Bolton Waterbury STP 2709(1)

Wildlife Connectivity Study

Final Report

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July 2016

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EXECUTIVE SUMMARY

Purpose of Study

This study was undertaken to answer the following questions:

- Is the habitat in the vicinity rich in wildlife?
- Is there an edge effect zone along the corridor?
- Is the I-89/Route 2 corridor currently a fragmenting feature?
- Is wildlife road mortality currently occurring?
- Are existing culverts and bridges facilitating wildlife movement?
- Would infrastructure modifications improve wildlife movements across barriers?

Methods

The study focused on medium- to large-sized, wide-ranging mammals. The principal means of collecting information on these species and answering the study questions included the placement of 40 wildlife cameras and winter tracking for two consecutive years. Wildlife cameras were placed at the larger existing culverts, the Little River bridge, along transects perpendicular to the roads, and in some locations more distant from the main roads. Winter tracking was undertaken at least twice each winter along transects, I-89, and a local road.

Responses to Study Questions

Results showed that a broad range of medium- and large-sized mammals occur on both sides of the corridor, near and far from the roads. The distribution of most species changes with distance from the road edge, so it is concluded there is an edge effect. Most focus species appear to be repelled by the road corridor, but others, such as deer and fox, may be attracted to the forest edge habitat or the open-canopy habitat between the road and forest.

Many more animals crossed the woodland transects than crossed River Road or I-89, and more crossed River Road than I-89. This suggests that these roads inhibit or deter animal movements, and that larger roads such as I-89 have a greater inhibitory effect than smaller roads. The road corridor therefore can be said to fragment habitats and wildlife populations in the general area. The degree of fragmentation appears to vary with the species and other factors such as the presence of natural and man-made barriers.

Some apparent road mortality was observed (8 dead animals along I-89 over two winters), and appear to confirm historical records of wildlife mortality on this segment of I-89.

Winter tracking showed that about one-fifth of animals entering the I-89 roadway passed through culverts and 10 percent passed under bridges. The most frequently used structures

included the Pineo Brook box culvert, a 36-inch CMP near Sharkeyville Road, a 42-inch RCP west of Little River, and the Little River bridge. Several other structures carried a few sets of tracks, including two bridges, two 36-inch CMPs, a 48-inch CMP, and a 48-inch RCP. Some structures under I-89 did not show animal usage during this study's tracking rounds.

Tracking showed relatively little use of the two bridges over US Route 2. The Joiner Brook structure, an approximately 32-foot wide bridge under US Route 2, also had no animal tracks and no trail camera photos of wildlife. The Sharkeyville Stream inlet, a 60-inch CMP, had one set of mink tracks and no wildlife photos.

In short, some structures are frequently used and facilitate wildlife movement, while other structures, including bridges, do little to facilitate movement. There are presumably certain features which make some culverts or bridges hospitable and others inhospitable for animal travel. For example, the wildlife shelf under the Little River bridge is clearly a success, while the bridge over Joiner Brook is not conducive to wildlife movement. These features should be investigated, and the information used to guide future structure placement and design. The likelihood of the structure to be utilized by wildlife should be considered in planning future roadway infrastructure improvements, with higher priority given to areas that showed more wildlife activity.

A number of other structures may impede animal movement across the corridor. Chain-link fencing, woven wire fencing, Jersey barriers, and steep embankments may deter certain species from crossing roads. The potential impact to wildlife movement should be evaluated and weighed against the other benefits provided by these structures. For example, chain-link fence is impermeable to most medium and large-size wildlife species, and could result in animals spending more time on the road, increasing the chances of wildlife-vehicle collisions. This risk could be compared with the fence's benefits, such as the ability to deter humans from the roadway.

Importance of I-89 Segments to Connectivity

The I-89 roadway within the study area was evaluated for its ability to facilitate wildlife crossing and improve habitat and population connectivity. The evaluation takes into account the camera and tracking results, existing landscape conditions along the corridor, and existing impediments to wildlife movement.

High priority areas: The Pineo Brook crossing and the roadway segment between Pineo Brook and the bridge over US Route 2 at Farr's Landing Road. There were relatively high numbers of wildlife crossings in this area, usage of culverts by wildlife, a perennial stream corridor, conservation land both north and south of the corridor, and moose and bear roadkill records

along this stretch of I-89. The Sharkeyville Road and stream area had a particularly high level of wildlife activity.

Medium priority areas: West of Bolton Valley Road and Joiner Brook (high value habitat north of I-89); Bolton Valley Road to Pineo Brook Road (high value habitat but fragmented by chain link fence, farmland, and residential land); US Route 2 bridge at Farr's Landing Road to Exit 10 (conservation land nearby, somewhat fragmented landscape, moderate wildlife crossings, small culverts); and the Little River bridge (an important wildlife crossing but already suitable for passage).

The Bolton Valley Road / Joiner Brook area is considered lower priority because of existing habitat fragmentation and the relatively low amount of wildlife activity observed during the study.

RATIONALE FOR STUDY

The Green Mountains run north-south through Vermont and represent a nearly continuous band of habitat with some of the largest remaining unfragmented habitat blocks in Vermont (Figure 1). Perhaps the largest single fragmenting feature within this mountain range is the Interstate 89 corridor. I-89, a railroad line, the Winooski River, a local road, and scattered development traverse this corridor east to west and present a partial barrier to wildlife movement. The segment between Waterbury and Bolton Village, shown on Figure 2, is the focus of this project. North and south of this corridor are large habitat blocks with extensive upland forests along with many habitat features such as ridge lines and stream valleys, rare species and habitats, and deer wintering areas (Figure 3). Figure 1 shows that these habitat blocks are highly rated based on physical and ecological diversity, and Figure 3 shows that the habitat linkage value is mostly high.

There are many potential impediments to wildlife movement along I-89, including fencing, Jersey barriers, rock cuts, and steep slopes (Figure 4). Opportunities for wildlife to safely cross the roadway corridor are limited and take the form of road or railroad bridges, stream culverts, and perhaps other structures that were not designed or located with wildlife in mind.

How these fragmenting features and associated infrastructure affect wildlife populations and movements is not well understood, and there is interest in improving the connectivity of this habitat. Until this study, neither the permeability of the existing roads nor the potential for improved wildlife crossings had been studied at this location.

STUDY QUESTIONS

This study addresses this lack of information on local wildlife occurrence, movement, and interaction with the road corridor by posing the following questions:

Is the habitat in the vicinity rich in wildlife?

Is there an edge effect zone?

Is the I-89/Route 2 corridor currently a fragmenting feature?

Is wildlife road mortality currently occurring?

Are existing culverts and bridges facilitating wildlife movement?

Would infrastructure modifications improve wildlife movements across barriers?

Figure 1. Vermont Ecological Habitat Blocks

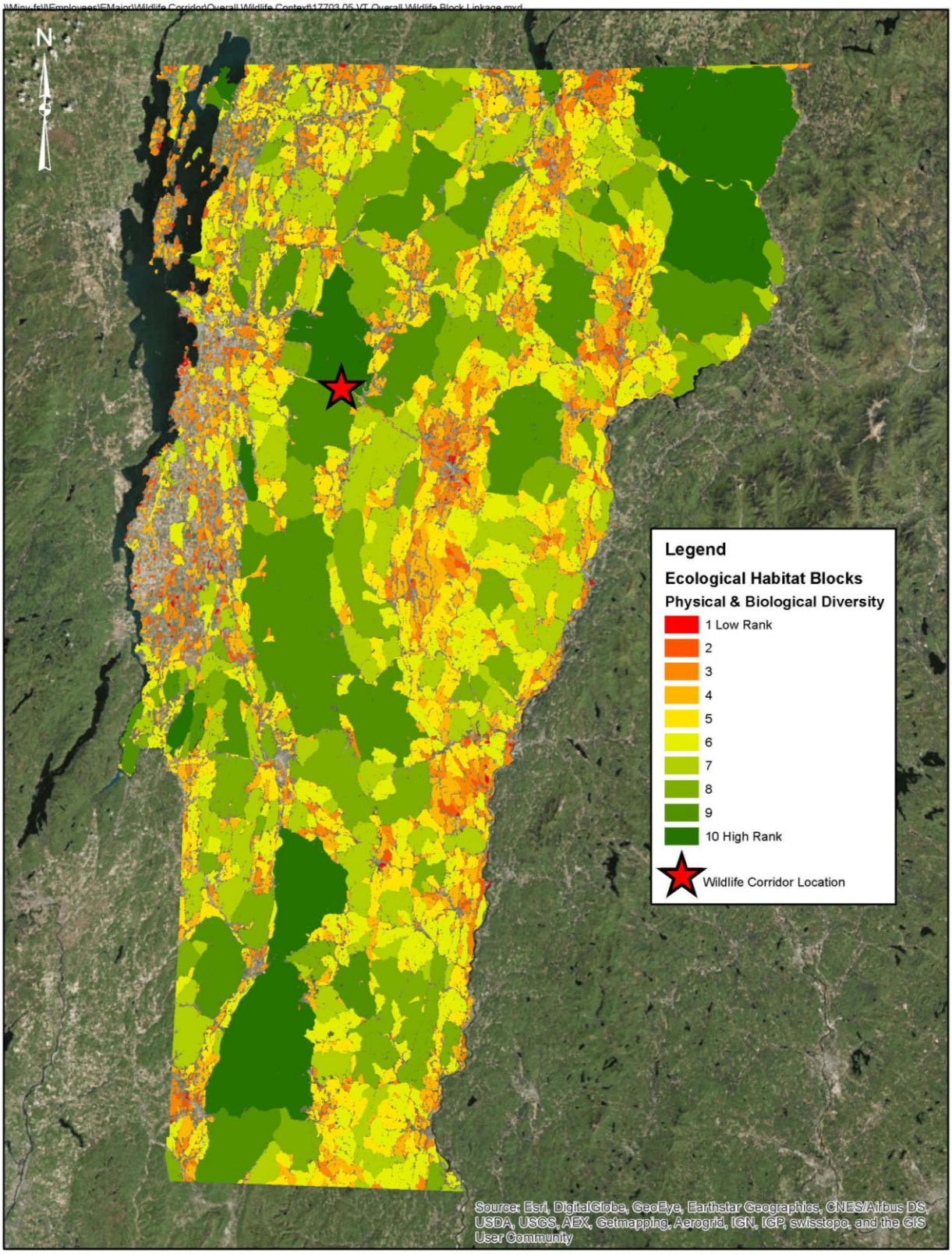

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Figure 2. Study area with roadway study segments highlighted

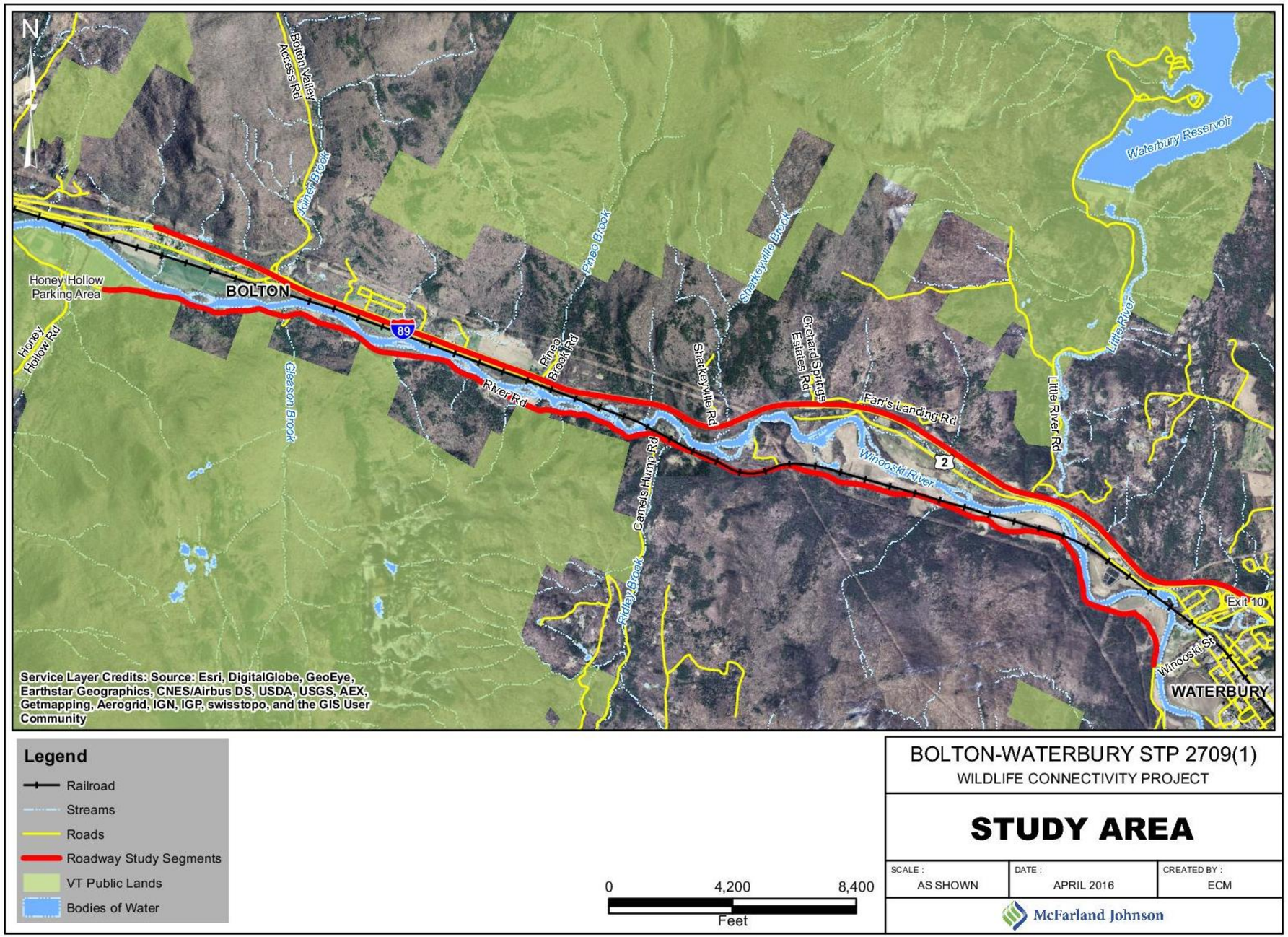


Figure 3. Previously mapped habitat features and wildlife crossing values for study area

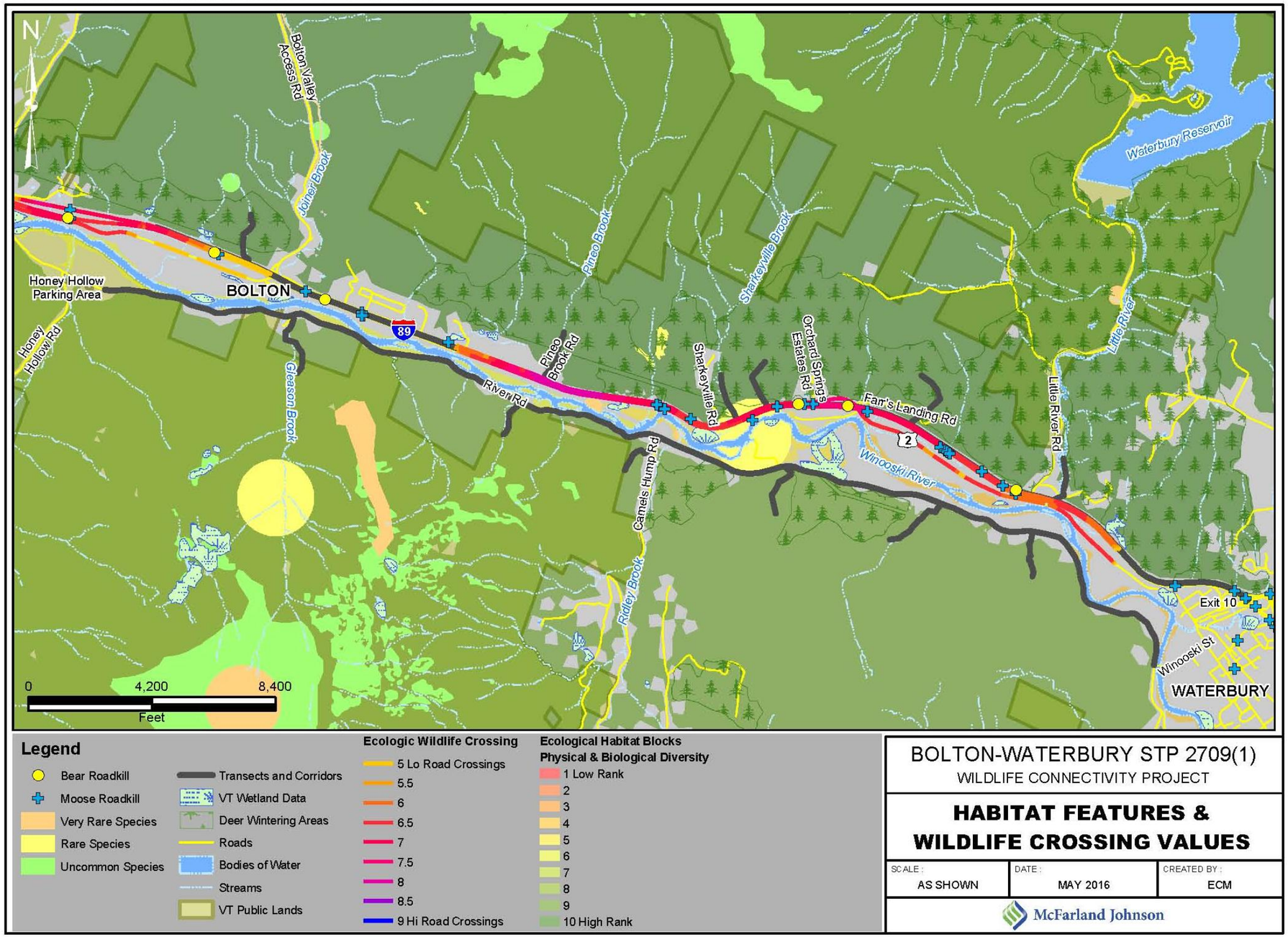


Figure 4. Potential impediments to wildlife movement across I-89

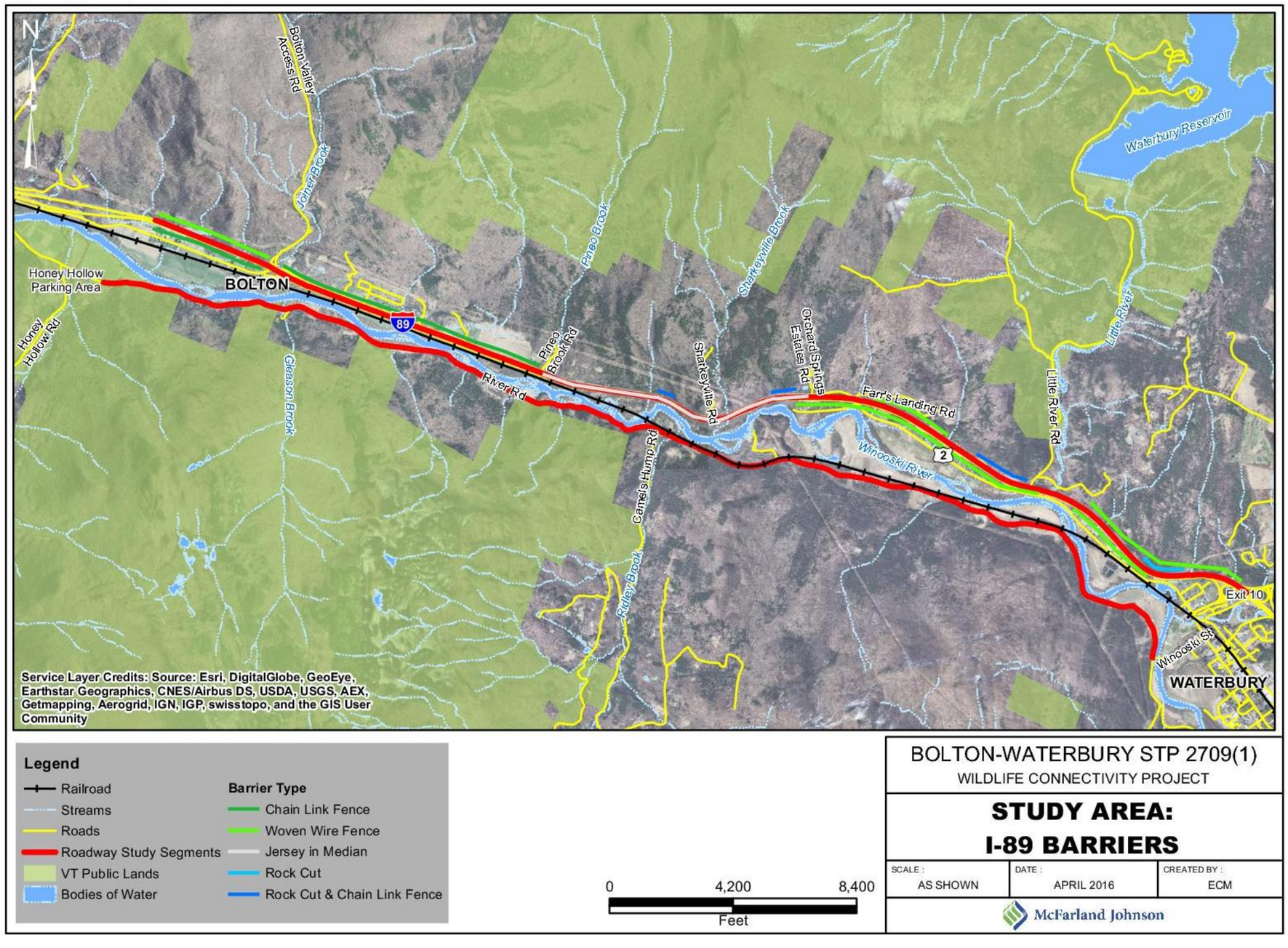
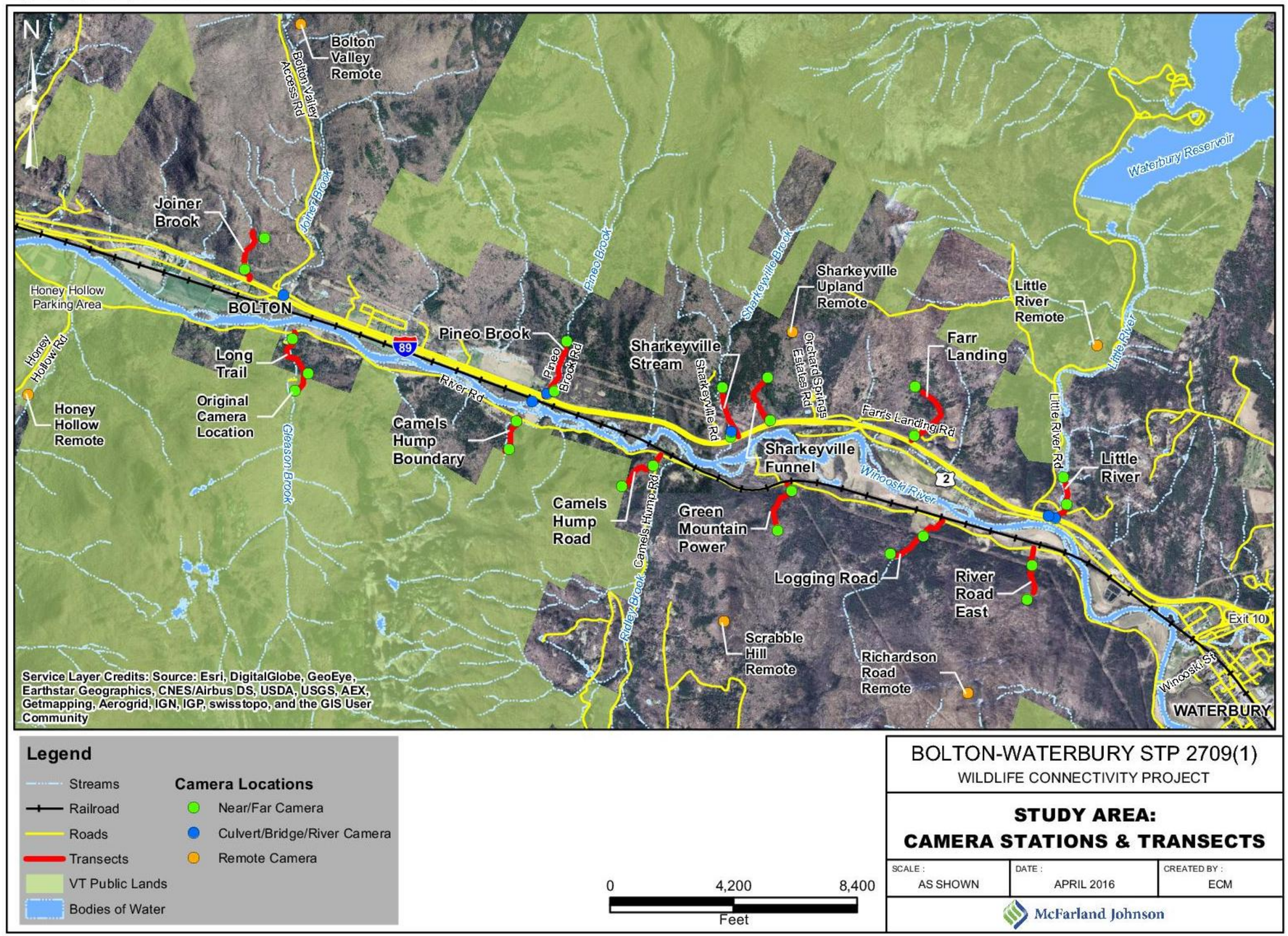


Figure 5. Transect and camera station layout



METHODS

The study focused on medium- to large-sized, wide-ranging mammals (Table 1). The principal means of collecting information on these species and answering the study questions included wildlife cameras and winter tracking. The data were compiled and analyzed, and combined with other information such as roadkill records and GIS habitat mapping, to address the study questions.

