Effectiveness of Amphibian Mitigation Measures Along a New Highway

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Abstract: In 2004-2005, a new highway bypass was constructed through an area of predominantly upland forest with many vernal pools in southern New Hampshire. The highway is complete but is not yet open to traffic. Potential impacts to vernal pool amphibians (spotted salamanders (Ambystoma maculatum) and wood frogs (Rana sylvatica)) and their habitat include habitat loss, barriers to animal movements, potential mortality on roads, and changes in water quantity and quality in breeding pools. Measures to maintain viable vernal pool-breeding amphibian populations along the bypass were implemented and monitored. Effectiveness as used in this paper refers to the ability of the various mitigation measures to contribute to the overall goal of maintaining viable populations, as well as the ability of each measure to provide its specific functions. The mitigation measures and results of their effectiveness to date include:

- Bridges: Two bridges were constructed for general wildlife habitat connectivity.
- Wildlife crossing structure and diversion walls: A 1.2 m by 1.2 m (4' by 4'), 17-m (55') long concrete box culvert and diversion walls were installed. After three years of monitoring spring amphibian migrations, it appears the diversion wall is successfully diverting the few vernal pool-breeding amphibians that encounter it, but there is no evidence the crossing structure has been used.
- Seasonal pool construction: Two new pools were constructed in an effort to maintain viable amphibian habitat and populations on both sides of the new road. Post-construction monitoring shows the new pools are used by a relatively diverse community of amphibians (including spotted salamanders in one pool) and macroinvertebrates, although the pools' long-term value to vernal pool amphibians is not yet certain.
- Drainage: Natural hillside drainage was maintained across the new roadway to maintain existing vernal pool hydrology to the extent feasible. Where possible, roadway drainage was routed to swales and detention basins that discharged outside of vernal pool watersheds. Based on two years of observations, vernal pools immediately adjacent to the roadway have been hydrologically altered, but other pools do not appear to have been affected by the changes.
- Habitat preservation: The land around the greatest concentration of existing vernal pools, all on one side of the new highway, was purchased to preserve habitat integrity. Six years of pre-construction and two years of post-construc tion monitoring show that spotted salamander breeding (as measured by egg mass counts) has not changed substantially compared to pre-construction levels. However, there is a great deal of variation in breeding activity from year to year and pool to pool, and longer-term monitoring may reveal different trends. Opening the highway to traffic may also affect populations.

Introduction

Southern New Hampshire is part of the metropolitan Boston area and is experiencing rapid development of new residential subdivisions and increasing traffic volumes and traffic congestion. In the early 1990's, the New Hampshire Department of Transportation (NHDOT) proposed improvements for the local highway network in the towns of Windham and Salem, NH that included a new highway bypass to relieve traffic congestion. Figure 1 shows the general project location and identifies the area (labeled "bypass segment") that is the subject of this paper. An Environmental Impact Statement was prepared which identified an important wildlife corridor, an upland habitat area, and two vernal pools along the proposed bypass route. Follow-up studies identified several more vernal pools in the vicinity of the bypass. This paper describes measures implemented to mitigate the bypass's wildlife impacts, focusing on vernal pool-breeding amphibians and their habitat. The paper describes the general wildlife impacts and mitigation measures; the range of possible impacts to vernal pool species and habitats; measures to mitigate those impacts; and the results of pre- and post-construction monitoring.

The portion of the highway bypass which passes through the vernal pool area (figure 2) is approximately 1.2 km (0.75 miles) long, with one lane in each direction and a roadway pavement width of 13.2 m (44 feet). It was constructed in 2004-2005 through an area of predominantly upland forest with many vernal pools. Highway construction has been completed, but the highway is not yet open to traffic.

