CREATING RESILIENT WILDLIFE UNDERCROSSINGS WITH INTERLOCKING PAVEMENT BLOCKS

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ABSTRACT

From 2005-2011, Nebraska rebuilt Interstate 80 between the cities of Lincoln and Omaha by dividing the corridor into 8 projects to replace the existing 4-lane interstate with 6 lanes. Mahoney Interchange to Ruff Road is a 4-mi (6.4 km) segment that crosses the Platte River with 4 sets of reconstructed bridges.

The mainline I-80 bridges within the entire corridor were redesigned to increase the span of the existing channels and the channel slopes were modified to provide a larger undercrossing for wildlife with a better field of view. A concern was raised about scouring of the wildlife undercrossing with water off the overhead bridges. Typical design includes rock riprap (solid rock with a maximum diameter of 2 feet) installed under the drip line of the bridge. Wildlife biologists believe large diameter riprap would preclude deer and other wildlife from using the undercrossings. We decided to use interlocking pavement blocks (IPBs) that would be resistant to erosion, allow local grasses to proliferate, and facilitate wildlife use. We monitored deer and other wildlife use of the undercrossings with motion-activated infra-red cameras.

The IPBs were effective over the 5 year evaluation in maintaining erosion protection to the wildlife undercrossings and allowing vegetative growth to occur during occasions of high water and a year of severe drought. We recorded 11,901 deer and 15 additional species of wildlife using the undercrossings. By implementing the effective use of low-cost undercrossing improvements with IPBs, transportation designers can promote ecological services such as habitat connectivity and vegetative growth while reducing long-term maintenance costs.

INTRODUCTION

The current design standard for armoring bridge piers and abutments in channels includes rock riprap, which is the placement of several tons of 2-ft (0.6 m) diameter solid rock. The riprap typically surrounds the abutment and piers to prevent scouring of the channel bank (Figure 1) from high water and to catch storm water falling off the bridge deck. Although a minor cost in comparison with the multi-million dollar structure that is being protected, riprap does not allow vegetative growth to occur for several years, if at all. In addition, as the riprap is placed on top of the soil and does not become a cohesive part of the slope, maintenance personnel check the riprap locations every few years for movement from the concerned areas to determine if reapplication is needed. Wildlife biologists believe the large diameter riprap prevents deer and other wildlife from using the undercrossings and instead forces movement across roadways (Austin and Garland 2001, Cramer and Bissonette 2005).

FIGURE 1. Typical scour protection on Nebraska bridges.

Roadway culverts and earth ditches often use "interlocking pavement blocks" (IPB, Figure 2). These IPBs are available throughout the world as an erosion control block with applications for retention basins, shoreline protection, and drainage ditch lining. Interlocking pavement blocks can be substituted in place of riprap in some instances and may provide additional ecological benefits. IPBs allow growth of local vegetation between voids eventually creating an unnoticeable erosion grid that is accessible to wildlife and will continue to provide long-term scour protection.

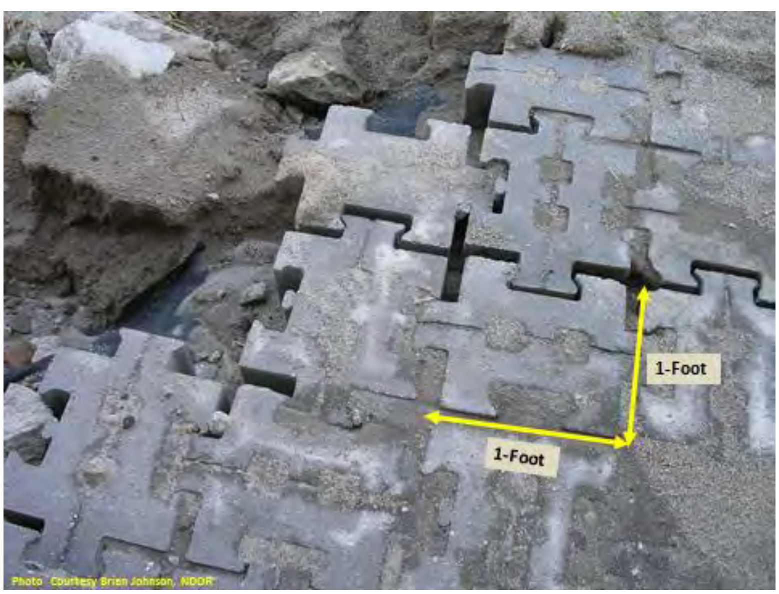

FIGURE 2. Interlocking pavement blocks.

