15 YEARS OF BANFF RESEARCH: WHAT WE’VE LEARNED AND WHY IT’S IMPORTANT TO TRANSPORTATION MANAGERS BEYOND THE PARK BOUNDARY

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ABSTRACT

Since 1996, a long-standing program of research, monitoring, and evaluation has played a critical role in assessing the performance of mitigation measures on the Trans-Canada Highway (TCH) in Banff National Park, Alberta. This is the longest-running research project in the world that specifically investigates solutions that help reduce the conflicts between busy highways, wildlife conservation, and habitat connectivity. The wildlife crossings in Banff have been and continue to be a model of worldwide importance. The quality of science that went into their design and construction and the contribution it is has made to the critical and emerging field of road ecology is undisputable. The long history of TCH mitigation projects, the unrivaled number and types of mitigation measures, all embedded within a study area teeming with baseline ecological data, securely places Banff on the leading edge of road ecology research. Research needs to be designed to inform management. We have recently completed a comprehensive analysis of mortality and wildlife crossing data from our study area that spans nearly 15 years (Clevenger et al. 2009). Herein, we focus on the following assessments and analyses that have practical applications in transportation and environmental management: (1) Comparisons of wildlife overpass vs. underpass use, (2) the relationships between population size and rates of wildlife crossing structure use (are crossing rates surrogate measures of relative abundance?) and (3) a complete revisit of animal adaptation periods to crossing structures and how important learning curves are to determining how long monitoring should be conducted. I conclude by summarizing what we recognize as some of a dozen key contributions and discoveries from the research that has advanced the science and aided transportation agencies plan and design highway mitigation measures for wildlife.

INTRODUCTION

Canada’s Rocky Mountain front harbors the richest diversity of large mammals remaining in North America. This landscape is among the continent’s last remaining undisturbed natural areas, and provides an important trans-boundary landscape linkage with the United States (Weaver et al. 1996; Chester 2006). Today the entire Rocky Mountain cordillera on both sides of the border is experiencing rapid change. More people are moving to the area, the energy sector continues to grow and expand, recreational use is on the rise, and highway and rail traffic are on the upswing. Burgeoning suburban development is causing increasing use and expansion of transportation infrastructure throughout the Rocky Mountain cordillera (Hansen et al. 2002). New destination resort developments and their amenities are being built or expanded in most regions. As a result, landscapes that were once relatively intact are becoming increasingly fragmented. Roads are of particular concern in the Yellowstone-to-Yukon bioregion as they have been identified as one of the most severe human-caused impacts in the ecoregion (Carroll et al. 2001).

Impacts of roads on the environment are attracting the attention of the scientific and conservation community worldwide (Forman et al. 2003, Davenport and Davenport 2006, Beckmann et al. in preparation). In recent years there have been a growing number of international conferences, symposia, and special issues of scientific journals devoted to road ecology (Evink et al. 1996; Hourdequin 2000, Luce and Wemple 2001). The anticipated growth in population and projected highway expansion plans in the Rocky Mountain cordillera, coupled with the resounding concern for maintaining large-scale, landscape connectivity, will continue to generate interest in conservation tools and applications for addressing the diverse issues linking transport, ecology and local communities (Hansen et al. 2002).

A concern among many land managers is the effect roads have on fragmenting wildlife populations. A recent study of bobcat (Lynx rufus) and coyote (Canis latrans) populations bisected by a busy southern California freeway was able to show that although individuals successfully crossed the freeway, they did not always contribute to gene flow through reproduction (Riley et al. 2006). The home ranges of these two territorial species abutted but did not cross the highway, resulting in significant genetic differentiation between populations on either side (Strasburg 2006). Further, a recent
review paper published in the journal Conservation Biology found that currently there is no evidence demonstrating that highway wildlife overpasses are effective at preventing genetic isolation (Corlatti et al. 2009).

Banff National Park (hereafter referred to as Banff) possesses the first large-scale complex of highway mitigation for wildlife of its kind in the world. Nowhere in the world are there as many and diverse types of wildlife crossing structures and associated biological data on wildlife distribution, movement and ecology. Over the past 25 years, the wildlife crossings in Banff have been a model of worldwide importance (Evink 2002; Hilty et al. 2006). The significance of the Trans-Canada Highway (TCH) wildlife crossing structures has led to Banff assuming international leadership in highway mitigation performance and evaluation, design criteria, and connectivity studies for wide-ranging animals at a landscape scale (Evink 2002). In short, it is the perfect natural laboratory for understanding the conservation value of highway overpasses and underpasses for a variety of wildlife species.

Conservation Challenges and Management Needs

The effects of roads on wildlife generally, and of the TCH in Banff specifically, are to reduce wildlife population viability through increasing mortality and disrupting rates of gene flow across the highway. Attempts to minimize these effects must therefore focus on reducing wildlife–vehicle collisions, while ensuring wildlife can access food, shelter and mates across the landscape and throughout the year to enable populations to persist. Achieving ecological integrity under these circumstances requires cooperative efforts from a suite of disciplines including civil engineering, environmental design, transportation planning and biological sciences (Forman 1998).

In 1978, the federal government proposed to expand the width of the TCH in Banff from two to four lanes, a process known as “twinning” the highway (McGuire and Morrall 2000). Measures designed to mitigate impacts of the expanding highway were built in each successive twinning project. Twinning projects have proceeded in a series of phases, beginning with Phase I in 1979 and continuing through the current day with Phase IIIB. Today the TCH through Banff and Yoho National Parks supports the highest volume of through traffic of any North American national park and it is recognized as an important stressor to the ecological integrity of the park ecosystem (Banff Bow Valley Study 1996). Parks Canada’s mandate is to maintain or enhance ecological integrity. Therefore resource managers need to determine whether mitigations are reducing risks of road-related mortality of wildlife, improving the permeability of the highway for all organisms, and providing for the long-term sustainability of populations in the area.

Generally, there has been a lack of indicators or criteria developed pre-construction to adequately assess how well wildlife crossing structures ultimately perform in meeting land management and transportation objectives. Management within Banff has evaluated mitigation performance through long-term monitoring (Clevenger et al. 2002a). Results of monitoring and research of Phase I, II and IIIA mitigation measures were used to guide the planning and design of mitigation on Phase IIIB. This adaptive management approach was sought by Parks Canada to streamline planning by obtaining recommendations based on credible science.

Research needs to be designed to inform management. Herein I describe the transportation management objectives over the course of the 15 years in Banff. For each objective I examine how they were addressed by research and monitoring, what the key findings were, how research results were translated to changes in transportation practices by Parks Canada’s Highway Service Centre, and why these are important beyond the park boundary to provincial and state transportation agencies.

We have recently completed a comprehensive analysis of mortality and wildlife crossing data from our study area that spans nearly 15 years (Clevenger et al. 2009). Herein we focus on the following assessments and analyses that have practical applications in transportation and environmental management: (1) Comparisons of wildlife overpass vs. underpass use, (2) the relationships between population size and rates of wildlife crossing structure use (are crossing rates surrogate measures of relative abundance?), (3) a complete revisit of animal adaptation periods to crossing structures and how important learning curves are to determining how long monitoring should be conducted, and (4) whether transportation managers should be concerned that crossing structures are prey traps and are more harmful to prey species than good.

STUDY AREA

The research for this project is situated approximately 120 km west of Calgary, Alberta, in the Bow River Valley along the Trans-Canada Highway in Banff (Fig. 1). The TCH is the major transportation corridor through Banff and Yoho National Parks, covering 76 km between Banff’s eastern park boundary and the park’s western boundary at the Alberta–British Columbia border. Traffic volume along the TCH is relatively high for the region, with an average of 17,970 vehicles per day in 2008 and increasing at a rate of 2.5 percent per year (Highway Service Centre, Parks
In the 1970s, safety issues compelled planners to upgrade the TCH within Banff from two to four lanes, beginning from the eastern boundary and working west. Large animals were excluded from the road with a 2.4-m-high fence erected on both sides of the highway, while underpasses were built to allow wildlife to cross the road. The first 27 km of highway twinning (Phases I and II) included 10 wildlife underpasses and was completed in 1988 (Fig. 2). The next 18 km section (Phase IIIA) was completed in late 1997 with 11 additional wildlife underpasses and two wildlife overpasses (Fig. 3). The final 30 km of four-lane highway to the western park boundary (Phase IIIB) has been divided into phased twinning projects. A first, 10-km section referred to as Phase IIIB-1 includes eight wildlife crossing structures, including two 60-m-wide wildlife overpasses will be completed in 2011. A second project recently funded by the federal government will twin the remaining sections of Phase IIIB between Castle Junction and the Kicking Horse Pass. Construction on the Phase IIIB-2 and IIIB-3 sections began in 2009 and completion is scheduled for 2012 or 2013. In total, on Phase IIIB there will be 21 crossing structures, including 4, 60-m-wide wildlife overpasses. This is the most ambitious highway mitigation project ever for Parks Canada.

