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Abstract

The Pennsylvania Department of Transportation (PENNDOT) District 3-0 initiated a study in North Central Pennsylvania evaluating existing bridges and culverts for use as underpasses by wildlife. This project was a two-phase study to investigate animal passage through existing drainage box culverts, arch culverts and bridges on existing highway systems. The objective of this study was to (1) determine whether wildlife are using existing structures as passageways based on wildlife sign and remote camera monitoring and (2) determine underpass dimensions, interior characteristics, location, topography, and adjacent habitat features that contribute to and enhance usage of underpass corridors by wildlife. These data will contribute to future highway design and mitigation measures in addressing wildlife corridors.

WILDLIFE USE OF EXISTING CULVERTS AND BRIDGES IN NORTH CENTRAL PENNSYLVANIA

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Abstract: The Pennsylvania Department of Transportation (PENNDOT) District 3-0 initiated a study in North Central Pennsylvania evaluating existing bridges and culverts for use as underpasses by wildlife. This project was a two-phase study to investigate animal passage through existing drainage box culverts, arch culverts and bridges on existing highway systems. The objective of this study was to (1) determine whether wildlife are using existing structures as passageways based on wildlife sign and remote camera monitoring and (2) determine underpass dimensions, interior characteristics, location, topography, and adjacent habitat features that contribute to and enhance usage of underpass corridors by wildlife. These data will contribute to future highway design and mitigation measures in addressing wildlife corridors.

Introduction

Pennsylvania contains the nation's fifth largest state highway system. With increasing volumes of vehicular traffic and new highway development to meet these demands, there are growing concerns among wildlife authorities and transportation specialists about the effect of highways on wildlife populations and wildlife-vehicle interactions. The growing number of transportation corridors can fragment wildlife habitat and wildlife populations, impede wildlife movements and at the same time cause safety hazards for motorists when wildlife attempt to cross roadways. Providing safe passageway for wildlife across transportation corridors will (1) provide habitat connectivity (2) reduce animal road-kill and (3) improve motorist safety. Agency reviews of transportation projects are more frequently requiring wildlife corridor considerations during the environmental review process. PENNDOT is interested in opportunities to provide safe passageway for wildlife across transportation corridors, provide habitat linkages, and reduce wildlife/vehicle collisions.

Purpose of Study

Many species of wildlife use riparian valleys as travel corridors and may encounter bridges and culverts along intersecting highway routes. Limited research has been published regarding wildlife movements across highway corridors and the use of underpasses in Pennsylvania.

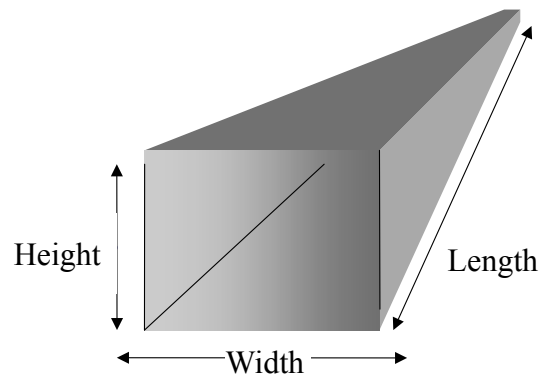
A.D. Marble & Company (ADM) in conjunction with PENNDOT District 3-0 conducted this research to investigate animal passage through existing drainage box culverts, arch culverts and bridges on existing highway systems. The objectives of this study are to determine whether wildlife are using existing structures as passageways based from field screening surveys and remote camera monitoring, and determine underpass dimensions, interior characteristics, location, topography, and adjacent habitat features that contribute to and enhance usage of underpass corridors for wildlife in North Central Pennsylvania (see fig. 1). ADM evaluated existing structures being used and/or their potential use by wildlife based on field evaluation of structures, adjacent habitat cover, nearby land uses, identification of wildlife sign, and an infrared remote camera monitoring study.



Fig.1. Study Area of the Wildlife Underpass Evaluation.

Underpass Dimensions Characteristics

The width and height of the underpass opening, as well as the underpass length, are important factors in determining the type and size of animals that can use the underpass. These measurements are used to calculate an openness index (OI) (width x height/length) (see figure 2). The openness of an underpass influences the amount of light that penetrates the interior and the view of the other side. For example, an 80-foot long, 10-foot wide and 8-foot high box culvert has an OI = 1.0. Doubling the width or height to 20 feet, increases the OI to 2.0. Length, width and height of underpasses, and other factors including its “openness,” can greatly influence animal use. The Openness Index number, however, does not differentiate between height and width, and special attention should be made to species’ tolerance for recommended heights and widths.