Poorly designed roadways can serve as barriers that hinder wildlife movement and pose conservation challenges (Wilcox and Murphy 1985, Ferreras 2001). Genetic divergence has been reported in both small and large species of wildlife as a result of roads that function as barriers to the movement of wildlife (Epps et al. 2005, Kendall et al. 2009, Clark et al. 2010). Wildlife-vehicle collisions pose a risk of injury or death to wildlife and humans. Huijser et al. (2008) estimates more than 1 million accidents with large animals occur in the United States annually resulting in over 26,000 human injuries and 200 human fatalities. Undercrossings designed with wildlife use in mind can help maintain habitat connectivity and aid in reducing wildlife-vehicle collisions.

The objectives of this project are to:

1) determine the efficacy of interlocking pavement blocks at preventing erosion along bridge drip lines
2) determine the efficacy of interlocking pavement blocks at permitting vegetative growth within and among blocks, and
3) determine wildlife-use of undercrossings constructed of interlocking pavement blocks

STUDY AREA/BACKGROUND

An environmental assessment (EA) of the Interstate 80 (I-80) corridor between Lincoln and Omaha, Nebraska began in 1999 to determine the impacts for widening the interstate to 6 lanes. Interstate 80 is a major arterial highway in the regional transportation network connecting to other east/west and north/south interstate routes. The 6-lane expansion corridor extended for 35 mi (56.3 km) from NW 56th Street, west of Lincoln, to Ruff Road, which is east of the Platte River (Figure 3). Total reconstruction costs associated with this corridor were estimated to be near $400 million.

Interstate 80 needed to be expanded to 6 lanes because: traffic was expected to increase beyond the lane capacity of the existing 4-lane section; various sections of I-80 had substandard vertical and horizontal geometry for a 75 mph (120.7 km/h) interstate; it was over 40 years old; and cross-over accidents through the depressed medians separating each direction were a safety concern.

FIGURE 3. Project location. Red line represents the 35 mile reconstruction project. Undercrossing redesign occurred near the Platte River in between Lincoln and Omaha.

The existing cross section of I-80 was a 4-lane roadway with 2 lanes in both directions and a 64-foot (19.5 m) depressed median measured between the edges of each inside lane. The depressed median was turf except for the 4-foot (1.2-m) paved inside shoulder. The outside shoulders were 10-feet (3-m) wide and paved with a 4:1 turf foreslope free of obstacles to 30 ft (9.1 m) from the edge of travelled lane.

The reconstructed 6-lane cross section of I-80 has 3 lanes in both directions and a 76-foot (23.2 m) depressed median measured between the edges of each inside lane. The depressed median is turf except for the wider 12-foot (3.7-m) paved inside shoulders. The outside shoulders also are wider, with 12-foot (3.7-m) paved and a flatter foreslope at 6:1 with obstacles to 35 ft (10.7 m) from the edge of travelled lane.

All existing mainline bridges were reconstructed to accommodate the wider median and to provide the 3 lanes with 12-foot (3.7-m) inside and outside shoulders. A hydraulic analysis was performed on the structures to determine if longer channel spans were necessary to provide capacity for long-term flood issues. The Platte River Bridge and Sarpy Ditch Bridge (Figure 4) had the vertical profile raised 6 feet (1.8 m) to accommodate a 100-year flood and the number of piers within the channels reduced to lessen the ice jam impact on adjacent land.

