5.2 Management of Forested Lands

5.2.1 History of Quabbin Watershed Forestry 1930 – 1960

5.2.1.1 Land Taking and Development for Water Supply

Forest Management Highlights:

1. Early forest management (1930-1970) at Quabbin focused on planting of 6,760 acres, pruning, limited non-commercial thinning, and extensive commercial improvement thinning. This was followed first by clearing of plantations to improve water yield (1980s), and then by deer herd reduction and small group selection silviculture to produce diverse forest structure (1990s to present).
2. From the approximately 47,000 acres considered to be actively managed at Quabbin, just over 1,000 acres has been treated annually since 1960. In recent years, about 400 acres of the treated area has been regenerated annually to form new age classes.
3. Forest management guidelines include cutting no more than 25% of the stocking of any given subwatershed in any given 10 year period and strict adherence to conservative Conservation Management Practices.
4. Harvesting is also limited by hydrologic zones based on proximity to water resources. Regeneration openings in Zone 1 will not exceed ½ acre; Zone 2 will not exceed 1 acre; and 90% of Zone 3 openings will not exceed 2 acres, while 10% will be larger.
5. Efforts to build diversity in size/age classes and in species composition are designed to build resistence and resilience in the face of disturbances ranging from wind and heavy snow/ice to diseases, insects, and climate change.
6. Management plan review, annual internal review of proposed harvesting and roadwork, and post-harvesting summary reports and public meetings provide wide-ranging internal and public review of DWSP forest management practices.

With signing of Chapter 321 of the Acts of 1927, the Quabbin Reservoir project had official approval to begin work. The bulk of the land purchasing in the Quabbin Reservation came with the "General Taking" of March 28, 1938. The "General Taking" is defined by the "fire line", a 40 foot clearcut swath along the DWSP boundary. Besides land taking, the agency was busy constructing dams, dikes, aqueducts, roads, highways, buildings, a power station, and Quabbin tower, and clearing the 24,000 acre reservoir and planting trees on 10,000 acres of open land. Most of this work was done in a period of 10 years. During this time, two major floods and a catastrophic hurricane occurred.

The clearing of 24,000 acres of all trees, and the subsequent flooding, impacted the Swift River Valley by eliminating most of the pine types, both white and pitch, all of the small ponds, miles of streams and significant wetlands. The clearing process created huge amounts of waste wood (slabs, branches etc.), which had to be removed; the only practical way was through burning. In the process of burning the debris, most of the present islands and hundreds of acres along the Reservoir shore and most of Quabbin Hill were extensively burned. These woodland fires stimulated the development of hardwood sprouts and seedlings throughout the burned areas. Tremendous amounts of deer food were produced by both the clearing and burning. Although the fires burned hot and killed small trees, they did not kill larger overstory trees. An exception was a later fire in 1957 which did kill the overstory. This fire was just north of Route 122 in New Salem and resulted in the death of 100 year old pines and hemlocks on 400 acres.

The construction of two large earth dams required huge amounts of soil. This resulted in the development of several open pit mines adjacent to the Reservoir and the stripping of 2-3 feet of top soil from most fields on agency lands in the town of Ware. Most stripped areas were planted to conifers. These plantations have shown the effects of soil loss, often including disease, stunted growth, and frequent wind-throw.

During World War II, the military established a presence at Quabbin with a firing range at the south end of Little Quabbin and several bombing and strafing ranges for aircraft. Most of this activity had little impact on the land except for fires started by 100 lb. practice bombs. Many bombs ended up a considerable distance from the targets, and one of these ignited a fire that burned 2,000 acres of the northeast corner of Prescott Peninsula. It was a hot ground fire fueled with blow-down from the 1938 hurricane. The fire crossed several roads before topography and wetlands stopped its spread. The fire opened the forest, fostering the production of an understory of hardwood sprouts and seedlings.

In the first years after it acquired watershed lands, the MDC harvested forest products to provide for its own lumber needs. A private sawmill owner could bid on sawing a certain amount of lumber for the agency. Sawmills would be set up near the forest where the trees were to be cut. During the late 1940s and through the 1950s at least four cuttings were made to meet these needs. In addition, several private timber sales were conducted in the 1950s both inside and outside gated areas of the Quabbin. Prior to 1960, the total volume of timber removed by these cutting operations after MDC attained care and control of the properties was less then 5 million board feet (excluding hurricane salvage).

5.2.1.2 Establishment and Management of Plantations on Open Lands

A forestry program for the reforestation of open land and of areas growing brush was initiated in 1934 for the better protection of the watershed, with the goal of establishing a revenue-producing watershed forest. Coniferous trees were chosen for the following benefits:

- Prevention of the growth of deciduous trees so that leaves are kept from entering the water and undesirable color and taste produced by decomposing organic material is minimized.
- Reduction of the force of heavy rains through dispersal of rain drops into a fine spray by the coniferous foliage, thereby increasing the absorption of precipitation by the soil.
- Control of snowmelt in the spring due to the dense shade beneath the coniferous canopy as opposed to the rapid melting and evaporation that takes place in open areas and in deciduous forests.
- Conservation of soil moisture in deeper soils due to the shallow rooting of conifers.
- Fast growth of coniferous trees and the value of the quality timber they produce.
- Ability of conifers to grow well on a wide range of sites.

Red pine was specifically favored because it was resistant to blister rust and white pine weevil, was easily grown in the nursery, and survived transplanting well. During the period from 1935 to 1946 approximately 8,243,600 pine trees were planted on roughly 6,760 acres of open land. These areas consisted of:

- Arable land. This land grew agricultural crops for human consumption or forage for feeding domestic animals. When agriculture declined much of this land was used as pastureland. Most of the soils consist of fine sandy loams such as the Charlton series.
- Pasture land. This is land on which domestic animals had been pastured, but it was open land, not pastured woodland. The majority of these soils were moderately well-drained fine sandy loams such as the Scituate series.
- Sproutland. This land had dense shrubby vegetation or trees of seedling or sapling size. The land had recently (1 - 15 years) been withdrawn from agricultural use and was not cut over woodland.

Many of the 6,760 acres of original plantation failed, generally by succumbing to competition from native species. Plantations survived beyond the establishment stage on approximately 3,200 acres. Trees were planted in straight rows, mostly five feet on center. This "five-by" spacing insured a rapid closing of the crowns in order to prevent the development of large branches on the lower portions of the trees, produce straighter stems, and eliminate much of the danger of insect damage.

With this spacing, crown closure occurred within 15-20 years. At this point, these stands were to receive some kind of silvicultural treatment such as a thinning. This did not happen due to lack of labor and available markets. As a result of overcrowding and competition for water and nutrients, growth rates in many stands became stagnated. The stands remained stagnated, except for a limited number that were commercially thinned in the late 1950s. During the 1960s, approximately 630 acres of plantations were pruned and 730 acres received some type of pre-commercial thinning. In most instances, these operations occurred simultaneously.

The decade of the 1970s saw a move from non-commercial to commercial silviculture, and thinnings occurred on about 800 acres of pine plantations. During this period the region experienced a drought and water quantity became a great concern. Ongoing studies on the Cadwell Creek experimental watershed and others showed that water yields could be increased by lowering the stocking of the forest and that greatest increases in yield occurred when the forest was completely removed from a watershed area. With water yields as the goal, approximately 400 acres of stagnated or diseased plantations were clear-cut and converted back into fields during the decade of the 1980s. This figure was considerably less than the 3,000 acres of plantation clearings that were outlined in the 1986 Forest Management Plan (the difference between the planned and actual removals was due to the need for careful supervision of private contractors and the limited number of available contractors).

During the 1980s, both intermediate and regeneration cuts continued, covering approximately 900 acres of plantations that decade. While many of these plantations were on hardwood sites, white pine regenerated well in most instances but hardwood regeneration was very limited due to deer browsing. Toward the end of the decade, MDC management philosophy changed with respect to pine plantations, when water conservation measures proved successful and the need to increase water yields was no longer a primary concern. Today, DWSP's principal concerns with its pine plantations are to maintain their ability to protect water quality, by increasing structural and species diversity and by replacing high risk stands (growing on wetter soils) through natural regeneration with native species more likely to persist on these sites.

5.2.2 Objectives and Accomplishments of Previous Quabbin Management Plans

5.2.2.1 Hunt's 1961 Assessment

The first "management plan" for the Quabbin forest was actually a Master's thesis written by MDC Forester Fred M. Hunt in 1961 and titled "Forest Resources on the Metropolitan District Commission Lands Surrounding Quabbin Reservoir." The management objectives outlined in this thesis were:

- Provide, through Continuous Forest Inventory (CFI), detailed information on the condition of the forest so that the forest manager could carry out sound management practices designed to improve the productivity of the watershed for both water and timber values.

- Determine through a study of the literature on the subject, the types of vegetative cover that would best suit the needs of this particular watershed.

- Develop, for each of the major timber types on the area, management procedures that would produce the types of cover determined above.

The recommendations necessary to meet these objectives were put forth in this document. The inventory, present condition of the forest, characteristics of good watershed cover and recommendations for watershed management were discussed in detail. Ideal forest conditions for the watershed were described as forest composed of native species that were long-lived and suited to the site conditions. White pine, red oak, hemlock and white ash best fit these criteria. The forest would be of moderate stocking, have good growth and quality and include equal areas in each age class. This forest would promote a forest floor that allowed precipitation to rapidly infiltrate the soil and would enhance both aesthetic and wildlife values.

The recommendations were to conduct commercial silvicultural operations on 10,560 acres and remove approximately 35 million board feet of timber. Much of this work would be salvaging trees that had been partially damaged by the 1938 hurricane or trees which were of poor health, vigor and quality. Several thousand acres of non-commercial silviculture was also recommended, primarily in dense pine plantations and hardwood stands that had regenerated from the 1938 hurricane. These cutting practices were designed to improve stand health and where possible to allow regeneration to develop. Deer browsing was considered to be inhibiting forest regeneration on much of the reservation.

The recommendations of the plan were closely followed and a total of 32.5 million board feet was harvested on approximately 9,000 acres of watershed. Although a few hundred acres of non-commercial silviculture was completed with MDC personnel, this work stopped in 1964 when the workforce was assigned to maintenance of the Quabbin Park area.

During this decade a significant drought occurred and the Quabbin Reservoir dropped 34 feet below full elevation, the lowest level since its construction. The role of forest management in defending against such dramatic drops became an important topic of discussion.

5.2.2.2 Spencer/Walker 1972 Quabbin Watershed Management Plan

The first official MDC management plan was prepared by Bruce Spencer and Charles Walker in 1972 and titled "Watershed Management Plan for Metropolitan District Commission Lands Surrounding Quabbin Reservoir." The objectives of this plan were:

- Create and maintain an additional water yield of 10% annually from the Quabbin Reservation.
- Improve the health and quality of the Quabbin forest.
- Maintain healthy populations of native wildlife.
- Maintain, improve and protect an aesthetically pleasing landscape.

This plan followed and expanded upon most of the recommendations of Hunt's thesis. It also urged hiring more personnel to better care for the watershed. The condition of the forest was determined from inventory data collected from the remeasurement of several hundred permanent Continuous Forest Inventory plots (CFI). The implementation of silvicultural activities was detailed, especially commercial logging activities. Logging systems and methods to eliminate significant impacts to water, forest, wildlife and aesthetics were outlined. The watershed was zoned for forest management, administrative uses, and natural areas.

Deer still prevented regeneration on large areas of the watershed but the recommendation was to delay corrective action for 15-20 years, acknowledging that the absence of regeneration might enhance water yields. However, this plan stressed that a solution to heavy deer browsing be found at the end of that period, to compensate for the maturation and gradual break-up of the overstory.

Beaver, introduced in 1952, were spread throughout the entire watershed by 1972 and responsible for creating approximately 1,200 acres of ponds and marsh. Although the damage to forests and road culverts from beaver was noted, the benefits to other wildlife were also mentioned. Beaver management was recommended only where the road system was threatened.

The plan recommended silvicultural operations on 12,000 acres of natural stands, thinning 3,000 acres of pine plantations and clearing 500 acres of stagnated and diseased pine plantations. Thirty one million board feet of timber was expected to come from these operations.

During the plan period, silviculture was conducted on 9,500 acres, yielding 20.5 million board feet of timber and 30 thousand cords of firewood. Approximately 75 acres of pine plantations were salvaged and cleared due to storm damage or disease. A new demand for firewood allowed thinning of overstocked stands that had been scheduled for work by MDC crews in the first plan. Only a small amount of thinning was done in pine plantations because there was little commercial demand for the wood and no budget to pay for non-commercial thinning. The difference between planned and completed work during this decade highlights the importance of market conditions in accomplishing necessary work.

5.2.2.3 Spencer/Lyons 1986 Quabbin Watershed Forest and Wildlife Management Plan

The second MDC management plan was prepared by Bruce Spencer and Paul Lyons in the early 1980s. The plan was titled "A Ten Year Forest and Wildlife Management Plan for the Quabbin Watershed." The objectives of this plan were:

- Identify and protect critical, sensitive, rare or otherwise valuable habitat.
- Thin forest stands to reduce stocking levels to 20-40% (i.e., savannah forest) or 60-70% (i.e., "thinned forest").
- Convert several thousand acres of conifer plantations to open grass cover.
- Plant important wildlife food/cover species.
- Diversify wildlife habitat conditions on the Reservation using a variety of other management practices.

These objectives supported the primary goal of increasing water yields while maintaining water quality and vigorous forest and wildlife communities. The plan strongly supported the addition of more MDC personnel to better care for the watershed. The plan expanded the discussion on all aspects of management such as the landscape design aspects of watershed management, methods of determining the recommended harvest, and a discussion of the dynamics of water yields.

The goal of striving for multiple age classes of native species suited to site conditions was reiterated, although browsing and associated herbaceous competition (ferns, barberry, and assorted others) had prevented and would continue to prevent the development of new age classes on 2/3 of the hardwood forest. The need for regeneration to replace the forest following a disturbance was again discussed.

Specific recommendations were made to work on 23,000 acres (20,000 acres of silvicultural practices and 3,000 acres of pine plantation conversions to fields) and harvest 33 million board feet, 150,000 cords and 400,000 tons of chips (red and white pine plantations).

The actual acreage worked was 11,450 acres from which 13.8 million board feet, 39,000 cords of firewood and 141,600 tons of whole tree chips were harvested. Of the 3,000 acres of pine plantations to be converted to fields, 400 acres were actually completed. Although the pines could have been marketed and MDC would have realized income from this project, contractors with the proper equipment were not available.

The firewood market collapsed in the last half of the decade and therefore much of the hardwood thinning was not completed. The creation of savannah forest via harvesting, which would then be maintained through deer browsing, was discontinued. It was felt that water-rich areas produced similar yields regardless of whether the vegetation was mostly ferns or trees.

Additional staff and equipment were added to better care for the watershed and to maintain the roads and forest. Some roads had become an erosion problem due to insufficient staff and equipment. With a combination of new equipment and personnel plus monies from timber sales to supply gravel, trucking, culverts, gates and other equipment and supplies, much of the forest road mileage was restored to good condition. Equipment to operate within pine plantations while avoiding damage to walls, foundations, and advance regeneration was purchased for operation by MDC personnel. The purchase and installation of additional gates to control access was also accomplished. Starting in the last half of this management period, an action plan to solve the deer problem was implemented.

Table 38 presents the number of acres treated since the 1960s. A decline in acres treated in the 1980s was due to the decreasing ability of the forest to regenerate, changes in forest product markets, and the assignment of forestry staff to other projects including forest inventory, management plan preparation, boundary marking, and land acquisition.

Table 38: Acres of Silvicultural Treatment by Fiscal Year, 1960-1995

Year(s)	Acres treated	Year(s)	Acres treated
1960s	9,000	1987	645
1970s	9,500	1988	1,232
1980	2,202	1989	940
1981	1,037	1990	404
1982	1,831	1991	722
1983	1,598	1992	507
1984	1,369	1993	704
1985	1,512	1994	945
1986	1,169	1995	786

5.2.2.4 MDC Quabbin Land Management Plan 1995-2004

The third Quabbin Land Management Plan was prepared shortly after the initiation of deer impact control through public hunting (in 1991) and just before the management of these lands became the first public land management in North America to receive “green” certification from the international Forest Stewardship Council (in 1997).