(Height x Width) Divided by Length = OI (Openness Index)
Example (6ft. x 8ft.) / 150ft. = 0.32 OI

Fig. 2. R/C Box Culvert Dimensions.

Phase I Wildlife Underpass Study

The Phase I Study consisted of: (1) summarizing previous research regarding wildlife use of underpasses across highway corridors; (2) reviewing the District files to identify pertinent information on structures to be evaluated; (3) field screening study to evaluate existing bridges and culverts in North Central Pennsylvania for potential use by wildlife through the evaluation of site conditions and the observation of wildlife sign (tracks, trails, scat,); (4) camera monitoring study to monitor actual use by wildlife of selected culverts using infrared motion sensors and cameras and; (5) survey of other the PENNDOT Engineering Districts, the Pennsylvania Turnpike Commission and 12 other state DOT's in the northeast and mid-Atlantic region to determine how they addressed wildlife movements across transportation corridors.

In the Phase 1 Study, 46 existing road underpasses (18 bridges and 28 culverts) were studied to determine wildlife use. Dual structures that were separated by a median over 100 feet and twin cells culverts were evaluated as separate underpasses. The field screening study revealed that many of the larger bridges, i.e., multiple spans and viaducts that span the entire length of the floodplain, were used by a variety of wildlife from rodents to large mammals; however, it appeared most of the culverts were generally used by smaller mammals (e.g., raccoons, opossums, skunks). Wildlife signs were documented within 9 of 18 bridges; however, because of nearby animal signs and generally large travel spaces under bridges, we expect others may be used. No further study was conducted on wildlife movements under bridges.

Of the 28 culverts evaluated, all contained concrete bottoms, although approximately 50 percent had sediment and stream-bottom material deposited over the concrete. The average openness index for all culverts field evaluated was 0.5. Nine culverts were selected for infrared camera monitoring study. The majority of these culverts contained poor interior tracking conditions (i.e., concrete substrate and/or fast moving water) and could be better evaluated for wildlife use with a motion-sensor device and camera system.

Monitoring Device

Wildlife movements through culverts were recorded by the use of infrared sensor monitors. Three TM550 Passive Infrared Trail Master® Monitors™ were selected (Goodson and Associates, Inc., 10614 Widmer, Lenex, KS 66215, 800-544-5415). Each monitor consists of a one-piece unit, which is designed to detect the presence of body heat and motion. Both body heat (temperature differentials) and motion must be present at the same time for an event to be recorded. Any animal activity in the area will cause the monitor to register

these movements and take a picture called an “event.” A Trail Master TM35-1 camera kit was purchased separately, which consists of a Yashica T4 Super D camera, 25-foot camera cable, camera shield, and a tree pod for mounting. This camera requires 35mm film and has been specifically adapted for use with TrailMaster systems. The camera is triggered from the monitor to take a photograph when the infrared transmitter beam is broken. The monitor picks up any warm-blooded mammal movement through the area of sensitivity. This transmitter sends out an infrared beam which is 65 feet long and spreads an elliptical cone of 150° wide and 4° high. The 4°-vertical-beam height spreads one foot for every ten feet away from the monitor. Thus, at 40 feet, there is a four-foot-high beam. This monitor has a sensitivity setting, which allows the user to select the size and movement of the animals to be monitored. This sensitivity setting works by registering the amount of interrupted pulses within a selected time period. A larger animal (bear or deer) will interrupt more pulses in a given time frame than a smaller animal, such as a raccoon. There is also a camera delay setting allowing a delay between photographs from 0.1 to 98 minutes, so that a single event will not be counted multiple times.



Fig. 3. TM550 Trail Master Infrared monitor bolted to the culvert wall.