LONG-TERM MONITORING OF WILDLIFE CROSSING STRUCTURES

Methods

All wildlife crossing structures in Phases I, II and IIIA have been continuously monitored for large mammal use since 1996 using track pads (Clevenger and Waltho 2000, 2005; Clevenger et al. 2002a). Monitoring consisted of checking the crossing structures and recording animal movement across raked track pads. Track pads spanned the width of the wildlife underpasses and were set perpendicular to the direction of animal movement. Most track pads had a $\approx$2-m-wide tracking surface; however, at the wildlife overpasses only a single, 4-m-wide track pad was set across the centre. Tracking material consisted of a dry, loamy mixture of sand, silt and clay, 1–4 cm deep (Bider 1968). Each crossing structure was visited every two to four days throughout the year. The quality of tracking medium to detect tracks at each visit was classified as good, fair, poor or “inoperable,” the latter generally caused by accumulation of flooding, ice or snow drifts on the track pads.
Figure 2. Phase I and II wildlife crossing structures on the Trans-Canada Highway.

Figure 3. Phase IIIA wildlife crossing structures on the Trans-Canada Highway.
We identified tracks to species, estimated the number of individuals, their direction of travel and whether they moved through the crossing structure. Species consisted of wolves (Canis lupus), coyotes (C. latrans), cougars (Puma concolor), lynx (Lynx canadensis), black bears (Ursus americanus), grizzly bears (U. arctos), wolverine (Gulo gulo), deer (Odocoileus sp.), elk (Cervus elaphus), bighorn sheep (Ovis canadensis) and moose (Alces alces).

Since 2005, motion-sensitive cameras have been increasingly used to supplement track pads to monitor species use of the crossing structures. These cameras (Reconyx Inc., Holmen, Wisconsin) also provide information on time, animal behaviour, and ambient temperature during each crossing event. We found through monitoring animal movement at the crossing structures with both track pads and cameras that cameras were a more reliable, cost effective and less invasive means of monitoring crossing structure use than tracking alone (Ford et al. 2009).

**Results**

A total of 218,596 detections by mammals and humans have been recorded at the Phase I, II, IIIA and IIIB crossings structures. Excluding humans, there were 198,811 crossings by large mammals. Grizzly bear, moose and wolverine continue to be the only species that have been detected more times at crossing structures along Phase IIIA. Phase IIIB has been monitored for a relatively short time compared to Phase I, II, and IIIA. Since December 2009, grizzly bears have used the crossings along Phase IIIB more than black bears; while deer and elk are most commonly detected at the crossings (46 percent of all large mammal crossings). Coyotes, black bears, elk, deer and bighorn sheep remain more common crossing structures along Phases 1 and 2. Overall, approximately 70 percent of all wildlife crossing occurred along Phases 1 and 2, an increase from 66 percent in 2009.

Consistent with the latest summary of wildlife crossing use (Clevenger et al. 2009), deer made up 62 percent of all crossings detected, while elk were only detected 19 percent of the time. The proportion of large carnivore detections was < 8 percent. Wolverine detections increased from 4 to 13. Crossing detections by wolverines increased westward along the TCH beginning at Phase IIIA structures. Since 1997, grizzly bear use increased steadily and peaked in 2008 (n=180). However, grizzly bear use of the crossings has decreased in the last three years. This decrease can be partly explained by a reduced number of grizzly bears residing in the Bow Valley compared to previous years when at least two adult females with offspring were in the area and used the crossings on a regular basis. Among large carnivores, most grizzly bear and wolf crossings continue to occur at the two wildlife overpasses and the Healy underpass, however, wolf crossings at underpasses east of Banff have increased significantly with > 1200 detections at the Duthil underpass. Black bear and cougar use continues to be more dispersed among the crossings structures.

**COMPARISON OF WILDLIFE OVERPASS AND UNDERPASS USE**

Comparing animal movement at crossing structures placed within a few hundred meters of each other enables us to control for potential effects of habitat type and species distributions on wildlife crossing structure use. Both Redearth and Wolverine overpasses have an adjacent underpass structure within 300 m. We pooled wildlife overpass crossing events together from the two sites and compared them with pooled wildlife underpass (n=2) crossing events for large mammals species during the last 12 years (Table 1). For each year, we calculated the percentage of movements at each structure type using a crossing structure selection factor, S, based on the formula:

\[
S_y = \frac{(\text{Overpass-Underpass})}{(\text{Overpass + Underpass})}
\]

where Overpass and Underpass are the number of crossing events by each species for year y. As S increases animals are more likely to use overpasses than underpasses, and a value of 0 indicates equal movement distribution among crossing structure designs.

We found that there are species-specific preferences for which structures are used (Fig. 4). Grizzly bears, moose, deer and elk are almost always found using overpasses rather than underpasses. These species show the strongest and most consistent use among all species. Black bears show fairly inconsistent use of either structure, varying from S ≈ -1 to S ≈ 1 from year to year. Cougars and coyotes show a relatively equal distribution of movements at the two structure types, as S ≈ 0 most years. However, in the early years of monitoring it was found that most cougars preferred the underpasses and in the last year coyotes showed a preference for overpasses. Wolves, for the most part, tended to use the overpasses on a far more consistent basis than underpasses. However, before 2001 and during 2003, there was a tendency for wolves to use the underpasses more than the overpasses. For wolves, the changes in S over time may reflect their adaptation to crossings structure designs, with preference for underpasses in the beginning and then becoming more selective towards overpasses after a few years (see Clevenger et al. 2009).
Table 1. Species use of paired overpasses and underpasses, 1997–2009.

<table>
<thead>
<tr>
<th>Species</th>
<th>Overpass</th>
<th>Underpass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grizzly Bear</td>
<td>317</td>
<td>10</td>
</tr>
<tr>
<td>Black Bear</td>
<td>58</td>
<td>44</td>
</tr>
<tr>
<td>Wolf</td>
<td>597</td>
<td>172</td>
</tr>
<tr>
<td>Cougar</td>
<td>41</td>
<td>66</td>
</tr>
<tr>
<td>Coyote</td>
<td>319</td>
<td>341</td>
</tr>
<tr>
<td>Moose</td>
<td>84</td>
<td>1</td>
</tr>
<tr>
<td>Deer</td>
<td>10,377</td>
<td>636</td>
</tr>
<tr>
<td>Elk</td>
<td>1388</td>
<td>418</td>
</tr>
</tbody>
</table>

Figure 4. Use of paired wildlife overpass and nearest underpass by species, 1997–2009. Value of +1.0 represents exclusive overpass use, -1.0 represents exclusive underpass use and value of 0 (dashed line) represents equal movement at the two structure types.
RELATIONSHIP BETWEEN POPULATION SIZE AND PASSAGE RATES

Long-term monitoring of wildlife crossing structures along the TCH in Banff has generated an impressive collection of wildlife activity and distribution data since 1996. However, passage rates at wildlife crossing structures have yet to be directly associated with actual population sizes of wildlife in the surrounding landscape. We used aerial and ground survey records of the Bow Valley elk population from 1996–2007 to compare frequency of crossing structure use over time. We calculated the frequency of crossing events at each wildlife crossing structure as a function of population size. We looked for an association between the annual population estimate and the seasonal total of crossing structure passages at each site.

Elk population size and crossing events were strongly associated, particularly at the open span bridge designs along Phase I and II. The Powerhouse underpass had the best overall correlation with population size. Correlations between wolf crossing events and population size were weaker than correlations for elk. Passages at Healy were most consistently correlated with population size. Given the importance of management benefits from these initial findings, we recommend that population studies be carried out to allow for additional assessments of the proximity and strength of association of the two types of data in the Banff and Lake Louise, Yoho, Kootenay (LLYK) Field Units.

Use of Wildlife Crossing Design Types

Analyses from our earlier research showed that some species display a preference for the types of crossing structures they use. Grizzly bears, wolves, moose, deer and elk tended to prefer large, open structures with good visibility, while cougars, and to some extent black bears, tended to prefer smaller structures that provide more cover. We analyzed our 12 years of monitoring data in a paired comparison of each of the wildlife overpasses with its nearest wildlife underpass (Clevenger et al. 2009). This side-by-side comparison found species-specific preferences similar to the previous results: grizzly bears, moose, wolves and the three ungulate species almost always used overpasses rather than the nearby underpasses, while black bears were inconsistent in their use of the two structure types, and coyotes and cougars showed a relatively equal distribution of movements at the two types of structures.