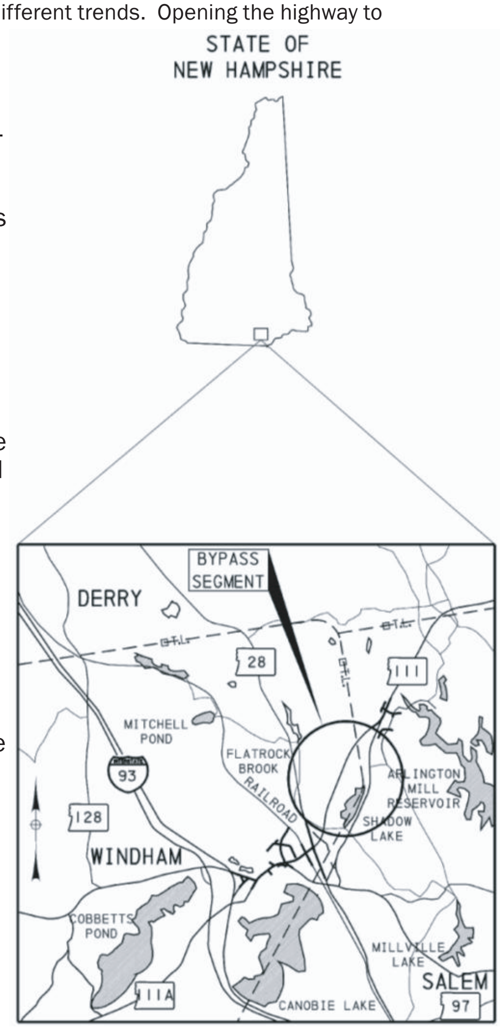

Figure 1. Project location.