For this study, the level of sensitivity was set at high/medium. This setting is optimal for capturing animals ranging from small mammals (e.g., weasel) to large mammals (e.g., deer or bear). The camera delay was set to take a photograph every six seconds when an animal was within the zone of sensitivity. The Trail Master infrared monitor was housed in a metal container and the camera was mounted on top (figure 3.). The whole unit was then bolted to the inside of the culvert wall with lead anchors and 0.5in x 2in lag bolts for safety and security. The unit was always mounted at a height of 30 inches, a height recommended by Trail Master for best registering deer. We used Fuji Super HG, 1600-ASA speed film with 36 exposures for color prints. The film speed allowed for high quality photographs at night. During an initial test, we discovered that light illumination from the flash was bouncing off the bright sides of the concrete culverts causing the flash to prematurely shut down and blurring some photographs. To alleviate this problem, a 2ft x 3ft area adjacent to the camera flash was painted with a no-gloss flat black spray paint. In addition, black electrical tape was placed over a quarter of the infrared beam window to match the area with the camera view finder. Each camera unit remained in a culvert from Monday through Friday because of concern of vandalism, and each one was monitored for a total of a two-week time span separated by at least a month. Raccoons were the most abundant species using the drainage culverts in this study.



Fig. 4. Two examples of culverts monitored during the Phase I study with wildlife traveling through them.

Results of the Camera Monitoring Phase I

From September 18 to November 24, 2000, ADM monitored nine culverts to determine wildlife use. A variety of species were detected by the monitoring units, including white-tailed deer, black bear, raccoons, opossums (*Didelphis marsupialis*), long-tailed weasel (*Mustela frenata*), feral cat (*Felis domestica*), great blue heron (*Ardea herodias*), red fox (*Vulpes fulva*), striped skunk (*Mephitis mephitis*) and humans (see table 1). Only one culvert (structure #31) was confirmed through infrared monitoring to be used by white-tailed deer. This was the largest culvert monitored with an arch shape that was 19 feet high by 19 feet wide and 250 feet long. Bucks and does were observed heading in both directions on several nights during the monitoring session. All but one culvert, structure #34, had wildlife use.

The culverts evaluated in the Wildlife Underpass Study, "Phase I" of April 2001, varied considerably in size, interior substrate conditions, water depth, adjacent habitat, and presence of right-of-way (ROW) fencing. The average openness index (OI) of the culverts was 0.50. Because of a small sample size of culverts, statistical comparisons of structure characteristics between used and non-used culverts could not be made. A Phase II Study was initiated to further address the protection of wildlife travel corridors and roadway safety issues by gathering more data on wildlife underpass usage.

Phase II Mythology

An expanded study of culverts throughout PENNDOT District 3-0 was initiated to better determine what size drainage culverts would most likely be used by white-tail deer as underpasses. In this "Phase II" Study, ADM identified and studied culverts with larger openness indices (0.5 and above). ADM followed a methodology similar to the Phase I Study including (1) updated literature search, (2) structure identification, (3) field screening study, and (4) remote infrared camera monitoring survey. Each culvert was documented with regard to dimensions, interior characteristics, location, topography, and adjacent habitat features that contribute to and potentially enhance the usage of culverts by white-tailed deer. White-tailed deer were the target species as deer-vehicle accidents have dominated the yearly totals of incidents with alarming numbers of human fatalities, deer killed, vehicles damaged as well as increased personal liabilities in insurance costs (Romin 1994, Cook and Daggett 1995, Bruinderink and Hazebroek 1996, Danielson and Hubbard 1998, Jackson 1999).

A search of the Districts' database files was conducted for all the culverts within District 3-0. It was determined by PENNDOT to focus the study on reinforced concrete (R/C) box culverts which are commonly incorporated in their highway development plans for drainage. The search identified a listing of 70 potential box culverts that would be field screened to determine white-tailed deer use. A data form was filled out on-site for each of the culverts and photographs taken. From the final field screening efforts, 20 box culverts were considered to be the best potential underpasses for deer. Information for each of the selected culverts was collected from April 4 to April 19, 2002. Consistent with the Phase I Study, the evaluation information recorded included: length (opening to opening), width, height, openness index, interior substrate, percent visibility through the culvert, present/absent of right-of-way (ROW) fencing, nearby land use, habitat cover, roadway average daily traffic (ADT), and tracking conditions in and around culverts. The Phase II camera monitoring study was separated into two seasons: 10 culverts were monitored in the fall (September–November) of 2002, and 10 culverts in the spring (May–July) of 2003.

Results of the Phase II

A variety of species was detected in the culverts, including black bears, white-tailed deer, raccoons, ducks, muskrats, opossums, dogs and humans. The target species of the Phase II study, white-tailed deer, were photographed in nine culverts. Black bears were photographed in two culverts, and people were photographed in three culverts. Again, as in the Phase I study, raccoons were the most common species photographed in the culverts. However, white-tailed deer were the second most abundant species photographed in the culverts.