We also looked at the relationships between the four types of wildlife crossing designs used by the eight species to see whether they were constant over the 12-year monitoring period (Clevenger et al. 2009). The proportional use of the wildlife crossing design types (box culverts, metal culverts, open-span bridge underpasses, wildlife overpasses) was consistent year to year for many species. The most regular and consistent species in terms of design type usage were deer, elk, moose, grizzly bears, and wolves. The relative use of crossing design types by these five species varied slightly or not at all during the 12-year period. However, for cougars, black bears and coyotes the relative proportion of use by crossing design type changed markedly from year to year. It is noteworthy that these three species, which appear to be the least consistent in crossing design selection, are the same species whose use of the crossing structures we found to be affected most by larger conspecifics. These species are most subject to displacement and predation by the larger conspecifics, and this may suggest that cougar and black bear preference for smaller wildlife crossing structures is less a function of selection and more influenced by the presence of larger conspecifics in the study area.

ADAPTATION TO WILDLIFE CROSSING STRUCTURES

Current Knowledge

What do we know about adaptation periods and learning curves for animals using wildlife crossing structures? Our long-term monitoring has demonstrated that an adaptation period and learning curve does exist for large mammals and varies between ungulates and carnivores. Similarly, Dodd et al. (2007) found that elk required time to adapt to newly created wildlife underpasses in Arizona before using them on a regular basis. The average monitoring period of 18 studies reporting on wildlife crossing structure use by mammals was 17 months (Clevenger and Huijser 2011)—not even two years. The few studies that have had more than two years of monitoring showed that animals require an adaptation period and that animal learning is implicated in the regular use of crossings.

In Banff we have learned about the adaptation period in two ways. First, snow track transects were conducted around the entrances to newly constructed and established (>10 yrs old) wildlife crossing structures (Clevenger et al. 2002a). The “through-passage rate” was significantly lower (half the rate, on average) on the newly constructed Phase IIIA crossings compared to the established Phase I and II section. Through-passage rates for all species increased over the four-year period of study. Next, we examined the number of successful crossing events at wildlife crossing structures for ungulates and carnivores (Clevenger et al. 2002a). For carnivores it appeared that use levels out or reaches a threshold after annual increases (for some species a steep increase) over four to six years, whereas for ungulates it is a
two- to three-year period (Clevenger and Waltho 2003). The annual increases in grizzly bear use of the Banff wildlife crossings have been frequently used to demonstrate the importance of long-term monitoring (see Clevenger et al. 2009). This will be discussed in the next section, which details what we have learned from monitoring between Year 5 and Year 12 and the overall benefits of long-term monitoring in Banff and LLYK Field Units.

That an adaptation period exists is unequivocal—the questions that remain are how long the adaptation period is for each species of large mammal, and does it change if examined at two different time periods? In other words, would we expect to find the same result if we repeated field studies today under the same conditions? This is an important question to answer in order to design monitoring schemes of sufficient scientific rigor and length to provide strong inference when addressing wildlife adaptation and eventual performance assessment of crossing structures.

**What Does Adaptation and Learning Look Like?**

What would a simple graph look like that depicts adaptation of wildlife to crossing structures over time? In a generalized graph we would expect the amount of use to increase over time, but at some point in time (an inflection point or asymptote) use would begin to fluctuate annually. Subsequent fluctuations, however, would be smaller in amplitude than the amplitude exhibited during the rising use in the initial years (Fig. 5).

![Figure 5. Generalized concept of adaptation of wildlife to crossing structures over time. Y-axis refers to number of detected crossings by a given species. X-axis is a longitudinal reference to number of years monitoring takes place.](image)

In addition to the abovementioned data regarding wildlife adaptation to the Banff wildlife crossings from 1997 to 2001, we can look at much longer time-series of data between 1997 and 2008 to interpret what this adaptation or learning process looks like. The best way to do this is by looking at species-specific graphs of Phase IIIA crossing structure use. Phase IIIA is used because we can track usage from inception of mitigation once construction was completed (November 1997) to the present.

It is worth noting that this is the only data of its kind in the world. Nowhere has anyone been able to monitor consistently and systematically year-round animal use of wildlife crossings over long time periods. What we are able to infer from our long-term research data has not only implications for management and monitoring of wildlife crossings in Banff and LLYK Field Units, but provides evidence-based support for technical design recommendations and monitoring programs elsewhere.

We examined time-series data from eight species of large mammals (three ungulates and five carnivores) using the Phase IIIA wildlife crossings over a 12-year period, from inception (1997) to the present (2008) (Clevenger et al. 2009). We compiled for each species are two graphs: (1) the number of crossing events per year by wildlife crossing design
type \((n=4)\), and (2) the total number of crossings on Phase IIIA with their confidence interval and a fitted line that smooths out the points and indicates trend in use.

**Use of Crossings by Design Type**

What is clear from these figures is that the relationships between the design types used by the eight species are relatively constant over time. This suggests that use of a coefficient of variation, which assumes that individuals are moving through a greater variety of crossing structure types as time goes on (i.e., they are adapting), would not be a reliable method to measure adaptation. The results show that there are strong preferences (i.e., selection) for design types of wildlife crossing structures and they are consistent over time (Clevenger et al. 2009). The level of use may change at individual crossing structures, but overall the response to wildlife crossing design type does not change and has been relatively constant during the 12-year period.

The most consistent species in terms of use of crossing design types are deer, elk, moose, grizzly bears, and wolves. The relative use of crossing design types by these five species varied slightly or not at all during the entire 12-year period. The proportion of use by crossing design type for cougars, black bears and coyotes, however, changed markedly from year to year. Cougars were found to alternate between box culverts, metal culverts and creek bridge underpasses, while the wildlife overpasses were consistently used least of all. Black bears alternated between box culverts, metal culverts and wildlife overpasses, while creek bridge underpasses were consistently the least utilized. Last, the highest relative proportion of crossing structure use by coyotes alternated between box culverts and metal culverts, while wildlife overpasses and creek bridge underpasses were consistently used the least. It is noteworthy that these three species, which appear to be the least consistent in crossing design selection, are the same species that we found to be affected most by larger conspecifics when using the wildlife crossings. These species are most subject to displacement and predation by the larger conspecifics in the study area (grizzly bear/black bear; wolf/cougar; and wolf/coyote). This may suggest that cougar and black bear preference for smaller wildlife crossing structures (Clevenger and Waltho 2005) is less a function of selection and more influenced by sharing of wildlife crossing structures with larger conspecifics in the study area.

**Long-term Trends**

We plotted the total use of Phase IIIA crossing structures during the 12-year period and found usage trends increasing for four of the eight species, stable for two species, and decreasing for two species (Clevenger et al. 2009). Deer, moose, grizzly bears and wolves had increasing trends in use during the 12-year period and all were strongly positive increases with few outliers. Although cougar and coyote had stable trends over time, their annual use was highly variable. Elk and black bear use decreased over time, and the trends were highly variable with many outliers.

**Duration of Adaptation and Learning Periods**

The last part of this section examines the annual pattern of Phase IIIA crossing structure use from scatterplot figures shown above to estimate the duration of adaptation and learning periods (Clevenger et al. 2009). We examined the scatterplot for each species and identified the length of time required for use of crossing structures to reach an initial inflection point or asymptote (see above) since mitigation inception in 1997. We refer to this as the initial period. For the eight species we determined the number of years of monitoring that was required to reach a discernible initial inflection point. For example, in grizzly bears initial inflection occurred after six years, whereas for black bears it occurred after three years. For several species there was a second inflection point that closely followed the first. We determined the number of monitoring years to reach the second inflection point, as it may more accurately represent the adaptation period. The number of years that characterize the initial (first inflection) and second (subsequent inflection) adaptation periods for the eight species are shown in the scatterplot graphs above and summarized in Table 2. The estimated initial adaptation periods range from three years (cougar, black bear) to six years (grizzly bear, wolf). More liberal estimates of adaptation periods characterized by the second period range from three years (cougar, black bear) to nine years (grizzly bear, wolf). The average estimated initial adaptation period for the eight species was 4.4 years, while the average second period was 5.9 years.

The estimates provided results from a much longer time-series of data than used previously, yet they are remarkably comparable to our earlier estimates derived from four to five years of monitoring for carnivores and approximately three years for ungulates (Clevenger and Waltho 2003). The results we present are also congruent with data we presented earlier in the report based on four winters of snow tracking around newly constructed and established wildlife crossings (see Clevenger et al. 2002a).
Table 2. Number of monitoring years estimated for adaptation to wildlife crossing structures for eight species of large mammals in Banff National Park, 1997–2008.

<table>
<thead>
<tr>
<th>Species</th>
<th>Initial period (years)</th>
<th>Second period (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deer</td>
<td>4</td>
<td>6</td>
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<tr>
<td>Elk</td>
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<tr>
<td>Black bear</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Grizzly bear</td>
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<td>9</td>
</tr>
<tr>
<td>Wolf</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>Coyote</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Average (+ SD)</td>
<td>4.4 (1.2)</td>
<td>5.9 (2.4)</td>
</tr>
</tbody>
</table>

The value of long-term monitoring of the TCH Phase IIIB is critical to the maintenance of wildlife populations in Banff and the national park ecological integrity objectives (Banff Bow Valley Study 1996; Parks Canada 1997; Golder Associates 2004). Monitoring for Phase IIIB will be particularly important given the presence of species of high conservation concern, such as wolverine, lynx and grizzly bear. Currently there is virtually no information with respect to how two of these three species respond to crossing structures (wolverine, lynx). Thus, we recommend that monitoring of the TCH Phase IIIB wildlife crossings be carried out for a minimum of five years and preferably a longer period to be able to reliably assess crossing structure performance in meeting the ecological objectives of the twinning project.