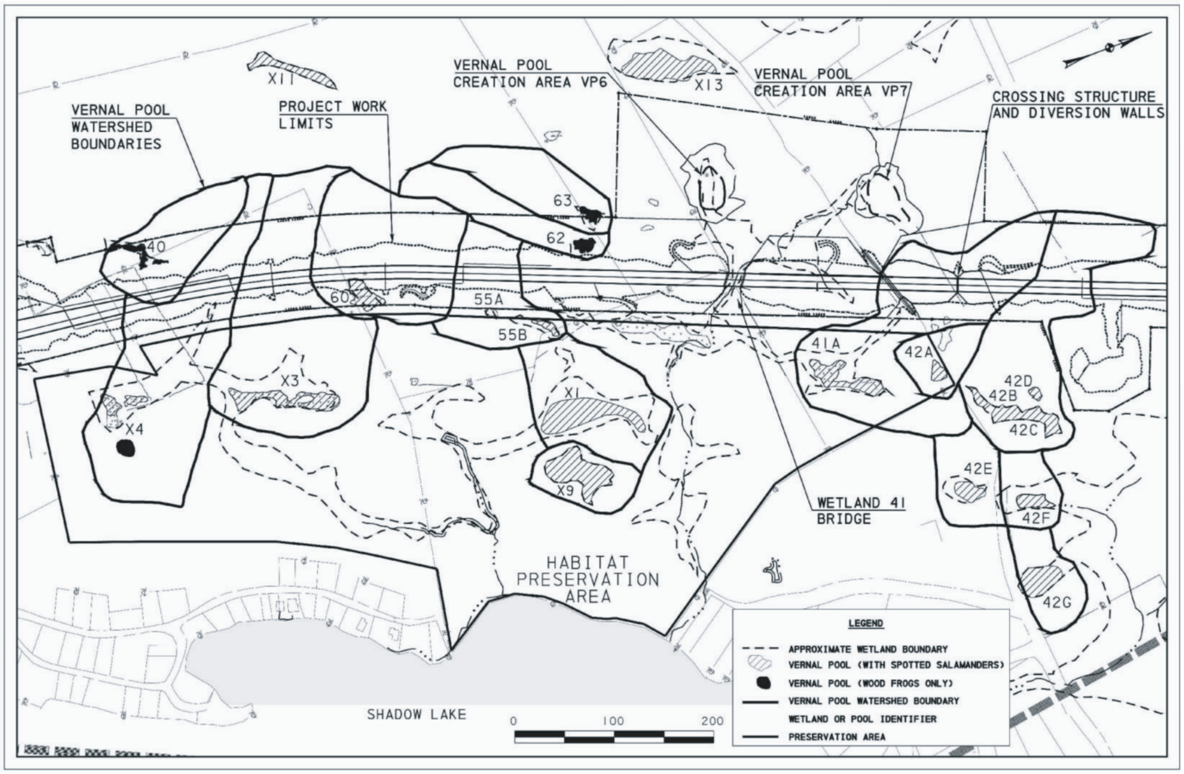

Figure 2. Windham-Salem Bypass Project within vernal pool area. (metric scale)

General Wildlife Habitat Impacts and Mitigation Measures

In the early stages of the study, the wildlife impact of greatest concern was habitat fragmentation. Measures to counteract this impact included two bridges and permanent protection of important habitat.

The only clear wildlife corridor along the bypass route is a stream corridor located about 200 m (650') south of the vernal pool area along a local road. The corridor includes a 4 to 6 m (13' to 20') wide perennial stream and adjacent floodplain and wetland. A bridge spanning 176 m (577') was constructed over an existing road along with the entire stream, floodplain, and wetland. The construction cost of the bridge was approximately $7 million, a figure which would have been substantially lower if the minimum size structure(s) had been built.

A second bridge with a 15-m (50') span was constructed nearer the middle of the bypass segment over an intermittent stream that connects a network of forested wetlands on each side of the bypass (the "Wetland 41 Bridge", figure 2). The purpose is general habitat connectivity, and the construction cost was approximately $760,000.

The land between the bypass and a nearby lake was purchased and permanently protected ("Habitat Preservation Area", figure 2). The land totals 18 ha (44 acres) and includes the only undeveloped shoreline left on this small lake. It also includes several vernal pools.

Vernal Pool and Amphibian Impacts

There are several ways in which the new highway may affect vernal pool-breeding amphibians and their habitat. These impacts are described below, followed by a description of mitigation measures and monitoring results.

Direct Habitat Loss

Within the vernal pool area, the new bypass will convert approximately 5 ha (12.5 acres) of forested habitat to pavement, embankments, detention basins, and other structures. Most of the affected land is former upland forested habitat that was presumably used by spotted salamanders and wood frogs that breed in the pools. If upland habitat, rather than vernal pool breeding habitat, is a limiting factor in these species' population sizes, then the habitat loss could result in smaller populations of these species.

One vernal pool has been directly impacted by the project. About a third of a particularly productive pool (pool 60) was filled in. It is smaller and possibly shallower than before and receives more sunlight, but continues to be used by both wood frogs and spotted salamanders. It remains to be seen whether, following the opening of the highway to traffic, this pool will continue to be viable habitat for these species.

Barriers to Animal Movements and Direct Mortality on Roads (Road Kill)

Spotted salamanders and wood frogs are known to travel several hundred feet or more to their breeding pools (Colburn 2004). Since several productive vernal pools (such as X1, X3, and 42C on figure 2) are 100 m or so (300' to 400') from the new highway, the road presumably crosses amphibian migration routes. The road may serve as a barrier in several ways: some amphibians may be reluctant to cross open spaces such as roads; some may be disoriented by the new landscape configuration; and, when the road opens to traffic, some may be run over by vehicles and killed on the road.

Water Quality and Hydrology

Hydrology is perhaps the single most important characteristic of vernal pools. The most productive vernal pools for pool-breeding amphibians are those that contain water long enough for amphibians to metamorphose, but that dry out periodically so they do not support predatory species such as fish or green frog tadpoles. The bypass passes through the surface watersheds of many vernal pools (pool watersheds are shown on figure 2), and may affect runoff/recharge ratios, water temperature, and other factors affecting water quantity and quality.