The 1995-2004 plan identified both short-term (10 year) and long-term (60 year) objectives. The primary objective in the short term was to manage for the recovery of tree regeneration, a component of the forest structure that had been severely restricted for fifty years due to uncontrolled expansion of deer browsing. This objective was to be met through a combination of reductions in the size of the deer population and specific forest management practices, such as preparatory cuttings and enrichment plantings. The long-term objectives were to bring about the development of a multi-aged, species-diverse forest that was determined to be the most stable cover for this drinking water supply, especially in the face of potential large-scale disturbances by wind, ice damage, or insects and disease, among others. Long-range objectives also included a proposed effort to identify priority areas for treatment based on a “sub-basin” analysis, to determine which areas had the greatest influence on water quality. The plan also called for the creation of a Scientific and Technical Advisory Committee to assist Division staff in setting priorities for management.

The first objective of the plan, to reduce deer impacts, was addressed very successfully during the 1995-2004 period, and this success continues today. Deer populations across the watershed were reduced to levels that allow tree regeneration to become established and begin to grow into new age classes. The specific silvicultural objective was to regenerate one-third of approximately 1,500 to 2,000 acres treated per year, or about 500 to 600 acres regenerated annually. **Table 39** details the silviculture that was actually completed during the decade of this plan, which averaged 388 acres regenerated annually from a total of approximately 1,000 acres treated.

Table 39: Harvesting Summary for FY1995 through FY2005

Fiscal Year	Total Acres Harvested	Total Acres Regenerated[1]	Board Feet	Cords	Tons	Revenue
1996	659	85	2,645,494	1,994	3,458	$306,048
1997	1,274	682	7,447,357	3,495	9,215	$727,993
1998	1,253	385	4,894,431	4,908	1,569	$677,017
1999	1,332	382	5,327,581	4,974	7,410	$567,504
2000	1,110	419	5,042,700	3,884	6,221	$1,028,977
2001	745	371	4,532,600	2,703	8,059	$524,075
2002	808	380	4,196,880	2,646	7,665	$571,601
2003	1,003	397	5,575,799	4,150	8,645	$704,882
2004	890	337	2,873,334	4,095	5,170	$381,540
2005	1,205	439	5,146,694	5,598	6,864	$757,708
TOTAL	**10,279**	**3,877**	**47,682,870**	**38,447**	**64,276**	**$6,247,345**
Average	*1,028*	*388*	*4,768,287*	*3,845*	*6,428*	*$ 624,734*

[1] Note that the regeneration objective was to regenerate approximately one third of each harvesting sale area, unless the treatment was exclusively intermediate thinnings. The difference between harvested area and area regenerated is intentional and does not imply regeneration failure.

5.2.2.5 Regeneration Changes during the Previous Management Period

Regeneration has been systematically and intensively monitored on the Quabbin Reservoir watershed since 1989 and throughout the previous management period. A summary of results from this monitoring is included as an Appendix to this plan, entitled "2004 Quabbin Regeneration Summary Report." Shorter updates are produced by DWSP annually, to serve as the backdrop for annual deer impact control management programs (see summary of deer program results in Section 5.4.4.4.). The deer impact control program that is in place has been very successful in reaching DWSP goals for the re-establishment of regeneration potential and diverse plant succession throughout even the most heavily impacted areas of the watershed. **Table 40** provides a comparison between the conditions encountered in the regeneration surveys conducted in the late 1980s and early 1990s and the conditions recorded in the most recent watershed-wide intensive regeneration survey.

White pine and black birch regeneration beneath thinned red pine plantation on Prescott Peninsula

Table 40: Regeneration Comparison 1989, 1994, 2004

Area / Block	Year	Stems per acre 1' to 4.5' tall	Stems per acre >4.5' tall	TOTAL
Off Reservation	1989	1,960	1,140	3,100
	1994	2,750	1,840	4,590
	2004	2,071	1,404	3,475
On Reservation	1989	770	130	910
	1994	2,955	417	3,372
	2004	3,187	1,344	4,531
Hardwick	1994	1,840	581	2,421
	2004	2,634	1,333	3,967
New Salem	1994	3,846	212	4,058
	2004	3,399	950	4,349
Pelham	1994	930	71	1,001
	2004	2,102	901	3,001
Petersham	1994	4,369	1,054	5,423
	2004	4,438	2,008	6,446
Prescott	1994	3,789	167	3,956
	2004	3,267	1,331	4,598

5.2.3 DCR/DWSP Quabbin Forest Management Objectives 2007-2017

DWSP has concluded that the forest conditions that best meet the combined objectives of the agency – to deliver predictable quantities of high-quality drinking water at a reasonable cost while protecting the fullest possible suite of associated natural resources – include vigorous trees of broad, site-suited species composition and age classes well-distributed across the watershed and capable of rapid regeneration and active growth following a wide range of both natural and deliberate disturbances. This conclusion was reached through critical review of past and current research literature, consultation with an extensive array of academic and field professionals in natural resources management and related disciplines, and more than four decades of direct experience with watershed forest management. The conclusions of the agency have been open to critical and timely revision by the public that is served by these objectives. Throughout this management period DCR will continue to solicit public input as adaptive revisions are proposed during annual progress reviews, based on additional experiences and changing objectives.

Note that the objectives listed in the following sections refer to those areas of the DWSP holdings around Quabbin Reservoir that are actively managed, an area that includes approximately 46,000acres. These objectives specifically exclude those areas that are identified as reserved from management, as described in Section 5.5.4, Areas with Special Management Restrictions, and totaling approximately 12,000 acres.

5.2.3.1 Primary Objectives

The primary objective of forest management of the Quabbin forest is to create and maintain a complex forest structure, which forms a protective forest cover and a biological filter on the watershed land. This watershed protection forest is designed to be vigorous, diverse in species and age, actively accumulating biomass, conserving ecological and economic values, actively regenerating, and most importantly maintaining a predictable flow of high quality water from the land.

From 1960 to 1990, the primary objective of forest management at Quabbin was to maintain vigorous forest growth through silvicultural thinning and stand improvement harvests. Regeneration of all species was not possible throughout much of the Quabbin until the successful deer impact management program that began in 1991. Regeneration potential is essential to restore the forest cover as quickly as possible following any disturbance and to enable the deliberate creation of diverse age classes. Based on results from past surveys, the primary regeneration objective of this plan is for areas that have been deliberately regenerated to contain an average of at least 2,000 trees per acre greater than 4.5 feet in height, of a diverse mix of species appropriate to the site, within 3-7 years of the disturbance This management plan will be the first of five plans to work with an actively regenerating forest throughout the Quabbin reservation, enabling the gradual fulfillment of our watershed protection forest structure objectives.

The present Quabbin forest overstory originated as stands that regenerated following farm abandonment from 1850-1900 and subsequent cutting, or by stands that regenerated following the hurricane of 1938 and by the deliberate planting of trees on agricultural fields at approximately the same time, so that the range of overstory ages is generally between 65 and 160 years of age. During the past decade, the Division has successfully regenerated approximately 3,900 acres, or 8.5% of the actively managed forest (approaching the objectives of the 1995-2004 Quabbin Land Management Plan to regenerate approximately 1/3 of the managed forest every 30 years).

Converting the present day even-aged forest stands into a multi-aged forest is a long process (Kelty, et al, 2003) that will not be fully implemented for many decades, and will most certainly be disrupted by frequent small and infrequent large disturbances. The guiding objective for silviculture during the decade of this plan will be to regenerate approximately 1% of the managed forest annually, so that by the end of the decade, an additional 10% of the managed forest will have been converted to a new age class. Large, unmanaged stands that will include individuals and groups of trees living to biological maturities ranging from 100 to 400 or more years of age, will, barring major disturbances, continue to be a component of the watershed protection forest surrounding Quabbin Reservoir..

The managed forest that was regenerated in the past decade was distributed throughout the forest types and origins, with some emphasis on replacing failing pine plantations established in the late 1930s (some of these plantings were established on sites not suited to their long-term growth and development). Managing the mix of stands from the 1930s and those from an earlier time has required the application of varied silvicultural systems. Generally, stands dominated by long-lived trees, well suited to the site, have been treated with uneven-aged silvicultural methods ranging from single tree to small group selection harvests (up to one acre in size). In stands dominated by trees not suited to the site, various methods within the even-aged silvicultural system have been used to more rapidly regenerate these stands to trees better suited to the site conditions. The vast majority of the Quabbin forest is currently occupied by species growing on suitable sites.

Over the next decade, the Division intends to refine its silvicultural techniques while continuing to implement the primary objectives stated in the previous plan. Silvicultural practices will work to maintain or enhance species diversity. Age structure will become more diverse. Approximately 1% of the managed forest will be regenerated annually to create a new age class. The majority of the harvesting will focus on regeneration openings ranging from single-tree to small group selections (less than one acre in size) and patch cuts up to 2 acres in size. On a limited basis, larger openings will be implemented to more rapidly regenerate some areas and to meet green certification recommendations to enhance landscape-level horizontal forest diversity. Full details of the proposed zoning and silvicultural approach are included in Section 5.2.3.3.

The Division will consider the current condition of individual management units (such as the presence of significant insects or diseases), and inventory the condition of the access network (roads, staging areas) in order to plan for upgrades as necessary and limits on the size and type of equipment that can operate the area. Areas with special management restrictions, such as rare species habitats or cultural features requiring heightened protection, will be identified, and then the specific silvicultural prescription will be proposed through the annual Lot Review process (see Section 5.2.7).

5.2.3.2 Subwatershed Administration of Forest Management

While the focus of DWSP's mission is the overall condition of the watershed and the quality of the water in the reservoir, those conditions reflect the collective conditions of a group of smaller drainages, or subwatersheds that comprise the whole. The planning process for land management, public recreation, and other watershed activities is therefore most logically done on a subwatershed basis.

Historically, records on forest management activities on Quabbin Reservation have been based on a "compartment" system. 94 compartments were established on the reservation, usually bounded by roads, streams, the reservoir shoreline, or other obvious natural features. As new lots were sold and operated, their locations and other pertinent information were added to maps and tables for each compartment, first manually and later by computer.

While this system has proven useful for record-keeping purposes, it does not allow for the efficient monitoring of land management activities on a drainage area basis. However, with the advent of Geographic Information Systems (GIS), Global Positioning Systems (GPS), and high-quality digital orthophotos of the watershed, it is now possible to efficiently keep track of our management work by hydrologic units or subwatersheds.

5.2.3.2.1 Quabbin Subwatersheds

A subwatershed is defined in most cases as the land area that drains to a perennial tributary of the reservoir. Drainage areas were delineated using the MassGIS watershed delineation tool, starting from the point where the tributary met the reservoir. In most cases, these were 2nd or 3rd order streams. Where those tributaries represent higher-order streams or rivers however, they were further subdivided. This process resulted in the identification of 56 subwatersheds on Quabbin (**Figure 14**). There are areas within the watershed, and in particular along the shorelines, that drain directly to the reservoir via subsurface flow rather than via a distinct tributary. These areas are not distinct subwatersheds flowing through a unique collection point at the reservoir's edge, but are critical direct drainage areas that lie immediately adjacent to the reservoir.

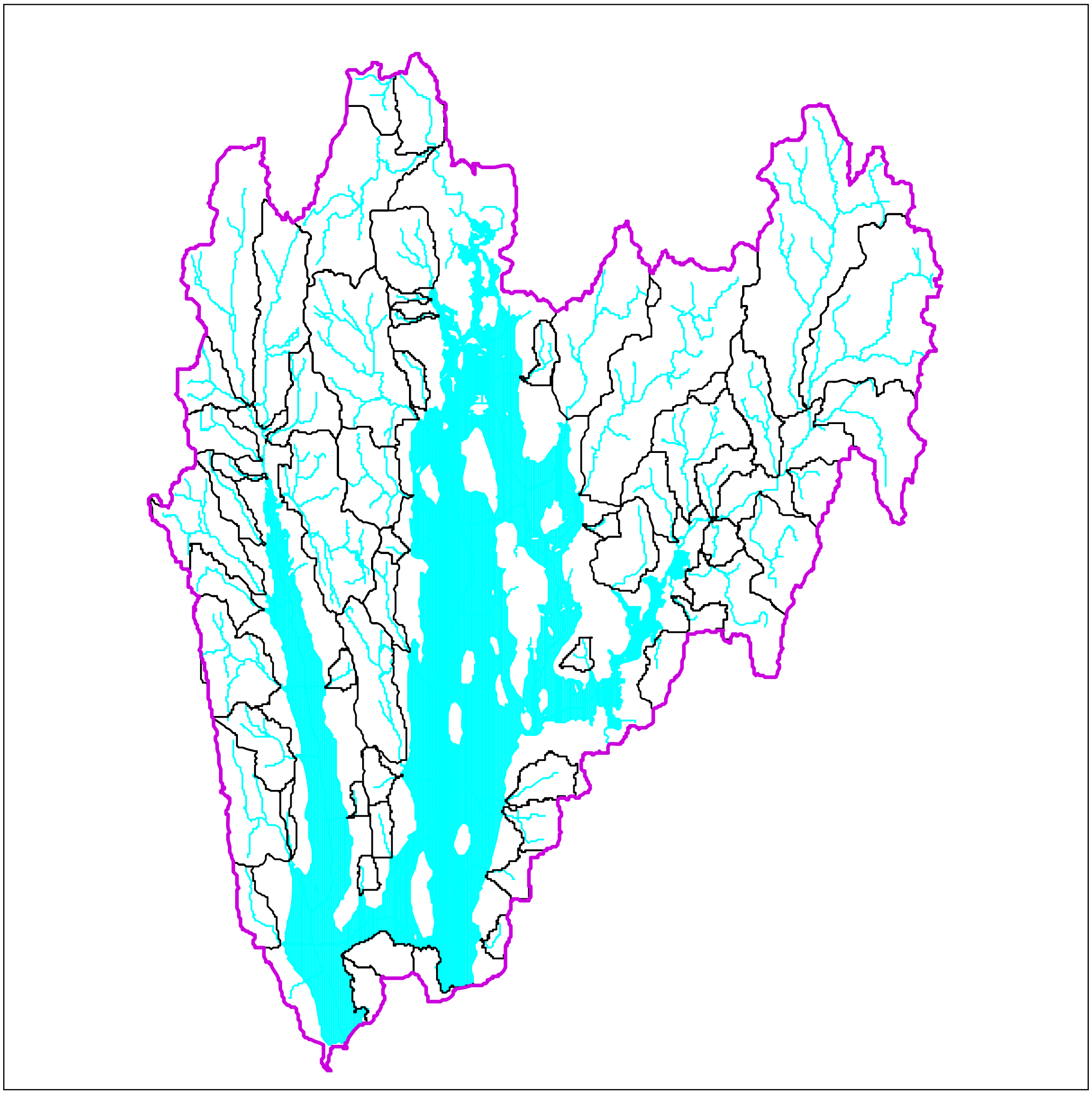


Figure 14: Subwatersheds and direct drainage areas within the Quabbin Reservoir watershed

5.2.3.2.2 Implementing Subwatershed-Based Planning

The general theory behind the use of subwatershed-based planning is to control the proportion of a drainage area that is "disturbed" by management activities (e.g., logging or roadwork) during the management period in order to reduce the chances of water quality impacts. This approach is partly based on research on experimental watersheds throughout the eastern US that indicate that until approximately 25-30% of the watershed forest overstory stocking is harvested (assuming nearly 100% forest cover type), there is a no detectable increase in water yield (Hornbeck and Kochenderfer, 2004; Hornbeck et al., 1993). As increases in transport of sediments and nutrients to tributaries and the reservoir are directly related to increases in water yield, it follows that the 25-30% threshold also applies to water quality changes (so long as Conservation Management Practices are in place, the greatest concern is with the movement of nutrients rather than sediments; see Section 5.2.5). The same research also demonstrated that water yield generally returns to pre-harvest conditions as the harvested area regenerates – usually within 3-10 years.