Fig 5. Four examples of culverts with white-tailed deer traveling through them.

Discussion

The Phase II study evaluated the use of box culverts by white-tailed deer as travel routes to access either side of the highway. A range of sizes of box culverts were included in the evaluation to determine the size most likely to be used by deer. Nine box culverts out of the twenty (9/20 = 45%) monitored were found to have deer movement. The average Openness Index of these nine culverts was 0.92. The average width was 15.3ft, the average height was 8.2ft and the average length was 164ft (table 2). The Openness Index of the culverts used by white-tailed deer ranged from 0.46 to 1.52. In the Phase II Underpass Study the longest culvert used by white-tailed deer was 286 feet long. Two culverts monitored with longer lengths of 356ft and 370ft had no white-tailed deer use. By comparison, the average dimensions of box culverts not having deer movements in this study was 212ft long, 7.5ft high and 14.8ft wide. The average Openness Index for those culverts that did not have deer movement was 0.68 and ranged from 0.19 to 1.62.

A culvert's suitability for wildlife should not be evaluated based solely on its Openness Index, but for new construction it should be a major consideration. Other criteria, such as surrounding habitat, fencing, noise levels, and approaches, also need special consideration in the design of successful underpasses.

Based on the field screening studies from the Phase II study, a majority of the culverts (50/70 = 71%) evaluated appeared not to have sufficient structural and surrounding characteristics to facilitate deer movements and were not monitored. Many culverts had longer lengths (300ft +) with small widths and heights which led to a tunnel effect. A number of culverts had irregular entrances, such as large plunge pools, blockages from woody debris, or overgrown vegetation concealing the culvert openings. Other culverts did not contain natural topographic features or right-of-way fencing to aid in directing the animals to the underpass.

Water Within the Culverts

All nine culverts with deer usage contained some level of water. Several culverts containing deeper water (0.5ft to 2ft) were found to be used by white-tailed deer. However, some culverts that were permanently inundated with several feet of water (3ft-5ft) were assumed not to facilitate deer and other mammal movements because of the submerged conditions. A field tracking and screening study of culverts in the winter of 2002-2003 revealed potential problems for deer movements through drainage culverts. The culverts that contained deer movements during the fall of 2002 monitoring were visited again during the winter screening study. In colder winter months with temperatures below freezing for extended periods of time, water inside of the structures froze. These conditions essentially turned the culverts into impassable barriers. No sign of deer was found within or around the culverts.

Substrate Within Culverts

Substrate surfaces within underpasses have been found to play an important role for certain species of wildlife using these structures (Jackson and Griffen 1998). Natural substrate compared to the concrete bottoms in the culverts did not appear to influence white-tailed deer movements in this study. No correlation between bare concrete bottoms and bottoms which contained a natural material were evident in influencing deer usage. Approximately two-thirds of the culverts (6/9 = 66%) which contained deer movements had bare concrete bottoms. The culverts, in which deer movements were photographed, contained a combination of substrates, including bare concrete, water up to 3ft deep, and natural sediment. Wildlife tracks in culverts with natural sediment are more apparent, which could cause the appearance of higher wildlife usage. One comparison was made between two culverts which were similar in size but containing different substrate in the highway median between the east and westbound lanes. Structure #105 contained a 310ft concrete chute between the east and westbound I-80 structures. This concrete surface did not allow any vegetation to grow within the stream corridor. Structures #103 also contained a 310ft open median between I-80 but did not contain the concrete chute which allowed vegetation to grow and provided a natural landscape between the culverts. Both culverts had deer use; however, structure #103 had a greater diversity of species use.

Other small mammal evidence (beaver and raccoon) were found in the median. Natural pool and riffle complexes containing small fish and macroinvertebrates were also noted in this median stream bed corridor of #103. Maintaining the natural stream bed and riparian corridor within a wide highway median can create some refuge for wildlife species when in the process of traveling through directed underpasses.

Approaches to Culverts

Approaches to the culverts (i.e., entrance and exit areas, land surfaces and surrounding vegetation) have been found to be an important factor in deer usage (Jackson and Griffen 1998). Eight of the nine culverts (8/9 = 88%) that had white-tail deer usage had a level approach, no vegetation obstacles, and no plunge pools. Numerous culverts during the field screening study were found to have steep drops resulting in large plunge pools (5ft-7ft wide with 3ft-5ft deep) on the downstream side of the culverts. This could affect deer and other wildlife's ability to reach the culverts' entrances. In several cases, trees and logs had fallen over or near the entrance, creating a barrier for large mammals such as deer to enter or exit the culvert freely. In the two most frequently culverts used by deer (structures #16A and #47B) entrances were open, and had level approaches.

