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FUNCTIONS AND VALUES OF FORESTED/SCRUB-SHRUB WETLANDS

RESEARCH SUMMARY

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INTRODUCTION

Under NH Wetlands Board Rules, Chapter 300 covers criteria and conditions for determining whether a wetlands permit should be granted or denied. These criteria and conditions are part of Wetlands Board Administrative Rules and are enforceable. This Chapter also contains statements which require the Board to provide more emphasis on preserving certain types of wetlands over others. Wetlands Board Rule Wt 302.01(b) (see Attached) states that "The Board shall place emphasis on preserving bogs and marshes." This statement insinuates and has been interpreted by the Wetlands Board to mean that other types of wetlands, such as "swamps" (wetlands dominated by trees and/or shrubs), are less important.

In addition, Wetlands Board Rules use the term "swamp" generically and, therefore, make no distinctions between the different types of wetlands in New Hampshire that fall into this category (i.e. Red Maple, Atlantic White Cedar, scrub-shrub etc.). Moreover, this generic approach makes it difficult to evaluate potential project impacts to these wetland types, since Wetlands Board rules that address impact evaluation criteria (Wt 302.04) also do not recognize the different types of wetlands which are called "swamps". The validity of this hierarchial approach to protecting wetlands, and the lack of evaluation criteria (specific to these types of wetlands) for assessing impacts under WB Wt 302.04 are of concern to the Wetlands Bureau.

Because of the above concerns of the Bureau, a scientific review of literature related to forested/shrub wetland types which are specific to New Hampshire was undertaken. The literature review focused on *Red Maple Swamps, Atlantic White Cedar Swamps, and scrub-shrub swamps.* The goal of the research is to compile scientific data that could be translated into evaluation criteria for assessing impacts to New Hampshire's forested/scrub-shrub wetlands. The results of the literature review are presented in terms of those wetland functions which the State's wetlands statute and Wetlands Board Administrative Rules recognize as important.

PRIORITY WETLAND FUNCTIONS UNDER RSA 482-A AND Wt 302.04

Wetlands are recognized as having the potential to perform one or more important functions. Whether a wetland performs a certain function(s) is determined by the interaction of biological and physical characteristics at the site. New Hampshire's Fill & Dredge in Wetlands (RSA 482-A) regulates wetlands as ecosystems that provide specific functions that are important to public health, welfare, and safety, and to the public trust. RSA 482-A recognizes the following wetland functions as important:

- nutrient support for finfish, crustacea, shellfish, and wildlife of significant value;
- habitats and reproduction areas for plants, fish, and wildlife of importance;
- commerce, recreation, and aesthetic enjoyment of the public;
- groundwater recharge;
- sediment trapping; and
- flood storage.

Wetlands Board Administrative rules also recognize wetlands as ecosystems which perform important functions. Wetland values that must be considered in project designs (under Chapter Wt 302.04 *Requirements for Application Evaluation*) include impacts to:

- plants, fish, and wildlife;
- nearby wetlands and surface waters;
- quality of surface and ground water;
- values and functions of the total wetland or wetland complex; and
- public commerce, navigation, and recreation.

The research information presented in the following summary is broken down into three headings: Red Maple Swamps, Atlantic White Cedar Swamps, and Forested Wetlands in general. The scientific information under each heading is presented in terms of the wetland functions and values that are recognized by NH statute and Wetlands Board Administrative Rules. Not many research articles that specifically dealt with scrub-shrub wetlands were found. However, scrub-shrub wetlands are indirectly discussed under the three main headings.

FUNCTIONAL VALUES OF RED MAPLE SWAMPS PER LITERATURE REVIEW

In red maple forested wetlands, more often referred to as red maple swamps (RMS), red maple is the dominant overstory species. It is an extremely broadly adapted species that occurs in both wetland and upland habitats. Of the five forest cover types in which it is a major component, three are upland forest types, one (composed of black ash/American Elm/red maple) is a wetland type, and one (composed of just red maple) may occur on either wetland or upland sites. What gives red maple its competitive edge is its ability to produce heavy seed crops nearly every spring, its rapid seed germination and its ability to vigorously sprout from stumps and damaged seedlings on a wide variety of disturbed sites. As of this writing, statewide area statistics based on US Fish and Wildlife Service's National Wetlands Inventory are currently unavailable for New Hampshire. However, US Forest Service statistics suggest that red maple forested wetland covers no more than 1% of the landscape in New Hampshire (Golet et al., 1993).

Nutrient Support for Finfish, Crustacea, Shellfish, and Wildlife

Red maple occurs on over 200 hydric (wetland) soil series or phases in the glaciated Northeast. The number of hydric soils on which red maple is the dominant tree in unknown. The two basic categories of soils found in RMS are organic (Histosols) and mineral soils. Generally, the proportion of organic material in a wetland soil is determined by soil temperature and the duration of anaerobic conditions, both which regulate microbial decomposition rates. Inn RMS, where soil saturation is seasonal, anaerobic conditions occur near the soil surface during only a portion of the growing season. Organic matter is more readily decomposed during aerobic periods. Because of this fact, the organic material in RMS soils is predominantly well decomposed (sapric) or, less commonly, moderately well decomposed (hemic) (Golet et al., 1993).

Northeastern RMS have primarily very poorly drained or poorly drained soils. Very poorly drained soils typically occur in seasonally flooded basins, although they are sometimes found on slopes where groundwater inflow keeps the soil wet for extended periods during the growing season. Poorly drained soils are saturated seasonally, but seldom have standing surface water. Organic soils are always very poorly drained, while mineral soils may occur in any drainage class.

RMS with organic soils most often occupy well-defined basins in the lowest areas of the landscape, where they are fed by the regional groundwater system, as well as by surface runoff and streamflow in some cases. RMS with mineral soils generally occur at the edge of organic swamps, on stream floodplains, or on hillsides where soil moisture is depleted earlier in the summer by evapotranspiration (Golet et al., 1993).

In most of the glaciated Northeast, soils of RMS are acidic and low in available plant nutrients. Most of the glaciated Northeast is characterized by bedrock and surficial deposits with low base content. These materials do not provide sufficient quantities of calcium and magnesium to groundwater to neutralize or markedly raise the base content of RMS soils (Golet et al., 1993).

In northeastern RMS, 75% to 90% of the annual radial growth of RM trees is accomplished by the end of July. On the other hand, root growth may continue into late October. Researchers have also found that water levels during one growing season may influence next year's tree growth.

There has been no research on organic matter decomposition and nutrient cycling in northeastern forested wetlands. The most complete data on this subject come from the Virginia section of the Great Dismal Swamp. Certain Virginia findings may, however, be applicable to the southern portion of the Glaciated northeast. It is generally agreed that the rate of organic matter decomposition is determined primarily by the quality of the litter, in combination with climate. Decay is generally retarded by high tannin or tannic acid content, high lignin content, and a high C/N ratio. Limited data show that RM litter is relatively high in value for all of these features. Temperature, water regime, and pH are also important factors influencing decomposition rates (Golet et al., 1993).

There has been so little research on nutrient cycling in northeastern forested wetlands that it is possible to develop only a very simplified scenario of some of the seasonal processes that occur in these swamps. The degree to which RMS retain and cycle nutrients is strongly influenced by hydrology, which has pronounced seasonal variability. Leaching and immobilization of nutrients from external sources may occur from fall into spring. Hydrologic events (such as backwater flooding which brings enriched waters into the wetlands, and flushing events which remove detritus) also influence the magnitude and timing of these processes. Streams carrying suspended sediments and dissolved nutrients overflow into may swamps during flood periods. As water velocities decrease in the wetlands, suspended particles and adsorbed constituents (e.g. phosphorus and heavy metals) settle to the soil surface, and dissolved nutrients in the water may diffuse within the soil and detrital layers. Significant loadings to wetlands may also be contributed by surface water runoff from surrounding upland areas. The following are conservative estimates for annual nutrient and metal removal via sediment deposition in 1 square meter of northeastern wetland soils: N, 1.5 g; P, 375 mg; Cu, Pb, and Zn, 25 mg; Cd, 0.2 mg; and Hg, 0.2-2.5 mg (Golet et al., 1993).

Habitats and Reproduction Areas for Plants, Fish, and Wildlife

Hydrogeologic setting of a RMS is a primary determinant of plant community structure and floristics. The great majority of plant species that occur in northeastern RMS can grow under a wide range of soil moisture conditions. Obligate wetland trees are rare in northeastern RMS, Atlantic white cedar being the only species so classified. Obligate wetland shrubs also are rare in northeastern RMS.

Plant species distribution has been shown to be influenced by the duration of soil saturation. Because most of the tree, shrub, and herb roots in RMS are located within 30 cm of the ground surface, the percentage of the growing season during which the water table is within that zone may be of considerable significance (Golet et al., 1993).

Community structure (the physical composition of the plant community in terms of vegetation height, density, percent cover, and similar characteristics, and the relative development of various life-form layers) and floristic composition are the two most fundamental aspects of the RMS plant community. Structure is of special importance because of its relation to certain wetland functions and values such as wildlife habitat, flood flow alteration, and forest biomass production. Changes in either species composition or structure over time may reflect significant changes in environmental conditions such as the prevailing water regime, nutrient status, microclimate, or land-use history (Golet et al., 1993).

RMS contain as many as 5 distinct vegetation layers: trees, saplings, shrubs, herbs, and ground cover. In mature RMS, (40-50 years of age) the tree canopy forms a layer approx. 8-15 m above the forest floor. Sapling crowns form a layer 3 - 6 m above the ground, although at most sites the sapling layer is the most poorly developed. The shrub layer, which includes woody plants that are usually less than 3 m tall, is commonly dense and often extends to within a meter of the ground. The herb layer is composed of nonwoody erect plants such as ferns, grasses, sedges, and broad-leaved herbs that are usually less than 1.5 m tall. The tree, shrub, and herb layers predominate in most RMS (Golet et al., 1993).

Tree Layer - Forest structural data from mature northeastern RMS suggests that height growth in RM is rapid during the first 30-40 years and then slows considerably. In mature RM forested wetlands, canopy cover commonly exceeds 80%. Lower values are likely in old stands, however, due to gaps created by tree mortality, extreme weather events, logging, or at sites too wet to support a continuous forest cover. Tree species commonly associated with RM in southern New England uplands, seaboard lowlands, and coastal plain include yellow birch, black gum, white ash, eastern white pine, American elm, and eastern hemlock. Black ash, gray birch, balsam fir, and northern white cedar commonly occur in RMS in southern NH. Atlantic white cedar is a common associate of RMS in coastal areas (Golet et al., 1993).