What have we learned from long-term monitoring of the Banff wildlife crossings? This will be answered in more detail in the following section but simply stated, much has been learned with regards to the right half of the scatterplot graphs, after the apparent peaks in crossing structure use in 2000–2002. We’ve also learned how use fluctuates over time. By examining time-series data from multiple species we have a much better understanding of what are the key factors that drive the observed patterns and the inter-species interactions and relationships regarding wildlife crossing use.

**GRIZZLY BEAR USE OF THE WILDLIFE CROSSINGS**

Grizzly bear use of the crossing structures increased dramatically since monitoring began over 14 years ago, from only five crossings in 1997 to 177 in 2008 (Fig. 6). Several factors may explain this relationship. First, the grizzly bear population appears to have increased in the Bow Valley since monitoring began in 1996. Second, grizzly bears could be learning that crossing structures provide safe passage across the TCH and thus may be repeat users. And third, many family groups have been documented using the crossing structures. Thus, young bears may be learning to use the crossings when part of a family group. When these subadult bears disperse from the maternal range they may continue to use the crossing structures. Ongoing graduate research by Mike Sawaya on the genetics of bear use of the wildlife crossings will shed more light on what is likely causing the trend toward increased use. However, in the last three years grizzly bear use of the crossings has decreased. This decrease can be partly explained by a reduced number of grizzly bears residing in the Bow Valley compared to previous years when at least two adult females with offspring were in the area and used the crossings as a family unit on a regular basis.
Figure 6. Total number of detected grizzly bear crossings at the Banff wildlife crossing structures between 1997 and 2010. The number of crossing structures available to grizzly bears is constant during the 14-year period.

KEY CONTRIBUTIONS THAT ADVANCE SCIENCE AND ASSIST MANAGEMENT

Fifteen years is longer than most research projects are conducted and a long time to dedicate to a specific research topic in one study area. A long-term approach to the Banff research can be justified for a variety of reasons, the main being the emerging nature of road ecology research worldwide and the extent of what is unknown about road impacts on wildlife populations (Forman et al. 2003; Transportation Research Board 2002; National Research Council 2005). The long history of TCH mitigation projects, the unrivaled number and types of mitigation measures, all embedded within a study area teeming with baseline ecological data, securely places Banff on the leading edge of road ecology research. Few, if any, places in the world are able to carry out this kind of research with the intensity and complexity as Banff-Bow Valley ecosystem, entirely due to the uniqueness of the attributes of the study area. Having long time-series data is one of the key attributes. As time passes, the value of the research data increases exponentially, given the increased opportunities to investigate novel research questions that can directly influence management and planning of transportation infrastructure designed to preserve the integrity of natural landscapes and ecosystems.

Summarized below are what we see as a dozen or more key contributions and discoveries from the research that has advanced the science and aided transportation agencies plan and design highway mitigation measures for wildlife populations. The contributions listed below are largely singular in that the research results from Banff have not been replicated elsewhere, or corroborated or challenged by findings obtained in other study areas and thus stand as key findings. The supporting publication for each contribution is cited.

1. Wildlife crossing structures and fencing have reduced wildlife vehicle collisions with large mammal species by >80% and ungulate species by 94% (Clevenger et al. 2001a). This is of critical importance in order to demonstrate that the measures are effective at reducing wildlife-vehicle collisions, improving motorist safety and are worthy investments by transportation agencies.

2. The location where wildlife are killed on roads does not occur in the same location where wildlife cross the highway successfully (Clevenger et al 2002a). When planning the location for wildlife crossing structures, often times road-kill hotspots are used. Our work has demonstrated that where wildlife move across highways successfully (without being struck by vehicles) is not always the same as where wildlife do not successfully cross highways (struck by vehicles).
3. There has been a high amount of wildlife use of the crossing structures (Clevenger et al. 2002a, 2009). As of April 2010, 11 species of large mammals have been detected using the Banff wildlife crossings nearly 220,000 times.

4. There are species-specific preferences to wildlife crossing structure types and design (Clevenger and Waltho 2000, 2005, Clevenger et al. 2009). Wildlife have preferences for specific landscape types and habitat elements within them, so it is not unusual to presume that wildlife species will have preferences for specific wildlife crossing structure design types. Simply tallying the number of times wildlife species use a suite of crossing structures will not provide rigorous or reliable information on what attributes of crossings facilitate animal passage.

5. There is an adaptation period for wildlife to use the wildlife crossings, therefore monitoring has to be long term (Clevenger et al. 2009). Clearly, wildlife need time to locate newly placed crossing structures and feel secure using them before they incorporate them into the daily or seasonal movements. These adaptation periods, even for common ungulate species, is far longer than the monitoring periods used in the majority of studies to date.

6. Human use at the wildlife crossings is a major deterrent to wildlife use (Clevenger and Waltho 2000). This finding is not surprising given what is known regarding the effects of human disturbance on wildlife habitat use and movements. Similarly, the conservation value of landscape corridors relies on minimal human disturbance for them to be effective in connecting habitat patches and moving wildlife between them.

7. Is it sufficient to state that wildlife crossings are functional if animals use them? Novel approaches to measuring function and performance of crossing structures go beyond this simple cognition. They look into the effects on different species and higher taxa and they account for the impact of different locations and landscapes. Once in place, wildlife crossings must be monitored and evaluated to determine their conservation value and ecological performance. Guiding principles for planning and measuring performance of mitigation crossings for wildlife are developed that consider a range of ecological goals, time-frames, and changes in landscape conditions (Clevenger 2005).

8. The Banff crossing structures provide population level benefits to grizzly and black bear populations (Sawaya, in preparation). More than 100 crossings per year by each of the bear species at the Banff crossings would suggest that the measures are effective and provide demographic and genetic benefits to their populations. However, skeptics among transportation practitioners and scientists believe that only objective research focused on population level consequences of the crossings will firmly demonstrate the conservation value of the Banff crossings. Further, a recent publication implied that there is no evidence that wildlife overpasses provide genetic connectivity (Corlatti et al. 2009).

9. Drainage culverts provide habitat linkages to small and medium sized mammals in Banff (Clevenger et al. 2001b). Ubiquitous drainage culverts can provide an important habitat linkage for small- and medium-sized mammals needing to connect habitats across highways. Currently there is no evidence that the culverts have positive effects at the population level, i.e., maintain or restore gene flow and/or have positive demographic consequences.

10. Models simulating wildlife movements based on empirical data are validated and can identify locations for placement of wildlife crossing structures (Clevenger and Wierzchowski 2006). Where empirical data are available, they can be used to construct species-specific movement models that help identify key linkages and crossing locations on highways and are a valuable aid in siting wildlife crossing structures.

11. Models simulating wildlife movements based on expert opinion are valid method for identifying locations for wildlife crossing structures (Clevenger et al. 2002b). Contrary to above, typically there are no empirical data available to develop species-specific movement models to help identify key linkages and crossing locations on highways and site wildlife crossing structures. Given this is the norm, habitat models that are surrogates for animal movement can be developed using a low-cost method of expert opinion to identify key linkages across highways and site mitigation crossings in a short amount of time.

12. Camera-based monitoring of wildlife crossing structures is equally effective as track pad monitoring and more cost-effective over the long term (Ford et al. 2009). Track-based methods have predominated monitoring at crossing structures for many years, however, remote camera-based monitoring is becoming more popular given the lowered costs of cameras and ability to leave cameras without checking for weeks or even months. Both methods are unable to detect 100% of the individuals that actually pass through a crossing structure, but there...
has never been a paired test of the two techniques together to accurately assess the advantages and
disadvantages of each, particularly in light of multi-year monitoring periods. This work has answered these
questions with a robust sample size of monitored crossings and over a lengthy time period.

13. The wildlife crossing structures in Banff are not prey traps for prey of large predators (Ford and Clevenger
2010) and there is little evidence that crossing structures are prey traps elsewhere (Little et al. 2002). This the
most common question posed to anyone reporting on monitoring results from crossing structures. There has
never been a public or technical presentation made by our research team in 15 years where this question does
not come forward. The question is valid from the perspective of agencies concerned with building traps or
creating more ecological problems compared to not installing crossing structures. We have put this one to rest,
at least with regards to wolves and their prey species in the Banff ecosystem.