Table 1. Primary and secondary focus species

Primary Focus	
Coyote	*Canis latrans*
American Black Bear	*Ursus americanus*
Fisher	*Martes pennanti*
Bobcat	*Lynx rufus*
White-tailed deer	*Odocoileus virginianus*
Moose	*Alces americanus*
American Mink	*Neovison vison*
River Otter	*Lontra canadensis*
Secondary Focus	
Red Fox	*Vulpes vulpes*
Gray Fox	*Urocyon cinereoargenteus*
Eastern Cottontail	*Sylvilagus floridanus*
Snowshoe Hare	*Lepus americanus*
North American Porcupine	*Erethizon dorsatum*
Common Raccoon	*Procyon lotor*
American Marten	*Martes americana*
Short-tailed Weasel	*Mustela ermine*
Long-tailed Weasel	*Mustela frenata*
Striped Skunk	*Mephitis mephitis*

Wildlife cameras: Wildlife cameras were placed at the larger existing culverts, the Little River bridge, along transects through adjacent forested habitat, and in more remote locations (Figure 5). The structures included the Little River bridge, Pineo Brook box culvert, Sharkeyville Stream corrugated metal pipe (CMP), and Joiner Brook bridge (see Appendix A, Photo Log). The

transects were situated along favorable habitats, such as stream corridors, ridge lines, or observable wildlife trails, where primary focus species were expected to be found. The transects started at the edge of forested habitat along the nearest road, and extended away from the road approximately 1,600 feet. The transects were not always straight or directly perpendicular to the road. One camera was placed near the road (the "Near" camera) and the second at the end of the transect ("Far"), which in most cases was approximately 1,600 feet from the road edge, with some variation to allow for flexibility in camera placement. There were 12 transects, 6 along the north side of the corridor and 6 along the south side, with 2 cameras each or 24 cameras total.

Six cameras were located further afield and are considered "remote" locations. These were placed at locations that appeared favorable for observations of primary focus species at distances ranging from approximately one to two miles from the nearest major road. There were an additional 5 cameras placed at the Little River bridge, 2 at the Joiner Brook inlet, 1 each at the Pineo Brook and Sharkeyville Stream inlets, and 1 along the Winooski River. To summarize, camera locations included:

- 5 cameras under the Little River bridge
- 4 cameras at 3 stream culvert inlets
- 1 camera along the Winooski River shoreline
- 24 cameras, 1 at each end of 12 transects: north and south, "Near" and "Far"
- 6 remote cameras; 3 on the north side and 3 on the south side

The camera models were the Reconyx PC800 and PC900. These models are reported to have a field of view of up to 50 feet (PC900) or up to 70 feet (PC800). They are triggered by a combination of temperature differences (such as a warm body against a cooler background) and movement across zones within the camera's field of view. Once triggered, they take a series of 3 photographs at 1-second intervals. They continue taking photographs until the trigger ceases (i.e., the animal moves out of the field of view or becomes immobile). Cameras were placed approximately 8 to 10 feet above ground in order to avoid theft, damage or disturbance from people. Cameras were attached to a tree or, under the bridge, to a bridge abutment or pier. The camera body was angled down at a roughly 45-degree angle.

Winter tracking: Each transect illustrated above was visited two times each winter over two winters (2013-2014 and 2014-2015) when snow conditions were appropriate. Tracking was conducted along I-89 (five times total) and River Road / Duxbury Road (twice per winter or 4 times total). I-89 was tracked from the crossover between the I-89 barrels (Mile Marker 71.4) about 4,400 feet west of the bridge over US Route 2 in Bolton Village, to the Route 100 overpass at Exit 10 in Waterbury (Figure 4). The total I-89 segment is approximately 7.35 miles long, which equates to 97 total 400-foot segments. River Road was tracked from the

Catamount Trail parking lot (just east of Honey Hollow Road) in Duxbury to the Winooski Street intersection, equating to 7.73 miles and 102 total 400-foot segments. Tracks were identified to species (where possible), the track locations were recorded on GPS units, and it was determined whether the animal crossed the road. Along I-89 (and US Route 2, which closely parallels I-89), culverts and bridges were checked to determine whether animals crossed via those means. Tracks were particularly abundant along River Road and at times, all sets of tracks within a 50-foot stretch of road were combined and recorded at one GPS point.

TRAIL CAMERA RESULTS

Introduction

The camera results were tabulated and reported here as the numbers of animals photographed. This refers to the numbers of animals photographed in each different photo series or triggering event. If there was a continuous series of photos triggered by a single animal, that was counted as one animal; if there was a brief gap (seconds to a minute) between camera triggers but it was clearly the same animal, it was still counted as one animal. Two animals in the same series of photos counted as two animals. If the same individual animal was photographed at different times, each photo event was counted as an additional animal photographed.

Each camera was deployed for approximately two years, and the dates of deployment of each camera were used to convert results to a "per camera per year of deployment" basis, in the following way:

- For individual cameras, the number of animals photographed was divided by the number of years the camera was deployed and functional. For example, the Pineo Brook Inlet camera was deployed and functional for 759 days, or 2.08 years. The results for that camera were divided by 2.08 to obtain the results per camera per year. This method was used to generate the results in the *Camera Results by Station* section below.
- For tabulating results by corridor location (Culvert/Bridge, Near, Far, Remote), the cumulative results for that location were divided by the cumulative number of years of deployment of all cameras at that location. This method was used to generate the results in the Camera Results by Corridor Location section below.

Refer to the table in Appendix B, which shows camera deployment dates and calculation of camera-years.

The Winooski River camera results are not included in the Corridor Location results, since that camera station does not fit into the Corridor Location scheme (Culvert/Bridge, Near, Far, and Remote).

Mice and domestic animals are excluded from this analysis.

Overall Results (combined results of all cameras)

Over 116,000 wildlife photos were taken by the 40 trail cameras over the two years of the study. The results of all camera data combined were tabulated by species and are shown in Table 2 in order of abundance within each focus grouping. White-tailed deer were by far the most abundant species, with 84% of all animals observed and nearly 20 times the next most abundant species, coyote. Relatively low numbers of fishers and bobcats were photographed, and no mink or otter were photographed. During winter tracking, there were tracks of smaller animals within range of the cameras that were not captured in photographs. It may be that animals were either too small, moving too fast to be captured on camera, or moving in a direction relative to the field of view that would not cause a trigger.

Table 2. Numbers of animals of all species photographed at all cameras

Common Name	Total Number*
Primary Focus	
White-Tailed Deer	**5102**
Coyote	**264**
Black Bear	**114**
Moose	**65**
Fisher	**13**
Bobcat	**9**
Secondary Focus	
Fox	*51*
Raccoon	*34*
Non-Focus	
Wild Turkey	207
Waterfowl	83
Songbird	40
Unknown	31
Squirrels	29
American Beaver	5
Raptors	4
Heron	3
Chipmunk	3
Groundhog	2
Virginia Opossum	1
Grand Total	**6080**

* Number of animals indicates the number of different times animals were photographed; the results do not necessarily indicate or correlate with the actual number of animals present in the area. These are the total numbers of animals photographed and are not divided by camera-year.

Camera Results by Station

The graphics below show the trail camera results for all camera stations. Results are shown for individual focus species. Although it cannot be known whether the results reflect the numbers of animals in these areas or repeated observations of a few animals, the results presumably give an indication of the relative abundance of each species across the project area.

In general there appears to be higher numbers of focus species in the eastern half of the study area. Looking at the individual primary focus species, in order of abundance:

- Deer (Figure 6) were the most common species overall and were found at all but a few camera stations. Deer were most abundant at the Near camera stations, especially on the north side of the corridor.
- Coyotes (Figure 7) were also found at most camera stations but had pockets of abundance: on the Joiner Brook transect (where they also crossed I-89 in winter), Farr Landing Far, and Little River Remote (Figure 6). Overall, they were more common at the Near than the Far stations, but were most abundant at the Remote stations, primarily due to the Little River Remote station.
- Black bears (Figure 8) were also found throughout the study area, and were most frequently photographed at Green Mountain Power Near, Richardson Road Remote, and Little River Remote. Overall they were more common at the Near than the Far stations, but were most abundant at the Remote stations.
- Moose (Figure 9) were most common in the eastern half of the study area, which is consistent with roadkill data discussed below. They became more abundant as one moved away from the road edges, displaying the clearest evidence of edge effect of all the focus species.
- Fishers and bobcats (Figures 10 and 11), based on a relatively small number of photographs, were most abundant at the Far and Remote camera stations. Fishers were only photographed at one Near camera, at no culvert or bridge cameras, and at only one camera in the western half of the study area. Bobcats were photographed at two Far cameras, one Remote camera, and the Little River bridge, all on the north side of the corridor.

Figure 6. Number of deer photographed at each camera station (per camera/year)

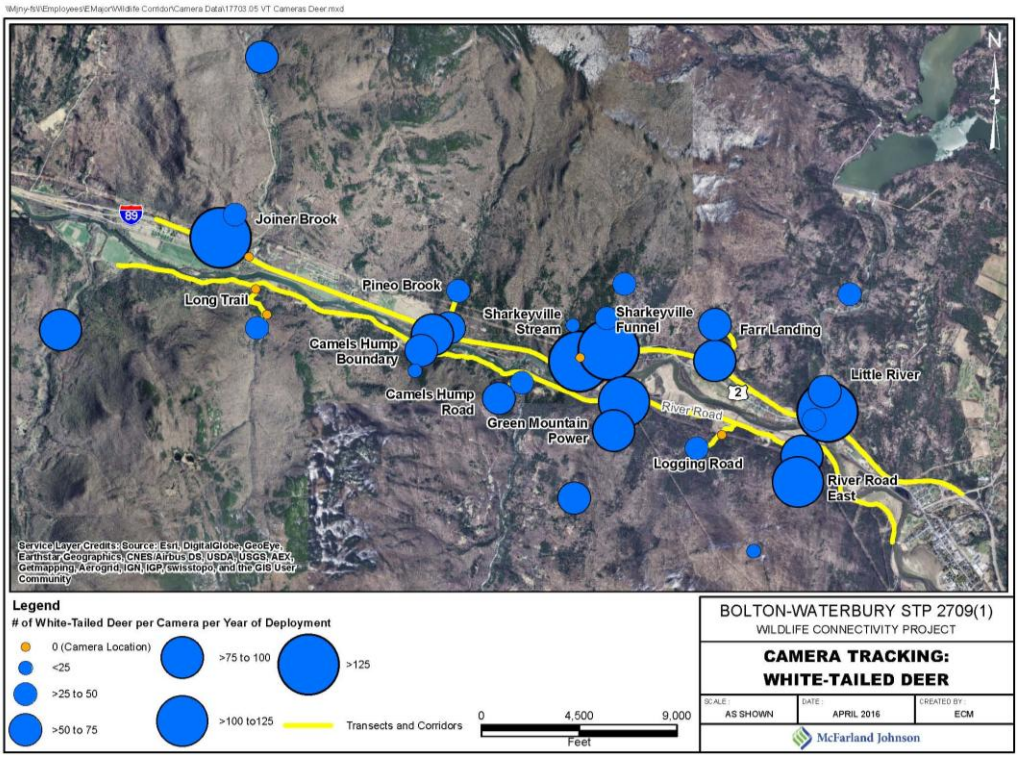


Figure 7. Number of coyotes photographed at each camera station (per camera/year)

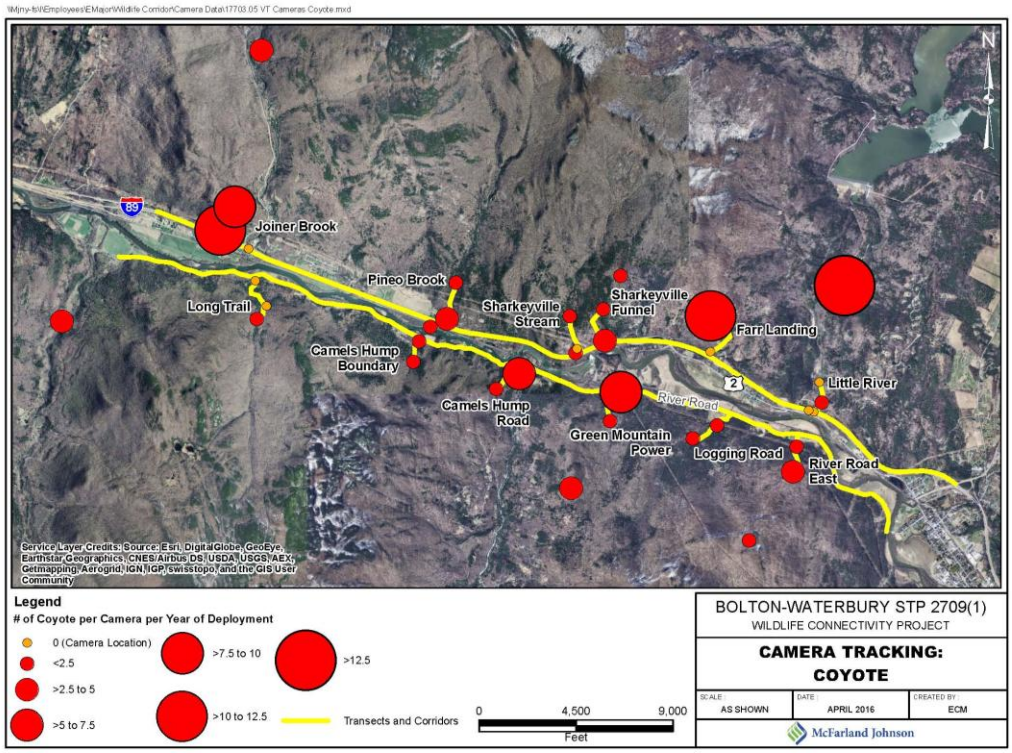


Figure 8. Number of black bears photographed at each camera station (per camera/year)

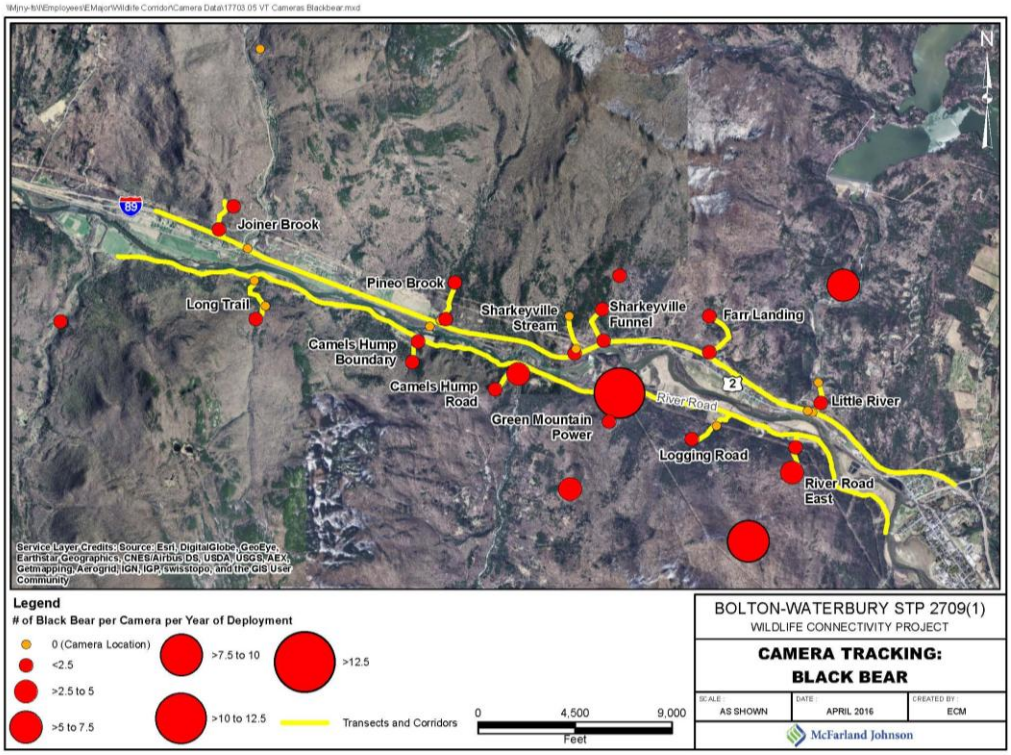


Figure 9. Number of moose photographed at each camera station (per camera/year)

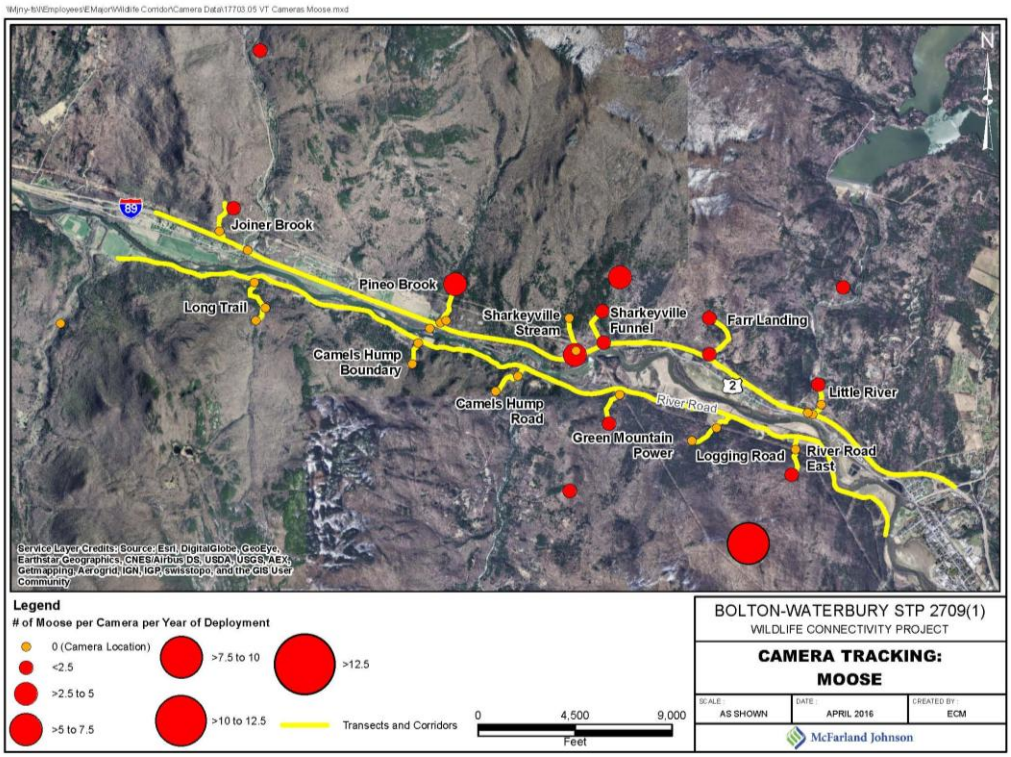


Figure 10. Number of fishers photographed at each camera station (per camera/year)

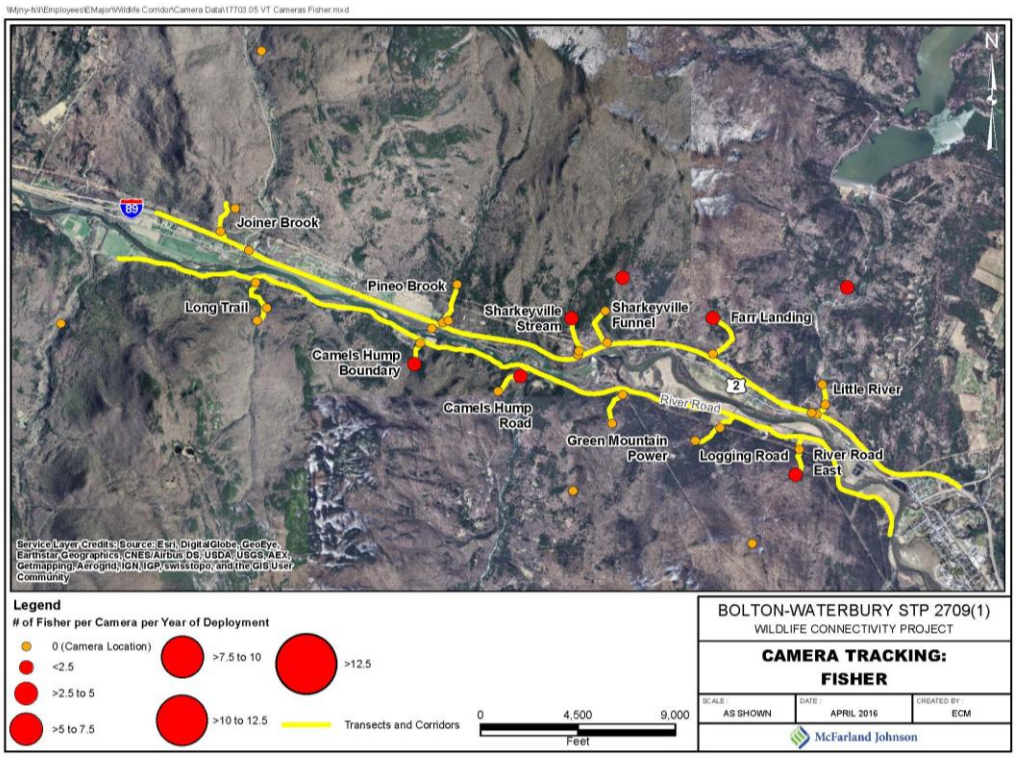


Figure 11. Number of bobcats photographed at each camera station (per camera/year)