Shrub Layer - Most RMS have a dense, well-developed shrub layer. In most RMS, shrub cover exceeds 50%, but can range from as low as 21% to as high as 99%. While the shrub layer is well developed in most undisturbed RMS, it may be practically nonexistent in young forests that have developed directly from wet meadows without an intervening shrub stage, or in forests that are grazed by cattle. Shrub abundance may vary widely within a swamp as well. The shrub layer's density may also vary, but often is exceedingly high. Some examples of shrubs commonly found in RMS in southern New Hampshire include highbush blueberry, common winterberry, sweet pepperbush, spicebush, swamp azalea northern and southern arrowwood, poison sumac, mountain laurel, sheep laurel, and poison ivy (Golet et al., 1993).

Herb Layer - In many RMS, the herb layer varies noticeably in height, density, and percent cover. Because site conditions such as forest structure, hydrology etc. are unique to each swamp and because the herb layer is particularly sensitive to environmental gradients, a "typical" herb layer structure cannot be described. Because the abundance of herbs is influenced by light intensity at the forest floor, tree and shrub cover and foliage density are key controlling factors.

Because the roots of herb species are quite shallow, they are more responsive than shrubs or trees to differences in soil moisture at or near the surface of the ground. As a result, the herb layer of RMS frequently contains a greater diversity of species in terms of wetland indicator status. Herb layer composition varies along the moisture gradient extending from a swamp into the bordering upland area.

Some examples of herbs found in RMS include cinnamon fern, sensitive fern, royal fern; sedges and grass such as bluejoint and manna grass; skunk cabbage, marsh marigold, wild lily-of-the-valley; and various species of mosses; liverworts and lichens (Golet et al., 1993).

Species Richness - Various combinations of the plant species listed above occur in RMS. The composition of a particular RMS's plant community is strongly related to its hydrogeologic setting. Certain studies have shown that highly varied hydrologic conditions in a wetland are one of the chief reasons for high overall species richness and community heterogeneity. RMS that occur on river terraces, in oxbows, behind natural levees, and on the low-lying inner floodplain of rivers (alluvial swamps) are commonly more nutrient-rich than nonfloodplain swamps, and often support a more diverse plant community (Golet et al., 1993).

In RMS which occur primarily in undrained basins in either till or stratified drift (seasonally flooded basin swamps), trees and shrubs are rooted primarily in mounds which are elevated slightly above the seasonal high-water level. This characteristic feature, known as microrelief, occurs in nonfloodplain forested wetlands in the Northeast, and is usually most pronounced in the wettest swamps. Pronounced microrelief allows species with widely differing soil moisture requirements or tolerances to coexist in a limited area in RMS. One New York study found plant species richness to be positively correlated with microrelief (Golet et al., 1993).

RMS can also occur on slopes or in shallow depressions along intermittent or upper perennial streams where till predominates. They are fed primarily by groundwater seepage and overland flow. Shallow flooding may occur along watercourses during the early spring and after heavy rains, but surface water seldom persists. Most of these sites have a seasonally saturated water regime, and surface microrelief is limited except where the ground is strewn with glacial erratics (Golet et al., 1993).

From a regional perspective, the flora of RMS is rich, including at least 50 species of trees, more than 90 species of shrubs and vines, and more than 300 species of nonwoody plants. However, a few species usually predominate at any single site. For the tree layer, the average number of species per swamp is about four (ranging from 1-9). For the shrub layer, the number of species per swamp ranges from 1-15. The number of herb species per site is generally less than 20. The variety of habitats provided by pronounced microrelief is one reason for the relatively high herb species richness found in forested wetlands (Golet et al., 1993).

As mentioned earlier, most RMS in the northeast are acidic and nutrient poor, due to the low base content of bedrock and surficial geologic deposits found throughout most of the region. However, in several areas of the northeast, calcareous groundwater or surface water derived from limestone, marble, or lime-rich surficial deposits enters wetlands and has a dramatic effect on the composition and richness of the plant community. Such wetlands are called calcareous seepage swamps. With respect to New Hampshire, such swamps which are dominated by RM occur primarily in southern part of the state. Up to 28 species of shrubs and vines have been found in individual RMS fed by calcareous seepage, while the number of species of herbs reported per site may exceed 60. Black ash is often associated with RM in calcareous seepage swamps, and American elm, white pine, tamarack and swamp white oak are also common. Some examples of shrubs found in calcareous seepage swamps include red-osier dogwood, alderleaf buckthorn, shrubby cinquefoil, stiff dogwood, meadowsweet. The most frequently encountered herbs include lakebank sedge, tussock sedge, cinnamon fern, royal fern, and tall meadow-rue. Certain herbs (i.e. bristly-stalked sedge, marsh marigold, golden saxifage, fen orchid and small purple-fringed orchid) are strong indicators of either calcareous groundwater discharge or calcium rich soils, although they occur less frequently than those listed above (Golet et al., 1993).

As an added note, approximately fifty acres of forested/scrub-shrub wetlands that fall into the category of calcareous seepage swamp are located in the vicinity of the Pease Air Force Base Main Gate and their high wetland functions and values are recognized in the 1995 draft supplemental EIS for the Disposal and Reuse of Pease Air Force Base. The draft EIS also mentions a 130 acre predominantly forested/scrub-shrub wetland which occurs along the southeastern boundary of the base which falls into the category of southern New England acidic seepage swamp--also a state-identified rare and unique habitat. The EIS also states that under the 1991 Proposed Action, these high value wetlands may be directly and indirectly impacted.

Plants of Special Concern - Many species observed in RMS also appear in the official rare-plant lists published by the various northeastern states. In New Hampshire (based on 1989 NHNHI data), 24 species of plants which occur in RMS are listed as either critically endangered (13 species), endangered (9 species), or threatened (2 species). Some of the critically endangered plants include: Swamp Birch, Canada Moonseed, Northern Prickly-Ash, Yellow Lady's Slipper, Showy Lady's Slipper, Turk's Cap Lily, and Spring Cress. Endangered plant species include: American Hackberry, Great Rhododendron, Swamp Azalea, Bog Twayblade, Climbing Hempweed, and Pink Pyrola. Those plants cited as threatened include Bladdernut and Gall-of-the-Earth.

Vertebrate Fauna - Although RMS is the most abundant freshwater wetland type in the glaciated Northeast, relatively little research has been conducted on its fauna and their habitat requirements. This is particularly noteworthy since several states, including New Hampshire, include wildlife habitat as a recognized value of wetlands within regulatory acts. Vegetation structure has been shown to be a primary factor in wildlife habitat selection, especially in forested areas. Based on 1990 NHNHI data, the vertebrates of special concern that have been observed in northeastern RMS include 5 critically endangered species (Marbled salamander, Eastern box turtle, Timber rattlesnake, Peregrine falcon, Red-headed woodpecker, and Lynx); 7 endangered species (Jefferson salamander, Acadian flycatcher, Blue-gray gnatcatcher, Cooper's hawk, Orchard oriole, Ring-necked duck, and Eastern pipistrelle); and 8 threatened species (Blue-winged warbler, Eastern screech-owl, Great blue heron, Green-winged teal, Hooded merganser, Red-shouldered hawk, Turkey vulture, and New England cottontail).

Amphibians and Reptiles - Studies of amphibians and reptiles in northeastern forested wetlands are rare, even though these habitats appear to be of major importance to forest-dwelling species. One study carried out by DeGraaf and Rudis in 1986 identified 45 New England species of amphibians and reptiles that use forest cover at some time during the year. Of the 11 forest cover types reviewed, RM was the most frequently preferred (by 12 species), and was used but not preferred by an additional 30 species. An example of some of the amphibians and reptiles that preferred RMS include: spotted salamander, redback salamander, marbled salamander, Jefferson salamander, spring salamander, five-lined skink, eastern ribbon snake, and ringneck snake. The wood turtle, which is being considered for protection under the Endangered Species Act, uses RMS but does not prefer them (Golet et al., 1993).

The majority of amphibians require standing water for breeding. Because of this fact, vegetation structure may be less important to them than water regime. The seasonal flooding of many RMS provides suitable breeding areas for several species. Another 1990 study by DeGraaf and Rudis compared the herpetofauna of three forest cover types in New Hampshire: northern hardwoods, balsam fir, and RM. All three forest types supported the same number of species of reptiles and amphibians (11); however, the relative abundance was significantly higher in RM and northern hardwood stands than in balsam fir. RM forests containing streams supported a higher number of species and more than twice as many individuals as RM forests lacking streams. Three of the species –wood frog, redback salamander, and American toad–accounted for over 90% of the total captures in each stand; these species were present in comparable numbers in northern hardwood stands (Golet et al., 1993).

Of all the vertebrates inhabiting northeastern RMS, birds are the best documented. The avian community is chiefly composed of species that commonly occur in upland forests as well. Those that are most commonly associated with wetland forests include the Northern waterthrush, Canada warbler, and Veery. The Northern waterthrush is the only species that does not breed in upland habitats. Of all northeastern raptors, the Red-shouldered hawk exhibits the strongest affinity for forested wetlands, both for nest sites and for hunting areas. Other birds of prey that frequently inhabit northeastern RMS include the Broad-winged hawk, Barred owl, Eastern screech-owl, and Northern saw-whet owls.

Birds - Factors that most significantly affect avian richness and abundance include wetland size, vegetation structure, and water regime. Several studies indicate that although factors other than the size of a RMS also affect avian species richness, size clearly is a key determinant. Swamps 4 ha or smaller in size had significantly lower species richness than sites ranging from 6 to 19 ha. Larger swamps(30-40 ha) had even higher species richness. Whether swamp size has any effect on breeding bird density or relative abundance in unclear (Golet et al., 1993).

Species richness and diversity of breeding birds are higher in forest habitats that contain several vegetation layers than in simpler communities dominated by herbs or shrubs. Studies have documented significantly higher avian abundance in forested-shrub wetlands, which contain more structural diversity, than in mature forested wetlands. However, species richness was similar for the two types. Species present only in forested-shrub wetlands include the yellow warbler, warbling vireo, swamp sparrow, and red-winged blackbird. The presence of a dense, extensive shrub layer within RMS appears to add significantly to habitat complexity. Avian species richness and abundance have also been shown to be positively correlated to percent cover of surface water, presence of streams, and peat depth, while the degree of water level fluctuation throughout the summer was negatively correlated with these characteristics (Golet et al., 1993).