Once drainage areas have been delineated and the locations of harvest operations have been digitized, the GIS provides straightforward techniques to estimate the percentage of a subwatershed forest that has been harvested in any given time period. That information will be available to DWSP Foresters before they propose their logging operations for the coming year. Where the forest stocking across any given subwatershed has been reduced during the previous decade by an amount approaching 25-30% of full stocking, further harvesting in those drainages will be postponed. This percentage may be estimated based on the area of regeneration openings versus the total area of the subwatershed, or through stocking estimations.

While the 25-30% figure provides a guideline for meeting water quality standards, other factors, such as soil types, topography, proximity of the management work to water courses, and the concentration and distribution of the harvesting can affect the decision about acceptable levels of harvesting. Another consideration in subwatershed-based planning is the proximity of a subwatershed to the water intake structures. Those subwatersheds that are far removed from the intakes could be considered less sensitive to management effects than those in close proximity. In each individual instance, subwatershed–based recommendations will be tempered by best professional judgment.

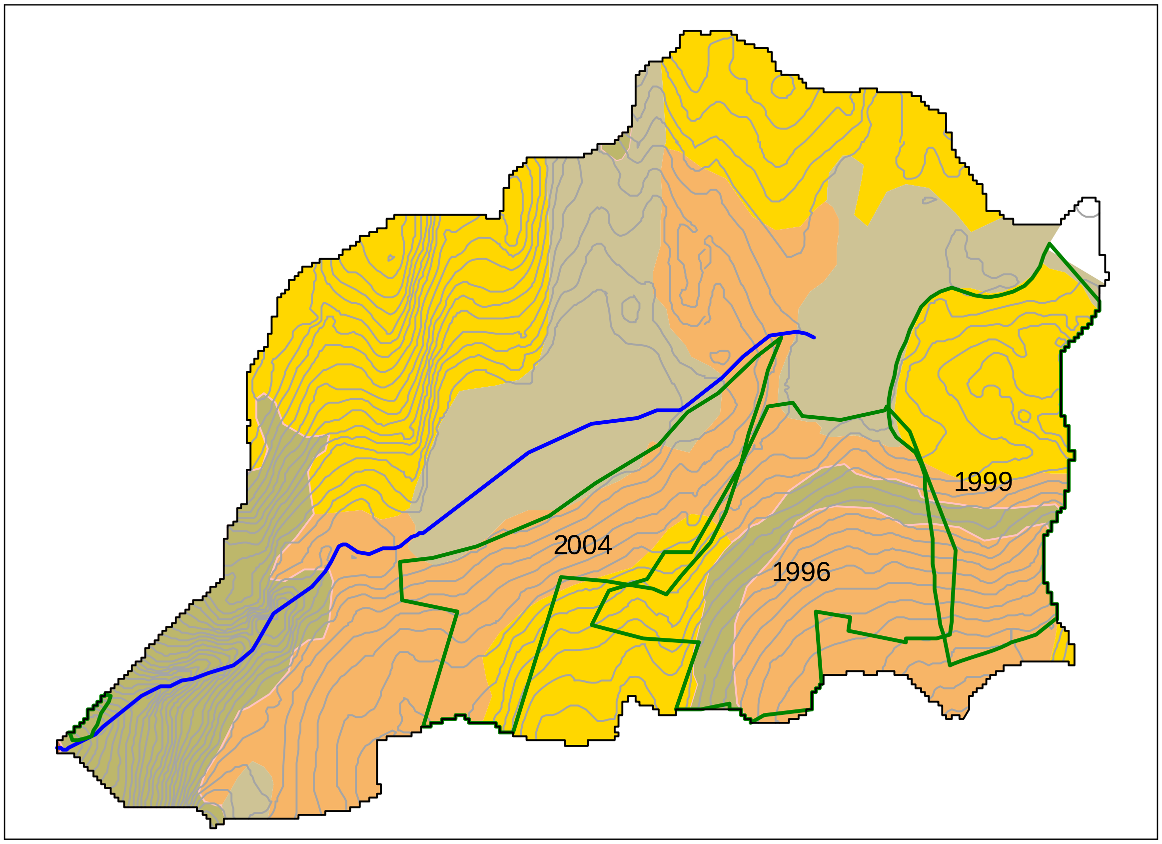
To facilitate the use of subwatershed information in land management planning, maps of each subwatershed will be produced, showing boundaries, topography, soils, roads, and locations of logging operations conducted during the past 10 years. Foresters will then consult these subwatershed maps prior to planning their coming year's work.

An example of an individual subwatershed map is shown in **Figure 15**. This subwatershed is approximately 638 acres in size, with topography ranging from 531 to 954 feet. The mouth of the drainage is within 1.3 miles of the Shaft 12 intake, and approximately 6.6 miles from the CVA intake. Soil composite types in the subwatershed include: Well-drained thin soils – approximately 33% of subwatershed; Well-drained thick soils – 12%; Moderately-well drained soils – 34%; Poor to very poorly drained soils – 21%. During the past 10 years, 3 logging operations occurred in the subwatershed, covering a total of approximately 210 acres (33% of the subwatershed). However, this work harvested the overstory trees on only 70 acres (11%) of the actual area, and mostly occurred on the moderately or well-drained soils in the subwatershed, so this area remains well below the 25-30% threshold.

5.2.3.2.3 Coordination with OWM Environmental Quality staff

The Environmental Quality (EQ) staff at Quabbin have developed a multi-tiered system for subdividing the watershed for the purpose of organizing the tracking and analysis of management or development activities on private as well as public lands and for monitoring the effects of these activities on water quality. The Quabbin Reservoir watershed is divided by EQ into Districts, Subdistricts, and Stream Compartments. The Stream Compartments correspond most directly with the subwatersheds designated above for the purposes of land management, with some important differences. For example, the shoreline direct drainage areas are merged into Stream Compartments for EQ analysis. For land management purposes and the determination of the 25-30% threshold described above, the only portions of shorelines that can be used in this analysis are those with distinct watersheds. The remainder of the shorelines is primarily drained by subsurface direct flow to the reservoir. Despite this difference in the systems, the EQ and Natural Resources (NR)/Forestry staffs will accumulate information at the EQ Subdistrict level on at least an annual basis in order to better coordinate responses to mutual concerns. For example, EQ will inform NR/Forestry on the status of private land activities within each subdistrict, and NR/Forestry will provide EQ with a summary, by subdistrict, of past and proposed regeneration harvesting.

Figure 15: Example of a Subwatershed Planning Map Including Topography, Soils, and Previous Harvests



5.2.3.3 Establishment of Forest Management Zones

5.2.3.3.1 Guidance from existing zoning strategies

Once subwatersheds are established, DWSP next establishes three zones within the areas that are to be actively managed. These zones were developed following consideration of other regulatory zoning that affects watershed management practices. DEP, the primary regulator for MA surface water supplies, established three zones to delineate those areas included in 310 CMR 22.00, the Massachusetts Drinking Water Regulations, as Surface Water Supply Protection Zones:

- ***ZONE A**:* represents a) the land area between the surface water source and the upper boundary of the bank; b) the land area within a 400 foot lateral distance from the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a); and c) the land area within a 200 foot lateral distance from the upper boundary of the bank of a tributary or associated surface water body.

- ***ZONE B**:* represents the land area within one-half mile of the upper boundary of the bank of a Class A surface water source, as defined in 314 CMR 4.05(3)(a), or edge of watershed, whichever is less. Zone B always includes the land area within a 400 ft lateral distance from the upper boundary of the bank of the Class A surface water source.

- ***ZONE C:*** represents the land area not designated as Zone A or B within the watershed of a Class A surface water source, as defined in 314 CMR 4.05(3)(a).

In addition, the Watershed Protection Act established regulatory zones restricting land use and activities within critical areas of the Quabbin Reservoir, Wachusett Reservoir and Ware River watersheds. These zones include two distinct areas, the *Primary Protection Zone*, which is the area 400 feet from the edge of the reservoirs and 200 feet from tributaries and surface waters, in which alterations are prohibited, and the *Secondary Protection Zone,* which is the area between 200 and 400 feet from the banks of tributaries and surface waters, and within which storage, disposal, or use of hazardous materials, the alteration of bordering vegetated wetlands, and dense development are prohibited.

Finally, in 1999, the Division identified a "Pathogen Control Zone" designed to limit the risk of pathogen infection of the water supply at the intakes. At Quabbin, this zone is focused on protecting the Chicopee Valley Aqueduct, and includes the stream and hillside drainages in the Pelham Block and within Quabbin Park that most directly affect the CVA (see **Figure 22,** Section 5.4.4.1.1**).**

5.2.3.3.2 DWSP Forest Management Zones

For the purpose of guiding and limiting forest management activities within Quabbin watershed, DWSP has incorporated principles from the DEP zoning for surface water protection, the Watershed Protection Act, and the Division's Pathogen Control Zones and has developed the following forest management zones (see **Figure 16**):

5.2.3.3.2.1 DWSP Forest Management Zone 1

Zone 1 includes the buffer strips along public roads, the variable width filter strip along streams and water bodies, the DWSP filter strips around all vernal pools, and all other land that is within 200 feet of the bank of tributaries to the Quabbin Reservoir or within 400 feet of the bank of the reservoir itself.

Buffer strips are required by Chapter 132 along publicly maintained ways, but not including forest management roads in public forests, parks or reservations. These buffer strips are 50 feet from the edge of the road unless the road is a designated scenic road, in which case the buffer strip extends 100 feet from the highway. Within these buffer strips, cutting is limited to not more than 50% of the basal area and cuttings in these strips must be separated by at least five years time.

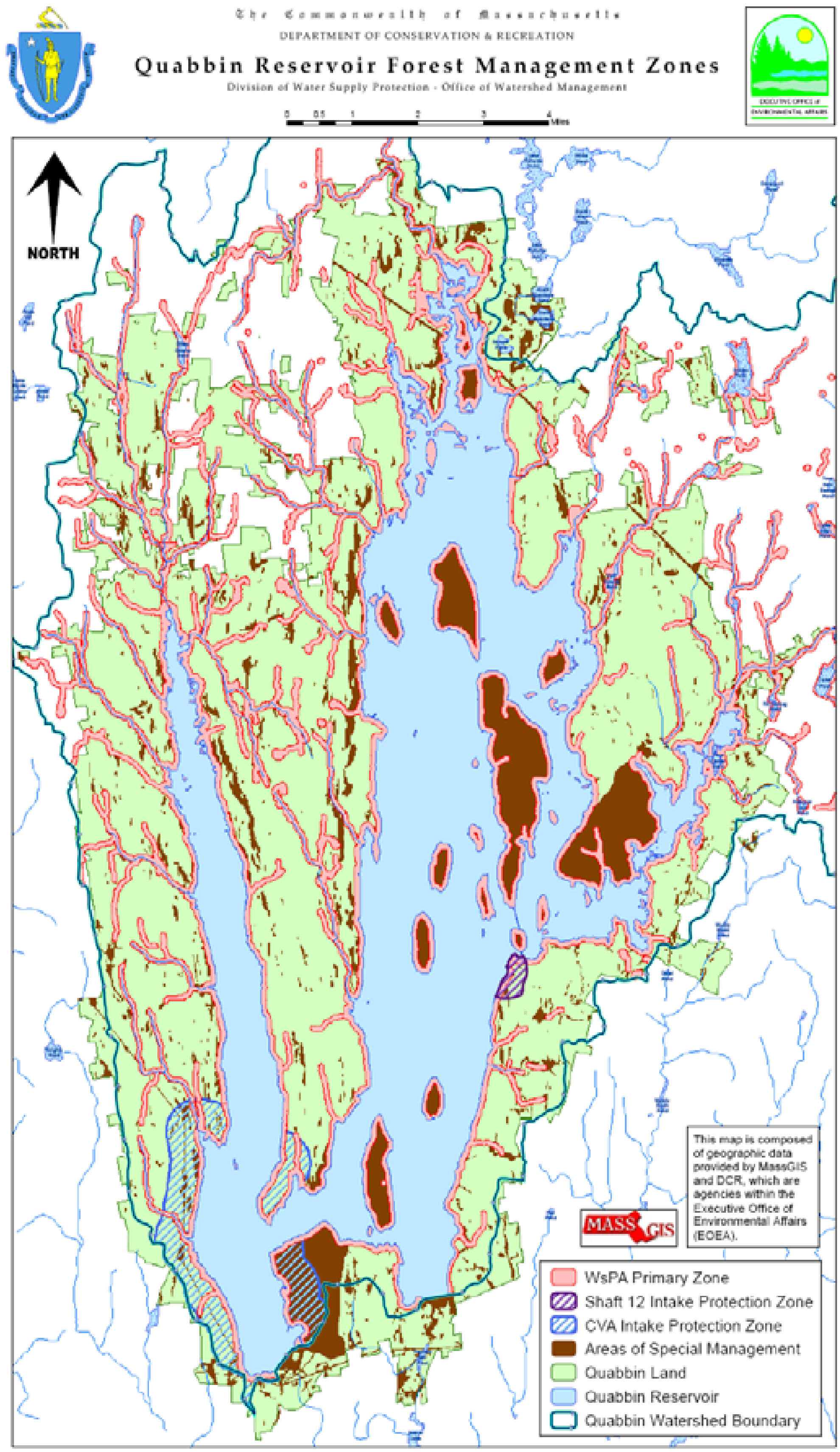
Filter strips are required along all water bodies and certified vernal pools (note that the Division treats all vernal pools as certified, whether or not they have been officially certified). Filter strips are a minimum of 50 feet in all cases, and are of variable width depending on slope along Outstanding Resource Waters (ORW) and their tributaries. Since Quabbin Reservoir is an ORW, all tributaries under DWSP control that also lead into the Reservoir are treated with variable width filter strips.

Vernal pools within DWSP holdings are treated as certified, and therefore subject to the 50 foot minimum filter strip requirement, within which not more than 50% of the basal area may be cut within any five year period. Further details for harvesting around vernal pools are included in **Figure 18 (page 180)**.

In some cases, variable width filter strips may exceed the limits of Zone 1 (for example, where a steep bank mandates a variable width filter strip that is greater than 200 feet wide). Where this is the case, the filter strip boundary determines limitations on harvesting.

In total, Zone 1 covers at least 13,857 acres (this is the acreage in DEP Zone A), or about 24% of the DWSP properties surrounding Quabbin. A smaller area of 7,933 acres is in Zone A and within the manageable portions of the property (i.e., not including islands, steep slopes, Pottapaug Natural Area, etc.; see **Table 41**). Zone 1 represents about 17% of the manageable area.

Figure 16: Quabbin Forest Management Zones



5.2.3.3.2.2 DWSP Forest Management Zone 2

Zone 2, also referred to here as the Intake Protection Zone, is a modified version of the Pathogen Control Zone and the DEP Zone B. For the CVA, this zone includes the area within ½ mile of the portions of the reservoir identified in the Pathogen Control Zone. For the Shaft 12 intake, this Intake Protection Zone is the land that is within a ½ mile radius of the intake, but also no further east than the watershed divide that sheds water either to the west or the east of the baffle dam. The CVA Intake Protection Zone includes 2,435 acres; the Shaft 12 Intake Protection Zone includes 128 acres.

Zone 2, CVA Intake Protection Zone

5.2.3.3.2.3 DWSP Forest Management Zone 3

Zone 3 is the land that is outside Zones 1 and 2 and is hydrologically the most remote zone from the reservoir. This zone covers approximately 36,179 acres or about 62.3% of the DWSP properties surrounding Quabbin. Zone 3 covers about 77.5% of the manageable area.

5.2.3.4 Harvesting Limits Within and Among Zones

As described in section 5.2.3.2, the Division will limit harvesting on a subwatershed basis to not more than 25% of the subwatershed forest cover in any given 10 year period. To reflect both the regulatory limitations and the hydrologic sensitivity of the three zones described in section 5.2.3.3, DWSP will further limit its harvesting activities within each zone.

- In Zone 1, harvesting and wetlands protection regulations require certain limitations on silvicultural practices. In order to address these regulations and the heightened hydrologic sensitivity of these areas, cutting within Zone 1 will be limited to:
  - Single-tree selection or small group or patch selection up to 0.5 acres in size, unless Chapter 132 is more limiting.
  - Within filter and buffer strips, cutting is limited to 50% of the basal area at one time, with a five-year waiting period between harvests, and the residual forest trees must be well-distributed and in good, vigorous health following the harvest.
  - Cutting around vernal pools is described in detail in **Figure 18 (page 180)**.

