wildlife. In areas where good snag trees are lacking, poorer quality trees will be retained until better trees develop.


T. Kyker-Snowman

Snag tree

Recommended Practices:

- When possible, leave all snags within 100 feet of wetlands and riparian areas.
- Maintain a minimum of 6 snag trees per acre; 4 should be > 24” dbh and 2 <24” dbh.
- Avoid disturbing snags from April to July to stay away from nesting birds and denning mammals.
- If snags must be felled during management operations, leave them in place instead of removing them.
- When possible, identify current or potential snags through exterior signs such as fungal conks, butt rot, burls, cracks, wounds/scars from lightening, fire, or mechanical damage, woodpecker holes or cavities, or dead or broken limbs or tops so they can be salvaged.

5.5.2.1.11.3 Den Trees

D. Clark

Potential den tree

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 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). 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.

5.5.2.1.11.4 Den Tree Management Objectives

MDC/DWM will provide a continuing supply of good to excellent quality den trees, distributed over time and space in order to maintain self-sustaining populations of 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 2 or more trees >29" dbh per 100 acres.
- Leave at least 1 tree 15-29" dbh per acre.
- Leave at least 1 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.

5.5.2.1.12 Downed Woody Material

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. 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.

Logs are generally considered to be the most valuable downed woody material because of their slow decay and longer persistence. Long logs >16" dbh 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.

T. Kyker-Snowman

Surveying coarse woody debris

5.5.2.1.13 Downed Woody Material Management Objectives:

MDC/DWM 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:

- If snags must be felled during management operations, leave them in place where they fall.
- Avoid disturbing existing downed woody material during harvesting, particularily large (>16" dbh) hollow logs and stumps.
- When possible, leave at least 4 logs of decay class 1 and 2 per acre (Fig. 11); at least 2 of these logs should be >12" dbh and >6 feet long. Hollow butt sections of felled trees can be used.
- Retain as many logs as possible of classes 3, 4, and 5 (Fig. 11).
- 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.

5.5.2.1.14 Woodland Raptor Nests

Hawks, eagles, owls, falcons, and vultures are all also known as raptors. There are 19 species of raptors that breed in New England. Seventeen of the 19 species are known or potential breeders at Wachusett (Table 34).

T. Kyker-Snowman

Bald eagle nest (Quabbin)

TABLE 34. ACTUAL AND POTENTIAL BREEDING RAPTORS ON WACHUSETT WATERSHED*

Species	Breeding Status	Nest Site Selection
Turkey Vulture	Potential Breeder[1]	Rocky outcrops, ledges, cavities
Osprey	Potential Breeder	Stick nests in trees, snags, poles
Bald Eagle[2]	Potential 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 within the Wachusett watershed, 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.

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 ranges (60->900 acres) in order to meet their food and nesting requirements. Raptor nests are widely dispersed across the landscape in a variety of habitats and forest conditions.

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 a 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 identifying good potential 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 will be 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 (squirrel nests are saucer-shaped) and lack of leaves (squirrel nests are made mostly of leaves).
- If unsure, consult with an experienced birder or wildlife biologist.

5.5.2.1.15 Woodland Raptor Nest Management Objectives

MDC/DWM will maintain suitable nesting sites for woodland raptors across the landscape over time, and will avoid disturbing nesting pairs of raptors.

Recommended Practices:

- Contact Division's wildlife biologist when planning forest management activities in the vicinity of a bald eagle nest (none currently present on MDC Wachusett properties).

- 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 stick nests in closed-canopy forests.

- If an active raptor nest is located before or during a scheduled harvest operation, maintain an uncut buffer of at least 66 feet around nest tree, and do not harvest within 330 feet of the nest during April-June.

- If an active raptor nest can be positively identified as belonging to a common or tolerant species (i.e. red-tailed or broad-winged hawk), then harvesting schedules and buffer zones may be relaxed.

- Retain several supercanopy pines near the reservoir shoreline as potential future nest trees for bald eagles.

- Follow appropriate snag tree management guidelines.

5.5.2.2 Considerations During Timber Marking, Harvesting, and Other Land Management Activities.

While careful planning and preparation can mitigate many of the potentially negative impacts on wildlife resources, some specific impacts or events cannot be discovered until operations begin in the field. Locations of active raptor nests, quality den and snag trees, and seeps may not be discovered until 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 should be addressed in the field.

5.5.2.2.1 Timing of Operations

The timing of land management activities can have a dramatic impact on 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. In addition, 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. Luckily, most wildlife species tend to nest or den during the spring and early summer when land management activities are restricted. When conflicts do arise, the following procedure will be followed:

- Division personnel will notify the wildlife biologist when land management activities have clearly disrupted a rare or uncommon species' breeding efforts.
- The Division wildlife biologist will assess the nature of the nesting/denning activities and determine what species is involved, what stage of breeding is occurring (courtship, incubation, brooding) and how they responded to the initial disturbance.
- The Division will determine what options will be used to mitigate and avoid further disturbance during the remainder of the breeding season.

Land management activities conducted at other times of the year may unknowingly impact wildlife species, and efforts should be made to reduce these conflicts. Maintenance (mowing, burning, etc.) of fields and open areas should be done after August 1 to avoid destroying nesting birds and mammals (Vernegaard et al. 1998, Jones and Vickery 1998). No activity should occur in or near seeps during winter. If possible, winter activity should be avoided in and around identified wildlife wintering areas.

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.

Land management activities conducted at any time of the year have the potential to disrupt some wildlife species. However, this disruption is usually small in scale and scattered over the watershed. The benefits derived from actively managing the land outweigh the localized disruption. Because impacts cannot be avoided everywhere, the Division will:

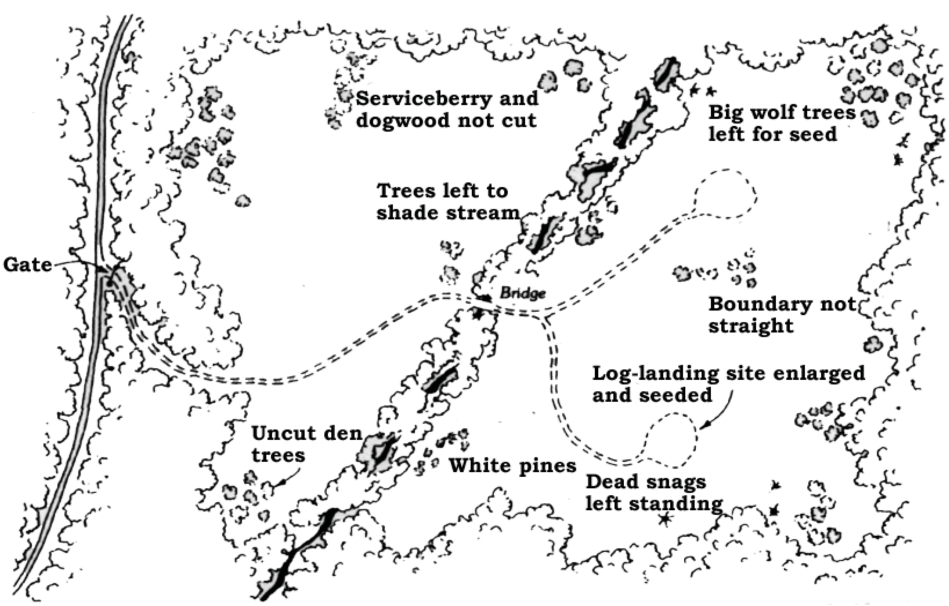
- Continue to gather data on critical and sensitive wildlife and their habitats on the watershed.
- Assess the effects of operations on a case-by-case basis to avoid impacts on special concern species.
- When feasible, shift the timing or location of an operation to avoid these impacts.

5.5.2.2.2 Harvesting Techniques

5.5.2.2.2.1 Group Selection Considerations

When forestry operations use group selection to remove trees in openings 1 acre or greater in size, certain techniques and considerations are used to enhance the area for wildlife. With proper planning, harvesting operations are conducted while still maintaining snags, den trees, and mast producing trees within the opening (Fig.12). In addition, creating an irregular, feathered border will help reduce nest predation and parasitism.

FIGURE 12. FOREST OPENINGS PLANNED WITH WILDLIFE CONSIDERATIONS



Source: Payne and Bryant 1994

5.5.2.2.2.2 Logging and Skid Roads

Access roads are used by the Division to remove wood, control fires, maintain watershed structures, and aid in navigation. Most Division roads within the watershed are narrow, grassy woods trails often referred to as logging roads. The Division's use of uneven-aged management requires harvest operations to extend over a relatively large area and use comparatively short rotation times (20-30 years). As a result, an extensive network of roads are created and maintained.

The effect of forest roads on wildlife and biodiversity depends on the size, type and location of the road. In addition, the frequency in which a road is used and its proximity to resources and other travel routes also determines 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. Roads may also fragment the forest and isolate individuals or populations.

Constructing and maintaining forest roads on Division property creates a relatively permanent change in the habitat structure of the area. Because traffic on Division roads, particularly at night, is minimal, there is little concern about direct mortality on 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) recently documented the barrier affect of forest roads on salamanders.

When logging roads, skid trails, and landings are being planned, certain design features can be incorporated to minimize wildlife impacts:

- Logging roads/skid trails should avoid vigorous patches of shrubs.
- New logging roads should be minimized, and existing roads should be upgraded instead, if possible.
- Roads should be as narrow as possible, ideally one-lane with occasional turnouts.
- Circular routes should be avoided; a cul-de-sac design is better.
- Abandoned roads, skid trails, and landing sites should be seeded with a grass-legume mixture.
- Road intersections should be angled to limit line of sight.
- Large-crowned hardwood trees should be left at the road’s edge to provide shade and leaf litter.

5.5.2.2.2.3 Record Keeping

Division foresters, rangers, and other natural resource managers spend a large amount of time walking, observing, and assessing lands within the Wachusett watershed. It is likely that they may 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. These observations must be reported to the Division wildlife biologist so that records may be routinely maintained and updated.

5.5.2.2.2.4 Miscellaneous Considerations

In general, the Division’s silvicultural practices include cutting trees with weak crown forms that are more susceptible to damage. Some of these trees have wildlife value, and Division foresters should continue to 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 examples of these trees, it is important to retain 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 within wildlife wintering areas. Small pockets of hemlock within hardwood stands can serve as significant wildlife cover. Both of these habitat conditions should receive special treatment when feasible.

5.5.3 Population or Impact Control Plans

As a water supply reservoir, the Division's primary responsibility is the long-term protection of the quantity and quality of drinking water. In recent years, the Division has identified certain wildlife species as posing a real and persistent threat to water quality. As a result, the Division has been working to address these wildlife concerns. In general, it is the Division's policy not to interfere with or actively manage native wildlife . However, when wildlife activities impact either the water quality of the reservoir or the integrity of watershed structures or resources, then the Division takes an active role in mitigating these problems. The species of concern and their associated risks are discussed below.

5.5.3.1 Beaver

5.5.3.1.1 General Comments

Beaver can dramatically alter habitats, which in turn can affect other wildlife species and humans. Beaver have been linked to water-borne pathogens and are potential carriers of both G*iardia spp.* and C*ryptosporidium spp* (MDC 1999). In addition, beaver can cause localized damage to roads, culverts, and trees, although the wetland habitat they create is seen as beneficial to a variety of wildlife species. Whether any one colony is seen as beneficial or detrimental depends on the resources affected. Division policy regarding beaver problems takes into account the variety of situations that may arise and applies solutions as needed to offer the best long-term remediation. Because beaver issues can become quite controversial, it is important to discuss and highlight the range of potential beaver impacts on a variety of resources.

5.5.3.1.1.1 Beaver Induced Alterations of Riparian Systems

Beaver are one of the few wildlife species that have the ability to dramatically alter the surrounding habitat to their benefit. These habitat alterations can have substantial impacts on the ecosystem. Changes in vegetation, biotic and abiotic features of the wetland, and effects on other organisms may result. Riparian areas, particularly second- to fourth-order streams and adjacent low-lying areas, are often colonized by beaver (Hammerson 1994). The presence or absence of beaver in an area or region can have a dramatic impact on the predominant vegetation. For example, in West Virginia, the widespread swamp forests common in the early 1900's were most likely the result of the eradication of beaver from the state by the early 1800's (Land and Weider, 1984 *in* Hammerson 1994). Most Division owned riparian areas are forested with a variety of tree species. It is interesting to note that these forested wetlands in Massachusetts may also be an artifact of the beaver's eradication from the state by the late 1700's until their eventual return in 1928. As a result, changes to the riparian landscape caused by expanding beaver populations during the last 20-30 years may appear even more dramatic because beaver were absent from the ecosystem for many decades.

The Division's primary interest is to preserve and protect water quality within the watershed, and riparian areas are certainly an important component to that protection. As a result, it is helpful to summarize the impacts of beaver on the biotic and abiotic components of riparian ecosystems in order to address potential negative impacts from their occupation of riparian areas. One of the most important factors related to changes in the environment is the structural integrity of beaver dams. Many of the components associated with beaver occupation of riparian zones are contingent on the longevity and stability of the dam itself. Dams that continually wash out may cause water quality problems associated with flooding and the sudden release of sediment and accumulated nutrients. It is usually dams on larger streams (above fourth-order) that are prone to washouts (Naiman et al. 1988). Most of the streams within the Wachusett watershed are first- to second-order streams, although the larger tributaries to the reservoir (Stillwater River, Quinapoxet River) are third-order. However, even some dams on these third-order streams can be prone to washouts, and this has occurred in the past (per. obs.).

The role of beaver in pathogen transmission is addressed separately (see *Quabbin and Wachusett Watersheds Aquatic Mammal Pathogen Control Zone Report***,** (MDC 1999), and beaver are intensively managed by the Division when colonies are located within the defined Pathogen Control Zone (see section 5.5.3.1.2). Beaver located outside the pathogen control zone are generally not assumed to be contributing to water degradation with regards to pathogen transmission or amplification.

The role of beaver in riparian systems was reviewed and is summarized below. The effects of beaver on riparian vegetation, water quality parameters, and ecology are discussed.

5.5.3.1.1.2 Vegetation

Beaver are strictly herbivores and have been described as choosy generalists (Novak, 1987). Beaver are also central place foragers because they return to their lodge or bank den after feeding (Naiman et al. 1988). This is a critical behavioral trait and as a result, beaver foraging is restricted to a relatively narrow band of forest surrounding their pond (Johnston and Naiman, 1990). One study indicated that beaver fed preferentially on a few deciduous species and the number of stems cut declined sharply as distance increased from the pond (Donker and Fryxell, 1999). Beaver will cut and consume a variety of woody vegetation in addition to feeding on aquatic vegetation during the spring and summer. Beaver have a strong preference for certain trees, for instance aspen species.