RMS of the northeast are important feeding and resting areas for migrating waterfowl. In most years, surface water levels in forested wetlands are highest from late fall through spring, allowing access to these areas by migrating waterfowl. Among the species that frequent flooded swamps during migration are the wood duck, American black duck, mallard, ring-necked duck, and hooded merganser. Waterfowl species that breed in northeastern forested wetlands include ground and stump nesters such as American black ducks and mallards, and cavity-nesting wood ducks, common goldeneyes, common mergansers, and hooded mergansers. Stumps and tree cavities with openings less than 1 m above the ground accounted for the majority of waterfowl nest sites in one study undertaken in central New York. Of all the waterfowl species that breed in the northeast, wood ducks are the most highly adapted for life in forested wetlands; RMS is the principal forest type used by breeding wood ducks in the northeast (Golet et. al., 1993).

Mammals - Nearly 50 species of mammals are known to live in northeastern RMS. Moose, black bears, white-tailed dear, raccoons, river otters, beaver, voles shrews, and bats are some examples. Significant research on the mammalian use of RMS has been limited to studies of small mammals and black bears. Research in New Jersey and Connecticut indicates that the small-mammal community of northeastern RMS often equals or exceeds that of common upland habitats in species richness, diversity, and abundance. In NJ, both upland and wetland (red-maple/sweet gum) forests had higher numbers of small mammals than did upland grasslands or the edges of freshwater marshes. In the Connecticut study, RMS had higher mammal species richness, higher abundance, and higher diversity than either deciduous or coniferous upland forests. Few studies have examined the factors affecting small-mammal species distribution and abundance in wetland forests. The Connecticut study found that RMS with abundant shrub cover had higher mammalian diversity and richness than either upland forests or RMS with a lesser abundance of shrubs. Mammalian species diversity was also positively correlated with the number of tree and shrub species.

Forested wetlands along watercourses commonly serve as major travel corridors for deer and other large mammals through areas of otherwise unsuitable habitat. For example, RMS are highly significant habitats for white-tailed deer, particularly in urban areas of the northeast, where swamps frequently are the wildest, most inaccessible habitats remaining. River otters, mink, raccoons, and opossums are most common in swamps containing perennial streams or located along lakeshores. Beavers prefer to colonize lowgradient perennial streams in small forested watershed, many of which include RMS. A study conducted in western Massachusetts found that black bear have a strong habitat preference for wetlands from when they emerge from winter dens in mid-April until mid-August. The bears spent more than one-third of their time in spring and summer in wetlands. Swamps were used most heavily in spring when food was most scarce. Skunk cabbage was the most important food at that time (Golet et al., 1993).

Commerce, Recreation, and Aesthetic Enjoyment of the Public

In highly urbanized areas of the northeast, RMS provide a natural, low-cost form of open space. They are especially effective open-space areas since the trees and shrubs provide a tall, visual screen between developed areas and help to reduce noise emanating from major highways or commercial and industrial zones.

A variety of recreation activities take place in RMS. Depending on the water regime and the proximity of the swamps to open water, hunters may pursue waterfowl, deer, ruffed grouse, rabbits, squirrels, or even ring-necked pheasants in these habitats. Birdwatchers also frequent RMS, especially during late spring when migrating warblers and other songbirds feed on insects attracted to the flowers and breaking leaf buds of RM trees. Other recreational activities including canoeing, hiking, and nature photography may be pursued in and along the edges or RMS.

RMS are a distinctive part of the scenic beauty that characterizes the northeast. The scenic and aesthetic value of RMS is most obvious at the landscape level during the early fall when the brilliant yellow, red, and orange foliage of the swamps provides striking contrast to the upland vegetation whose foliage has not yet changed from the predominantly green shades of summer (Golet et al., 1993).

With respect to timber harvesting, the degree of impact of timber removal on wetland functions and values depends on the intensity of cutting. Clear-cuts radically alter habitat values and may result in slightly higher water levels during the summer because of reduces transpiration losses. Selective cutting may have far less impact (Golet et al., 1993).

Ground Water Recharge
Hydrogeologic setting of a RMS primarily determines the elevation of the water table and the degree of its fluctuation to the land surface over time, water chemistry, and groundwater recharge and discharge relationships (Golet et al., 1993).

RMS occur in many different landscape locations. Most RMS are either groundwater depression wetlands (where a basin intercepts local groundwater table) or groundwater slope wetlands (where groundwater discharges as springs or seeps at the land surface and drains away as streamflow). RMS may also be surface-water depression wetlands or surface-water slope wetlands, but not as often (Golet et al., 1993).

Groundwater Depression Wetlands - In the glaciated Northeast, RMS which are groundwater depression wetlands are most likely to occur in stratified drift. During periods when the wetland water level is higher than the local groundwater table (e.g. after major precipitation events in dry season), groundwater recharge may occur. Groundwater may enter the wetland basin from all directions, or it may discharge in one area and recharge in another. In such wetlands, water levels decline throughout the growing season, but at a slower rate than in surface-water depression wetlands because groundwater inflow replaces some of the water lost by evapotranspiration. Continuing groundwater inflow can cause wetland water levels to rise in the fall, when evapotranspiration declines, often in excess of direct precipitation (Golet et al., 1993).

Groundwater Slope Wetlands - RMS which are groundwater slope wetlands occur where groundwater discharges as springs or seeps at the land surface and drains away as streamflow. These wetlands often occur on hillsides over till deposits or at the base of hills where stratified drift and till come into contact. The vast majority of RMS located at the headwaters of streams are groundwater slope wetlands. In these wetlands, the local water table slopes toward the wetland surface. Where groundwater inflow is continuous, the soil remains saturated. Most often, groundwater inputs cease during late summer or early fall as evapotranspiration depletes soil moisture in the root zone, in which case the soil is only seasonally saturated. Due to the sloping land surface, permanent ponding does not occur, however, isolated depressions may temporarily collect water. Groundwater recharge may occur in the wetland after such events, but amounts are likely to be negligible(Golet, et al., 1993).

In northeastern RMS, water levels are normally highest during the winter and spring, and lowest during late summer or early fall. The elevation and degree of fluctuation of the water table with respect to the land surface over time are highly dynamic in RMS. Most RMS which are groundwater depression wetlands are seasonally flooded. RMS which are groundwater slope wetlands are seasonally saturated. (RMS which are surface-water depression or surface slope wetlands are temporarily flooded regimes).

In one Rhode Island study where water levels were monitored for 7 years in six relatively wet swamps containing organic matter, in nearly every year, water levels were clearly influenced not only by total precipitation, but also be distinct weather patterns or unusual events. The study found that monthly evapotranspiration was relatively constant from year to year. Thus, water level fluctuation within each year was due primarily to seasonal variations in evapotranspiration rates, while yearly differences in water levels were caused by annual variations in precipitation (Golet, et al., 1993).

Except for surface-water depression wetland that are perched above the regional groundwater table, natural recharge in most RMS is likely to be a relatively brief seasonal phenomenon. It occurs mainly during the late summer or early fall when, due to cumulative evapotranspiration losses, groundwater levels have dropped below the wetland surface, and groundwater discharge has ceased. One study of a RMS in eastern Massachusetts determined that the swamp recharged the regional groundwater body with 7 million gallons of water during a 6-week period in the fall, and that recharge could be significant during dry periods. In most cases, however, the volume of groundwater recharge in RMS probably is far less than in the surrounding uplands--depending on the slope and soil permeability of the uplands--particularly on an annual basis (Golet et al., 1993).

RMS lying on slopes or in basins that intersect the regional groundwater table are predominantly areas of groundwater discharge. These swamps exist precisely because groundwater is emerging at the surface in the form of springs or seeps. The discharge of groundwater is important in itself because this water supplements public surface-water supplies, maintains fish and wildlife habitats, and improves the water quality of lakes and streams degraded by excess nutrient loads, toxic chemicals, or thermal discharges. Groundwater discharge maintains base flow of streams and keeps stream and lake temperatures low during the late summer, when both of these conditions are critical to aquatic invertebrates and cold-water fishes (Golet et al., 1993).

The spatial association of wetlands and groundwater aquifers is also of great significance. A 1981 study by Motts and O'Brien determined that, on an area basis, about two-thirds of Massachusetts wetlands overlaid potential high-yield aquifers, and that at least 60 communities in that state were obtaining water from wells located in or near wetlands. Because the best location for municipal wells, from a purely hydrologic standpoint, is often near wetlands, and because wetlands are often hydrologically linked to underlying aquifers, this study concluded that the protection of wetlands and their surroundings from pollution should be an integral part of any groundwater management program (Golet et al., 1993).

Sediment Trapping

No research data that dealt specifically with the sediment trapping values of RMS were found. Trees, shrubs, and herbaceous plants growing in swamps do impede the flow of floodwaters, and the resultant reduction of floodflow velocity enables sediments to settle out.

Flood Storage

Flood-tolerance levels for tree species found in northeastern RMS varies. Except for green ash, trees that are classified very tolerant (i.e. able to survive continuous flooding for 2 or more growing seasons) are not important species in RMS. Trees most commonly found in RMS are typically classified as tolerant (i.e. able to withstand flooding for most of 1 growing season) or intermediately tolerant (i.e. able to survive flooding for periods between 1 and 3 months during the growing season). Tolerant species include red maple, Atlantic white cedar, American elm, black gum, and balsam fir. Intermediately tolerant species include the eastern white pine. Eastern hemlock and gray birch are classified as intolerant species, since they cannot withstand flooding for short periods (1 month or less) during the growing season (Golet et al., 1993).

The ability to reduce the peak level of floods and to delay the flood crest is one of the most widely recognized functions of inland wetlands. This function is accomplished mainly through 1) the storage of surface water in wetland basins after snowmelt and major precipitation events, and 2) the reduction in floodflow velocity as water passes through wetland vegetation and over the soil surface. The social significance of the flood abatement function is enormous, particularly if areas downstream from major wetlands are urbanized and vulnerable to flood damage.

How much an individual RMS contributes to flood abatement is heavily influenced by its geomorphic setting and land use within its watershed. Swamps with the greatest potential value for flood abatement are those that 1) are located in a well-defined basin capable of storing floodwater; 2) have a relatively large watershed or one that has been extensively altered by humans, and 3) receive floodwaters directly from an overflowing stream or lake. Hillside seepage swamps have relatively low floodcontrol value compared with temporarily or seasonally flooded basin swamps or swamps associated with lower perennial rivers. Trees, shrubs, and herbaceous plants growing in swamps further aid in flood abatement by physically impeding the flow of floodwaters. In this regard, swamps are more effective than open water or nonpersistent emergent wetlands (Golet et al., 1993).

Quality of Surface and Ground Water
Most of the research on the water quality improvement function of forested wetlands has occurred outside of the glaciated northeast. Hardwood swamps in other parts of the United States have been shown to significantly reduce concentrations of nitrogen and phosphorus in surface water during periods of inundation, and the potential capacity of forested wetlands for removing pesticides and heavy metals is believed to be high. Two Rhode Island studies have, however, dealt with the water quality improvement capacity of northeastern RMS.

