Best Development Practices

Conserving Pool-Breeding Amphibians in Residential and Commercial Developments in the Northeastern United States

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PREFACE

Vernal pools and adjacent upland habitats contribute a vast amount of biodiversity to landscapes of the northeastern United States. However, due to their small size, and a variety of other issues, these habitats are disproportionately impacted by development trends associated with regional urban and economic growth. As a result, vernal pools—and the species that depend on them—are disappearing at a rapid rate. We must come to terms with the complexities that surround the protection of vernal pools. The Best Development Practices (BDPs) in this publication present a new approach to accomplish this goal. This document also outlines steps to identify those vernal pools worthy of protection. These BDPs are not, and we repeat ***not***, new layers of regulation. They provide a decision-making pathway that builds upon the strong tradition of home rule within our region; they add value to that home rule by enabling municipalities to become more effective stewards of their natural resources. We consider this a win-win solution—one that should eliminate costly delays in project approval by giving local decision-makers the ability to reliably identify wetlands worthy of protection and, by default, other areas where a community can plan for additional growth and development.

As conservationists with real-world experience working in communities throughout New England and New York, we realize our dual obligation. We need to help those communities plan for their conservation needs. However, for conservation planning to be truly effective, we must also provide information to help those communities plan for their infrastructure and development needs. Ultimately, we view these BDPs as an exercise in empowering local decision-makers to make better, scientifically credible, and consistent decisions. In short, we seek to replace site-by-site reactive decision-making with a framework for making multiple decisions. This is, in essence, planning. We are thankful to the many people who contributed their time and efforts in the development of these guidelines, including our colleagues in academia, resource management, municipal government, and the development community. This is a work in progress. We look forward to receiving feedback from users of these BDPs as to their effectiveness, and we welcome suggestions for improvement.

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I. INTRODUCTION

Vernal pools, and the adjacent critical terrestrial habitat used by vernal pool amphibians during the non-breeding season, often overlap with land slated for residential or commercial development. These Best Development Practices (BDPs) provide a pragmatic approach to stewardship that encourages communities to attain a more complete knowledge of their vernal pool resources, gather the information that enables them to designate pools that are exemplary and worthy of protection, and then develop strategies to protect them. Implementing these BDPs will better balance the needs of vernal pool wildlife with human activities.

Best Development Practices for vernal pools are recommended conservation strategies for residential and commercial development that minimize disturbance to vernal pools and the surrounding critical terrestrial habitat. These BDPs:

- provide a framework for decision makers to assess the quality of individual pool habitats;
- have positive effects, or minimize negative effects, of development on natural resources;
- provide standards based on the best available science;
- were developed with the participation of state agencies, scientists, resource managers, and developers in the New York-New England region (the Region); and
- are offered under the premise that voluntary compliance, reinforced with education, is an effective strategy for protecting natural resources.

CAUTION! This document addresses only one element of the vernal pool conservation equation. Specifically, it targets pools located on privately owned, relatively small parcels of land (usually less than several hundred acres) at the suburban-rural frontier, which have been slated for development. We recognize that a comprehensive protection strategy for vernal pools must also include large tracts of unfragmented habitat (thousands of acres) with multiple pools. In New England and New York, these lands are primarily held by Federal and state government, and by the timber industry. To address management of these large habitat blocks in a working forest landscape, see *Forest habitat management guidelines for vernal pool wildlife in Maine* (Calhoun and deMaynadier 2001). Owners of small woodlots may also apply the harvest principles outlined in that document.

What is a Vernal Pool?

Vernal pools are wetlands of great interest to ecologists because, despite their small size, they are characterized by high productivity and a unique assemblage of species adapted to breeding in seasonally flooded wetlands (Skelly et al. 1999, Semlitsch 2000). Within the last decade, interest in vernal pools has increased dramatically because of well-publicized declines of amphibians, many of which breed in vernal pools and other small wetlands (Pechmann et al. 1991, Lannoo 1998).

Plants and animals dependent upon vernal pools vary from state to state, as does the definition of a vernal pool. The following is an operational definition based on those common ecological functions identified by all states in the Region:

> *Vernal pools are seasonal bodies of water that attain maximum depths in spring or fall, and lack permanent surface water connections with other wetlands or water bodies. Pools fill with snowmelt or runoff in the spring, although some may be fed primarily by groundwater sources. The duration of surface flooding, known as hydroperiod, varies depending upon the pool and the year; vernal pool hydroperiods range along a continuum from less than 30 days to more than one year (Semlitsch 2000). Pools are generally small in size (< 2 acres), with the extent of vegetation varying widely. They lack established fish populations, usually as a result of periodic drying, and support communities dominated by animals adapted to living in temporary, fishless pools. In the Region, they provide essential breeding habitat for one or more wildlife species including Ambystomatid salamanders* (Ambystoma *spp., called "mole salamanders" because they live in burrows), wood frogs* (Rana sylvatica), *and fairy shrimp* (Eubranchipus *spp.*).

A review of vernal pool definitions either adopted or developed by each state in the Region is provided in *Appendix 1*; despite varying definitions, all pools share a unique ecology. Where available, vernal pool-associated amphibian species are listed for each state. Some states have not yet developed a definition for vernal pools, while others have extremely specific definitions. Some definitions focus on physical characteristics of pools while others are defined by the species of amphibians and invertebrates breeding in the pools. Vernal pool identification guides are available to help citizens recognize these habitats. Information about these guides is provided in *Appendix 3*. See Figures 1, 2, and 3 for images of vernal pools and associated amphibian breeding habitats.

What is Critical Terrestrial Habitat?

Pool-breeding amphibians depend upon both aquatic *and* terrestrial habitats for survival. Most adult vernal pool amphibians in the Region spend less than one month in breeding pools; the rest of their annual cycle is spent in adjacent uplands and wetlands (Semlitsch 1981, 2000). The surrounding forest provides critical terrestrial habitat for adult amphibians and newly emerged juveniles throughout the year (Semlitsch 1998). In their upland habitats, both young and adults need areas of uncompacted, deep organic litter; coarse woody debris; and shade. These elements provide a suitable forest floor environment for amphibians as they move through the forest, feed, and hibernate (deMaynadier and Hunter 1995, DiMauro 1998). This dependence on the surrounding landscape for survival has prompted one researcher (Semlitsch 1998) to refer to this critical terrestrial habitat around pools as a "life zone," instead of a "buffer zone." Conservation strategies that focus only on protecting breeding pools and associated wetlands will most likely fail to maintain healthy amphibian populations. Protection of critical terrestrial habitat must also be a priority (Marsh and Trenham 2001).

SIX REASONS TO CONSERVE VERNAL POOL LANDSCAPES

(1) UNIQUENESS

Fish-free pools provide optimal breeding habitat for a specialized group of amphibians that have evolved to use these wetlands. Vernal pool amphibian eggs and larvae are extremely vulnerable to fish predation. Even though vernal pool amphibians may breed in wetlands where fish are present, survival of eggs and larvae in such environments is limited (Petranka 1998).

Many vernal pool amphibians return to breed in the pools where they developed (Duellman and Trueb 1986, Berven and Grudzin 1990, Sinsch 1990) and show little tendency to relocate if their breeding habitat is disturbed (Petranka et al. 1994). Protecting vernal pools is a critical first step in conserving vernal pool amphibians.

(2) HABITAT

Small wetlands and vernal pools contribute significantly to local biodiversity by supporting an abundance of plants, invertebrates, and vertebrates that would otherwise not occur in the landscape (Semlitsch and Brodie 1998, Gibbs 2000). Many small mammals, birds, amphibians, and reptiles use these wetlands for resting and feeding. The average travel distance for frogs, salamanders, and small mammals is less than 0.3 km (Gibbs 1993, Semlitsch 1998, Semlitsch and Bodie 1998). The destruction of small wetlands in the landscape increases the distances between remaining wetlands. Often, these distances are greater than these animals can travel. Large mammals (e.g., bear, moose) use these small wetlands as a food source. Rare wildlife, including state-listed species, may use pools (see Tables 1 and 2).

(3) WEB OF LIFE

Vernal pools contribute a significant amount of food (e.g. amphibians and insects) to adjacent habitats (Semlitsch et al. 1996, Skelly et al. 1999). This food production is fueled by decaying leaves (organic matter) that are deposited in these pools each fall. After emerging from the vernal pool, wood frogs and salamanders may be eaten by a wide variety of forest animals including snakes, turtles, birds, and small mammals (Wilbur 1980, Pough 1983, Ernst and Barbour 1989). For example, in one Massachusetts vernal pool, Windmiller (1990) found that the weight of all the vernal-pool breeding amphibians exceeded the weight of all breeding birds and small mammals in the 50-acre upland forest surrounding his study pool. He concluded that vernal pool amphibians exert a powerful influence on the ecology of surrounding forests, up to 0.25 miles from the edge of the pool.

(4) SAFETY NET

Vernal pools are so small that they frequently fall through the regulatory cracks. Because vernal pools are often small in size and hard to identify, they are inadequately protected by state or local wetland regulations. An overview of state regulations for vernal pools is presented in *Appendix 1*.

(5) EDUCATIONAL RESOURCE

A vernal pool is a small ecosystem, easy to “wrap your arms around.” As such, it makes an ideal outdoor laboratory for school children and adults. Often, a local pool can be visited or people discover that they have a vernal pool on their own property. These pools are often rich with life and easier to become intimate with than lakes or rivers.

(6) AESTHETICS

The rich array of moss-covered logs, delicate shades of greens and browns through dappled sunlight, and the beauty of the vividly marked or masked amphibians that breed in these sylvan gems, are all inspirations.

Amphibians, reptiles, and small mammals also need suitable upland habitat *connecting* wetlands. These animals live in small populations or small units that, together, make a larger population. These small populations often mix through dispersal of juveniles. For example, small populations may replenish one another with new breeding stock when natural catastrophes (e.g., drought or freezing) eliminate breeding adults or cause larval failures in certain pools.

The average distance that a spotted salamander moves from a pool into the surrounding forest is 386 feet; Jefferson salamanders may travel 477 feet (see Figure 4; Windmiller 1996; Semlitsch 1998; Faccio, *in prep.*) with as much as half the population, in some instances, travelling even greater distances. Wood frog juveniles, on average, disperse approximately 1,550 feet from a breeding pool (Berven and Grudzien 1990). *Therefore, long-term persistence of vernal pool amphibian populations depends on the availability of habitat that connects local populations and enables dispersal among them* (Semlitsch and Bodie 1998).

Other animals (including reptiles, birds, and small mammals) also depend on these small wetlands. Beetles and water bugs, for example, that overwinter in permanent water migrate to vernal pools to breed and feed during the spring and summer. Medium- to large-sized mammals, including raccoon, skunk, fox, deer, moose, and bear, visit pools to feed on amphibian eggs and fresh green shoots emerging in spring or, later in the season, on amphibians and insects. Therefore, the loss of individual vernal pools may weaken the health of entire wildlife communities.

The bottom line: Connections between pools, through the upland landscape, must be maintained to accommodate population movements—dispersal to and from pools for breeding, foraging (feeding), resting, and replenishing locally extinct populations.

Vernal Pool Animals

Many definitions of vernal pools contain language referring to “obligate” or “indicator” species. Obligate species depend upon vernal pools for successful breeding. However, many so-called obligate species, such as wood frogs and spotted salamanders, breed in other wetlands, including roadside ditches, artificial wetlands, and small ponds. However, in many of these breeding sites, the survival of the eggs and production of juveniles may be greatly diminished. We suggest using the term “indicator” species as a more ecologically accurate term. A list of vernal pool indicator species of the Region, with state conservation status information, is provided in Table 1; images of representative indicator species are provided in Figure 5.

The term “facultative” species commonly refers to animals that use the pools for resting and foraging; they might reproduce in vernal pools, but use other habitats for reproduction as well. A list of vernal pool facultative species in the Region, with state conservation status information, is provided in Table 2; images of representative facultative species are provided in Figure 6.

Table 1. Vernal pool indicator species and state conservation status
(E = endangered, T = threatened, SC = special concern, P = present, A = absent).