When beaver colonizes a new riparian area, several important events take place. Typically, a dam is constructed, and the raised water level kills trees within the flood zone. In addition, beaver cut down trees along the shoreline. Although a substantial number of trees may be lost due to flooding, the wetland continues to be buffered by a forested habitat. The forested zone has been pushed back to a new high water level as opposed to lining the stream bank. Along the shoreline, some canopy trees are killed or toppled by beaver, allowing more light to reach the forest floor. Increased light, along with a decrease in competition for water and nutrients, will stimulate regeneration and a release of the forest understory (Johnston and Naiman, 1990). The light penetration may be sufficient enough to allow regeneration of shade-intolerant species (Donker and Fryxell, 1999). While the individual tree selection procedure may differ, this process is similar to that being proposed by the Division (section 5.2.1.5.5) to increase regeneration and vertical diversity along riparian zones. The amount of canopy being removed along the shoreline can vary. After 6 years of continuous occupation, one study site had a 43% reduction in basal area of stems > 2 inches dbh (Johnston and Naiman, 1990). Other studies have indicated that perceived damage may be quite different from actual damage to forest resources. King et al. (1998) indicated that beaver in a wetland in the southern United States were having minimal effect on the forest. In this case it was determined that although tree damage was highly visible by casual observation, beaver were having little impact on tree survival.

In some cases where the overstory is primarily comprised of aspen (some western streams), a majority of the overstory may be removed, and the riparian area could go through a shrub stage until non-browsed tree species grow and overtop the shrub layer. On the Wachusett watershed, aspen species are a relatively minor component of forested riparian areas. Most riparian areas consist of a diversity of species, making it less likely that all trees will be removed, although the shrubby component of the riparian area may become more dominant as canopy trees are killed.

Beaver induced changes to vegetation along riparian zones can be dramatic when compared to conditions prior to beaver occupation. The primary result of these changes will be a shift in the species composition before and after beaver occupation. The shift may be undesirable if the species being lost are of high economic value (pine, oak, etc.). This is a particular problem in many southern states. In summary, the riparian wetland, although different, is still buffered by a forested habitat that may be more diverse and/or contain a larger shrubby component.

Beaver lodge inspection

5.5.3.1.1.3 Water Quality

As mentioned previously, the Division has a policy in place to address the impact of beaver on pathogen transmission within the watershed. However, because beaver can alter the hydrologic regime of a riparian area, it is important to consider their impact with regards to general water quality parameters. As mentioned previously, most streams within the Wachusett watershed are low-order (first-to-third) systems, and beaver dams constructed in these sites are most likely to remain stable for many years. In recent years, the Division is aware of only a single isolated natural failure of a beaver dam on the Wachusett Reservoir watershed, which occurred on a third-order stream during spring floods (per. obs.).

In many situations, beaver dams can transform a lotic system into a lentic habitat that may resemble a lake or pond. Some important changes associated with this transformation include increased water depth, elevation of the water table, an increase in the wetted surface area of the channel, and storage of precipitation, which is gradually released (Hammerson 1994). In addition, the storage of precipitation can reduce variability in the discharge regime of the stream (Hammerson 1994). Ponding riparian areas can also increase aerobic respiration because the amount in a pond is 16 times that in a stream riffle (Hammerson 1994). In low-order streams there is a shift to anaerobic biogeochemical cycles in soil layers beneath the aerobic pond sediments (Hammerson 1994).

Ponded areas behind beaver dams reduce current velocity within the riparian area, which decreases erosion and stabilizes streambanks (Brayton 1984, Hammerson 1994). In some western states, beaver were introduced into riparian ecosystems that had eroded streambanks and little vegetation along the shoreline (Brayton 1984). The result was a dramatic decrease in sediment transport downstream, streambank erosion was stabilized, and diversity of vegetation began to grow (Brayton 1984). In addition, by slowing down water velocity, there is increased trapping of sediments behind beaver dams, and a resultant decrease in turbidity downstream (Brayton 1984, Hammerson 1994, Maret et al. 1987, Naiman et al. 1994, Naiman et al. 1988). Several studies have shown a substantial amount of sediment being collected behind beaver dams, ranging from 1.5-6 feet (Hammerson 1994).

Some important changes in the chemical and physical properties of the stream occur when an area is dammed. Generally there is a reduction in DO, Al, and SO_4^{2-} and an increase in pH, DOC, Fe, and Mn (Smith et al. 1991, Hammerson 1994). DO reduction is the result of increased retention of organic matter and associated decomposition processes (Smith et al. 1991). By trapping large amounts of sediments and particulates, beaver ponds also trap associated nutrients, including phosphorus (Maret et al. 1987). Other studies have shown that beaver activities may actually increase concentrations of P within the impoundment (Klotz 1998). However, in these studies it is clearly shown that increased concentrations of

P only occur for short distances downstream of beaver ponds before equilibrium processes reduce the concentration (Klotz 1998). Phosphorus is an important element in water supply reservoirs because it is often the limiting factor in the growth of aquatic plants and algae in reservoir systems (Lyons 1998).

One potential problem associated with beaver is the increase in dissolved organic carbon (DOC) within the beaver pond. Though DOC does not directly affect drinking water quality parameters, it is a concern because of disinfection by-products. DOC in beaver ponds increases for several reasons. First, a large amount of wood is transferred into the stream channel, either directly through cutting or indirectly through flooding. In addition, more leaves are collected within a pond than in a stream channel. The carbon turnover rate for this material is less in a ponded area than in a stream with flowing water (Hammerson 1994). Although increases in DOC are a potential concern, a recent study conducted at Quabbin suggested that biological processes and the sheer size of the reservoir prevented these elevated DOC levels from reaching the intake (Garvey 2000). In fact, this study suggests that algae are a much greater concern regarding disinfection by-products at reservoir intakes.

The overall effect of ponding riparian areas is the translocation of chemical elements from the inundated upland to the pond sediments or downstream. A portion of the chemical elements are transported downstream, while most are accumulated in the pond sediments and are available for vegetative growth if the pond drains and succession begins (Naiman et al. 1994).

5.5.3.1.1.4 Ecological Results

As the beaver transforms the stream channel into a ponded area, there are ecological results. The most immediate effect could be the potential loss of habitat for species either requiring large expanses of deciduous trees along a stream or those species living within the stream channel. Because a beaver dam influences only parts of a riparian area, it is unlikely that beaver activity would result in the disappearance of species relying on wooded streams. In New York, experts agree that even after 30 years of expanding beaver populations, species or communities requiring wooded wetlands were probably not adversely affected on a regional or statewide level (Hammerson 1994).

There is often a good deal of concern regarding cold water fisheries and the impacts of beaver impoundments. It is likely that beaver both enhance and degrade suitable fish habitat. Hägglund and Sjöberg (1999) indicated that beaver enhance fish species diversity in Swedish streams. In addition, they speculate that beaver ponds serve as habitat for larger trout in small streams during drought periods. Snodgrass and Meffe (1998) indicated that in low-order streams, beaver had a positive effect on fish species richness. The maintenance of this effect however required the preservation of the dynamics of beaver pond creation and abandonment. The warming of stream water is often cited as a cause of concern regarding cold water fish habitat. McRae and Edwards (1999) indicated that large beaver impoundments would often warm downstream temperatures slightly, but they also served to dampen temperature fluctuations immediately downstream. In addition, when beaver dams were experimentally removed, there was no reduction in the difference between upstream and downstream temperatures. In some cases, dam removal increased the warming rate of the stream (McRae and Edwards 1999). It has been suggested that air temperature (not impoundments) is the single most important determinant of stream temperature in the absence of direct thermal inputs (McRae and Edwards 1999).

The greatest potential negative impact on fish species within the Wachusett watershed may be the inability of spawning salmon to migrate upstream past beaver dams. There has been a noticeable decline in reproduction for landlocked salmon migrating from Wachusett Reservoir (see Section 5.5.5.1), which is partly due to beaver dams impeding migrating fish. Although reproduction has been reduced, recent data indicate that reproduction is high enough to sustain populations (J. Bergin, pers. comm.). In addition, beaver ponds can alter the suitability of the bottom substrate for both salmon eggs and fry.

The impacts on other organisms are less understood. Amphibian and reptile communities have been studied recently. Russell et al. (1999) reported that species richness and abundance of amphibians were not significantly different among old beaver ponds, new beaver ponds, and unimpounded streams. Reptiles did show a difference among sites. Richness and total abundance of reptiles was significantly higher at old beaver ponds (Russell et al. 1999).

Invertebrate communities exhibit a strong ecological shift as running water taxa are replaced by pond taxa when streams are impounded. This results in an increase in the number of collectors and predators and a decrease in the number of shredders and scrapers (Naiman et al. 1988). While total density and biomass may be 2-5 times greater in ponds than in stream riffles, the total number of species in ponds and streams appear to be similar (Naiman et al. 1988).

5.5.3.1.1.5 Summary

Beaver populations within the Wachusett watershed continue to expand, as beaver mortality rates remain low. 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, 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 Wachusett watershed 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, beaver control will be addressed as described in section 5.5.3.1.2.

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 and 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.

There are some localized negative aspects of beaver occupation primarily centered on the migration of salmon from Wachusett Reservoir to upstream spawning sites. This is more fully addressed in the next section. 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.

5.5.3.1.2 Beaver Management Policy

Beaver management issues within the Wachusett watershed can be broken down into two categories: Water Quality Protection and Damage to Structures or Resources.

5.5.3.1.2.1 Beaver and Water Quality Protection

There is consensus in the scientific community that beaver can play an important role in the transmission of harmful pathogens to humans through water supplies. The Division recently 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 protection zone around each reservoir where beaver will be eliminated and excluded on a continual basis for water quality protection. The report does not address beaver management for water quality protection outside this protection zone. Situations outside the protection zone and in which water quality is being threatened will be handled on a case-by-case basis.

5.5.3.1.2.2 Damage to Structures or Resources

Outside the water quality protection zone, it is the Division's general policy to allow unrestricted beaver occupation. However, the following situations are examples where beaver activity may be discouraged, mitigated, or modified:

- Beaver dams on unstable or flashy streams with a history of, or potential for, regular washouts.
- 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.

When there is a conflict with a beaver colony, the following procedure will be used to mitigate the damage. Division personnel encountering problem beaver sites will fill out the Beaver Dam Observation Form and return it to the Division wildlife biologist and Wachusett section superintendent. Upon review, the wildlife biologist and superintendent will decide the most appropriate control activity for each site. Guidelines for determining proper mitigation are discussed below in Section 5.5.3.1.2.3. Appropriate permits will be obtained when they are necessary (e.g., removing a section of dam to install a flow control pipe). When lethal measures are determined to be the best alternative to alleviate the problem, specific guidelines will be followed.

5.5.3.1.2.3 Guidelines for Determining Proper Mitigation for Problem Beaver

MDC/DWM personnel who encounter problem beaver sites will fill out the Beaver Damage Observation Form and return it to the MDC wildlife biologist and Wachusett Superintendent. Upon review, the wildlife biologist and superintendent will decide on 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 will be chosen based on site conditions, history of the site, and type of damage occurring. The goal is to try to provide the most effective control possible that mitigates the problem. Lethal removal will be a viable option, but will only be used if all of the following criteria for the site are met (except beaver problems associated with water quality issues as addressed in the report; *Quabbin and Wachusett Reservoirs Watersheds Aquatic Wildlife Pathogen Control Zones,* (MDC 1999):

- Beaver are causing documentable (observation, photographs, etc.) damage to MDC 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.
- The MDC 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.

When lethal measures are to be used, the following procedure must be followed:

- The above criteria must be documented (using Beaver Damage Observation Form) prior to any action.
- Beaver will be removed through shooting (12 gauge shotgun), or live-trapping using Hancock, Bailey or cage traps followed by shooting. Conibear traps can only be used after non-lethal measures have been tried and have failed and live trapping has been conducted for 15 days.
- Two staff will be present at all time and will include one supervisor. The supervisor will be a Water System Storage Foreman II or higher. All staff participating will have a Firearms ID card. Any persons using live-traps must be properly trained beforehand by a designated trainer.
- Every attempt will be made to retrieve beaver carcasses, and upon retrieval they will be buried at a suitable location.
- Personnel taking part in beaver control activities will take adequate precautions (washing hands/wearing rubber gloves) to prevent transmission of *Giardia* and *Cryptosporidium* and other pathogens.
- The supervisor in charge will document all actions and complete the proper form (Beaver Removal Documentation Form) copies of which will be sent to the Wildlife Biologist and Superintendent.

5.5.3.2 Muskrat

In the past, most of the attention regarding water quality and wildlife has focussed on beaver and their role in pathogen transmission. Recently, the Division identified muskrat as another key species in their pathogen prevention program. The muskrat impact control program in this plan is focussed on water quality protection within the reservoir. A detailed description of the program can be found in the MDC document**,** *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.

5.5.3.3 Gulls, Geese, and Other Waterfowl

5.5.3.3.1 Gulls

Wachusett Reservoir provides a daytime loafing area and nighttime roosting site for a variable number of gulls. Three species (ring-billed, herring, great black-backed) of gulls are the most common. Gulls 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 landfills and fast-food eateries. By late afternoon, most gulls are returning to the reservoir to spend the night. As a result, harassment efforts are focussed during the late afternoon to early evening.

The Division has been monitoring bird populations at Wachusett Reservoir since 1991. Early studies provided evidence that a high number of gulls in the northern portion of the reservoir correlated with high fecal coliform counts at the Cosgrove Intake. In response to these studies, the Division initiated a bird harassment program in 1993. Since 1993, the Division has conducted a yearly harassment program to scare birds out of the Bird Harassment "Gull-Free" Zone (Fig. 13). The harassment program is a year-round effort, although active harassment activities usually occur from September until the reservoir freezes. Daily harassment activities are supervised and/or carried out primarily by MDC Environmental Quality personnel. In addition, MDC maintenance personnel conduct harassment from boats when necessary. MDC Natural Resource staff are responsible for program monitoring, passive harassment techniques, and program development. Active harassment is done using pyrotechnics, a human presence, and boats. Birds are either scared from shore using "Shell-crackers," or a boat is used to scare and herd the birds to the southern end of the reservoir.