BIOGRAPHICAL SKETCH

Since 1996 Tony has been directing long-term research assessing the impacts of highways and performance of their
mitigation measures designed to reduce fragmentation of wildlife habitat. Since 2002, while continuing his Banff
research and living in Harvie Heights, Alberta, he has been a research wildlife biologist for the Western Transportation
Institute (WTI) at Montana State University. Tony was a member of the U.S. National Academy of Sciences Committee
on Effects of Highways on Natural Communities and Ecosystems. He has published his results in leading international
scientific journals (over 50 articles) and co-authored three books including the seminal work on this emerging
discipline, Road Ecology: Science and Solutions (Island Press, 2003) and Safe Passages: Highways, Wildlife and
Habitat Connectivity (Island Press, 2010). Tony uses his findings to educate transportation professionals and wildlife
ecologists as well as guide the design of other highway projects. He has made his Banff research the highest profile
and most scientifically productive wildlife-highway research project in the world. Tony is a graduate of the University of
California, Berkeley, has a Master’s degree from the University of Tennessee, Knoxville and a PhD in Zoology from the
University of León, Spain.

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MAINTAINING WILDLIFE CONNECTIVITY ACROSS ROADS through TESTED WILDLIFE CROSSING DESIGNS

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ABSTRACT

A permeable road network that allows all types of wildlife to move across the roaded landscape is based on the science of animal behavior and physiology; specifically, how animals respond when they encounter roads and potential crossing structures. This synthesis takes an individual species and taxonomic approach to crossing structures and modifications of existing infrastructure that are proven to pass wildlife. Although designing crossings for ecosystem function rather than individual target species are far more important, this paper can help readers understand the designs that are confirmed to work for different species groups and, in turn, how those design aspects may be combined to help pass a variety of wildlife and ecosystem processes such as the flow of water. The authors present two classification systems to achieve this: Species Movement Guilds, which organize wildlife into classes based on similar sizes and reactions to culverts and bridges; and Structure Functional Classes, which classify culverts, bridges and large span viaducts based on size and how different species respond to them. Tested wildlife crossings designs for the eight different Species Movement Guilds are presented. Low mobility fauna such as frogs and ground insects prefer passages that mimic ambient conditions. Crossings for them must provide specific habitat consistent with the outside environment. Moderate mobility small fauna are small to medium sized mammals and reptiles. These animals typically need some hiding cover and may use all kinds of wildlife crossings. Adaptive high mobility fauna are the medium sized carnivores that can use closed spaces such as culverts. They will also pass under bridges and use overpasses. High openness high mobility carnivores are the grizzly bear, mountain lion, and wolf. They prefer good visibility and typically need larger sized structures such as large bridge underpasses and wildlife overpasses. Adaptive ungulates such as deer, moose, and mountain goat prefer good visibility in a crossing and need a certain degree of openness. They will tolerate culverts up to 120 feet (36 m) long; longer culverts will have a higher rate of repellence. Very high openness fauna are the more wary ungulates such as elk, pronghorn, and bighorn sheep. These species are very wary of being enclosed and, for the majority of populations will not use culverts, instead requiring medium to large underpasses, extensive bridge, or overpasses. Typical Arboreal fauna are flying squirrels. They move through canopies and need canopy-level structures such as a rope bridge or towers that allow them to jump from perch to perch over a road. Aerial fauna are birds and insects that need to be directed to fly over the flow of vehicles. Vegetation improvements and diversion structures may be used to keep these animals up and over the roadway. This paper helps to elucidate the characteristics of new structures or the changes needed to retrofit structures that make them more functional for the movement of species from all of these guilds.

INTRODUCTION

A wildlife crossing is a structure that allows wildlife to pass over or under the road and was designed and built specifically or in part to assist in wildlife movement (Bissonette and Cramer 2008). In addition to new structures, existing culverts and bridges can be modified for wildlife passage, meaning enhancements (retrofits) can be made to the structure to render it more wildlife-friendly. Such enhancements may include adding dirt pathways along waterways, removing rip-rap, attaching wildlife proof fence, and many other actions.

The term ‘wildlife underpass’ connotes many different structures, from the smallest culverts that may pass a salamander to the spaces under highway viaducts, tens to hundreds of feet above the landscape. To clarify this range, the classification of ‘Structure Functional Classes’ offers a definitive set of conditions for four different underpasses, overpasses, and two distinct designs for passages, and the types of wildlife that may use each of these types of structures. This classification of structure types provides standardized terminology for transportation planners, biologists and engineers relating wildlife passage needs to a specific structure type.

Departments of Transportation (DOT’s) and wildlife agencies also need a range of options for passing wildlife under and over roads in different situations that are proven through research to work. The process of gathering the necessary data across peer reviewed sources, grey literature, and contacts with other agencies to make decisions for each new project can deter or slow the planning and design process. In addition, comprehensive analyses of the available information

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can be arduous; for some species their use of transportation infrastructure, such as culverts and bridges, has never been studied. Transportation biologists and decision-makers need a way to categorize North American species into groups of species that move in similar ways, react to roads and their infrastructure in similar ways, and are on the same trophic level, meaning they are either prey or predator. By understanding the needs and design features that facilitate movement for each class, this knowledge can be applied to members of the same class, even those that are more poorly studied. The Species Movement Guilds defined in this paper provide such a classification and can be used to assist in designing new structures or enhancing existing ones so they are more functional for the suite of species present in a given area.

METHODS

This paper is a synthesis of the results of the research from five research endeavors. The knowledge base began with the investigations for the National Cooperative Highway Research Program (NCHRP) project, ‘Evaluation of the use and effectiveness of wildlife crossings’ (Bissonnette and Cramer 2008). During the four-year study the primary author interviewed over 300 professionals across the United States and Canada to learn as much as possible about all wildlife mitigation measures installed and planned in North America. Specific data on how wildlife uses wildlife crossings was obtained from the above study and three field research projects. The prime author began a study in Utah in 2007 that will continue until 2013 titled ‘Evaluation of Wildlife Use of Wildlife Crossings Under Different Scenarios.’ Through the use of remote motion-triggered cameras, the research project sought to better understand the how the different configurations of wildlife crossing bridges and culverts affected mule deer, elk, and moose use of those structures (Cramer 2011). In 2008 the prime author also began the study ‘Montana US Highway 93 South Wildlife Crossings Research,’ which is designed to learn how wildlife and specifically white-tailed deer uses wildlife crossings on Highway 93 and whether the wildlife mitigation efforts reduce the deer-vehicle collisions on this highway (Cramer et al. 2011). This study continues into 2015. In Colorado, the second author worked with colleagues to identify wildlife crossing zones along the I-70 mountain corridor, monitor wildlife at existing culvert and bridge locations, and to develop preliminary mitigation recommendations (Kintsch et al. 2011). In 2010 the two authors initiated the Washington study, ‘Permeability of Existing Structures for Wildlife: Developing a Passage Assessment System’ (Kintsch and Cramer 2011). The objective of this study was to create an assessment process to evaluate existing transportation culverts and bridges, in their ability to pass full suites of wildlife species. During the development of the Passage Assessment System the authors defined Species Movement Guilds and further refined Functional Structure Classes in conjunction with the third author. These two classification systems have fostered an understanding of which types of structures work for different types of wildlife. These classification systems allow transportation biologists to evaluate the physical and environmental conditions and potential constraints to movement from the perspective of groups of species, and thereby develop mitigation strategies that carefully account for the behavior and preferences of each target species.

Data from all these studies were synthesized to produce this paper.

RESULTS AND DISCUSSION

Structure Functional Classes

The classification scheme created for transportation infrastructure, ‘Structure Functional Classes’ provides an organization of the types of road crossing structures and the wildlife for which each can provide safe passage under or over a roadway. The critical dimensions defining the four classes of underpasses are based on heights and widths of structures, which are dictated by engineering design constraints as well as the characteristics that define individual species’ willingness to move through a structure (Table 1). This classification of structure types can help transportation planners, biologists and engineers to relate wildlife passage needs to a specific structure type or types using a common vocabulary. This classification was first proposed in Bissonnette and Cramer (2006) and was updated and modified in Kintsch and Cramer (2011).

Species Movement Guilds

The Species Movement Guilds (Table 2) are a classification of terrestrial wildlife species based on their responses to roads and crossing structures – behavior that is largely influenced by predator detection and avoidance strategies, as well as an animal’s size and capacity for locomotion. Traditional species classifications are based on taxonomic groupings based on biologic similarities among species. Previous studies in road ecology have proffered classifications more closely tied to taxonomic classifications (e.g., Grillo et al. 2010), or based on body size (Clevenger and Kociolek 2006) and how species respond to habitat fragmentation (Cavallaro et al. 2005). Clevenger and Huijser (2009) developed a size-based taxonomic classification that considers fragmentation impacts as well as species area requirements. In contrast, our Species Movement Guilds classification was developed specifically for the purpose of
designing species-specific wildlife crossings and evaluating the influential characteristics that render a structure functional or non-functional for wildlife permeability.