INDICATOR SPECIES	RI	CT	MA	NH	VT	ME	NY
Blue-spotted salamander	A[1]	T/SC[2]	SC	P	SC	P	SC
Jefferson salamander	A	SC	SC	SC	SC	A	SC
Spotted salamander	P	P	P	P	P	P	P
Marbled salamander	P	P	T	SC	A[3]	A	SC
Tiger salamander	A	A	A	A	A	A	E
Wood frog	P	P	P	P	P	P	P
Spadefoot toad	T	E	T	A	A	A	SC
Fairy shrimp[4]	P	P	SC[5]	P	P	P	P
Featherfoil	SC	SC	P	P	A	T	T

[1]The blue-spotted salamander is extirpated in Rhode Island.
[2]Blue-spotted pure diploid populations are listed as Threatened; the blue-spotted hybrid complex is listed as Special Concern.
[3]Unsubstantiated historic records; no populations have been located (Andrews 2001).
[4]Fairy shrimp comprise a group of several related crustaceans throughout the region; "P" indicates presence of one or more species.
[5]In Massachusetts, the Intricate Fairy Shrimp is listed as Special Concern.

Table 2. Vernal pool facultative species and state conservation status[1]
(E = endangered, T = threatened, SC = special concern, P = present, H = historical record only, A = absent).

FACULTATIVE SPECIES	RI[1]	CT	MA	NH	VT	ME	NY
Northern cricket frog	A	A	A	A	A	A	E
Western chorus frog	A	A	A	A	E	A	P
Four-toed salamander	P	P	SC	P	SC	SC	P
Spotted turtle	P	P	SC	SC	E	T	SC
Wood turtle	SC	SC	SC	P	SC	SC	SC
Blanding's turtle	A	A	T	SC	A	E	T
Eastern box turtle	P	SC	SC	A	A	E	SC
Eastern ribbon snake	SC	SC	P	P	SC	SC	P
Eastern hognose snake	SC	SC	P	P	A	H	SC
Ringed boghaunter dragonfly	SC	E	E	E	A	E	H

[1]For the purposes of this table, we have combined RI's categories of SI (State Interest) and C (Concern) to equal Special Concern (SC).

In-depth natural history accounts of pool-breeding amphibians and other species can be found in *Amphibians and Reptiles of Connecticut and Adjacent Regions* (Klemens 1993), *Amphibians and Reptiles in Connecticut: A Checklist with Notes on Conservation Status and Distribution* (Klemens 2000), *Maine Amphibians and Reptiles* (Hunter et al. 1999), *A Field Guide to the Animals of Vernal Pools* (Kenney and Burne 2000), *A Guide to Amphibians and Reptiles* (Tyning 1990), and *Salamanders of the United States and Canada* (Petranka 1998). See Figure 7 for examples of various stages within a mole salamander (*Ambystoma*) life cycle.

II. PLANNING AND ASSESSMENT

This section complements Section III; Management Goals and Recommendations, by providing step-by-step guidelines to develop a locally based conservation plan for vernal pools. Conservation of vernal pool-breeding amphibian habitat is often most effective at the local level where neighbors, planners, and other concerned citizens play an active stewardship role. The planning process will take time and many hands to develop and implement, and should not take the place of, or delay, the application of management recommendations to individual projects as they arise.

Effective planning for vernal pool conservation at the municipal level requires long-term vision instead of short-term crisis reaction. This enables communities to plan for the protection of vernal pool resources as a subset of their overall master planning process. Therefore, it is not viewed as inconsistent or discretionary, but rather as a legitimate part of the jurisdiction's accepted and approved development goals. Three sequential steps for local conservation are presented: (1) vernal pool mapping and inventory, (2) vernal pool ecological assessment, and (3) developing conservation actions.

> **NOTE:** Clustering development away from vernal pools and other key resources is an important planning tool. It not only conserves open space, but also reduces impervious surfaces and accessory infrastructures.

> **CAUTION!** The absence of a local vernal pool inventory and assessment should ***not*** forestall implementation of Management Recommendations for individual projects and small scale conservation initiatives. To address development and conservation concerns at individual vernal pools, proceed to Section III: Management Goals and Recommendations.

The goal of municipal-wide inventory and mapping exercises is to identify exemplary pools or pool clusters in each community. This enables decision-makers, developers, and citizens to understand which sites are considered to be of special significance as a community resource.

Step 1. Vernal Pool Mapping and Inventory

Identifying vernal pools in your town might at first seem like a daunting task. In this section we present some simple steps to get you started. Further tips and details for identifying and mapping vernal pools are provided in *Appendices 2* and *3*.

Some vernal pools can be located by using aerial photography and National Wetland Inventory (NWI) maps (see *Appendix 2* for details). Inventory methods will vary according to the availability of resources, the region of interest, and level of expertise. A primer on identifying and mapping vernal pools using aerial photography and Geographic

Information Systems is available in the publication *Massachusetts Aerial Photo Survey of Potential Vernal Pools* (Burne 2001).

Pre-inventory checklist:

Towns should consider the following issues *before* beginning the inventory process:

- Assess the status of wetland and vernal pool mapping in your town. It is possible that outside contractors or researchers have already located vernal pools for various projects.
- Is aerial photography available for your town? Is it appropriate for the mapping project? (See *Appendix 3* for aerial photo resources.)
- Do you have skilled volunteers for photo-interpretation and field identification of vernal pools (using whatever criteria are applicable to your State or town)?
- What is the availability of funding (Federal or State) for conducting an inventory or for contracting professionals to photo-interpret vernal pool resources?
- Is there a local university, land trust, or non-profit environmental organization willing to offer guidance or other support?

Conducting the inventory:

1. Locate vernal pools through mapping, ground surveys, or a combination of both. If possible, use a Geographic Positioning System (GPS) to obtain coordinates, so that a vernal pool data layer can be created in a Geographic Information System (GIS).
2. Mark locations of pools on tax maps, topographic maps, and, if available, in GIS.
3. Identify clusters of pools.
4. Conduct a biological inventory/field verification of as many pools as possible (see Ecological Assessment steps, below).
5. Identify pools or pool complexes of conservation interest and work to develop a protection strategy (see details provided later in this document).

Step 2. Ecological Assessment: Prioritizing Conservation Targets

Towns will not be able to protect every vernal pool. Therefore, it is important to know which pools have the greatest ecological significance, and thus merit greater protection. This can be accomplished by examining pools in the field and collecting biological data to determine each pool's relative local importance. The following "Vernal Pool Assessment Sheet" provides a means for doing this. Issues associated with such assessments are described in the text below.

Vernal pools, or clusters of pools within a town, may vary tremendously in quality or ecological significance. In general, towns should focus their conservation efforts on:

1. ecologically significant pools along size and hydroperiod (length of time the pool holds water) gradients in order to protect a wide diversity of pool-breeding invertebrates and amphibians;
2. pools with intact critical terrestrial habitat;
3. pools with long-term conservation opportunities (e.g., pools on public land, not-for-profit lands, or in large tracts of relatively undisturbed private ownership); and
4. maintaining or restoring the adjacent terrestrial habitat for pools in agricultural or suburban lawn/landscaped settings where the amount of forest cover is limited. (Note: Although forested landscapes are preferred habitat, unfragmented agricultural lands support dispersal of many amphibians and have the potential to become even more valuable following old field succession or reforestation.)

Rating the ecological significance of an individual vernal pool is not a simple process. For this reason, we provide general guidance for assessment of vernal pool ecological significance based on two parameters: (1) biological value of the vernal pool, and (2) condition of the critical terrestrial habitat. Assessment of a pool's biological value factors in species abundance, species diversity, and pool vulnerability. Assessment of the critical terrestrial habitat includes the integrity of the vernal pool's envelope (land within 100 feet from the pool's edge) and critical terrestrial habitat (land from 100 to 750 feet from the pool's edge).

Note: The egg mass thresholds and critical thresholds of development around the pool are based on current available science. Egg mass numbers may vary regionally (Calhoun et al., unpub. data). We urge you to complete your own biological inventory and assess egg mass densities that indicate important breeding pools in your area. These numbers may be influenced by whether pools occur in clusters or are isolated. Low numbers in clustered pools do not make the pool less valuable; instead, they may indicate that the population has dispersed its breeding among all the pools.

We identify pools with 25% or less developed area in the critical terrestrial habitat as having high priority. The few studies that have been conducted on this topic suggest that development pressures (buildings, impermeable surfaces, roads, lawns) higher than 25-30% cause declines in breeding populations (see "Translating Science into Conservation," below). See Figure 8 for examples of vernal pools and critical terrestrial habitats under varying development scenarios.

VERNAL POOL ASSESSMENT SHEET

A. Biological Value of the Vernal Pool

(1) Are there *any* state-listed species (Endangered, Threatened, or Special Concern) present or breeding in the pool?
Yes______ No__________

(2) Are there two or more vernal pool indicator species breeding (i.e., evidence of egg masses, spermatophores [sperm packets], mating, larvae) in the pool?
Yes______ No__________

(3) Are there 25 or more egg masses (regardless of species) present in the pool by the conclusion of the breeding season?
Yes______ No__________

B. Condition of the Critical Terrestrial Habitat

(1) Is at least 75% of the vernal pool envelope (100 feet from pool) undeveloped?
Yes______ No__________

(2) Is at least 50% of the critical terrestrial habitat (100-750 feet) undeveloped?
Yes______ No________

NOTE: For these purposes, "undeveloped" means open land largely free of roads, structures, and other infrastructure. It can be forested, partially forested, or open agricultural land.

Cumulative Assessment

Number of questions answered YES in category A	Number of questions answered YES in category B	Tier Rating
1-3	2	Tier I
1-3	1	Tier II
0	1-2	Tier III
1-3	0	Tier III

CAUTION! *This rating system is designed strictly as a planning tool, not as an official assessment tool.* It will enable you to determine the relative ecological value of pools within your community. A Tier I rating—which will most likely apply to only a minority of sites—denotes exemplary pools; Management Recommendations should be applied at these sites. For pools rated as Tier II, proceed with care; you need more information! Tier II pools will probably constitute the majority of your vernal pool resources; Management Recommendations should be applied at these sites to the maximum extent practicable. Tier II pools might also be likely candidates for restoration efforts (e.g., reforestation of the critical terrestrial habitat).

TRANSLATING SCIENCE INTO CONSERVATION

Very little published research has addressed conservation concerns as they relate to vernal pool habitats and wildlife. Therefore, the recommendations made in this document are based primarily upon decades of field observations made by the authors. Those observations have repeatedly demonstrated that pool-breeding wildlife populations experience precipitous declines in response to developments within vernal pool envelopes and critical terrestrial habitats.

Vernal pool research conducted in Massachusetts by Bryan Windmiller (unpub. data) corroborates the authors' conclusions. In one study, 25 acres (10 hectares) of upland forest adjacent to a vernal pool in an urban setting was almost completely cleared. Within two years, the pool's wood frog population was extirpated (i.e., wood frogs became locally extinct). This occurred despite the maintenance of an untouched 150-foot wide buffer of forested upland around the pool and a forested wetland corridor adjacent to the pool. These findings underscore the fact that narrow buffers alone—which are usually less than 150 feet—are insufficient to protect wildlife populations.

In a second study, Windmiller tracked large populations of spotted salamanders, blue-spotted salamanders, and wood frogs over a five-year period at two vernal pool breeding sites located in close proximity. The land surrounding one of the pools remained largely intact throughout the five years. At the second pool, approximately 25% of the existing forested upland within about 1,000 feet (300 meters) was cleared for residential development after the first year of the study. That development also greatly fragmented the remaining forested upland, although a 100-foot wide buffer was left untouched.

Within four years of the beginning of construction, spotted salamander numbers declined by 53%; the wood frog population was reduced by 40%. Blue-spotted salamander numbers also declined over a two-year period following initial construction but subsequently recovered to pre-development levels. In contrast, there was no reduction in amphibian breeding population sizes at the undeveloped pool.

This study demonstrated that even a relatively small degree of development—covering approximately 25% of the surrounding critical terrestrial habitat—can negatively impact vernal pool wildlife. As in the first study, these impacts occurred despite the maintenance of a forested buffer.