A 1991 study by Groffman et al. demonstrated that denitrification rates were significantly greater ($P<0.05$) in poorly drained soils of RMS than in well drained soils of adjacent upland forests. The 1990 study by Gold and Simmons found that removal of nitrate from groundwater generally exceeded 80% in both poorly drained and very poorly drained soils of RMS throughout the year. In almost all cases, nitrate attenuation was significantly higher ($P<0.05$) in the swamps than in the moist forest soils of the bordering upland. Both studies concluded that forested wetlands are likely to be more effective than upland forests as sinks for nitrate. Prolonged anaerobic soil conditions and high soil organic matter content appear to be mainly responsible for the greater denitrification potential of the swamp soils. In addition, high water tables bring groundwater contaminants closer to the surface where they may be picked up by plant roots (Golet et al., 1993).

Values and Functions of the Total Wetland or Wetland Complex
Detritus Export and Food Chain Support - Many RMS are hydrologically linked to streams, lakes, or estuaries. The link may take the form of overland flow through the wetland during storms or after snowmelt; groundwater discharge and subsequent flow through the swamp; or inundation followed by recession, of floodwaters from an adjacent stream or lake. Organic detritus that is not fully decomposed and nutrients that are not immobilized in the forested wetland become available for export to adjacent surface waters. It has been shown that rivers that drain watersheds with extensive areas of bordering wetlands contain more organic material (i.e. dissolved and total organic carbon) than rivers in watersheds without such wetlands. The organic carbon exported from swamps in both particulate and dissolved forms may serve as an energy source for consumers in adjacent riverine or lacustrine ecosystems. No studies have dealt with either the export of detritus or nutrients from RMS to adjacent water bodies or the influence of such export on aquatic food chains. However, since cumulative inputs from numerous wetlands in many subwatersheds determine the characteristics and functions of lower perennial riverine systems, even relatively small wetlands with only intermittent surface-water discharge may play a significant role in nutrient export and food chain support (Golet et al., 1993).

Buffer Zone Functions and Values - Surrounding uplands are essential habitat for both wetland wildlife species, which reside primarily in the wetland, and upland species, which use the wetland on an occasional basis or for breeding. In addition to providing wildlife habitat directly, undisturbed surrounding uplands also reduce the impact of noise and other human activity on wetland wildlife, and may provide a refuge for wildlife during periods of exceptionally high water. In one 1990 study of upland habitats directly adjacent to RMS in Rhode Island (Husband and Eddleman), it was found that the most remote, least disturbed site had the highest number and diversity of reptiles and amphibians, while the most disturbed sites had the highest number and diversity of mammals (Golet et al., 1993).

Undisturbed buffer zones perform other important hydrologic functions. They may reduce the velocity of storm-water runoff, thereby allowing infiltration of water into the soil and reducing the volume of runoff entering wetlands during major storm events. This storm water abatement function prevents the drastic fluctuations in wetland water levels that may be hazardous to ground-nesting birds and other wildlife. Establishment of natural, undisturbed buffer zones around wetlands helps greatly in minimizing the inflow of pollutants to the wetland by capturing sediment, reducing nutrient loads, and filtering other pollutants before they reach the wetland. A recent study which researched the pollution attenuation abilities of natural buffer systems (Hall et al., 1986) found that forest buffer zones in Maryland and North Carolina removed as much as 80% of the excess nitrogen and phosphorus from agricultural runoff (Golet et al., 1993).

In a 1990 study undertaken in southern Rhode Island (Gold and Simmons), a "spike" of nitrate, copper, and a tracer was injected into the ground upgradient from forested upland and RMS monitoring stations at three sites. Complete attenuation of copper was found at all stations. Nitrate removal ranged from 14-87% in the forested upland, where soils were moderately well drained or somewhat poorly drained. In the RMS, nitrate removal was almost complete in both poorly drained and very poorly drained soils. The highest attenuation occurred where groundwater levels were closest to the surface. The study concluded that forested buffer zones can protect wetland and surface-water systems from water quality degradation throughout the year. However, long-term performance may vary because plant uptake and microbial immobilization of nitrate are temporary nutrient sinks (Golet et al., 1993).

Upland habitats along the wetland edge have also been cited as the main source for seeds contributing to the spatial heterogeneity of wetlands. Also, buffer zones are high in species richness. As a transitional area between wetland and upland, the buffer zone commonly contains species that are representative of both communities (Golet et al., 1993).

RMS clearly perform many functions that bear directly on public safety, health, and welfare. The great abundance of RMS in the northeast suggests that the social significance of these functions may be great both locally and regionally. Functions are considered to be processes or actions that the swamps perform; values are the benefits of those functions to society.

Impacts to Nearby Wetlands and Surface Waters

Stormwater and Wastewater Discharges - The addition of stormwater runoff and Wastewater effluent to RMS may alter both the hydrologic regime and water quality. As upland areas become urbanized, the volume of stormwater runoff entering the wetland may increase dramatically. This increase can be expected to cause more drastic fluctuations in wetland surface-water levels, especially where the wetlands are located in isolated basins with restricted outlets. The greater fluctuation and generally greater volume of surface water entering the wetland may reduce plant productivity and eventually change both the structure and species composition of the plant community. Wildlife habitat values may also be seriously affected. Without the proper management of runoff in major land development projects, swamps receiving such waters may become little more than detention basins (Golet et al., 1993).

A wide variety of pollutants (e.g. road salt, oil, grease, gasoline, suspended sediment, fertilizers, pesticides, heavy metals, and chlorinated hydrocarbons)may be introduced into a RMS by stormwater runoff. The effects of many of these pollutants on red maple swamps is unknown, but it is highly likely that the accumulation of such substances in wetland soils adversely affects plant growth, invertebrate life in the soil and in surface waters, amphibians, and other forms of wildlife higher in the food chain. A 1989 study by Ehrenfeld demonstrated increased flooding and significant changes in plant species composition and water chemistry in southern New Jersey swamps receiving runoff from urbanized areas (Golet et al., 1993).

The effects on wetland hydrology and water quality from discharges of wastewater from sewage treatment facilities are similar to those from stormwater runoff, but often much more pronounced because of the greater volume of water discharged, the greater concentration of pollutants in the water, and more sustained discharge (Golet et al., 1993).

Alteration of Surrounding Upland - Human activities in upland areas immediately adjacent to RMS also may adversely affect the functions and values of those wetlands. Some common examples of such activities include clearing of natural vegetation, reduction of groundwater recharge through paving, and installation of belowground sewage disposal systems (Golet et al., 1993).

Roadway Construction - Sediment accumulation in culverts under roads may cause gradual changes in water regimes resulting in the impoundment of water on the upstream side of the road and a reduction in surface-water flow to the downstream side. Such impoundments commonly convert RMS to marshes or shrub swamps.

Boundary Delineation - The task of boundary location is especially difficult in many RMS because the dominant plants in the swamps are usually facultative species (FACW, FAC, or FACU) that also grow in adjacent uplands. RMS located on hillsides or over perched groundwater systems pose a particular problem because changes in surface elevation may not directly correspond to variations in soil moisture. In a 1989 Rhode Island study of RMS (Allen et al.), it was found that herb layer vegetation exhibited the most clearly defined moisture gradient, correlated best with hydric soil status, and permitted the most precise discrimination between upland and wetland. A moisture-related gradient was reflected in the tree layer also, but it was not as consistent as in the herb layer. The shrub layers were found to be of little value in locating a wetland-upland vegetation break because the predominance of facultative species along the entire length of most wetland-to-upland transects obscured moisture-related gradients in vegetation. For these reasons, it seems appropriate to place major emphasis on the hydric status of soil in the delineation or RMS (Golet et al., 1993).

FUNCTIONAL VALUES OF ATLANTIC WHITE CEDAR SWAMPS PER LITERATURE REVIEW

Atlantic white cedar (*Chamaecyparis thyoides*) is geographically restricted to freshwater wetlands in a narrow band along the eastern coastal US ranging from Maine to Mississippi. In New England, Atlantic White Cedar (AWC) is most abundant in southeastern MA, RI, and eastern CT. Throughout the glaciated northeast, only a fraction of earlier stands remains. Little has been published about NH's cedar wetlands; their continual loss is documented repeatedly in Baldwin's short notes (1961, 1963, 1965) and unpublished letters, and in unpublished records of the New England Nature Conservancy and the Society for the Protection of New Hampshire Forests(Laderman, 1989).

Generally, AWC decreases in abundance with increasing distance from the coast. AWC grows from sea level to 457 m elevation, but the great majority of stands are found between sea level and 50 m. It is probable that the distribution of the species was always restricted to sites too wet for most other northeastern trees. There is standing water in many northern cedar swamps for half the growing season or longer; the soil is primarily organic (commonly termed "peat" or "muck"); and ground water is highly acidic (Laderman, 1989).

Cedar-dominated wetlands are most commonly called cedar swamps or cedar bogs. AWC occurs almost exclusively with other hydrophytes on hydric soils. AWC forests may be composed exclusively of an even-aged monospecific stand of close-ranked trees. In forests successfully managed for harvest and regeneration, as well as in many natural stands that originated after fire or flood, this is often the picture. However, in many natural or selectively harvested situations, cedars grow in uneven-aged mixed stands which provide a greater diversity of habitats that support a more species-rich fauna and flora (Laderman 1989).

Cedar swamps are situated shoreward of lakes, river or stream channels, or estuaries; on river floodplains; in isolated catchments; or on slopes. They may also occur (rarely) on bars or island in lakes or rivers. Slightly elevated hummocks dominated by cedar are often interspersed with water-filled hollows in a repeating pattern that forms a readily identified functionally interrelated landscape. In the Northeast, glacial lakebeds, kettleholes of the glacial moraine, and outwash plain streambeds are landscape features that now support cedar communities (Laderman 1989).

In New Hampshire, 30 swamp systems or sites distributed across 20 towns are known to contain AWC. The total extent of swamps where cedar forms at least 25% of the canopy is estimated at approximately 479 acres. There has been a general decline of many AWC populations in the state, but some excellent swamps still remain. Changes in the hydrology, in particular the raising of water levels, has resulted in the historical extirpation of AWC from a number of wetlands in New Hampshire. Any efforts aimed at protecting the remainder of these communities will have to insure that a suitable hydrologic regime can be maintained (Sperduto and Ritter 1994).

Statewide, the distribution of AWC is highly clumped. The three major centers of distribution are: 1) the "northern" coastal systems of Rye and Portsmouth, 2) the "southern" coastal systems of Newton and Kingston, and 3) the inland "corridor" systems.