- In areas of Zone 2, the Intake Protection Zone, that overlap Zone 1, the restrictions on Zone 1 will prevail. In the remainder of Zone 2, harvesting will be limited to single-tree or small group or patch selection, with group/patch size limited to a maximum of one acre.

- Within Zone 3, considered to be hydrologically the most remote zone, harvesting will be in single tree, small group, and patch cutting, with the majority in groups and patches under 2 acres in size, but also including a limited number of larger openings as described below.

With a target of regenerating approximately 400 acres per year, regeneration harvesting will be controlled among all zones. Each year, at least 90% (360+ acres) of the regeneration cutting will be in single tree or small group selection harvests not to exceed 2 acres, and completed within Zone 1 (single tree and small group selection up to 0.5 acre), Zone 2 (single tree and small groups not larger than 1 acre), and Zone 3 (single tree and small groups not larger than 2 acres).

On a limited basis, DWSP will harvest patches greater than 2 acres in size. During the original Forest Stewardship Council certification of Quabbin land management practices by auditors from SmartWood in

1997, the audit report recommended that the Division should include "new management strategies that will maintain and promote biodiversity at the landscape level" (SmartWood, 1997). This recommendation derives from SmartWood observations under Criteria 3.11 for certification, regarding silvicultural prescriptions. SmartWood expressed the concern that, "In many areas on the Quabbin Watershed, the exact same silvicultural prescription is being marked and implemented. The ecological concern is that this will, over time, create a homogenous forest and greatly reduce horizontal diversity." The auditing team recommended that canopy gap sizes should be adjusted to address this concern. While the Division remains committed to the concept of diversifying the forest on the stand level in order to build resistance and resilience, there are hydrologically more remote areas on which achieving landscape-level horizontal diversity through the creation of larger openings is desirable.

In addition, there are occasionally situations in which full removal of the overstory of a stand of trees, even within an overall silvicultural strategy of developing stand level diversity, makes more sense than partial removal. Examples include densely planted artificial stands that were located on wetter sites and were never thinned. Due to the very weak form of the individual trees in these stands, partial cutting frequently leads to wind throw of the remaining stand. There may also be situations in which disease has entered a stand and is threatening to spread farther. In these situations it is sometimes desirable to cut out the entire diseased portion of the stand to prevent further spread and/or to more rapidly regenerate the stand to a more resistant mix of species. Finally, there are areas within the watershed forest that are hydrologically remote from the reservoir and on which it would be desirable to open a large area in order to produce early successional habitat for the benefit of certain wildlife species. Larger openings focus the harvesting on a smaller percentage of the management unit and can thereby reduce the percent of the area that is traveled by the harvesting equipment. Furthermore, these larger areas of regeneration do not require additional tending to release established regeneration. As the actual transport of the harvested trees presents a greater challenge to protecting water quality than the cutting of those trees, the reduced transport traffic may be an important benefit of larger openings in some areas.

In response to the recommendations for maintaining structural diversity at the landscape level, and to allow some flexibility for full overstory removals, each year up to 10% (40 acres) of the regeneration cutting will be in patches greater than 2 acres in size. These larger openings will be completed within Zone 3 only.

In addition to being at least 400 feet from the bank of the reservoir and at least 200 feet from the bank of any tributary to the reservoir, openings greater than 5 acres will *not* take place within the Pathogen Control Zone (see **Figure 22, page 219)**, will be on land that is hydrologically remote from the CVA and Shaft 12, and will be justified on the basis of meeting secondary objectives for biological diversity (early successional habitat creation) or to address a silvicultural concern. These larger openings must also be proposed within reasonable constraints on slope, soil and forest types, and will have additional public notice and review before implementation. The specifics of these proposed larger openings will be reviewed internally each year, as a component of the annual internal review of proposed harvesting (see Section 5.2.7).

By GIS analysis, the breakdown of DWSP properties by zones within the manageable portions of the Quabbin Reservoir watershed is shown in **Table 41.**

Table 41: Acres by Management Zone

Area	Acres	% of Total	% of Manageable
Total Quabbin DWSP holdings	58,412	100.0	NA
Areas with Special Management Restrictions			
Islands	3,674		
Steep slopes	1,712		
Wetlands	2,272		
Pottapaug Natural Area	1,183		
Quabbin Park (western portions)	1,058		
Others (cultural, rare species habitats, etc.)	1,837		
Total Areas with Special Management Restrictions	11,737	20.1	0.0
Manageable Area			
Manageable area in Zone 1	7,933	13.6	17.0
Zone 2, the Intake Protection Zones	2,563	4.4	5.5
(Zone 1 areas *within* Zone 2)	(734)	-	-
Manageable area in Zone 3	36,179	61.9	77.5
Total Manageable Area	46,675	79.9	100.0

5.2.3.5 Protection Provided for Water and Wetland Resources by Zones

Water and wetlands are the most important resources on drinking water supply watersheds. The zoning strategy outlined in Section 5.2.3.3 is designed to provide exceptional protection for these resources on the Quabbin Reservoir watershed. This protection is provided by overlapping policies, and in summary provides the following:

1. Tree harvests will not exceed 25% of any given subwatershed in any given 10 year period in order to protect against undesirable increases in water yield and associated increases in sediment and nutrient transport.

2. A minimum fifty foot filter strip will be maintained along all water bodies and vernal pools, as provided by Chapter 132, in which harvesting is limited to 50% of the basal area. As Quabbin Reservoir is an Outstanding Resource Water, this filter strip is of variable width, increasing with slope along the edge of the reservoir and all tributaries to the reservoir.

3. All stream crossings within 1,000 feet of the reservoir will use a portable bridge, as required by Chapter 132. A "stream" for these purposes is defined as "a body of running water, including brooks and creeks, which moves in a defined channel due to a hydraulic gradient, and which flows within, into, or out of an area subject to protection under the Wetlands Protection Act…Such a body of running water, which does not flow throughout the year (intermittent) is a stream except for the portion up-gradient from all bogs, swamps, wet meadows, and marshes." The Division furthers this protection by committing to cross all flowing water, regardless of its location or permanence, on a portable bridge so that even intermittent streams that are up gradient of wetlands will be crossed using a bridge if they are flowing or are likely to flow during the time that the work is being conducted.

4. Cutting practices and opening sizes will be restricted in areas of the Division's Zone 1 that are within 400 feet of the edge of the bank of the reservoir and 200 feet of the edge of the bank of all tributaries to the Reservoir. The minimum expression of this zone is shown in **Figure 14**. The Division recognizes that the mapping data used to define the area covered by DEP Zone A (and therefore, the Division's Zone 1) has missed some significant tributaries that flow to the reservoir.

This map, and its application in the field, will be subject to interpretation. A significant tributary that is not shown on the map will still receive the protection provided by Zone 1. An intermittent stream that is not shown will be protected according to Chapter 132 and the Division policy regarding stream crossings.

5.2.3.6 Species Composition Objectives

5.2.3.6.1 Diversity of Species Composition

The current species composition for the Quabbin forest is described in Section 2.4.2. The dominant species in the overstory of this forest are white pine and red oak, and the top ten species are shown in **Table 42**. There is no current plan to deliberately alter this landscape level species composition, with the exception of red pine, which occurs on the watershed due to planting rather than through natural regeneration and is frequently susceptible to the root rotting fungus *Heterobasidion annosum* (formerly called *Fomes annosus*). The Division has worked to replace red pine plantations with diverse natural regeneration of native species. As a result, the overstory stocking of red pine declined from 7.3% of the total stocking in 1990 to 2.8% of the total in 2000.

While there is no plan to deliberately alter the composition of the overstory (other than to reduce planted red pine), a number of changes in overstory composition are occurring naturally that will influence future composition. The Hemlock Woolly Adelgid, discussed in detail in section 5.2.4.1, arrived on the watershed within the past decade and is reducing the overall stocking of this species at a relatively rapid rate. The adelgid affects all ages of hemlock, from mature overstory trees to the youngest regeneration. Among other species impacts, white ash remains in decline as a result of a suite of pests. As the Quabbin forest has been maturing without catastrophic disturbance for many decades, the early successional species such as grey birch continue to decline.

Table 42: Top Ten Quabbin Overstory Species in 2000

Species	% of 2000 Stocking
White pine	28.2%
Red oak	19.6%
Red maple	13.3%
Hemlock	8.9%
Black oak	6.8%
Black birch	4.9%
White oak	3.8%
White ash	3.5%
Red pine	2.8%
Sugar maple	1.8%

In the most recent regeneration surveys for the Quabbin watershed, white pine dominated the understory trees species, with red maple and black birch also well represented across the watershed. The oaks were less abundant and are notoriously more challenging to regenerate successfully (it is well-established that the dominance of oak in the current overstory forest relates in part to the intensity of precedent land use disturbances, including fires and clearcutting, as well as lower deer pressures at the initiation of these stands). While the oaks are well-represented in regenerating stands, they are not as strong in the understory as they are in the overstory at Quabbin, a trend that is likely to continue due to a variety of difficulties in regenerating these species. Hemlock regenerates well, but the regeneration is as susceptible to the Hemlock Woolly Adelgid as the overstory. Protracted deer browsing impacts have resulted in a variety of challenges to replacing the current overstory. White pine and black birch each persisted in areas with mildly elevated deer numbers and on large segments of the watershed they are likely to dominate the species composition there at least through the current rotation. This condition may also have consequences for water yield, due to the higher annual potential evapotranspiration of the conifers versus the deciduous hardwoods.

Allowing more options for group/patch size in zone 3 should enhance species diversity due to the greater variety of microclimate and shade conditions that can be produced with a greater variety of opening sizes. Shadows from overstory trees adjacent to forest openings can be very long for much of the day during the growing season. Therefore species requiring full sun for much of the day to compete well should benefit from larger openings and/or from orienting irregular-shaped openings to reduce shading (e.g., north/south rather than east/west). The number of native species in this region that compete best in full sun is greater than the number of species that compete best in partial sun.

In the past decade, a moose population has established itself at Quabbin and the effects of this population on species composition are locally apparent. In studies from areas other than Quabbin, moose have shown strong preference for red oak, red maple, hemlock, striped maple, black and yellow birch, ash, sugar maple, poplar, blackberry, and witch hazel. Once again, white pine is not preferred by this browser, so that as the moose population rises, white pine regeneration is likely to benefit further.

5.2.3.6.2 Species/Site Suitability

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

Quabbin soils are predominantly acidic in nature due to underlying granitic rock. Acidic soils support our most common trees: white pine, red and black oak, hemlock, and red maple. Trees that require more alkaline soils, such as sugar maple or basswood, are present but not common to this area. Soil moisture availability and soil drainage are also important factors in site suitability. The pines do well on well-drained soils, where these evergreens can capture moisture throughout much of the growing season with an extensive root system. Optimal conditions for white pine are well-drained sandy loam soils in river valleys with available moisture, three to four feet below the surface. The oaks do well on soils that are moderately well-drained and have moisture available for much of the growing season. Optimal conditions for oak occur on terraces at the base of steep slopes, where moisture and nutrients accumulate.

Site/species associations on the Quabbin landscape have been influenced, sometimes dramatically, by human land-use practices. The use of fire to clear land as well as fires started accidentally in the remains of past harvesting practices has favored the establishment of oak simply because it is among the species most capable of recovering (through vigorous sprouting) following fire. Tree planting that occurred in the 1930s and 1940s often placed non-native conifer species on sites where they would grow well (mesic agricultural fields), but where they also were more susceptible to such problems as *Heterobasidion annosum* (formerly called *Fomes annosus*) root-rot. Grazing practices left behind species that were not preferred by the grazing animals, but that might not be the native species best able to grow vigorously on these sites. There are vast acreages throughout New England of former grasslands into which white pine was able to establish seed and grow, but under conditions that favored the white pine weevil. As a result, the pine growing on these sites tends to carry a weak form caused by repeated weevil-kill of its terminal shoot.

It is an objective of Quabbin forest management to grow a vigorous, low-maintenance forest. This objective will be met more successfully as the species combinations growing on any given site are assessed for their suitability and, if necessary, moved toward more vigorous combinations. For instance, while DWSP has aggressively converted off-site red pine plantations to mixed combinations of native species, some of this type of conversion remains to be completed. Likewise, poorly formed white pine growing on old field sites will continue to be converted to mixed species combinations that are likely to persist longer in the face of both chronic and catastrophic stressors.

5.2.3.6.3 Water Use by Species

It is a goal of this management plan to maintain current water yields (see Water Yield Goals, Section 4.1.2). As the annual potential evapotranspiration rates are significantly higher for evergreen/conifer types than for hardwood/deciduous types, maintaining the current balance of these types will be important in meeting the goal to maintain current water yields. In spite of the conditions that favor an increased dominance of white pine in the regeneration of the next forest, it will be an objective of the Division to retain the current balance of evergreen overstory types versus deciduous types. At the present time, softwoods occupy 21% of the Quabbin forest, hardwoods occupy 47%, and mixed types occupy 25%. While white pine types may increase at the expense of some of the more difficult to reproduce oak types, this will be balanced by the conversion of red pine and hemlock types to mixed or hardwood composition.

5.2.3.6.4 Nutrient Control

Research indicates some variability among eastern US forest species in their ability to control nitrogen losses (Lovett, et al., 2002; Lewis and Likens, 2000; Christ et al., 2002). The carbon to nitrogen (C:N) ratio in and at the surface of the soil is important among the causes of these differences; a high ratio results in a high demand for N by soil microbes, so that nitrification rates are lower and the export of N off the site is less likely when the C:N ratio is high. C:N ratios relate predictably to overstory tree species composition in areas of the eastern U.S. For instance, C:N ratios in the Catskills in New York were higher under red oak and red maple stands than under sugar maple stands, and N export was higher from sugar maple stands than from red oak or red maple stands (Lovett, et al., 2002).

Studies in Eastern hemlock stands have indicated similar relationships. Hemlock produces an acidic duff layer as well as a cool, dark understory that in combination result in slow decomposition rates and a high C:N ratio. This high C:N ratio also supports low nitrification rates and low nitrate or cation export (Yorks, et al., 2000; Finzi, et al., 1998). Where mortality occurs in hemlock stands, temperature, decomposition, and nitrification rates increase; nitrification rates in gaps in the hemlock forest can be as high as twice those within the undisturbed hemlock forest (Mladenoff 1987). The conversion of hemlock to deciduous replacement types can result in an increase in pH and in mineralization/nitrification rates, as well as a long-term decrease in stored cations leached by nitrate and other anions. These changes are of particular concern where hemlock is growing adjacent to streams due to the increased possibility of moving nutrients into the stream water (Yorks, et al., 2000). Research has further shown that *Betula lenta* (black birch), which commonly regenerates beneath damaged hemlock stands, is capable of capitalizing on nitrate availability more efficiently than some other species (Crabtree and Bazzaz, 1993).

The Division recognizes that changes in species composition are brought about by a wide range of variables, and thus has not set rigid species objectives. The concern for long-term nutrient dynamics will nevertheless be a consideration in silvicultural practices that are likely to alter forest type.

5.2.3.6.5 Economic Value

Economic value does not directly influence a tree's value for water supply protection. However, the options for silvicultural treatment of these forests may be enhanced to the extent that the commercially more valuable species can be regenerated and grown. The commercial value of a particular species is subject to the variations in consumer demand, although some species have remained relatively high in value for long periods of time.

White pine is a versatile species that is easy to use in a wide variety of commercial applications, is relatively easy to reproduce and grow, and can be produced in higher volumes on a given acreage than most other species. Red and white oaks are more difficult to regenerate, but have maintained a high market value until recently, and even recent declines leave the oaks still among the top species for value per board foot. Red maple has traditionally been a relatively low value species, sold primarily for fuelwood or pallet stock, but recent consumer preference for the light-colored hardwoods has significantly increased the value of sugar maple and even the better quality red maple. Most of the region's birches (paper, yellow, black) have traditionally sold to fuelwood or hardwood pulp markets, although the very best birches can be sold to the veneer market, where the clear-faced logs are peeled to make birch-veneered cabinets. Black birch can command high prices when individual stems reach veneer log dimensions without degradation. The frequent occurrence, however, of the *Nectria* fungal canker results in damage to the tree that prevents it from reaching full potential value.