The recommendations in this document would limit the footprint of development to <25% of the area surrounding productive vernal pools. This is a relatively conservative recommendation, given the results of the second study. However, this threshold may be less detrimental to resident amphibians if impacts are further reduced by following site-specific recommendations made in Section III of this document.

Step 3. Putting a Conservation Plan into Action

From Awareness to Action

Informed with the results of a town-wide vernal pool survey and assessment, local decision-makers can begin targeting for protection those significant vernal pools and vernal pool clusters identified by their inventory and assessment. The advantage of such a proactive planning exercise is that it replaces the site-by-site debate, which is focused on individual pools, with an objective, scientifically informed process that can be applied to all of a town's vernal pool resources. From a developer's perspective, it provides certainty as to where locally important or significant resources are located. This should replace the *status quo* of vocal opposition to almost every development near a vernal pool, regardless of the relative ecological viability of the pool.

Why is it important to simplify the presently confused process? Concern for vernal pools has risen dramatically over the last decade. However, unless clarity and fairness become integral parts of the decision-making process, we risk creating a backlash that could undo all that has been achieved in heightening public awareness of these vital resources. With increased knowledge and authority comes a responsibility to act in a consistent and fair manner.

The most difficult task will be to determine from the Assessment and Mapping Exercise where a community should focus their efforts. We recognize that it is impossible to protect every vernal pool and its critical terrestrial habitat. Therefore, each community should prioritize its efforts based on the results of its inventory and assessment. The driving impetus for this priority-setting exercise is that a smaller number of well-protected vernal pools (ideally those with intact envelopes and 75% undeveloped critical terrestrial habitat) is far preferable, from a conservation standpoint, to a greater number of pools "protected" in name only but lacking a sufficient envelope and critical terrestrial habitat to sustain populations of vernal pool species. Once conservation priorities are established, there are a variety of mechanisms local jurisdictions can employ to achieve these goals.

CAUTION! The priority-setting exercise will focus conservation efforts on certain parcels of property, and de-emphasize the importance of others. Because of the political and emotional nature of such decisions, this priority-setting should be conducted with maximum public input, so that the community understands the reasoning behind this exercise. Priorities set by a small group, in the absence of broader public involvement and understanding, are likely to be challenged, and will ultimately be ineffective.

Incorporation into Comprehensive, Development, or Master Plans

Community Master Plans should incorporate the goals of these vernal pool protection strategies, justification for those goals, and locations of exemplary pools that have been targeted for stewardship. There are two primary reasons for doing this.

- Clarity: It is very important that all stakeholders (property owners, citizens, developers, and local decision-makers) are aware of the goals of vernal pool protection and which properties are considered essential to achieving those goals. This provides some level of certainty in what is now a chaotic case-by-case debate.
- Security: If a community clearly articulates its goals and objectives in a written, publicly adopted document, and then consistently follows those guidelines, it is less susceptible to legal challenges. Legal challenges against municipal decisions are most successful if it can be demonstrated that those decisions are capricious, without reasoned basis, and therefore inconsistent with a community's articulated goals and policies.

Acquisition

Acquisition is expensive and therefore not often feasible for communities. It is important to spend limited acquisition dollars wisely. However, under certain circumstances it might be possible for a community or land trust to acquire key properties. We recommend acquisition measures for individual vernal pools only if they receive a Tier I rating during the Vernal Pool Assessment Exercise; this acquisition should include at least 750 feet of land from the vernal pool depression in all directions. In addition, acquisition efforts are appropriate for large blocks of open space with clusters of pools of any Tier.

Easements

Easements provide another mechanism to protect pools and their contiguous critical terrestrial critical habitat. On subdivision projects where open space with vernal pools is reserved we recommend that the developer convey a conservation easement to a local land trust, the municipality, or a conservation or scientific not-for-profit organization. In our experience this conservation strategy is far superior to reliance on a homeowner's association to protect these resources. The holder of the easement would be responsible for ensuring that the terms of the easement are being met, and for informing the neighbors about the stewardship needs of the property.

Overlay Zones

A resource overlay zone specifically designed to protect vernal pools can be adopted by the town. This would be particularly effective where clusters of Tier I and Tier II pools occur. While leaving town zoning in place, additional standards, requirements, and incentives are applied in the overlay zone. It is recommended that a town adopt a resource overlay zone to encompass those vernal pools and critical terrestrial habitats that have been designated as protection priorities. The zone could provide a mix of regulations and incentives to conserve vernal pools and preserve economic equity including (but no limited to):

- minimal lot-clearing restrictions within the zone, allowing for more dense clustering of development;
- density bonuses for tightly clustered, conservation-oriented subdivisions;
- reductions in road width standards including cul-de-sac radii, and prohibiting hard 90 degree, vertical curbing;
- establishment of a transfer of development rights (TDR) program where a landowner gets credits in a developable portion of town in exchange for giving up development credits in the overlay zone. TDRs are complicated to set up, because one needs a sending district (the overlay zone) as well as a receiving district (an area where development can be intensified). Therefore, this may not be an appropriate strategy for many towns. However, towns could incorporate some, if not all, of the practices recommended in this document as standards to guide development in an overlay zone.

Vernal Pool Ordinances

Some municipalities have developed ordinances specifically to protect vernal pools and their associated terrestrial habitat. Some of these use rating systems that place undue emphasis on number of species present or on larger vernal pools. A better approach would be to develop a local ordinance that incorporates ***both*** the assessment and best development practices presented herein.

Recognition and Voluntary Stewardship Programs

Programs that encourage vernal pool stewardship could be set up to provide technical advice and recognition to landowners who voluntarily protect and manage these resources. Similar programs to register natural areas on private property have been successful both as conservation strategies and in raising public awareness. Another approach would be to publicly recognize those developments that incorporate vernal pool Best Development Practices. Apart from demonstrating that it is possible to develop responsibly, such recognition may be an important marketing tool. In Farmington, Connecticut, a small development has been created that has turned a vernal pool and its resources into the centerpiece of the development and its marketing (see Case Study: Jefferson Crossing—Innovative Conservation Design for a Subdivision, page 14).

For other ideas for forming local partnerships for vernal pool conservation, see *Vernal Pool Conservation in Connecticut: An Assessment and Recommendations* (Pressier et al. 2001).

CASE STUDY

Jefferson Crossing

Innovative Conservation Design for a Subdivision

On Talcott Mountain—a trap-rock ridge lying west of Hartford, Connecticut—a unique conservation subdivision was created, incorporating many of the design principles contained in this manual. Unlike most subdivisions, where natural resources are expected to "fit" around a pre-conceived development pattern, Jefferson Crossing was designed with great sensitivity to the site's natural features. The subdivision is named for the rarest vernal pool breeding amphibian found on the site, the state-listed Jefferson salamander, *and* for the fact that the salamanders will be able to cross freely through the site to their breeding pool. To accomplish this, all structures and infrastructure were placed outside of the vernal pool envelope. In addition, the design of the site maximized protection of the critical upland habitat zone through a combination of conservation easements and lot-clearing restrictions. Finally, the design allows for unimpeded movement of amphibians and other wildlife throughout the forested site.

The execution of this novel design required a commitment from the developer to engage a team of professionals to simultaneously integrate design, engineering, and natural resource protection. For example, the proposed entrance road (using an existing access from a demolished single family house) was determined to be too close to the vernal pool. The developer acquired an additional lot of land specifically to enable relocation of the entrance road well beyond the vernal pool envelope. The houses were clustered several hundred feet away from the vernal pool; this, combined with lot clearing restrictions (no more than 50% per lot) and conservation easements, resulted in 75% of the site being protected in its natural state.

The roadways internal to the site have "Cape Cod curbing" to allow salamanders to move freely. Stormwater is handled through swales and a single catch basin. To minimize mortality of amphibians and other wildlife caught in the catch basin system, the water moves through a grassy swale and into an open, biofiltration wetland. By using low gradient curbing and eliminating the need for hydrodynamic separators, amphibian mortality is minimized. Additional restrictions govern the design of individual driveways; the use of pesticides, herbicides, and salts; and exterior lighting.

Jefferson Crossing will incorporate its unique conservation design as part of its marketing strategy. The location of the homes tucked amongst the hemlock trees and nestled between trap rock outcrops will attract a distinctive type of buyer, one that is looking to live in greater harmony with the natural world. Ms. Anitra Powers, who developed this property on the site of her family homestead, rejected conventional development patterns. Her vision has turned what many would consider a liability into an asset.

III. MANAGEMENT GOALS AND RECOMMENDATIONS

Management goals are described below for each of three vernal pool management areas: the vernal pool depression, the vernal pool envelope (100 ft. from spring high water), and the critical terrestrial habitat (100 to 750 ft from spring high water). See Figures 8 and 9 for schematics of vernal pool management areas and recommendations.

Management Areas and General Recommendations

Vernal Pool Depression

Description and Function:
This area includes the entire vernal pool depression up to the spring high water mark. Due to seasonal fluctuations in water levels, the vernal pool depression may or may not be wet during the period when a development review is initiated. During the dry season, the high-water mark generally can be determined by the presence of blackened leaves stained by water or silt, aquatic debris along pool edges, water marks on surrounding trees or rocks, or a clear change in topography from the pool depression to the adjacent upland. The pool basin is the breeding habitat and nursery for pool-dependent amphibians and invertebrates.

Desired Management:
For all Tiers, maintain the pool basin, associated vegetation and the pool water quality in an undisturbed state.

Rationale:
Creating ruts or otherwise compacting substrates in and around the pool can alter the pool's water-holding capacity, disturb eggs or larvae buried in the organic layer, and alter the aquatic environment. Excess slash, construction debris, or channeled stormwater in the pool basin can hinder amphibian movement and alter water quality. Removal of pool vegetation reduces the availability of egg-attachment sites.

Vernal Pool Envelope

(area within 100 feet of the pool's edge)

Description and Function:
The envelope consists of a 100-foot area around the pool, measured from the spring high water mark. In the spring, high densities of adult salamanders and frogs occupy the habitat immediately surrounding the pool. Similarly, in early summer and early fall, large numbers of recently emerged salamanders and frogs occupy this same habitat. This zone also maintains the water quality of the pool depression and provides a source of leaves, which constitute the base of the pool food web.

Desired Management:

- Maintain an undeveloped forested habitat around the pool, including both canopy and understory (e.g., shrubs and herbaceous vegetation).
- Avoid barriers to amphibian dispersal (emigration, immigration).
- Protect and maintain pool hydrology and water quality.
- Maintain a pesticide-free environment.

Rationale:
The integrity of the forest immediately surrounding the pool depression is critical for maintaining water quality, providing shade and litter for the pool ecosystem, and providing suitable terrestrial habitat for pool-breeding amphibian populations. Juvenile salamanders are especially vulnerable to drying during the first months after emergence (Semlitsch 1981). Such desiccation is much more likely where habitat elements described above (e.g., leaf litter, shade) are lacking.

Critical Terrestrial Habitat
(area within 100-750 feet of the pool's edge)

Description and Function:
The critical terrestrial habitat extends 650 feet beyond the upland edge of the vernal pool envelope (i.e., 750 feet beyond the edge of the pool). This area provides habitat for amphibians during the non-breeding season for foraging, dispersing, and hibernating. During the breeding season, adults migrate to pools through this zone.

Desired Management:

- Maintain or restore a minimum of 75% of the zone in contiguous (i.e., unfragmented) forest with undisturbed ground cover.
- Maintain or restore forested corridors connecting wetlands or vernal pools.
- Provide suitable terrestrial habitat for pool-breeding amphibian populations by maintaining or encouraging at least a partially closed-canopy stand that will provide shade, deep litter, and woody debris.
- Minimize disturbance to the forest floor.
- Where possible, maintain native understory vegetation (e.g., shrubs and herbs).

Rationale:
This area is needed to support upland populations of amphibians that breed in vernal pools. Juvenile and adult wood frogs and mole salamanders select closed-canopy forests during emigration and dispersal in managed forest landscapes (deMaynadier and Hunter 1998, 1999). Spotted salamanders often occur under, or closely associated with, woody debris on the forest floor (Windmiller 1996). Other mole salamanders in the Region have similar habitat needs. Rutting and scarification of the forest floor may prevent

salamanders from traveling to breeding pools by creating barriers along travel routes (Means et al. 1996). Furthermore, if shallow ruts fill with water, vernal pool amphibians may deposit eggs in ruts that do not hold water long enough to produce juveniles. Created treatment wetlands (e.g., detention ponds) that are located near to vernal pools often cause similar problems.