Nutrient Support for Finfish, Crustacea, Shellfish, and Wildlife

The water of AWC wetlands that are dependent on precipitation for water and minerals (as in many glacial kettles) is generally deficient in ions, has low specific conductance, and is low in pH. Cedar stands that grow in stream-side or stream-fed swamps or are subject to significant lateral flow (as in the Great Dismal Swamp) often have a more neutral pH, since their water is enriched by mineral soils through which it passes (Laderman 1989).

In a 1988 study of a cedar wetland bordering a tidal creek in Maryland (Whigham and Richardson), it was found that AWC leaf tissue is significantly higher in Ca, Al, Pb, and Sr, and poorer in N and P than other plants associated with it. The study also found that soil of cedar-dominated wetlands has higher Ca, Mg, Al, and Fe levels, and lower P content than surrounding wetlands (Laderman 1989).

Habitats and Reproduction Areas for Plants, Fish, and Wildlife

Obligate wetland trees are rare in the glaciated Northeast. Atlantic white cedar is the only relatively common species so classified (Golet et al., 1993).

AWC is the only member of its genus east of the Rockies and is an uncommon tree species within NH, but it is not on the state endangered species list. The species is highly susceptible to loss in the northern reaches of its range due to changes in water levels within swamps, and cutting practices. It is known to grow very slowly (eight-inch trees over 200 years old were reported by Baldwin, 1963) and virtually nothing is known about its rate of reproduction or its relative reproductive success.

One study suggests that any adequate conservation efforts with this species must include an evaluation of its genetic structure. Based on the study's findings, AWC populations in NH and Maine appear to be truly discrete from one another in a genetic sense, and that some stands may exist which are unique, as in the case of the Kingston, NH stand. The study also discovered that stands can be reasonably discrete from each other if only separated by 1/4 mile. This indirectly supports a hypothesis put forth by Belling (1977) suggesting that it is not time or distance that is important in the spread of this species (and by implication the genetic relatedness of populations), but rather it is the ecological history of the landscape (i.e. fire, water levels, and cutting events) that are important. An AWC stand that has a long history in an area (perhaps 2,000 to 4,000 years) contains adaptive gene complexes for the existing set of site conditions. For this reason, special consideration should be given any stands located on unusual sites. The distribution of protected stands should be as wide as possible so that a range of ecological conditions are included (Eckert 1988).

Seed Production and Dissemination - AWC is monoecious, but the male (staminate) and female (pistillate) flowers are produced on separate shoots. The onset of seed production varies greatly with environmental conditions (i.e. climate, water level, substrate, and competition with other cedars and other species). Seed dispersal starts in early autumn, and is influenced by weather, the height and diameter of the parent tree, and the density and height of surrounding vegetation. Experiments by Little (1950) confirmed that density and height of the surrounding vegetation can almost completely prevent the dispersal of seeds beyond the edge of a stand. The first seed crops of a tree have a lower average germination rate than later production. Under natural conditions, much AWC seed does not germinate until the start of the 2nd or 3rd growing season after seed fall. Overwinter storage in a cool, moist medium, such as the moss and peat of a swamp floor, apparently promotes germination (Laderman 1989).

Microrelief, also referred to as mound-and-pool topography is a characteristic feature of nonfloodplain forested wetlands in the Northeast. Microrelief creates a variety of microhabitats and thus has a major effect on species composition and distribution of swamp flora. It is usually most pronounced in the wettest swamps. According to certain studies, microrelief appears more highly developed in Atlantic white cedar swamps (compared to RMS), which had significantly higher meant water levels as well. Pronounced microrelief allows species with widely differing soil moisture requirements or tolerances to coexist in a limited area (Golet et al., 1993).

Microrelief in an AWCS is important in providing suitable cedar seedbed. Logs, stumps, or hummocks that are above water during the spring high-water periods form favorable seedbeds, but seedlings starting there may die from lack of moisture during later dry periods. However, seedlings growing in lower places frequently drown during subsequent high-water periods. Seedlings sprouting at intermediate positions had better survival than those starting either at the highest or lowest spots. Suitable substrates include rotten wood, peat, and *Sphagnum* moss. Hardwood and shrub leaf litter and pine needles inhibit cedar germination to less than one percent. The floor of a wetland previously supporting AWC is the most favorable substrate. Relatively open conditions are necessary for healthy growth of seedlings, although they may survive for 1 to 3 years under a mature cedar canopy, where light intensity averages 4% to 6% of full sunlight. Warm open areas, such as cleaned clearcut cedar stands, abandoned cranberry bogs, recent burns over waterfilled swamps, or peatlands partly drained after floodling, provide satisfactory conditions for AWC reproduction (Laderman 1989).

Flora - Plant species growing with AWC manage to thrive in a waterlogged environment with a varying hydroperiod, and generally acidic, nutrient-poor and often anaerobic soil and water. Major physical and physiologic adaptations to these extreme conditions are a hallmark of the biota of the AWC community, but no quantitative work has been published on the subject (Laderman, 1989).

Canopy layer - A monospecific dense, mature, even-aged stand may have a sparse to nonexistent subcanopy, shrub, herb, or reproduction layer, except at breaks in the canopy, and at the edges of the stand. In mixed stands throughout the cedar's range, the most frequently encountered trees are red maple and black gum. Additionally, in the northern states, gray birch (*Betula populifolia*), black spruce, white pine, and hemlock are most widely distributed (Laderman 1989).

Shrub layer - Relatively open-canopy cedar stands generally have a well-developed shrub layer. More cedar-associated shrubs are in the heath family (Ericaceae) than in any other. The most widely distributed shrubs (including woody vines) associated with AWC are red chokecherry (*Aronia arbutifolia*), sweet pepperbush, bitter gallberry (*Ilex glabra*), fetterbush (*Leucothoe racemosa*), swamp honeysucke, poison ivy (*Toxicodendron radicans*), poison sumac (*T. vernix*) and highbush blueberry (Laderman 1989).

Herbaceous layer - The most abundant herbaceous cover is found with cedar on bog mats and as a temporary feature shortly after disturbance that either eliminates the shrub layer or opens the canopy. Where there is open water, submerged and emergent aquatics may be present. A continuous carpet of sphagnum mosses (*Sphagnum* spp.) is often seen where there is adequate light. The most widely distributed cedar-associated herbs are: sedges (*Carex* spp.), round-leaved sundew (*Drosera rotundifolia*), partridge-berry (*Mitchella repens*), cinnamon fern, and royal fern (*O. regalis*) (Laderman 1989).

Sphagnum has unique characteristics and creates unique conditions. It requires cool, moist conditions for its growth, and these conditions may characterize regions of large area or may occur locally. Sphagnum as a living plant has certain distinctive characteristics of structure and growth habits. Dead sphagnum also has pronounced physical and chemical properties. These characteristics and properties play their part in enabling this plant to develop a habitat in which certain plants flourish while others are excluded. The long, slender leafy stems grow vigorously at the tip and die at the basal portion without immediate disintegration. Both stems and leaves of Sphagnum contain large cells whose active portion dies by the time the cells are mature, leaving only the wall which is characterized by small pores and is supported by ring-like thickenings on the inside (known as hyaline cells). Hyaline cells take up and hold large quantities of water. Almost any species of Sphagnum will take in and hold ten times its own weight of water and the more robust and leafy species may hold twice that much. Sphagnum causes water with which it remains in contact to have an acid reaction. This is true not only of living Sphagnum but also of its dead remains (Rigg 1940).

Microflora - The acid, nutrient-poor waters of AWCS might be expected to support few species of algae. However, cedar bog water contains a high diversity of protists in all seasons: flagellated, ciliated and ameboid; spined, smooth, testate, walled, naked, rigid and flexible; colonial, filamentous and unicellular; swimming, floating, gliding and sessile; colorless, green, blue, yellow, orange, red, brown, and black; epibiontic on plants, animals and inert surfaces; of every conceivable shape, and ranging in size from barely macroscopic to below the range of the light microscope (Laderman/Atlantic White Cedar Wetlands Symposium

1984).

In one study undertaken in an AWC wetland in coastal Massachusetts, algal assemblages of undisturbed and disturbed sites were assessed and compared. The stable site was relatively undisturbed, protected from roadway runoff by a thick herbaceous and shrubby border 3 m wide. At the disturbed site, runoff eroding since 1972 from a housing site on an adjacent morainal hill had cut a 30 cm wide, virtually vegetation-free channel to the swamp. As might be expected of acid-water microflora, both sites had a species richness that is high for fresh water. However, the stable site had a much greater total number of species and subtaxa than the disturbed site, in the ratio of 3:2. The stable site had twice as many chlorophycean species. Of the characteristic acid-bog species, the stable site had three times as many desmids. *Gonyostomum*, the sole chloromonad, was present only in the stable site. The two cyanophyceans (blue-green algae) present were found only in the disturbed site. The presence of blue-greens may reflect an altered availability of resources not detected by standard chemical analysis. The stable site had a much greater skew in its taxonomic clustering at every phyletic level (e.g. species per family, families per order). Conversely, the disturbed site's microflora was more evenly distributed among families and orders (Laderman/Atlantic White Cedar Wetlands Symposium 1984).

In general, NH cedar communities fall into the following types: Seasonally flooded AWCS community, North Coastal AWC-Yellow birch-Sweet pepper bush community, and Boreal AWCS community. Another potential type corresponds to "seepage swamps", where species usually associated with seepage conditions (e.g. green wood orchis, purple-fringed orchid) exist. Such habitats are not presently considered as a distinct type, since they appear to occupy small areas. But further research is needed to determine if some of these areas (e.g. Cedar Boulevard and Portsmouth cedar swamps in Portsmouth) may be larger than believed and if sufficient floristic differences exist to justify a new type (Sperduto and Ritter 1994).

One hundred ninety vascular plant species are associated with AWCS in New Hampshire, including several rare plants. One rare coastal plain plant, Walter's sedge (*Carex striata* var. *brevis)* is new to the state. The factor which appeared to have the greatest effect in determining the number of species at a system was the number of cover types which the system possessed and perhaps the degree of flooding. Those systems which contained closed canopy stands, open canopy swamp, and areas of scrub-shrub or shrub swamp were the richest systems. The capacity of a system to possess a number of cover types, appears to be most strongly linked to hydrologic factors and differences in nutrient regimes associated with hydrology (Sperduto and Ritter 1994).