Right-Of-Way Fencing

Of the 20 culverts selected for camera monitoring, 13 included right-of-way fencing that was tied into the culvert's wing walls (13/20 = 65%). The camera monitoring revealed that of the nine culverts that had white-tailed deer usage, six included R-O-W fencing (6/9 = 66%). In many underpass research studies, some type of fencing appeared to help guide wildlife species into underpasses and culverts (Jackson and Griffen 1998). In Europe, fences have been used extensively to keep wildlife off major highways. In past studies, research that endorses using fencing stresses the need for regular maintenance of the fencing, as deer will regularly test and look for holes or breaches to cross the fencing. In this study, white-tailed deer were crossing into the right-of-way at breaches in the fence near three sites (structures #16A, #12, and #105). PENNDOT has used taller fencing in the areas of known high wildlife/vehicle collisions in the past with moderate success. Surrounding topography can also play a part in naturally directing deer into culverts.

Conclusions

Based on the results of the Phase I "Wildlife Underpass Study" and the Phase II "White-Tailed Deer Use of Existing Culverts," it is evident that white-tailed deer and other wildlife species do use culvert structures. Whether they are being used specifically as underpasses or by accident, culverts can provide a safe conduit under highways. Some animals were only photographed using the structures in one direction, perhaps indicating that they were traveling for dispersal reasons or returned by crossing the road. Other wildlife were observed nightly, presumably as part of their routine search for food or travel patterns. Overall, the majority of culverts field screened and surveyed for the Phase II Underpass Study appeared not to facilitate deer usage. Seventy culverts were field evaluated for the Phase II Study, but only 20 culverts showed potential for deer usage (20/70 = 28%). Of these 20 culverts, nine contained deer movements. Consideration must be made that these culverts were placed specifically for the conveyance of waterways underneath highway corridors and not for animal corridors. Focusing on the features associated with culverts which had deer use will offer the best insight into designing successful underpasses. Culverts that did not have deer movements through them contained too many variables to conclude the reason for their non-usage. The average dimensions in this study of the culverts with white-tailed deer movement was 8.2ft (ht.) x 15.3ft (width) / 164 (length), suggesting these may be minimum ranges for underpass sizes. Ranges and averages of culverts that white-tailed deer traversed are available from this study (see table 2). The length of the culvert is often fixed based on the width of the roadway. Based on our data of no white-tailed deer usage in culverts over 286ft in length, we recommend

when the length of the culvert is increased, the height and width should also be increased to help offset a narrow Openness Index for white-tailed deer.

Many states are using culverts of varying size in upland areas for a wide variety of wildlife species from small mammals to ungulates, as reported by Evink (2002), but he asserts there is a lack of formal research as the states experiment with different designs. Providing dry areas and/or upland culverts for wildlife could help to alleviate such problems and allow the structures to operate as underpasses throughout the year. Modifying existing drainage culverts to accommodate wildlife by constructing shelves, elevated concrete walkways, and docks have been successful for small mammal use, amphibians and reptiles in Texas, Montana and The Netherlands (Evink, 2002). There are many variables for different species and site conditions. In this study, features surrounding the culverts appeared to play an important role in increasing deer usage of culverts. A combination of right-of-way fencing, topography, land approaches, habitat cover, visibility and deer densities contributed highly to white-tailed deer movements through culverts. Post-construction monitoring of modified and constructed wildlife structures provides vital data in building successful wildlife underpasses.

Features such as eight-foot or higher fencing tied into the structures may funnel movement toward the underpass and encourage their use, but the fences need to be maintained. Maintenance for wildlife features can be easily overlooked in the planning, documentation, design and construction of wildlife structures; however, it can be critically important to the long-term success of such features (Evink, 2002). Jackson and Griffin (1998) recommend a height of at least 8 feet and the fencing should be tied into the opening of the underpass for a directional effect. This practice should also be incorporated to existing culverts and bridges as they have been documented as wildlife underpasses.