FIGURE 4. Locations of modified undercrossings. Colored arrows indicate the locations of the 6 undercrossings.

Overhead structures were reconstructed to span the new interstate and the 35-foot (10.7 m) lateral obstacle clearance. Some were realigned in new locations to eliminate geometric deficiencies. The Pflug Road Bridge (Figure 4) was relocated west of the existing structure as the county officials agreed to remove the old Pflug Road Bridge and Ruff Road Bridge and combine funds for a larger structure.

The Mahoney to Ruff Road project began in July 2005. All undercrossings were functional by July 2008, and roadway work was completed by May 2009. This extensive period was due to the realignment of I-80 over the Platte River, avoiding certain aspects of the bridge construction during pallid sturgeon (*Scaphirhynchus albus*) spawning and interior least tern (*Sterna antillarum athalassos*) nesting periods, a profile grade raise of 6 ft (1.8 m) to the east of the Platte River, and the phased construction while coordinating interstate traffic.

Prior to the project, a field check of the existing bridges was made to determine the functionality of the undercrossings. At the Sarpy Ditch Bridge (Figure 5), a deer path was clearly visible which skirted past the bridge and headed directly toward interstate traffic.

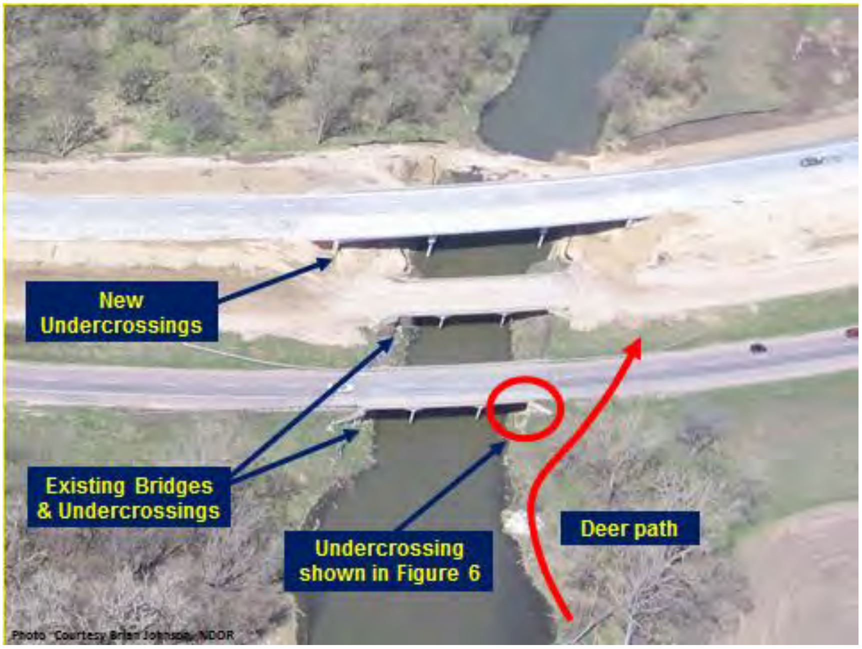

FIGURE 5. Sarpy Ditch Bridge, April 2007

As these bridges were constructed in the 1960's, the only engineering standard considered as part of the design was to provide an opening which met the hydraulic needs of the channel. No design standards for animal crossings were available or even considered at that time. Each bridge could be classified as an inoperable deer undercrossing as these did not provide a good field of view, had broken concrete strewn about the potential pathway, and did not meet the minimum 6-ft (1.8 m) vertical clearance necessary for antlered deer (Figure 6).

FIGURE 6. Existing Sarpy Ditch Bridge undercrossing.

The EA determined that special design considerations were needed near the Platte River for white-tailed deer (*Odocoileus virginianus*) crossing under I-80. The document requested placing deer fence on the east side of the Platte River Bridge to roughly 2 mi (3.2 km) east, with the intent of funneling deer to the bridges in the area. After the Pflug Road Bridge was relocated, this became the terminal location east of the Platte River.