Hemlock has grown well in the Quabbin forest, but has not generally commanded high prices, although the demand for hemlock as pulp increased significantly during the past decade. The Hemlock Woolly Adelgid has increased the volumes of hemlock sent to market, which can further depress market value as landowners rush to salvage value from threatened stands.

5.2.4 Implementation of the Forest Management Approach

Zones 1, 2 and 3 have been identified and mapped, as well as most subwatersheds. As mentioned above, there are forest management limitations imposed by the zoning scheme to help protect water quality but these zones do not provide specific harvesting locations. Our goal is to regenerate 10% of the managed forest over the next 10 years, distributed throughout all three management zones. The decision on which 10% will be regenerated and which 90% will not be regenerated will be based primarily on stand conditions For administrative purposes, Division holdings on the Quabbin watershed have been divided into five management blocks. These blocks will be divided into 20 -50 working units per management block. The management units in north Quabbin will use existing compartments as working units (there are currently 93 compartments averaging 580 acres in size at Quabbin). The management units in south Quabbin will be divided into 20 to 50 working units, delineated by streams, roads, stone walls or other permanent features. Each management block is about 12,000 acres and is treated as a separate sustainable unit. . Within the next 10 years, the working units/compartments within each block will be divided into stands and inventory data will be collected on these stands. Each working unit/compartment and all stands within those working units/compartments will be visited on ten-year intervals. Stand examinations will be conducted on these visits and the data collected will be used to prioritize stands needing silvicultural treatment. These data will be entered into a database to create long term profiles of stand and forest level change to augment the CFI system. Data collected for each stand will include:

- relative stand density (basal area - high, medium, low for stands of this type)
- stand height (20' ht classes)
- forest type
- stand age (20 yr age classes)
- regeneration type and adequacy
- relative stand condition (vigor/quality - high, medium, low)
- special features (unique habitats, vernal pools, significant forest and wildlife features)

Silvicultural activities will be dispersed across the watershed to enhance diversity and aesthetic amenities by following a sequential pattern. Working units will be numbered one through n (n=number of units for this management unit). Each year about 10% of the working units/ compartment will be examined, starting the first year with compartments/ units 1,11,21,31,41, etc., with 2,12,22,32,42, etc., examined the second year, and so on until the entire forest has been covered. This planned pattern may be disrupted by the need to address pest or weather disturbances, but will generally dictate the areas to be treated.

Priorities for treatment will be set using stand examinations in each year's working units/compartments. To achieve a diverse age structure, about 1% will be cut in each zone each year. This may vary from year to year but will equal 10% after ten years.. Over time, this cutting regime will begin to balance the age structure of the forest in these areas, adding resistance and resilience to the forest cover.

Stands within zones 1, 2 or 3 will be prioritized for silvicultural work as follows:

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

While approximately 12,000 acres will be designated as unmanaged areas within the Division's holdings surrounding Quabbin Reservoir, the remaining 46,000 acres will be actively managed to maintain resistance and resilience through deliberate improvements in age and species diversity within any given subwatershed. The silvicultural disturbance of these managed areas will reflect the average rate of natural disturbance in these forests, which ranges from approximately 0.5% to approximately 2.0% per year (Attiwill, 1994), or approximately 1.0% per year on average. To meet this objective, approximately 1% or approximately 400-450 acres of the managed forest will be regenerated annually, on average, during the next 10 years.

5.2.4.1 Silvicultural Practices

Forest management activities during the period covered by this management plan continue to emphasize the development of multi-aged or uneven-aged conditions on the majority of the managed area of approximately 46,000 acres. Uneven-aged stands are defined as those that contain at least three distinct age classes, differing in total height and age (Smith, et al., 1997), and managed on cutting cycles that enable established regeneration to be released sufficiently to be free to grow as new age classes. Uneven-aged silviculture, focused primarily on small-group selection, tends to favor shade-tolerant and mid-tolerant species. In order to regenerate the less tolerant species, and to provide a more varied forest structure across the landscape, the plan also accommodates patch cutting, in which opening size and shape provide conditions in some portion of the opening that are outside the influence of the mature trees on the edge of the openings (generally when the opening is at least twice as wide as the height of the tallest surrounding trees, although this will vary with slope and aspect). The combination of methods that includes patch cuttings supports a range of species and ages that may not strictly follow the definition of uneven-aged structure, and is referred to instead as multi-aged structure. While sustainability is often measured by the balance between growth and harvest, the silvicultural objective for the management of the watershed protection forest is primarily driven by the need to provide long-term protection for water quality, rather than the need to produce an optimized, consistent flow of wood products.

2-year post harvest multi-aged structure developed via small group selection on Prescott Peninsula

5.2.4.1.1 Regeneration methods

The proposed regeneration silviculture for this ten-year management period at Quabbin will consist primarily of small group and patch selection cutting. Regeneration establishment may also be encouraged through limited "enrichment" planting if necessary. So long as herbivore pressure and competing native or exotic vegetation are kept under control, regeneration establishment is generally very successful in the Quabbin forest. Seed sources are diverse and frequently prolific, and regeneration monitoring shows high numbers of seedlings established on the forest floor with few exceptions. In the few cases where this natural regeneration has been impaired, a limited amount of

Recently harvested small group selection and patch cuts, New Salem block planting may occur to enhance the diversity and/or the density of the seedling pool (enrichment planting during 1995-2005 is summarized in **Table 44**).

The majority of the harvesting that will take place at Quabbin over the next decade will be made to release regeneration that has become established in the understory or will become established within 5 years , thus developing new age classes capable of persisting to mature overstory trees. Advance regeneration will not be required on all lots due to the relatively small average opening sizes proposed in this plan. Seed sources are abundant in most of the forest and the proposed openings provide environmental conditions that allow a diversity of regeneration to become established in a short time period on most sites.

The overall DWSP silvicultural objective remains focused on the development of a multi-aged forest for water supply protection, with age diversity ranging from multi-aged or uneven-aged conditions in stands where small group selection cutting is the chosen silvicultural method, to primarily even-aged conditions on the limited number of small stands that are regenerated with patch cuts greater than two acres. The general distinction between a "small group" and a "patch" revolves around the influence of edge trees over regeneration within the opening. Where the shape and size of the opening retain the influence of the surrounding trees, it is considered a small group. Where portions of the opening are beyond the influence of the surrounding trees, it is considered a patch. Small groups may be as small as the area released by cutting a single large tree, or as large as two acres if the cut area is relatively narrow in shape.

In timber sales where the average size group is under ½ acre, all groups will be estimated to the nearest 1/10 acre and all groups over 1/10 acre will be measured using GPS units. In timber sales where the average opening size is ½ acre or more all groups/patches will be estimated to the nearest ¼ acre and all groups over ¼ acre will be measured using a GPS unit. Residual basal areas under 10sqft will be ignored when calculating regeneration acres. In areas that lack regeneration, shelterwood and seed tree type cutting will be an option provided the seed cuts are not larger than the allowed opening size for the zone in which the cutting takes place.

Table 44: Enrichment Planting of Tree Seedlings, 1995 - 2005

Year	Red Oak	White Pine	Norway Spruce	Red Pine	Sugar Maple	White Ash	White Oak	Hemlock	Others	Total
1995	5,900	20,000	10,000	0	2,600	6,600	0	0	0	**45,100**
1996	10,000	33,000	0	3,000	0	0	0	2,000	0	**48,000**
1997	14,000	10,000	0	0	2,000	0	1,500	0	0	**27,500**
1998	13,000	9,000	0	0	2,000	0	1,000	0	0	**25,000**
1999	21,000	0	7,500	0	0	0	1,500	0	0	**30,000**
2000	20,000	23,000	0	0	0	0	0	0	0	**43,000**
2001	300	4,000	2,000	2,000	280	0	0	0	500	**9,080**
2002	6,000	2,000	2,000	2,000	0	0	0	0	300	**12,300**
2003	11,500	5,100	4,000	4,000	0	0	0	0	0	**24,600**
2004	5,000	0	0	6,000	0	0	0	0	0	**11,000**
2005	NO SEEDLINGS PLANTED									**0**
Total	**106,700**	**106,100**	**25,500**	**17,000**	**6,880**	**6,600**	**4,000**	**2,000**	**800**	**275,580**

5.2.4.1.2 Post Harvest Monitoring of Regeneration Cuttings

Many things influence the outcome of regeneration cutting. Site conditions such as shade, soils, aspect, seed sources, forest floor disturbance, or advance regeneration can have some impact on the desired regeneration. Herbivores such as moose, deer, and beaver as well as insects, diseases, weather conditions, and fire can also have very serious impacts on regeneration. Because many of the things that can influence the outcome of regeneration cutting are constantly changing, it is often difficult to predict in advance what their impact on regeneration will be several years after the harvest. In order to keep up with and adjust to these potential effects on regeneration success, all timber sales involving regeneration cutting will be inventoried 2 -5 years after harvesting. At this time our greatest concern is the impact of moose on regeneration; methods are under development to quantify this impact.

5.2.4.1.3 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. However, because the age structure at Quabbin is predominately older, maturing stands, it is difficult to avoid a regeneration response after an intermediate cut. If the regeneration that becomes established after an intermediate cut is not released within 10 years, intermediate thinnings will favor the more shade tolerant regeneration on many sites. In order to reduce the potential future impacts on species diversity (predominately shade tolerant species) we have reduced the amount of this type of cutting at Quabbin. As the age structure of the Quabbin forest changes to include more trees in the 20 to 60 year old age classes, the amount of intermediate treatment may increase.

Due to the relative scarcity of purely pole-sized stands on Division property at Quabbin, intermediate cuttings are rarely performed as the sole objective. Most intermediate operations are performed simultaneously with regeneration cuts, especially in stands that are being treated for the first time without the benefit of prior or recent management or those that have not been treated for many years. During the next ten years, intermediate cuttings may occur on up to 200 acres per year.

5.2.4.1.4 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. Studies show, however, that it is the activity associated with removing trees that is associated with these impacts, not the act of cutting them. DWSP recognizes these zones as the final and therefore most critical opportunity to slow or capture nutrients and sediments released by the variety of natural and human-caused events on the watersheds,

Lower reaches of Underhill Brook

and therefore does not categorically exclude them from management.

The preferred vegetative structure of riparian zones is an actively growing, diverse, self-perpetuating, and disturbance-resistance forest cover. Carefully planned and implemented human intervention may be the best method to maintain this forest structure throughout the variety of disturbances that impact all New England forests. To some degree, when these forests are within the bottom of stream and river valleys, they may be sheltered from winds. However, as riparian forests mature, and especially when they are in the path of destructive storms, they become vulnerable to sudden and dramatic change. When wind-throw or flooding occurs, it is of great concern to watershed managers because it can result in substantial amounts of soil and nutrient transport. Additional concerns include sudden changes in stream temperatures due to loss of forest cover and heavy accumulations of woody debris and sediments when trees fall directly into streams or the streams are dammed.

The most important source of resistance and resilience to build into the riparian forest 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 forest following most disturbances. Riparian forest that is simply left alone may establish sufficient regeneration as the overstory begins to age and decline in vigor. However, where full crown closure is maintained for long periods of time (especially in hemlock stands), 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, DCR managers intend to systematically "condition" certain vulnerable riparian forest to be better able to maintain their critical buffering functions throughout significant disturbances.

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

5.2.4.2 Silviculture by Forest Type

The principal forest types on Quabbin are described below, with a brief description of silvicultural approaches applicable to each type within the context of watershed management. These types may occur as pure stands, or more often as mixed forest with either gradual or sharp type changes related to soil types, aspect and elevation, and past land use history. **Table 18** in section 2.4.2.1 above provides details on all types and subtypes from the most recent aerial photo and field interpretation.

1) Oak Types

Red, black, scarlet, white, and chestnut oak comprise the five major species in this type, with red oak generally the most vigorous, dominant component. The type grows best on the more fertile, moist, moderately well-drained sites. Because of its superior vigor, red oak will be favored where moisture is sufficient to support its growth. While Quabbin is host to some of the largest contiguous oak stands in the Northeast, it is important to recognize that these stands were established through dramatic clear-cutting and burning, landuse practices of the past that were tolerated better by oaks than by most other competing species. Regenerating red oak through more conventional silviculture has been difficult, especially as these are desired species for browsing ungulates (deer, moose). It is likely, therefore, that the multi-aged silviculture proposed by this plan will ultimately result in the replacement of these oak stands with a wider diversity of species. While this replacement may compromise other values of these contiguous stands, such as hard mast (acorn) production, it supports the Division goal of increasing species diversity to improve stand resilience.

Scarlet and black oaks are plentiful on some well-drained upland sites (where lack of moisture limits red oak) but are generally of poor vigor. Gypsy moth infestations in the past have been most severe on these drier sites. Consequently, efforts have been made to increase the component of other species on these uplands, e.g. by salvaging dying oaks and underplanting with white pine in the resulting openings. White pine survives and grows well on these sites and the majority of these black and scarlet oak stands will eventually be converted to mixed stands of oak, white pine, and other species.

White oak, like black and scarlet oak, is also found growing on dry upland sites. However, it exhibits its best growth on moister soils. The acorn of the white oak is less acidic than that of the other, more abundant oak species, and consequently more valuable to wildlife. On the Quabbin watershed, white oak was a primary host to the gypsy moth and, due to physiological differences, suffered more severe mortality than the red oaks. White oak that is surviving and growing vigorously will receive preferential treatment in order to maintain the species as a component on the watershed.

Chestnut oak is primarily found growing on the poorest of upland sites on southern and eastern exposures in shallow soils, especially inside of Route 202. North of Route 202 in the West Branch of the Swift River, chestnut oak was commonly found growing with red and white oak. However, gypsy moth infestations of the early 1980s eliminated most of the chestnut oaks from these stands. Regeneration of chestnut oak has been successful where deer pressure has been reduced by hunting. Because this species occurs in relatively few sections of the watershed, it is desirable to maintain it where possible as the major component of a mixed stand as opposed to aggressively converting these sites to white pine.

2) White Pine Types

White pine is among the fastest growing species in the region and responds well to management. It is found most often on dry, sandy sites where hardwoods do not grow well or in abandoned pastures and fields where its heavier seed was capable of penetrating the thick grasses more successfully than hardwood seed (Spurr and Barnes 1980:444). White pine grows most vigorously on moist sandy and silty loams, but it is difficult to establish on these sites because of hardwood competition. Where deer browsing levels have been moderate, there are moist sites where white pine has become established on moist sites due to preferential browsing on hardwoods. These areas will eventually support a more mixed composition, but will tend toward white pine for the next generation.

Most of Quabbin's white pine stands are 65 to 100 years old, the result of natural seeding in old, abandoned pastures and fields, vestiges of stands damaged during the 1938 hurricane, and remnants left over from silvicultural operations prior to DCR ownership. White pine that becomes established in low densities in abandoned pastures is often exposed to repeated white pine weevil infestation. The resulting multiple-leader crown is often more susceptible to wind and ice damage and subsequent fungal invasion than high-density, forest-grown white pine.. Where these occur as isolated trees, they do not constitute a risk to watershed cover maintenance. However, where they comprise the majority of a stand, their gradual removal and replacement with understory trees that will develop a stronger form is desirable.

Some of the Quabbin white pine component is within plantations established in the 1930s and 1940s. Many of these plantations were planted as a mix of red and white pine. The sites chosen were often moist, rich agricultural sites, where red pine grew much more vigorously than white pine. In addition, these moist sites correlate with high infestations of the white pine weevil. As a result, much of the white pine that has survived in plantations is suppressed beneath the red pine, and shows signs of repeated weeviling. Intermediate cuts in the few remaining mixed pine plantations will continue to preferentially remove the white pine.