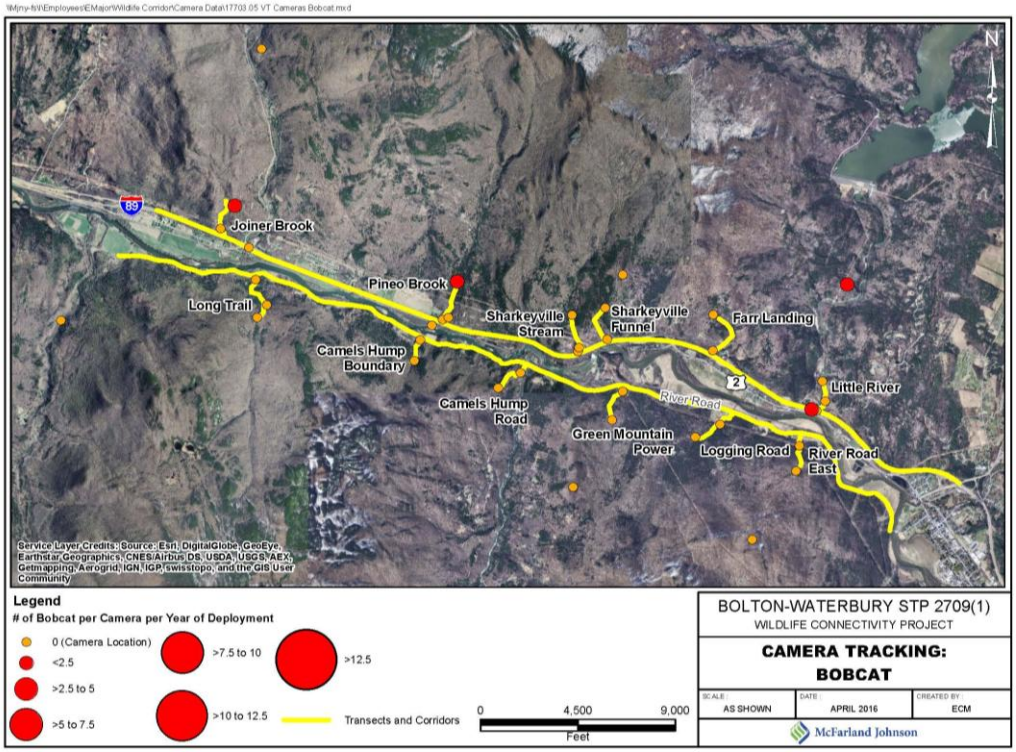


Figure 12. Number of foxes photographed at each camera station (per camera/year)

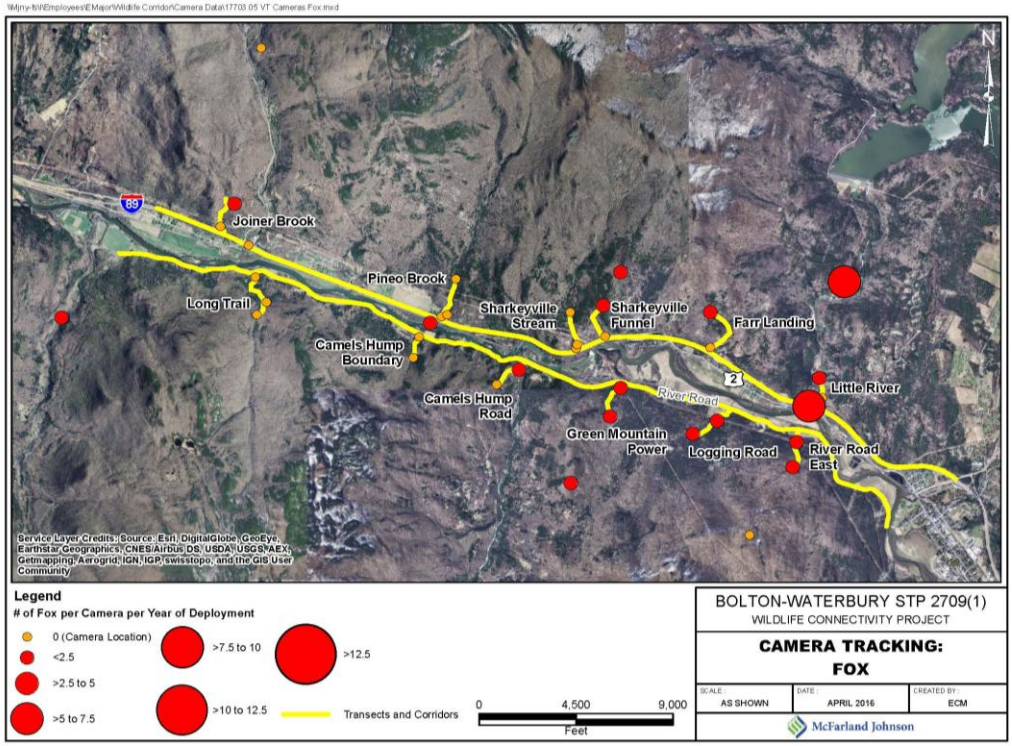
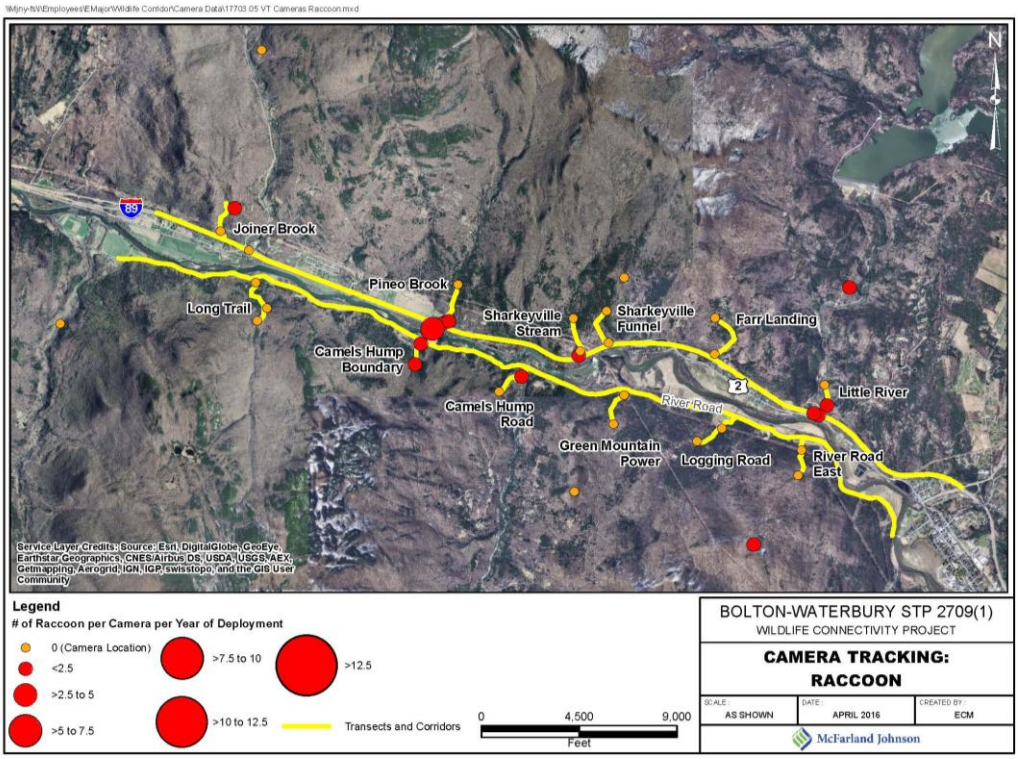


Figure 13. Number of raccoons photographed at each camera station (per camera/year)



Camera Results by Corridor Location

Results were tabulated by corridor location, which was divided into four locations with respect to the road corridor:

- Bridges and culverts, where cameras were placed under bridges or at culvert inlets;
- Near camera stations, which were placed near the forest edge along the closest major road;
- Far camera stations, which were located roughly 1,200 to 2,000 feet from the closest major road; and
- Remote camera stations, which were located 0.6 to 1.7 miles from the closest study road segment (but closer in some cases to smaller local roads).

The results are reported in terms of numbers of animals photographed per camera per year. Because of the high numbers of deer, results are reported both with and without the deer numbers included. Refer to Figures 14 through 25 below.

In all of the figures, one can see the relatively low numbers of animals photographed at the culverts and bridges. Most of the animals in this category were photographed under the Little River bridges. There was little use of the other structures with cameras: none at all photographed at the Joiner Brook bridge or Sharkeyville Stream culvert, and 13 deer and one raccoon at the Pineo Brook culvert. Based on winter tracking results discussed further below, some smaller animals, such as mink, were missed by these cameras. Winter tracking also showed there was a small amount of movement under the two bridges over US Route 2, where no cameras were placed.

The numbers of all species, of primary and secondary species combined, and of primary species only, all paint a similar picture. When deer are included in the analysis, the Near cameras have the highest numbers, and the Far and Remote cameras have comparable numbers. However, when deer are excluded, the Near and Far cameras have similar numbers, and the Remote cameras have higher numbers of photographed animals.

The distributions of individual focus species reflect the distributions at camera stations shown in Figures 6 to 13 above: few animals photographed at most culvert and bridge cameras, a high abundance of deer at the Near cameras, and for other animals, a general trend of higher abundance at Remote cameras.

Figure 14. Number of animals/camera/year - all species

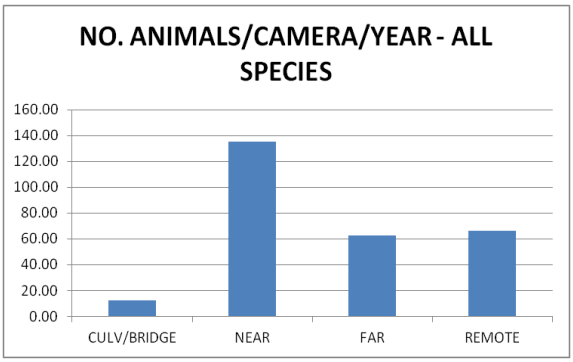


Figure 15. Number of animals/ camera/year - all species excl. deer

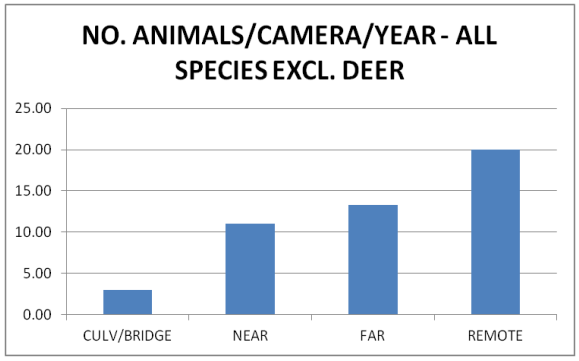


Figure 16. Number of animals/ camera/year – primary and secondary species

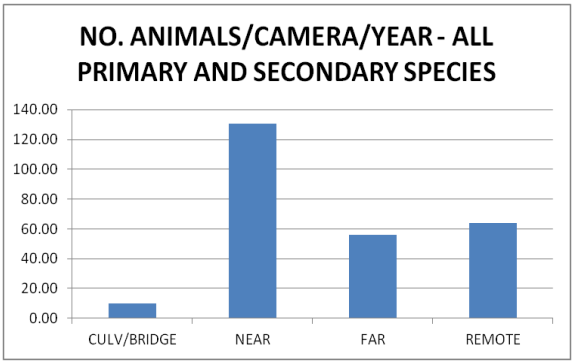


Figure 17. Number of animals/ camera/year – primary and secondary species excl. deer

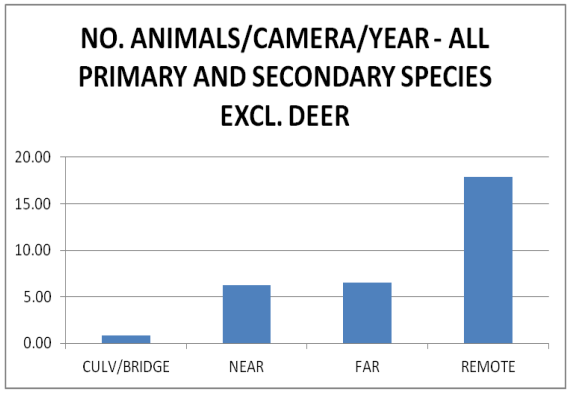


Figure 18. Number of animals/ camera/year - primary species

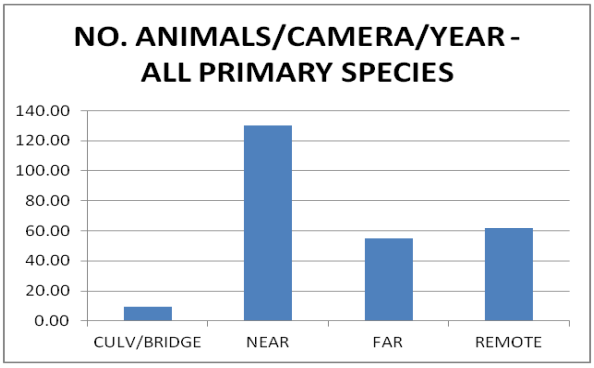


Figure 19. Number of animals/ camera/year - primary species excl. deer

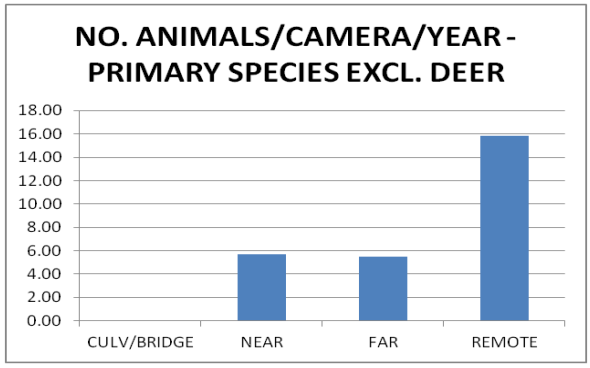


Figure 20. Number of animals/camera/year - deer

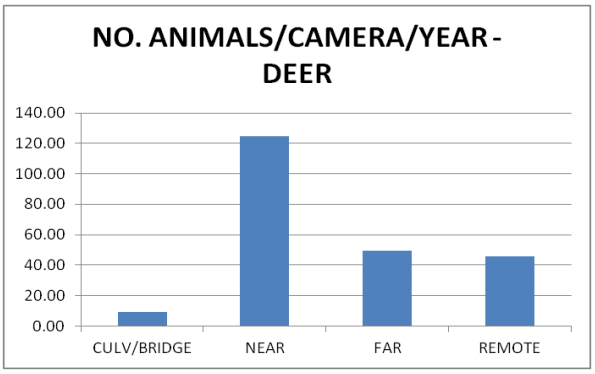


Figure 21. Number of animals/camera/year - coyote

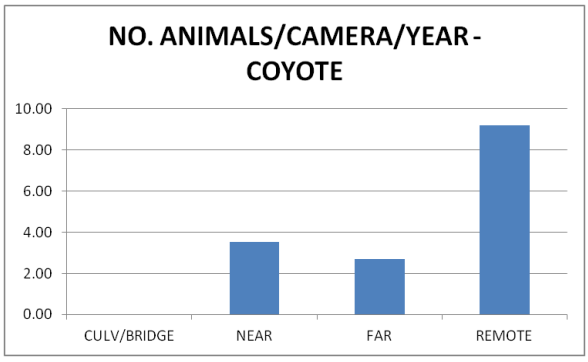


Figure 22. Number of animals/camera/year – black bear

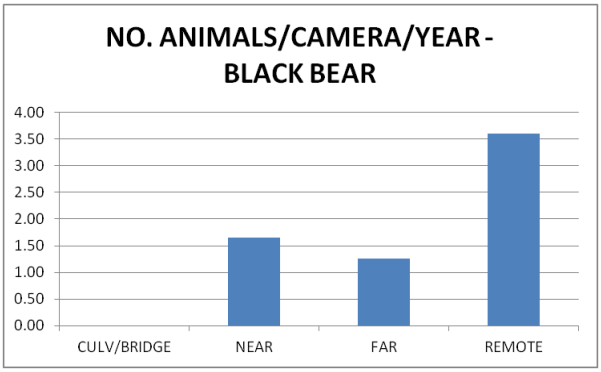


Figure 23. Number of animals/camera/year - moose

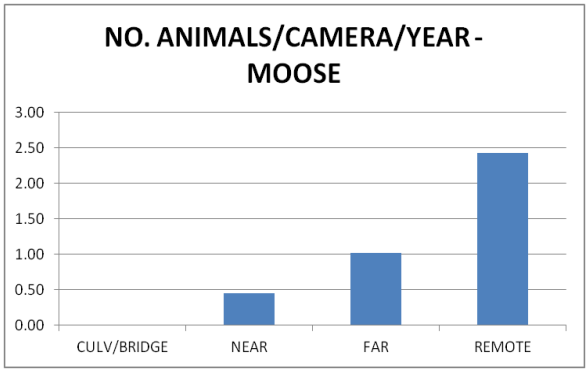


Figure 24. Number of animals/camera/year - fisher

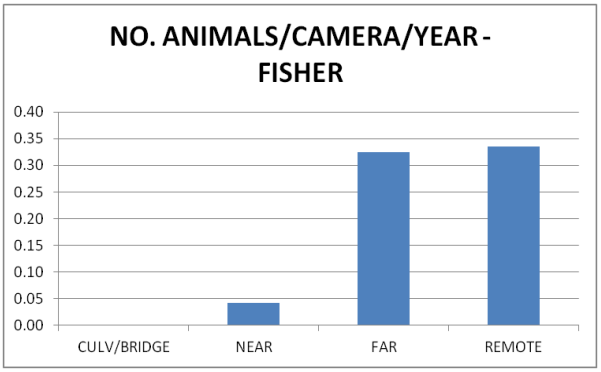
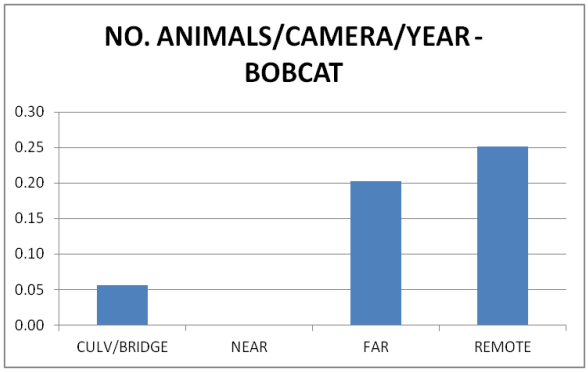


Figure 25. Number of animals/camera/year - bobcat



WINTER TRACKING RESULTS

Introduction

For both transect and road tracking, data are expressed as the number of track sets per 400 feet per 90 days. Table 3 below summarizes the numbers of tracking rounds, antecedent track nights, and lengths of transects. Appendix C provides detail on the lengths of each transect and segment and the conversion factors used.

- A "track" is a series of footprints in the snow produced by one animal that creates a curvilinear track through the snow.
- "Number of tracks" means the number of individual tracks which intersected the transect line or entered the road. For transects, each time a track crossed the transect line, a track was counted. For road tracking, each time the animal entered the pavement was counted, and it was determined whether the animal crossed to the other side.
- "Antecedent track nights" is the numbers of nights of good track-producing snow prior to each survey. These were estimated based on weather reports and observation of snow conditions while tracking. The track numbers were divided by the number of antecedent track nights, then multiplied by 90 to express results in tracks per 90 days or one winter season.
- All tracks were assigned to distance categories based on their straight-line distance from the road where the transect originated (I-89, US Route 2, or River Road). (A few more lightly traveled roads, including Pineo Brook Road, Sharkeyville Road, Farr's Landing Road, and Little River Road, were closer to some transects than the busier roads but were not believed to have as strong of an edge effect.) The distance categories were each 400 feet long, beginning at the edge of the road shoulder. There were five distance categories (0 to 400 feet, 401 to 800 feet, etc.). Because transects were not perpendicular to the road, the length of each transect within the distance categories varied. In order to express results in terms of 400 feet of transect, the lengths of each transect within each distance category were measured (using GIS). The track numbers were divided by this figure to convert the tracking data to a per 400 feet basis. Since most transects did not extend 2,000 feet from the road edge, the furthest distance category (1601-2000 feet from road) had only half as much transect length as the other categories. The results for this segment were heavily skewed by two locations with high numbers of deer, so results

from the 1601-2000 feet category were not included in the analysis. The tracking effort, antecedent track nights, and conversion factors are listed in Table 3.

- As an example, the Camels Hump Boundary transect was tracked four times. There were 3 consecutive nights of good track-producing snow before the first visit, and 2 nights on each of the other 3 visits, for a total of 9 antecedent track nights. The data were divided by 9 to obtain a per-night basis, then multiplied by 90 to convert to a 90-day basis (one winter season). In the first segment of the transect, there was 408 feet of transect, or 1.02 times a 400-foot segment, within 400 feet of the road. The total number of tracks within this segment was therefore divided by 1.02 to express the results per 400 feet. Refer to Appendix C for the lengths of each transect and segment and conversion factors used.

- For road tracking, the location of each set of tracks was determined using a GPS unit. To make data collection more manageable, during the 2015 River Road tracking, tracks were counted in 50-foot lengths of transect lines, with the location entered as the midpoint of the 50-foot line. Using GIS, the roads were then divided into 400-foot segments and the number of tracks within each segment was tabulated to obtain tracks per 400-foot segment.

- Mice and domestic animals were not counted on all tracking efforts and are excluded from the analysis.

Table 3. Comparison of road and transect tracking effort

	I-89	**River Rd**	**Transects**
Number of Rounds of Tracking	5	4	4
Total Number of Antecedent Track Nights*	13	9	9 or 10 (varied by transect)
To Convert Results to a 90-Day Basis, Multiply by:	90/13	90/9	90/9 , 90/10
Length of Road or Transects (Miles)	7.3	7.7	4.09
Number Of 400-Foot Segments	97	102	47

* Total number of nights with good track conditions prior to survey days

Transect Tracking Results: Distance from Road

The following figures show the numbers of tracks found within each of the four distance-from-road categories. Overall, the least number of species was found within the segment closest to the road edge, and the greatest numbers were found in the next segment. Deer were most abundant at the furthest segment (1201-1600), while coyote and fisher were most abundant within the second segment (401-800). There were also large numbers of deer further out, in two of the 1601-2000 foot segments, which were not included in the analysis. It is not clear how these spatial patterns relate to the roads. It is possible the road is a repellant while the forest edge is an attractant.