Traffic volumes on I-80 were highest in the area of the Platte River with Average Daily Traffic (ADT) equal to 36,500 in 2002 and estimated to be 83,200 by 2030. We reviewed accident reports from the NDOR Traffic Safety Division and determined that 2.4 DVCs/mi/yr (1.5 DVCs/km/yr) occurred to the east of the Platte River and 4.2 DVCs/mi/yr (2.6 DVCs/km/yr) occurred in the 1 mi (1.6 km) stretch west of the Platte River to the Mahoney Interchange between 1998 and 2003. The NDOR further decided to construct a deer fence west of the Platte River to the Mahoney Interchange. The exclusionary deer fences were erected between the Highway 66 interchange (MP 426.26) and the Pflug Road Bridge (430.61) between December 2010 and October 2011.

METHODS

Resilient Undercrossings

We looked at options for removing the riprap from the undercrossing that would provide similar scour prevention and selected IPBs. IPBs were placed along the inside and outside edges of the eastbound and westbound interstate bridges over the shores of the Platte River and Sarpy Ditch at a total of 16 locations. Typical gross area per block is 1 ft^2 (0.09 m^2) and the block thickness is 6 in (15.2 cm). Each weighed 52 lbs (23.6 kg) and had a compressive strength of 4000 psi (281.2 kgf/cm^2). Although other thicknesses are available, we determined that the 6-in (15.2-cm) block thickness should be used in an undercrossing to resist instability during high water in which scouring may occur around the grid. The blocks were situated on filter fabric and filled with local soil to allow vegetation to propagate. We evaluated construction costs between riprap and the IPBs by comparing a 100 ft^2 (9.3 m^2) area.

We limited riprap placement to protect the abutment bank and allow the flat berm to be free of obstacles (Figure 7). Redesigned underpasses ranged in width from 36 feet (11 m) at the Sarpy Ditch Bridge to 104 feet (31.7 m) at the east shore of the Platte River. The bridge spans at the Sarpy Ditch and Platte River bridges were extended due to the hydraulic needs for conveying water during ice jams and facilitation of wildlife use. As part of the 6-lane expansion project, we constructed 6-ft (1.8-m) wide grids with IPBs centered under the drip line of each side of the bridge decks to eliminate scouring and reduce the velocity as the water spreads onto the adjacent soil berm.

FIGURE 7. New wildlife undercrossing at Sarpy Ditch Bridge, May 2009.

Unprotected soil under bridges can be scoured easily (Figure 8), requiring significant maintenance work on a frequent basis as well as making the undercrossing impassable for wildlife. We specified that the blocks toe into the riprap to collect any water flowing off the abutment bank.

FIGURE 8. Example of the erosion that can occur along the drip line of an unprotected undercrossing. Salt Creek Bridge, Mile Marker 407.97, October 2010.

Monitoring

We monitored deer movements through 6 undercrossings using motion-activated, infra-red Reconyx cameras (Reconyx Silent Image, LaCrosse, Wisconsin, USA). We installed camera systems in tamper-proof boxes on secure metal posts adjacent to the undercrossing abutments at the north and south openings of each of the undercrossings in early May, 2009. The names and locations by MP for each undercrossing were: 1) Burlington (BU, MP 426.97), 2) Platte West (PW, MP 427.29), 3) Platte East (PE, MP 427.44), 4) Sarpy West (SW, MP 427.7), 5) Sarpy East (SE, MP 427.75), and 6) Little Creek (LC, MP 428.31).

Cameras were operational from May 5, 2009 – December 31, 2012 at each of the undercrossings. All cameras, except those at BU, were programmed to expose 1 frame per second and continuously capture images when motion was detected. The 2 cameras at BU were programmed to expose 1 frame per 3 seconds when motion was detected due to the high volume of train and vehicle traffic at the site. We checked cameras and changed memory cards once per month and changed batteries every 2 months. We recorded location, date, time, sex, age-class, and number of deer for each series of images from all cameras. We recorded the location, date, time, and number for all other species of wildlife. Images from both cameras at undercrossing sites were cross-checked. If both captured images within 3 minutes of each other, the image was deleted from 1 of the 2 cameras to prevent double counting. We chose 3 minutes as the cut-off time to provide enough time for a deer to move past both cameras.