Roads (and associated development) within this zone limit the amount of terrestrial habitat available to amphibian populations, fragment and isolate remaining pieces of habitat, facilitate further development, and directly result in mortality of individuals. Recent research conducted within Rhode Island has demonstrated that vernal pool-breeding amphibians may be extremely sensitive to roads constructed within 0.62 miles (1 km) of the vernal pools in which they breed (Egan 2001; Egan and Paton, *in prep*.). Within this area, a mere 16 linear feet of road per acre (12 m/ha) was linked to significant declines in numbers of wood frog egg masses; only 25 feet of road per acre (19 m/ha) appeared to cause significant declines in numbers of spotted salamander egg masses. Beyond these thresholds, even slight increases in road density severely limited the potential of the areas surrounding pools to serve as nonbreeding habitat. Research by Klemens (1990) has suggested that actual road configuration and pattern (i.e., “roads to nowhere” and cul-de-sacs servicing subdivisions vs. linear roads connecting urban centers), as well as road density, likely factors into amphibian population declines.

Although much of amphibian terrestrial life history is still unknown, researchers have documented travel distances from breeding pools of juvenile wood frogs and adult mole salamanders (see Figure 4 and reviews by Windmiller 1996, Semlitsch 1998). These distances, along with all of the other factors discussed above, demonstrate that pond-breeding amphibians require significant habitat surrounding pools.

Summary of Management Areas

To ensure successful breeding, vernal pool depressions must be left intact and undisturbed. Excluding development and minimizing disturbances to the area immediately surrounding the vernal pool (i.e., the pool’s envelope) will provide breeding amphibians with a staging ground and will also help to maintain pool water quality. Additional upland habitats are required during the nonbreeding season; such “critical terrestrial habitats” can be maintained by limiting development and by applying Management Recommendations (discussed in the following section). By carefully considering the recommendations made for each of these three management areas, viable populations of pool-breeding amphibians may be maintained. A summary of management areas and desired outcomes is presented in Table 3.

Table 3. Recommended guidelines for vernal pools and surrounding management areas in developing landscapes

Management Area (distance from pool edge)	**Area of Managed Zone** (acres)[1]	**Primary Wildlife Habitat Values**	**Desired Management**	**Recommended Guidelines**
Vernal Pool Depression (0 ft)	0.2	Breeding pool; egg attachment sites.	Good water quality and water-holding capacity; undisturbed basin with native vegetation along the margin.	No disturbance.
Vernal Pool Envelope (100 ft)	1.4	Shade and organic inputs to pool; upland staging habitat for juvenile amphibians.	Maintain forested envelope around pool; avoid barriers to amphibian movement; prevent alteration of water quality or pool hydrology.	No development and implementation of Management Recommendations for this zone.
Critical Terrestrial Habitat (750 ft)	40	Upland habitat for pool-breeding adult amphibians (for foraging, dispersing, and hibernation).	Partially shaded forest floor with deep, moist uncompacted litter and abundant coarse woody debris.	Less than 25% developed area; implementation of Management Recommendations for this zone.

[1] Approximate area, based on a 100-ft. diameter pool.

Specific Issues and Recommendations

In the following section management recommendations and standards for specific development issues (e.g., road construction, stormwater management, and locations of outbuildings) are provided. We encourage application of relevant recommendations.

Roads and Driveways

Conservation Issues:

- Road mortality is a major contributing factor in amphibian declines. This occurs by direct mortality from vehicular traffic as well as increased vulnerability to depredation and desiccation when amphibians cross roads.

- A number of studies have shown that roads (and urbanization) limit amphibian dispersal and abundance (Gibbs 1998; Lehtinen et al. 1999; deMaynadier and Hunter 2000; Egan and Paton, *in prep*.). Certain species are reluctant to cross open, unvegetated areas, including roads. Roads create barriers to amphibian dispersal. Curbs and catch basins act as traps that funnel and collect amphibians and other small animals as they attempt to cross roads.
- Roads are sources of chemicals and pollutants that degrade adjacent aquatic and terrestrial habitats. These pollutants include, but are not limited to, salts, particulate matter, and heavy metals. Eggs and larval amphibians are especially sensitive to changes in water quality. Influxes of sediment can smother eggs, while salts and heavy metals are toxic to larvae (Turtle 2000).
- Roads create zones of disturbance characterized by noise and light pollution. Both of these pollutants interfere with the ability of amphibians to disperse across the landscape. Noise pollution can also interfere with frog calling activity, which is an essential part of their reproductive ecology.
- Roads can change hydrology (thus changing vernal pool quality and hydroperiod).

Management Recommendations:

- Roads and driveways should be excluded from the vernal pool depression and vernal pool envelope.
- Roads and driveways with projected traffic volumes in excess of 5-10 cars per hour should not be sited within 750 feet of a vernal pool (Windmiller 1996). Regardless of traffic volumes, the total length of roads within the critical terrestrial habitat should be limited to the greatest extent possible (Egan and Paton, *in prep*.).
- Use Cape Cod-style curbing (see Figure 10) or no-curb alternatives on low capacity roads.
- Use oversize square box culverts (2 feet wide x 3 feet high) near wetlands and known amphibian migration routes to facilitate amphibian movement under roads. These should be spaced at 20-foot intervals *and* use curbing to deflect amphibians toward the box culverts.
- Use cantilevered roadways (i.e., elevated roads that maximize light and space underneath) to cross low areas, streams, and ravines that may be important amphibian migratory routes.
- Cluster development to reduce the amount of roadway needed and place housing as far from vernal pools as possible.

Site Clearing, Grading, and Construction Activities

Conservation Issues:

- Site clearing may result in crushing large numbers of amphibians and other animals.
- Site clearing and subsequent construction activities reduce terrestrial habitat available to amphibians by decreasing the extent of the habitat, compacting soil, removing downed woody debris, diminishing invertebrate food supplies, and decreasing the number of small mammal burrows used for refuge by salamanders.
- Site clearing removes shade trees, which alters local climate, resulting in elevated vernal pool water temperatures and increased drying of the forest floor. Amphibians are sensitive to alterations in temperature and are highly subject to desiccation. Elevated temperatures in vernal pools can increase algal productivity, thereby reducing oxygen available to developing amphibian larvae and increasing the likelihood of larval die-offs.
- Site clearing and grading increase erosion rates, which may result in sedimentation of vernal pools. Increased sediment loads stress and kill both amphibian eggs and developing larvae and can alter the structure and composition of in-pool vegetation
- Site clearing and grading create barriers to amphibian dispersal by stockpiling mounds of soil, altering topographic contours, and creating open areas which amphibians may be reluctant to cross because of increased vulnerability to predation and desiccation.
- Use of silt fencing to control erosion creates major obstacles to movement of amphibians and other small animals. Removal of silt fencing is rarely addressed, or often overlooked in sedimentation and erosion control plans. The prevailing belief is that more fencing, for longer periods, provides better environmental protection. Therefore, fences are often left in place indefinitely, impeding the migratory patterns of tens of thousands of animals. Erosion control structures should be removed within 30 days of final site stabilization. Erosion control berms—a sediment control measure accepted in some states—are effective sediment barriers when properly installed and provide less of an obstacle for amphibians and reptiles. Installation of sediment control barriers to control erosion and sedimentation should be limited to the down-gradient edge of any disturbed area and adjacent to any drainage channels within the disturbed area.
- Site clearing and grading can de-water vernal pools by altering surface-water drainage patterns associated with the pool.
- Site clearing can create water-filled ruts. These ruts intercept amphibians moving toward the vernal pool and may induce egg deposition. Often the ruts do not hold water long enough to allow development of the amphibians and therefore act as "sinks" that result in population declines.
- Perc test holes act as pitfall traps, collecting large numbers of amphibians, turtles, and other animals. Unable to climb the vertical walls of the perc scrape, these animals perish.

- Site clearing and grading creates habitat for the establishment of invasive plants and facilitates the movement of amphibian predators (edge species) into the forest interior.

Management Recommendations:

- Minimize disturbed areas and protect down-gradient buffer areas to the extent practicable.
- Site clearing, grading, and construction activities should be excluded from the vernal pool depression *and* the vernal pool envelope.
- Site clearing, grading, and construction activities should be limited to less than 25% of the entire vernal pool habitat (i.e., the pool depression, envelope, and critical terrestrial habitat).
- Limit the area of clearing, grading, and construction by clustering development.
- Minimize erosion by maintaining vegetation cover on steep slopes.
- Avoid creating ruts and other artificial depressions that hold water. If ruts are created, refill to grade before leaving the site.
- Refill perc test holes to grade.
- Use erosion and sediment control best management practices to reduce erosion. Stagger silt fencing with 20 foot breaks to avoid disrupting amphibian movements or consider using erosion control berms. Use combinations of silt fencing and hay bales to reduce barrier effects. Re-seed and stabilize disturbed areas immediately; permanent stabilization for revegetated areas means that each area maintains at least 85% cover. Remove silt fencing as quickly as possible and no later than 30 days following final stabilization. Minimize use of silt fencing within 750 feet of vernal pools. Erosion control berms can be leveled and used as mulch or removed upon final stabilization.
- Limit forest clearing on individual house lots within the developed sections of the vernal pool management zones to no more than 50% of lots that are two or more acres in size. Encourage landscaping with natural woodland, containing native understory and groundlayer vegetation, as opposed to lawn.
- Silt fencing *should* be used to exclude amphibians from active construction areas. At Jefferson Crossing (see Case Study), each house construction site was encircled by a silt fence barrier to keep salamanders away from heavy machinery, excavation, and stockpiling. However, construction activities should, ideally, occur outside of peak amphibian movement periods (which include early spring breeding and late summer dispersal).

Stormwater Management

Stormwater management provides an excellent example of how addressing one set of environmental issues can result in creation of other environmental impacts, as follows.

Conservation Issues:

- Systems of curbs, catch basins, and hydrodynamic separators—designed to capture and treat road runoff—intercept, trap, and kill amphibians and other small animals crossing roads. These systems can also de-water vernal pools by releasing water into another watershed**,** or downslope of a vernal pool. Hydrodynamic separators are especially problematic because they remove particulate matter from stormwater via swirl chambers. These devices cannot distinguish between sediments and small vertebrates; thus, thousands of amphibians can be killed in one unit.
- Systems of gutters, leaders, and infiltration systems designed to capture and manage roof runoff can drain wetlands if the roof water is captured and released in another watershed, or below the vernal pool area.
- Systems designed to capture road and roof runoff can alter how long pools hold water by transporting additional water into the vernal pool watershed. This is especially critical in short hydroperiod pools that support fairy shrimp.
- Vernal pools and other small wetlands have been inappropriately used as stormwater detention pools and biofiltration basins. These practices create a degraded aquatic environment subject to sediment loading, pollutants, and rapid changes in water quantity, quality, and temperature.
- Stormwater detention basins and biofiltration ponds can serve as decoy wetlands, intercepting breeding amphibians moving toward vernal pools. If amphibians deposit their eggs in these artificial wetlands, they rarely survive due to the sediment and pollutant loads, as well as fluctuations in water quality, quantity, and temperature.

Management Recommendations:

- Vernal pool depressions should never be used, either temporarily or permanently, for stormwater detention or biofiltration.
- Detention and biofiltration ponds should be located at least 750 feet from a vernal pool; they should never be sited between vernal pools or in areas that are primary amphibian overland migration routes, if known.
- Treat stormwater runoff using grassy swales with less than 1:4 sloping edges. If curbing is required, use Cape Cod curbing. Maximize open drainage treatment of stormwater.
- Use hydrodynamic separators only in conjunction with Cape Cod curbing or swales to avoid funneling amphibians into treatment chambers, where they are killed.
- Maintain inputs to the vernal pool watershed at pre-construction levels. Avoid causing increases or decreases in water levels.