The Species Movement Guilds presented are intended as a refinement of these previous classifications, with discussion and justification for the groupings. The Guilds categorize wildlife based on body size—which puts a physical limit on the structures that a given species can use—how they move, how they respond to roadway traffic or potential threats such as predators, and the crossing structure characteristics, such as vegetation cover, ambient conditions and visibility, that may affect their willingness to use different structures to move under and over roads. Predator avoidance is a key factor for most wildlife. As different species have different detection and avoidance strategies, crossing structures must address the strategies of the target wildlife at a given location. The classification system allows transportation biologists to evaluate the physical and environmental conditions and potential constraints to movement of wildlife from the perspective of groups of species, and develop mitigation strategies that carefully consider the behavior and preferences of each target species. The Guilds facilitate an understanding of why certain species have specific requirements and ‘what works’ for different types of species.

Table 1. Structure Functional Classes of Transportation Culverts and Bridges as Related to Wildlife Use.

<table>
<thead>
<tr>
<th>Class Name</th>
<th>Approximate Dimensions (Span x Rise)</th>
<th>Typical Species the Structure Type is Known to Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small Underpass</td>
<td>Metal pipe culverts or small box culverts 1.5 m (5’) span or less</td>
<td>Amphibians, small mammals</td>
</tr>
<tr>
<td>Medium Underpass</td>
<td>Underpasses larger than 1.5 m (5’) span, to 2.4 m (8’) span x 2.4 m (8’) rise</td>
<td>Coyote, bobcat</td>
</tr>
<tr>
<td>Large Underpass</td>
<td>Underpasses with minimum dimensions: 6.1 m (20’) span x 2.4 m (8’) rise, or 3.1 m (10’) span x 3.1 m (10’) rise, and open span bridges</td>
<td>Deer, elk, black bear</td>
</tr>
<tr>
<td>Extensive Bridge</td>
<td>Bridge extending over several spans. Designed for each site so dimensions vary. May allow more sunlight under structure than other types.</td>
<td>Most wildlife – wary species</td>
</tr>
<tr>
<td>Wildlife Overpass</td>
<td>Overpass structure for wildlife to pass over roadway, as small as 6.7 m (22’) wide, but preferably ≥50 m (164’) wide.</td>
<td>Most wildlife, including birds</td>
</tr>
<tr>
<td>Specialized Culverts</td>
<td>Current designs are small culverts less than .5 m (24”) span but could be larger structures.</td>
<td>Reptiles &amp; amphibians</td>
</tr>
<tr>
<td>Canopy Bridges</td>
<td>Adequate to cross all traffic lanes. May be connected to trees in the median.</td>
<td>Flying squirrels, arboreal rodents</td>
</tr>
</tbody>
</table>
### Table 2: Terrestrial Species Movement Guilds. A functional categorization of terrestrial wildlife based on body size, predator avoidance strategies, and species behavior relative to road infrastructure, traffic and crossing structure characteristics.

<table>
<thead>
<tr>
<th>Species Movement Guild</th>
<th>Species Attributes &amp; Examples</th>
<th>Preferred Passage Attributes</th>
<th>Preferred Structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Mobility Small Fauna</td>
<td>Small, slow-moving species that require specific ambient conditions such as moisture and light. Frogs, toads, salamanders, ground insects.</td>
<td>Need species-specific habitat consistent with external conditions (light, moisture) throughout the entire structure.</td>
<td>Extensive bridges, wildlife overpasses, trench drains.</td>
</tr>
<tr>
<td>Moderate Mobility Small Fauna</td>
<td>Adaptable; can negotiate different types of structures. Small and meso mammals, some salamanders, reptiles, some ground birds.</td>
<td>Variety of structure types. Water-free pathway preferred and usually required. Cover needed: rocks, vegetation etc.</td>
<td>Sm. to lrg. culverts and bridges and larger: overpasses.</td>
</tr>
<tr>
<td>Adaptive High Mobility Fauna</td>
<td>Medium-sized mammals that naturally use enclosed spaces for dens, and can tolerate a same enclosure. Black bear, bobcat, coyote.</td>
<td>May use a variety of structure types and prefer to have suitable habitat directly adjacent to the structure entrances.</td>
<td>Sm. to lrg. culverts and bridges and larger: overpasses.</td>
</tr>
<tr>
<td>High Openness High Mobility Carnivores</td>
<td>Species that prefer good visibility in structure. Larger animals with larger minimum structure size requirement than Adaptive High Mobility Fauna. Wide ranging. Grizzly bear, puma, wolf.</td>
<td>Open structures that provide good visibility, can tolerate longer structures (&gt;100’, 31m). Prefer more open structures but can be tolerant of enclosed structures.</td>
<td>Large bridge underpasses, extensive bridges, wildlife overpasses.</td>
</tr>
<tr>
<td>Adaptive Ungulates</td>
<td>Need good visibility on a horizontal plane and some of cover. Prefer natural substrate, adjacent cover. Mule and white-tailed deer, moose, mountain goat.</td>
<td>Passages with good visibility in and around structure, clear lines of sight. Preferred structures are wider than they are tall and are less than 100’, 30m in length.</td>
<td>Med. to lrg. culvert and bridge underpasses: larger: overpasses.</td>
</tr>
<tr>
<td>Very High Openness Fauna</td>
<td>Very wary of predators and require wide vistas and clear lines of sight. Prefer moderate hiding cover but still need to detect predators and escape. Elk, pronghorn, bighorn sheep, open habitat grouse.</td>
<td>Large passages with wide openings (at least 15’) that are less than 100’ long, excellent visibility within and around the structure, and clear lines of sight from one end of a crossing structure to the other.</td>
<td>Large culvert or bridge underpasses, extensive bridges, wildlife overpasses.</td>
</tr>
<tr>
<td>Arboreal Fauna</td>
<td>Species that move primarily through the canopy. Flying squirrels, some bats, arboreal voles.</td>
<td>Features provide a continuous canopy-level structure across the roadway.</td>
<td>Treetop rope bridges, towers.</td>
</tr>
<tr>
<td>Aerial Fauna</td>
<td>Species who fly. Songbirds, raptors, bats, flying insects (including butterflies).</td>
<td>Features for these species aim to divert flying species out of the path of traffic.</td>
<td>Diversion poles, extensive bridges, wildlife overpasses.</td>
</tr>
</tbody>
</table>

### Research Summary of Species Preferences

This section provides an overview of each of the Species Movement Guilds and the individual species research that informed the categorization scheme. For each Guild, a discussion of the trends found in transportation ecology is presented and specific conditions preferred by different species are noted. This discussion is presented with the understanding that a given crossing may be constructed for suites of species rather than a single target species, in which case crossing designs should draw from the ‘preferred characteristics’ listed for the suite of species present at that site. There is no perfect crossing structure, as any structure is mitigation – at best, adequate compensation for the natural landscape connectivity that has been lost. As such, the potentially conflicting needs of multiple species must be
balanced at any given site. Additional research and information sharing across states and countries will help to further improve crossing designs of the future.

**Low-Mobility Small Fauna**

Members of this guild include small, slow-moving animals that require specific ambient conditions (for example, moisture or light) through the length of a crossing structure, such as frogs, toads, some salamanders, some ground insects, and other invertebrates. Structures for these species may be open at the top to permit moisture and light to enter the structure and to allow navigation with respect to celestial navigation. The structures may be enclosed as well, thus protecting the animals from road pollution and traffic noise. Some species in this guild may take several generations to move the length of a crossing structure, such as insects. Salamanders and frogs need moisture in their passages, and crossings designed for these species should include some mechanism for allowing rain to enter and moisten the substrate within the underpass. Jackson (1996) suggests when considering more than two lane highways for tunnels, take into account animals freezing along the way and either minimize the length of the passage, or provide island-stop over habitat that could serve as half-way points for migrating amphibians. A typical amphibian crossing is circular or rectangular; generally less than 1.6 feet (0.5 m) in cross section, as short as possible, and with a floor lined with a natural soil substrate (Aresco 2005, Jackson 2003).

Specific guidelines for designing amphibian crossings include the following considerations. The tunnel should be open at top and fitted with iron grate flush with road surface to allow ample light, rain, and air to circulate (Jackson 2003). Because some amphibians and reptiles use olfactory cues to assist them in their movements, Jochimsen et al. (2004) suggest allowing for a layer of detritus and leafy substrate to remain undisturbed along the length of passages. Tunnels should be situated so that they can be easily accessed and not prone to flooding (Puky and Vogel 2004). Maintenance of amphibian tunnels is also extremely important for functional crossings; tunnels should be cleaned on an annual basis before the start of the migration period (Puky and Vogel 2004). Crossing structures should be spaced within 200 feet (61 m) of one another (Jackson 2003); Puky and Vogel (2004) found a maximum spacing distance of 260-328 feet (80-100 m) to be adequate, but recommend determining the spacing between crossing structure on the basis of the migration radius of the target species under normal conditions. Locate crossings in the center of migration routes rather than at the edges. To find these migration routes, the species need to be studied for at least two years because routes vary from year to year (Puky and Vogel 2004).