3) Red Pine Type

Red pine is an uncommon native species in this area, but was successfully established, in conjunction with planted white pine, on approximately 2,750 acres on the Quabbin watershed during the 1930s and 1940s. Red pine is capable of growing well on a variety of sites, but is most stable on moderately well-drained, sandy loams, where root depth is less limited. On the more moist and fertile sites, red pine has grown to a total height of 90 feet and a diameter at breast height in excess of 24" within 50 years from planting. However, it is on these same sites that red pine has exhibited susceptibility to root rot disease (*Heterobasidion annosum*, formerly called *Fomes annosus)* and to wind throw. For watershed purposes, it has therefore been an objective for more than a decade to convert these sites to a more reliably stable cover of mixed native hardwoods. This conversion was aggressively promoted during the previous management period, and many of these susceptible stands have been successfully converted. Where root rot diseases have killed more than scattered trees, sanitation clearings will continue to be conducted in remaining moist-site red pine plantations, both to halt the spread of the disease (which passes from tree to tree through root grafting) and to hasten the conversion to site-suited species.

4) Birch/Red Maple Type

Black and paper birch, as well as red maple, will occur as pioneer species on many sites, but this overstory type is generally found growing only on moist sites, where red maple is usually the dominant species. While it tolerates these sites better than most species in the establishment phase, maturing red maple is quite susceptible to heart rot where soil drainage is slow. Generally, the black and white birches that establish successfully in these areas do not thrive beyond about forty years of age. Black or sweet birch is particularly susceptible to *Nectria* canker, and paper birch in these areas may develop red heart, a fungal complex. Both the stems and branches of the birches are damaged easily by ice and heavy snows.

In some cases, birches dominate the overstory because they were a less preferred deer browse in early stages of succession, or were able to outgrow livestock grazing on pasture sites. The same browsing/grazing pressure apparently prevented later successional stage components, such as oaks, ashes, sugar maple, and hemlock, from replacing the pioneers. Where there are scattered stems or small groups of more long-lived species, intermediate cuts will favor their growth and development as seed sources. Where long-lived species are missing, regeneration cuts will reestablish more comprehensive stand development.

5) Hemlock Type

Hemlock grows most often in cool moist areas along brooks and streams and on north-facing slopes, but is also found on a wide variety of other sites. Hemlock stands are generally the best winter deer cover on the watershed and have been heavily browsed. As a result, hemlock regeneration has been extremely limited across the Quabbin Reservation. While gypsy moth and the hemlock looper have attacked individual trees or stands for many decades, their impact pales compared to the devastating impact of the hemlock woolly adelgid. See section 5.2.4.1 for much greater detail on this pest and the agency's forest management response.

Due to these pressures on the species, the majority of silviculture within the type during this decade will be salvage operations and scattered intermediate cutting to maintain vigor and seed-producing capabilities. However, where diversification of vertical structure within hemlock stands is desirable, regeneration cuts may be conducted within the constraints of the current hemlock woolly adelgid management policy.

6) Spruce Type

The majority of the spruce trees growing at Quabbin were planted in the late 1930s and early 1940s. Norway, red, and white spruce were planted. While some of the Norway spruce plantations have grown very well (in particular, on Prescott Peninsula), the red and white spruce generally did poorly. Approximately 500 acres of spruce plantations survived establishment. Limited silviculture was conducted in these stands during the past decade, taking advantage of the ability of mechanized harvesting equipment to fell and process the typically limby stems within these dense, generally unthinned plantations. Markets have been fairly strong for this species in recent years. These improved opportunities will be utilized to create additional forest layers as needed in these uniform stands. Spruce regeneration has been most successful in more open conditions and efforts will be made to gradually enlarge existing openings and create new openings to perpetuate this unusual component of the forest.

There is evidence in the literature that some of the spruces are among the best choices of species for wind tolerance. Spruce wood is generally quite strong relative to other conifers, and its stem tapers very slowly, increasing resistance to breakage. Spruces cones are well-utilized by a variety of wildlife. Black spruce is also particularly tolerant of wet conditions and an appropriate plant for revegetating deforested riparian areas. For all the above reasons, spruce will be among the species considered for planting in wetter riparian areas.

7) Northern Hardwoods

Northern Hardwoods include sugar maple, black and yellow birch, beech, and white ash growing on fertile sites on thick, moist, moderately well-drained, fine, sandy loams. Although they have survived insect attacks, dieback, acid deposition, and increased ozone concentrations, the perpetuation of these stands has been most heavily influenced by wildlife impacts. Seeds that manage to escape animal consumption and germinate into seedlings, with the exception of black birch and beech, were browsed heavily by deer during the previous decade. Because this type often grows in the moist bottomlands, mature trees are often girdled or felled by beaver, especially where deer browsing has eliminated other food sources. While there are a few pure stands of these species, they are usually found scattered throughout other types and will receive preferential treatment over most other species, due to their rare occurrence.

5.2.4.3 Summary of Planned Silvicultural Activities

The following summarizes the silvicultural strategy to be applied in the Quabbin forest over the next decade:

1. The total holding is ~58,000 acres, ~12,000 of which are unmanaged (islands, wetlands, steep slopes, designated natural areas), so that approximately 46,000 are considered manageable. As areas are assessed for management, small reserves from a few trees to multiple acres will be added to the unmanaged category, which may rise to 25% or more of the total holding as a result. The overall (and continuing) objective is to diversify age structure in the managed area by regenerating approximately 1% annually, or about 400 acres. This cutting will be restricted in several ways, described below.

2. DWSP will not regenerate more than 25% of any given subwatershed within any given 10 year period (this is an application of the results from research on paired watershed studies, which

conclude that with Conservation Management Practices (CMPs) in place, there is generally no increase in water yield, which in turn implies no increase in sediment or nutrient transport, until 25-30% of a watershed forest's basal area is cut within any given 3-10 year period (Ice and Stednick, 2004)).

3. Silvicultural practices will occur within three management zones:
   a. **Zone 1** includes the buffer strips along public roads, the variable width filter strip along streams and water bodies, and DWSP limits within filter strips around all vernal pools, and the area within 400 feet of the bank of the reservoir or within 200 feet of the bank of a tributary to the reservoir.
   b. **Zone 2, the Intake Protection Area** includes two protection areas, around the CVA and Shaft 12 intakes. For the CVA, this zone includes land within the watershed that is within ½ mile of the reservoir portion of the Quabbin Pathogen Control Zone. For the Shaft 12 intake, this Intake Protection Zone is the land that is within ½ mile of the intake, but also no further east than the watershed divide that sheds water either to the west or the east of the south baffle dam. The CVA Intake Protection Zone includes 2,435 acres, 695 of which are also in Zone 1. The Shaft 12 Intake Protection Zone includes 128 acres, 39 of which are also in Zone 1.
   c. **Zone 3** is the land that is outside Zones 1 and 2 and hydrologically most remote from the reservoir and intakes. This zone covers ~36,000 acres, or about 77% of the manageable area.

4. Cutting will be limited in all cases as follows:
   a. Zone 1 – single tree or small group selection up to 0.5 acre
   b. Zone 2 – single tree, small group, and patch selection up to 1 acre in size
   c. Zone 3 – single tree, small group, and patch cutting, with the majority in a diverse mix of groups and patches under 2 acres in size and a maximum of 10% of the total annual cutting (no more than 40 acres) in larger openings greater than 2 acres in size.

5. Cutting will be further limited as follows:
   a. Each year, at least 90% (360+ acres) of the regeneration cutting will be in single tree or small group selection harvest less than 2 acres in size, and completed within Zone 1 (single tree selection and small group selection up to 0.5 acre only), Zone 2 (single tree selection and small groups not larger than 1 acre), and Zone 3 (single tree selection and small groups with a target size of 1 acre or less, but not larger than 2 acres).
   b. In response to green certification recommendations that structural diversity at the landscape level should include some larger single-aged blocks and concerns for declining migratory birds and other species that require early successional habitat and certain silvicultural situations, each year up to 10% of the regeneration cutting will be in patches greater than 2 acres in size and completed within Zone 3 only.

6. In addition, up to 200 acres of intermediate thinnings will occur each year where necessary to increase group or stand vigor.

5.2.4.4 Comparison of Forestry in the 1995-2004 versus the 2007-2017 Quabbin Land Management Plans

- In the 1995-2004 Land Management Plan, the vast majority of the regeneration cutting was concentrated in small groups ranging up to 1 acre in size. The proposal was to regenerate 500-600 acres per year during the 1995-2004 management period; 388 acres per year were actually regenerated on average, plus 640 acres of preparatory or intermediate cutting. That plan allowed full overstory removal in special cases (red pine on disease-prone wetter sites; old grazing areas with low species diversity; and old field white pine stands with very poor form and vigor), and limited this type of cutting to a maximum of 50-60 acres of the managed forest annually.

- The current plan calls for regenerating 400 to 450 acres annually, still primarily in openings from single tree to about 2 acres in size, and with options to create larger openings where the site is hydrologically removed from the Reservoir and where these can be justified for silvicultural reasons or to enhance horizontal diversity in support of uncommon species. This target acreage would annually regenerate about 1% of the managed forest area during the coming decade. Openings larger than 2 acres would not total more than 10% of the annual regeneration cutting (not more than 40 acres per year). Intermediate thinnings are proposed on up to 200 acres annually.

- The proposed 2007-2016 LMP is a continuation of the overall strategy of diversifying the forest structure, but includes a stronger correlation between harvesting and hydrologic sensitivity through an on-going analysis of the percentage of any given subwatershed that has been treated in the previous decade, and through the establishment of the hydrologic zoning system described in Section 5.2.3.3.

Table 43: Harvesting at Quabbin Fiscal Years 1996-2005

Fiscal Year	Total Acres Harvested	Total Acres Regenerated	Board Feet	Cords	Tons	Revenue
1996	659	85	2,645,494	1,994	3,458	$306,048
1997	1,274	682	7,447,357	3,495	9,215	$727,993
1998	1,253	385	4,894,431	4,908	1,569	$677,017
1999	1,332	382	5,327,581	4,974	7,410	$567,504
2000	1,110	419	5,042,700	3,884	6,221	$1,028,977
2001	745	371	4,532,600	2,703	8,059	$524,075
2002	808	380	4,196,880	2,646	7,665	$571,601
2003	1,003	397	5,575,799	4,150	8,645	$704,882
2004	890	337	2,873,334	4,095	5,170	$381,540
2005	1,205	439	5,146,694	5,598	6,864	$757,708
TOTAL	**10,279**	**3,877**	**47,682,870**	**38,447**	**64,276**	**$6,247,345**
Average	*1,028*	*388*	*4,768,287*	*3,845*	*6,428*	*$ 624,734*

Table 44: <u>Example</u> of a *Possible* Cutting Pattern during FY 2007-2017, by Forest Management Zones

Type	Zone 1	Zone 2	Zone 3	TOTAL	Percent of type total
Regeneration cuts	*Acres by Treatment Type*				
Single tree	50	10	15	75	18.75% of regen cuts
Small groups to 0.25 acre	20			20	5.00% of regen cuts
Small groups to 1 acre		10	185	195	48.75% of regen cuts
Small groups to 2 acres			70	70	17.50% of regen cuts
Patches 2-5 acres			20	20	5.00% of regen cuts
Patches 5-10+ acres			20	20	5.00% of regen cuts
Total regeneration cuts by zone	*70*	*20*	*310*	*400*	
Intermediate thinnings	35	10	155	200	
Treatment totals	*105*	*30*	*465*	*600*	

5.2.5 Current Threats: Forest Insects, Diseases, and Invasive Exotic Plants

In the Quabbin 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. Generally, only large-scale outbreaks that threaten to alter tree species diversity or forest structure are of concern. Chestnut blight was such a disease. It was first discovered in the Quabbin forest in the early 1900s and fairly rapidly eliminated all overstory trees of the species. 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, playing a much less significant role in the protection of the water supply and in support of biological diversity through its significant production of mast. Fortunately, both of these roles have been replaced by the now common oak component of the Quabbin forest.

The gypsy moth is another example of a serious pest. It was first found in the forest surrounding the Wachusett Reservoir in 1910. A great deal of effort was spent in trying to control the inexorable spread of this insect. Epidemics of this insect can result in significant mortality of a wide range of tree species in both the overstory and understory resulting in alterations to forest structure, composition and vigor. Insect defoliations have also been demonstrated to affect water quality. Research from North Carolina has demonstrated that concentrations of stream nitrate nitrogen were elevated 4-5 times background rates during peak defoliations by cankerworm (Swank, et al., 1981).

Both the fungus that causes chestnut blight (*Cryphonectria parasitica*) and the gypsy moth (*Lymantria dispar*) are introduced organisms that came to the watershed forests without their co-evolved complement of predators and parasites; a recipe for the development of an altered ecological condition. Other examples that have in the past affected or are currently affecting the Quabbin forest include Dutch elm disease, beech bark disease, and white pine blister rust. The most significant current threat to the Quabbin forest is the hemlock woolly adelgid, a pest for which the Division has developed the policy that follows in Section 5.2.4.1.

5.2.5.1 Hemlock Woolly Adelgid and DWSP Policy for Managing Impacts

Hemlock woolly adelgid, *Adelges tsugae*

The hemlock woolly adelgid (HWA; *Adelges tsugae*) is a small aphid-like insect native to Japan. It arrived in North America in the 1920s, and was first recognized on the east coast of the US in 1951 and in Connecticut in 1985. It is spreading in all directions across the range of eastern hemlock (*Tsuga canadensis*). It is a serious pest on both eastern hemlock and Carolina hemlock (*Tsuga caroliniana Engelm*), but does not seriously injure the western hemlocks (*Tsuga heterophylla* or *Tsuga mertensiana*). Chinese hemlock (*Tsuga chinensis*) planted at the Harvard University Arnold Arboretum resists HWA (Peter Del Tredici, Senior Research Scientist, Arnold Arboretum, personal communication).

Eastern hemlock grows throughout the watersheds under the care and control of DWSP, but is concentrated in three forest types: relatively pure hemlock stands; in mixes where white pine dominates; and in mixes where hardwoods dominate. Forest typing completed in the past several years indicates that out of the approximately 58,000 acres of Quabbin watershed forest that DWSP controls, 1,642 acres (~3%) is in pure hemlock stands; an additional 5,434 acres (~9%) is in stands with a significant component of hemlock in mixes with other softwood and hardwood species. About 9% of the overall basal area on Quabbin permanent inventory plots was in hemlock in 2000, and hemlock sawlog volume based on those plots was approximately 30-35 MMBF. On DWSP properties on the Ware River watershed, about 7% of the overall stocking is in hemlock, the vast majority of which is in mixed white pine/hemlock stands, which total approximately 4,325 acres. A rough estimate puts the hemlock volume at Ware River in excess of 10 MMBF. Hemlock is <2% of the stocking, on just over 120 acres of hemlock/hardwood type on the Wachusett Reservoir watershed. A significant portion of the hemlock stocking overall is located on wet soils, on steep slopes, or in riparian zones, some of which are steep-sided ravines, while other stands are on drier and flatter terrain.

The hemlock woolly adelgid is a particularly troublesome pest on DWSP watersheds (and elsewhere) for several reasons:

1. The insect is without natural enemies in the northeastern US. Several potential biocontrols have been imported from Japan and China, reared in laboratories, and released at HWA sites, but to date these have had very limited impact for a variety of reasons. Successful chemical controls are mostly limited to systemics and dormant oil spraying. These can be effective in ornamental plantings, but are virtually impossible to apply in an extensive forest infestation.

2. The HWA is parthenogenic, which means that every adult is capable of reproduction. Each adult lays 50-300 eggs, typically about 100. Furthermore, the population successfully completes two generations within a year. The first eggs are laid in March and April. Crawlers hatch from these eggs and begin feeding at the base of needles, where they remain throughout development. This generation matures in mid-June, when adults lay eggs again. These hatch in July, move to new hemlock growth and then become dormant until October, when they begin feeding again. They continue feeding throughout the winter (the species evolved in high elevations in Asia and tolerates low temperatures), maturing by spring to begin the process again. Mortality rates observed during the winter of 2002-2003 were as high as 75% (Jen Pontius, USDA FS, personal communication), but the fecundity of this species will likely allow its rapid recovery.

3. While hemlocks that are under attack eventually become incapable of supporting the infestation, resulting in a population crash in the HWA on that tree, these trees are also incapable of recovering from this level of damage. Trees that are infected may die within 4-5 years, although some may persist for longer in a weakened condition. The insect attacks all ages of trees, though it prefers younger foliage. There is no clear evidence of resistance sufficient to allow any individual eastern hemlock tree to survive once infested with the hemlock woolly adelgid (Orwig et al., 2002).