Data Analysis

We examined all drip lines protected by IPBs for signs of eroded soil causing a rill or gully and vegetative growth within the block voids. We rated every grid on two criteria, each worth 50% of the total score: 1) the percent of grid that is scour-free and 2) the percent of grid containing vegetation. A grid with 0% erosion and 100% growth would be rated as a 10.

We analyzed the patterns of deer crossings by month to determine if any differences in crossings occurred between individual sites. Crossing data also were sorted by time to determine peak travel times. We calculated an openness-ratio (height x width/length; Reed et al. 1979) for each undercrossing to determine if a relationship between the number of crossings at each site and undercrossing dimensions. Sites were categorized based on their openness ratio (Low ≤ 10, High > 10). We generated descriptive statistics and t-tests (Proc REG; SAS Institute, Inc. 2010) to compare dependent and independent variables.

RESULTS

We completed a field review of the undercrossings in April 2013, nearly 5 years after being exposed to natural erosion. None of the IPB grids, except for one due to shore failure, exhibited signs of erosion. The grids remain flush with the adjacent soil and are not vertically shifting or separating. An average of 65% of IPBs show signs of vegetative growth, with the grids shaded by the bridges experiencing slightly less growth (Table 1).

TABLE 1. Interlocking pavement block field evaluation, April 2013

Bridge	I-80	Shore	Side	In Sun or Shade	Eroded Grid Rating	Vegetative Growth Rating	Total Rating	Other Impacts
Platte	WB	west	in	Sun	10	6	8	ATVs driving across IPBs
Platte	WB	west	out	Shade	10	5	7.5	ATVs driving across IPBs
Platte	EB	west	in	Shade	10	5	7.5	ATVs driving across IPBs
Platte	EB	west	out	Shade	10	6	8	ATVs driving across IPBs
Platte	WB	east	in	Sun	10	6	8	
Platte	WB	east	out	Shade	4	5	4.5	Shoreline has eroded
Platte	EB	east	in	Shade	10	6	8	
Platte	EB	east	out	Sun	10	8	9	
Sarpy	WB	west	in	Sun	10	9	9.5	
Sarpy	WB	west	out	Shade	10	5	7.5	
Sarpy	EB	west	in	Shade	10	6	8	
Sarpy	EB	west	out	Sun	10	9	9.5	
Sarpy	WB	east	in	Sun	10	8	9	
Sarpy	WB	east	out	Shade	10	5	7.5	
Sarpy	EB	east	in	Shade	10	7	8.5	
Sarpy	EB	east	out	Sun	10	8	9	

We recorded 11,901 deer in undercrossings from May 5, 2009-December 31, 2012. In addition to deer, we observed raccoons (*Procyon lotor*), Virginia opossums (*Didelphis virginiana*), coyotes (*Canis latrans*), red fox (*Vulpes vulpes*), bobcats (*Lynx rufus*), striped skunks (*Mephitis mephitis*), badgers (*Taxidea taxus*), house cats (*Felis catus*), groundhogs (*Marmota monax*), eastern cottontail rabbits (*Sylvilagus floridanus*), Canada geese (*Branta canadensis*), wild turkeys (*Meleagris gallopavo*), great blue herons (*Ardea herodias*), barred owls (*Strix varia*), and mice (*Peromyscus* or *Mus* spp).

The number of deer crossings differed considerably among undercrossings (Figure 9). Burlington, SE, and SW combined for 72% (24%, 25%, and 23%, respectively) of all undercrossings. Deer-use of undercrossings was highest in June and November and least common from December-May (Figure 10). Burlington had the highest openness-ratio, and SE and SW had the lowest (38.8 and 3.96, respectively). We observed no relationship in the number of crossings between sites with a low ($\bar{x}$ = 2,168, SD = 833) and high ($\bar{x}$ = 1,614, SD 1,792) openness ratio (t=-0.56, P=0.6076, df=4). Deer-use of undercrossings was highest between 0200-0600 hrs and 1900-2100 hrs and lowest between 0800-1700 hrs (Figure 11).