To determine the hydrologic impact of the project on vernal pools, efforts were made to understand the hydrology of existing vernal pools. The hydrology of a typical existing pool (pool 60 on figure 2) was studied by placing three water table wells around the pool: one just upslope, one on a lateral slope, and one just downslope. Water depth was also measured within the pool. It was found that in springtime, there are both surface water and groundwater inputs to the pool. Snowmelt, precipitation, and a groundwater table that is higher than the pool's water level combine to fill the pool. Over the course of the growing season, the groundwater elevation gradually drops to a level below the bottom of the pool. The surface water elevation of the pool drops more slowly than groundwater drops, so that in summer and early fall the pool's water may be perched above the groundwater table.

The bypass is constructed in a cut section upslope of the pools. This has the potential to intercept both surface water and groundwater that would normally flow into the pools.

Vernal Pool and Amphibian Mitigation Measures

Wildlife Crossing Structures

One way to address the travel barrier and road kill effects of the new highway is to make the highway permeable to amphibian movements. One approach to making a road permeable to amphibians is to install wildlife crossing structures (culverts or bridges). Amphibians have been found to be sensitive to moisture, light, temperature, and other physical characteristics of wildlife crossing structures (Jackson and Griffin 2000). There have been mixed results in getting vernal pool-breeding amphibians (particularly spotted salamanders and wood frogs) to pass through crossing structures. An amphibian crossing structure installed in Amherst, MA reportedly allowed 76% of amphibians to cross the road safely (Jackson 1996). However, that design involved a smaller road crossing and was able to incorporate slotted tops that allowed rain water to enter the crossing structures.

For this project, efforts were made to develop a structure design that would provide the requisite conditions, particularly moist substrates, for amphibian crossing. Slotted top and open grate designs were considered, but highway maintenance personnel believed the safety risks and maintenance concerns of such a design (particularly during snowplow operations) would be unacceptable. There were also concerns about the effects on amphibians of road runoff entering the structure. Other design concepts, such as grates in road shoulders or swales or pipes carrying road runoff into a crossing structure, were found to have potential maintenance problems or water quality concerns.

The selected wildlife crossing structure location is shown in figure 2, and the design is shown in figure 3. The structure cost approximately $100,000 to construct. The design has the following features:

Location: There were no clear amphibian travel corridors within the project area, and the target species do not converge along common travel routes. The wildlife crossing structure was therefore constructed where the road approaches the most productive vernal pool (in terms of spotted salamander egg mass counts), pool 42C, as this area was likely to have the greatest number of amphibian movements.

Length: 17 m (55'). The length was shortened as much as possible by constructing headwalls and wingwalls just outside the road shoulders.

Opening: 1.2 by 1.2 m (4' by 4'). The opening is larger than those generally recommended for amphibians (e.g., Jackson and Griffin 2000).