Figure 26. Number of track sets/400 feet/90 days - all species

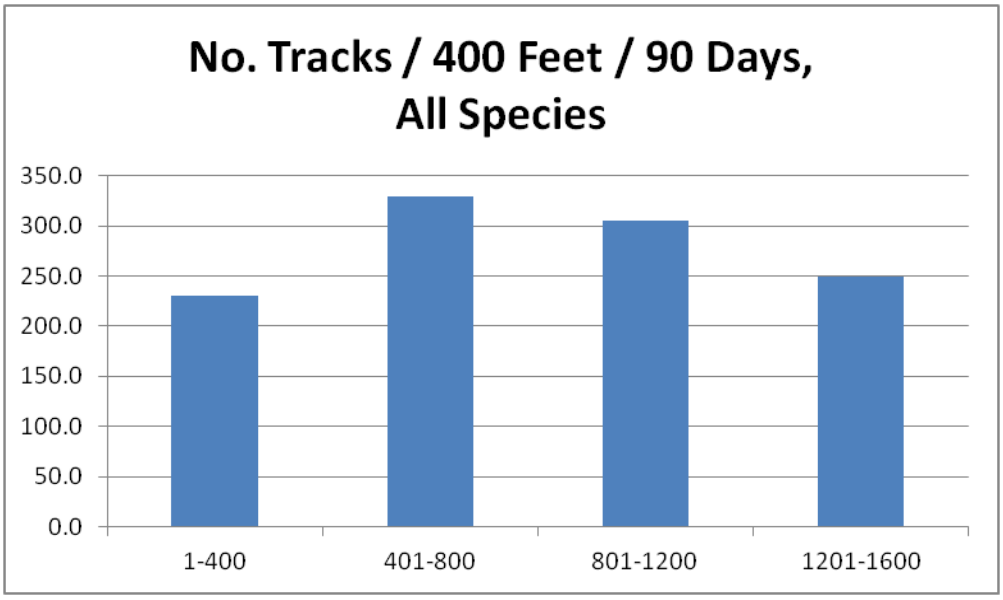


Figure 27. Number of track sets/400 feet/90 days – primary and secondary species

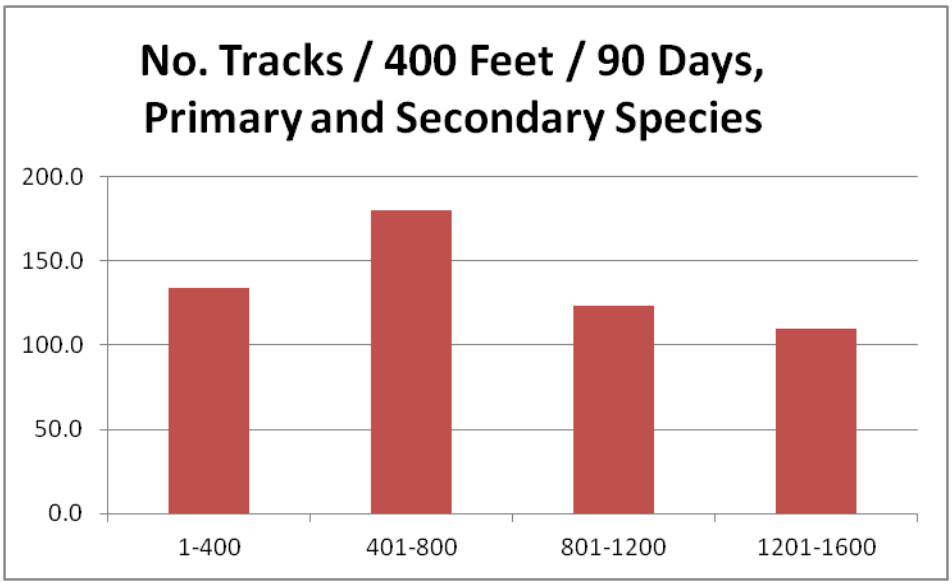


Figure 28. Number of track sets/400 feet/90 days - primary species

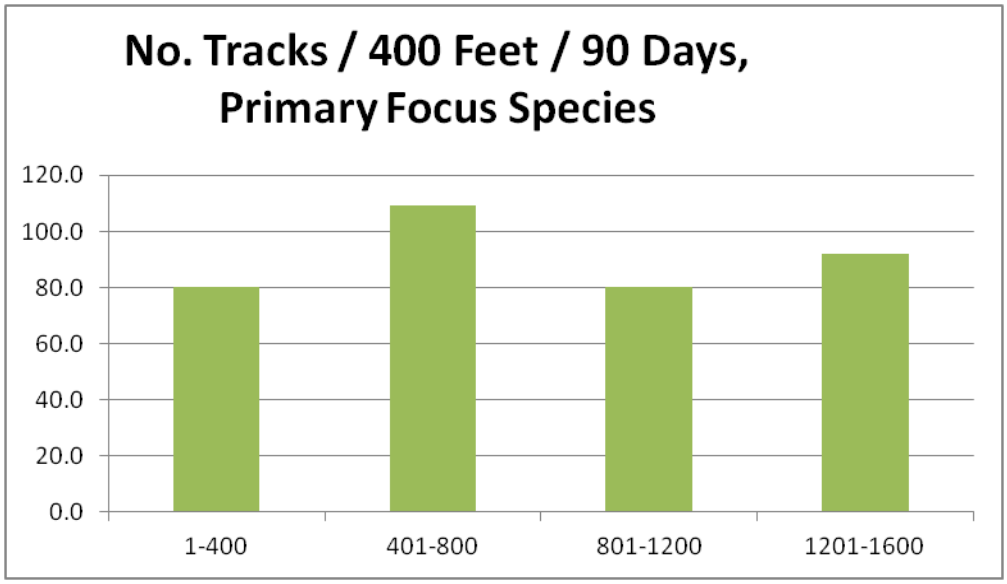


Figure 29. Number of track sets/400 feet/90 days – primary species excl. deer

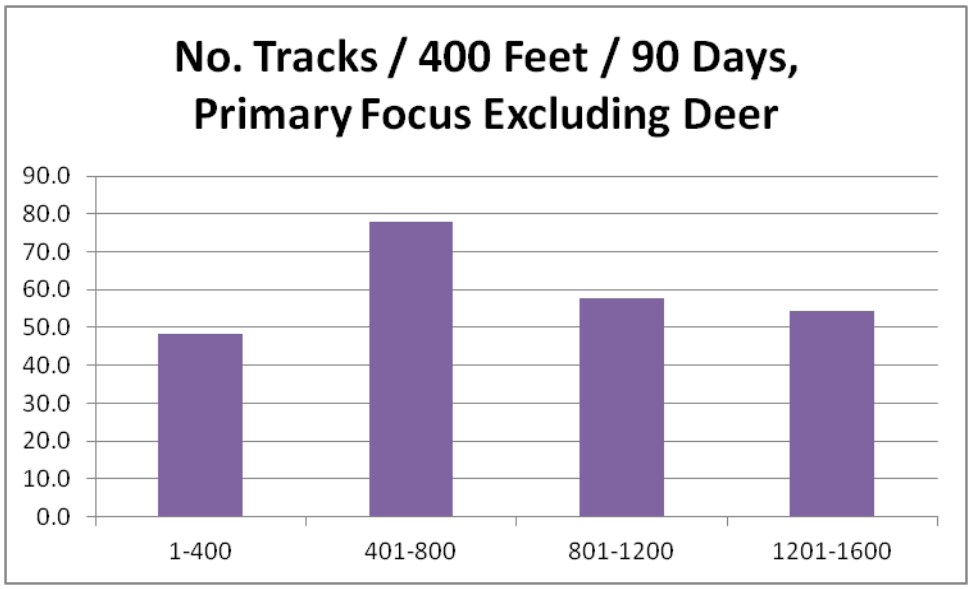


Figure 30. Number of track sets/400 feet/90 days - deer

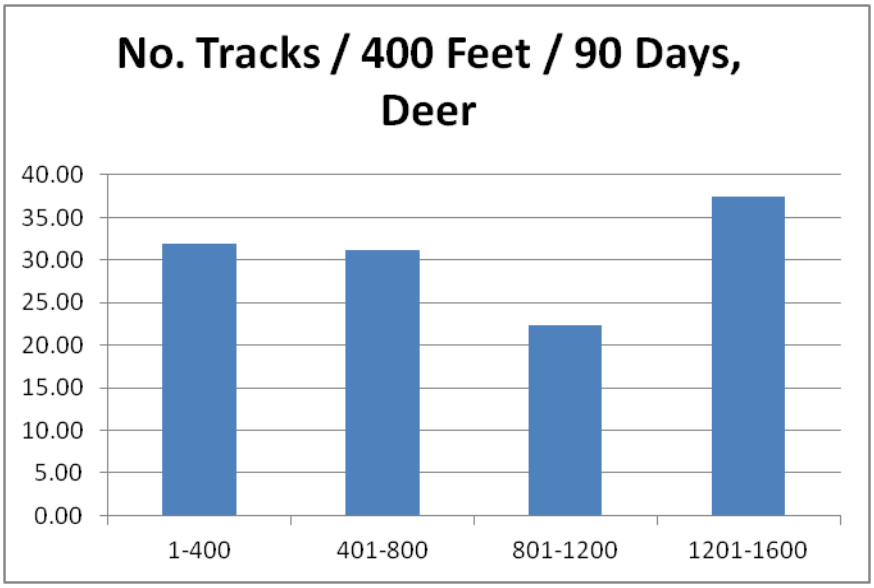


Figure 31. Number of track sets/400 feet/90 days - coyote

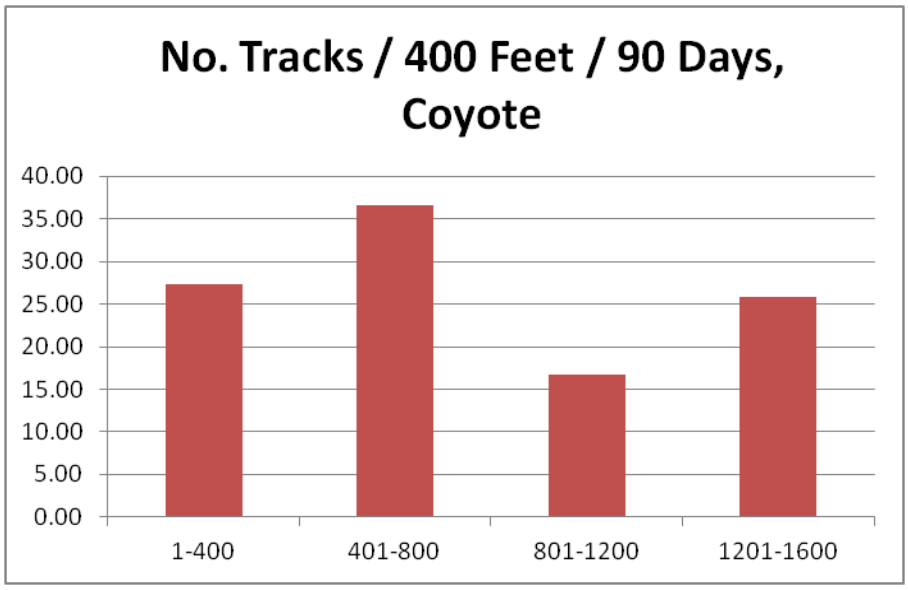
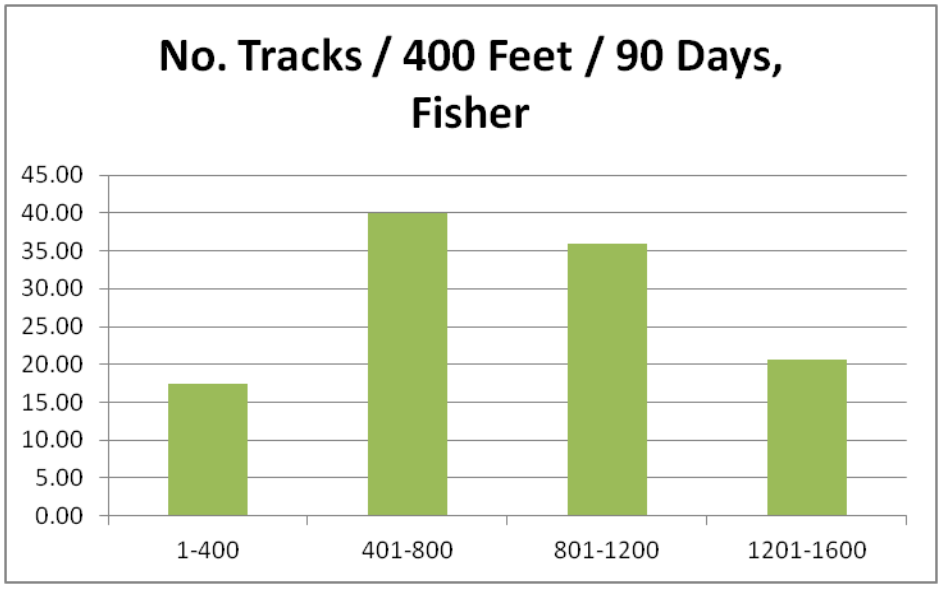


Figure 32. Number of track sets/400 feet/90 days - fisher



Road Tracking Results: Overall

During I-89 tracking efforts, bridges and culverts were checked for tracks, and an effort was made to determine whether animals fully crossed the road, either over the surface or via structures. Eight dead animals, presumably killed in vehicle collisions, were found, but were not included in the results.

A total of 285 animals crossed the road at least part way, 203 or 71% over the road surface, 53 or 19% via culverts, and 29 or 10% via bridges (Table 4). There were 211 animals crossing both barrels of I-89 (and some US Route 2 also), 130 over the road surface, 29 under bridges, and 52 via culverts. There were 74 that crossed part way, 73 over the surface and 1 in a culvert. Most of the bridge crossings were at the Little River bridge, with a few tracks observed under the US Route 2 bridges. Animal species and crossing locations are shown on Figure 13.

On River Road, culverts were very small, and all observed tracks were from animals crossing over the road surface. Only animals that fully crossed the road were counted.

Table 4. I-89 winter tracking summary

Track Location	Total Number of Track Sets	Percent of Total
Total tracks on or under I-89	285	100%
Road surface	203	71
Crossed both barrels	*130*	
Crossed part Way	*73*	
Culvert	53	19
Crossed both barrels	*52*	
Crossed part Way	*1*	
Bridges	29	10

Road and Transect Tracking Results: Track Density

Comparison of Roads and Transects

The numbers of tracks varied among transects and roads, as well as among transect and road segments. To allow comparison among the roads, transects, and segments, the data were converted to the same standardized units used for transect tracking analysis: tracks per 400 feet per 90 days. For purposes of analysis, the roads were divided into continuous 400-foot segments. For the transects, the same 400-foot distance-from-road categories were used as described above.

The results were calculated in the following way, using I-89 track numbers as an example. The track numbers of animals that crossed both barrels of I-89 were pooled (211 tracks), including animals crossing over the road surface to the opposite side, passing under bridges, or passing through culverts. The track numbers were divided by the number of antecedent track nights (13) to obtain per-night numbers (16.2), multiplied by 90 to convert the data to a per-90-day basis (1,461, and divided by the number of 400-foot road segments (97) to convert to a per-400-foot basis (15.1 tracks per 400 feet per 90 days). The same calculation was carried out for all primary focus species, primary plus secondary species, and the five most common focus species. All full crossings, whether over the road surface or through structures, were included. Animal crossings under bridges and through culverts are described and illustrated in more detail in the next section of the report.

The transects are included in this analysis to provide a basis for comparing wildlife road crossing density with wildlife movements in typical forested settings. In comparing the two roads and transect results, it is important to acknowledge the differences between them. The broader I-89 / Winooski River / River Road corridor has a number of different land uses and possible impediments to wildlife movement, including a railroad line, farm fields, and developed land. I-89 has two barrels, each with two lanes in each direction, a median between, Jersey barriers in places, and right of way fencing. I-89 is also immediately adjacent to US Route 2, a railroad line, and the Winooski River in portions of the study area. River Road is a two-lane road with forest and occasional farm fields and human dwellings along its edge. In most places the tree canopy overhangs the road on both sides. The culverts are believed to be small and impermeable to most wildlife.

The transects follow a single line through predominately forested habitat. In some places they follow woods roads which are much less travelled than the paved roads and have closed canopies and unpaved surfaces. The transects do not necessarily represent undisturbed forested habitat, as they begin near road edges and human development, and often follow human trails or woods roads.

The overall track densities of I-89, River Road, and the transects are listed in Table 5 below. For all species combined, primary, secondary, and the most common focus species, the transects have substantially higher numbers of animal tracks than either I-89 or River Road. For all of these categories except coyotes and mink, River Road had higher numbers than I-89. Coyotes were relatively common on both roads, and foxes were common on River Road. The other species crossed both roads in relatively low numbers. In addition to those listed, smaller numbers of hare, cottontail, otter, raccoon, skunk, and weasel also crossed one or both roads and transects. Moose (3 sets of tracks) and bobcats (6 tracks) crossed transect lines but none of their track sets crossed roads.

Table 5. Comparison of transect and road tracking results, per 400 feet per 90 days

	Crossed Transect Line	Crossed River Road	Crossed I-89 (Both Barrels)
All Animals	278.7	118.2	15.1
Primary + Secondary	139.2	29.2	12.7
Primary Focus	95.0	13.8	7.5
Most Common Focus:			
Coyote	26.4	5.9	3.6
Fox	25.9	13.0	3.4
Deer	36.6	2.8	1.4
Mink	2.3	1.3	1.6
Fisher	27.9	3.8	0.7

The transect lines are believed to be fully permeable to wildlife, i.e., there are no known obstacles that impede their movement across the transect lines. Roadway traffic or roadside habitat may affect wildlife occurrence or movement as one approaches roads (either as an attractor or repellent), but compared to road crossing, transect crossing is relatively risk-free and permeability should still be relatively unimpeded. If the permeability of transects for wildlife movement is considered to be 100%, the amount of movement across River Road and I-89 can be expressed as a percentage of the movement across the transects, indicating the permeability of the roads relative to the transects (Table 6). Looked at this way, River Road and I-89 were 42% and 5% as permeable to all animals as transect lines, respectively. Considering only primary focus species, the relative permeability is 15% and 8%.

Table 6. Comparison of transect and road permeability, assuming transect line represents 100% permeability

	Crossed Transect Line	Crossed River Road	Crossed I-89 (Both Barrels)
All Animals	100%	42%	5%
Primary + Secondary	100%	21%	9%
Primary Focus	100%	15%	8%
Most Common Focus:			
Coyote	100%	22%	14%
Fox	100%	50%	13%
Deer	100%	8%	4%
Mink	100%	57%	70%
Fisher	100%	14%	3%

The density of tracks within each 400-foot road and transect segment is displayed graphically in Figures 33 through 40. Note that the unit ranges in Figure 33 (listed in the legend) are different from the ranges used in the other figures.

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Figure 33. Track densities along I-89 and River Road segments - all species

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

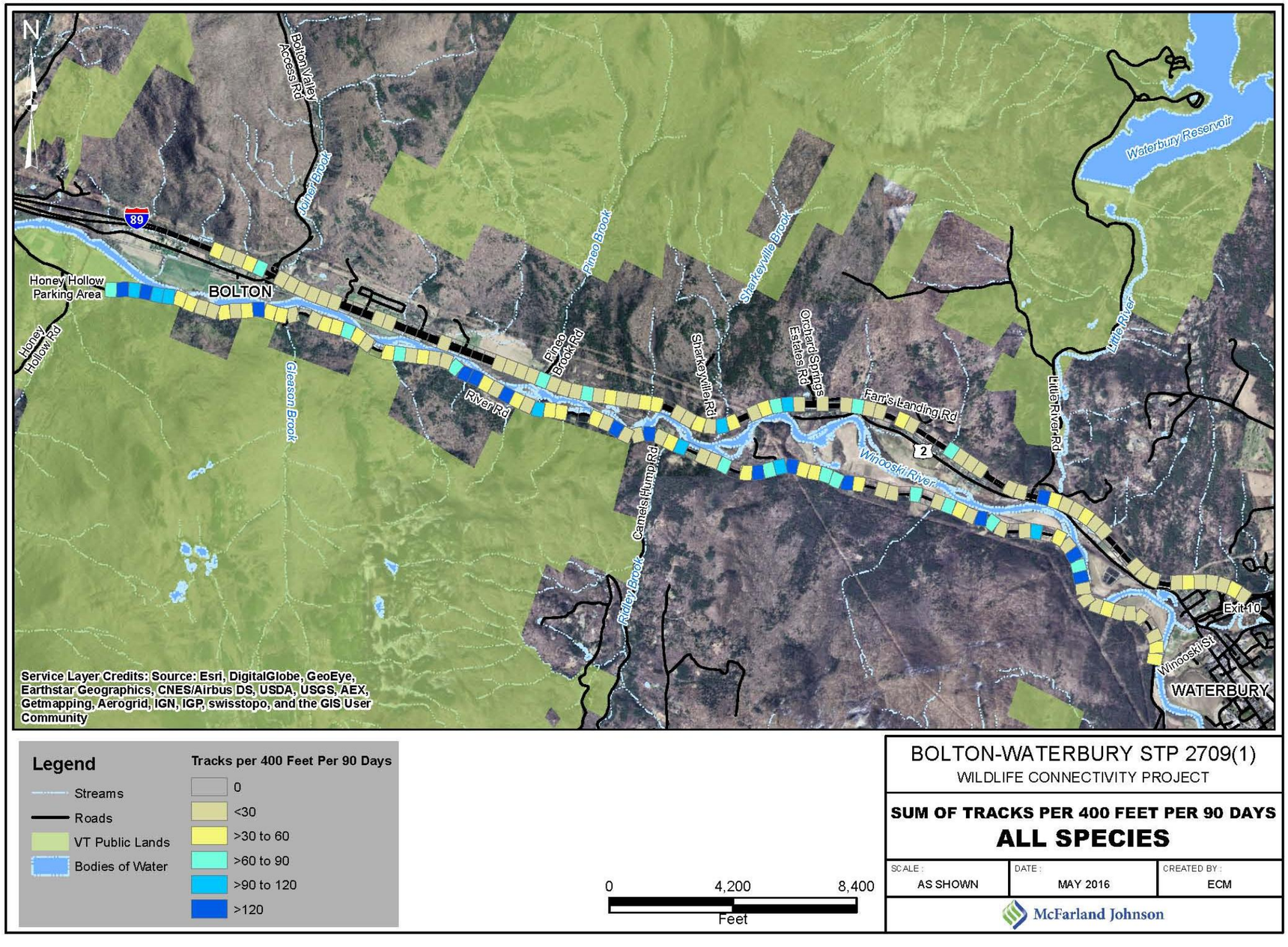


Figure 34. Track densities along I-89 and River Road segments – primary and secondary focus species