Culverts and bridges are inspected routinely for safety and maintenance measures. By expanding criteria over standard inspected items with wildlife use in mind, e.g., vegetation control, woody debris blockages in and around culvert entrances, condition of fencing around the structure and along the R-O-W, you could increase the usage of culverts by deer and other wildlife. Maintenance of fencing can be one of the most expensive activities for wildlife mitigation techniques. Run-off-the-road vehicles and falling trees often damage fencing and, unless quickly repaired, animals will find their way through these breaches and on to the right-of way (Evink 2002).

The size and openness of the culvert are important considerations; however, many other factors contribute to their use. Indigenous plantings adjacent to underpass openings may promote use. Avoiding the use of palatable plant species in roadside and median plantings may keep animals from entering the roadway, thus decreasing the chances of a wildlife-vehicle collision. To increase the chances of underpass use, they may be constructed in areas of known animal movements (e.g., valleys or riparian corridors). Wildlife movement corridors may be evaluated in the planning/environmental phases of a project to help identify potential areas where underpasses may be considered. Post-construction monitoring of modified and/or constructed wildlife structures is vital for refining information necessary to design and build successful wildlife underpasses. In defining species needs and requirements during early phases of the highway planning process, mitigation procedures in the form of underpasses can often offset potential fragmentation, wildlife mortality and wildlife-vehicle collisions. Of various mitigation measures, we feel box culverts can be used as successful white-tailed deer underpasses if constructed with the appropriate surrounding features, suitable size and proper placement.

Table 1.
Results of the Culverts Monitored During the Phase 1 Underpass Study.

Structure #	4A - eastbound	7	7A	8	10	11	31	34	52
BMS	59 0080 2000 1250	49 0180 0514 0644	Not available	41 0180 0484 0864	41 0180 0430 0105	41 0180 0420 1542	41 0015 0620 2614	41 0015 0701 0648	58 0015 0710 0000
Structure Type	RC Box Culvert	RC Box Culvert	Arch Culvert	Twin Cell RC Box Culvert	RC Box Culvert	RC Box Culvert	RC Tied Arch Culvert	RC Box Culvert	RC Box Culvert
Length (feet) ¹	105	360	184	356.75	450.75	406.25	250	378	315.5
Width (feet)	12	10	16	2@15	8	8	19.1	12	8
Height (feet)	9	6.5	10	7	4.5	8	19	9.5	5
Openness Index ²	1.03	0.18	0.87	0.29	0.08	0.16	1.45	0.30	0.13
Stream/Road Crossing	Lick Run	B. Warrior Run	B. Warrior Run	Glade Run	Turkey Run	Twin Run	Trout Run	Steam Valley Creek	Bentley Creek
Visibility (%)	80	10	80	15	5	25	75	25	10
Land Use - N/E Approach ³	forest / rangeland	forest / rangeland	forest / rangeland	forest / rangeland	agriculture	forest / rangeland	forest / rangeland	forest / rangeland	forest / rangeland
Land Use - S/W Approach	forest / rangeland	forest / rangeland	forest / rangeland	forest / rangeland	agriculture	forest / rangeland	forest / rangeland	forest / rangeland	forest / rangeland
1st Monitoring Session	Oct. 9-13, 2001	Oct 16-20, 2001	Oct 16-20, 2001	Oct. 2-6, 2001	Sep. 25-29, 2001	Sep. 25-29, 2001	Sep. 18-22, 2001	Sep. 18-22, 2001	Oct. 23-27, 2001
Wildlife Use	Raccoons	Raccoons	Great Blue Heron, Raccoons, Opossum, Long tailed Weasel, Feral Cat	2 sets of People, Raccoons, Skunk	Raccoons	2 Black Bears	White-tailed Deer- Several bucks, doe w/ fawn, Great Blue Heron, Raccoon	None	Red Fox
2nd Monitoring Session	Nov 13-17, 2001	Nov. 18-24, 2001	Nov. 18-24, 2001	Nov. 6-10, 2001	Oct. 30 - Nov. 3, 2001	Oct. 23-27, 2001	Not monitored ⁴	Oct. 9-13, 2001	Nov. 13-17, 2001
Wildlife Use	Opossum, Person	Raccoons	Feral Cat, Opossum, Raccoons	Raccoons	Raccoons	None	NA	Person	Raccoons

¹ Length, width and height are of the underpass. Height represents clearance within the center of the underpass.

² Openness Index (OI) = (Height * Width) / Length

³ Predominant land use within 1/4 mile of approach based on aerial photos, USGS topographic maps and field observations.