- Minimize impervious surfaces (i.e., surfaces that do not absorb water) to reduce runoff problems and resulting stormwater management needs. Use of grass pavers (concrete or stone that allows grass to grow) on emergency access roads and in low use parking areas is recommended. Use of phantom parking is also recommended. Zoning formulae often require more parking spaces than are actually needed. Under a phantom parking strategy, sufficient land is reserved for projected parking requirements, but only a portion of the parking area is constructed at the outset. Additional areas are paved on an as-needed basis.
- Examine the feasibility (which varies by location) of reducing the road width standard to achieve conservation goals (i.e., minimize the footprints of roads). This is often done in tandem with development clustering, to reduce impervious surfaces and disturbance areas.

Accessory Infrastructure

Conservation Issues:

- In many communities, a different standard is employed when evaluating impacts of accessory structures and functions (e.g., outbuildings, pools), as compared to homes and other buildings. There appears to be no legal basis for this distinction, but rather a discretionary sense that, for example, the construction of a swimming pool in a regulated area surrounding a wetland is different (i.e., less harmful) than construction of a house within the same area. For pool-breeding amphibians, there is no distinction; the siting of accessory structures near vernal pools is a major conservation issue resulting in the loss of millions of amphibians and other small creatures each year.
- Below-ground swimming pools may function as large animal traps, capturing salamanders, frogs, small mammals, snakes, and turtles. Trapped animals either drown or are killed by chlorinated water.

Management Recommendations:

- Accessory structures should be excluded from the vernal pool depression and vernal pool envelope.
- Below-ground swimming pools located within the critical terrestrial habitat of a vernal pool should be surrounded by some sort of barrier. A fine mesh wire at the base of a picket fence or a one-foot high, 90-degree, curb or barrier would deter amphibians from travelling into the pool.

Lighting

Conservation Issues:

- Light spillage in wetlands and woodlands affects a diversity of wildlife species (e.g., see www.urbanwildlands.org). Recent increases in the use of security and garden lighting have intensified problems associated with light spillage. Scientific experiments and anecdotal evidence suggest that changes in lighting may affect frog reproduction, foraging, predator avoidance, and social interactions (Buchanan 2002). Buchanan demonstrated in laboratory experiments that dark-adapted frogs exposed to rapid increases in illumination may be temporarily 'blinded', unable to see prey or predators until their eyes adapt to the new illumination. Similarly, there is evidence that salamanders are strongly attracted to light (S. Jackson, University of Massachusetts, pers. comm.). This behavioral response could divert salamanders away from breeding sites; it could also make them more vulnerable to predation or road mortality during migrations. Artificial lights that emit unusual spectra may especially disrupt these migration patterns (Wise and Buchanan 2002). Research on the effects of lighting on amphibian behavior and larval development is ongoing.

Management Recommendations:

- Exterior and road lighting within 750 feet of a vernal pool should use low spillage lights—those that reflect light directly downward onto the area to be illuminated. A variety of products to accomplish this goal are now on the market. Avoid using fluorescent and mercury vapor lighting.

Wetland Creation and Alteration

Conservation Issues:

- Extensive structural complexity (i.e., the arrangement of different layers of trees, shrubs, and plants in a small wetland) supports a diversity of small vertebrates and invertebrates. When wetlands are altered through clearing of vegetation, impoundment of water, or dredging, the microhabitats used by many species of wildlife are changed or lost. This results in unsuitable breeding habitat for many amphibians, including vernal pool species.
- Wetland creation is another byproduct of development and landscape alteration. Created wetlands are often mandated as replacement for other wetlands lost during development; sometimes, they are also incorporated as design features in a subdivision. Similar to altered wetlands, created wetlands usually lack the structural diversity, microhabitats, and hydrology to support vernal pool breeding amphibians.

- Altered and created wetlands often support highly adaptable, widespread, “weedy” species (e.g., bullfrogs or green frogs). These species prey upon, or successfully outcompete, vernal pool-breeding amphibians, which reduces or locally eliminates populations of these habitat specialists.
- Created wetlands that do not have the appropriate habitat often attract breeding amphibians. Eggs laid in these “decoy” pools often do not survive. Such pools serve to trap breeding amphibians and might result in local population declines.

Management Recommendations:

- Alteration of existing conditions within vernal pools and other small wetlands should be avoided.
- Creation of ponds and similar wetlands should be avoided within 750 feet of a vernal pool.
- Redirect efforts from *creating* low value, generalized wetlands to *enhancing* terrestrial habitat around vernal pools. These enhancements could include reforestation of post-agricultural lands within 750 feet of a vernal pool, restoration of forest, importing additional cover objects (e.g., logs, stumps), and removal of invasive plants and animals.

Post-Construction Activities

After a construction project has been completed, there are long-term development issues that continue to affect vernal pools. Even projects that are designed with ecological sensitivity can cause problems over time, due to the day-to-day activities of humans. Many of these longer-term problems can be anticipated and avoided during the overall design and approval process of the project.

Conservation Issues:

- Pest animals are those species that humans encourage by subsidizing food resources and fragmenting habitats. Raccoons, foxes, and skunks fall into this category. These artificially inflated mammal populations often prey heavily on vernal pool amphibians during the breeding season.
- Domestic animals, including pets, can threaten pool wildlife through predation or physical disturbance of habitats.
- Protected areas around wetlands, over time, are intruded upon by humans. Impacts include dumping, forest clearing, dirt biking, introduction of free-ranging dogs and cats, favoring of invasive plant species, fires, collection of native wildlife, and other activities that degrade the vernal pool and its envelope.

- Increased pesticide use is usually associated with suburban landscaping. These toxins often enter into the vernal pool watershed and compromise the pool's ability to serve as a breeding site and nursery for vernal pool species.

Management Recommendations:

- Discourage predators by making garbage and other supplemental food sources unavailable.
- *Consider keeping cats indoors at all times.* This would reduce predation on a wide variety of species, ranging from pool-breeding amphibians to ground-nesting birds. Attaching bells to cat collars does *not* significantly reduce the ability of cats to prey on small vertebrates.
- Mark the edge of a protected area (e.g. the critical terrestrial habitat) with permanent markers. Well-marked boundaries make enforcement of restricted areas clear to both homeowners and the local wetlands enforcement agency. For example, granite monuments or stone cairns could be placed every 10 feet around a protected area. In cases where intrusion is a concern, small sections of stone wall could be erected; these walls should be discontinuous, so that they do not impede amphibian dispersal.
- Use covenants or deed restrictions to assure that the vernal pool and its envelope are conserved and that pesticide use, lot clearing, and other degrading activities are kept out of associated areas. Assign the homeowner or homeowner's association with responsibility for ensuring that conditions of the covenant or deed restriction are met. Provisions should also be included to allow a third-party, such as the town or local land trust, with adequate notice, to enter the property and conduct appropriate management and remediation, charging the homeowner for these services.
- In the case of a homeowner's association or other type of multiple tenant arrangement, a stewardship manual could be prepared that would educate each purchaser, or lessee, as to the unique nature of the property they are purchasing or renting, what their collective obligations to protect the resource entail, and where to obtain additional assistance or information.
- A conservation easement, covering at minimum the vernal pool depression and vernal pool envelope (and, preferably, including land within the "critical terrestrial habitat"), could be held by a municipality, land trust, or other non-governmental organization.

© D. Demello/WCS

A "classic" vernal pool lying in a basin, or depression, in deciduous woodland.
Although these habitats are important for vernal pool-breeding species, only a small percentage of pools within the Region have this distinctive signature. Many cryptic (i.e., non-classic) vernal pools are found within larger wetland systems. Figure 3 provides some examples of the wide diversity of these cryptic vernal pools.

Large vernal pool.
Although vernal pools average considerably less than one acre in size, some are as large as two acres. Large vernal pools are not uncommon in the northern part of the Region.

© Aram J. K. Calhoun

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Small vernal pool.
Most vernal pools are quite small, as typified by this 0.25-acre pool. This photograph depicts two important components of vernal pools: ***microtopographic complexity*** *(as illustrated by a patchwork of hummocks, moss, and logs) and* ***vertical stratification*** *(which consists of a variety of layers of herbaceous plants, low shrubs, tall shrubs, and trees). Collectively, these elements provide a tremendous variety of microhabitats, which support the rich diversity of life in and around vernal pools.*

Aerial view of vernal pool.
Many pools exhibit this concentric, ring-like pattern of habitat zones.

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Figure 1. Vernal Pool Size and Structure

© Nicole S. Klemens

Snowbound vernal pool in late March.
Vernal pool levels are generally highest during winter and spring. This pool contains breeding populations of Jefferson salamanders, spotted salamanders, and wood frogs.

Drying vernal pool in late June.
Low water levels—and resulting low oxygen levels—exclude fish from vernal pools, which would otherwise decimate larval amphibian populations. This site provides breeding habitat for Jefferson salamanders, spotted salamanders, and wood frogs. Blanding's turtles, wood turtles, and box turtles also use this pool.

© Michael W. Klemens

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Dry vernal pool in August.
Most vernal pools will begin to refill in the autumn, when plants become dormant and use less water. Spotted salamanders and wood frogs breed at this site. The pool is also used by spotted turtles and box turtles.

Figure 2. Vernal Pool Seasonality

© Michael W. Klemens

Semi-permanent pool.
Jefferson and spotted salamanders breed in this wetland. This pool rarely dries up completely, as opposed to classic vernal pools, which dry up annually.

© Michael W. Klemens/WCS

Floodplain swamp.
Blue-spotted salamanders and wood frogs breed in depressions and oxbows within river floodplains. When floodwaters recede, these pools become isolated; therefore, they do not provide breeding habitat for fish. Four-toed salamanders, spotted salamanders, and wood turtles also use this habitat.

© Michael W. Klemens

Pool with seasonally flooded wet meadow.
Larval amphibians exploit the rich food resources and warmer water of the meadow. As the meadow dries, the larvae retreat into the deeper pool to complete their development. Tiger salamanders breed here; the site also provides habitat for box turtles and ribbon snakes.

© Laura Tessier

Red maple swamp with carpet of *Sphagnum* moss.
Spotted and four-toed salamanders, as well as wood frogs, breed in deeper pools of forested wetlands. These water-filled pockets are often created when trees are uprooted during severe storms.