FIGURE 13. BIRD HARASSMENT "GULL-FREE" ZONE

Control efforts during the active harassment period of the program are conducted 7 days/week until the reservoir freezes. During icy conditions when boat use is impossible, the Division uses a hovercraft to harass the birds. In addition to the active harassment efforts carried out, the Division employs several passive techniques designed to be used 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, the Division has worked with other EOEA 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.

A unique feature of Wachusett Reservoir has been the occurrence of a nesting colony of herring gulls on an island in the northern portion of the reservoir. Historical records indicate that gulls were nesting on the island in the 1960's and even makes reference to attempts by the Division to collect gulls eggs in order to discourage nesting. Nesting most likely continued until the 1990's when more active measures were taken to remove and discourage nesting by these birds. In 1997, a small colony of ring-billed gulls attempted to nest on the same island. Again, these birds were actively controlled to prevent successful nesting. Since 1997, gulls at the Reservoir have made no nesting attempts. However, it is the Division's policy for zero tolerance of nesting gulls on the Reservoir. Left uncontrolled, nesting gulls colonies have the potential to expand greatly, which would be counterproductive to harassment goals.

Since 1993, the bird harassment program has been very successful in reducing the number of birds located in the northern portion of the reservoir. As a result, fecal coliform counts for that time period have been extremely low as well. There has only been 1 exceedance since the program began in 1993. The Division will continue the harassment program indefinitely and continue to make modifications and adjustments to ensure its long-term success.

5.5.3.3.2 Geese

Canada geese are present at Wachusett Reservoir year round. There are approximately 100 resident geese that only leave the area when the reservoir freezes. In addition, during the fall and winter, several hundred more geese utilize the reservoir during migration. From a water quality perspective, geese are a lower priority species than gulls because of their feeding behavior and population levels. However, the Division 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.

In addition to actively harassing geese at the Reservoir, there has been a strong effort to reduce the local goose population through an intense population reduction program. Since 1995, an attempt to identify all Canada goose nests on the Reservoir has been made. 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.

T. Kyker-Snowman

Canada goose on nest

5.5.3.3.3 Other Waterfowl

Other than Canada geese, Wachusett Reservoir also harbors a variety of waterfowl. During the spring and summer, there is a relatively small number of resident mallard ducks. During the fall and winter, this number can increase substantially, and on some occasions there may be several hundred ducks at the Reservoir. In addition, during peak migration times, other duck species (e.g., ring-necked, mergansers, ruddy) utilize the reservoir as a layover. 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.

A final species of concern is the double-crested cormorant. A seasonal resident at the reservoir, cormorants typically begin to show up in mid-late summer after the breeding season has ended. They are present during the fall and winter and typically leave the reservoir in the spring. Although relatively scarce (100-200 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.

5.5.3.4 Burrowing Animals

The burrowing activity of certain wildlife species such as woodchucks, moles, and voles can cause damage to the integrity of earthen dams, dikes, and other watershed structures. To date, Wachusett Reservoir has not had a situation where this type of damage was occurring. However, if an engineering survey concluded that such activity was damaging watershed structures, then appropriate mitigation steps would be taken. Most likely, lethal control methods would be used to remove the animals and then habitat modification would occur to discourage reoccupation.

5.5.3.5 White-Tailed Deer

White-tailed deer populations are increasing in most of the northeast. There is growing concern about these increasing populations and their impact on natural resources (Healy 1999, Alverson and Walker 1999, McShea and Rappole 1999). Deer populations within Massachusetts are increasing in the central and eastern part of the state (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.

Deer populations within the Wachusett watershed have been estimated at 15-20 per mi^2 (MassWildlife, pers. comm.). There is further evidence to suggest that populations within the watershed are expanding. Although expanding deer populations may pose a concern within portions of the Wachusett watershed, it is doubtful that the same large-scale problem witnessed on the Quabbin Reservation would occur here. Landuse patterns and land history at Wachusett differ dramatically from both the Quabbin Reservation and Ware River watersheds. Quabbin Reservation did not allow deer hunting for many decades, and its large blocks of contiguous forest nurtured very high deer densities (40-60 mi^2). These high deer densities severely impacted forest regeneration and necessitated the initiation of a deer reduction program that has been conducted on the Reservation since 1991 (See *Quabbin Reservation White-tailed Deer Impact Management Plan*, MDC 1991). In contrast, the Ware River watershed has allowed unrestricted hunter access to its properties since its establishment. To date, there have been no overbrowsing or regeneration problems, even on the larger blocks of land.

The Wachusett 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 the Division and were traditionally hunted. Division land at Wachusett is separated into hunting and no-hunting zones (Fig. 14). The no-hunting zone is concentrated on lands immediately surrounding the reservoir. Public hunting is allowed on a majority of the Division's lands away from the Reservoir. Given the high degree of fragmentation within the watershed, the Division recognizes the potential for some of its lands within the no-hunting zone to serve as refuges for an increasing deer population. It is important to note that although no public hunting is allowed within this zone, there is anecdotal evidence to suggest that poachers access these areas. In addition, domestic dogs have been observed chasing deer with this zone.

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. The Division does not scientifically monitor forest regeneration within the Wachusett watershed. However, Wachusett foresters routinely walk and inspect a variety of forest stands and sites within the watershed and make anecdotal observations about regeneration. To date, there have been no concerns regarding the amount or diversity of tree regeneration (G. Buzzell, pers. comm.). It is interesting to note that although forest regeneration does not appear to be impacted, there are indications of localized severe browsing. The arborvitae hedge surrounding the reservoir has a well-defined browse line that has been visible for many years. In addition, several ornamental plants in surrounding residential areas have been severely browsed (pers. obs.).

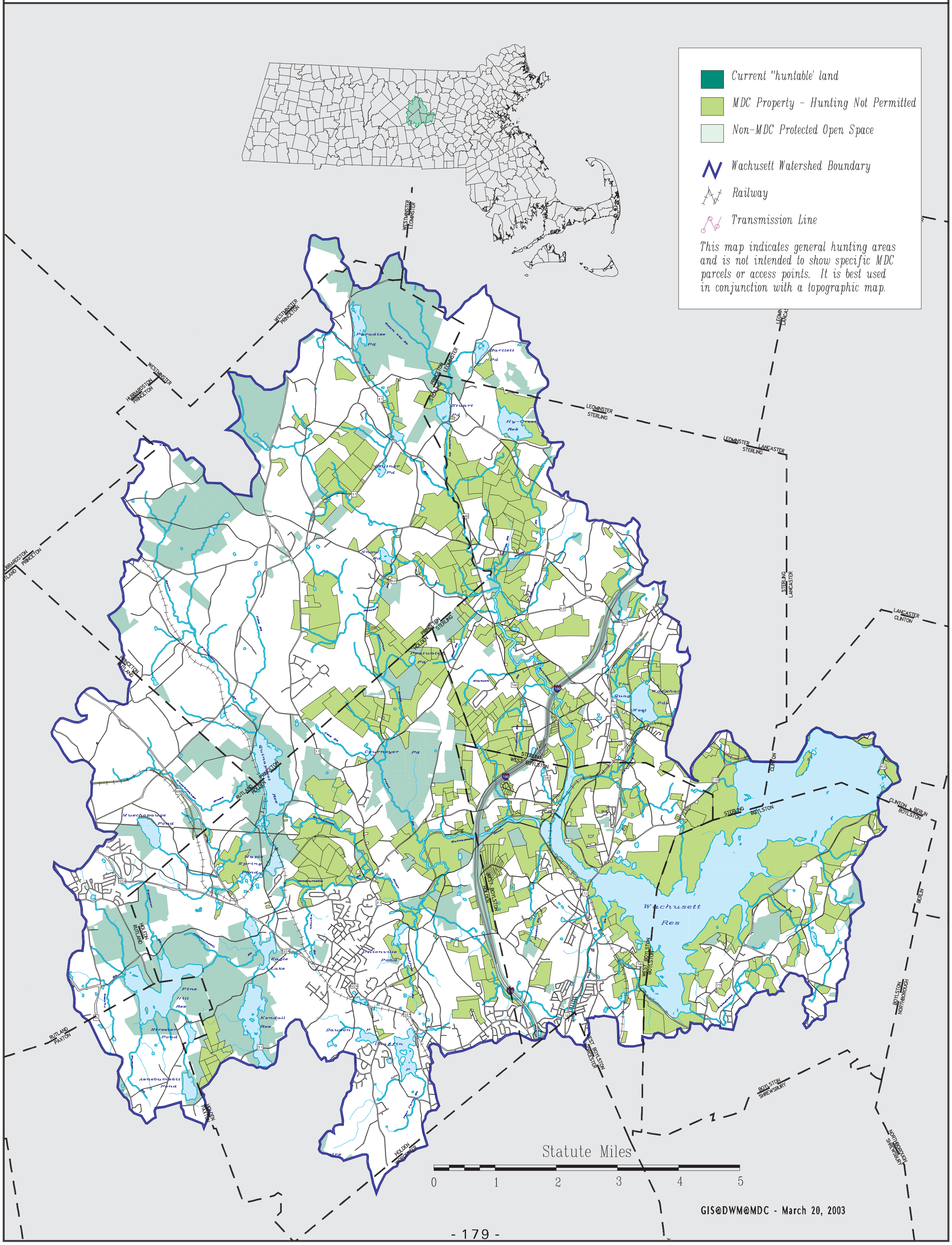
Given the trend of rising deer populations, shrinking hunting opportunities, and a declining hunter base, the Division recognizes the potential for some of its no-hunting lands to experience overabundant deer populations. Although primarily focussed on the impacts of overabundant deer on tree regeneration, the Division also recognizes that other social issues related to overabundant deer may become more prevalent. These include increased deer/vehicle collisions and personal property damage. As a result, the Division will examine the feasibility of initiating long-term monitoring of both deer herd dynamics in the no-hunting zone and tree regeneration across the watershed. Regeneration plots would be established and monitored in both hunted and non-hunted areas to scientifically assess the impact of white-tailed deer browsing on tree regeneration and growth. In addition, surveys may be initiated to monitor deer population trends over time. The Division would collaborate with MassWildlife to design a combination of spotlight surveys and/or line transects to index the deer population within the no-hunting zone. Further the MDC will consider expanding its hunting zone to include more lands east of Interstate I-190. Finally, if deemed necessary, the MDC will consider initiating a controlled hunt inside the gated properties that surround the reservoir in order to reduce deer densities.

FIGURE 14

Areas on MDC Land Where Hunting is Permitted, Fall 2000

Wachusett Reservoir Watershed

Massachusetts Executive Office of Environmental Affairs - 2003



5.5.4 Active Management to Enhance Habitat for Selected Wildlife Species

5.5.4.1 Early Successional and Contiguous, Mature Forest Habitats

Land management activities at Wachusett primarily focus on enhancing the multi-aged, multi-species forest. As a result of this decision, some wildlife species will benefit greatly while other species will be restricted. Although the DWM forest management will focus on uneven aged, small group selection silviculture, it is still possible to manage for a mosaic of habitat types where conditions allow. There is widespread concern about wildlife species that utilize or depend upon early successional habitat (including some species in Table 29) because the amount and quality of available habitat continues to shrink. Similarly, there is concern for species dependent on closed canopy mature forest. As more land becomes developed and fragmented, there remain fewer tracts of unbroken forest, reducing available habitat for species requiring closed canopy mature forest.

Management techniques needed to create and sustain these types of habitat differ substantially from the predominant management techniques employed by MDC/DWM. In general, large-scale even-aged forest management techniques are needed to create large areas of early successional habitat, and subsequent stands of contiguous, mature, closed-canopy forest. Large-scale even-aged forest management is impractical and undesirable within the Wachusett watershed given the relatively small size or narrow configuration of both public and private forests scattered around the landscape. In addition, an abundance of wetlands and streams criss-cross the landscape, restricting large-scale removal of complete overstories. In order to be beneficial for the most wildlife species, even-aged blocks need to be a minimum of 10 acres in size. While scarce, there are areas on the watershed where the Division may be able to utilize this management activity to provide early successional forest habitat. It is also feasible that already existing fields, brushy meadows, and young forest areas can be maintained and enhanced to provide early successional habitat. The MDC recognizes the importance of field habitat within the watershed, and as described in Section 5.4.6, will take active measures to maintain and enhance existing fields.

5.5.4.2 Common Loon Management and Research

Common Loons (*Gavia immer*) are a listed species of Special Concern in Massachusetts. These birds typically nest on large lakes and reservoirs with an abundance of fish and suitable nesting locations (typically small islands or peninsulas). Of the 22 territorial pairs in Massachusetts, 18 occur on MDC water bodies, and 5 pairs are within the Wachusett watershed. Because the MDC is responsible for a majority of the nesting loons in the state, significant time and effort is expended protecting and enhancing these birds. Artificial loon rafts are constructed and deployed, individuals are monitored during the nesting season, and certain management activities that could disturb nesting loons are suspended during the nesting season. To further enhance the MDC's ability to effectively manage this species, an intensive research project has been initiated (pending adequate funding) to provide more detailed information about loons nesting on MDC water bodies.

The proposed research project will provide an in depth study of all loon pairs on MDC property.

Specifically, the goals of the project are as follows:

- Identify potential stressors that may impact loon presence and reproductive success. Rank stressors and habitat features to create a quantitatively comparative index of loon territory quality.

- Weekly, monitor territorial pairs of Common Loons to ascertain reproductive status and success. Include other lakes with potential habitat when relative.
- Continue the capture and color marking of loons for remote monitoring of individual reproductive performance and movements.
- Collect blood and feather samples from captured loons for contaminant analysis and evaluation of the effects of contamination and other stressors through biomarkers.
- Establish a volunteer network of lake residents and other interested parties for long-term monitoring efforts that will be coordinated by the Loon Preservation Committee.
- Construct a management plan that addresses territory-specific requirements.
- Integrate collected information into a regional model to spatially construct risk assessments for multiple stressors.

When the project is complete, the MDC should have acquired intimate knowledge of each pair of territorial loons and been provided with specific recommendations to take to ensure continued reproductive success and survival.

5.5.5 Fisheries Management

5.5.5.1 General status of fishery

Wachusett Reservoir is a large, deep, cold water body that provides abundant trout and salmon habitat. These fish provide a popular resource for fisherman, as well as an abundant food source for piscivorous birds such as Common loons, mergansers, and herons. A 1998 MDC survey showed approximately 27,000 anglers spend over 83,000 hours fishing for lake trout, landlocked salmon, smallmouth and largemouth bass, stocked trout, yellow perch, and other panfish between April 1 and November 30. This ranks Wachusett Reservoir in the top ten most popular fishing areas in the state.