<u>Fauna</u> - Information on animals and associated wildlife values of AWCS is more limited than for plants. Cedar wetlands can be considered as ecological islands. Large, connected natural areas are of greatest value in promoting wildlife species diversity because there are more species per unit area than in separated islands, and there are fewer species lost due to genetic drift. Large blocks of unbroken territory are important for non-game birds species that nest on or near the ground or in open areas, or for species that are obligate forest-interior inhabitants, migrate long distances, or are shy of humans. According to the USFWS, a cedar forest managed for maximum wildlife habitat will contain a diverse mixture of old growth, mature, intermediate, and regeneration areas (Laderman 1989).

Birds - Maximum variation in vertical stratification is of particular significance to avifauna. In a 1984 study, 13 species of breeding birds (21 pairs) were counted in one 40.5 ha AWCS in Barrington, NH. The bird species included Blue jay, Black-capped chickadee, Brown creeper, Gray catbird, Hermit thrush, Veery, Red-eyed vireo, Black-and-white warbler, Ovenbird, Northern waterthrush, Common yellowthroat, and the Canada warbler. The same area had supported 16 species (23 breeding pairs) in 1951. In 1965, five distinctive cedar stands were described and mapped in the plot. By 1984, cedar densities in the study plot had decreased due to cutting and natural causes. There was a general increase of shrubs and tree seedlings and the proportion of larger diameter cedar had increased over the 33 year time span. Changes in breeding bird species composition generally reflected vegetative change (Miller et al./Atlantic White Cedar Wetlands Symposium 1984).

Avian communities have been shown to respond to the layering of vegetation within similar habitats, as well as to varied habitats. Specifically, foliage height diversity has been linearly correlated to bird species diversity, while percent vegetation cover and foliage volume have been shown to be less powerful predictors. One of the findings from a study of the Great Dismal Swamp was that older stands of AWC provide important breeding habitat for birds. In the study, two cedar stands that differed in age and size were selected. The study looked at the species composition and density of breeding birds, the differences in avifauna of the two selected stands, and sought to compare the density and diversity of breeding birds in the AWC to those in surrounding maple/gum communities. Study findings revealed that shrub and tree densities of cedar stands were markedly higher than in the maple/gum forest. The cedar community supported approximately the same number of nesting species, but a much higher density than the Maple/Gum site. The study also showed that a small patch of overmature cedar surrounded by maple/gum forest provides habitat that is as valuable for cedar-nesting birds as the interior of a large cedar stand (Terwilliger/Atlantic White Cedar Wetlands Symposium 1984).

Mammals - AWC provides excellent cover for deer, and rabbits. In the northeast, AWC foliage and twigs is the preferred winter browse for white-tailed deer. Cottontail rabbit and meadow mouse feed on cedar seedlings (Laderman 1989).

Insects - The larva of one butterfly--Hessel's Hairstreak (*Mitoura hesseli*)--feeds exclusively on AWC. It is an emerald-green butterfly which has been found in cedar swamps. The federally endangered Banded bog skimmer dragonfly's (*Williamsonia lintneri*) few extant populations are in or near AWCS in New Jersey, New York, Rhode Island Massachusetts, and New Hampshire (Laderman 1989).

Much more information is needed on the potential distribution of Hessel's Hairstreak butterfly among NH's cedar swamps. This rare AWC-obligate species has only been documented from one swamp--the Hampstead Cedar Swamp, and has not been relocated recently. This butterfly often feeds high in the cedar canopy and is difficult to detect (Sperduto and Ritter 1994).

Species Richness - In New Hampshire, seasonally flooded AWCS community types often occur in association with open or moving water such as along lake, pond and stream borders and in basins with impounded drainage. The type is characterized by the presence of numerous herbaceous species typical of marsh or open wetland habitats. Of the different AWCS communities sampled by the NH Natural Heritage Program during June-October 1993, this type was the highest in species richness, although composition varied widely. All the sampled areas classified as seasonally flooded occur in the near coastal zone, although it is likely that a boreal seasonally flooded type also exists. pH measures taken in seasonally flooded AWCS were generally among the highest recorded for cedar swamps in New Hampshire with a range of 4.4 to 6.5 (Sperduto and Ritter 1994).

Areas of Special Concern - The NH Natural Heritage Program's study of New Hampshire's AWCS indicates that there are relatively few high quality AWCS in the state with potential long-term viability and a continuing trend of decline of many historic populations. The study recommends that a concerted effort be made to protect remaining viable populations that span the vegetative and ecological diversity among AWCS observed in the study. Research indicates (Ecker 1992) that larger complexes of individual cedar swamps close together may be more likely to have unique genetic potential and genetic variability important for the long-term evolution of the species. Close proximity of stands (ideally on the order of 0.25 miles or less) also enables gene flow through pollen migration and thus the potential for maintaining unique genes. The Kingston-Newton cedar swamp complex seems to be the only assemblage of swamps in NH with an adequately large enough AWC meta-population to potentially form an "evolutionary reserve", that is one with the potential to contain genetic resources significant to long-term evolution of the species (Sperduto and Ritter 1994).

The highest quality viable Coastal Community Type swamp systems include the Manchester Cedar Swamp (in Manchester), Portsmouth Cedar Swamp (in Portsmouth), and Locke Pond (in Rye); the highest quality viable Boreal Community Type swamp systems include Loverens Mill Swamp (in Antrim--considered the best boreal AWC swamp in the state and perhaps in New England), and Ring Brook Swamp (in Sutton). It is recommended that as many AWC swamps as possible be retained from future harvesting since no old-growth cedar swamps are presently known. Large, recently uncut and mature cedar swamps have the best potential to reinstitute ecological and vegetation dynamics which may be associated with unmanaged cedar ecosystems (Sperduto and Ritter 1994).

Commerce, Recreation, and Aesthetic Enjoyment of the Public

Logging - Slash left after logging severely reduces cedar seedling establishment. Few seeds germinate, and fewer survive under the 0.6 to 1.2 m of dense slash often left after logging. Hardwood sprouts and shade-tolerant shrubs grow out over the slash and are rapidly covered with vines to form a virtually impenetrable mass (Laderman 1989).

Repeated logging together with hydrologic disturbances appear to be the main reasons for the drastic decline of AWC in the Carolinas. Even without hydrologic disturbance, it seams likely that repeated logging in the absence of fire leads to stepwise reduction in area and loss of cedar habitat to deciduous swamp forest, with eventual extirpation of the species (Frost/Atlantic White Cedar Wetlands Symposium 1984).

In the Pinelands of NJ where individual AWC harvests are small-scale operations (less than 10 acres), various AWC harvesting techniques are currently employed. Harvesting methods are especially critical to the continued preservation and maintenance of cedar because there is usually no subsequent management of harvested areas. Several factors need to be considered when harvesting AWC. Dense slash adversely affects the establishment of adequate cedar production. Loggers often compound the slash problem by transporting sawmill wastes to a harvest site for the construction of access roads. This practice should be discouraged. The age of a stand can affect reproductive success following a harvest cutting. Stands that are 45 years old usually have sufficient seed stored in the soil to restock the area, but reproduction that is dependent on stored seed may be affected in stands which are 30 years old or less. The low seed production of relatively young trees is compounded by their smaller stature, since the distance to which cedar seeds disperse is in part a function of the height of the parent tree (Zampella/Atlantic White Cedar Wetlands Symposium 1984).

Cultural Values - History cites many examples of native American adaptation to habitation and refuge in swamps, including coastal cedar swamps. Conflicts between New England colonists and Native Americans, including decisive battles of the Pequot and Metacom wars, took place in cedar swamps. In New England, pervasive stone and earthen ritual artifacts signal and connect natural environmental features such as swamps, rocky ridges and celestial bodies. The cedar swamp kettles of the Cape Cod moraines typically have groups or ritual stone mounds as likely parts of the vision quest, on their southeastern flanks. There is also evidence that earth and stone construction, found in freshwater wetlands today, may be the remains of a ritual wetland management system. There is evidence of structures which were built for waterway management for fishing, and frequent occurrences of earth and stone works within and near New England cedar swamps (Mavor and Dix/Atlantic White Cedar Wetlands Symposium 1984).

Aesthetics Besides being a rich source of information on cultural heritage, wetlands are visually and educationally rich environments because of their ecological interest and diversity. Very little is known about the biological and chemical processes that occur in these special environments. Cedar wetlands' complexity makes them excellent sites for research. Because of the low nutrient conditions in these swamps, they contain plants, animals, and microbes that have many special adaptations to the low-nutrient conditions.

Ground Water Recharge

Hydrology - Data on all quantitative and functional aspects of cedar forest water regimes are sparse and fragmentary. The most comprehensive information available on hydrological functions in a cedar wetland relates to the Great Dismal Swamp. In general, cedar swamp waters are highest in late winter and early spring. In late spring and early summer, evapotranspiration removes large quantities of water, with the water table dropping below ground surface in places. In autumn, swamps are driest, with standing water and water tables at their annual low point. Most water loss is via evapotranspiration. In winter, with declining temperatures and reduced evapotranspiration, the water table rises; in flowing systems, stream flow swells and lateral subsurface and surface flow increases (Laderman 1989).

AWC usually grows on hummocks slightly elevated above and surrounded by hollows where water level may be up to 1.2 m deep, or as low as 0.3 m below the surface. USFWS Classification of cedar-dominated wetlands is determined by the water regime in the hollows. AWC are found in the following water regimes: nontidal, seasonally flooded, saturated, semipermanently flooded, and permanently flooded. Cedar-dominated swamps generally have higher water levels than nearby RMS and are flooded for longer periods (Laderman 1989).

Water-table activity varies considerably among forests, and it varies even more among years. Seven years of research in six Rhode Island cedar swamps have determined that the amount and seasonal distribution of precipitation are major factors determining annual water regimes at most sites, but the relative effect of variations in precipitation depends upon each swamp's hydrogeologic setting. Variation in the size of the groundwater term in the wetland water budget is believed to be the major reason for differences in water-table activity among sites. Yearly variations in radial growth within individual cedar swamps may be related to variations in water levels, but the nature of the growth-water regime relationship differs markedly among swamps. A general relationship between water regime and annual radial growth is not evident. Based on this study, cedar growth rates appear to be more closely related to groundwater chemistry and forest stand characteristics (Golet and Lowry/Atlantic White Cedar Wetlands Symposium 1984).

Sediment Trapping

No data specific to the sediment trapping capabilities of AWCS were found. Trees, shrubs, and herbaceous plants growing in swamps do impede the flow of floodwaters, and the reduction of floodflow velocity enables sediments to settle out.

Flood Storage

No data specific to flood storage capabilities of AWCS were found. However, the ability to reduce the peak levels of floods and to delay the flood crest is one of the most widely recognized functions of inland wetlands.