Figure 3. Cryptic Vernal Pools

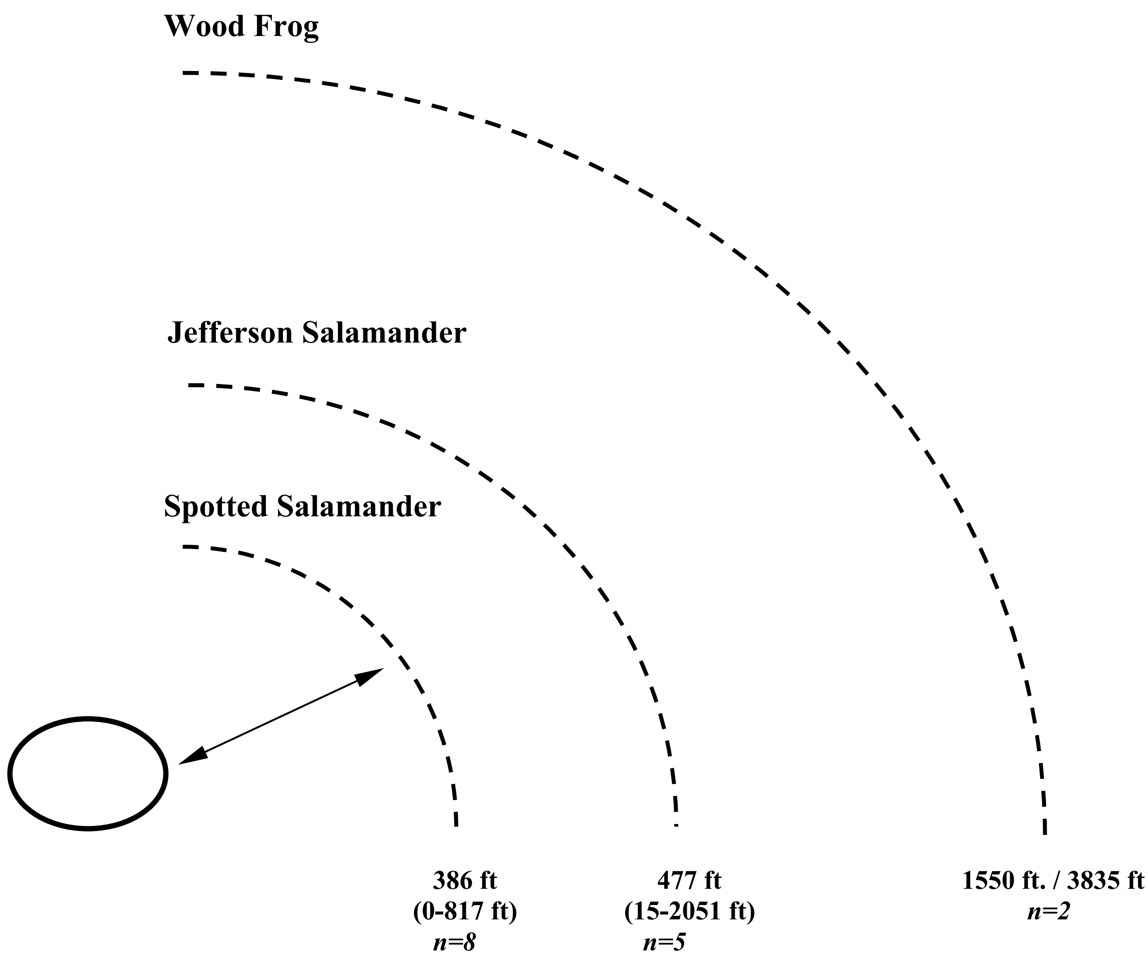

Figure 4. Migration Distances for Vernal Pool Amphibian Indicator Species*

Adult salamander migration distances are provided as means (and ranges). Two values are reported for wood frogs (*Rana sylvatica*)—mean juvenile dispersal distance and maximum adult migration distance. The number of studies contributing data *(n)* is listed for each species (sources include: Windmiller 1996; Semlitsch 1998; Berven and Grudzien 1990; Faccio, *in prep.*).

*Distances are not to scale.

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Jefferson Salamander *(Ambystoma jeffersonianum)*

© Richard G. Zweifel/AMNH

Spotted Salamander *(Ambystoma maculatum)*

© Richard G. Zweifel/AMNH

Wood Frog *(Rana sylvatica)*

© Richard G. Zweifel/AMNH

Eastern Spadefoot Toad *(Scaphiopus holbrookii)*

© Leo P. Kenney

Fairy Shrimp *(Eubranchipus* sp.)

© Maine Natural Areas Program

Featherfoil *(Huttonia inflata)*

Figure 5: Examples of Vernal Pool Indicator Species of the Region

© Don Sias

Four-toed Salamander *(Hemidactylium scutatum)*

© Geoff A. Hammerson

Spotted Turtle *(Clemmys guttata)*

© Michael W. Klemens

Blanding's Turtle *(Emydoidea blandingi)*

© Geoff A. Hammerson

Eastern Box Turtle *(Terrapene c. carolina)*

© Geoff A. Hammerson

Eastern Ribbon Snake *(Thamnophis s. sauritus)*

© Francis C. Golet/URI

Ringed Boghaunter *(Williamsonia lintneri)*

Figure 6: Examples of Vernal Pool Facultative Species of the Region

© Louis N. Sorkin

Male salamanders migrate to vernal pools under the cover of darkness and deposit spermatophores on the pool bottoms.

© Geoff A. Hammerson

Females enter the pond during nighttime rains, engage in courtship, and are fertilized by picking up the spermatophores. They then deposit clumps of jelly-coated eggs.

© Geoff A. Hammerson

Bushy-gilled larvae hatch. They are voracious feeders and develop rapidly for several months.

© Geoff A. Hammerson

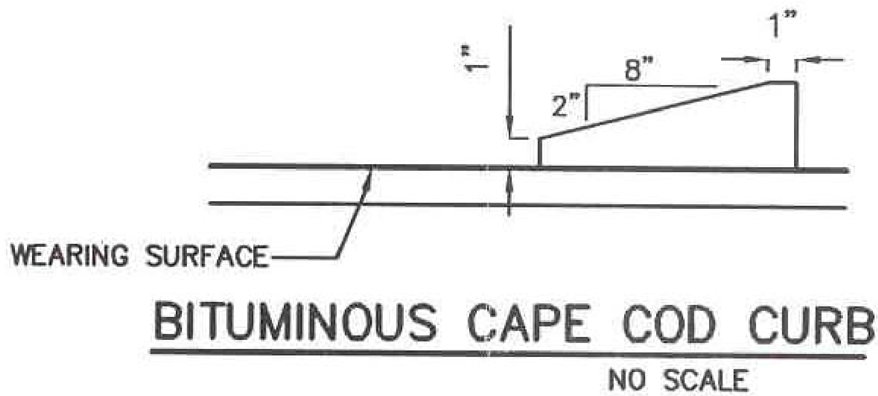
Larvae metamorphose. The pattern of this newly-transformed marbled salamander metamorph differs markedly from an adult.

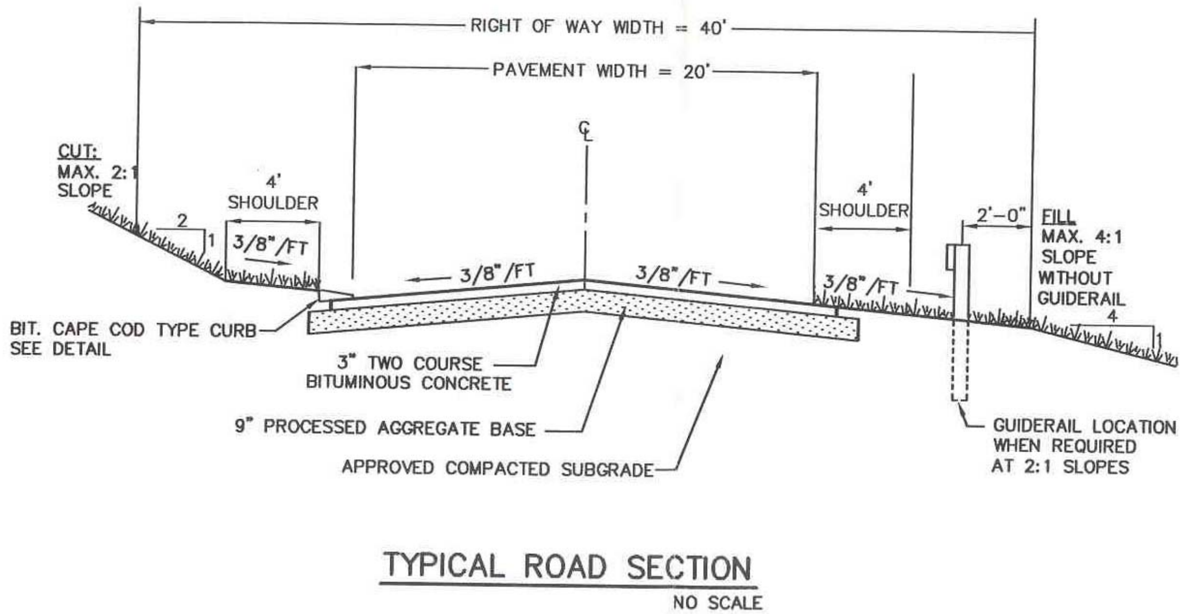
© Chris Raithel

Adult patterns appear several weeks to months after metamorphosis, as seen here in the adult marbled salamander (Ambystoma opacum).

Figure 7: Mole Salamander *(Ambystoma)* Life Cycle*

*Source: Klemens 2000. Text reprinted by permission of the author and the Connecticut Department of Environmental Protection.





Source: Jefferson Crossing, Farmington, CT; Buck and Buck Engineers, Hartford, CT.

Figure 10: Design Schematics for Road and Driveway Construction to Reduce Impacts on Pool-Breeding Amphibians

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Appendix 1

Vernal Pool Regulation and Definitions

Introduction

Wetlands are more extensively regulated than any other habitat or landscape unit within our Region, due in large part to their ecological sensitivity and the number of ecological services they provide (e.g., flood abatement, water quality improvement, groundwater recharge). However, despite the vast amount of resources devoted to wetlands—at Federal, state, and local levels—regulations addressing vernal pools are, for the most part, ineffective or nonexistent. Most wetland regulations contain lower size thresholds; therefore, impacts to small wetlands such as vernal pools often "slip under the radar" of regulatory agencies. In addition, although many regulatory agencies have jurisdiction over upland "buffers" or "setbacks" surrounding wetlands, such jurisdiction rarely extends beyond 150 feet from wetland edge—a distance that is insufficient for maintaining vernal pool wildlife populations. Another hurdle lies in the establishment of a standardized definition of "vernal pool;" numerous, widely varying definitions exist within the Region. The following text discusses the details and limitations of wetland regulations within the Region, as they pertain to vernal pools.

Federal Regulation

Dredge and fill activities in freshwater wetlands are regulated at the federal level through Section 404 of the Clean Water Act (CWA). The Army Corps of Engineers (the Corps) oversees this program. However, regulation does not necessarily equal protection. Keep in mind that the CWA was created to protect water quality, not wildlife habitat. Often, permits are issued for relatively small impacts; however, vernal pools often fall within the exempted size threshold. Most states in the Region have Programmatic General Permits (PGP), which currently replace all Nationwide Permits. PGP's are intended to expedite the review of "minimal" impact work in coastal and inland waters and wetlands. General permits are also supposed to be authorized for activities that are "substantially similar in nature." Any proposed project that does not qualify for the PGP must then go through the individual permit review process. A PGP is designed to work in concert with a State's wetland regulatory program. Ideally, the Corps allows the State regulatory agency to take the lead on permitting of smaller impact projects. Any of the Federal resource agencies can "kick out" a project for screening as an individual permit if the agency can document that the wetland or water body impacts would be more than "minimal," which really isn't difficult to do. The level of scrutiny and review is generally less for a PGP project than for an individual permit project. For example, all applicants have to demonstrate that they have first avoided and then minimized the amount of wetland impact, but the amount of documentation required by a PGP application is generally quite a bit less than for an individual permit.

Maine—Maine has a "kick out" for vernal pools from Category I of the Programmatic General Permit.

Connecticut, Vermont and Massachusetts—PGPs require screening reviews for fill in vernal pools. A vernal pool is defined in the PGP as an "…often temporary body of water occurring in a shallow depression that fills during spring rains and snow melt and typically dries up during summer months. Vernal pools support populations of specialized species, which may include wood frogs, mole salamanders *(Ambystoma)*, fairy shrimp, fingernail clams and other invertebrates. A feature common to vernal pools is the lack of breeding populations of fish. Some shallow portions of permanent waterbodies also provide vernal pool function by supporting breeding populations of vernal pool species. Old, abandoned, artificial depressions may provide these necessary breeding habitats."

Another administrative tool is known as the "pre-construction notification" process; this process allows so-called minor wetland fillings to be reported to the Corps after the fact, so that the Corps can track acreage lost. The Corps is aware of the limitations of these approaches, and recently has begun to curtail the use of these programs in areas of ecological concern, such as the New York City Watershed. However, in many sections of the Northeast, filling of small wetlands continues; among the hardest hit are those wetlands supporting vernal pool-dependent species.

Because of a recent Supreme Court decision (SWANCC; January 9, 2001), the Corps no longer regulates isolated wetlands by invoking the Migratory Bird Act. This ruling puts even more pressure on individual states to take the lead in protection of these resources.

Other federal agencies involved in wetland permitting include the US Fish and Wildlife Service, which serves in an advisory capacity on projects that may affect wildlife resources, and the Environmental Protection Agency, which has veto power over Corps decisions.

State Regulation

Each state in the Region has a wetland protection statute that regulates activities in jurisdictional wetlands. The specifics of the regulatory program and permit process vary from state to state, but small wetlands, including vernal pools, receive the least protection under most state regulatory programs. For example, New York has a regulatory minimum-size threshold of 12.4 acres, considerably larger than the majority of vernal pools. The only vernal pools protected at the state level in New York are those that: 1) contain a State-listed endangered or threatened species *and* 2) have been added, through a public hearing process, to the official map of State-regulated wetlands. Even Massachusetts, which has led the region with its program of volunteer-driven vernal pool certification, is unable to protect sufficient critical terrestrial habitat to sustain the amphibians that breed within those certified pools. In fact, most states do not include the terrestrial habitat associated with isolated wetlands in their wetland regulations.