E. Mitchell

Salmon on a fly!

Twenty-seven species of fish occur within the Wachusett watershed (Table 35); none of these fish are listed by the state as rare, endangered, or of special concern. Five species spend their entire lives in the reservoir tributaries. Five other species (American eel, brook trout, brown trout, rainbow trout, and landlocked salmon) must leave the reservoir to spawn. The remaining 19 species are able to complete their entire life cycles in the reservoir.

TABLE 35. SPECIES OF FISH FOUND WITHIN THE WACHUSETT WATERSHED.

Species	Reservoir	Direct Tribs	Indirect Tribs	Status[1]
Brook Trout	√	√	√	N,A
Brown Trout	√	√	√	I,P
Rainbow Trout	√	√		I,C
Lake Trout	√			I,A
Landlocked Salmon	√	√		I,C
Atlantic Salmon	√			I,R

Species	Reservoir	Direct Tribs	Indirect Tribs	Status[1]
Rainbow Smelt	√	√		I,A
Largemouth Bass	√	√	√	I,A
Smallmouth Bass	√			I,A
Rock Bass	√			I,A
Chain Pickerel	√	√	√	N,A
Yellow Perch	√	√	√	N,A
White Perch	√	√		I,C
Brown Bullhead	√	√		N,A
Yellow Bullhead	√			I,C
Golden Shiner	√	√		N,C
Bridle Shiner	√			N,C
Spottail Shiner	√			N,C
Fallfish	√	√		N,C
White Sucker	√	√	√	N,C
Banded Killifish	√			
Redbreast Sunfish	√			N,R
Pumpkinseed	√	√	√	N,C
Bluegill Sunfish	√			I,C
Black Crappie	√	√		I,C
Tesselated Darter	√	√		N,A
Walleye	√			I,E

[1] N=native; I=introduced; A=abundant; C=common; P=present, but not common; R=rare, limited presence; E=extirpated

5.5.5.2 Management objectives

The regular watershed protection that safeguards the water quality in the reservoir also adequately protects the 19 species of fish that reside and remain in the reservoir. Continued reservoir operations should provide long-term protection to these species. There is concern that the 5 fish species that spawn in reservoir tributaries may be subjected to management or natural events that negatively impact these species. Specifically, the installation of silt curtains at the mouths of certain tributaries, an increasing beaver population, and the erosion of stream banks are all potentially negatively impacting the 5 tributary spawning fish species.

5.5.5.2.1 Silt curtains

In 1998, the DWM installed two experimental silt screens in Gates Brook cove to detain and precipitate sediment from Gates Brook before it could enter the reservoir. The screens have been extremely successful in trapping sediment and particles. In approximately 1½ years since their installation, the curtains have trapped ~6 feet of sediment. In several locations, the trapped sediment has reached the top of the screens and water is flowing over the curtain. Both screens were designed with fish passage openings in the middle of the curtain. However, a limitation in the design impedes fish migration. The flow from Gates Brook caused the curtain to billow, moving the fish openings from a vertical to a horizontal position, thereby making it impossible for fish to detect and/or pass through the openings. In addition, the diffused discharge made it difficult for salmonids to find the openings in the curtain. Removal of the trapped sediment was done in the fall of 1999. In addition, a portion of the curtain was opened during the early fall of 1999 to allow salmon migration upstream. The DWM will reassess the design of the curtains and their impacts on migrating salmonids, with the hope of designing more effective openings.

5.5.5.2.2 Beaver effects on fish

Massachusetts's beaver population has grown steadily since their reintroduction in the mid 1950's. In 1996, a statewide trapping ban contributed to an increasing beaver population. Statewide estimates for beaver populations are approximately 60,000 animals, up from 18,000 animals in 1996. Beaver populations along the Stillwater River (a major spawning site for salmonids) are showing similar trends. A MassWildlife survey in 1995 located 4 beaver dams along the Stillwater River. The same survey done in 1999 located 25 beaver dams. Beaver impound streams to create stable water levels, which provides security and a storage site for winter food. Large beaver dams also block upstream passage for spawning adult salmonids. The few adults that manage to traverse the dams encounter unfavorable spawning sites. Water temperatures within the impoundment generally increase above ambient stream temperatures. Temperature sensitive species such as brook and brown trout may be killed when water temperatures in the impoundment are too high. Although of particular concern on the Stillwater River, there is significant potential for beaver dams on other tributaries in the watershed. The direst outcome could result in the extirpation of most salmonid populations from the watershed.

The DWM's policy on beaver is explained in section 5.5.3.1.2. It is unlikely that the DWM would be able to correct the problem in the foreseeable future. Further, it is doubtful that efforts to control beaver on the Stillwater River would have a lasting impact on either local beaver populations or migrating salmonids. The Stillwater River offers excellent beaver habitat, and under current DWM mandates and priorities, population control in this area is not possible. Unless regulated commercial trapping is reintroduced on a statewide level, beaver populations are likely to continue to grow on MDC/DWM properties.

5.5.5.2.3 Sediment

Sediment transport is a normal, natural process for a stream. Unfortunately, human activities can accelerate or increase sediment loads. While most MDC/DWM roads are not sanded during the winter, some roads are maintained. Sanding roads during winter can cause large sediment loads during spring. In addition, construction and human activity around streams can add sediment to streams. The increased sediment load results in fine sand settling over gravel stream bottoms in sections where stream flow is slow to moderate. Settling occurs because the stream cannot transport the additional load of sediment. When this fine material is deposited on graveled streambeds it suffocates salmonid eggs that were laid in or on the streambed.

The DWM is concerned about increased sediment loads entering the reservoir, although historical accumulations have been extremely low. Detention basins have been constructed at some locations to detain and trap sediments. Some potential solutions to this problem would include constructing catch basins with sediment traps on all direct road drains. In addition, old sediment basins could be rebuilt to include sediment traps. If installed, catch basins would be cleaned twice a year in the spring and fall.

5.6 Protection of Cultural Resources

The Wachusett watershed is rich both in its historic and pre-historic resources. Accordingly, safeguards have been build into the Division's land management program to protect cultural sites and artifacts, both through the identification and mitigation of possible impacts, and through a program of proactive vegetative management around significant historical sites.

5.6.1 Review of Proposed Silvicultural Projects

Without appropriate controls, forest management programs can be detrimental to archaeological resources. 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 prehistoric sites. Skidding logs can further disturb the soil. 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 type 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 piece of the archaeological record.

Accordingly, the foundation of MDC's Cultural Resource Management Program is a process for reviewing proposed silvicultural operations. The review involves evaluating and assessing the impacts that harvesting could have on archaeological resources should they exist at any given operation. This process has been developed over the past several years, and is formalized in this section.

5.6.1.1 Project Description Forms

After marking the boundaries of a planned silviculture operation, Division foresters submit a *Project Description Form* to the MDC Chief Archaeologist for in-house review. The form provides a detailed narrative of the proposed operation including: location and size, description of topography, forest cover and soils, goals of silvicultural operations, equipment limitations, notable historic features, plant and wildlife communities, and hydrology.

The primary analytical tool employed in the review of impacts to prehistoric archaeological sites is the evaluation of *site location criteria*, which are discussed below.

5.6.1.2 Site Location Criteria

5.6.1.2.1 Prehistoric Sites

At no time in prehistory did human populations roam haphazardly and endlessly across the landscape. Even Paleo Indians, who were the first human occupants of New England approximately 12,000 years ago, are believed to have maintained an economic subsystem that involved a seasonal pattern of restricted wandering within loosely defined territories (Snow 1980:152). Over the next 10,000 years, sea levels rose and the forests and vegetative communities became more constant. During this time, Native Americans adapted their tool kit and strategies in order to take advantage of the new resource mixes and opportunities the new environmental conditions afforded. Thus, the pattern of habitat use, and consequently the locations of prehistoric sites and artifacts are largely predictable.

The key criteria for determining the archaeological sensitivity of a given site include:

- The degree of slope (i.e., slope < 5 - 7 degrees).
- The presence of well-drained soils.
- Proximity to fresh water (i.e., within 1,000 feet) at the time of occupation.

Other variables such as aspect, availability of stone suitable for tool-making, and elevation above sea level, may also be important. When one or more of these criteria are met, the site of the proposed silviculture operation is considered to have been an attractive location for Native American habitation or subsistence activities, and are thus classified as *highly sensitive* or *moderately sensitive* for prehistoric resources.

5.6.1.2.2 Historic sites

In the past, Division foresters have used original land taking plans, as well as direct observation, to identify the location of historic building foundations. In 1994, the Division contracted with Boston University to inventory historic sites on the Prescott Peninsula at Quabbin Reservoir. This inventory identified a number of sites that were not on taking plans but were on 19th century town atlases. This project also improved the availability of information on the sites identified, by producing a data sheet and a map for each site. MDC hopes to continue this project over the next several years in order to complete the inventory of historic sites on its properties. The MDC Chief Archaeologist will use this information when reviewing proposed silvicultural operations.

5.6.1.3 Harvesting Restrictions and Limitations

For those silvicultural operations planned for sites that have been classified as *highly* or *moderately sensitive for prehistoric resources*, restrictions are recommended on the time of year and the types of equipment and techniques used. 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.

The following are types of restrictions that may be recommended for *highly sensitive* areas.

- The harvest should occur when soil conditions are frozen or dry enough to prevent soil compaction.
- Soil disturbances due to inappropriate or oversized equipment should be avoided.
- Feller-buncher-processors, with long reach and weight distributing tracks, should be encouraged.

For those proposed operations in areas classified as *moderately sensitive*, one or more of the above restrictions may be recommended. Details of appropriate restrictions will be fine-tuned through close interactions between the Division foresters and the MDC Chief 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. Here 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.

5.6.2 Vegetation Management at Historic Sites

Recognizing the realities of existing, and likely future fiscal constraints, the Division has developed a strategy for preserving its historic resource base. The strategy is extremely modest in man-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 archaeological remains will be of little value and interest at the time that the Commonwealth is once again prepared to undertake protective management.

Accordingly, a limited and selective management program to control vegetation growth in and around archaeological sites and historic buildings and structures is recommended. This same limited program has been employed on historic sites in the MDC Reservations & Historic Sites Division.

As a general site stabilization and preservation technique, vegetation management will entail:

- Removal of most small to medium sized brush, saplings, and trees from on, and within archaeological features (e.g., cellar holes and their foundation walls; channelized stream beds; mill dams; and historic buildings).

- Removal shall be by cutting as close to the ground as feasible. Vegetation should not be 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, the Fortech type feller-buncher may be appropriate. This machine has a long reach that limits the need to bring equipment too close to the structure. It picks the tree up, thus there is no concern about the direction of the fall; and the tracks tend to distribute the machine's weight, thereby limiting compaction to buried deposits.

In most cases, Division staff should perform the vegetation management around historic sites. However, there may be private loggers/contractors who are well known to Division foresters and are particularly skilled and careful, who could 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 could include clauses that direct the logger to take extra care and precautions around cellar holes/foundations, etc. Vegetation management will in most cases require periodic and cyclical treatment depending on the nature of the growth, the condition, and significance of a specific site.

5.6.3 Long Range Cultural Resource Management Initiatives

The following is a list of important initiatives that should be undertaken when funds and staffing are available:

- Inventory historic sites. Identify by age, owner, activities, and buildings. This data has been compiled for most of the Quabbin properties and will be used to help list priorities for vegetation management efforts and improve the review of silvicultural operations. Future inventories will cover the remaining MDC lands.

- Enter known prehistoric sites into the GIS mapping system.

- Map sensitivity criteria for prehistoric sites using GIS.

- 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.

- Develop educational signage and displays on Native American landuse of the region.

- Encourage local universities to conduct archaeological field schools on watershed lands to further test and refine site location criteria.

T. Kyker-Snowman

Old millsite

6 Research, Inventory, and Monitoring Needs

6.1 Introduction

The Division has supported a wide variety of watershed research, through access to its properties, directed management activities, and/or limited direct funding. Some of this research has primarily benefited the researcher, but the vast majority has also informed MDC managers and improved or supported watershed management practices. While the research budget at MDC is not constant, the value of contiguous, undeveloped watershed properties generally behind secure gates or patrolled on a regular basis has attracted many researchers who otherwise have their own funding. In addition, watershed properties have provided fertile backdrops for a wide range of graduate theses.

Listed below are a variety of research, inventory, or monitoring needs in the general areas of forests and forestry, wildlife, and cultural resources. These are listed in part to direct the Division'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 real need of the Division.

6.2 Forest Research Needs

1. ***Monitoring of Forest Management Activities:*** The MDC/DWM policy of "no measurable impact upon stream water quality from forest management activities" creates a need to establish a standard approach to measuring compliance. Streams should be monitored to correlate short-term water quality changes and active logging conducted on MDC lands within MDC/DWM standards. Monitoring should involve upstream and downstream and/or paired watershed sampling before planned operations, during active logging, and following the completion of the operations. The study should focus on storm event testing. Parameters should include pH, temperature, dissolved oxygen, turbidity, suspended solids, total particulates, total and fecal coliform, and nutrients. Based on this fieldwork, specific recommendations could be made outlining a low cost, statistically valid method of monitoring logging operations on a more wide-scale basis. Recommendations for adjustments in current MDC Conservation Management Practices would be made if necessary, based on this research.

2. ***Analysis of Optimal Riparian Vegetation:*** While the opportunity to shift species composition on the watersheds is limited by site, seed, overstory conditions, etc., it would be valuable to complete an investigative literature review to determine the water quality benefits/detriments associated with each of the common tree/shrub species. While species selection for an entire watershed should be based primarily on site suitability and species stability, in areas directly adjacent to tributaries and reservoir shorelines, a species' direct impact on water quality may have a measurable benefit. One result of this would be to generate a model of the ideal riparian forest for various sites. Models developed recently to quantify the buffering effects of riparian forest should be examined for applicability to Wachusett's forest.

3. ***Shoreline Vegetation Practices and Shoreline Hedge Effects:*** A great deal of time and effort has gone into the establishment and maintenance of the arborvitae shoreline hedge (see section 5.3.2). It would be useful to quantify the water quality benefits of this feature. Would there be water quality effects if the shoreline were allowed to revegetate to trees? Does the hedge actually provide significant water quality protection, per its original design?