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

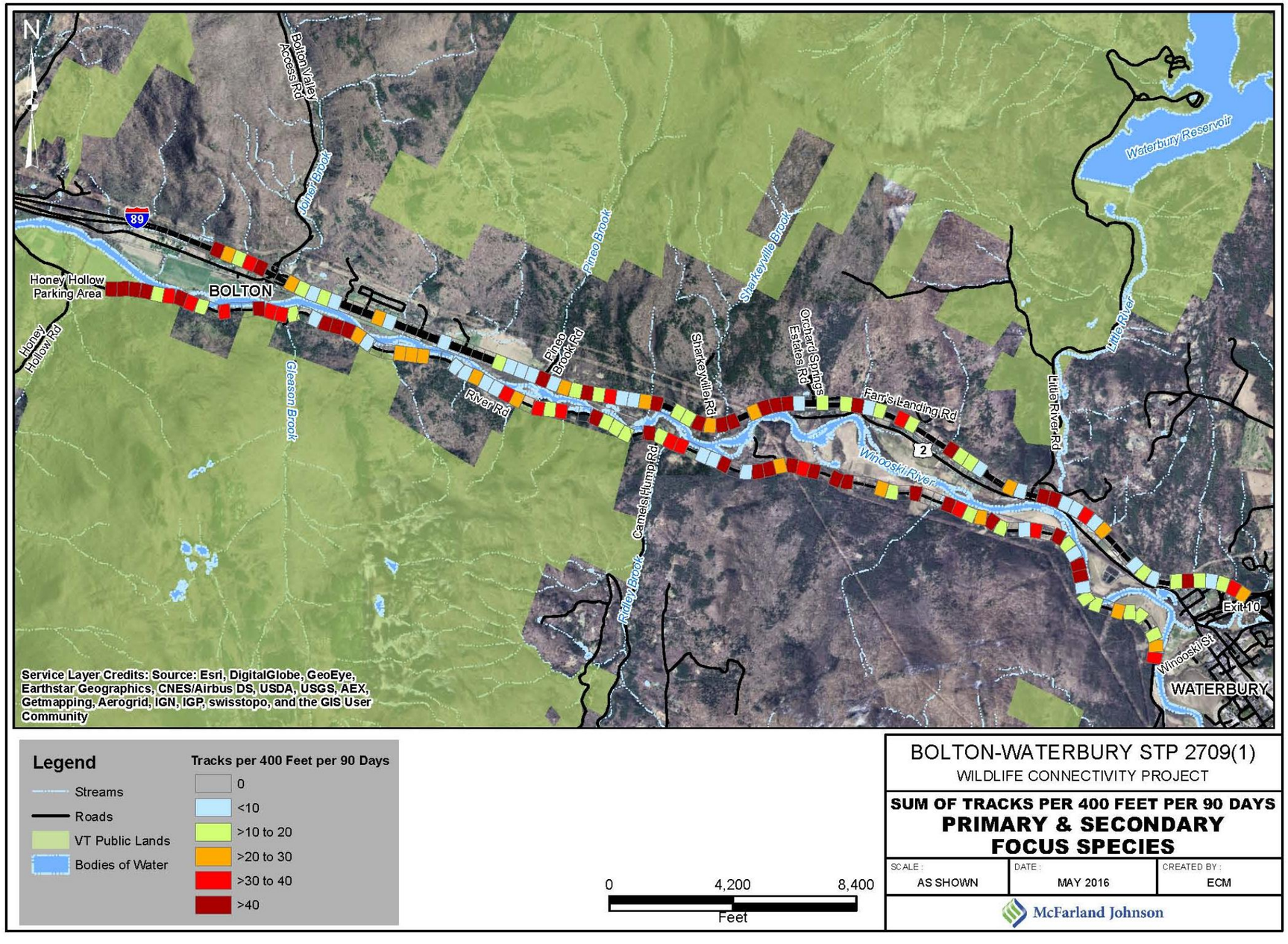


Figure 35. Track densities along I-89 and River Road segments – primary focus species

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

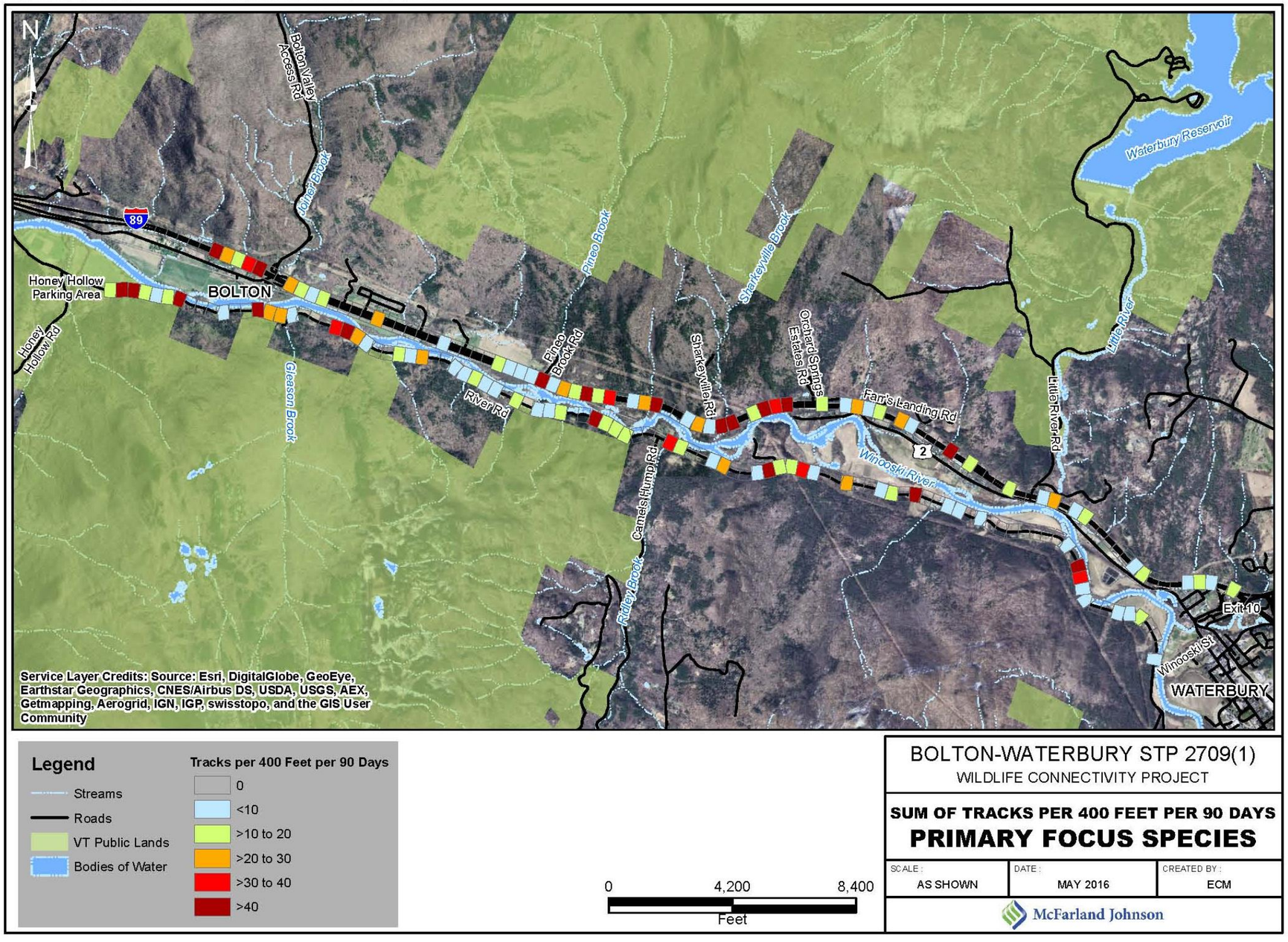


Figure 36. Track densities along I-89 and River Road segments – deer

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

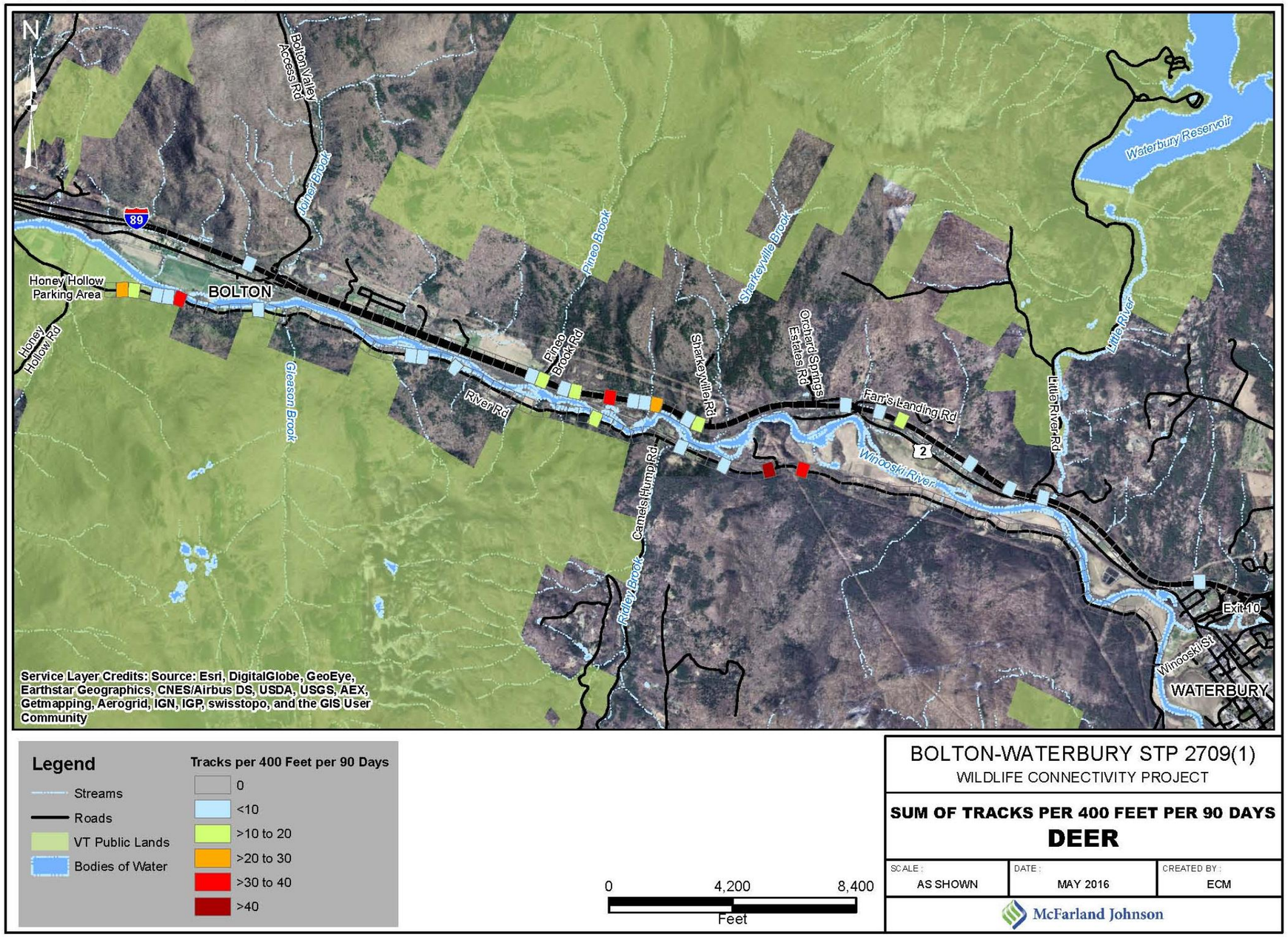


Figure 37. Track densities along I-89 and River Road segments – coyote

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

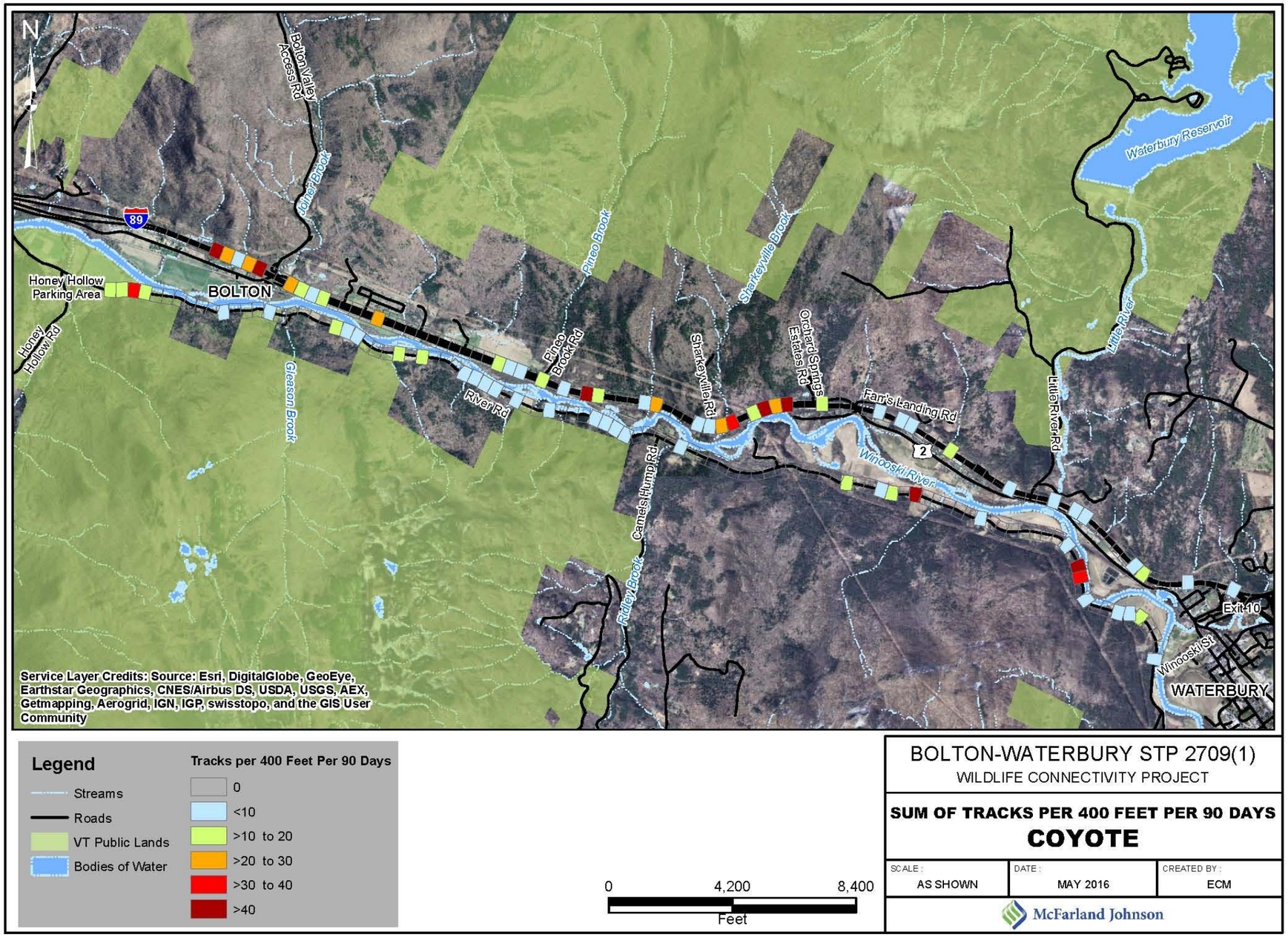


Figure 38. Track densities along I-89 and River Road segments – fox

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

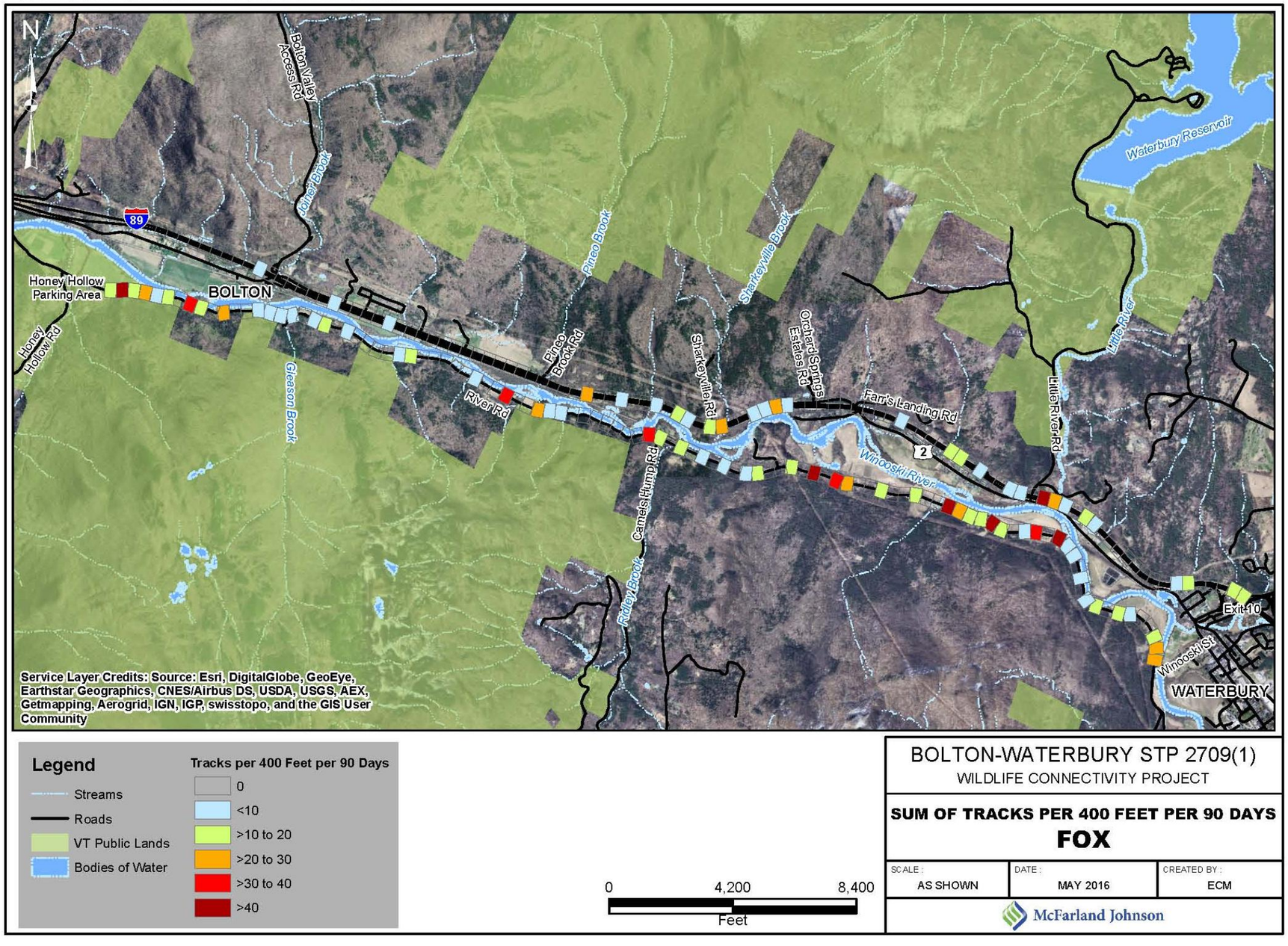


Figure 39. Track densities along I-89 and River Road segments – fisher

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges

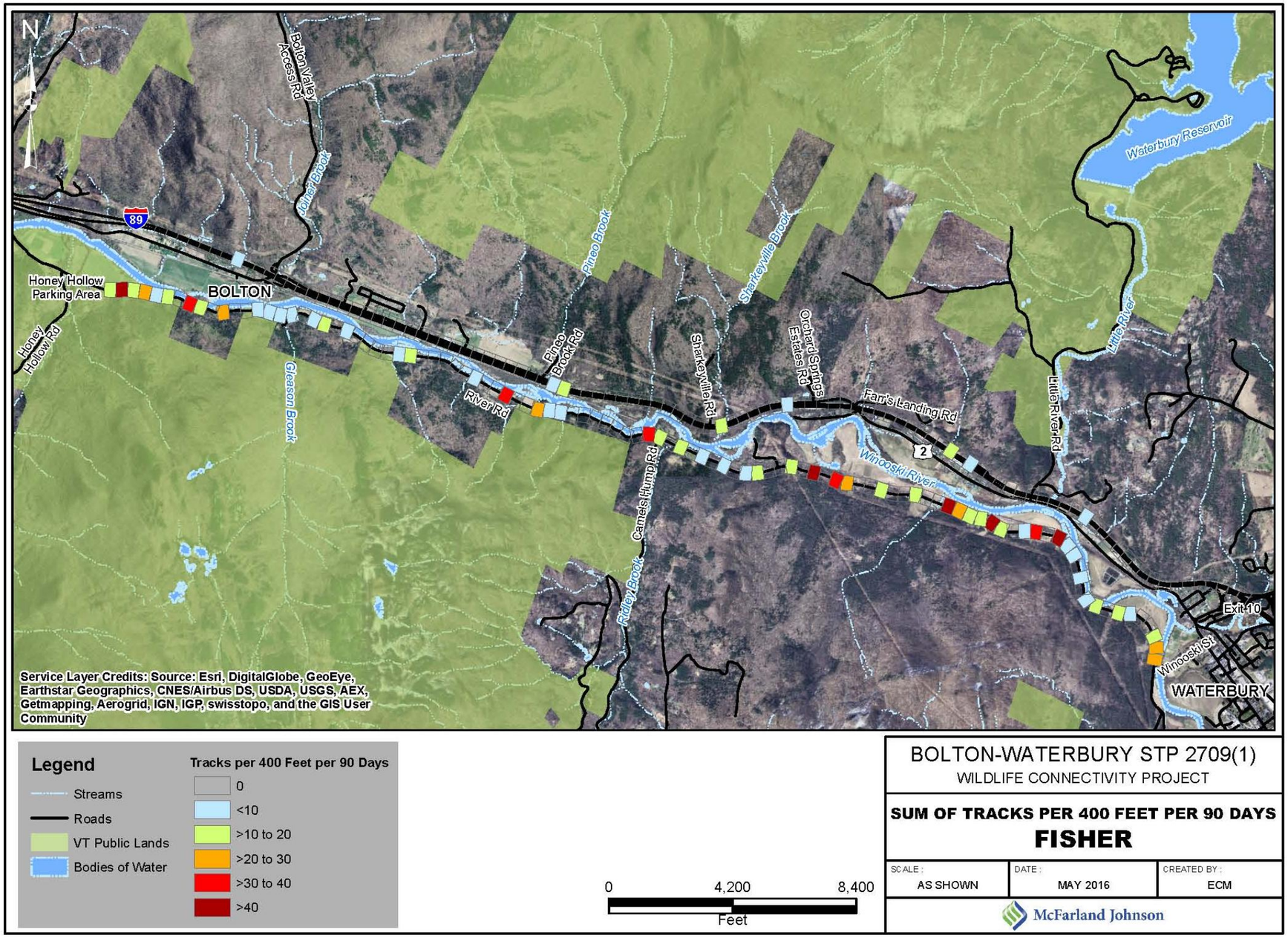
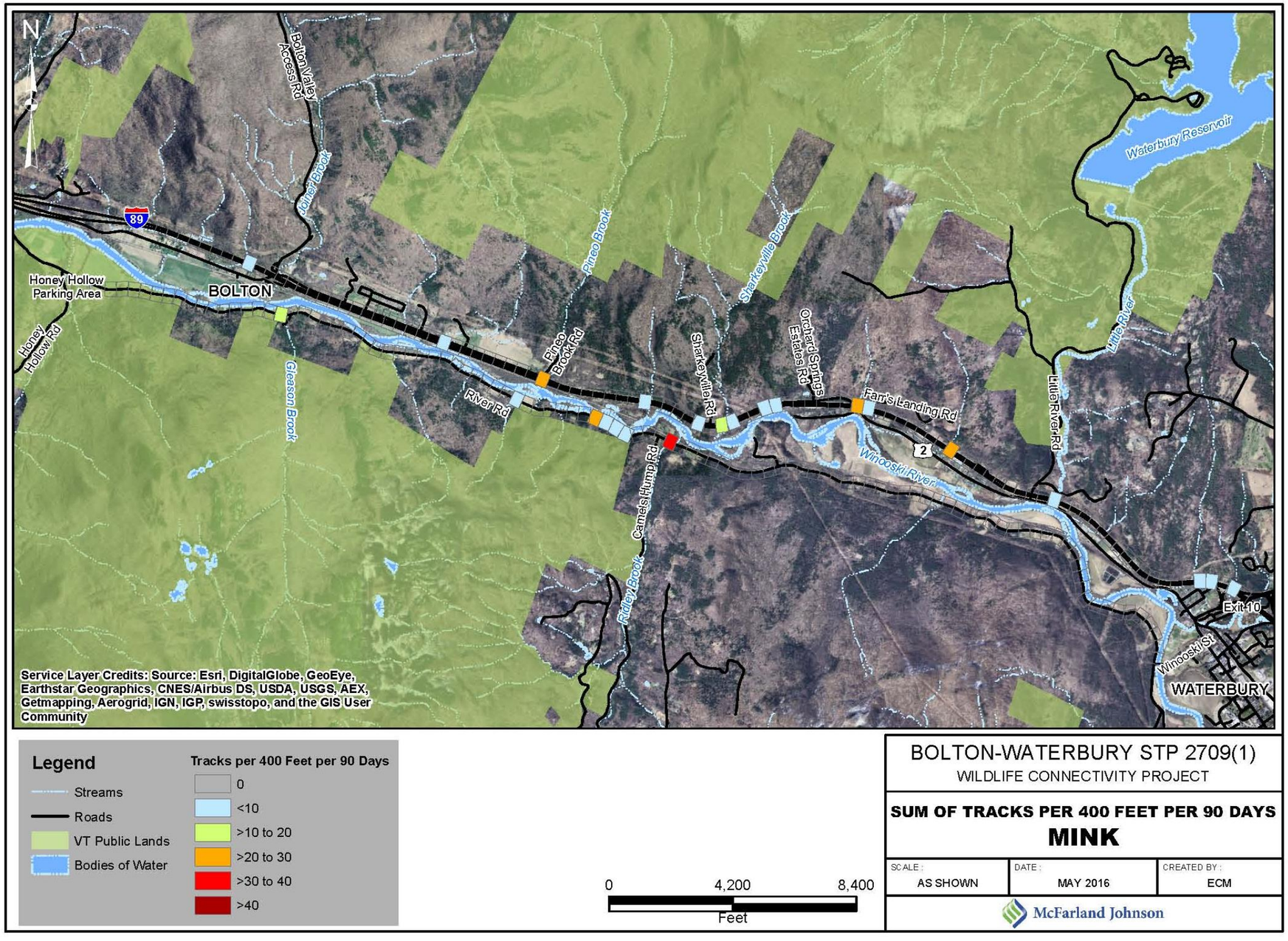


Figure 40. Track densities along I-89 and River Road segments – mink

Note: Track densities include partial road crossings, full road crossings, and crossings through culverts and bridges



Track Density Along I-89 Segments

These track density maps show substantial variation in the concentration of tracks along the corridor. Below is a detailed description of the tracking results along the entire length of the I-89 study corridor. Bridge and culvert usage is noted here but discussed in more detail in the report section following this one.