Many of the considerations for amphibians are identical for reptiles. The more recent Lake Jackson ecopassages (crossings) along Lake Jackson north of Tallahassee, Florida were installed in 2010. Prior to the installation of the wall and culverts for turtle movement, Aresco (2005) was able to temporarily reduce the high mortality of moving turtles with a drift fence and monitoring of the stretch of road for 44 months. A website (Aresco 2011) gives a thorough review of the entire process of identifying a deadly stretch of road for turtles, and raising public awareness and agency support, and finally a mitigation system that includes culverts and a concrete wall like those along Paynes Prairie, Florida. Overall, research indicates that reptilian species preferences for crossing types and placement are varied among species (Jochimsen et al. 2004, Little et al. 2002), underscoring the importance of local research on the target species of interest to inform the design of mitigation solutions (Woltz et al. 2008). For further reference, see Jochimsen et al (2004), which provides an overview of how various structural and ecosystem characteristics effect structure effectiveness at moving amphibians and reptiles. In addition, the Minnesota Department of Natural Resources recently updated a publication on designs and practices for the repair and reconstruction of culverts, bridges, and storm water outfalls (Leete 2010).

**Moderate Mobility Small Fauna**

Moderate Mobility Small Fauna are small animals such as ground squirrels, rabbits, voles, raccoons, snakes, badgers, marmots and weasels that are fairly adaptable to a variety of structure types and sizes. Members of this guild are typically prey and require protective cover through a structure (Foresman 2004). Such cover may be vegetative, wood debris, rock, or even artificial cover. While some members of this guild may require a natural substrate through a culvert, others may be tolerant of an artificial surface. Most of the species in this guild prefer a non-submerged pathway through a crossing structure. If there is any flow of water through a structure, passage can be greatly increased with wildlife shelves. Overall, crossings that would promote movement of Moderate Mobility Small Fauna need: to have vegetation right up to the crossing structure entrance; have a small size relative to other wildlife crossings; water-free year round or a shelf structure placed to facilitate small and meso mammal movement; include a tube built in below the shelf for voles; and less than 300 feet (91 m) in length.

Studies of small and meso mammal use of bridged areas and culverts provide evidence of these species’ use of these structures, and also limitations. Foresman (2004) documented heavy use of culverts by rodents in Montana along U.S.
Bobcats have been documented using structures in Montana (Cramer et al. 2011), Colorado (Singer et al. 2011), California (Haas 2000, Lyren 2000, Ng et al. 2004), Utah (Cramer 2011), Florida (Foster and Humphrey 1995), North Carolina (McCollister and van Manen 2010), Colorado (Singer et al. 2011), Utah (Cramer 2011), Montana (Foresman 2004, and Cramer et al. 2011), Washington (Kintsch and Cramer 2011), and Alberta, Canada (Clevenger and Waltho 2005). Overall, scientists report black bear will use bridge crossings in Florida (Foster and Humphrey 1995), North Carolina (McCollister and van Manen 2010), Colorado (Singer et al. 2011), Utah (Cramer 2011), Montana (Foresman 2004, and Cramer et al. 2011), Washington (Kintsch and Cramer 2011), and Alberta, Canada (Clevenger and Waltho 2005). Overall, scientists report black bear will use bridge crossings in every state and province in the U.S. and Canada. Coyotes can also use a variety of structures, but are a wary predator and sometimes behave like a prey species, in part due to the continued hunting pressures from humans in every state. They may be hesitant to use certain crossing structures. They almost certainly use culverts and bridges in every state and province in the U.S. and Canada. Coyotes are tolerant of smaller spaces, such as drainage culverts, and can also adapt to bridge crossings. They are also known to cross at-grade over roads. Clevenger et al. (2001) and Foresman (2004) documented multiple coyote passages in culverts ranging from 3 feet (~1 m) up to 12 feet (3.7 m) high. Alternatively, Haas (2000) found coyote use of underpasses in California increased with underpass openness, and that fencing along with shoulder and median barriers were most effective in encouraging coyote use of underpasses. Lyren (2000) found the same population of coyotes experienced significantly higher mortality by vehicles in areas with no wildlife fencing as compared to areas with wildlife fencing. The volume of traffic appears to also affect coyote use of structures. Lyren (2000) found the frequency of underpass use by coyotes appeared to be suppressed by traffic volume. Clevenger et al. (2001) also found that traffic volume was the most important predictive factor in coyote use of culverts in Alberta, with their use negatively correlated with traffic volume. These findings may indicate an aversion to traffic noise and possible avoidance of human activity, possibly due to persecution.

Adaptive High Mobility Fauna

This guild includes medium-sized mammals that are naturally accustomed to enclosed spaces for denning and are tolerant, to a limited degree, of a more enclosed situation in an underpass than ungulates. Members of this guild include black bear, bobcat, coyote, and Canada lynx. These species adapt to a variety of structure types, so long as a minimum size requirement is met, proportional to the size of the animal. Black bear demonstrate use of wildlife crossings in Florida (Foster and Humphrey 1995), North Carolina (McCollister and van Manen 2010), Colorado (Singer et al. 2011), Utah (Cramer 2011), Montana (Foresman 2004, and Cramer et al. 2011), Washington (Kintsch and Cramer 2011), and Alberta, Canada (Clevenger and Waltho 2005). Overall, scientists report black bear will use bridge crossings in every state and province in the U.S. and Canada. Coyotes are tolerant of smaller spaces, such as drainage culverts, and can also adapt to bridge crossings. They are also known to cross at-grade over roads. Clevenger et al. (2001) and Foresman (2004) documented multiple coyote passages in culverts ranging from 3 feet (~1 m) up to 12 feet (3.7 m) high. Alternatively, Haas (2000) found coyote use of underpasses in California increased with underpass openness, and that fencing along with shoulder and median barriers were most effective in encouraging coyote use of underpasses. Lyren (2000) found the same population of coyotes experienced significantly higher mortality by vehicles in areas with no wildlife fencing as compared to areas with wildlife fencing. The volume of traffic appears to also affect coyote use of structures. Lyren (2000) found the frequency of underpass use by coyotes appeared to be suppressed by traffic volume. Clevenger et al. (2001) also found that traffic volume was the most important predictive factor in coyote use of culverts in Alberta, with their use negatively correlated with traffic volume. These findings may indicate an aversion to traffic noise and possible avoidance of human activity, possibly due to persecution.
documented with a preference for crossing roads at-grade, even in places where wildlife crossing culverts and bridges were present (Bellis 2008, Cain et al. 2003, Haas 2000, Lyren 2000, Ng et al. 2004), often becoming victims of vehicular collisions. Cain et al. (2003) also found that bobcats crossed roads most frequently in areas where distance between dense vegetation was shortest. When they do use structures, they appear to prefer larger structures over more confined culverts, although monitoring in Colorado captured photographs of bobcats using pipe culverts as small as 7.4 feet (2.3 m) in diameter, and as large as an open span bridge (Singer et al. 2011). Cain et al. (2003) found bobcat exhibited a preference for structures with high openness ratios. In Florida Foster and Humphrey (1995) recorded some of the first monitoring pictures of bobcats, which were under pairs of bridges on I-75. In Washington bobcats were recorded using a large arch culvert (Kintsch and Cramer 2011). In general, bobcat will use a variety of structures that maintain cover nearby. Being a wary species, they may also prefer areas with less human use.

High Openness High Mobility Carnivores

The carnivores of this guild, grizzly bear, wolf, and puma, prefer large structures with good visibility. Because of their larger body sizes, members of this guild have a larger minimum structure size requirement than black bear and coyotes. Species in this group tend to prefer more open structures than Adaptive High Mobility Fauna, but can be tolerant of structures longer than 100 feet (30.5 m) or enclosed structures. Few studies have analyzed how the group of carnivores encompassed by this guild use wildlife crossings as a whole. Clevenger and Waltho (2000) analyzed carnivore movement through 11 wildlife underpasses and found that grizzly bear, black bear, wolf, and puma use of crossings was more influenced by human activities than by structure variables. The most significant attribute influencing these species’ use of the wildlife crossings was underpass distance to town site (positively correlated), followed by human activities (negatively correlated). Individual species preferences have been analyzed in more detail in other studies. Pumas are habitat generalists, but as highly specialized ambush predators they require good cover or complex terrain for concealment (Sweanor et al 2000). Glyone and Clevenger (2001) reported on puma use of 22 crossing structures in Banff National Park in Alberta. They found a significant positive correlation between passages made by puma through the structures and the passages made by mule deer and white-tailed deer. Contrary to the Clevenger and Waltho (2000) publication just one year earlier for the same study site, they found no correlation between puma and human use of the wildlife crossings. Puma’s use of open span bridged underpasses was more than expected. Bridge underpasses spanning creek drainages were used in proportion to their availability, while all other crossing types were used significantly less than expected. The crossings with the highest number of puma passages were those situated close to high quality puma habitat. The general overview from this study was that puma tended to use underpasses more than overpass structures. Clevenger and Waltho (2005) in a later study of the Banff Crossing structures found puma favored more constricted spaces for crossings. The analysis in this study also found that distance to cover was the most important landscape attribute for successful puma usage of crossing structures, where the greater the distance to cover, the lower the likelihood of successful passage. Studies in Utah (Cramer 2011) and Montana (Cramer et al. 2011) have recorded puma presence approximately a dozen times. This species appears to be highly adaptable and has been photographed crossing at-grade over U.S. 93 in Montana, and under Interstates in Utah using box culverts and bridges, and repeatedly over an interstate on a narrow wildlife overpass. Although there is not enough data at this time for statistical analyses in these studies, it appears puma prefer to cross roads in areas with little human development. There are few studies that document wolf or grizzly bear use of wildlife passages. Clevenger and Waltho (2005) found grizzly bear and wolf tended to use crossings that were high, wide, and short in length. Given this Guild’s hesitancy to use crossings, in large part due to their cautious nature with humans, the recommendations from the above studies may be the best research at this time in their definitions of species’ preferences.