4. ***Invasive Plant Species:*** A wide variety of invasive plant species is currently established on and adjacent to MDC properties on the Wachusett watershed. Control of these species is important to the establishment of tree regeneration and the maintenance of native plant diversity. To begin to address this issue, a survey of invasive plant species on the watershed and the extent of their spread should be conducted and added to the MDC GIS, in part to establish an historical reference point for future distribution of these species. Once priorities have been established for control, further research needs to be conducted on the feasibility of mechanical controls and/or the relative benefits and threats associated with chemical or biological controls. See section 5.4.6 of this plan for further discussion of this issue.

5. ***Evaluation of Wachusett Access Roads:*** Given that roads are a potential source of pollution and sedimentation on MDC lands, a systematic evaluation of the Wachusett road system would be valuable. This project would include a watershed-wide mapping of road conditions to identify trouble spots including testing for 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 results of this study would be useful in the decision making process when planning new road construction on newly acquired property as well as improving the current road network.

6. ***GIS Projects:*** The use of GIS technologies in the management of the natural resources of the Wachusett watershed is in its infancy. The potential for future use is immense. Essentially every component of the Division's management efforts could utilize the analytical and mapping capabilities of this technology. There is a need to either establish contracts to generate GIS data, or to increase the capabilities of the current MDC in-house GIS capability.

7. ***Aerial Photography:*** The aerial photography and resulting orthophotographs from 1992-1993 have proven to be invaluable. A wide variety of datalayers based on these images have been and continue to be generated. However, this information becomes more outdated with time. To ensure that the Division is making decisions based on as accurate and up to date information as possible requires the regular collection and processing of aerial digital image information. Ideally, this will occur mid-way through each ten-year management period. The data that this will provide is useful not only because it will be up to date, but because it will allow the tracking of changes through time of a wide range of variables of interest to Division personnel.

8. ***Hemlock WoollyAdelgid Monitoring and Impacts:*** The recent invasion of the hemlock woolly adelgid into the Wachusett forest has generated wide-ranging discussion regarding the future of the eastern hemlock around the reservoir. The potential impacts to water quality and the forest ecosystem and what we should be doing in the face of these impacts are difficult puzzles. A long-term study is needed to track the extent of the invasion and infestation and monitor the impacts with an emphasis on water quality. This study could also monitor the effects of the salvage of dead and dying hemlock and therefore help inform future management decisions.

6.3 Wildlife Research Needs

Only limited wildlife research or monitoring has been conducted on the Wachusett watershed in recent years. Some monitoring of high priority species has occurred, but limited resources and personnel have prevented extensive monitoring efforts. The following projects represent a few areas where technical data would assist in managing wildlife resources more effectively.

1. ***Movements and Feeding Behavior of Ring-billed and Herring Gulls in Central Massachusetts:*** Gulls continue to be the species of greatest concern with regard to water quality. Although efforts to disperse and move gulls have been very successful, long-range control must be focussed on controlling food resources. Gulls are able to travel great distances and utilize obscure food resources. For the most part, it is unclear where and how gulls at Wachusett Reservoir are finding and obtaining food. This research would enable the Division to identify and control alternative food sources as well as provide information on seasonal roosting behavior.

2. ***Population Dynamics and Dispersal in a Suburban Beaver Population with Limited Trapping:*** Beaver are considered another high priority species. Since the passing of Question 1 in 1996, there has been effectively no trapping mortality on beaver in the Wachusett watershed. Even if Question 1 were modified, there are very few trappers left in the state. Wachusett reservoir probably serves as a natural deterrent to dispersing beaver, however increasing populations may change this. By determining the population dynamics and dispersal of beaver in the watershed, a better understanding can be gained of what role marginal habitat will play in populations with little mortality.

3. ***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 the MDC/DWM wildlife biologist. However, a single biologist is responsible for all 4 watersheds within the Division, and it would be impossible to physically inspect the hundreds of acres affected by these proposed activities. The Division 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 MDC efforts to protect these resources during land management activities. Information should also be incorporated into GIS datalayers.

T. Kyker-Snowman

Wood turtle

4. ***Vernal Pool Surveys:*** To date, no formal surveys have been done to locate vernal pools on the Wachusett watershed. Vernal pool locations are recorded opportunistically by Division personnel in the field. The Division recently completed a contract that mapped *potential* vernal pools on the watershed using color infrared photos. Over 300 potential pools were identified in the watershed. These pools need to be surveyed to determine their status and perhaps locate other unmapped pools as well. This mapping will be incorporated into GIS to facilitate land management planning.

5. ***Routine Monitoring Activities:*** Routine monitoring programs for selective species will continue during this management period. These surveys include biannual surveys for beaver and muskrat within the reservoir, monitoring Common loon nesting around the watershed, Canada goose breeding surveys, and occasional breeding bird surveys. Other surveys (permanent breeding bird surveys, locating rare and endangered species) may be conducted if resources and personnel are available.

6.4 Cultural Resources Research Needs

The principal research need for the continued protection of cultural resources within MDC properties on the Wachusett Reservoir watershed 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. The Quabbin inventory was completed by graduate students and faculty of the Boston University Department of Archaeology in collaboration with the MDC staff archaeologist. The process involved integration of locational and descriptive information from a variety of cartographic and historical resources, including MDC Real Estate Plans and a series of maps dating as far back as 1794. Information from these sources was used to complete a database and map record for several hundred sites. Many of these sites were subsequently field checked for current condition. Locational information is entered in MDC's GIS so that important sites can be identified when management activities are proposed for areas within MDC's properties. This process greatly enhances the ability of managers to protect historic cultural resources.

7 Public Involvement

7.1 Public Input to Watershed Management Plans

Public input is an important component in the effective management of MDC/DWM properties. As managers of public land, MDC/DWM staff has a responsibility to solicit public input in order to address concerns, explain existing management practices, and integrate new ideas when practical in order to provide the best possible protection for the water supply. The goals of the Division's public input process for land management on all watersheds are to:

- Understand the broad range of public issues and concerns regarding forest and wildlife management at the Division's watersheds so that the Division can better integrate the concerns of the public into protection strategies for maintaining watershed integrity.

- Improve the understanding of the technical aspects of forest and wildlife management on the Division's watersheds and to generate creative program ideas.

- Educate the public regarding the purposes and goals of the Division with regard to its watershed management program.

- Work to educate the public regarding strategies for the implementation of the land management program, in order to address concerns and retain public confidence in these strategies.

7.2 Regular Revisions to the Wachusett Land Management Plan

Progress on implementation of the Wachusett Land Management Plan will be presented as a component of an annual Wachusett public meeting. As a component of this meeting, Forestry and Natural Resources staff will review forest and wildlife management activities, land acquisition progress, and a variety of related research or policy developments. It is the intention of the agency that land management on MDC watershed properties will be an adaptive management activity. Adaptive management is an effort to account for the rapid developments in the science of land management by making appropriate operational changes within a time frame that is shorter than the ten-year perspective of the land management plans.

7.3 Scientific and Technical Review

Shortly following the writing of the most recent land management plan for MDC properties on the Quabbin watershed, the DWM organized the first meeting of the Science and Technical Advisory Committee (STAC). This committee was assembled in an effort to bring managers together with scientists to provide review and advice on the technical (as opposed to the political) aspects of management. The STAC is co-chaired by a scientist and an MDC staff member, and the group is indemnified in their role as outside advisors. The STAC, which includes approximately 30 scientists from colleges and organizations throughout the northeast, has met with MDC resource managers once a year since 1996, generally with a principal topic of focus. Topics have included optimizing opening sizes for forest regeneration and water protection; management recommendations for areas with special management restrictions (islands, wetlands, steep slopes, designated natural areas); strategies to respond to the effects of the hemlock woolly adelgid; protocol for the release of biocontrol agents (e.g., an imported beetle proposed for release to control the hemlock woolly adelgid); and recommendations for the management of "historic woodlots" (areas on the watersheds that have been managed, but have always been forested).

The Science and Technical Advisory Committee, although assembled to address issues arising from management at Quabbin, has always dealt with issues of broad importance across all Division properties. The writing of this Wachusett Watershed Land Management Plan has benefited from past STAC discussions, and has expanded on concepts developed during STAC meetings. It is the Division's intention to continue to use this advisory group to address the scientific and technical issues of management that arise in the implementation of this and other land management plans.

8 Literature Cited and General References

Aber, J.D., J.M. Melillo, and C.A. McClaugherty. 1989. Predicting long-term patterns of mass loss, nitrogen dynamics, and soil organic matter formation from initial fine litter chemistry in temperate forest ecosystems. Canadian Journal of Botany. 68:2201-2208.

Aber, J.D., J.M. Melillo, K.J. Nadelhoffer, J. Pastor, and R.D. Boone. 1991. Factors controlling nitrogen cycling and nitrogen saturation in northern temperate forest ecosystems. Ecological Applications, l(3), pp. 303-315.

Aber, J.D. 1993. Modification of nitrogen cycling at the regional scale: the subtle effects of atmospheric deposition. pp. 163-174. In: McDonnell, M.J. and S.T.A. Pickett (eds.), Humans as components of ecosystems: the ecology of subtle human effects and populated areas. Springer-Verlag, N.Y. 364 pp.

Aber, J.D. 1992. Nitrogen cycling and nitrogen saturation in temperate forest ecosystems. In: TREE. 7(7):220-224.

Aber, J.D., J. Knute, P.S. Nadelhoffer, and J.M. Melillo. 1989. Nitrogen saturation in northern forest ecosystems: excess nitrogen from fossil fuel combustion may stress the biosphere. Bioscience. 39(6):378-386.

Agren, G.I. and E. Bosatta. 1988. Nitrogen saturation of terrestrial ecosystems. Environmental Pollution, 54: 185-197.

Apple, L.L. no date. Riparian habitat restoration in cold desert, gully-cut stream systems: an innovative, cost effective, ecological approach. unpubl. manuscript. U.S. Bureau of Land Management, Rock Springs, Wyoming.

Arbogast, C., Jr. 1985. Marking guides for northern hardwoods under the selection system. USDA Forest Service, Lake States Forest Experiment Station Paper 56, 19 pp.

Art, H.W. and D.P. Dethier. 1986. Influence of vegetative succession on soil chemistry of the Berkshires. Water Resources Research Center Publication, University of Massachusetts, Amherst, Project No. G912-05.

Attiwill, P.M. 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. Forest Ecology and Management 63:247-300.

Austin, P., R. Bishop, D. Chandler, and P. Deslauriers. 1990. 1990 water quality report: Quabbin Reservoir and Ware River watersheds. Metropolitan District Commission, Division of Watershed Management. 89 pp.

Austin, P., R. Bishop, D. Chandler, P. Deslauriers, and M. Hopkinson. 1992. 1992 water quality report: Quabbin Reservoir and Ware River watersheds. Metropolitan District Commission, Division of Watershed Management. 120 pp.

Baker, John H. 1984. Sulfate retention by Forest Soils of Central New England. Publication No. 151, Water Resources Research Center, University of Massachusetts at Amherst.

Barnes, William J., and Eric Dribble. 1988. The effects of beaver on riverbank forest succession. Can. J. Bot. 66:40-44.

Batchelder, G.L., Yuretich, R.F. and W.C. Leonard. 1983. Hydrogeochemical cycling in a watershed-groundwater system: Fort River and Cadwell Creek, Massachusetts. Water Resources Research Center, University of Massachusetts. Pub. No. 145. 80 pp.

Benton, C., F. Khan, P. Monaghan, W.N. Richards and C.B. Shedden. 1983. The contamination of a major water supply by gulls (Larus sp.): a study of the problem and remedial action taken. Water Res. 17:789-798.

Bishop, R.P. 1992. Quabbin Reservation sanitary district: a survey of potential water pollution sources. Metropolitan District Commission, Division of Watershed Management.

Blodgett, D. 1985. Snag and den tree management guidelines. Habitat Highlights. Vol. 5. No. 4. 2pp.

Blodget, B. G. and R.A. Clark. no date. A check list for birds of the Quabbin Reservation, west central Massachusetts. Friends of Quabbin, Belchertown.

Bolgiano, C. 1989. A case for eastern old-growth. Amer. Forests. May-June:26-31,48.

Bormann, F.H. and G.E. Likens. 1970. The nutrient cycles of an ecosystem: measurements taken in a New Hampshire forest. Scientific American. 223(4).

Bormann, F.H. and G.E. Likens. 1979b. 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.

Bormann, F.H. and G.E. Likens. 1979a. Catastrophic disturbance and the steady state in Northern Hardwood Forests. American Scientist 67:660-669.

Bowden, R.D., M.S. Castro, J.M. Melillo, P.A. Steudler and J.D. Aber. 1993. Fluxes of greenhouse gases between soils and the atmosphere in a temperate forest following a simulated hurricane blowdown. Biogeochemistry, 21:61-71.

Branvold, D.K., C.J. Popp and J.A. Brierly. 1976. Waterfowl refuge effect on water quality: II. chemical and physical parameters. J. Wat. Poll. Control Fed. 48(4):680-687.

Brayton, D. Scott. 1984. The beaver and the stream. J. Soil Water Conser. March/April:108-109.

Bromley, P. T., J. Starr, J. Sims, and D. Coffman. 1997. A landowner's guide to wildlife abundance through forestry. Univ. Virginia Coop. Ext. Pub. 420-138.

Brown, G.W. 1976. Forestry and water quality. School of Forestry, Oregon State University, Corvallis, Oregon. Reprinted by the Oregon State University Book Stores, Inc.

Brown, K.A., P.H. Freer-Smith, G.D. Howells, R.A. Skeffington, and R.B. Wilson. 1988. Rapporteurs report on discussions at the workshop on excess nitrogen deposition, Leatherhead, September 1987. Environmental Pollution, 54:285-295.

Burns, R.M. and B.H. Honkala, tech. coords. 1990. Silvics of North America: Vol.1. Conifers, Vol.2. Hardwoods. Agricultural Handbook #654. U.S. Department of Agriculture, Forest Service, Washington, D.C. Vol.1. 675 pp.; Vol.2. 877 pp.

Buzzell, G. 1991. 1990 Wachusett storm salvage study. MDC Publication.

Carlson, J. 1994. Effects of a simulated hurricane on downed woody fuel loading in a central Massachusetts hardwood stand. Abstr. 5th Ann. Harvard Forest Ecology Symp., April 25.