4. Of particular concern to DWSP are location where hemlock dominates the riparian zone along streams leading to the reservoirs or the Ware River. Loss of this overstory may present short-term threats to water quality by raising stream temperatures and through uncaptured nitrogen and other cation losses following increases in nitrogen mineralization and nitrification rates. Regeneration may prevent significant losses to stream water.

5.2.5.1.1 Principle Issues From Current HWA Literature

1. All ages and sizes of Hemlock are susceptible to HWA infection, and infection will eventually kill the infected tree. Trees on poorer, drier, ridge top sites may die more rapidly than those on well-watered sites, but trees located on the full range of sites have become infected and ultimately died.

> Mortality was weakly related to aspect and stand size. Average mortality was highest on western aspects but exceeded 20% on most slopes. Remaining trees averaged over 50% foliar loss, with no significant

difference among aspects… Results suggest that as HWA becomes abundant, stands on xeric aspects succumb rapidly, but that stand and landscape variables such as overstory composition and structure, slope, and elevation, exert little control over susceptibility or eventual mortality. (Orwig et al., 2002)

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

> The total amount of N captured in recent harvests was about five times greater than HWA-damaged [unharvested] sites and nine times greater than undamaged sites….Compared with undamaged sites, inorganic N pools increased only slightly in HWA-damaged sites, but increased tremendously following logging.…Net nitrification rates were 41 times higher in HWA-damaged sites, 72 times higher in recent harvests, and over 200 times higher in old harvests when compared with the near-zero rates in undamaged hemlock sites.…Relatively large amounts of ammonium and nitrate captured in recent harvests indicate higher N availability, less vegetative uptake, and a greater potential for N leaching. Hemlock harvesting imposed more abrupt microenvironmental changes, and rapidly reduced vegetative cover while chronic HWA infestation led to gradually thinning canopies. Both disturbances led to black-birch dominated forests, although logging resulted in greater amounts of shade-intolerant regeneration, higher soil pH and nitrification rates, and reduced forest floor mass. Pre-emptive cutting of undamaged forests may lead to greater N losses than those associated with HWA infestation or logging of deteriorated hemlock forests, because of reduced vegetative uptake. Silvicultural methods that allow for vegetation establishment prior to harvesting will probably lessen the ecological impacts of hemlock removal.…We predict in sites infested with HWA, the slow and progressive hemlock decline and gradual development of a hardwood understory may result in the least amount of nitrogen loss. Pre-emptive cutting of undamaged sites appears to pose the greatest threat for nitrate leaching, followed by logging of declining sites. (Kizlinski, et al., 2002)
>
> There is clearly a strong potential for significant losses of N and nutrient cations to soil water in hemlock stands with high mortality. These losses reduce site nutrient capital and may affect future productivity, especially on sites that were nutrient-poor prior to hemlock mortality. Nutrient losses to soil water may also lead to declines in surface water quality (i.e., increases in nutrient concentrations) in areas with significant proportions of hemlock and where hemlock is typically dominant in

> ravines and on steep slopes. Such effects on surface water quality will be particularly important to those managing forested watersheds that provide a domestic water supply. (Yorks, et al., 2000)

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

> Stand productivity and water use appear little impacted until an intermediate threshold of damage has occurred. Enhanced soil moisture availability may first be noticed toward the end of the growing season. Once trees reach heavily damaged status, water uptake and transpiration are severely reduced throughout the growing season, leaving substantially more water available for evaporation, runoff, and/or use by other plant species. (Kimple and Schuster, 2002)

4. There remains some uncertainty about the fate of individual hemlock stands. While trees eventually succumb once infected, the distribution of infection has been moderated at least by the variability in distribution vectors. Selected stands within large forests that have escaped infestation and remain healthy may be worth protecting, even at high cost. The possibility that they can persist beyond the infestation and provide landscape points from which hemlock might eventually recover, especially if natural and introduced controls eventually strengthen, should be considered (Orwig and Kittredge, 2005; U.S.D.A. Forest Service, 2005)

5. Scientists throughout the range of *Tsuga canadensis* are working to find and release safe predators shown to be effective in controlling HWA, including a wide variety of predatory coccinelid beetles and fungi. To date, these efforts have not produced controls able to keep pace with the reproduction and spread of HWA. However, our experiences with *Lymantria dispar* (gypsy moth) and the dramatic reduction of its threat brought on by the growth of *Entomophaga maimaiga*, a population-controlling fungus, raise a glimmer of hope that science and natural systems might combine to moderate the demise of the hemlock population throughout its range.

> Management of forest pests such as HWA in natural areas relies on natural controls that are simple to use and of low cost. To date the major emphasis of research in this area has been on the rearing and release of exotic coccinelid predators. However, rarely will one biological control organism—a "silver bullet"—effectively suppress serious exotic pest populations below damaging levels. More realistic is a multifaceted approach using several compatible agents that together reduce pest populations. Entomopathogenic fungi comprise a group of naturally occurring organisms that penetrate, multiply within, and ultimately kill their insect hosts. These represent a group of promising, but as yet underutilized biological control agents for management of HWA and other exotic insect pests. Fungi are particularly promising for HWA management for several reasons. They have been found infecting HWA naturally in the eastern United States and in low-level adelgid populations in China. Many species of these fungi are relatively easy and inexpensive to mass-produce, and most have little or no negative impact on the environment, humans, or non-target organisms. Production is species and strain specific, and under ideal conditions, enough material for 1ha can be prepared for under $20.00 (Wraight et al., 2001). Naturally occurring epizootics caused by fungi have been

> observed in populations of scales and various aphids demonstrating the potential for their use. An additional benefit of entomopathogenic fungi is their potential to persist in an infected population, providing an ongoing chronic fungal infection. Such conditions may cause an overall reduction in health and fecundity of the pest species. This stress may sufficiently reduce the pest population to a more manageable level—a level perhaps that coccinelid predators could reduce even further. (Reid, et al., 2002)

5.2.5.1.2 DWSP Policy for Hemlock Management in Response to HWA

It is DWSP's primary objective to make forest management choices that conservatively protect the drinking water supply. Secondary objectives include the protection of biological diversity and meeting the market demand for renewable resources, in part to offset the costs of protecting the water supply. The policy outlined below factors in background information as well as these objectives, in attempting to conservatively address the hemlock woolly adelgid problem.

1. Because of the uncertainty associated with hemlock mortality and the possibility of natural or introduced biological controls, DWSP will not conduct pre-emptive harvests of hemlock. Forest stands containing greater than 50% stocking of hemlock will be monitored for the presence of HWA. When the majority (>50%) of the hemlock trees in an operable stand are infected with HWA, the stand will be considered to be infested and will be considered for a harvest/salvage operation. Exceptions include operable, infested stands within areas such as the Pottapaug Natural Area on the Quabbin Reservoir, where harvesting is generally excluded unless managers determine that it is needed to prevent the spread of an insect or disease to other parts of the watershed.

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

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

DWSP will not cut infested hemlock stands located in seasonally flooded wetlands, and will avoid running equipment in hemlock stands growing on hydric soils, except when these soils are dry or frozen enough to carry logging equipment without damage. In riparian areas, cutting practices regulations limit cutting to 50% of the basal area, thus limiting the opportunity to stimulate shade intolerant regeneration except by increasing cutting adjacent to the filter strip. Harvesting stimulates mineralization and nitrification, leading to higher inorganic N pools. Black birch is competitively enhanced by high N levels and moderate light levels. Therefore, partial harvesting in riparian areas may favor black birch rather than diverse regeneration, the opposite of the desired effects. The Division has experimented with planting in conjunction with partial cutting in riparian zones, and is working to document examples in which these trees have successfully competed with natural black birch regeneration. Riparian areas will eventually lose their hemlock to HWA, but leaving them to gradually die may reduce the risk of nutrient transport to adjacent streams, although this has not yet been adequately documented. In light of all the above, DWSP will not cut within the variable width filter strip defined by Chapter 132 regulations during salvage operations in hemlock stands infested with HWA, unless hemlock occupies less than 30% of this filter strip, in which case up to 20% of the filter strip stocking may be cut from the non-hemlock species, to add structural diversity. This policy will be in effect until evidence from stream and soil water sampling and/or regeneration research recommends modifications.

In summary, DWSP policy regarding management of hemlock includes:

1. Monitoring of stands with greater than 50% stocking in hemlock for presence of HWA.
2. Conducting salvage cuts only in infested stands, defined as stands in which the majority of the hemlock trees are infected.*
3. Designing salvage cuts to stimulate regeneration of both shade tolerant and shade intolerant species, while retaining scattered healthy hemlock individuals, and attempting to leave sufficient stocking of other species to meet forest structural goals.
4. Leaving the variable-width filter strip (as defined in Chapter 132) uncut in hemlock salvage operations, except when hemlock occupies less than 30% of that filter strip, in which case up to 20% of the filter strip stocking may be cut from the non-hemlock species.
5. Avoiding hemlock salvage in seasonally flooded wetlands and keeping equipment off of hydric soils in hemlock stands except when they are dry enough or frozen enough to support logging equipment.

5.2.5.2 Other Insect or Disease Threats

There are many insects and diseases present in the Quabbin watershed forests, but most of these are well-controlled, endemic features of the local ecosystem and do not present significant, landscape level threats. Examples include such insects as the eastern tent caterpillar and fall webworm, hemlock looper, oak leaf skeletonizer, and diseases such as the target canker (*Nectria*) in black birch. Some pests have been brought into the system from the outside and either have already had a major impact (chestnut blight; Dutch elm disease) or have been around long enough that the system has developed controls that appear to be limiting further disastrous impacts (gypsy moth). Still others are in the middle of a gradual but ultimately devastating impact on certain species (beech bark disease, ash yellows). Finally, some long-present pest problems that have been brought under control in the past are threatening revival, e.g., white pine blister rust.

There are also threatening insects and diseases that have not yet been identified on the watershed but that have some potential to cause significant damage if they become established. The following are examples, with brief notes on their preferred hosts, biology, and potential impacts are listed below:

- Sudden oak death is a fungal disease that has killed oaks and a variety of other trees in California in as little as 2-4 weeks following infection (thus "sudden death"). So far, this disease is a problem in the western U.S., but there are concerns that it could travel via cross-continental nursery trade. With demonstrated susceptibility to this disease, the red oaks that dominate large areas of the Quabbin forest would likely be severely impacted if this disease arrives on the watershed.

- Asian long-horned beetle is a large insect (0.75-1.5 inches long) with long black and white banded antennae. It was introduced in New York City in 1996 via overseas packaging materials and has also been discovered in Chicago, New Jersey, and Toronto, among others. Millions of dollars have been spent trying to locate and destroy all infected trees in order to contain and

* Because these are salvage operations that require more rapid response than typical silvicultural operations, the DWSP internal lot review process will be conducted within four weeks of the identification of a stand as sufficiently infested to warrant a salvage cut. This determination will be made by field consultation between Forestry and Natural Resources Staff using methods mutually agreed upon to determine the condition of the stand.

eventually eradicate this insect from the U.S. If it escapes these efforts, it is potentially devastating to maples and birches.

- Winter moth has recently reached outbreak levels in coastal areas of Massachusetts. While it has not yet moved westward, it is potentially a serious problem. In Nova Scotia, it has been responsible for mortality of 40% of oak stands and is known to feed on oaks, maples, basswood, ash, and apples (www.umassgreeninfo.org/fact_sheets/defoliators/winter_moth.pdf). Control efforts on the east and west coasts of the US and Canada have included both biological controls and insecticidal chemicals.

- Sirex woodwasp was only recently discovered (2004) in New York state, the first discovery in North America of this insect, which is on the top ten list of worst forest pests around the globe. Most pines, including Eastern white pine, are susceptible, and there are no known native natural controls for this insect. New York State has recently launched a comprehensive program to try to limit the spread of this insect.

5.2.5.3 Invasive Plants

See Section 5.5.6 for a complete review and discussion on invasive plants.

5.2.5.4 Salvage Policy

Some disturbances that move through the Quabbin forest can damage standing trees in ways that result in a rapid decay in their merchantable value, sometimes in combination with an increase in fire danger, hazards to users of the forest, or blockage of access roads. Strong winds and heavy snow or ice can break or fell trees in haphazard patterns that create access dangers. Insect defoliations can kill trees rapidly and create short-term fire hazards as well as access danger. Some species lose value rapidly, for instance when white pine is felled or killed by wind during warm seasons, when the blue-stain fungus can infect the wood rapidly, significantly dropping its merchantable value.

It is Division policy that salvage cutting will only take place in forest areas that have lost (or are likely to lose in a short time period) 50% or more of their stocking, due to storms (ice, snow, or wind), fires, insects, or pathogens. Salvage sales will not go through the normal annual internal review process, but will be subject to approval by the Regional Director, the Natural Resources Section Director, and the Chief Forester before cutting can start. Salvage sales will only take place on an emergency basis when there will be significant loss of wood product value or marketability by waiting to sell these products at the next scheduled timber showing, or when access issues caused by damaged or fallen trees need immediate resolution.

5.2.6 Conservation Management Practices (CMPs) for Watershed Forest Management

NOTE: DWSP utilizes the Canadian term "Conservation Management Practices" instead of "Best Management Practices." Both terms refer to efforts to create resource-protecting standards for management activities.

Forest management at Quabbin is done to improve watershed protection. As a minimum Conservation Management Practice, DWSP will uphold the standard that no measurable negative impact will occur on the quality of water, as measured at locations downstream from a logging project. DWSP 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 DWSP 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, DWSP management practices will meet or exceed the revised standards.

Strict adherence to DWSP'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 20-30 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 protecting water quality if not carefully regulated.

Among the areas of greatest concern is 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.

5.2.6.1 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.

5.2.6.2 Logging Equipment

Logging equipment has changed dramatically in the 40 years that forest management has been active on DWSP 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 4-wheel drive articulated skidders or 4-8 wheel drive articulated forwarders with 70-260 hp, widths of 7-10', and weights of 6-24 tons (empty) or more. Skidders drag logs attached to a rear-mounted cable and winch or a grapple, while forwarders carry logs on integrated log bunks.

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 fells, de-limbs, and cuts trees, leaving piles of logs or cordwood, which are retrieved by forwarders. Machines that process felled trees into logs, pulpwood, or firewood are generically referred to as "cut-to-length", or C.T.L., machines.

Small skidders are useful for logging on watersheds whereas larger 100-230 hp models, that weigh from 8-18 tons and are 8-10' 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 or rubber-tired feller-processors and forwarders have all worked successfully on DWSP watersheds. **Table 45** shows typical combinations of equipment that work on various types of harvesting operations on DWSP watersheds.

Table 45: Harvesting Methods/Equipment Used on DWSP Watershed Lands

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 or rubber tired CTL with forwarding	✓	✓	

In an effort to specify equipment that is appropriate on specific soils and within specific forest types, DWSP 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 46** (skidders) and **Table 47** (forwarders).

Rubber-tired skidder.

Forwarder with tracks

Table 46: Sample Skidder Sizes and Ground Pressures

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

(Sources: Firestone Tire Co. – LS-2, Forestry Dimension Special Table)

Table 47: Sample Forwarder Sizes and Ground Pressures

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

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

Some of the logging equipment available is too large or heavy to meet DWSP requirements in certain vegetation or soil conditions; 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. DWSP specifies equipment requirements for each site in its harvest bidding. This includes machine width and ground pressure limits, as well as specific equipment requirements. While each site has unique conditions that require the experienced judgment 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. Machine widths are limited in intermediate cuttings of dense, unthinned stands with moderate topography, most typically to around 8.5 feet.

An example of a "preferred logging system," that accomplishes DWSP goals under difficult conditions is a small C.T.L. 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 trees, with minimal damage to the young growth. Generally, when trying to save and promote growth of advance regeneration, fixed head processors are required. Dangle heads are allowed when damage to advance regeneration is not a concern, due to its scarcity or poor condition.

Rubber-tired C.T.L. machine with a dangle head processor

While smaller tracked feller-processors are limited to stable ground conditions (few rocks and gentle slopes) and trees less than 16" DBH, current models can fell trees up to 30" DBH and come equipped with self-leveling cabs that allow work on slopes up to 30% and rubber tires that allow work on rocky ground. In old stands where the trees are generally large, hand felling is necessary. Multi-aged stands 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 48 summarizes some of DWSP's effort to match equipment and logging systems with site conditions. The methods listed in **Table 49** are taken from **Table 46**.