The west end of the corridor, west of Joiner Brook and Bolton Valley Road, was an area of high coyote activity. There were also single records of fox, deer, mink, and fisher, and a few unidentifiable tracks. All of these crossings were over the road surface. This area includes a ridge line north of I-89 and residential and farm fields along the south side. The north side of the highway has standard ROW fencing and the south side has chain link fencing.

Only 3 squirrel tracks and one unidentifiable track were found under the I-89 bridge over US Route 2 and Joiner Brook in Bolton Village, even though there appears to be ample room for wildlife movement (Photo 1). There are, however, a river, adjoining road, school, homes, and other potential barriers in this area.

Photo 1. I-89 bridge over US 2 and Joiner Brook in Bolton Village

(Bolton Valley Road is on the right – Google Maps image)

There were only a few tracks on I-89 between Bolton Valley Road (Joiner Brook) and Pineo Brook Road. There was no culvert usage in this segment. This entire segment has a chain link fence

between I-89 and US Route 2, as shown in Photos 2 and 3 below. Portions of the fence have fallen down or become overgrown with vegetation, but the fence is largely intact and may be a barrier to some species. There are anecdotal reports of the fence deterring animals from successfully crossing the roadway corridor.

Photo 2. End of chain link fence and beginning of median Jersey barrier

(Facing west in the vicinity of Pineo Brook Road - Google Street View image)

Photo 3. Condition of chain link fence

(Between I-89 and US 2 between Pineo and Joiner Brooks – Google Maps image

From Pineo Brook Road and continuing east past Sharkeyville Road and the east end of the Jersey barriers roughly to Orchard Springs Estates, there were relatively high numbers of tracks, crossing both over the highway (55 animals) and through culverts (27 animals). The most common animals crossing over the road included coyote, deer, and fox, plus 3 fishers and 1 raccoon. The common animals using culverts included mink and fox, along with 3 raccoons and 2 each of coyote, weasel, and fisher. The effect of the Jersey barrier on animal movement is not known, though it may deter smaller animals from crossing. There is a possible divide at the sharp curve in the road, where there is a rock cut and a segment of chain link fence (see Figure 4 and Photos 4 and 5 below).

Photo 4. Segment with Jersey barrier in median and rock cuts on both sides of I-89

(east of Pineo Brook - Bing Maps image)

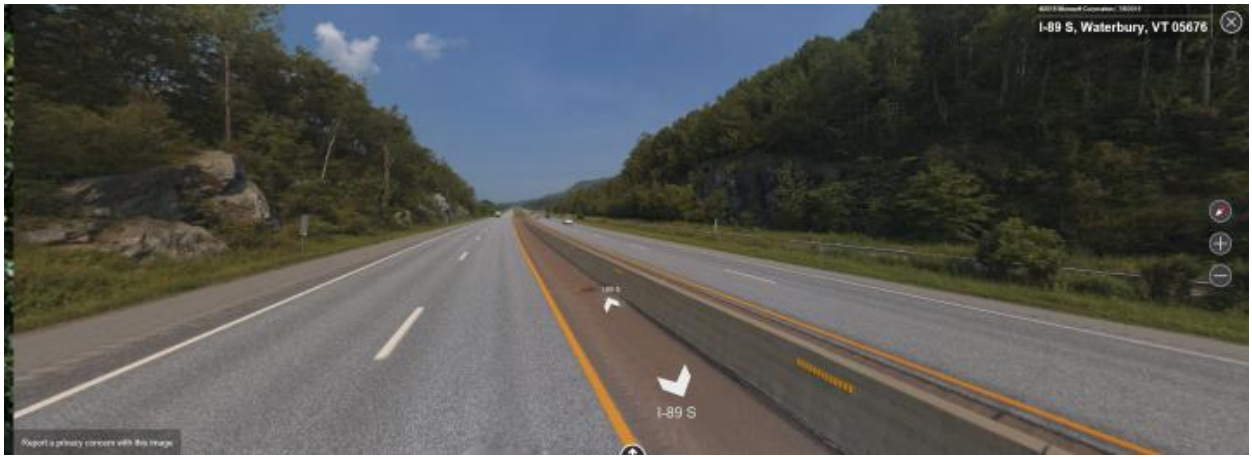


Photo 5. Chain link fence meeting rock cut section

(Between Sharkeyville and Orchard Estates near MM 67.1 – Google Maps image)

East of Orchard Springs Estates, continuing to Little River, was an area of scattered wildlife travel. In this segment, 66 animals crossed over the road surface, 18 via culvert, and 4 under the bridge over US Route 2 by Farr's Landing Road. The road crossings were mostly coyotes and foxes, plus 6 deer, 3 mink, 3 raccoon, 2 fisher, and 1 weasel. The culvert crossings included 7 mink, 2 each of fisher, fox, raccoon, and weasel, with 1 squirrel and several unidentifiable. Passing under the bridge were 2 skunks, 1 raccoon, and 1 squirrel. One segment has a rest area with two parallel chain link fences (Photo 6).

Photo 6. Rest area with parallel chain link fences and smaller rock cut

(West of Little River – Google Maps image)

Many animal tracks were observed under the I-89 bridge over Little River. A total of 22 tracks were seen, including 11 fox, 1 coyote, 1 mink, 1 otter, 1 squirrel, and 7 unidentifiable. An additional 4 unidentifiable tracks were found crossing I-89 over the road surface.

East of the Little River bridge to the Exit 10 ramps (Photo 7), animal tracks were spotty. Of 40 sets of tracks, 32 crossed over the road surface and 8 passed through culverts. Crossing over the road were 7 coyotes and lesser numbers of fox, weasel, hare, mink, deer, fisher, raccoon, and cottontail. Using culverts were 6 foxes and 2 raccoons.

Photo 7. I-89 forested both sides to pavement edge with no obvious barriers

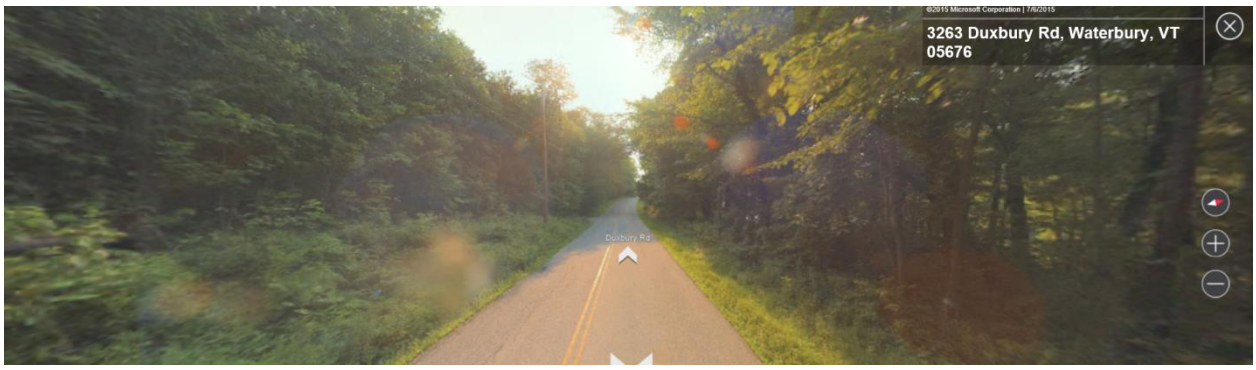
(East of Little River – Google Maps image)

Track Density Along the River Road Study Corridor

River Road had a generally higher density of animal tracks than I-89. There are few obvious patterns along River Road, and most of the road appears to be highly permeable to wildlife movement. The two sections of River Road immediately west of the Camel's Hump Boundary transect and the Logging Road transect both had relatively few animal tracks. These correspond to segments of I-89 with relatively low numbers of tracks. The primary focus species may be more concentrated on River Road near the middle and western sections of the road, which correspond to concentrations on I-89. However, the patterns are not distinct and it is difficult to draw any conclusions regarding links between findings on I-89 and River Road. Comparing the numbers of individual species on I-89 and River Road, there was more coyote traffic on I-89 and more fisher and fox activity on River Road.

Photo 8. Typical segment of River Road (Duxbury Road) in study area

(Western portion of road – Bing Maps image)



Road Tracking Results: Culvert and Bridge Usage

Table 7 lists culverts and bridges under I-89 where tracks indicated usage by animals. The culvert type, size, and the actual numbers of tracks of each species observed are listed. All but one of the animals crossed under both barrels of I-89. Figures 41 through 44 show the culvert locations and species on an aerial photo base. Note that not all culverts were used. For example, the Joiner Brook structure is an approximately 32-foot wide bridge, but no crossings were observed within it – either during tracking or from trail cameras. Key findings included:

- The study corridor includes the following structures under I-89, based on VTrans databases:
    - Two bridges over US 2 and one bridge over Little River and a local road. The US 2 bridge over Joiner Brook is under one of these I-89 bridges.
    - Four large culverts ranging from 6 to 14 feet in width or diameter.
    - 182 small culverts, including 93 18-inch pipes, 55 24-inch pipes, 7 30-inch pipes, 17 36-inch pipes, 8 pipes ranging from 42 to 66 inches, and 2 pipes of unspecified size.
- The total length of all of these structures (longitudinally along I-89) is 1,175 feet: 352 feet of small culverts, 38 feet of large culverts, and 785 feet of bridges. It is not known how much of this length is suitable for animal passage. The total roadway length is approximately 38,808 feet.
- Under the three bridges, a total of 29 sets of tracks were observed over the course of tracking efforts, mostly foxes (11) and other unidentifiable canines (7). The Little River bridge had 22 track sets. The other 7 were at the two bridges over US Route 2.
- A total of 16 culverts were used, including 1 box culvert (Pineo Brook), 8 corrugated metal pipes (CMP), 6 reinforced concrete pipes (CMP), and one unspecified type.
- One box culvert was used 9 times, including 4 mink, 2 coyotes, 2 raccoons and 1 squirrel. This structure (Pineo Brook) is approximately 12 feet wide.
- The 8 corrugated metal pipes (CMP) were crossed 24 times, by fox (12), mink (5), fisher (2), raccoon (2), weasel (1), and 2 unknown animals. Pipe sizes ranged from 18 inches (with 1 fox) to 60 inches. The most frequently used CMP (9 animals) was Culvert 5, a 36-inch CMP located between Sharkeyville Road and the 60-inch Sharkeyville Stream CMP. At this location there is both forested and power line habitat to the north and a wide swath of forested land along the river to the south.
- The 6 reinforced concrete pipes (RCP) had 18 animal track sets: mink (6), weasel (3), fox (3), raccoon (3), fisher (2), and 1 unidentifiable. The most frequently used, with 6 tracks, was Culvert 13, a 42-inch structure along the straight segment of I-89 between Farr's Landing and Little River Road. There is a mixture of forest and old field habitat to the north and residential land and farm fields to the south.
- No deer were found using any of the structures during tracking efforts, although cameras recorded deer at the entrance to the Pineo Brook inlet and passing under the Little River bridge.

Table 7. Numbers of tracks of each species found using structures under I-89 during winter

Note: Only those culverts with wildlife movement are listed; other culverts of similar size or type are present within the corridor.

Structure or Culvert No.	Type	Size (in.)	Coyote	Fisher	Fox	Mink	Otter	Rac-coon	Skunk	Squir-rel	Un-known	Un-known Canine	Wea-sel	Grand Total
US 2/Bolton	BRIDGE	Bridge								3				3
1 (Pineo Brook)	BOX	144+-	2			4		2		1				9
2	CMP	36			3									3
3	RCP	48				1								1
4	RCP	48				1		1					2	4
5	CMP	36		2	4	2					1			9
6 (Sharkeyville)	CMP	60				1								1
7	RCP	24									1			1
8	CMP	36				2					1			3
9	CMP	36											1	1
US 2/middle	BRIDGE	Bridge						1	2	1				4
10	?	?				1				1				2
11/12	RCP	30						2						2
13	RCP	42		2	2	4							1	9
Little River	BRIDGE	Bridge	1		11	1	1			1		7		22
14	RCP	36			1									1
15	CMP	18			1									1
16	CMP	48			2			1						3
17	CMP	42			2			1						3
Grand Total			**3**	**4**	**26**	**17**	**1**	**8**	**2**	**7**	**3**	**7**	**4**	**82**

Table 8. Numbers of tracks of each species found using structures under I-89 during winter, grouped by structure size

Note: Only those culverts with wildlife movement are listed; other culverts of similar size or type are present within the corridor.

Structure or Culvert Size (inches of diameter or width)	Coyote	Fisher	Fox	Mink	Otter	Rac-coon	Skunk	Squir-rel	Un-known	Un-known Canine	Wea-sel	Grand Total	No. of Species
18-30			1			2			1			4	3
36-60		4	14	11		3			2		4	38	6
?				1				1				2	2
144	2			4		2		1				9	4
Bridge	1		11	1	1	1	2	5		7		29	8
Grand Total	3	4	26	17	1	8	2	7	3	7	4	82	11

Figure 41. Culverts and bridges used by wildlife (1)

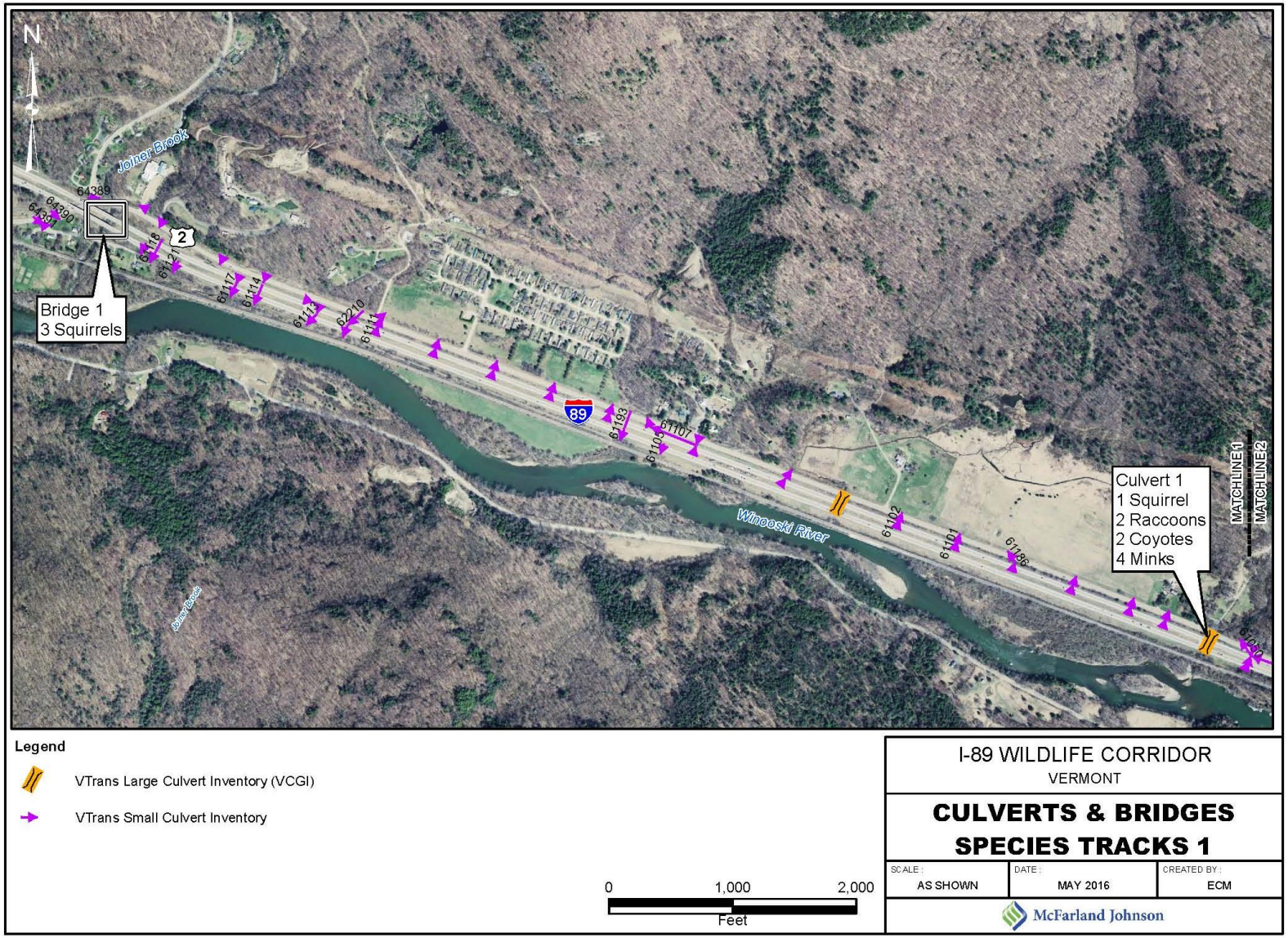


Figure 42. Culverts and bridges used by wildlife (2)

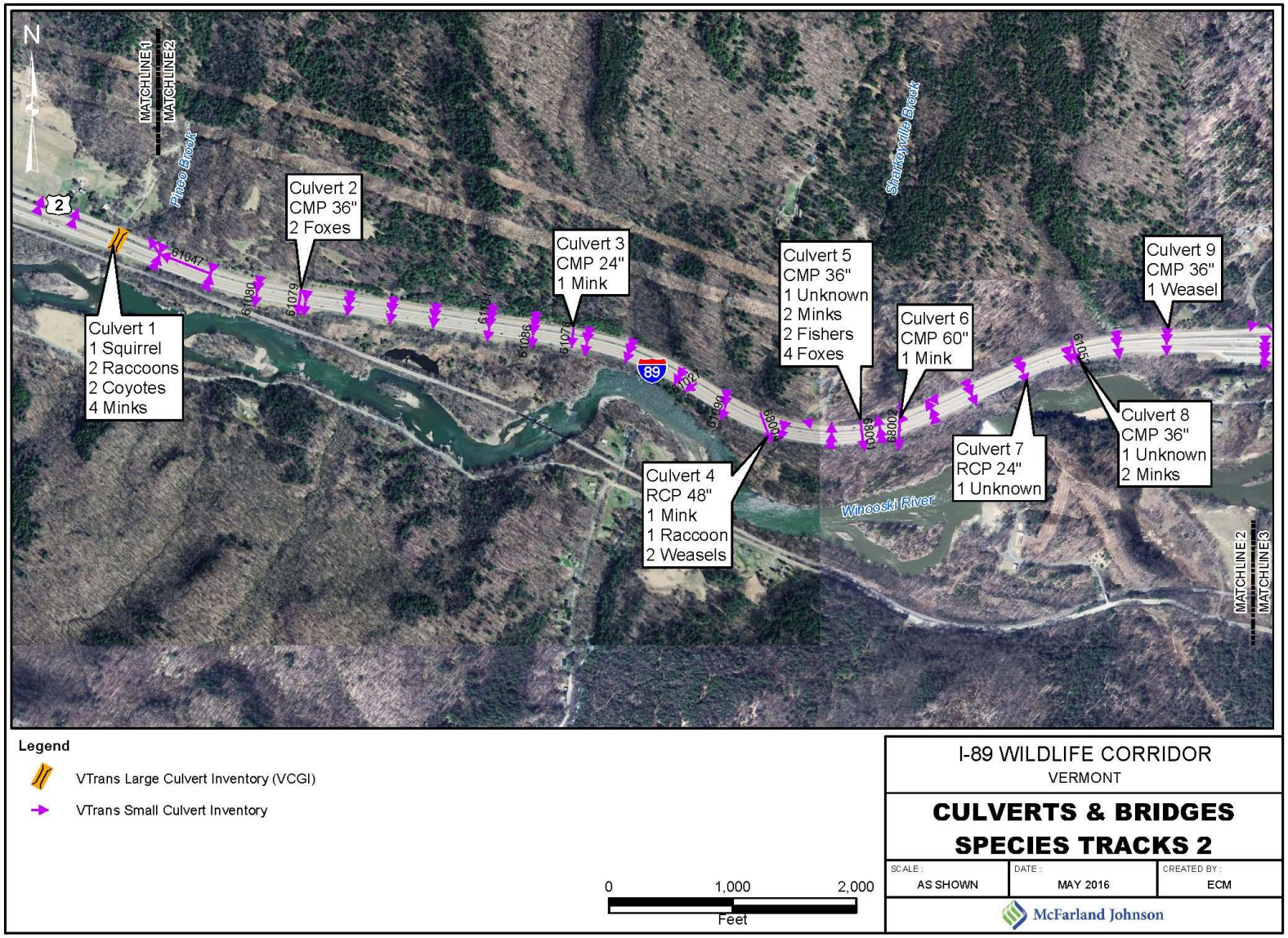


Figure 43. Culverts and bridges used by wildlife (3)