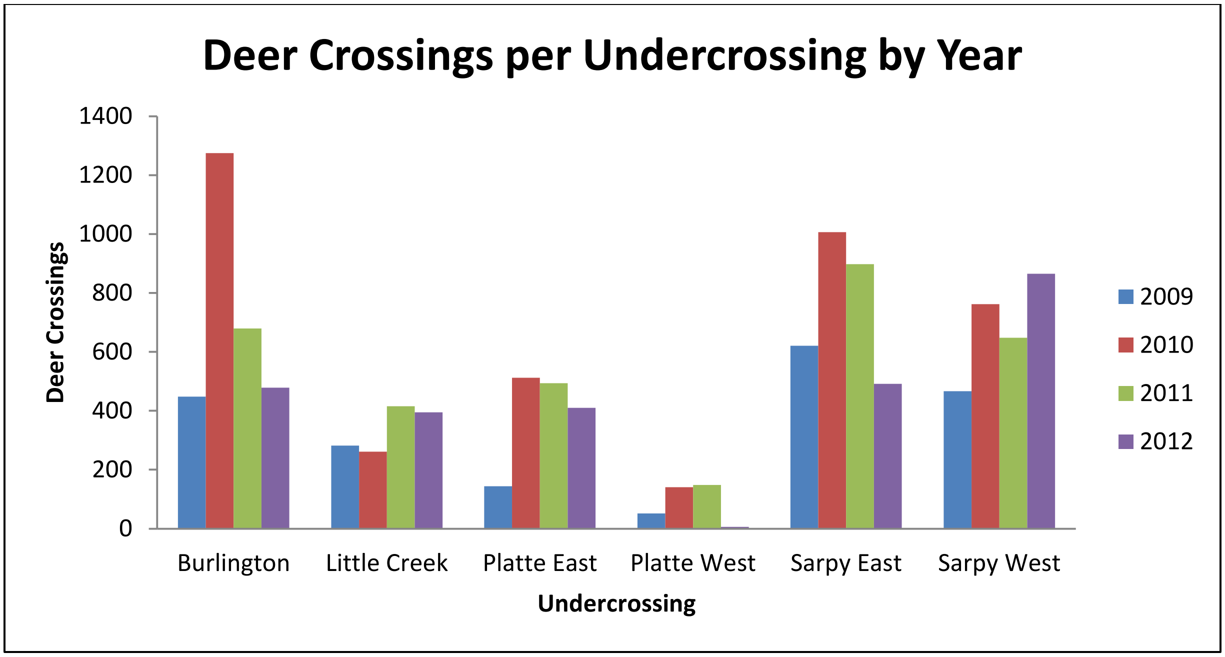

FIGURE 9. Total number of deer crossings for 6 modified undercrossings per year along I-80 in eastern Nebraska, USA, May 2009-December 2012.