Quality of Surface and Ground Water

Although no specific data were found concerning the role of AWCS in influencing surface and ground water quality, wetlands have been shown to remove organic and inorganic nutrients and toxic materials from water that flows through them. The accumulation of organic peat, which is a common component of AWCS, causes the permanent burial of chemicals.

Values and Functions of the Total Wetland or Wetland Complex

For AWCS, consideration of the ecosystem must go beyond the technically defined wetland boundary. The adjacent area may be critical determinant in the structure and function of the entire wetland. The hydrological regime of a cedar wetland is a major determinant of the biota in both flowing (lotic) and nonflowing (lentic) systems. Mature AWC are adapted to a wide rang of water depths, but rapid, prolonged change in water depth kills seedlings outright and stresses or kills mature specimens. In streamside, lakeside, and estuarine-border cedar swamps, the depth of water adjacent to and contiguous with a wetland is a major controlling influence on the wetland's water regime (Laderman 1989).

Impacts to Nearby Wetlands and Surface Waters

Impacts of Disturbance by Fire and Water - AWC occupies a narrow hydrologic position toward the wet end of the moisture gradient, and intermediate between that of deciduous swamp forest and evergreen pocosin. It requires periodic catastrophic fire, but with a medium to long fire-return interval (Frost/Atlantic White Cedar Wetlands Symposium 1984).

The destructiveness of a fire is inversely related to the amount of water present. At lower water, more peat burns. The deeper the peat burn, the lower the possibility that viable seed will remain in the forest floor, and the lower the possibility that a new cedar stand will develop. However, a light fire at high water tends to eliminate shrubs and brush, and favors cedar seedling germination and survival. The relationship of AWC to fire and water appears paradoxical: cedar stand are destroyed by fire, but light fire clears competition from the substrate surface, permitting cedar reproduction. A very hot prolonged fire at low water burns off peat, which can result in more standing water. Cedar seedlings are drowned by flooding; mature trees are stressed by permanent inundation. However, flooding severe enough to kill undergrowth prepares a seedbed favorable to cedars, and high moisture content is essential for cedar reproduction and growth (Laderman 1989).

While hurricane or tornado blowdowns might fell substantial tracts of white cedar, only fire can be expected to both kill standing timber and remove debris, exposing the open seedbed required for regeneration. In this respect, white cedar seems to be dependent upon cyclic wildfire in a way similar to that reported for jack pines (*Pinus banksiana*) in Michigan and sand pine (*Pinus clausa*) in Florida. One of the most shade-tolerant trees, white cedar does not reproduce beneath its own living canopy or that of deciduous swamp forest. Only following fire does it have the opportunity to repopulate a site or colonize adjacent sites occupied by other wetland communities (Frost/Atlantic White Cedar Wetlands Symposium 1984).

Other Natural Factors - Natural forests can also be impacted by storms (windthrow, ice damage, salt spray, saline water inclusion); deer browse, herbivory by mice and rabbits; and beaver activity. By far the most significant influence on the creation and destruction of cedar wetlands by natural forces is the slow rise of sea level. With each episode of disturbance, history is intrinsically a factor, as the cedar community at each site is adapted to a particular range of water, light, weather, etc. regimes. An abrupt change is, by itself , a stress factor (Laderman 1989).

Suburban Encroachment - Studies in the NJ Pinelands indicate that suburbanization eliminates the characteristic cedar-associated species and erodes water quality. Residential development is accompanied by an increase in species richness, with an initial increase in drier-site species followed by a large increase in non-indigenous species as native plants disappear. Regional water chemistry is strongly influenced by surface inflow of storm drainage carrying heavy sediment loads and by septic tank eutrophication. Water acidity is reduced, and ammonia, phosphates, and chlorides increase via subsurface routes. The greatest overall impact is created by direct runoff (Laderman 1989).

The combination of tight hydraulic connection between wetlands and uplands and the interdigitation of wetlands and uplands throughout the landscape suggests that land-use changes in the upland areas are likely to affect cedar swamps. Numerous studies on the impacts of urbanization on water resources have documented changes in a variety of parameters such as water table height, water flow rates, stream flooding characteristics, and water quality. These variables have been shown to be critical to the structure and function of wetlands. Initial study of Pinelands swamps in NJ demonstrated that in developed watersheds, species characteristics of Pinelands wetlands were replaced by weedy species and Inner Coastal Plain species not normally found in the Pinelands. Other studies documented similar changes in the algal flora and in the plankton community. Thus, regional land-use changes have well-documented effects on the composition of cedar swamps in the NJ Pinelands (Schneider and Ehrenfeld/Atlantic White Cedar Wetlands Symposium 1984).

Until recently, there were no data that indicated which aspects of suburbanization affected AWC wetlands, or that demonstrated what level of disturbance was associated with changes in wetland structure. A study of 18 cedar swamps in NJ Pinelands was undertaken to determine which hydrological parameters of cedar swamps were being affected by suburban development, and whether different levels of suburbanization were causing different levels of change in cedar swamps. The study sites represented a gradient of suburban disturbance effect. They were located either in least disturbed areas (near sites), within 10 m of the edge of the swamp behind a house (developed sites) or at a stormwater sewer outfall (runoff sites) within a suburban development.

Study results indicated that suburbanization has substantial impacts on the plant community and physical environment of AWCS in the NJ Pinelands. There is an increase in species richness across the development gradient: a slight increase in species from upland Pinelands communities is seen in the least disturbed sites, a small influx of upland Pinelands species, weeds, and Inner Coastal Plain species occurs in the developed sites, and a large influx of non-native species of many habitat types and life forms occurs in the runoff sites. The change in species richness is accompanied by a change in structure, particularly in the runoff sites. The physical environment also changes along the disturbance gradient. Subtle changes in hydrology suggestive of drier conditions are correlated with the observed influx of upland species into the swamp. Water chemistry reflects the input of both surface stormwater pollution and below-ground septic tank effluent inputs. The combination of surface and below-ground inputs at the runoff sites causes more extreme differences from undisturbed conditions than do the effects of below-ground septic inputs alone. Study results suggest that suburbanization causes more pronounced changes in water chemistry than in water level, and that the enrichment of surface waters permits the influx of non-Pinelands species. Even the presence of roads proximate to swamps causes small but noticeable changes in species composition. It is clear that runoff sites experience much greater impacts than do developed sites or near sites (Schneider and Ehrenfeld/Atlantic White Cedar Wetlands Symposium 1984).

In 1990 and 1991, researchers Ehrenfeld and Schneider documented the link between human disturbances and vegetative changes at a series of cedar wetland sites in the NJ Pinelands defined by differing levels of suburban intrusion. They found that cedar wetlands directly influenced by stormwater runoff were much more strongly altered than all other wetland sites. AWCS are unique communities. The extreme acidity with low nutrient availability of the environment results in a sensitive plant community with low diversity structure. For this reason, species composition in cedar wetlands in highly sensitive to development. Virtually all water entering these wetlands is derived from infiltration in the uplands. This tight hydraulic connection assures that upland development will impact the quantity and quality of the water.

Study findings showed that the control sites (i.e. sites within undisturbed watersheds and isolated from development) were highly dominated by species indigenous to cedar swamps. However, as development impacts progressed, indigenous species were dramatically displaced by species not traditionally associated with cedar swamps. Thus, cedar swamps impacted by development gradually lost species that define their uniqueness. Reproduction of white cedar itself proved especially sensitive to development stress. Mean densities of white cedar seedlings were greatly reduced in the developed and runoff sites. This decline in cedar seedlings may be directly related to the decline in Sphagnum in these sites. Sphagnum is the most common substrate on which cedar reproduction is generally found and holds a large reservoir of buried viable seed. Unfortunately, the plant is especially sensitive to chloride, trampling, hydrological changes, elevated nitrogen concentrations, and other consequences of suburban development (Center for Watershed Protection, Technical Note 22, 1994).

<u>Non-point Source Load</u> - Both agriculture and suburban development add significantly to the nutrient, heavy metal, total solids, and non-biodegradable content of the wetland water and soil into which they drain. Peat acts as a sink for DDT and other similar non-biodegradable absorbable molecules. Fertilizer, pesticides, herbicides, and animal and human wastes contribute to the non-point source load of ground and surface water

(Laderman 1989).

Roadways - The long-term effects of roadway construction are not fully comprehended. It is clear that they temporarily act exactly as any dam which floods adjacent areas and prevents the free flow of water and nutrients downstream. Also, the effect on water quality of roadbase materials and runoff must be considered. The complex hydrological effects of drainage ditches have a major overall impact on AWC forests. Normal water retention and slow subsurface sheetlfow are replaced by rapid channelized surface flowthrough of water made virtually unobtainable to the wetlands (Laderman 1989).

Damage due to deer browse, winterkill, and windthrow are exacerbated at road edges where the growth of competing subcanopy vegetation is stimulated by the additional light and nutrient inflow. Likewise, increased light and heat favor the germination and rapid growth of cedar seedlings immediately adjacent to road cuts, and the local increase in moisture due to the channeling of water has a similar effect (Laderman 1989).

Other Human Impacts - Large scale disruption of hydrology, leading to flooding in some areas and drainage in others, peat subsidence, oxidation and exposure of mineral soil.

Conversion of muck lands to agriculture.

Post-logging site preemption by understory or stump sprouting species.

Shading of seedbed by logging slash.

Destruction of sapling by post-logging fires in slash, especially in the second to tenth years after logging.

Fire suppression, eliminating opportunity for white cedar to invade patches occupied by other species.

The tendency to selectively log cedar patches, leaving adjacent swamp forest intact, eliminating possibility for expansion of the cedar stand. At best a new stand can reoccupy 100% of the original site. Historical and field evidence suggests at least a portion of the site is lost to other species each time a stand is logged (Frost/ Atlantic White Cedar Wetlands Symposium 1984).

FUNCTIONAL VALUES OF FORESTED WETLANDS IN GENERAL PER LITERATURE REVIEW

Nutrient Support for Finfish, Crustacea, Shellfish, and Wildlife

Water and nutrient balance studies in riverine forested wetlands have shown that isolation or uncoupling of wetlands from the stream channel leads to higher concentrations of phosphorus and nitrogen in the stream water. The export of these materials was more erratic without the wetland, and the quality of the organic material differed from that when the stream and floodplain forest were coupled. Without the forested wetland, waters became eutrophic and algal production was partly responsible for the change in quality of organic material. The excess phosphorus and nitrogen in the stream isolated from the forested wetland was considered a measure of the biotic activity of wetlands when water was allowed to flood them (Ecosystems of the World: Forested Wetlands, 1990).