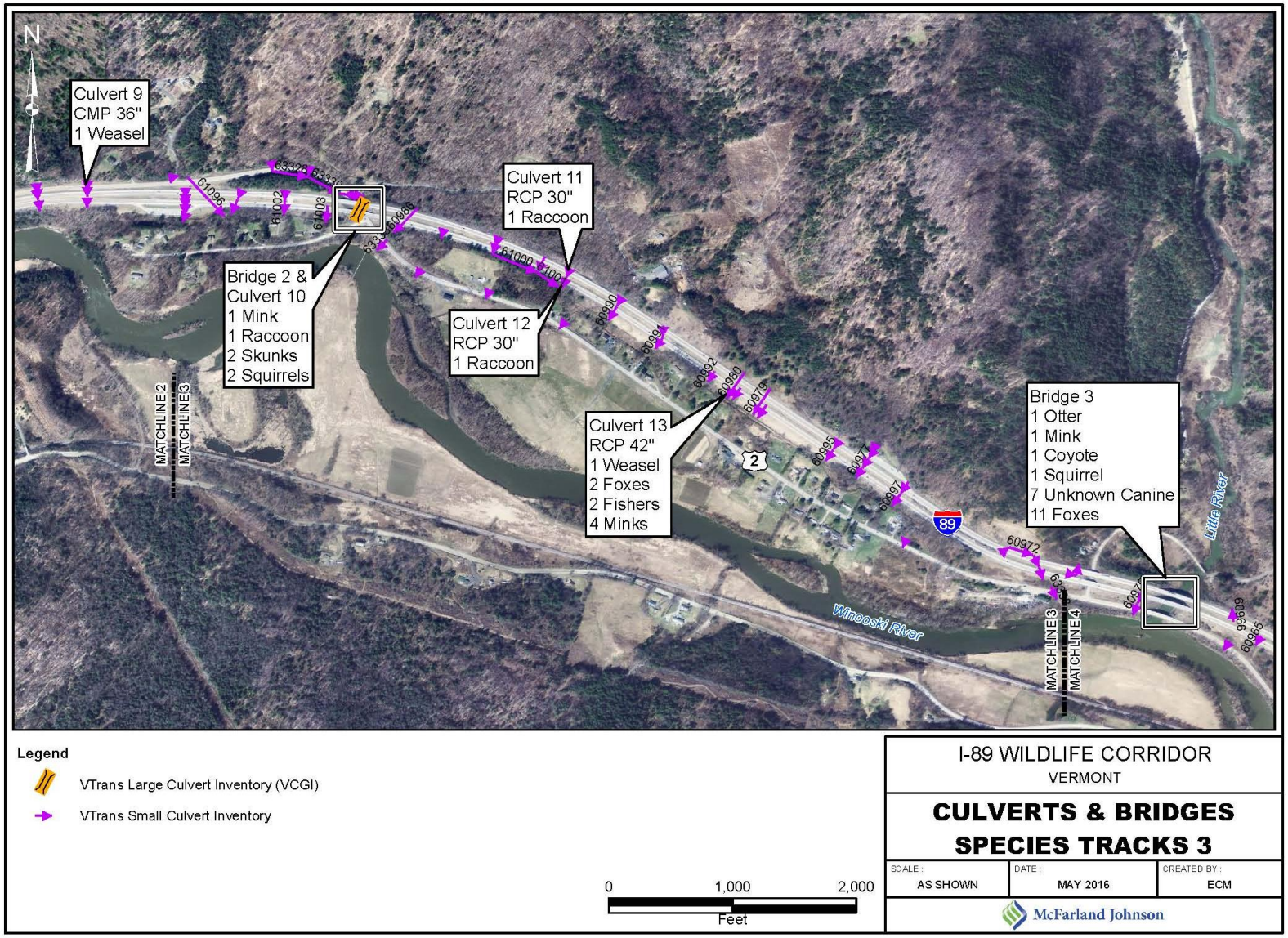
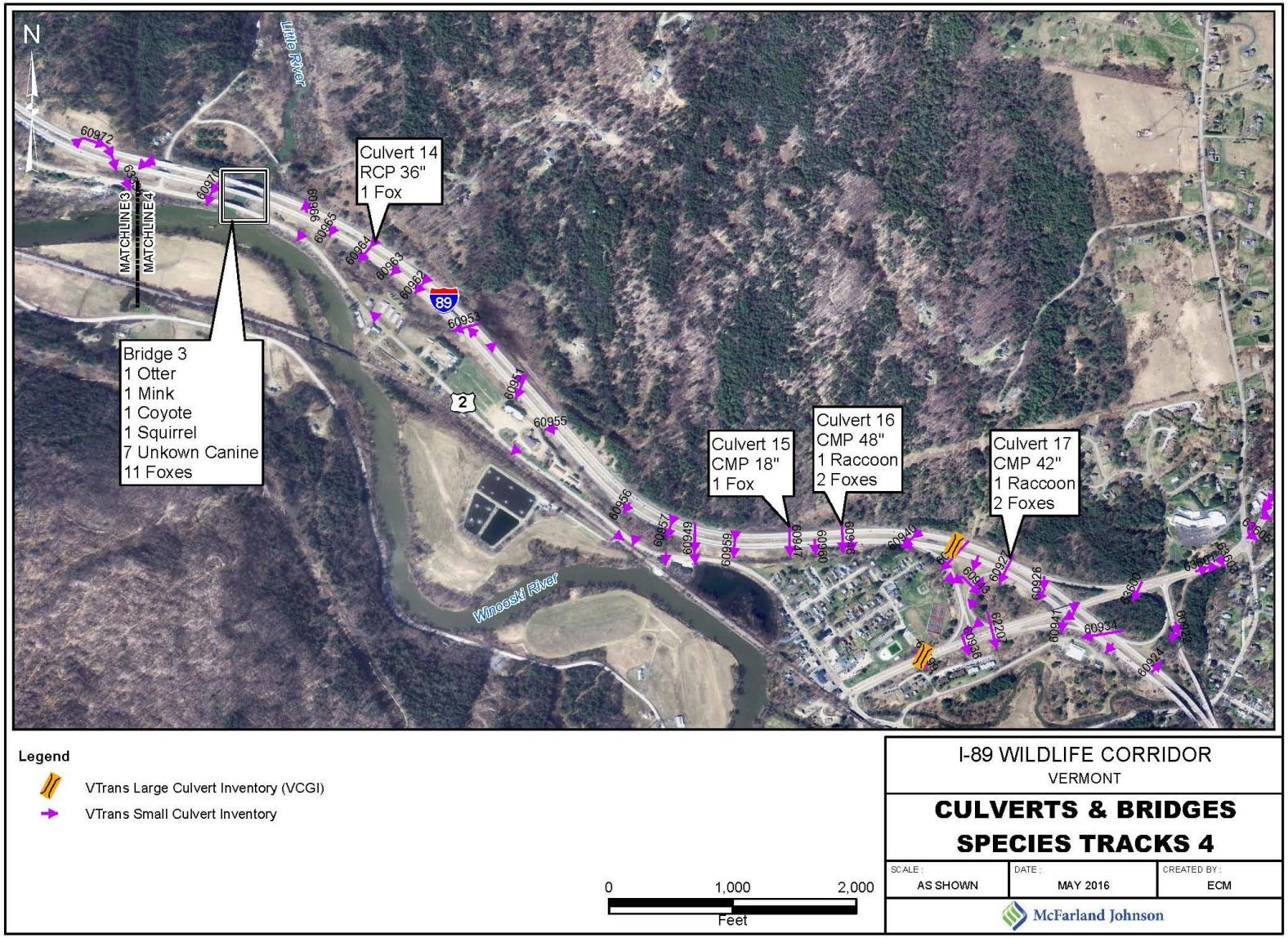


Figure 44. Culverts and bridges used by wildlife (4)



DISCUSSION

Comparing Tracking and Camera Results

In general the camera and tracking results correspond, but some differences were encountered: tracking results showed fewer bear and moose, more small mammals, and different spatial distributions of deer compared to camera results.

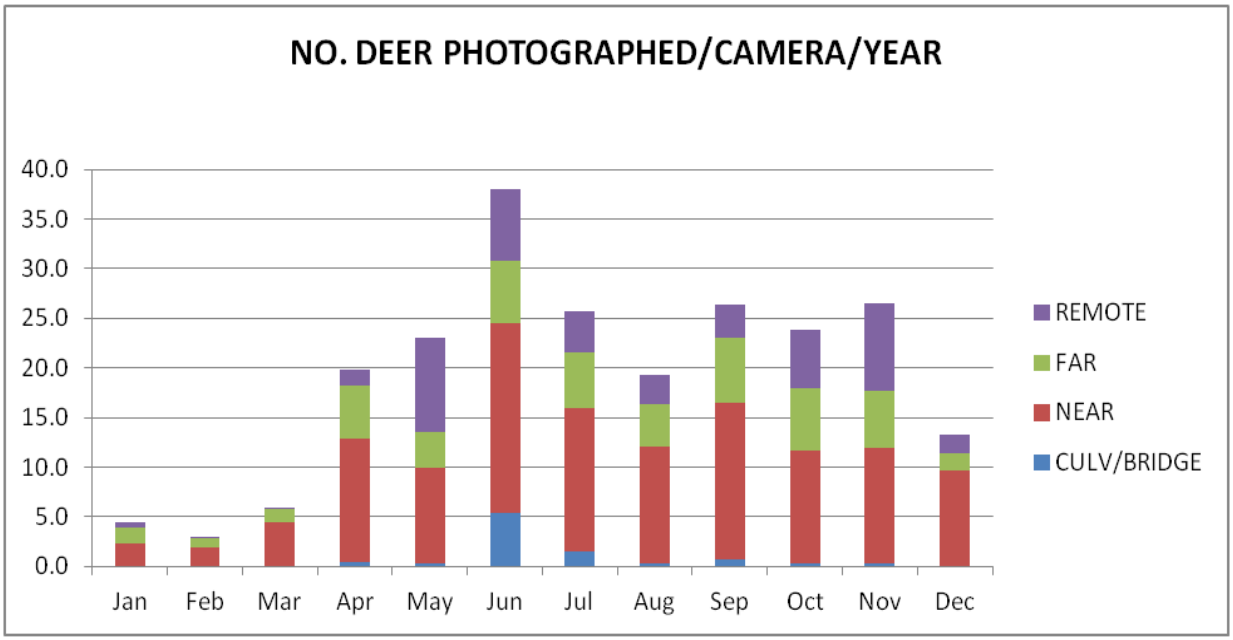
Black bears and moose were frequently photographed at camera stations. Black bears hibernate in winter and hence are absent from the tracking data. Only three sets of moose tracks were encountered during transect tracking, and none during road tracking. Moose, and probably other focus species to some degree, alter their habitats and movement patterns in the winter. The patterns seen in tracking results, therefore, do not represent the distribution of wildlife the remainder of the year. We know from roadkill data that bear and moose cross I-89, yet they are absent from winter tracking results. These are large animals that pose a greater danger to motorists and may have smaller populations that are more vulnerable to adverse effects of road mortality.

Compared to cameras, tracking recorded higher numbers of smaller mammals such as mink, fisher, and rabbit. Since some of these tracks were found within the reported range of the cameras, it is believed that the cameras are triggered by the presence of smaller animals as well as by larger animals. Therefore, smaller animals are likely underrepresented in the camera results.

Cameras showed more deer near the roadways (Near cameras), while winter transect tracking encountered more deer at the more distant portions of the transects. To determine whether the deer have a different winter distribution that would explain this result, the camera data were analyzed by month (Figure 45).

As shown in the figure, there are more deer at the Near cameras (compared to the Far and Remote cameras) all year round, including winter, when tracking found more deer further from the roads. It is possible that either the transect or camera results reflect pockets of deer activity that skew the results. It is a reminder that the study, while covering a broad area, relies on specific locations – camera stations, roads, and transects – for the data, and does not necessarily yield results that can be extrapolated to the entire study area.

Figure 45. Numbers of deer photographed by month of year and corridor location



Study Questions

This study was intended to address several specific questions regarding the interaction of wildlife with the I-89 corridor through the Green Mountains. Those questions, and responses based on our findings, are discussed below.

1. **Is the habitat in the vicinity of the I-89 corridor where it bisects the Green Mountains rich in wildlife?**

The purpose of this question is to determine whether the wildlife found in other parts of the Green Mountains and Vermont are also found in proximity to the highway corridor; in other words, whether there are existing populations that could be affected by the road and could benefit from roadway infrastructure modifications.

Both trail cameras and winter tracking showed that many different wide-ranging, medium- and large-sized mammal species occur throughout the corridor. Most focus species were found on both the north and south sides of the corridor, from the eastern to the western end, and in both forest edge and forest interior locations. The only primary focus species that were not widely distributed in the study area were bobcats and river otters. Bobcats have sparse populations with large ranges, yet were found in four locations on the north side of the corridor. This may be a function of their reported preference for south-facing slopes (Sue

Morse, pers. com.). Otters also have large ranges and sparse populations. They probably move up and down the Winooski River and some of its tributaries and even overland on occasion, but they were not detected by the trail cameras. Only one camera was aimed directly at the river and that camera only detected animals near one shoreline.

We conclude that most of the primary and secondary focus species are relatively common and widespread within the habitats on either side of the I-89 corridor.

2. Is there an edge effect along the I-89 corridor?

Trail cameras showed more individuals of all primary focus species other than deer further from the roads. Deer were most abundant between 400 and 800 feet from the road edge.

Transect tracking, based only on winter animal movements, did not show a clear edge effect. Overall there were fewer tracks within the first 400 feet of the road edge, but this varied by species. Some species, such as fisher, were much less common within 400 feet of the road edge, possibly indicating an aversion to the road edge. Many species were most abundant between 400 and 800 feet of the road edge, though the reasons are unclear.

Taken together, the trail camera and tracking results show the distribution of most species changes with distance from the road edge, so it is concluded there is an edge effect. Most focus species appear to be repelled by the road corridor, but others, such as deer and fox, may be attracted to the forest edge habitat or the open-canopy habitat between the road and forest.

3. Is the I-89/Route 2 corridor currently a fragmenting feature?

The transects provide a baseline showing what animal movements are like in the nearby forest matrix, where there are essentially no barriers to movement. In terms of primary and secondary focus species, the numbers of animals crossing I-89 and River Road were 13% and 21%, respectively, of the numbers observed crossing the transects. (The I-89 figures include culvert and bridge crossings along with partial crossings.) This suggests that these roads inhibit or deter animal movements, and that larger roads such as I-89 have a greater inhibitory effect than smaller roads.

In short, the roads were found to inhibit animal movement, and therefore can be said to fragment wildlife populations in the area. The degree of fragmentation appears to vary with the species and other factors such as the presence of natural and man-made barriers. Some alert, fast, and intelligent species such as the coyote cross over one section of I-89 regularly. Other species take advantage of culverts and other species rarely cross. Chain-link fence, Jersey barriers, rock cuts, and other features probably affect the ability or willingness of animals to cross the road corridor in some places.

4. Is wildlife road mortality currently occurring?

Existing moose and bear roadkill data are shown on Figure 3. Caution should be used in interpreting this data, as the locations may not be accurate, not all records represent roadkill, and some records could be duplicated. Nevertheless, they show a much higher concentration of dead moose records in the eastern half of the study area, and few records of either moose or bear in the chain link fence section to the west.

An effort to systematically gather roadkill data for this project was attempted but was not productive in terms of time spent and information gathered, so the effort was discontinued.

During winter tracking, 8 road-killed animals were encountered along I-89. These included 4 deer, 1 mink, 1 raccoon, 1 cottontail, and 1 unidentifiable species. No road-killed animals were encountered along River Road.

Based on these records, it is clear that wildlife mortality continues along I-89. It is not possible at this time to draw conclusions regarding the scale of the problem or the effects on wildlife populations from this study.

5. Are existing culverts and bridges facilitating wildlife movement?

Winter tracking showed that about one-fifth of animals entering the I-89 roadway passed through culverts and another 10 percent passed under bridges. Measured along the roadway, these structures only make up a fraction of the total road segment length available for crossing, so compared to the available roadway they were heavily used. It is apparent that these structures are important travel corridors for wildlife, and could probably be even more frequently utilized with modifications designed to accommodate wildlife movement.

In this study, some species used culverts as small as 18 inches, and some culverts had frequent wildlife usage while others of similar size were not used during the study's tracking rounds. The most frequently used structures included:

- Pineo Brook: 9 track sets. This is an approximately 12-foot wide box culvert with a shallow perennial stream and a concrete substrate. There were 9 sets of animal tracks in winter, although cameras showed deer approaching the inlet several times but never passing through it.
- A 36-inch dry storm drainage CMP near Sharkeyville Road: 9 track sets
- A 42-inch RCP west of Little River: 9 track sets
- The Little River bridge: 22 track sets

Several other structures carried 3 or 4 sets of tracks, including two bridges, two 36-inch CMPs, a 48-inch CMP, and a 48-inch RCP.

Both trail cameras and winter tracking revealed wildlife use of the Little River bridge, despite the relatively small amount of terrestrial habitat south of the bridge. The recently constructed shelf on the west side of this bridge was the most common wildlife travel route there; the east side of the bridge, with a steep rocky slope and road, was little used by wildlife.

Tracking showed relatively little use of the two bridges over US Route 2. The Joiner Brook structure, an approximately 32-foot wide bridge under US Route 2, also had no animal tracks and no trail camera photos of wildlife. The Sharkeyville Stream inlet, a 60-inch CMP, had one set of mink tracks and no wildlife photos.

In short, some structures are frequently used and facilitate wildlife movement, while other structures, including bridges, do little to facilitate movement.

6. Would infrastructure modifications improve wildlife movements across barriers?

There are presumably certain features which make some culverts or bridges hospitable and others inhospitable for animal travel. For example, the wildlife shelf under the Little River bridge is clearly a success, while the bridge over Joiner Brook is not conducive to wildlife movement (though possibly because of the adjacent land use rather than the structure itself). These features should be investigated, and the information used to guide future structure placement and design. The likelihood of the structure to be utilized by wildlife should be considered in planning roadway infrastructure improvements. For example, the Sharkeyville area had high numbers of wildlife and some culvert usage, so infrastructure improvements would have a high likelihood of success. The Joiner Brook bridge area saw less activity despite its relatively large openings, and may not be a good candidate due to the surrounding land use (multiple roads, school, etc.).

A number of other structures may impede animal movement across the corridor. Chain-link fencing, woven wire fencing, Jersey barriers, and steep embankments may deter certain species from crossing roads. The potential impact to wildlife movement should be evaluated and weighed against the other benefits provided by these structures. For example, chain-link fence is impermeable to most medium and large-size wildlife species, and could result in animals spending more time on the road, increasing the chances of wildlife-vehicle collisions. This risk could be compared with the fence's benefits, such as the ability to deter humans from the roadway.

Importance of I-89 Segments to Connectivity

Ultimately it would be desirable to identify and prioritize segments of I-89 that are important for wildlife crossing, and that could be targeted for infrastructure improvements to facilitate wildlife crossing. There is presumably some set of landscape conditions, habitat characteristics, and structure design features that would better facilitate animal passage and improve habitat connectivity. It is not possible based on this study to identify and rank all possible variables and draw firm conclusions regarding wildlife crossing structure types, sizes, or locations.

There are certain areas within this corridor where higher numbers of wildlife are found, either crossing the roads or adjacent to the roads, and other areas where there is little wildlife activity. The habitat adjacent to the roads and both natural and man-made barriers clearly play a role in determining areas of concentrated crossing. All of these factors should be considered in evaluating locations for new or improved wildlife crossing infrastructure.

Below is an evaluation of the relative wildlife crossing value of each segment of I-89 within the study area. The intent is to identify areas with the greatest potential to improve connectivity between habitats and wildlife populations on both sides of the roadway corridor. The evaluation takes into account the camera and tracking results, existing landscape conditions along the corridor, and existing barriers to wildlife movement. Each segment of the study area is summarized below and the rankings are illustrated in Figure 46.

West of Bolton Valley Road: Medium Priority

There was high wildlife crossing over the road here, but it was mostly coyotes, and there is extensive residential land use south of the road. However, the Joiner Brook transect, on the north side of the highway, had relatively high numbers of wildlife, so the area could be important for wildlife movements. Therefore, this segment is considered medium priority in terms of its potential for improving connectivity.

Bolton Valley Road/Joiner Brook Area: Low Priority

This is a complex vehicular intersection with US Route 2 crossing under I-89, Bolton Valley Road branching off, and Joiner Brook passing under both US Route 2 and I-89. On the north side of I-89 and US Route 2, there is a school on the east side of the stream and Bolton Valley Road on the west side, both of which may inhibit wildlife movement. There are already structures (the US Route 2 and I-89 bridges over Joiner Brook) that are large enough to accommodate wildlife movements, but little wildlife activity was found in this area. It is possible that habitat modifications adjacent to the roads, school, and other development, could improve wildlife movement. Overall, this area is considered low priority.

Bolton Valley Road to Pineo Brook Road: Medium Priority

This segment of road had little wildlife crossing activity, although local residents report wildlife making it across this section of I-89 only to be turned back by the fence. US Route 2 closely parallels I-89, creating essentially a three-barrel roadway; a chain link fence separates the two roads and presents an impediment to wildlife movement along this entire segment; the north side of the road has a mixture of farm fields and mowed lawns; and the south side has minimal amounts of terrestrial habitat between the roads and the Winooski River. Nevertheless, this is a long segment and ideally there should be some wildlife passage potential. The costs, benefits, and impacts of the chain link fence should be reevaluated. This segment is considered medium priority.

Pineo Brook to I-89 over US Route 2 Bridge: High Priority

This segment includes Pineo Brook, a rock cut, the Sharkeyville residential area, Sharkeyville Stream, and a power line. The Pineo Brook and Sharkeyville crossings are discussed individually below. Winter tracking revealed several concentrations of wildlife crossings across I-89 along this segment, both over the road surface and through culverts. Additionally, there are multiple records of past moose and bear roadkill. Mt. Mansfield State Forest is less than one mile north of this segment, and Camel's Hump State Park is close to River Road to the south. This is a high priority segment for wildlife connectivity.

Pineo Brook Culvert: High Priority

There were relatively high numbers of road crossings in this area and some usage of the culvert. As an existing perennial stream corridor with a relatively large structure, this crossing has high potential wildlife crossing value. Mt. Mansfield State Forest is less than one mile north of the crossing, and Camel's Hump State Park abuts River Road directly to the south. For these reasons, this structure is considered high priority for wildlife connectivity.

Sharkeyville Area: High Priority

Trail cameras revealed a very high concentration of deer, along with photos of moose, coyote, and bear in the vicinity of Sharkeyville Road and Stream. Winter tracking revealed that coyote, fox, fisher, mink, and weasel cross over or under the highway in this area. There was little use of the Sharkeyville Stream culvert, but a 36-inch dry storm drainage culvert was used by three species. This appears to be an area of potentially high importance for wildlife connectivity.