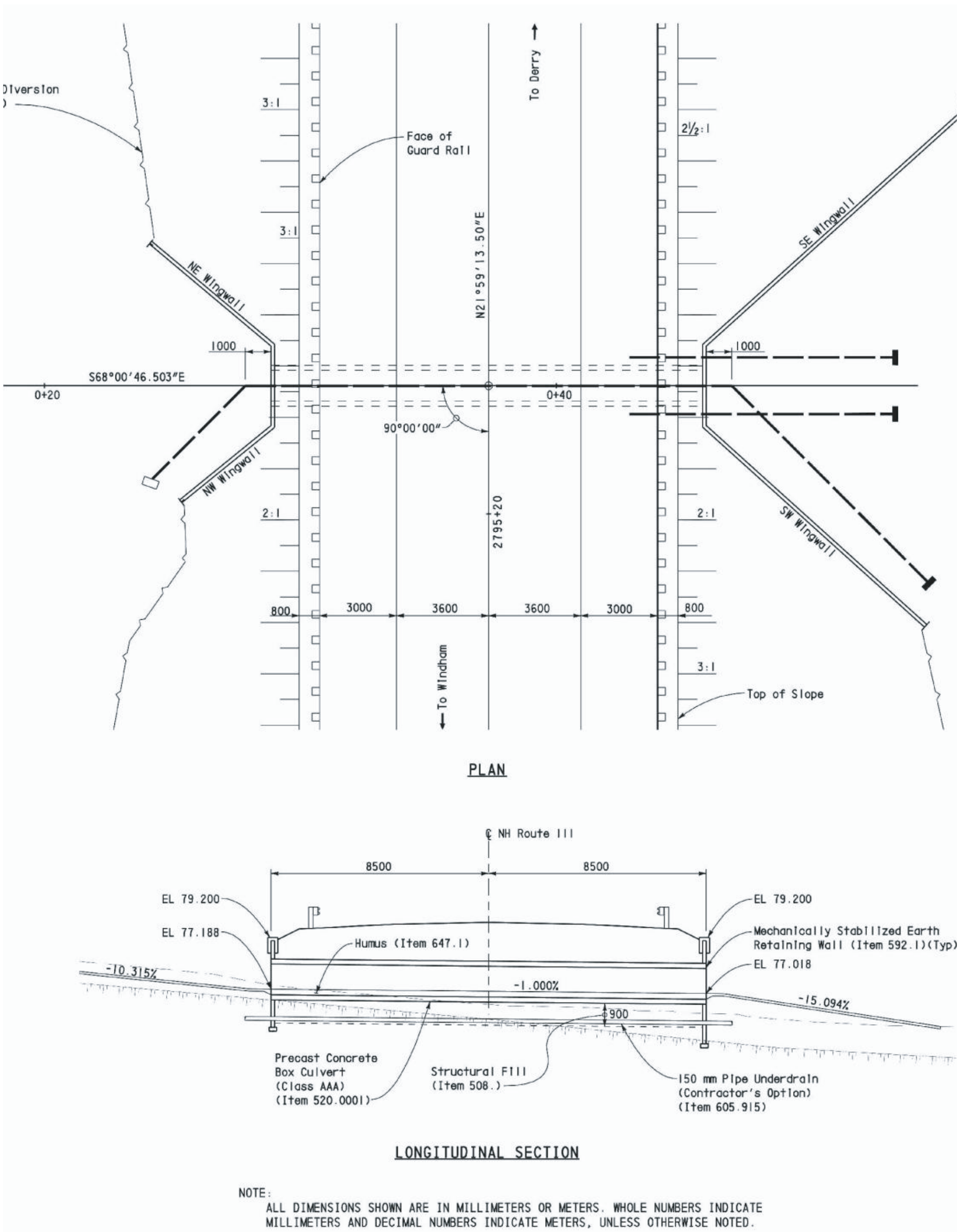

Figure 3. Crossing structure plan and section (in metric units).

Substrate: The substrate was a loamy soil material which would allow absorption of moisture and some resistance to erosion. The soil material was sloped across the width of the structure so that any stream flow would be confined to one side, potentially resulting in a gradient of moisture conditions and allowing passage of animals along the higher ground.

Moisture: The wildlife crossing structure was placed in a landscape position in which it can receive a small amount of overland flow from the surrounding land, but not enough to create stream conditions, which spotted salamanders may avoid. In early spring, especially while snow is still melting and the ground thawing, a small amount of water flows into the structure and creates moist conditions along one side of it. Following snowmelt, the substrate gradually dries out.

Wildlife diversion wall: Also designed and implemented was a “wildlife diversion wall”, a low wall intended to prevent amphibians from crossing over the road surface and to funnel them to the crossing structure. Wildlife diversion walls were 0.3 m (12 inches) or higher and extended from the wildlife crossing structure opening to a stone-lined stream channel on one side and a larger pedestrian culvert with a crushed stone substrate on the other side. The diversion wall was specified as a smooth wall, but the final specifications were ambiguous and a rough concrete block ("Versa-Lok") was used by the contractor.