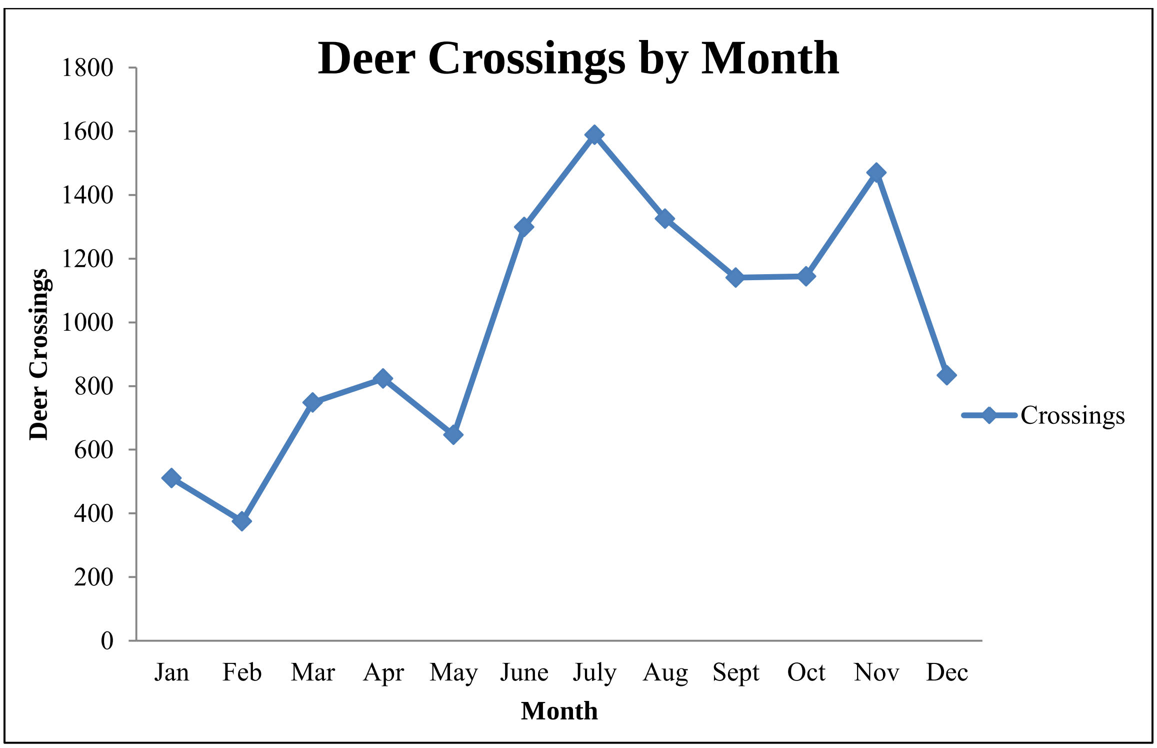

FIGURE 10. Total number of deer crossings per month for 6 modified undercrossings along I-80 in eastern Nebraska, USA, May 2009-December 2012.