US Route 2 Bridge to Little River Road: Medium Priority

This segment had a moderate number of wildlife crossings and little use of culverts. There are no perennial stream culverts. However, there is abundant undeveloped forested habitat along the north side of I-89 and south of River Road. Approaching Little River, there is conservation land (Little River State Park, part of Mt. Mansfield State Forest) less than one-half mile north of I-89, but south of River Road, conservation land is over one mile away. Overall, this area is medium priority for improving wildlife connectivity.

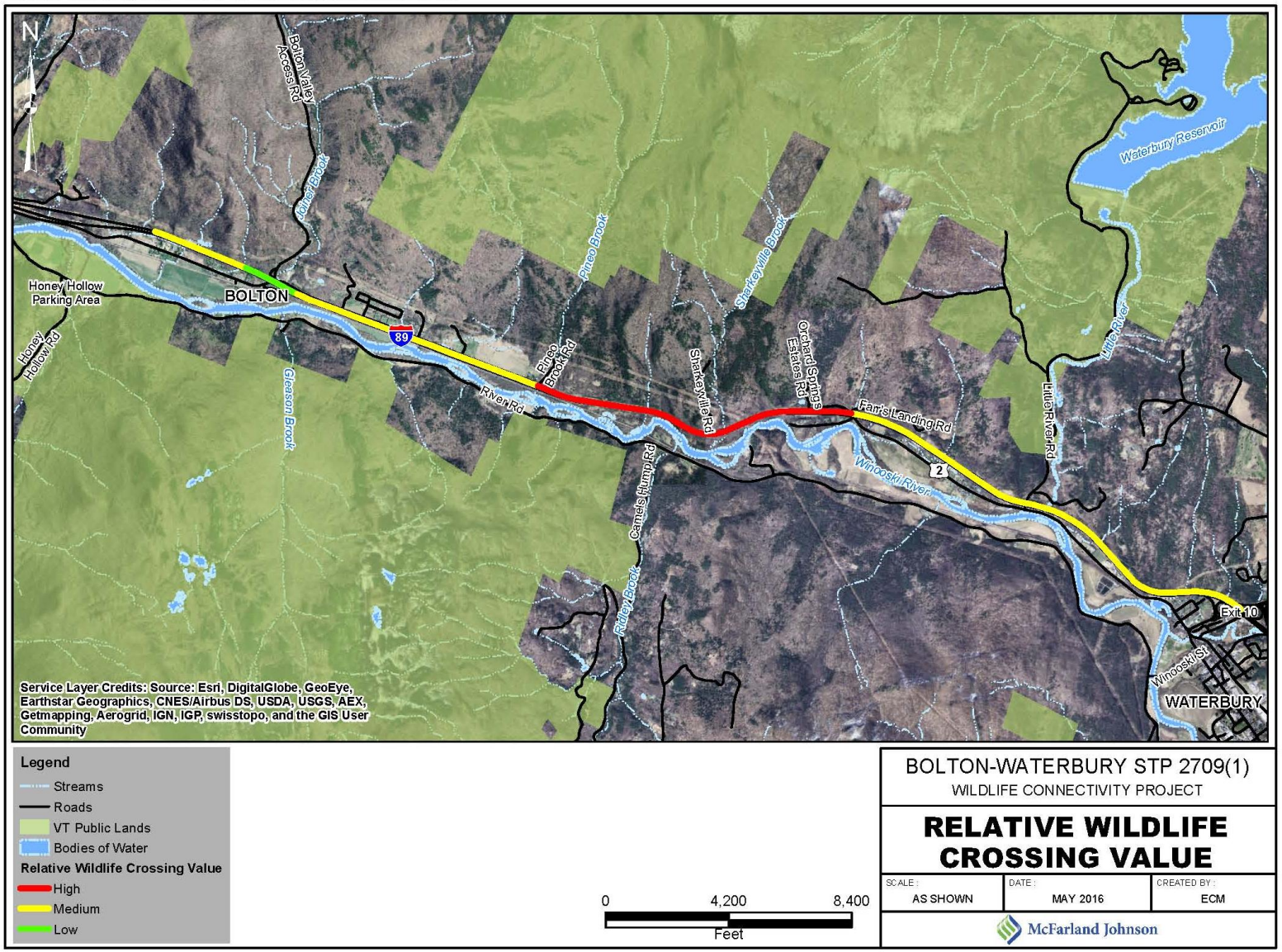
Little River Bridge: Medium Priority

Although there is a limited amount of terrestrial habitat south of the bridge, tracking and cameras showed many animals passing under the bridge. Tracking and cameras also showed that the Little River corridor upstream of the bridge had relatively high numbers of wildlife. This is an important wildlife habitat area and wildlife travel corridor, and the bridge links that habitat to the Winooski River riparian corridor. Because it already facilitates wildlife crossing, it is designated a medium priority crossing from a connectivity perspective.

Little River Bridge East to I-89 Exit 10: Medium Priority

East of the Little River bridge to Exit 10, tracking showed relatively light amounts of wildlife travel over the road and through culverts. North of I-89 is a mixture of forest and residential land use; between I-89 and the Winooski River are commercial development and a wastewater treatment plant; and south of River Road is extensive forest land. The fragmented landscape along this segment suggests this is a medium priority crossing area.

Figure 46. Relative wildlife crossing value of road segments



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Wildlife Connectivity Study

Appendix A

PHOTO LOG

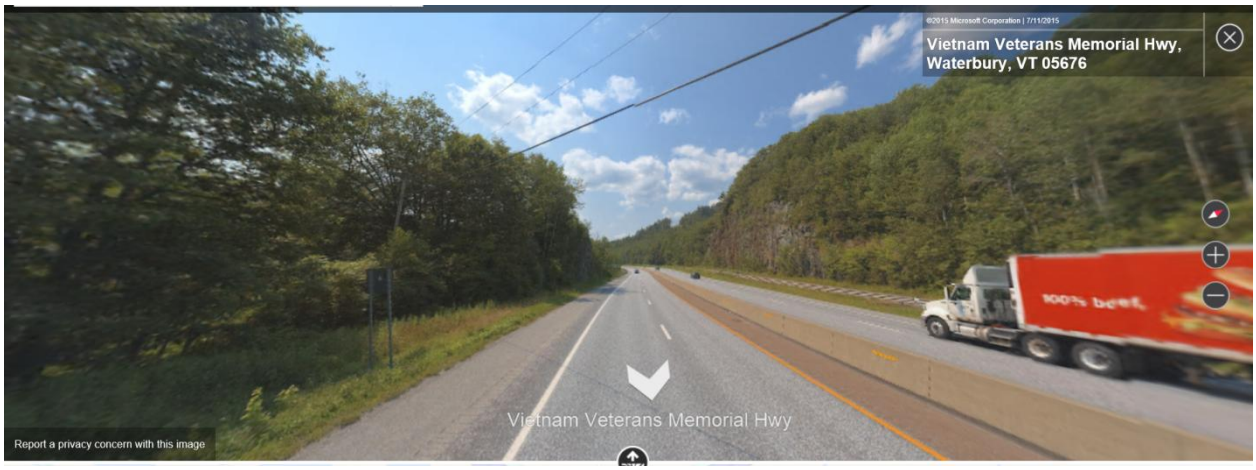
PHOTO LOG

Contents

I-89 WITHIN STUDY AREA

Eastern portion of I-89, west of Exit 10, facing west (Bing Maps image)

I-89 east of Sharkeyville, showing median barrier and rock cut, facing west (Bing Maps image)

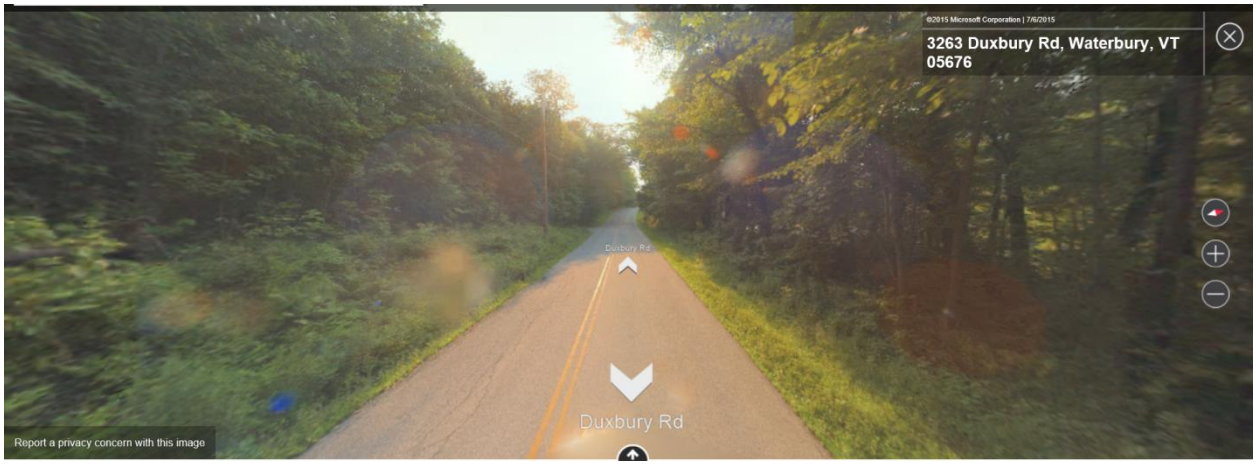


I-89 in western portion of study area, facing west (Bing Maps image)

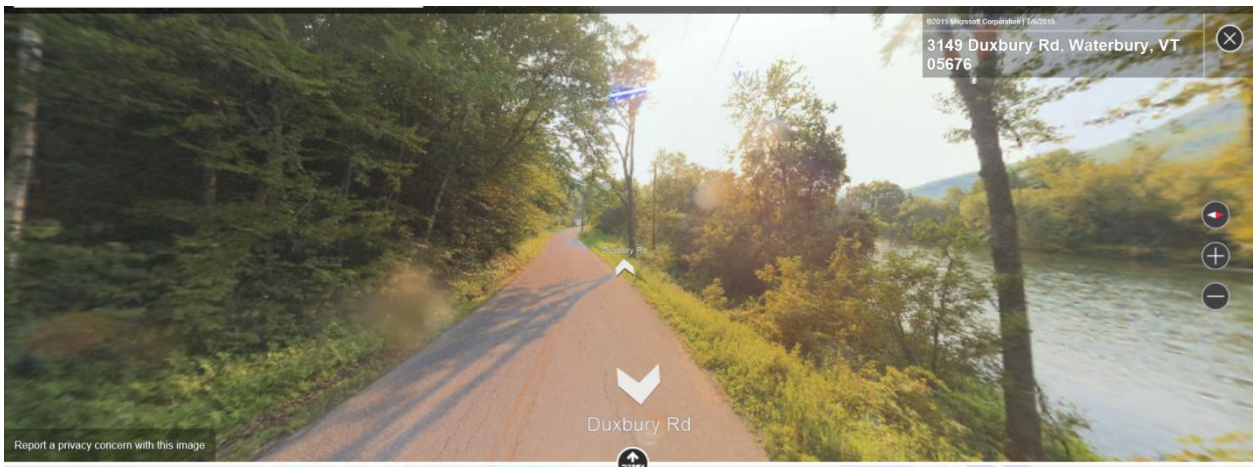
RIVER ROAD WITHIN STUDY AREA

Eastern portion of River Road, a mixture of farm fields and forest (Google Maps image)

Western portion of River Road (Duxbury Road), forested on both sides, no shoulders, nearly closed canopy in places (Bing Maps image)



Western portion of River Road (Duxbury Road), with river close to road in places (Bing Maps image)



LARGER STRUCTURES WITHIN STUDY AREA

I-89 and US Route 2 bridges over Little River, facing south

Constructed shelf on west side under Little River bridge

Pineo Brook inlet, north side of US Route 2, facing south

Interior of Pineo Brook culvert, with I-89 median opening visible

US Route 2 bridge over Joiner Brook

I-89 over Joiner Brook

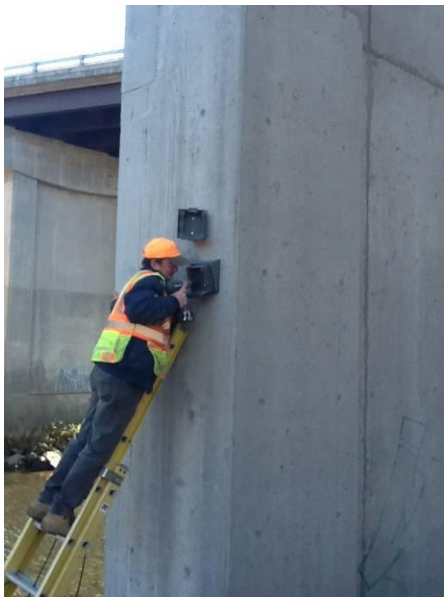
CAMERA HARDWARE AND DEPLOYMENT AT LITTLE RIVER BRIDGE

Fabricated housing for angling camera down

Fabricated housing for angling camera to the side

Back side of fabricated housing for angling to the side

Cameras being installed on abutment, one angled down, the other angled to the side



Camera on western bridge abutment

SELETECTED WILDLIFE PHOTOGRAPHS

Deer on constructed shelf under Little River bridge

Bear and cubs, Little River Remote

Barred owl, Green Mountain Power Far

Black bears interacting

Bull moose, Little River Remote

Bobcat playing with chipmunk, Joiner Brook Far

Fisher with squirrel

Deer along right-of-way fence

Turkeys in courtship behavior

Bobcat on constructed shelf under Little River bridge

Fox exiting culvert (VTrans photo)

1960 PHOTOGRAPHS OF CORRIDOR

Pre-construction

During construction

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Wildlife Connectivity Study

Appendix B

CAMERA DATES OF DEPLOYMENT AND CALCULATIONS

APPENDIX B. Camera Dates of Deployment and Calculations

CORRIDOR LOCATION (BOLD) AND CAMERA STATION	INSTALLED	LAST CHECKED OR CEASED FUNCTION	TOTAL DAYS OUT	DAYS NON-FUNCTIONAL BEFORE LAST DATE (SEE COMMENTS)	NET DAYS OUT	NET YEARS OUT	NET DAYS/ CORRIDOR LOCATION	NET YEARS OUT/ CORRIDOR LOCATION	COMMENTS
CULV/BRIDGE							**6556**	**17.96**	
Joiner Brook Inlet 18	10/18/2013	10/29/2015	741	0	741	2.03			THIS CAMERA HAD NO WILDLIFE PHOTOS THROUGHOUT
Joiner Brook Inlet 5	9/30/2013	10/29/2015	759	0	759	2.08			
Little River Bridge East Pier to River	11/4/2013	10/13/2015	708	0	708	1.94			
Little River Bridge East Pier to Slope	11/4/2013	10/13/2015	708	0	708	1.94			
Little River Bridge West Abutment	11/4/2013	10/6/2015	701	0	701	1.92			
Little River Bridge West Pier to River	11/4/2013	10/13/2015	708	0	708	1.94			
Little River Bridge West Pier to Slope	11/4/2013	10/13/2015	708	0	708	1.94			
Pineo Brook Inlet	9/9/2013	10/8/2015	759	0	759	2.08			
Sharkeyville Stream Inlet	9/9/2013	10/13/2015	764	0	764	2.09			
FAR							**8986**	**24.62**	
Camel's Hump Boundary - Far	9/17/2013	10/6/2015	749	0	749	2.05			
Camel's Hump Road - Far	9/17/2013	10/6/2015	749	0	749	2.05			
Farr Landing Far	9/20/2013	10/6/2015	746	0	746	2.04			
Green Mountain Power Far	9/17/2013	10/8/2015	751	0	751	2.06			
Joiner Brook Far	10/2/2013	10/12/2015	740	0	740	2.03			

CORRIDOR LOCATION (BOLD) AND CAMERA STATION	INSTALLED	LAST CHECKED OR CEASED FUNCTION	TOTAL DAYS OUT	DAYS NON-FUNCTIONAL BEFORE LAST DATE (SEE COMMENTS)	NET DAYS OUT	NET YEARS OUT	NET DAYS/ CORRIDOR LOCATION	NET YEARS OUT/ CORRIDOR LOCATION	COMMENTS
Logging Road Far	9/17/2013	10/6/2015	749	0	749	2.05			NO PHOTOS 11/22/2013 TO 5/8/2014, BUT THIS IS SIMILAR TO FOLLOWING WINTER; ASSUME CAMERA ACTIVE THRUOUT
Little River Far	9/20/2013	10/6/2015	746	0	746	2.04			
Long Trail Far	9/17/2013	10/6/2015	749	0	749	2.05			
Pineo Brook Far	9/9/2013	10/8/2015	759	0	759	2.08			
River Road East Far	9/17/2013	10/6/2015	749	0	749	2.05			
Sharkeyville Funnel Far	9/24/2013	10/6/2015	742	0	742	2.03			
Sharkeyville Stream Far	9/9/2013	10/6/2015	757	0	757	2.07			
NEAR							**8815**	**24.15**	
Camel's Hump Boundary Near	9/17/2013	10/6/2015	749	0	749	2.05			
Camel's Hump Road Near	9/17/2013	10/6/2015	749	107	642	1.76			NO PHOTOS 7/30/2014 THRU 11/13/2014 (107 DAYS); LAST PHOTO 7/29 SHOWS KID THROWING ROCK. ASSUME CAMERA DAMAGED.
Farr's Landing Near	9/20/2013	10/6/2015	746	0	746	2.04			
Green Mountain Power Near	9/17/2013	10/8/2015	751	0	751	2.06			
Joiner Brook Near	10/2/2013	10/12/2015	740	69	671	1.84			NO PHOTOS 9/6/2014 THRU 11/13/2014 (69 DAYS) DUE TO LEAF PHOTOS
Logging Road Near	9/17/2013	10/6/2015	749	0	749	2.05			
Little River Near	9/20/2013	10/6/2015	746	0	746	2.04			

CORRIDOR LOCATION (BOLD) AND CAMERA STATION	INSTALLED	LAST CHECKED OR CEASED FUNCTION	TOTAL DAYS OUT	DAYS NON-FUNCTIONAL BEFORE LAST DATE (SEE COMMENTS)	NET DAYS OUT	NET YEARS OUT	NET DAYS/ CORRIDOR LOCATION	NET YEARS OUT/ CORRIDOR LOCATION	COMMENTS
Long Trail Near	9/17/2013	10/6/2015	749	0	749	2.05			THIS CAMERA HAD NO WILDLIFE PHOTOS THROUGHOUT
Pineo Brook Near	9/9/2013	10/6/2015	757	0	757	2.07			
River Road East Near	9/17/2013	10/6/2015	749	0	749	2.05			
Sharkeyville Funnel Near	9/17/2013	10/6/2015	749	0	749	2.05			
Sharkeyville Stream Near	9/9/2013	10/6/2015	757	0	757	2.07			NO PHOTOS AUG/SEP 2014, BUT CAMERA BELIEVED TO BE FUNCTIONING
REMOTE							**4353**	**11.93**	
Bolton Valley Remote	9/17/2013	10/8/2015	751	0	751	2.06			
Honey Hollow Remote	9/20/2013	10/6/2015	746	0	746	2.04			
Little River Remote	9/10/2013	10/6/2015	756	0	756	2.07			
Richardson Road Remote	9/24/2013	10/12/2015	748	0	748	2.05			
Scrabble Hill Remote	9/24/2013	10/6/2015	742	0	742	2.03			
Sharkeyville Upland Remote	9/9/2013	5/12/2015	610	0	610	1.67			NO PHOTOS AFTER 5/12/2015
WINOOSKI RIVER							**759**	**2.08**	
Winooski River	9/9/2013	10/8/2015	759	0	759	2.08			
GRAND TOTALS			**29645**	**176**	**29469**	**80.74**	**29469**	**80.74**	
GRAND TOTALS EXCLUDING WINOOSKI RIVER (MANY WATERFOWL)			**28886**	**176**	**28710**	**78.66**	**28710**	**78.66**	

Bolton Waterbury STP 2709(1)

Wildlife Connectivity Study

Appendix C

TRANSECT LENGTHS AND CALCULATIONS

APPENDIX C. Transect Lengths and Calculations

Transect and Segment	Length of Transect or Segment (Feet)	Length in 400-Foot Segments	Antecedent Track Nights	Conversion to 90-Day Basis	Net Factor to Convert to per 400 Feet per 90 Days
CAMELS HUMP BOUNDARY	1803				
1-400	408	1.02	9	10	9.81
401-800	517	1.29	9	10	7.73
801-1200	438	1.09	9	10	9.14
1201-1600	440	1.10	9	10	9.09
CAMELS HUMP ROAD	1216				
1-400	410	1.02	9	10	9.77
401-800	450	1.12	9	10	8.90
801-1200	356	0.89	9	10	11.22
FARR'S LANDING	2299				
1-400	465	1.16	9	10	8.60
401-800	562	1.41	9	10	7.11
801-1200	497	1.24	9	10	8.05
1201-1600	775	1.94	9	10	5.16
GREEN MOUNTAIN POWER	1939				
1-400	550	1.38	9	10	7.27
401-800	557	1.39	9	10	7.18
801-1200	424	1.06	9	10	9.44
1201-1600	408	1.02	9	10	9.81
JOINER BROOK	1903				
1-400	559	1.40	9	10	7.16
401-800	417	1.04	9	10	9.58
801-1200	449	1.12	9	10	8.91
1201-1600	478	1.20	9	10	8.36
LITTLE RIVER	1539				
1-400	504	1.26	9	10	7.93
401-800	407	1.02	9	10	9.83
801-1200	445	1.11	9	10	8.98
1201-1600	182	0.46	9	10	21.96
LOGGING ROAD	1748				
1-400	441	1.10	9	10	9.07
401-800	457	1.14	9	10	8.74
801-1200	419	1.05	9	10	9.55
1201-1600	431	1.08	9	10	9.28
LONG TRAIL	2136				
1-400	406	1.02	9	10	9.85
401-800	436	1.09	9	10	9.17

Transect and Segment	Length of Transect or Segment (Feet)	Length in 400-Foot Segments	Antecedent Track Nights	Conversion to 90-Day Basis	Net Factor to Convert to per 400 Feet per 90 Days
801-1200	849	2.12	9	10	4.71
1201-1600	445	1.11	9	10	9.00
PINEO BROOK	1716				
1-400	425	1.06	9	10	9.42
401-800	435	1.09	9	10	9.19
801-1200	444	1.11	9	10	9.01
1201-1600	411	1.03	9	10	9.72
RIVER ROAD EAST	1670				
1-400	409	1.02	10	9	8.80
401-800	412	1.03	10	9	8.75
801-1200	414	1.04	10	9	8.69
1201-1600	435	1.09	10	9	8.28
SHARKEYVILLE FUNNEL	1952				
1-400	546	1.36	9	10	7.33
401-800	445	1.11	9	10	8.99
801-1200	404	1.01	9	10	9.91
1201-1600	558	1.39	9	10	7.17
SHARKEYVILLE STREAM	1684				
1-400	404	1.01	9	10	9.89
401-800	406	1.02	9	10	9.85
801-1200	417	1.04	9	10	9.59
1201-1600	456	1.14	9	10	8.77
ALL TRANSECTS	21603	54.01	The "All Transect" results were		
Length of 0-400	5526	13.81	tabulated using transect data		
Length of 401-800	5502	13.76	which was first converted to		
Length of 801-1200	5556	13.89	a 90-day basis		
Length of 1201-1600	5019	12.55			