⁴ Structure #31 was not monitored a second time due to confirmed use and time constraints.

⁵ Structure #34 was monitored a third time (Oct. 30 - Nov. 3) to determine the effects of culvert modifications on wildlife use. No wildlife use was recorded during this third monitoring session.

Table 2.
Results of the culverts utilized by white-tailed deer during the Phase II Wildlife Underpass Study.

Structure #	#99	#105 West	#132	#46 A-East	#47 B-West	#103-West	#37	#16 A	#16B
BMS #	59-0015-0270-0000	59-0080-1965-1903	59-0015-0300-0044	47-0080-2180-0299	47-0080-2181-0354	59-0080-1951-2134	41-0973-0570-0000	41-6015-0380-0693	41-6015-0380-0693
County	Union	Union	Union	Montour	Montour	Union	Lycoming	Lycoming	Lycoming
Structure Type	R/C Box Culvert	R/C Box Culvert	R/C Box Culvert	R/C Box Culvert	R/C Box Culvert	R/C Box Culvert	R/C Box Culvert	Twin Cell Box Culvert	Twin Cell Box Culvert
Length (ft) ¹	129	142	235	112	116	89	81	286	286
Width (ft) ¹	18	13	12	19	19	13	12	16	16
Height (ft) ¹	10	7	9	8.5	8	6.5	7	9	9
Openness Index ²	1.4	0.64	0.46	1.52	1.31	0.95	1.04	0.5	0.5
Median Width (ft)	N/A	310	N/A	330	330	300	N/A	N/A	N/A
Stream Corridor	T. Susq. River	Kurtz Gap Run	T. Susq. River	T. Beaver Run	T. Beaver Run	SandSpring Run	T. LoyalSock	Beautys Run	Beautys Run
Substrate ³	concrete/silt	concrete	concrete	concrete/silt/ 6-12" water	silt/sand/ 6-12" water	concrete	concrete/silt	silt/1' water	silt/water
Visibility %	80%	85%	75%	80%	80%	80%	90%	75%	75%
R-O-W Fencing	no	yes	no	yes	yes	yes	no	yes	yes
Land Use-N/E Approach ⁴	Susq. River	forest	deciduous forest	agriculture	agriculture	mixed forest	deciduous forest	wetland/ag	wetland/ag
Land Use - S/W Approach ⁴	agriculture	forest	agricul/forest	mixed forest (median)	mixed forest (median)	shrub/scrub (median)	mixed forest	wetland/shrub	wetland/shrub
Attractors ⁵	corn field	none apparent	corn field	corn field	agriculture	thermal cover	PGC game farm	agriculture	agriculture
ADT ⁶	20,000	20,000	23,000	13,738	14,345	20,000*	1165	16,000*	16,000
1st Monitoring Session	June 2 - 6, 2003	June 23 - 30, 2003	June 2 - 9, 2003	Oct. 21-28, 2002	Oct. 21-28, 2002	Oct. 7-14, 2002	Sept. 30-Oct. 7, 2002	Sept. 30-Oct. 7, 2002	Sept. 30-Oct. 7, 2002
Wildlife Use	Raccoons	White-tailed deer	Person (fisherman)	No	White-tailed deer	Raccoons / Beaver	White-tailed deer, Bear	White-tailed deer	White-tailed deer
2nd Monitoring Session	June 30- July 7	June 23 - 30, 2003	June 23 - 30	Nov. 11-18	Nov. 11-18	Nov. 4-11	Oct. 28 - Nov. 4	Oct. 28-Nov. 4	Oct. 28 - Nov. 4
Wildlife Use	White-tailed deer, raccoons	No	White-tailed deer	White-tailed deer	White-tailed deer	White-tailed deer, Raccoons	White-tailed deer, Raccoons	White-tailed deer	White-tailed deer
Average Dimensions	8.2 (Height)	15.3 (Width)	164 (Length)						

¹Length, width and height are of the underpass. Height represents clearance within the center of the underpass

²Openness Index (OI)=(Height*Width)/Length

³Material within culvert (e.g. concrete/natural bottom/water/sediment/silt)

⁴Predominant land use within 1/4 mile of approach based on USGS topographic maps and field observations

⁵Habitat features that may attract wildlife to the area

⁶ADT-Average Daily Traffic-based on file review and * asterisks are from Type 4 maps

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