Table 48: Harvesting Methods/Equipment Used in Various Soil/Terrain Combinations

Slope	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 machines
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

5.2.6.3 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 and optimal protection of water resources are dependent upon careful advance planning (see **Figure 17** for an example of silvicultural planning). For example, the best possible stream crossing is the one that is avoided by planning.


A well-planned harvest

5.2.6.4 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. DWSP, however, maintains tight control over loggers working on the watersheds and exercises its right to remove operators who fail to adhere to contract standards. Furthermore, every harvesting operation receives a written post-harvest inspection and evaluation report that is filed for future determination of the operator's commitment to good workmanship. It is important that foresters and loggers develop mutual respect that is based upon a shared commitment to the sustainable stewardship of the land over long periods of time.

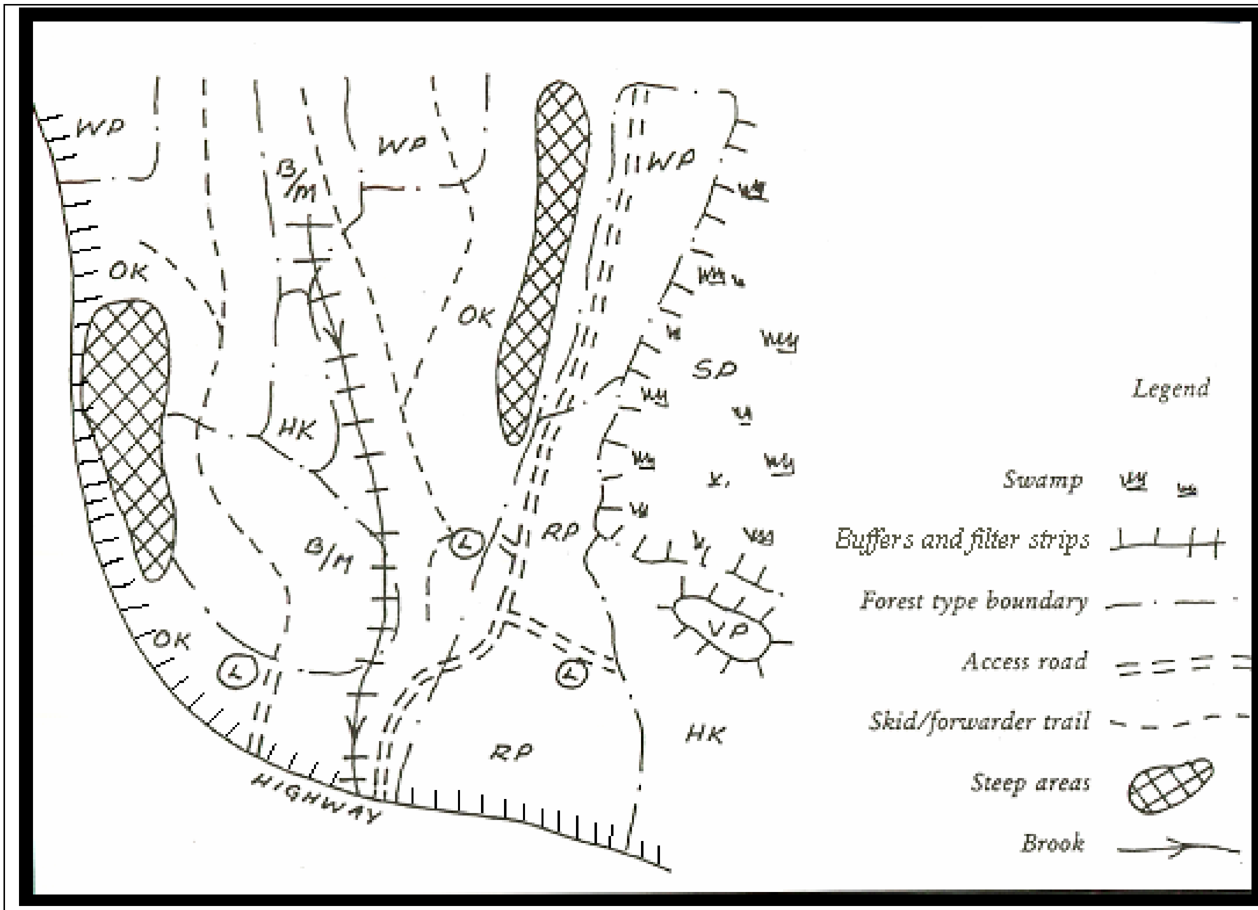
5.2.6.5 Filter Strips

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 on 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. DWSP 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.

5.2.6.6 Buffer Strips

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.

Figure 17: Hypothetical Example of Silvicultural Planning



This approximately 200 acre area of DWSP 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 filter strips 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 improvement thinnings within the past 30 years, and the understory has developed in response to deer control. Additional work in this area will release advance regeneration and/or establish new age classes by harvesting overstory trees in patches averaging 1 acre in size. 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.

5.2.6.7 Wetlands

DWSP'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 or land within 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.

All DWSP 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 5.4.3.1.1 and **Figure 18**), 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, DWSP 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 DWSP lands at Quabbin are included within the designated wetlands on the watershed. DWSP has identified and mapped 3,012 acres of wetlands within the Quabbin property, which are generally avoided when lot boundaries are drawn for proposed annual silvicultural operations. DWSP 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 18**).

Figure 18: 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 — *100 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.

5.2.6.8 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 sub-sections. A cutting plan still relies upon the judgment and common sense of the logger and forester to make the right decisions in order to protect the land and associated resources.

5.2.6.8.1 Landings

A well-organized log landing

Landings are permanent sites that should be located on well-drained ground and soils that will support the logging equipment. 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.

5.2.6.8.2 Skid Roads

Skid roads are designed to be re-used and are therefore located on soils that can support the skidder, such as well-drained gravel or well-to-moderately-drained stony till soils. Some soils, regardless of their drainage capacity, are wet in the spring, early summer and late fall; 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 48 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 sensitive Division watershed lands. 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. This task is accomplished through the construction of water bars. 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.

5.2.6.8.3 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.

5.2.6.8.4 Stream Crossings

Stream crossings are usually avoidable on DWSP watershed properties. Frozen conditions are favored whenever possible when streams must be crossed. 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.

Skidder on a temporary bridge

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 location of crossings 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 within 1,000 feet of the reservoir high water mark, including intermittent streams downstream of the highest wetland, must be crossed with portable bridging. Division foresters will frequently monitor all unbridged crossings, and discontinue or mitigate them if conditions deteriorate or downstream water quality is threatened.

DWSP crosses 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 49 outlines the various stream-crossing situations encountered on DWSP watersheds and level of protection these crossings are given.

Table 49: Protection Measures Applied to Various Stream Crossing Situations

Type of Crossing Situation	Level of Protection		
	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" 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.

5.2.6.9 Point-Source 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. In addition, see Section 5.3.6.4, Pre-Planned Spill Response for Silvicultural Operations. The following are definitions used within this Section.

- Petroleum products: All machines are inspected by DWSP foresters for leaks prior to arrival and for the duration of their stay on the watershed. Checks are made of all hydraulic components, fuel tanks and lines, engine, transmission and axles. Trucks, forwarders, skidders and other equipment that carry petroleum products must have a sufficient number of petroleum-absorbent pads to contain a 10-gallon spill per machine on site. Immediate action to contain and stop any petroleum spills followed by prompt notification of the forester is required. The forester in turn contacts DWSP 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" type of 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.

5.2.6.10 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 DWSP 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 DWSP forester before entering the site.

5.2.6.11 Protection of 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 by using the proper logging system. Division contracts include the right to suspend operations due to operator inexperience or negligence.

5.2.6.12 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 for a more detailed discussion on this subject).

5.2.6.13 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 loggers feel about their work and the land. This perspective cannot be forced, but it can be encouraged and learned. When work is done correctly it is not conspicuous, but when done carelessly it is obvious to all. DWSP watershed land is public property; the general public regularly passes through 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.

5.2.7 Control of Harvest Operations through Timber Sale Permit

5.2.7.1 Introduction

In conducting silvicultural operations that remove forest products from the forest, DWSP policy is to protect watershed resources such as water quality, soils, residual trees, and cultural resources. Both the timber sale permit, discussed in this Section, and Conservation Management Practices, presented in Section 5.2.5, address these concerns. In general, the Permit to Harvest Forest Products specifies the performance standards, whereas the CMPs explain how these permit specifications are met.

The timber sale permit 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.) General Conditions; b.) Water Quality Specifications; c.) Harvesting Specifications; d.) Utilization Standards; e.) Silvicultural Specifications; f) Harvesting Systems; and Bidding, Payment and Bonding Specifications. Parts b, c, and f pertain most directly to protecting watershed resources.

5.2.7.2 Water Quality Specifications

Water quality 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, should one occur. All associated refuse from maintenance and repair is required to be stored in appropriate containers and removed from DWSP lands as soon as possible. Human waste is required to be deposited in DWSP toilets or toilets supplied by the operator.

5.2.7.3 Harvesting Specifications

Harvesting specifications are concerned primarily with the process of cutting trees and removing forest products from the forest. DWSP timber harvesting permits specify conditions for lopping slash to enhance decomposition and reduce fire hazards.. The penalty for cutting unmarked trees is set at three times the value of the tree. Utilization standards are specified in each permit 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 permit specifies the condition in which these areas must be left at the completion of the operation. The permit makes it clear that the logging operation may be suspended due to wet or extremely dry conditions, at the forester's discretion.

5.2.7.4 Harvesting Systems

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. DWSP 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.

5.2.8 *Internal Review of Proposed Harvesting*

The key to the proper protection and management of the resources under the care and control of DWSP is the care and expertise of the staff. As the on-the ground implementers of DWSP's 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. It is impossible, however, for any one individual to assimilate all aspects of the diversity of knowledge in the evolving fields of natural and cultural resource management. A secondary key to implementing sensitive management, therefore, is 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 DWSP, these supporting disciplines include wildlife biology, forest planning, water quality and environmental engineering, civil engineering, and cultural resource protection. Experts available outside DWSP include rare species botanists and zoologists (Massachusetts Natural Heritage and Endangered Species Program) and cultural resources specialists (Massachusetts Historic Commission). DWSP also has available a wide variety of experts conducting academic research on the watersheds at any given time, in part because of the research value of the resources under DWSP's care and control. These professionals and interested non-professionals who spend time studying and exploring the watersheds contribute invaluable observations that complement DWSP's understanding of its watershed resources.

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

- Each December, DWSP'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 following natural disturbance 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).

- Quabbin foresters or Natural Resources staff digitize the maps of the planned operations, which include the location of wetlands and previously identified critical cultural and wildlife sites. The foresters then submit these maps and completed forms describing the proposed silviculture in detail to the DWSP Natural Resources Section. Natural Resources staff prepare area summaries of these operations, and check the overall consistency of the operations with management plan silvicultural and resource protection objectives. These proposals will also identify the subwatersheds intersected by the proposed lots, as well as the proportion of each lot that falls within Zones 1, 2, and/or 3. Natural Resources staff will compare the proposed subwatershed and zone coverage to target objectives for the year and for the decade. After Natural Resources staff have reviewed the proposed operations, the Natural Resources Director then forwards copies to the watershed Regional Director, the DCR archaeologist, and the DWSP wildlife biologist.

- For proposed lots with openings that exceed 2 acres in size, the forester proposing the lot will also detail the relative hydrological sensitivity of the area on which these are proposed as well as the value of the larger openings as early successional habitat that benefits rare and uncommon species and as uncommon forest habitat for more common species. These lots will be reviewed internally on that basis, but prior to being approved, they will also be presented to the general public, for review and comment, at the annual spring public meeting and will also be presented for review and comment to the Quabbin Watershed Advisory Committee.

- From 1986 to 1996, a variety of consultants, in collaboration with Boston University's Department of Archaeology and the Swift River Historical Society compiled cultural resource maps for Division watershed properties (available for review through DWSP Interpretive Services at the Quabbin Visitor Center). These maps denote known and likely historic sites. When forest management is planned for areas containing or likely to contain cultural resources, the DCR archaeologist identifies types of activity that could damage these resources, such as soil compaction or disruption of existing structures such as walls or foundations. The 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, DWSP's wildlife biologist reviews the planned forest management operations. Where necessary, the wildlife biologist 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 biologist, 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 5.4.3 of this plan.

- Each spring, DWSP's Environmental Quality staff reviews the planned forest management and, where necessary, conducts site examinations. The Environmental Quality staff may give site-specific guidelines regarding special precautions designed to increase the protection of site water quality.

- In 1995 and 1996, the Division contracted with a professional botanist to review all proposed harvesting 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. In the 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. If there are any changes in the area to be harvested and/or in the proposed practices, the forester is responsible for notifying the Natural Resources Section in order to determine if further review is required by the changes. 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), which the logger is required to follow. The Forest Cutting Plan is submitted to the DCR Bureau of Forestry and copied to the local Conservation Commission.

- After the lot has been advertised and awarded to a private timber harvester, Chapter 132 requires DCR Bureau of Forestry staff to conduct a site visit prior to the start of the operation if wetland resources are involved. These regulations also require that DCR Service Foresters check all cutting plans against the Natural Heritage maps of rare and endangered species habitats and, if they overlap, submit these plans to Natural Heritage for review and comment. Training sessions were held in 2004 to enhance the relationship between DCR foresters and the Natural Heritage staff (which remains overburdened with review responsibilities), and an Interagency Service Agreement is being completed to enable improvements in this critical collaboration.

Throughout the active operation, it is the responsibility of the forester in charge to continuously monitor compliance with water quality protection measures, including: 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 DWSP "Permit to Harvest Forest Products" includes detailed specifications for each harvesting operation. During the operation, DWSP reserves the right to suspend the harvesting activity if warranted by weather, soil, or wildlife conditions. Upon completion of silvicultural operations, 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.

A separate review process is required for proposed access road development or the opening of new gravel operations. See Section 5.3.6.6., page 198 for details of this process.

5.2.9 Post-harvesting Monitoring and Reporting

All active timber harvesting is regularly monitored by DWSP field foresters to assure compliance with both state regulations and DWSP policies for the protection of natural and cultural resources. Immediately following the completion of a timber harvesting operation, the treated area is carefully reviewed in the field by the responsible DWSP forester to assess the operator's adherence to Conservation Management Practices and other requirements of the harvesting permit. This includes a review of the operator's protection of the residual forest, soils, wetlands, and identified special habitats or plant populations, as well as the proper post-harvest treatment of access roads (back blading and the installation of water bars to divert water on steep sections), stream crossings (removal of temporary bridging materials and smoothing of approaches), and landings (removal of unutilized materials, smoothing, seeding if necessary). The Division holds a performance bond on all harvesting contractors and the return of this bond is contingent on the operator's compliance with all permit requirements.

In addition to post-harvest monitoring of operator compliance, timber sale areas are monitored for the silvicultural success of the operation. In areas expected to regenerate, regeneration surveys are conducted 3-5 years following the treatment, to assess the density and diversity of the understory response. The most common method used by the Division is to collect tree, shrub, and herbaceous information within small circular plots along transects, to determine both the success of the tree regeneration and possible competition presented by both native and alien, invasive plants. Browsing surveys are also conducted in these areas to monitor the effects of deer and moose on the forest's regeneration. Rare plant populations and wildlife utilization of unusual habitats (e.g., vernal pools) are monitored both before and following the harvest, to determine positive or negative effects.

5.2.10 Annual Reporting of Implementation Results

In advance of the annual public meeting to present progress on the plan (see Section 1.7.3), Foresters and Natural Resources Staff prepare an annual report that includes a listing of the timber sales conducted and the acres treated, a detailed description of wildlife management activities, and reports from new or ongoing research and monitoring efforts. These reports are presented to the public at the annual meeting, at which public comment is also sought for any proposed refinements or modifications to the 10-year land management plan. While it is the intent of the Division to regularly update the plan to incorporate new information either from internal monitoring efforts or from outside research, these proposed changes will only be incorporated after public review and comment have been sought through the annual meeting or a similar type of well-advertised public meeting.