Carlton, M. 1990. Literature review: water quality implications of converting forested watersheds to principally herbaceous cover - implications to the Quabbin watershed. MDC Publication.

Chadwick, N.L., D. R. Progulske, and J. T. Finn. 1986. Effects of fuelwood cutting on birds in southern New England. J. Wildl. Manage. 50(3):398-405.

Cline, A.C. 1939. The restoration of watershed forests in the hurricane area. Journal of the New England Water Works Association. 53(2):223-237.

Cline, A.C. and S.H. Spurr. 1942. The virgin upland forest of central New England: a study of old growth stands in the Pisgah Mountain section of southwestern New Hampshire. Harvard Forest Bulletin No 21, 58 pp.

Connecticut Department of Environmental Protection. 1991. Guidelines for enhancing Connecticut's wildlife habitat through forestry operations. Dept. Environ. Prot. Wildl. Div. 14pp.

Corbett, E.S. and W. Spencer. 1975. Effects of management practices on water quality and quantity: Baltimore, Maryland municipal watersheds. In: Municipal Watershed Management Symposium Proceedings, USDA Forest Service General Technical Report NE-13, pp 25-31.

Cosby, B.J., Wright, R.F., Hornberger, G.M., and J.N. Galloway. 1985. Modeling the effects of acid deposition: estimation of long-term water quality responses in a small forested catchment. Water Resources Research 21(11):1591-1601.

Craun, G.F. 1984. Waterborne outbreaks of giardiasis, current status. IN: Erlandsen and Meyer (eds.). Giardia and giardiasis. Plenum Press. N.Y. pp. 243-261.

Currie, W. and J.D. Aber. 1994. Modeling litter decomposition and N dynamics across LTER sites as part of the LIDET study. Abstracts from the 5th Annual Harvard Forest Ecology Symposium. Petersham, MA.

Curtis, J.T. 1959. The vegetation of Wisconsin. Univ. Wisconsin Press, Madison. 657 pp.

Davies, R.B. and C.P. Hibler. 1976. Animal reservoirs and cross-species transmission of Giardia. pp. 104-126 IN: Jakubowski and Hoff (eds). Waterborne transmission of giardiasis. U.S. EPA - 600/9-79-001.

Davis, J.W., G.A. Goodwin, and R.A. Ockenfels. 1983. Snag habitat management: proceedings of the symposium. U.S. For. Serv. Gen. Tech. Rep.RM-99. 226pp.

DeGraaf, R.M., and K.E. Evans. 1980. Management of northcentral and northeastern forests for nongame birds. U.S. For. Serv. Gen. Tech. Rep.NC-51. 275pp.

DeGraaf, R.M., and W.M. Healy. 1988. Is forest fragmentation a management issue in the northeast? U.S. For. Serv. Gen. Tech. Rep. NE-140. 32pp.

DeGraaf, R.M. and D.A. Richard. 1987. Forest wildlife of Massachusetts: cover type, size class and special habitat relationships. Univ. Mass. Coop. Ext. Serv. Publ. C-182.

DeGraaf, R.M., and D.D. Rudis. 1986. New England wildlife: habitat, natural history, and distribution. U.S. For. Serv. Gen. Tech. Rep. NE-108. 491pp.

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. 21pp.

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. 271pp.

DeMaynadier, P. G., and M. L. Hunter, Jr. 2000. Road effects on amphibian movements in a forested landscape. Nat. Areas. J. 20:56-65.

Devito, K. J., and P. J. Dillion. 1993. Importance of runoff and winter anoxia to the P and N dynamics of a beaver pond. Can. J. Fish. Aquat. Sci. 50:2222-2244.

Diesch, S.L. 1970. Disease transmission of water-borne organisms of animal origin. pp. 269-285 IN: T.L. Willrich and G.E. Smith (eds). Agricultural practices and water quality. Iowa St. Univ. Press.

Dincauze, D.S. 1974. An introduction to archaeology in the greater Boston area. Archaeology of Eastern North America. 2(1):47.

Dobson, J.E., R.M. Rush, and R.W. Peplies. 1990. Forest blowdown and lake acidification. Annals of the Association of American Geographers. 80(3):343-361.

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.

Douglass, J.E. and W.T. Swank. 1972. Streamflow modification through management of eastern forests. U.S.D.A. Forest Service, Research Paper SE-94, 15p.

Driscoll, Charles T., G.E. Likens, L.O. Hedin, J. S. Eaton and F.H. Bormann. 1989. Changes in the chemistry of surface waters: Twenty-five year results at the Hubbard Brook Experimental Forest, NH. Environ. Sci. Technol. 23(2):137-143.

Dunne, T. and L.B. Leopold. 1978. Water in environmental planning, W.H. Freeman and Company, New York, NY, 818 pp.

Dyrness, C.T. 1965. Erodibility and erosion potential of forest watersheds. In: Forest Hydrology: Proceedings of a National Science Foundation Advanced Science Seminar at Pennsylvania State University, University Park, PA, August 29-Sept 10, 1965, Edited by William E. Sopper and Howard W. Lull, Pergamon Press, London, pp 559-611.

Edwards, Nicole T., and David L. Otis. 1999. Avian communities and habitat relationships in South Carolina Piedmont beaver ponds. Am. Midl. Nat. 141:158-171.

Elliot, C. A. 1988. A forester's guide to managing wildlife habitats in Maine. U. Maine Coop. Ext. 46pp.

Erlandsen, S.L. and W. J. Bemrick. 1988. Waterborne giardiasis: sources of Giardia cysts and evidence pertaining to their implication in human infection. pp. 227-236 IN: P.M. Wallis and B.R. Hammond (eds). Advances in Giardia research. Univ. Calgary Press, Calgary, Alberta.

Eschner, A.R. and D.R. Satterlund. 1965. Forest protection and streamflow from an Adirondack watershed. Wat. Res. Res. 2(4):765-783.

Executive Office of Environmental Affairs, Commonwealth of Massachusetts. 2000. The state of our environment. 150 pp.

Fed Register. 1987. 52(212):42178. Nov. 3.

Fennell, H., D.B. James and J. Morris. 1974. Pollution of a storage reservoir by roosting gulls. Wat. Treat. Exam. 23:5-24.

Flatebo, G., C. R. Foss, and S. K. Pelletier. 1999. Biodiversity in the forests of Maine: guidelines for land management. Univ. Maine Coop. Ext. #7147 167pp.

Forman, R.T.T. and M. Godron. 1986. Landscape ecology. Wiley & Sons, N.Y.

Foster, D.R. 1988. Species and stand response to catastrophic wind in central New England, U.S.A. Journal of Ecology 76:135-151.

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. 1999. Thoreau's Country. Harvard University Press, Cambridge, MA.

Foster, N.W., Nicolson, J.A., and P.W. Hazlett. 1989. Temporal variation in nitrate and nutrient cations in drainage waters from a deciduous forest. Journal of Environmental Quality 18: 238-244.

France, R. L. 1997. The importance of beaver lodges in structuring littoral communities in boreal headwater lakes. Can. J. Zool. 75:1009-1013.

French, J.M. 1988. MDC-DFWELE land acquisition program: MDC watersheds. Unpublished MDC report.

French, J.M. and G.S. Buzzell. 1992. Wachusett Reservoir Arborvitae Hedge Report. MDC.

Garrett, J.D., T. Cassidy, K. McGarigal, K.B. Searcy, and R. Harrington. 2000. Rare, unique, and exemplary natural communities of Quabbin watershed. University of Massachusetts, Department of Natural Resources Conservation report prepared for MDC/DWM.

Geldreich, E.E. 1972. Water-borne pathogens. Chapter 9 IN: Mitchell (ed.). Water pollution microbiology. John Wiley & Sons.

Goldstein, R.A., Chen, C.W., and S.A. Gherini. 1985. Integrated lake-watershed acidification study: summary. Water, Air, and Soil Pollution 26:327-337.

Gould, D.J. and M.R. Fletcher. 1978. Gull droppings and their effects on water quality. Water Res. 12:665-672.

Hägglund, Å., and G. Sjöberg. 1999. Effects of beaver dams on the fish fauna of forest streams. For. Ecol. Manage. 115:259-266.

Hakanson, L., T. Andersson, and A. Nilsson. 1990. New method of quantitatively describing drainage areas. Environ. Geol. Sci 15(1):61-69.

Hall, C.A.S. and J.W. Day, Jr. 1977. Ecosystem modeling in theory and practice. Wiley-Interscience, New York, N.Y. 684p.

Hammerson, G.A. 1994. Beaver (*Castor canadensis*): Ecosystem alterations, management, and monitoring. Nat. Areas J. 14(1):44-57.

Hartman, E.M., P.E. Austin, and K.M. Keohane. 1992. Quabbin tributaries: water quality data report. Commonwealth of Massachusetts, Department of Environmental Protection and Metropolitan District Commission. Pub. No. 17158-195-50. 196 pp.

Healy, W. M. 1997. Thinning New England oak stands to enhance acorn production. N. Journ. Appl. For. 14(3):152-156.

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., R.T. Brooks and P.J. Lyons. 1987. Deer and forests on Boston's municipal watershed after 50 years as a wildlife sanctuary. IN: Proceedings: deer, forestry, and agriculture: interactions and strategies for management. June 15-17, 1987. Warren, PA. Allegheny Society of American Foresters.

Hemond, H., K. Eshleman, K. O'Connor, B. Gordesky, and D. Chen. 1987. Surface hydrology and wetland roles in acid deposition on the Bickford Pond watershed. Commonwealth of Massachusetts, Dept. of Environmental Quality Engineering, Project 84-26-WPC. 71 pp.

Hemond, H.F. and K.N. Eshleman. 1984. Neutralization of acid deposition by nitrate retention at Bickford watershed, Massachusetts. Water Resources Research. 20(11):1718-1724.

Herkert, J.R., R. E. Szafoni, V. M. Kleen, and J.E. Schwegman. 1993. Habitat establishment, enhancement and management for forest and grassland birds in Illinois. Ill. Dept. Conserv. Div. Nat. Herit. 1. 19pp.

Hewlett, J.D. and W.L. Nutter. 1969. An outline of forest hydrology. University of Georgia Press, Athens, GA, 137 pp.

Hibbert, A.R. 1967. Forest treatment effects on waters yield. IN: International Symposium on Forest Hydrology, W.E. Sopper and H.W. Lull, eds, Pergamon Press, Oxford, England, pp 527-543.

Hill, E.P. 1982. Beaver. pp. 256-281 IN: J.A. Chapman and G.A. Feldhammer (eds), Wild mammals of North America: biology, management and economics. John Hopkins Univ. Press.

Hobbie, J.E. and G.E. Likens. 1973. Output of phosphorus, dissolved organic carbon, and fine particulate carbon from Hubbard Brook watersheds. Limnology and Oceanography, 18(5):734-742.

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. 172pp.

Hodkinson, I.D. 1975. Energy flow and organic matter decomposition in an abandoned beaver pond ecosystem. Oecologia (Berl.) 21:131-139.

Hoekstra, T.W., and J. Capp. 1988. Integrating forest management for wildlife and fish. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-122. 63pp.

Hornbeck, J.W., and W.B. Leak. 1992. Ecology and management of northern hardwood forests in New England. U.S.D.A. For. Serv. Gen. Tech. Rep. NE-159. 44p.

Hornbeck, J.W., C.W. Martin, R.S. Pierce, F.H.Bormann, G.E. Likens and J.S. Eaton. 1987. Northern hardwood forest ecosystem: ten years of recovery from clearcutting. U.S.D.A. Forest Service, Northeastern Forest Experiment Station. Broomall, PA. NE-RP-596. 30 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 of northeastern USA. Journal of Hydrology, 150:323-344.

Horsley, S.B. and D.A. Marquis. 1982. Interference by weeds and deer with Allegheny hardwood reproduction. Can. J. For. Res. 13:61-69.

Hunt, F.M. 1961. Forest resources on Metropolitan District Commission lands surrounding Quabbin Reservoir. Master's Thesis. University of Massachusetts, Department Forestry and Wildlife Management, Amherst, MA. 128 pp.

Hunt, P.,and D. De Luca. 1997. Survey and management recommendations for grassland and shrubland birds in New Hampshire. Audubon Soc.of NH. 46pp.

Hunter, M.L. 1990. Wildlife, forests, and forestry; principles of managing forests for biological diversity. Prentice Hall, Englewood Cliffs, N.J. 370 pp.

Hunter, M.L. Jr. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press. 698pp.

Hussong, D., J.M. Damare, R.J. Limpert, W.J.L. Sladenk, R.M. Weiner and R.R. Colwell. 1979. Microbial impact of Canada geese (*Branta canadensis*) and whistling swans (*Cygnus columbianus columbianus*) on aquatic ecosystems. Appl. Envir. Microbiol. 37:14-20.

Indiana Department of Natural Resources. Undated. Managing woodlands for wildlife. DNR. Manage. Series No. 3. 9pp.

Johnson, D.W. and R.I. VanHook, eds. 1989. Analysis of biogeochemical cycling processes in Walker Branch watershed. Springer-Verlag, New York, NY. 401 pp.

Johnston, W.S., G.K. Maclachlan and G.F. Hopkins. 1979. The possible involvement of seagulls (Larus sp.) in the transmission of salmonella in dairy cattle. Veterinary Record. 105:526-527.

Johnston, C.A. and R.J. Naiman. 1990. Browse selection by beaver: effects on riparian forest composition. Can. J. For. 20:1036-1043.

Johnston, C.A. and R. J. Naiman. 1990. Aquatic patch creation in relation to beaver population trend. Ecology. 71(4):1617-1621.

Jones, A.L., and P.D. Vickery. 1998. Conserving grassland birds: managing large grasslands including conservation lands, airports, and landfills over 75 acres for grassland birds. Mass. Audubon. 17pp.

Jones, A.L., and P.D. Vickery. 1998. Conserving grassland birds: managing agricultural lands including hayfields, crop fields, and pastures for grassland birds. Mass Audubon. 17pp.

Jones, A.L., and P.D. Vickery. 1998. Conserving grassland birds: managing small grasslands including conservation lands, corporate headquarters, recreation fields, and small landfills for grassland birds. Mass. Audubon. 16pp.

Jones, C.G., J.H. Lawton, and M. Shachak. 1997. Positive and negative effects of organisms as physical ecosystem engineers. Ecology. 78(7):1946-1957.

Jones, W.R. 1951. The deer herd of Prescott Peninsula, Quabbin Reservation, and its ecology. M.S. Thesis, Univ. of Massachusetts, Amherst. 126 pp.