Habitats and Reproduction Areas for Plants, Fish, and Wildlife

Deciduous forested wetlands appear to be very productive habitats for breeding birds. Breeding bird populations were studied in eight deciduous forested wetlands in the southern half of the Connecticut Valley region of MA to provide baseline information on these habitats. The study areas ranged from permanently wet sites with dense shrub growth and widely spaced small trees, to seasonally saturated sites with a mature forest cover and variable understory profiles. Red maple was the dominant tree species on all sites; American elm, yellow birch, black ash, hemlock, and black gum were much less abundant but frequent in young stands and as subcanopy trees in mature stands.

Nearly 2700 bird observations were recorded during the above study, comprising 46 species. Overall, foliage gleaning birds were most abundant, followed by ground feeders and bark gleaners, respectively. The most common species in order of decreasing abundance were: Common Yellowthroat, Veery, Canada Warbler, Ovenbird, Northern Waterthrush, and Gray Catbird. The effects of variables that appeared most important to avian abundance and richness in deciduous forested wetlands were: small shrub density, dead tree abundance, average tree height, height of lowest branches, crown closure, amount of surface water, presence of streams, depth of mineral soil, and magnitude of annual ground water fluctuation. The results suggest that avian community values of deciduous forested wetlands are directly related to foliage distribution, primary productivity, and hydrologic patterns of a site (Swift 1980).

Vernal pools form in topographic depressions found in forested swamps. These areas contain water in spring and fall, and provide extremely important breeding habitat for amphibians. Mole salamanders of the genus <u>Ambystoma</u> (spotted, blue-spotted, Jefferson's), as well as the wood frog breed exclusively in vernal pools. These salamanders travel in mass migrations along traditional routes to return to the pools where they were born to breed. Loss of these pools can eliminate entire breeding populations in localized areas (Pedevillano 1995).

Other wildlife species are attracted to vernal pools because of the abundant amphibian prey. These include Blanding's turtles, spotted turtles, great blue herons, green herons, and garter snakes. Invertebrates are an essential component of vernal pools and provide food for amphibian larvae. Fairy shrimp only live in vernal pools and lay drought-resistant eggs that hatch when the pool fills with water. Fingernail clams and freshwater snails are often found in the pools as well as a variety of other mollusks, insects, and crustaceans. Vernal pools are extremely productive, valuable ecosystems that are often overlooked and undervalued (Pedevillano 1995).

Scrub-shrub wetlands are utilized for feeding, nesting, breeding, and cover by a variety of wildlife species. Scrub-shrub wetlands are dominated by woody species in the sapling and shrub stages. Vegetation commonly found in these areas includes highbush blueberry, sweet pepperbush, swamp azalea, spicebush, arrowwood, winterberry, willow, alder, dogwood, common elder, buttonbush, and meadowsweet. Associated herbs often include cinnamon fern, sensitive fern, spotted jewelweed, sphagnum, sedges, rushes, and hydrophilic grasses. These wetlands frequently flood in the spring or contain pockets of standing water. Dense shrubs serve as excellent nesting habitat for songbirds that may also feed on the fruits of berry-producing shrubs or perch on shrubs when catching flying insects. Some birds often found in these wetlands include: common yellowthroat, alder flycatcher, yellow warbler, chestnut-sided warbler, blue-winged warbler, American redstart, Canada warbler, song sparrow, gray catbird, and American goldfinch. American woodcock, a migratory game bird, frequents dense alder thickets where it nests on the ground and feeds on earthworms found in the soft muddy substrate (Pedevillano 1995).

Shrub swamps that are flooded in spring are frequently used as breeding ponds by the northern spring peeper and gray treefrog. The proliferation of these amphibians attracts predators such as the great blue heron, raccoon, and mink. Shrub swamps that are adjacent to emergent marshes provide shrubby cover for nesting waterfowl. Snowshoe hare, cotton-tail and white-tailed deer also use shrub swamps for food and cover (Pedevillano 1995).

Commerce, Recreation, and Aesthetic Enjoyment of the Public
Hunting, fishing, birding, hiking, and canoeing are just a few of the recreational activities that take place in forested wetlands. You don't need scientific data to underscore the importance to the public of this wetland value.

Ground Water Recharge
No additional data on ground water recharge values of forested wetlands was found.

Sediment Trapping
Deposits of fine sediment typically contain large concentrations of associated contaminants and trace elements from farms and urban areas. This sediment and contaminant trapping function of wetlands is commonly acknowledged, despite limited understanding of the transport and deposition of sediment and associated contaminants. A study of sediment and trace-element trapping in forested wetlands and their effects on water quality was undertaken at sites along the Chickahominy River in southeastern Virginia. Initial study results show that rates of sediment deposition along the River between Richmond and Providence Forge, as determined from growth-ring analysis of excavated trees, differed in forested wetlands. These rates are related to stream gradient, stream power, percent wetlands, hydroperiod, and land use. Sedimentation rates are higher along broad, flat-gradient reaches with low stream power and high percentages of mapped wetlands(extended hydroperiod) than along relatively steep gradient reaches with high steam power and low percentages of wetlands. Sedimentation rates are highest (5.7 mm/yr) downstream from urban-industrial areas (Hupp et al. 1993).

The above study shows that substantial amounts of sediment and trace elements (i.e. zinc, cadmium, lead, copper, chromium, tin and nickel) are trapped in forested wetlands near Richmond, which supports the contention that forested wetlands improve water quality downstream from urbanized areas. Trace-element concentrations are clearly related to sediment deposition and distance from urban sources and are highest where sedimentation is highest (Hupp et al., 1993).

Flood Storage
In comparison with upland ecosystems, basin-type forested wetlands may conserve water by reducing evapotranspiration rates. Basin forests also affect runoff by reducing peak flows, retarding the time to peak flow, and increasing the magnitude and length of base flow conditions. The storage capacity of the flooded area determines how much peak flow will be retarded. On a regional level, the area of wetlands in catchments, as well as their storage capacity, determines the overall effect wetlands have on stream and flood flows. An analysis of the flood characteristics of streams in Wisconsin suggested that the relative flood flow was curvilinearly related to the relative area of wetlands and lakes within the catchments. Although the analysis was based on a theoretical reduction in wetland and lake area, the analysis suggested that with only

40% of the catchment area composed of wetlands and lakes, flood flows were reduced to 20% of those for catchments without wetlands. Flood flows were reduced by 50% with as little as 5% of the catchment in wetlands. (Ecosystems of the World: Forested Wetlands, 1990).

Quality of Surface and Ground Water

A study in Maryland found that forested wetlands act as a buffer between the upland watersheds and the bogs. Weekly samples of surface and/or interstitial water were collected from six bogs and contiguous forested wetlands in Maryland to determine what changes in eight water quality parameters (i.e. pH, ammonia, nitrate, nitrite, phosphate, calcium, potassium, and dissolved organic matter) occurred as water moved into and through the upstream forested wetland and into and through the bogs. Only one bog contained AWC. The forested wetlands were dominated by red maple, sweet bay and black gum. The other objective of the study was to identify water quality parameters that could be used to monitor potential changes that might occur in the bogs as a result of upstream watershed development. Calcium and pH were found to be important at three sites. Three forms of inorganic nitrogen were important at the most eutrophic site, while phosphorus and ammonia were important at another site (Whigham/ Atlantic White Cedar Wetlands Symposium 1984).

Values and Functions of the Total Wetland or Wetland Complex

Freshwater wetlands, including forested wetlands, are part of the biosphere, and play roles that in many respects we do not yet comprehend. One general wetland attribute, which on a global basis may prove to be very important, is that wetlands are among the few chemically reducing ecosystems which are closely coupled with the atmosphere. Thus, they may play a major role in atmospheric chemistry. We do know that fluxes of methane and carbon dioxide are associated with wetlands, although there is very little quantitative information on just how important the wetlands may be in their contribution as sources or sinks of these gases. It is also evident that wetlands may be very active with respect to several additional atmospheric trace tests, some of which are important to the greenhouse effect, to the atmospheric deposition problem, or to the ozone question. These gases include nitrous oxide, carbonyl sulfide(potentially one of the most important sulfur gases to atmospheric sulfur chemistry), and dimethyl sulfide (Hemond/Atlantic White Cedar Wetlands Symposium 1984).

Strong evidence about the critical role of riparian forests play in stream ecosystems has emerged in a recent 1993 research study. The physical and ecological characteristics of headwater streams that had two different types of riparian cover--second growth forest and grassy meadows--were compared. The first and second order streams used in the study were located in the White Clay Creek watershed in the Piedmont of Pennsylvania. It was observed that the channels of headwater streams with forest cover were about 2.5 times wider than those with only grass cover. This "stream narrowing" associated with headwater streams without riparian forest cover was attributed to the formation and slumping of grass sod from the banks that gradually encroached into the channel. The channel gradually narrowed in width and became deeper.

The ecological consequences associated with stream narrowing were as follows. Fifty-four percent less surface area was present on the stream bottom to support the benthic habitat needed for aquatic organisms. Also, forested streams had 7.5 times as much woody debris and 27 times as much total snag volume in their channels compared to streams without forest cover. Debris and snags are extremely valuable habitat areas for many aquatic insects and help the stream retain more of its organic matter inputs. Thirty-eight times more leaf litter and fine woody debris were present in forested streams, as compared to those with only grass or meadow cover. The greater retention of organic matter in forested streams is of critical significance because leaf litter serves as an important energy source in the aquatic food web.

The wider and shallower channels of forested streams had nearly 17 times more wetted rock area than the deeper and narrower meadow streams. Submerged cobbles and rock surfaces are where aquatic insects cling to avoid high water velocity. Exposed rocks are sites where aquatic insects emerge to begin the aerial phase of their life cycle. Reduced wetted rock area results in poorer habitat for aquatic insects.

The study also found that shade to streams provided by forest cover resulted in water temperatures in forested streams that were much cooler (an average of four degrees C) than meadow streams. Aquatic ecosystems in headwater streams without forested cover have reduced diversity and productivity (Center for Watershed Protection, Technical Note 14, 1994).

Impacts to Nearby Wetlands and Surface Waters

One consequence of the intense development in the Northeast has been forest fragmentation, or breaking up of large contiguous tracts of woodland into smaller and smaller pieces. This lessens the overall habitat value of an area by excluding certain species (i.e. deer, mink, river otter and long-tailed weasel) that have larger home ranges and are more sensitive to human disturbance. Habitat fragmentation also creates easier access to nests and young by predators such as fox and skunk, and allows nest parasitism by brown-headed cowbirds. The decline of forest interior birds (i.e. warblers, vireos, thrushes) that nest exclusively in large, undisturbed tracts of woodland, has been in part attributed to fragmentation of Northeast forests (Pedevillano 1995).

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