Note: Under all Federal and state regulations, even where vernal pools are regulated, the critical terrestrial habitat around them is not. Sometimes a small buffer around the wetland is maintained, but this does not provide the necessary upland habitat for pool-breeding amphibians.

Connecticut

Overview:
Legislation passed in 1995 (P.A. 95-313) and included in the Inland Wetlands and Watercourses Act (originally passed in 1972) expanded the definition of "watercourse" to include, "all other bodies of water, natural or artificial, vernal or intermittent." Regulation occurs at the municipal level via town Inland Wetlands Commissions. While not specifically defining "vernal pools" this amendment promoted their inclusion in municipal inland wetland regulations. However, no towns have developed regulations regarding vernal pools specifically. The Connecticut Department of Environmental Protection has model regulation and guidance documents.

Definition:
There is no official definition for a vernal pool. The University of Connecticut and the Forest Stewardship Program (Donahue 1995) have issued guidance for identification and protection of vernal pools. They recommend the following physical features and the presence of one or more obligate species:

a. water for approximately 2 months during the growing season,
b. a confined depression that lacks a permanent outlet stream,
c. no fish, and
d. dries out in most years.

The following definition of a vernal pool was prepared by the Connecticut Vernal Pool Working Group: "seasonal or permanent watercourse in a defined depression or basin, that lacks a fish population and in most years supports breeding and development of amphibian or invertebrate species recognized as obligate to such watercourses.

Proposed obligate species:
fairy shrimp, spotted salamander, eastern spadefoot toad, Jefferson salamander, marbled salamander, wood frog.

Maine

Overview:
In organized towns, wetlands are regulated by the Department of Environmental Protection (DEP) through the Maine Natural Resources Protection Act (NRPA

1996). Vernal pools generally meet Federal and State wetland definitions and are subject to regulation. However, the degree of environmental review in Maine depends upon the size of the *impact* to the wetland. Impacts to wetlands that are less than 4,300 ft^2 (approximately 0.1 acres) require no reporting. Impacts between 4,300 ft^2 and 15,000 ft^2 (approximately 0.3 acres) require the lowest level of review, Tier 1, and have an expedited 30-day review process with no requirement of compensation for wetland loss. Tier II (impacts >15,000 ft^2 to 1 acre) and Tier III (impacts > 1 acre) require greater documentation and require input from professional delineators.

In the unorganized towns and plantations, the Land Use Regulation Commission (LURC) regulates activities in wetlands. LURC's language on vernal pools is consistent with the statutory provisions in NRPA. However, LURC's regulatory authority over vernal pools is tied to the Maine Department of Inland Fisheries and Wildlife's (MDIFW) ability to define and identify vernal pools. In unorganized towns, MDIFW is relying on a voluntary, cooperative strategy for protecting vernal pools.

"Significant vernal pools" (SVPs) were listed as "Significant Wildlife Habitat" in Maine's 1995 revision of the NRPA. Designation of SVP's is pending formal adoption of a definition of "significant vernal pools" and development of a system to pre-identify vernal pools.

Proposed definition:
The following definition has been approved by the Maine Vernal Pool Working Group, and will be incorporated into the Natural Resources Protection Act.

"Vernal pools are naturally-occurring, temporary to permanent bodies of water occurring in shallow depressions that typically fill during the spring and fall and may dry during the summer. Vernal pools have no permanent or viable populations of predatory fish. Vernal pools provide the primary breeding habitat for wood frogs, spotted salamanders, blue-spotted salamanders and fairy shrimp, and often provide habitat for other wildlife including several endangered and threatened species. Vernal pools intentionally created for the purposes of compensatory mitigation are included in this definition."

Indicator species:
wood frog, spotted salamander, blue-spotted salamander, fairy shrimp

Massachusetts

Overview:
The Massachusetts Wetlands Protection Act Regulations (310CMR 10.00, 1996) include measures for the regulation of vernal pool habitat, as long as it is located within another category of wetland regulated by the Act, and as long as it has

been certified by the Massachusetts Division of Fisheries and Wildlife (MDFW) prior to the filing of a Notice of Intent by an applicant. A vernal pool must be certified and mapped by the Natural Heritage and Endangered Species Program (NHESP) prior to permitting of a wetland impact. Criteria are available through NHESP.

Definition:
The Massachusetts Wetlands Protection Act Regulations (310 CMR 10.00,1996) define vernal pools as "confined basin depressions which, at least in most years, hold water for a minimum of two continuous months during the spring and/or summer, and which are free of adult fish populations, as well as the area within 100 feet of the mean annual boundaries of such depressions."

Obligate species:
fairy shrimp, spotted salamander, blue-spotted salamander, Jefferson salamander, silvery salamander, Tremblay's salamander, marbled salamander, wood frog

New Hampshire

Overview:
In New Hampshire, there is no minimum size limit to projects that require a wetland permit. Vernal pools are regulated in New Hampshire only if they are located within other regulated wetlands (Wetlands Board Code of Administrative Rules 1993); they have traditionally been assessed as low-value wetlands.

New Hampshire Fish and Game (NHFG) developed a vernal pool identification manual (Tappen 1997) to initiate local conservation efforts. Following documentation, the information is supposed to be forwarded to NHFG and the local conservation commission for informational purposes. However, there are no state or local regulations that give added protection to documented vernal pools.

Definition:
There is no official regulatory definition of a vernal pool. New Hampshire Fish and Game defines a vernal pool as "A temporary body of water providing essential breeding habitat for certain amphibians and invertebrates and does not support fish." For a pool to be documented, it must be demonstrated that:

a. the pool occupies a confined depression without a permanently flowing outlet;

b. the pool contains water for at least two months in the spring/summer;

c. the pool dries up and therefore does not support fish;

d. indicator species are present (i.e., there is evidence of amphibian breeding or the presence of certain invertebrates in a flooded pool)

Indicator species:
fairy shrimp, spotted salamander, blue-spotted salamander, Jefferson salamander, marbled salamander, wood frog

New York

Overview:
Vernal pools are not specifically recognized and would only be subject to regulation under the following conditions (NYS DEC Article 24 Freshwater Wetlands law):

1. greater than 12.4 acres,
2. demonstrating unusual local importance for one or more of the specific benefits set forth in subdivision seven of section 24-0105,
3. contain a State-listed endangered or threatened species *and* have been added, through a public hearing process, to the official map of State-regulated wetlands, or
4. located within Adirondack park (minimum regulated size 1 acre).

An act to amend the environmental conservation law was introduced in February 2000 (A9561) that specifically describes vernal pools and recommends lowering the State regulated wetland size from 12.4 acres to 3 acres.

Definition:
There is no regulatory definition of a vernal pool. Ecological Communities of New York State (Reschke 1990) describe the natural vernal pool community as follows:

"…a wetland in a small, shallow depression within an upland forest. Vernal pools are flooded in spring or after a heavy rainfall, but are usually dry during summer. Many vernal pools are filled again in autumn. This community includes a diverse group of invertebrates and amphibians that depend upon temporary pools as breeding ponds. Since vernal pools cannot support fish populations, there is no threat of fish predation on amphibian eggs or invertebrate larvae. Characteristic amphibians include wood frog (*Rana sylvatica*), mole salamanders (*Ambystoma* spp.), American toad *(Bufo americanus*), green frog (*Rana clamitans*), and red-spotted newt (*Notophthalmus viridescens*)."

Indicator species:
The New York Natural Heritage Program is reviewing the literature and will produce a list of obligate species, most likely matching those listed in Massachusetts.

Rhode Island

Overview:
The Rhode Island Fresh Water Wetlands Act (RIFWWA) does not specifically regulate vernal pools but defines *pond* as a place not less than one-quarter (1/4) of an acre in extent, natural or manmade, wholly or partly within the state of Rhode Island, where open standing or slowly moving water shall be present for at least six (6) months a year.

To ensure enhanced protection for vernal pools, the 1994 rules included a new wetland category, *special aquatic site* defined as a body of open standing water, either natural or manmade which does not meet the definition of 'pond' but which is capable of supporting and providing habitat for aquatic life forms as documented by:

a) presence of standing water during most years as documented on site or by aerial photographs; and
b) presence of habitat features necessary to support aquatic life forms of obligate wildlife species, or the presence, documented use, or evidence of aquatic life forms of obligate wildlife species (except biting flies).

There is no size minimum but, because most are smaller than 1/4 acre, they do not meet the definition of "pond"; therefore, there is no protection of the adjacent upland. DEM can regulate land use within 50 feet of the edge of ponds but not smaller water bodies. The applicant is expected to recognize special aquatic sites—based on the presence of aquatic life forms of obligate wetland species or their habitats—and to put them on plans for proposed development. DEM checks those sites, and other wetlands, in the field during the project review.

Definition:
None (but see definition of "special aquatic site," above).

Indicator species:
fairy shrimp, spotted salamander, blue-spotted salamander, Jefferson salamander, marbled salamander, wood frog

Vermont

Overview:
Vernal pools can be protected under Vermont's wetland rules only if they are part of a Class II wetland or better (i.e., show up on Vermont Significant Wetland Inventory maps derived from National Wetland Inventory maps). If a Class II wetland is protected under the wildlife habitat section or any other section, the maximum protection would be for the wetland and a 50-foot buffer. Class 1 wetlands can be protected with a 100-foot buffer, but there are few Class 1

wetlands at this time. Vernal pools are potentially protected under this rule only if they are within a mapped wetland or are contiguous to such a wetland. Again, only up to 50 feet of the adjacent land around such a pool could be protected for a Class II wetlands

Vermont Wetland Rules (Water Resources Board 1990) do not specifically address vernal pools. Under the rules, Vermont evaluates wetlands based on 10 functions and values, wildlife habitat being one of those. The likely impact of a project on those functions is then assessed. If it is determined that a pool provides significant amphibian breeding habitat, this could trigger a larger buffer requirement or a potential denial of a project.

According to Rule 5.4 c (1), the following considerations are made in designating *wetlands significant for wildlife*:

a. The wetland provides habitat that supports the reproduction of uncommon Vermont amphibian species including: Jefferson salamander, blue-spotted salamander, spotted salamander, and others found in Vermont of similar significance;

b. The wetland supports or based on its habitat, is likely to support, breeding populations of any uncommon Vermont amphibian species including: mountain dusky salamander, four-toed salamander, Fowler's toad and others found in Vermont of similar significance.

Definition:
None.

Local Regulation

Building upon a long tradition of home rule in New York and New England, towns may adopt more stringent protective wetland regulations than those mandated at the state and federal levels. There are two specific aspects of vernal pool protection where local ordinances add considerable value to conservation efforts. First, local laws are able to extend protection to very small wetlands, including vernal pools that fall beneath the regulatory threshold of state or federal governments. Second, local laws are able to protect upland habitat surrounding a vernal pool. The Connecticut towns of Guilford and Redding have proposed statutory protection of vernal pools by maintaining large areas of critical upland habitat surrounding vernal pools and the upland connections between pools.

The downside to this approach is the creation of a patchwork pattern of wetland protection, varying from town to town. It is not unusual for a wetland that spans two political jurisdictions to be conserved in one town, and be totally unprotected in the other. The level of diligence and expertise in enforcing and interpreting local wetland ordinances also varies from town to town. Even the most comprehensive wetland ordinance is vulnerable to the lack of political will and due diligence by local decision-makers in its application. Another downside to vernal pool regulation is that groups opposing development are beginning to use vernal pools indiscriminately—regardless of their relative biological value—as a tool to thwart applications in the local review process.

Appendix 2

Using Aerial Photography to Locate Vernal Pools

The practicality of using aerial photography to identify vernal pools varies with predominant forest cover-type, scale, timing, and type of photography. A primer on identifying vernal pools through aerial photography and using Geographic Information Systems to create a database is available in *Massachusetts Aerial Photo Survey of Potential Vernal Pools* (Burne 2001). Aerial photo coverage can provide a landscape overview to aid during reconnaissance-level (i.e., field) surveys. From aerial photographs one can identify areas most likely to have pools. For example, topography and breaks in the forest canopy give clues to vernal pool location.