Vernal Pool Habitat Creation

Despite the above design features, there remained uncertainty about the wildlife crossing structure's ability to succeed in accommodating vernal pool amphibians, particularly considering the mixed success that other amphibian crossing structures have reportedly had in New England (B. Butler and B. Windmiller, pers. com.). The crossing structure was therefore considered experimental, and more attention was paid to ensuring sufficient vernal pool habitat on both sides of the highway to support viable amphibian populations.

As shown in figure 2, there is more vernal pool habitat on the east side of the new highway, and three of the four most productive pools in the area are located there. In an effort to ensure there is sufficient vernal pool habitat on both sides of the highway to support viable populations, two new pools (VP6 and VP 7 on figure 2) were constructed. The size and hydrology of these two constructed pools were designed to mimic that of existing pools in the area. A 60-m (200') upland buffer was preserved around both pools. Conditions found in these pools are discussed in the *Monitoring Results* section below.

Mitigation for Hydrologic and Water Quality Impacts

To minimize the potential hydrologic effects of the bypass intercepting surface water and groundwater flowing into the pools, as well as possible water quality effects of road runoff, the following mitigation measures were implemented:

- The integrity of each pool's watershed was maintained to the extent possible by allowing natural hillside drainage to cross under the new roadway, separate from road runoff.
- Road runoff, where feasible, is collected and discharged to detention basins and swales that discharge away from vernal pool watersheds.
- Underdrains were installed at many places along the bypass to ensure a stable road bed. This is clean groundwater and is discharged directly to the adjacent land, so most of the affected groundwater stays within the pools' watersheds.

There are no baseline data of preconstruction vernal pool hydrology or water quality to determine the effectiveness of these measures. Visual observations suggest that the hydrology of most existing vernal pools has been little affected. However, three existing pools located immediately adjacent to the roadway appear to have altered hydrology. These include pool 60, which was partially filled by the project, but still has wood frog and spotted salamander egg deposition; pool 40, which continues to have wood frog egg deposition but appears smaller and drier than previously; and pool 62, which supported wood frogs and now has spotted salamander breeding activity, and appears deeper and wetter than previous conditions.

Additional Habitat Preservation

The 44-acre parcel that was preserved for general habitat mitigation includes many of the most productive vernal pools (in terms of amphibian breeding activity) in the vicinity of this bypass segment. When the extent of vernal pool and amphibian habitats and impacts in this area became known, NHDOT agreed to extend the preservation land to the north to include approximately 20 additional acres, which contain several vernal pools (42C, 42F, 42G) along with upland and wetland forest habitat. NHDOT also agreed to preserve a 60-m (200') right-of-way buffer around two constructed vernal pools (discussed below).

Monitoring Results

Existing Vernal Pool Breeding Activity

Six years of pre-construction and two years of post-construction monitoring (with no traffic on the new road) show that spotted salamander breeding in existing pools (as measured by egg mass counts) has not changed substantially compared to pre-construction levels (figure 4). However, there is a great deal of variation in breeding activity from year to year and pool to pool, and longer-term monitoring may reveal different trends. Opening the highway to traffic may also affect populations.