Jones, F., P. Smith and D.C. Watson. 1978. Pollution of a water supply catchment by breeding gulls and the potential environmental health implications. J. Inst. Wat. Eng. & Sci. 32:469-482.

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.

Klein, R.M. and T.D. Perkins. 1988. Primary and secondary causes and consequences of contemporary forest decline. The Botanical Review. 54(1), Jan-Mar, 43 pp.

Klotz, R. L. 1998. Influence of beaver ponds on the phosphorus concentration of streamwater. Can. J. Fish. Aquat. Sci. 55:1228-1235.

Krug, E.C. and C.R. Frink. 1983. Acid rain on acid soil: a new perspective. Science. 221:520-525.

Kyker-Snowman, T.D. 1989. Quabbin forest regeneration study. MDC Publication.

Lawrence, G.B., D.A. Burns and P.S. Murdoch. 1993. Work plan of the Neversink watershed study. United States Geological Survey. Albany, N.Y.

Leak, W.B. and J.H. Gottsacker. 1985. New approaches to uneven-age management in New England. Northern Journal of Applied Forestry. 2:28-31.

Leak, W.B. and C.W. Martin. 1975. Relationship of stand age to streamwater nitrate in New Hampshire. USDA Forest Service Research Note NE-211, 5 pp.

Leonard, W.C., R.F. Yuretich, and S.J. Pohanka. 1984. Hydrogeology and processes of acid neutralization in Cadwell Creek, Quabbin Reservation, Massachusetts. Water Resources Research Center, University of Massachusetts, Pub. No. 148. 122 pp.

Lorimer, C. 1977. The presettlement forest and natural disturbance cycle of northeastern Maine. Ecology. 58(1):139-148.

Mader, D.L., W.P. MacConnell, and J.W. Bauder. 1972. The effect of riparian vegetation control and stand density reduction on soil moisture in the riparian zone. University of Mass. Agric. Exp. Sta. Research Bulletin No. 597, Sept.

Magill, A. and J. Aber. 1993. Changes in nitrogen mineralization, nitrification and nitrogen leaching in the chronic N plots at Harvard Forest. IN: Long Term Ecological Research at Harvard Forest, Foster, D.R. and D.R. Smith eds., 109 pp.

Malben, G. and J.B. Foote. 1955. Beaver activity and water quality. J. Amer. Water Works Assoc. 47:503-507.

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.

Marks, P.L. and F.H. Bormann. 1972. Revegetation following forest cutting: mechanisms for return to steady-state nutrient cycling. Science. 176:914-915.

Marquis, D.A., P.L. Eckert, and P.A. Roach. 1976. Acorn weevils, rodents, and deer all contribute to oak regeneration difficulties in Pennsylvania. USDA, For. Service Research Paper NE-356, 5 pp.

Marquis, D.A., T.J. Grisez, J.C. Bjorkbom, and B.A. Roach. 1975. Interim guide to regeneration of Allegheny hardwoods. USDA Forest Service Gen. Tech. Rep. NE-19.

Marquis, David A. 1991. Uneven-Aged Management in the Cherry-Maple Forest. Proceedings of the Allegheny Society of American Foresters Symposium on Uneven-aged Management.

Martin, C.W. and R.S. Pierce. 1980. Clearcutting patterns affect nitrate and calcium in streams in New Hampshire. Journal of Forestry. May: 268-272.

Mather, M. E. 1993. The Quabbin ecosystem: an interdisciplinary ecological review. Final report of the seminar. University of Massachusetts, Department of Forestry and Wildlife Management.

Matthews, J.D. 1989. Silvicultural systems. Oxford University Press, New York, NY.

McAvoy, D.C. 1989. Episodic response of aluminum chemistry in an acid-sensitive Massachusetts catchment. Water Resources Research. 25(2):233-240.

McColl, J.G. and D.F. Grigal. 1975. Forest fire: effects on phosphorus movement to lakes. Science. 188:1109-1111.

McKee, W. 1993. Personal communication. Southeastern Forest Experiment Station, U.S.D.A. Forest Service.

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.

MDC, Division of Watershed Management. 1988. Water quality report: Quabbin Reservoir and Wachusett Reservoir: watershed monitoring results. Unpublished MDC report.

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.

Melillo, J.M., J.D. Aber, P.A. Steudler and J.P. Schimel. 1983. Denitrification potentials in a successional sequence of northern hardwood forest stands. Environmental Biogeochemistry Ecological Bulletin, Stockholm. 35:217-228.

Metzmaker, J.B. and A.E. Rosquist. 1986. Watershed monitoring to assess the risk of a Giardia lamblia contamination of unfiltered municipal water supplies. International Symposium on Water-Related Health Issues, American Water Resources Association, November, pp 145-151.

Meyer, J.L. and G.E. Likens. 1979. Transport and transformation of phosphorus in a forest stream ecosystem. Ecology. 60(6):1255-1269.

Micks, P., R. Boone and S. Scott. 1994. Abiotic N fixation by forest floor material from the chronic N plots. Abstr. 5th Annual Harvard Forest Ecology Symposium. April 25, 1994.

Miller, D.R., M.J. Focazio, and M.A. Dickinson. 1986. A user's guide to a model for estimating the hydrological effects of land use change (BROOK). Cooperative Extension, University of Massachusetts, University of Connecticut.

Mladenoff, D.J., M.A. White, J. Pastor, and T.R. Crow, 1993. Comparing spatial pattern in unaltered old-growth and disturbed forest landscapes. Ecological Applications 3(2):294-306.

Monaghan, P., C.B. Shedden, K. Ensor, C.R. Fricker and R.W.A. Girdwood. 1985. Salmonella carriage by herring gulls in the Clyde area of Scotland in relation to their feeding ecology. J. Appl. Ecol. 22:669-680.

Monzingo, D.L., Jr. and C.P. Hibler. 1987. Prevalence of *Giardia sp*. in a beaver colony and the resulting environmental contamination. J. Wildlf. Dis. 23(4):576-585.

Moore, S.T. 1966. Management of a municipal supply watershed. Symposium of Forest Watershed Management: Practical Aspects. Society of American Foresters, Corvallis, Oregon. pp 61-68.

More, M.E. and J.W. Soper. 1990. GEIR forestland management practices. Massachusetts Department of Environmental Management, EOEA File Number 6307, 475 pp.

Motzkin, G., D. Foster, A. Allen and J. Harrod. 1994. Vegetation and regional physiographic and disturbance gradients. Abstracts from the 5th Annual Harvard Forest Ecology Symposium. Petersham, M.A.

Mrazik, B.R, D.L. Mader, and W.P. MacConnell. 1980. Integrated watershed management: an alternative for the northeast. Mass. Agricultural Experiment Station, Research Publication Number 664, Univ of Mass, Amherst.

Murdoch, P. 1993. Personal communication. USGS Water Res. Div., Albany, N.Y.

Murdoch, P.S. and J.L. Stoddard. 1992. The role of nitrate in the acidification of streams in the Catskill Mountains of New York. Water Resources Research. 28(10):2707-2720.

Nadelhoffer, K.J., J.D. Aber and J.M. Melillo. 1984. Seasonal patterns of ammonium and nitrate uptake in nine temperate forest ecosystems. Plant and Soil, 80: 321-335.

Naiman, R.J., J.M. Melillo and J.E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). Ecology 67(5):1254-1269.

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. and J.M. Melillo. 1984. Nitrogen budget of a subarctic stream altered by beaver (*Castor canadensis*). Oecologia (Berlin) 62:150-155.

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.

Nihlgard, B. 1985. The ammonium hypothesis - an additional explanation to the forest dieback in Europe. Ambio. 14(1):2-8.

Nilsson, A. and L. Hakanson. 1992. Relationships between drainage area characteristics and lake water quality. Environ. Geol. Water Sci. 19(2):75-81.

Nolet, B.A., A. Hoekstra, and M.M. Ottenheim. 1994. Selective foraging on woody species by the beaver (*Castor fiber*), and its impact on a riparian willow. Forest. Biol. Cons. 70:117-128.

Norton, D.A. 1999. Chapter 16, Forest Reserves in M.L. Hunter, Jr. 1999. Maintaining biodiversity in forest ecosystems. Cambridge University Press. 698pp.

Norvell, W.A. and C.R. Frink. 1975. Estimation of potential nutrient enrichment of Lake Wononscopomuc by wild geese. unpubl. manuscript. Conn. Agric. Exp. Station., New Haven.

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

Odum, E. P. 1969. The strategy of ecosystem development. Science. 164:262-270.

Ollinger, S., J. Aber and C. Federer. 1994. A GIS modeling approach to estimating regional carbon and water balances for the Northeastern U.S. Abstracts from the 5th Annual Harvard Forest Ecology Symposium. Petersham, M.A.

Ottenheimer, D.G. 1992. Hurricane susceptibility and water quality at Quabbin Forest, Massachusetts. M.S. Thesis. State University of New York, Syracuse. 70pp, +app.

Parsons, W.F.J., D.H. Knight and S.L. Miller. 1994. Root gap dynamics in lodgepole pine forest: nitrogen transformations in gaps of different size. Ecological Applications. 4(2):354-362.

Patric, J.H, J.O. Evans, and J.D. Helvey. 1984. Summary of sediment yield data from forested land in the United States. J. For. 82(2): 101-104.

Patric, J.H. 1978. Harvesting effects on soil and water in eastern hardwoods forests. Southern Journal of Applied Forestry 2(3):66-73.

Payne, N.F. and F.C. Bryant. 1994. Techniques for wildlife habitat management of uplands. McGraw-Hill, Inc. 840pp.

Peters, N.E. and P.S. Murdoch. 1985. Hydrogeologic comparison of an acidic-lake basin with a neutral-lake basin in the west-central Adirondack Mountains, New York. Water, Air, and Soil Pollution. 26:387-402.

Petersen, C. and G.C. Smith. 1989. Are the forests of Massachusetts in decline?. IN: Current issues in forestry, Cooperative Extension, University of Mass., Amherst, Vol I, No 2, May, 4 pp.

Portnoy, J.W. 1990. Gull contributions of phosphorous and nitrogen to a Cape Cod kettle pond. Hydrobiologia 202:61-69.

Putz, F.E. and R.R. Sharitz. 1991. Hurricane damage to old-growth forest in Congaree Swamp National Monument, South Carolina, U.S.A. Can. J. For. Res. 21: 1765-1770.

Raup, H.M. 1957. Vegetational adjustment to the instability of site. in Proc. 6th Tech. Meet. 1956 Int. Un. Conserv. Nature Nat. Resources, Edinburh. pp 36-48.

Reese, K.P. and J.D. Hair. 1976. Avian species diversity in relation to beaver pond habitats in the Piedmont region of South Carolina. Proc. Southeast Assoc. F & W Agencies Conf. 30:437-447.

Reich, P.B. and R.G. Amundson. 1985. Ambient levels of ozone reduce net photosynthesis in tree and crop species. Science. 230:566-570.

Reid, J. 1992. Personal communication. Hampshire College, Amherst, MA.

Reinhart, K.G. and A.R. Eschner. 1962. Effects on streamflow of four different forest practices in the Allegheny Mountains, J. Geophys. Research. 67:2433-2445.

Reinhert, R.H. and J.A. Hroncich. 1990. Source water quality management. pp. 189-228 IN: F.W. Pontius (ed). Water quality and treatment: a handbook of community water supplies. AWWA. McGraw-Hill.

Remillard, M.M., G.K. Gruendling and D.J. Bogucki. 1987. Disturbance by beaver (*Castor canadensis*) and increased landscape heterogeneity. Chapt. 6 IN: M.G.Turner (ed), Ecological Studies: Vol 64. Landscape heterogeneity and disturbance. Springer-Verlag, N.Y.

Reuss, J.O. and D.W. Johnson. 1986. Acid deposition and the acidification of soils and waters. Ecological Studies. Springer-Verlag; New York, N.Y.

Rittmaster, R.L. and J.B. Shanley. 1990. Effects of atmospheric wet deposition on the water quality of two streams in the Quabbin Reservoir watershed, central Massachusetts, 1983-85. U.S. Geological Survey. Water-Resources Investigations Report 90.

Rose, J.B. 1988. Occurrence and significance of *Cryptosporidium* in water. J. Amer. Wat. Works Assoc.:53-58.

Rothacher, J. 1970. Managing forest land for water quality. IN: Proceedings of the Joint FAO/U.S.S.R. international symposium on forest influences and watershed management, Moscow, U.S.S.R. by USDA Forest Service.

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.

Sample, D.W. and M.J. Mossman. 1997. Managing habitat for grassland birds: a guide for Wisconsin. Wis. Dept. Nat. Res. 154pp.

Savill, P.S. 1983. Silviculture in windy climates. Forestry Abstracts. 44(8):473-488.

Schindler, D.W., R.W. Newbury, K.G. Beaty, J. Prokopowich, T. Ruszczynski, and J.A. Dalton. 1980. Effects of a windstorm and forest fire on chemical losses from forested watersheds and on the quality of receiving streams. Canadian Journal of Fisheries Aquatic Science. 37:328-334.

Schindler, D.W. 1988. Effects of acid rain on freshwater ecosystems. Science. 239:149-157.

Schofield, C.L., J.N.Galloway, and G.R. Hendry. 1985. Surface water chemistry in the ILWAS Basins. Abstract. Water, Air, and Soil Pollution. 26:403-423.

Scudder, J.H. 1949. A preliminary study of forest succession in central New England. Masters thesis, Harvard University. 69 pp.

Searcy, K.B. 1996. 1996 rare plant survey: Quabbin,Ware River,Wachusett, and Sudbury watersheds. Final report to MDC.

Searcy, K.B. 1995. Quabbin rare plant survey, June-August, 1995. Final report to MDC.

Shanley, J.B. 1993. Personal communication. United States Geological Survey.

Sheehan, K.C. 1982. Development of environmental impact criteria for recreational use of the Quabbin Reservoir. Master's thesis, Dept. Civil Engineering, University of Massachusetts. 95 pp.

Shepard, J.P., M.J. Mitchell and T.J. Scott, and C.T. Driscoll. 1990. Soil solution chemistry of an Adirondack spodosol: lysimetry and N dynamics. Canad. Journ. Forest Resources, 20:818-824.

Skeffington, R.A. and E.J. Wilson. 1988. Excess nitrogen deposition: issues for consideration. Environmental Pollution. 54:159-184.