Use of aerial photography must be followed with ground-truthing. *In fact, finding existing vernal pools in the field and then characterizing the way they appear on aerial photography (i.e., defining the* ***signature*** *of vernal pools) may help in picking out other potential pools on photography.* NOTE: Even with good aerial photography and experienced photo-interpreters, many vernal pools are easily missed; this may be due to pool size, forest cover type, the presence of tree shadows, or because the pools are embedded in other wetlands). It is critical to ground-truth!

Below are some common challenges and solutions for using photography for pre-identification of pools based on work done in Maine, Massachusetts, and Rhode Island.

What do I use?

- **Stereo coverage:** Try to obtain aerial photographs in stereo pairs and view them with a stereoscope. Subtle changes in relief can provide clues to potential vernal pool sites.
- **Season and ground conditions:** Photos taken when the leaves are off the trees, the ground is free of snow, and water levels are high provide the best opportunity for identifying vernal pools. Early spring (March-May) is generally the best period for capturing these conditions, but late fall (November-December) may also provide good visibility for aerial coverage. Identification of vernal pools is least reliable on photos taken during very dry years or in the middle of summer when tree canopies obscure ground conditions.
- **Scale and film type:**

  Scale

  The larger the scale (e.g., 1:4,800 is a larger scale than 1:12,000), the easier it is to identify small ground features. Generally, scales at least 1:4,800 to 1:12,000 should be obtained to identify small pools. However, scales as small as 1:31,680 (2 inches per mile) have been used successfully to identify vernal pools that are 0.25 acre in size (L. Alverson, Forest Resource Consultant, pers. comm.). Ultimately, the scale of photography needed to successfully pre-identify vernal pools will depend on the type of film, time of year photos were flown, forest cover type, and size of the pool.

Film Type

Color Infrared—CIR is the most reliable photography for picking out vernal pools because water absorbs color infrared light and appears black in contrast to the lighter colored (pink, magenta, orange, yellow) vegetation. A study conducted at the University of Massachusetts, Amherst (MacConnell et al. 1992) found that large-scale CIR (1:4,800 or 1:12,000) was the best tool for delineating wetlands, particularly forested wetlands. Specifically, they found that CIR is very sensitive to water and chlorophyll—key features for wetland identification. Photo interpretation was faster, more consistent, more accurate and required less corollary information and field work to maintain a high level of accuracy. CIR had much finer resolution than black and white film at the same scale, permitting the use of smaller scale photography. Tiner (1990) and Stone (1992) discuss the advantages of CIR film in photo-interpreting wetlands. The disadvantage of using CIR photography is that it is considerably more expensive than black and white photography.

Black-and-White—A pilot project in York and Penobscot counties evaluating the use of black-and-white aerial photography at 1:4,800 or 1:12,000-scale found it to be an effective pre-identification tool in deciduous forests in southern Maine. Pre-identification using 1:4,800-scale photography resulted in both a higher percentage of correct predictions and less omissions than did 1:12,000-scale photography. However, in lower Penobscot valley, pre-identification of vernal pools less than 0.5 acre was not effective in mixed and evergreen forests (both wetland and upland). In some cases, known pools could not be identified on the photography (K. Huggins, Champion International, pers. comm.).

True Color—An evaluation of true color photography and vernal pool pre-identification has not been conducted. Fall true color photography is effective in picking out red maple swamps in softwood mosaics. These forested wetlands potentially harbor vernal pools. True color photography taken under leaf-off conditions, especially in early spring, may reveal considerable detail of the forest floor. Small waterbodies such as vernal pools may appear as dark spots, or occasionally as white patches if light is reflected off the water surface. Spring leaf-off true color at 1:9000-scale is available for much of southern and central Maine at Maine Forest Service District offices and USDA Natural Resource Conservation Service offices.

What do I look for?

1. Vernal pools may appear as small openings in the forest canopy on winter or spring photos; in deciduous forests they can be detected through the canopy.
2. In forests that have not been harvested for 15-20 years, look for a hole or gap in the canopy that seems larger than the typical shadows caused by individual trees. If the gap is black with no visible vegetation, it may be a vernal pool.
3. Use signature color and relief when attempting to distinguish vegetated vernal pools dominated by ferns, sedges, or grasses. Vegetation growing in water or in very wet soils

imparts gray shades to black and white photos, grayish green tones in color photographs, and grayish pink colors in color infrared photos (CIR).

4. Identifying subtle pockets of variation in relief can be especially helpful when distinguishing vegetated vernal pools in larger wetland complexes. Uneven ground and shallow depressions can be seen through a stereoscope on aerial photographs.
5. Vernal pools might occur in clusters due to uneven topography and the composition of the bedrock or soil type (particularly soils with shallow confining layers or shallow to bedrock). It is often possible to pick out clusters on topographic maps or aerial photography.
6. In central and southern Maine, vernal pools are commonly associated with red maple swamps or mixed evergreen-deciduous swamps. Because pools may be included within larger wetlands, identification can be difficult. If a wetland is in the southern portion of a photo, there might be enough reflection of light off of water surfaces to highlight vernal pools. When viewing stands dominated by softwood, a cluster of red maple is sometimes an indicator of a potential vernal pool (particularly when working with fall true color photography). Conversely, patches of softwoods in hardwood uplands may indicate small areas of wet soils that could include vernal pools.

Common problems with photo-interpreting vernal pools

Many features can mimic vernal pools, including:

- overstory or superstory trees with large crowns that cast shadows over the top of the surrounding canopy and appear to be black spots. (This is particularly true of photos flown in spring or fall when solar angles are low. Looking at photos in stereo may eliminate some of these tree shadows);
- shadows created by narrow pockets in bedrock or streams with deep narrow gorges;
- gaps and openings in the canopy from recent forest harvesting operations; or
- tree shadows along skid trails and near large openings.

Vernal pools might be difficult to see because:

- they are small (often less than 2,000 ft^2);
- tree species typically associated with depressional pools in upland settings (particularly red maple and hemlock) often extend their branches into the pool opening, or the pool itself may be forested by flood-tolerant species.
- pools associated with forested wetland complexes, particularly in mixed and softwood stands, may be obscured by canopy cover or hard to distinguish from the overall wetland complex.

Are National Wetlands Inventory (NWI) maps useful for finding potential pools?

Vernal pools range widely in the types and amount of vegetation they contain and the duration of inundation (i.e., flooding); for that reason, individual pools might be classified as ponds (POW* or PUB), marshes (PEM, PAB), wet meadows (PEM), shrub swamps (PSS), or forested wetlands (PFO).

A 1997 pilot study in southern and central Maine was conducted to test the effectiveness of NWI maps in identifying potential vernal pools. Results from this study suggest:

- NWI maps can be used to locate many of the larger natural pools (isolated wetlands with PUB, PSS and PFO status are often good candidates), but keep in mind that the resolution of NWI maps is often limited to wetlands ≥ 15,000 ft^2 (~0.3 acres). Many of the PUB or POW classifications are likely to be permanent ponds (average mapping unit for NWI is 1-3 acres).
- Effectiveness of NWI maps for locating potential vernal pools depends on local knowledge of types of wetlands in which pools occur. For example, in this pilot study, vernal pool species occurred in some wetlands with temporary inlets and outlets and in forested wetland complexes associated with other wetland types. Therefore, NWI categories of PFO, even with outlets, were considered potential sites.

Ideally, NWI maps are used as one of a number of interpretive tools, including aerial photography.

* National Wetland Inventory classification codes (Cowardin et al., 1979).

Appendix 3

Resources for Identifying Vernal Pools

Note: This is a listing of potential resources; it is not an endorsement of these products or suppliers.

Vernal Pool Manuals

Calhoun, A. J. K. 1999. Maine citizen's guide to locating and documenting vernal pools. Maine Audubon Society, Falmouth, ME.

Maine Audubon Society
20 Gilsland Farm Road
Falmouth, ME 04105

Colburn, E. A. (ed.) 1997. Certified: A citizen's step-by-step guide to protecting vernal pools. Massachusetts Audubon Society, Lincoln, MA.

Massachusetts Audubon Society
Educational Resources Office
208 South Great Road
Lincoln, MA 01773
tel: (781) 259-9506 ext. 7255

Kenney, L. P. 1995. Wicked big puddles. Vernal Pool Association. Reading Memorial High School, Reading, MA.

Reading Memorial High School
Vernal Pool Association
62 Oakland Road
Reading, MA 01867
http://www.vernalpool.org

Tappan, A. (ed.) 1997. Identification and documentation of vernal pools in New Hampshire. New Hampshire Fish and Game Department, Concord, NH.

New Hampshire Fish and Game Department
2 Hazen Drive
Concord, NH 03301

Sources for Aerial Photography

Government Sources

- U.S. Geological Survey (USGS)

  U.S. Geological Survey
  Customer Services
  EROS Data Center
  47914 252nd Street
  Sioux Falls, SD 57198-0001
  tel. (800) 252-4547
  custserv@usgs.gov
  http://edcwww.cr.usgs.gov/

- U.S. Geological Survey (USGS) Business Partners

  http://mapping.usgs.gov

- U.S. Department of Agriculture (USDA)
  Natural Resources Conservation Service (NRCS)

  USDA Natural Resources Conservation Service
  East Regional Office
  5601 Sunnyside Avenue
  Mailstop 5410, Room 1-1290A
  Beltsville MD 20705-5410
  tel. (301) 504-2300
  eastregion@ea.nrcs.usda.gov
  http://www.nrcs.usda.gov

- "Inventory of Aerial Photography and other Remotely Sensed Imagery of New York State"

  a publication available from:

  Center for Geographic Information
  NYS Office for Technology
  State Capitol ESP
  PO Box 2062
  Albany, NY 12220-0062
  tel. (518) 443-2042

- *County planning departments* are also potential sources for aerial photos.

Private Sources

- James W. Sewall Company

  147 Center Street
  P.O. Box 433
  Old Town, ME 04468-0433
  tel. (207) 827-4456
  info@jws.com
  http://www.jws.com

- Aerial Survey and Photo, Inc.

  Airport Road
  P.O. Box 657
  Norridgewock, ME 04957
  tel. (207) 634-2006
  rod@aerialsurveyandphoto.com
  http://www.aerialsurveyandphoto.com

- Col-East, Inc.

  P.O. Box 347
  North Adams, MA 01247
  tel. (800) 359-8676
  http://www.coleast.com

- ADR Associates, Inc.

  9285 Commerce Highway
  P.O. Box 557
  Pennsauken, NJ 08110
  tel. (800) 257-7960
  rhickey@adrinc.com
  http://www.adrinc.com

- AirPhotoUSA, LLC

  7122 N. 27th Avenue
  Suite 500
  Phoenix, AZ 85051
  tel. (866) 278-2378
  http://www.airphotousa.com

Sources for Digital Orthophotography

Note: Small vernal pools are very difficult to detect consistently on digital orthophotography, due to pixel resolution issues.

- Rhode Island Geographic Information System (RIGIS)

  http://www.edc.uri.edu/rigis/

- Massachusetts Geographic Information System (MassGIS)

  MassGIS
  Executive Office of Environmental Affairs
  251 Causeway Street, Suite 900
  Boston, MA 02114
  tel. (617) 626-1000
  http://www.state.ma.us\mgis

- NYS Statewide Digital Orthoimagery Program

  http://www.nysgis.state.ny.us/orthoprogram.htm

National Wetlands Inventory Maps

- U.S. Fish and Wildlife Service (USFWS)

  http://www.nwi.fws.gov/

  for hard copies, contact:

  USGS/ESIC
  National Headquarters
  507 National Center
  Reston, Virginia 20192
  tel. (703) 648-5920 or (888) 275-8747

Field and Lab Equipment

- Forestry Suppliers, Inc.

  P.O. Box 8397
  Jackson, MS 39284
  tel. (800) 543-4203

- Ben Meadows Company

  P.O. Box 20200
  Canton, GA 30114
  tel. (800) 241-6401