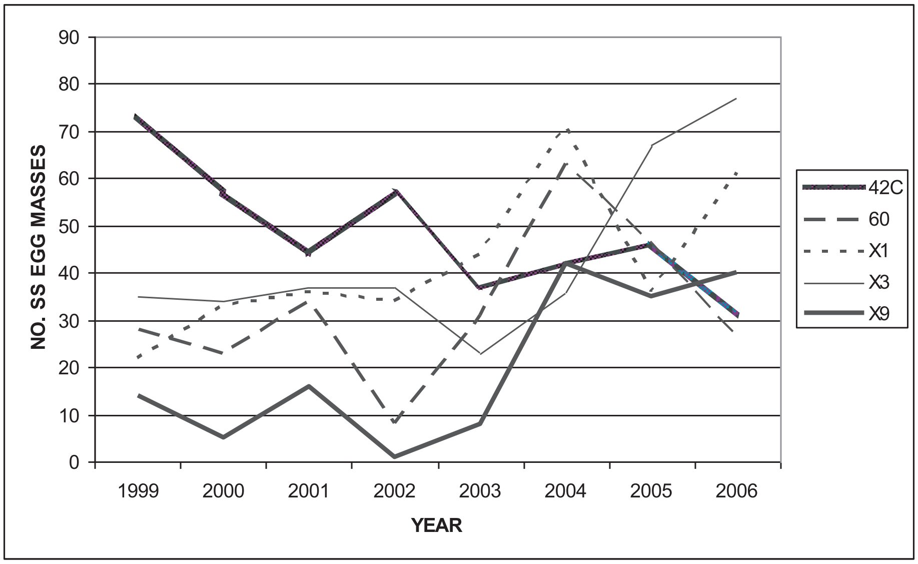

Figure 4. Spotted salamander (SS) egg mass counts in existing vernal pools by year. Vernal pool identifiers are at right; see figure 2 for pool locations. The highway bypass was constructed in 2004 and 2005.

Constructed Vernal Pools

Post-construction monitoring shows the new pools are used by a relatively diverse community of amphibians (including spotted salamanders in one pool) and macroinvertebrates. In the two years since construction, the pools have not dried out, although both years have been wetter than normal. It appears the pools are valuable amphibian habitat and are likely to provide habitat for at least one vernal pool breeding amphibian, although the long-term value to vernal pool amphibians is not yet certain. Other issues that have arisen include the relative lack of shading around new pools (necessitated by grading to construct the pools) and the resulting growth of dense emergent vegetation in portions of the pools.

Wildlife Crossing Structures

After three years of monitoring spring amphibian migrations, there is no evidence the wildlife crossing structure has been used by amphibians. Small numbers of spotted salamanders and wood frogs have been found moving along the wildlife diversion walls, but have not been found within the structure. Reasons most likely include a combination of substrate, opening size, and length of the structure. The diversion wall is diverting vernal pool-breeding amphibians, although spring peepers have been observed scaling the rough wall. There is also dense growth of grass in some places along the wall, which could make amphibian travel along the wall difficult, and could give amphibians the means to cross over the diversion wall.

Small numbers of spotted salamanders and wood frogs have also been found crossing the road in areas where there are no wildlife diversion walls or crossing structures, suggesting there will be mortality once the road is open to traffic.

Conclusions and Recommendations

Roads may affect vernal pool breeding amphibians and their habitats in a variety of ways, including by habitat loss, barriers to animal movements, mortality on roads, and changes in water quantity and quality in breeding pools; all of these potential impacts need to be considered for these species.

It is clear that more information is needed on ways to successfully design crossing structures for amphibians, especially across larger highways. For this project, it does not appear the highway will accommodate safe crossing by amphibians. However, through habitat preservation and the creation of new habitat, there is likely sufficient habitat to allow for viable amphibian populations on both sides of the new roadway. Occasional crossing by amphibians is likely to be sufficient to allow for gene exchange and recolonization needed for healthy metapopulations. Monitoring will continue at least through 2009, and should reveal the effects of roadway traffic, results of mitigation efforts, and population trends.

Biographical Sketch: Jed Merrow is with the consulting firm McFarland-Johnson, Inc. Jed has an MS in Natural Resources Science from the University of Rhode Island and specializes in wetland and wildlife ecology. He has particular expertise in reptiles and amphibians, and has worked on a variety of vernal pool studies, herptile inventories, rattlesnake habitat studies, as well as many bird surveys. He has also served on New Hampshire committees related to a vernal pool manual, vernal pool wetland regulations, and reptile and amphibian listings, and is active with the NH transportation/wildlife working group. He has over 15 years of experience on transportation projects.

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