Smith, D.M. 1986. The practice of silviculture, eighth edition. John Wiley and Sons, New York, NY. 527 pp.

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, W.H. 1981. Air pollution-effects on the structure and function of the temperate forest ecosystem. In: Air pollution and forests. Springer-Verlag, New York. 379 pp.

Snodgrass, J.W. 1997. Temporal and spatial dynamics of beaver-created patches as influenced by management practices in a south-eastern North American landscape. J. Appl. Ecol. 34:1043-1056.

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.

Snow, D.R. 1980. The archaeology of New England. Academic Press, New York, N.Y.

Sorrie, B.A. 1989. Massachusetts flora: a review of current distribution and conservation of rare species. Rhodora 91:116-120.

Speranza, D.E. 1988. An investigation of *Giardia lamblia* in the Quabbin and Wachusett reservoirs. M.S. Thesis, University of Massachusetts, Amherst.

Spurr, S.H. and B.V. Barnes. 1980. Forest ecology (third edition). John Wiley and Sons, Inc. New York, NY. 687 pp.

Standridge, J.H., J.J. Delfino, L.B. Kleppe and R. Butler. 1979. Effect of waterfowl (*Anas platyrhynchos*) on indicator bacteria populations in a recreational lake in Madison, Wisconsin. Appl. Envir. Microbiol. 38:547-550.

Stekl, P.J. 1985. A hydrogeologic investigation of two small watersheds of the eastern Quabbin basin. Masters Thesis, University of Massachusetts.

Stephens, E.P. 1956. The uprooting of trees: a forest process. Proceedings of the Soil Science Society of America. 20:113-116.

Stoddard, J.L. 1991. Trends in Catskill stream water quality: evidence from historical data. Water Resources Research. 27(11):2855-2864.

Stone, E.L., W.T. Swank, and J.W. Hornbeck. 1979. Clearcutting versus alternative timber harvest and regeneration systems: impacts on soils and streamflow in the eastern deciduous region. USDA Forest Service.

Suurballe, N.C. 1992. Effects of a wetland on quality of Natty Pond Brook, Massachusetts, 1985-86. U.S. Geological Survey. Water-Resources Investigations Report 91-4144. 52 pp.

Swank, W.T. 1972. Water balance, interception, and transpiration studies on a watershed in the Puget lowland region of western Washington. Ph.D. Dissertation, University of Washington, Seattle.

Tamm, C.O. 1991. Nitrogen in terrestrial ecosystems: questions of productivity, vegetational changes, and ecosystem stability. Ecological Studies. Springer-Verlag, New York, N.Y. 116p.

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. III and D.R. Dessecker. 1997. Management of early successional communities in central hardwood forests. USDA For. Serv. Gen. Tech. Rep. NC-195. 33pp.

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.

Tyrrell, L.E. and T.R. Crow. 1994. Structural characteristics of old-growth hemlock-hardwood forests in relation to age. Ecology 75(2):370-386.

Tzipori, S. 1983. Cryptosporidiosis in animals and humans. Microbiol. Rev. 47:84.

U.S.D.A. Forest Service. 1990. Silvics of North America. Vol.1 Conifers, Vol.2 Hardwoods. Agricultural Handbook 654. Vol.1 675 pp; Vol.2 877 pp.

U.S.D.A. Forest Service. 1991. Riparian forest buffers; function and design for protection and enhancement of water resources. NA-PR-07-91.

Van Miegroet, H. and D.W. Johnson. 1993. Nitrate dynamics in forest soils. IN: Nitrate: processes, patterns and management. T.P. Burt, A.L. Heathwaite, S.T. Trudgill, eds. John Wiley and Sons, New York, N.Y. 444p.

Veneman, P.L.M. 1984. Evaluation of the buffering capacity of Massachusetts soils to negotiate the impact of acid deposition on water quality. Completion Report to the Massachusetts Dept. of Environmental Quality Engineering Division of Air Quality control. University of Massachusetts at Amherst.

Vernegaard, L., R. Hopping, and D. Reid. 1998. Ecological management of grasslands: guidelines for managers. The Trustees of Reservations, Massachusetts. 20pp.

Verry, E.S. 1986. Forest harvesting and water: the Lakes States experience. Water Resources Bulletin. 22(6):1039-1047.

Vitousek, P.M., J.R. Gosz, C.C. Grier, J.M. Melillo, W.A. Reiners and R.L. Todd. 1979. Nitrate losses from disturbed ecosystems. Science. 204:469-474.

Vitousek, P.M. 1977. The regulation of element concentrations in mountain streams in the northeastern U.S. Ecol. Monographs, Vol. 47, pp 65-87.

Vitousek, P. M., W.A. Reiners, J.M. Melillo, C.C. Grier, and J.R. Gosz. 1981. IN: Stress effects on natural ecosystems. pp. 115-127.

Vitousek, P.M. and W.A. Reiners. 1975. Ecosystem succession and nutrient retention: a hypothesis. Bioscience Vol. 25(6) pp. 376-381.

Vitousek, P.M. 1985. Community turnover and ecosystem nutrient dynamics. Chapt. 18 IN: The ecology of natural disturbance and patch dynamics. S.T.A. Pickett and P.S. White (eds.). Academic Press. 472 pp.

von Oettingen, S.L. 1982. A survey of beaver in central Massachusetts for *Giardia lamblia*. M.S. Thesis, University of Massachusetts, Amherst. 57 pp.

Walters, C.J. 1986. Adaptive management of renewable resources. MacMillan Publishing Company, New York, NY.

Wandle, S.W. n.d. Estimating peak discharges of small, rural streams in Massachusetts. U.S. Geological Survey Water-Supply Paper 2214. 25 pp.

Waring, R.H. and W.H. Schlesinger. 1985. Forest ecosystems: concepts and management. Academic Press, Inc. Harcourt Brace Jovanovich. New York, N.Y.

Webster, B. 1983. The shy beaver: powerful effects on ecology seen in new research. N.Y. Times, Tues. Jan. 11.

Whigham, D.F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality:a landscape perspective. Environmental Management. 12(5):663-671.

Williamson, S. J. n.d.. Forester's guide to wildlife habitat improvement. Univ. New Hampshire, Coop. Ext. 41pp.

Wilde, S.A., C.T. Youngberg and J.H. Hovind. 1950. Changes in composition of ground water, soil fertility and forest growth produced by the construction and removal of beaver dams. J. Wildl. Manage. 14(2):123-128.

Wilen, B.O., W.P. McConnell and D.L. Mader. no date. The effects of beaver activity on water quantity and quality. Unpubl. manuscript. Univ. of Mass., Amherst, MA.

Woo, M-K. and J.M. Waddington. 1990. Effects of beaver dams on subarctic wetland hydrology. Arctic. 43(3):223-230.

Wright, R.F. 1976. The impact of forest fire on the nutrient influxes to small lakes in northeastern Minnesota. Ecology. 57:649-663.

Yuretich, R.F., P.J. Stekl and S.J. Pohanka. 1986. Hydrogeology and mineral weathering reactions in watersheds of Central Massachusetts. Water Resources Research Center, University of Massachusetts, Pub. No. 152. 85 pp.

Yuretich, R.F., ed. 1992. Impacts of acid deposition on watersheds of the Quabbin Reservoir. Water Resources Research Center, University of Massachusetts, Pub. No. 166. 229 pp.

9 Glossary of Terms

Listed in alphabetical order below are terms and definitions that the MDC uses throughout various watershed land management plans. Specific sources of definitions are shown in parenthesis, where applicable.

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 Society of American Foresters, 1971. Terminology of forest science, technology, practice, and products.)

aggradation: in Northern Hardwoods, a period of more than a century when the ecosystem accumulates total biomass reaching a peak at the end of the phase; preceded by the reorganization phase and followed by the transition phase. (from Bormann and Likens, 1979. Pattern and process in a forested ecosystem.)

advance regeneration: in silvicultural terms, young trees that have become established naturally in a forest, in advance of regeneration cutting; may become established following "preparatory" cuts.

allogenesis: changes in an ecological community primarily through periodic, acute, external (exogenous) disturbances, such as storms. These changes generally reset the successional progression of the community.

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 sq ft 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.

autogenesis: changes in an ecological community primarily through the regular, internal processes of growth, competition, and senescence, which are general endogenous (within community) forces that result in a steady successional progression of the community.

basin; sub-basin: 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 is used to refer to the basin of a tributary, or lower *order* stream (the higher the order, the greater the area drained).

basal area: the area in square feet of the cross section of a tree taken at 4.5 feet above the ground.

"beaver pipe"; flow control 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 level at a particular level.

Conservation Management Practices, CMPs: 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).

conservation restriction; conservation easement: 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. MDC also limits or retains the right to approve certain agricultural and silvicultural practices in its CR's.

Continuous Forest Inventory (C.F.I.): an extensive method of forest inventory in which permanent sample plots are remeasured at periodic intervals to determine forest growth and condition; MDC's CFI is composed of 1/5 acre permanent plots, located on a 1/2 mile grid, and 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.

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 that the cysts of other protozoa, and thus may be more difficult to remove from water supplies.

diameter at breast height; DBH: 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 most often used to refer to forest composition, and refers to both height or size diversity in trees, seeking a minimum of three distinct layers (understory, midstory, and overstory), and to diversity of species composition, with a general goal of avoiding monocultures and working to include components of hemlock, pine, oak, birch, and maple throughout the forest.

disturbance-sheltered: areas that are physically (based on slope and aspect) "sheltered" from the influence of a catastrophic New England hurricane blowing from the southeast, based on a model developed at the Harvard Forest; the most sheltered areas are steep slopes facing northwest.

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, the term has also 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 exogenous disturbance below).

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, though with rotations of 100 years or more, differences up to 30% of the rotation may be admissible. (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 endogenous disturbance above)

feller-buncher; feller-buncher-processor: logging machines that grasp a tree to be cut or "felled," sever it at the stump with either a saw or hydraulic shears, and directionally drop it to the ground. Some machines can accumulate, or "bunch" several trees before releasing them. The most complex machines are also capable of delimbing and sawing trees into predetermined lengths (processing).

forest canopy: the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth. (from SAF).

forest fragmentation: the separation of a previously contiguous forested area into discontinuous patches or "fragments." These fragments are less useful to wildlife 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 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 skidded through the woods.

G.I.S.: Geographic Information System - a computer-based analysis and mapping system for spatially-linked data sets.

***Giardia*:** A protozoan parasite found in humans and various wild and domestic animals that can be transmitted via water and often causes serious intestinal illness.

hurricane exposure ("exposed," "intermediate," "sheltered"): generally used in MDC 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 this typical New England hurricane, which includes slope and aspect. Actual damage will depend on the type and size of vegetation present.

intermediate cut: cutting of trees in a stand during the period between establishment and maturity. Objectives may include the improvement of vigor by reducing competition or the manipulation of species composition. Regeneration may occur following intermediate cuts, but it is incidental to the objectives.

irregular shelterwood: similar to the shelterwood silvicultural system except that overstory removals are protracted, taking as long as half the rotation, so that 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 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.

milacre: one one-thousandth of an acre as in "milacre plots for regeneration inventory."

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.

“naturally managed”: the results of a deliberate decision to allow natural disturbances and processes prevail by adopting a minimal management approach that protects forests from development or other land use changes and possibly human-caused fire, but which includes vegetation management only where it clearly counteracts a negative result from previous human disturbances.

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 and the establishment of natural regeneration (from SAF).

protected: refers to areas of the watershed that, according to the Harvard Forest model of hurricane disturbance, would suffer minimal damage from the recurrence of a hurricane similar to that of 1938, due primarily to topography and orientation.

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, or to exert any other beneficial forest influences (from SAF).

regeneration: recently established tree growth, generally smaller than one inch dbh; also, the process of establishing this growth, as in “bring about the regeneration of a forest area.”

regeneration cut: any removal of trees intended to assist regeneration already present or to make regeneration possible (from SAF).

riparian: pertaining to the bank of a stream or other water body. Vegetation growing in close proximity to a watercourse, lake, swamp, or spring, and often dependent on its roots reaching the water table (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 before their timber becomes worthless. In some situations, the motivation for removal is the reduction of 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 seepage, which is important to wildlife because it remains unfrozen, and generally uncovered, during periods when the ground is otherwise snow-covered, which makes it easier for wildlife to forage for seeds.

sere (seral): the series of successional stages in an ecosystem, from the pioneer stage through the climax. See definition of ‘succession’ below for further detail.

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 shelterwood cuttings. The first is ordinarily the seed 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 classified by the ability of specific trees to grow on them.

site index: the ability of a given site to grow a given species. As height growth is generally not density dependent, a common forestry site index is the height to which a given species will grow on the site in fifty years (so that a site with a red oak site index of 65 will grow red oak to that height in fifty years).

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 to remove 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, site preparation.

site-suited: species that have evolved to take advantage of a particular type of site. Where species are planted on other sites, they may succumb prematurely 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” logs from the woods to a landing or a forwarder road. Logs are either winched by cable to the skidder (cable skidder), or lifted on one end by a hydraulic grapple (grapple skidder), and then dragged.

stand: a community of trees possessing sufficient uniformity as regards composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities (from SAF).

steady state: “For the ecosystem as a whole, over a reasonable period of time gross primary production equals total ecosystem respiration, and there is no net change in total standing crop of living and dead biomass” (Bormann and Likens, 1979. p.4).

stocking: in forestry, the extent to which a site is occupied by trees compared to the maximum occupation possible at 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 classification of streams within watersheds. Small streams at the uppermost level of stream systems 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; it is “allogenic” when the causes of succession are external to and independent of the community (e.g., a storm or climate change), and “autogenic” when the developing vegetation is itself the cause. “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 trees, regardless of associated regeneration effects. Most thinning leave stands 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. Most common unit is the Nephalometric Turbidity Unit, NTU.

uneven-aged: a forest, crop, or stand composed of intermingling trees that differ markedly in age. By convention, a minimum difference between tree ages of 25% of the rotation age is generally accepted. Some texts require a minimum of three distinct age classes for a stand to qualify as “uneven-aged.” (from SAF).

vernal pool: a temporary body of fresh water that provides crucial habitat for several vertebrate and many invertebrate species of wildlife, but does not support fish populations.

wetland: generally refers in the MDC land management plans to areas defined as “wetlands” by MGL Ch.131, s 40 (the “Wetlands Protection Act”) and 310 C.M.R. 10.00 (the “Wetlands Protection Regulations”), updated as these are revised.