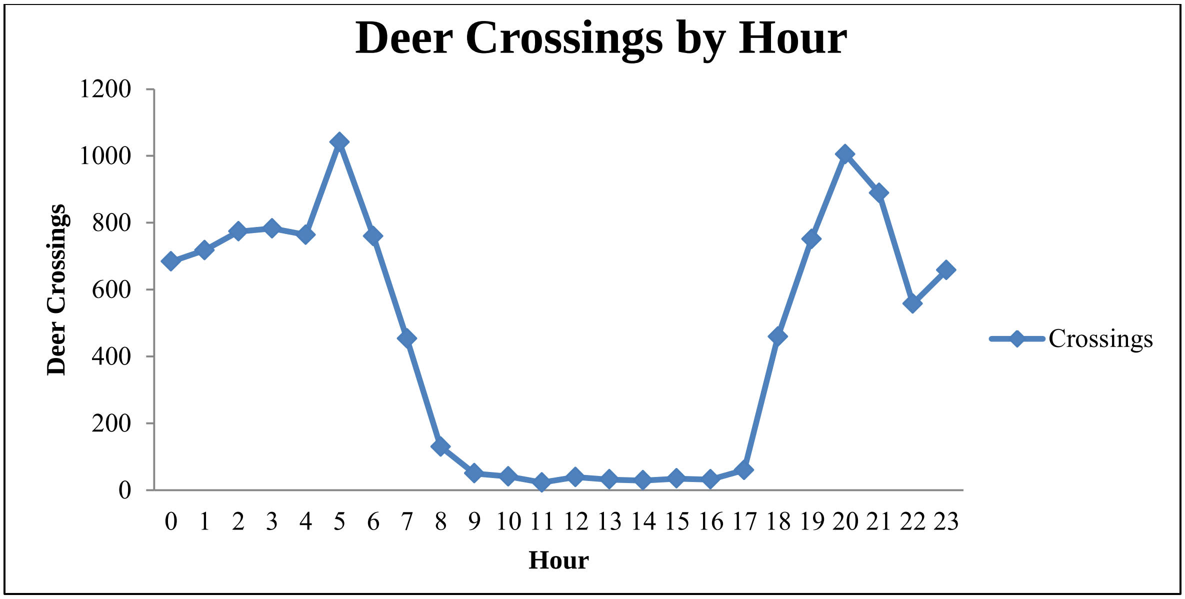

FIGURE 11. Total number of deer crossings at undercrossings by hour on I-80 in eastern Nebraska, USA, May 2009-December 2012.

DISCUSSION

After nearly five years of exposure to occasional high water and natural erosion, the IBPs have remained in place to provide an effective medium for allowing the proliferation of vegetation and preventing erosion from impacting the undercrossings. A limitation to the amount of vegetative growth is that Nebraska has been experiencing a severe drought the last two years. Several IBP grids show the presence of dead vegetation unable to survive the drought. The west Platte River vegetation was also reduced by people driving ATVs across the grids.

We did note that the IBP plans should provide more detailed construction information to provide a high point in the undercrossing constructed directly under the bridge. This will prevent storm water from accessing the middle of the bridge and eroding soil which typically does not have vegetation, as is evidenced at the east shore of the Sarpy Ditch Bridge (Figure 12).

FIGURE 12. East shore of Sarpy Ditch Bridge, April 2013

Nebraska Department of Roads average unit price for the 2012 construction season for rock riprap (Type C) was $39/ton, typically placed 2 ft (0.6 m) deep with 1.35 tons/cy (1.6 Mg/m^3), for a total cost of $390 (Nebraska 2007). The interlocking blocks are $7/$ft^2$, for a total cost of $700 per 100 ft^2 (9.3 m^2). Filter fabric was not calculated as this is present for both types of material. The Sarpy Ditch bridges needed a total of 1440 ft^2 (133.8 m^2) of erosion coverage under the drip lines, which would have been a riprap cost of $5,616 or $10,080 of IPBs.

A wide variety of wildlife readily used the modified undercrossings. The openness ratio at all undercrossings was well above the minimum recommended value of 0.6 reported by Reed et al. (1979). Foster and Humphrey discussed the importance of an unobstructed view on the far side of the undercrossing and open divided medians (1995). All undercrossings in this analysis had a clear view of the far side and had an open divided median allowing additional light to filter into the undercrossing.

Modified undercrossings that facilitate wildlife use help maintain habitat connectivity, and they may aid in reducing wildlife-vehicle collisions, especially when combined with fences. We observed an 85% reduction in reported roadkill in a 12-mile section of I-80 surrounding the Mahoney to Ruff Road project after modification of the undercrossings and installation of deer fences (A. M. Hildreth unpublished data). We noticed similar trends among months when roadkill and deer crossings occurred. Roadkill were most common in June and November and least common from December-April and July-October.

MANAGEMENT IMPLICATIONS

Minor modifications can be done to existing or reconstructed bridges using IPBs which will provide a suitable undercrossing with increased costs comparable to that of a single DVC. The material is commonly used by contractors and requires no significant training or extensive plans for placement. Long-term maintenance-free undercrossings are able to be created which provide the desirable access for wildlife. Those maintenance-free undercrossings should be combined with deer-proof fences to reduce roadkill and DVCs in select areas, while maintaining habitat connectivity that would otherwise be lost with fencing alone.

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Scott E. Hygnstrom is a professor in the School of Natural Resources at the University of Nebraska−Lincoln specializing in wildlife damage management. He received a B.S. degree from the University of Wisconsin−River Falls, M.S. degree from the University of Wisconsin−Stevens Point, and Ph.D. degree from the University of Wisconsin−Madison. He is a Certified Wildlife Biologist and past-chair of the Wildlife Diseases and Wildlife Damage Management Working Groups of The Wildlife Society.

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