Adaptive Ungulates

All ungulates in North America have been recorded using wildlife crossing structures. However, several of these species are significantly more adaptable to a variety of wildlife crossing structures than others; these are the Adaptive Ungulates. This guild includes white-tailed deer, mule deer, moose, and mountain goat. Mule deer (including Black-tailed deer) have successfully used almost all wildlife crossings built for them (Bissonette and Cramer 2008). Mule deer and white-tailed deer are adaptive species and over time can learn to use bridges and culverts as passageways, particularly if eight-foot (2.4 m) high guide fencing is present. White-tailed deer have proven to be very adaptive to transportation structures across the U.S. and the preferences for mule deer below can generally apply to them as well.

Mule deer will use culverts as well as bridges for passage (Ford 1980, Gordon et al. 2003, Gordon and Anderson 2003, Rosa 2006). Gordon and Anderson (2003) implemented an experimental design culvert in Wyoming and found the smallest functional culvert dimension for mule deer in this study was 12 feet x 20 feet (3.6 m x 6m) under a two lane road where the culvert was 60 feet (18 m) in length. As a result, these dimensions have become the minimum standard for the design of crossing structures for large herds of mule deer rather than just occasional individual animals. It is important to note this height and span pertained to a two lane road. Cameras at culverts slightly larger than this along
the studied road have recorded tens of thousands of mule deer passes (Sawyer and LeBeau 2011). Longer culverts are less successful at passing mule deer. Cramer (2011) found that the longer wildlife crossing culverts were, the higher the rate of repellence for mule deer, which was the number of animals that approached a structure and left without passing, divided by the total number of animals at the structure. Culverts less than 100 feet (30 m) had rates of repellence under 5%. Culverts 120-150 feet (36-46 m) had rates of repellence 20-30%, and culverts 155 to 165 feet (47-50 m) had the highest rates of repellence, 30-35%. If culverts can be kept under 120 feet (36 m) even along interstates where culverts can be paired with separate structures for the opposing traffic lanes and an open median can be created, mule deer can use structures with 85 to 95% success rates.

Bridges of all types and sizes are proven to function for mule deer. Mule deer have been documented traversing under roads with two to four lanes with span bridges in Idaho (C. Class, personal communication), Utah (Cramer 2011, Rosa 2004), Wyoming (Sawyer and Rudd 2005), Arizona (Dodd et al. 2007b), California (Ford 1980), Colorado (Barnum 2003, Singer et al. 2011), Montana (Cramer et al. 2011) and Washington (Kintsch and Cramer 2011), among many states. The rate of repellence is often not reported in studies or could not be measured. In Utah, rates of repellence at bridges that accommodate two to four lane highways ranges from 2.3 to 20% (Cramer 2011). The combined research suggests that any bridge that is a minimum of 10 feet (3 m) high and less than 100 feet long (30.5 m) as the animal traverses under the road has had success in passing hundreds of animals. In Montana, Cramer et al. (2011) documented white-tailed deer using bridges just under six feet (1.8 m) high. Success rates at these structures were much lower than nearby bridges over six feet (1.8 m). There are few to no studies of mule deer using bridges that are over 100 feet in length under the lanes of traffic. This is because often, when there are greater than two lanes, opposing traffic is accommodated on two separate bridges or culverts with an open median. In Utah, Utah DOT has been able to accommodate four and five lanes of traffic on bridges less than 100 feet in length as the animals traverse under the road. Mule deer have demonstrated an ability to pass over wildlife crossing bridges. Over 1,200 mule deer passes have been documented using North America’s first wildlife overpass in Utah, which is a pair of bridges that measure 210 feet (64 m) long by 22 feet (6.7 m) wide as they cross over I-15 (Cramer 2011). In 2009 in Montana, and 2010 in Nevada, pre-fabricated arch culverts were built around the two lanes of US 93 and dirt was filled over the culverts so wildlife could move over the traffic on wildlife overpasses approximately 100 feet (30.5 m) wide, in both states. Mule deer began using the Nevada overpass within days of completion (L. Bellis personal communication), and within weeks in Montana (P. Basting personal communication). Culvert overpasses such as these provide a cost-effective alternative (less than two million dollars) to wildlife bridges in areas where tunneling traffic is a viable option. In addition to the research on different types of crossing structures, numerous studies have shown that eight feet (2.4 m) high wildlife exclusion fencing is an important mechanism for boosting passage rates, preventing at-grade crossings, and helping animals to adapt to the crossing structures (Clevenger et al. 2002, Cramer 2011, Dodd et al. 2007a). Wildlife fencing to guide deer towards a structure is recommended for all crossing structures, regardless of type.

Moose exhibit an amazing ability to adapt to small structures. Given their restricted range in the United States, few states have experience in accommodating moose in underpasses. In Utah, moose have been documented using 10 feet x17 feet x 165 feet (3 x 5 x 50 m) corrugated steel culverts in the northern mountains (Cramer 2011). Sawyer and LeBeau (2010) have similarly reported moose use of culverts measuring 10 feet x 20 feet x 60 feet (3 x 6 x 18 m) in Wyoming. While this is not the recommended size of structures built for moose, populations have adapted to culverts that have been in place for years. It is believed moose will pass readily under bridges, though there is little documented evidence. An exception is an Alaska study, which documented moose movement under a specifically designed bridge crossing with a minimum passage height of 10.5 feet (3.2 m) along the length of the bridge and nine feet (2.7 m) high guide fencing (McDonald 1991).

Mountain goat demonstrated a willingness to pass under bridges in Montana, just outside of Glacier National Park (Singer and Doherty 1985). This study is the only study known to the authors that documents mountain goat movements through structures explicitly built for them.

Very High Openness Fauna

Unlike the Adaptive Ungulates guild, members of the Very High Openness Fauna guild are particularly wary of predators and require very wide vistas and clear lines of sight through a crossing structure. They tend to prefer no cover to moderate amounts of cover at the structure approaches or even inside the structure, depending in the surrounding landscape’s vegetation and how similar the crossing approaches appear. Cover must not infringe upon their ability to detect or escape from potential predators. While largely composed of ungulate species, including elk, bighorn sheep and pronghorn, other predator-wary species, such as grouse, are also included in this guild.

Elk are very cautious when approaching or passing through bridges and culverts. In over 35 years of studies monitoring wildlife crossings across the United States, elk were consistently extremely wary of using culverts of all shapes and
sizes as crossings. Regular use, defined as a minimum of dozens of passages per year, of culverts by elk has been documented at one location in the United States, along US Highway 30 through Nugget Canyon in Wyoming (Sawyer and Le Beau 2011). Elk use of box culverts at other locations has been largely incidental, with less than five animals per occurrence (e.g., Singer et al. 2011) and less than one dozen passes per year (Cramer 2011, Wakkinen et al. 2011). Prescriptions for wildlife crossings for elk should always involve a bridge. Elk showed a willingness to use bridged wildlife crossings in Arizona (Dodd et al. 2007a), Utah (Cramer 2011, Rosa 2006), Wyoming (Sawyer and Rudd 2005) Idaho (C. Class personal communication), Colorado (Singer et al. 2011) and Washington (Kintsch and Cramer 2011). In Arizona, Dodd et al. (2007b) found that the openness of the area under the bridge is an important factor influencing elk use of structures. This feeling of openness can be enhanced by angled natural substrate support slopes as opposed to vertical walls. In Washington, elk were willing to use areas under bridges that were less than 10 feet (3 m) high, but dozens of feet wide. Elk appear to be highly willing to use two overpass structures in Banff National Park in Alberta, Canada, where monitoring has documented elk passage numbers in the hundreds to thousands (Clevenger and Waltho 2005). In Utah only bull elk have been documented using a wildlife overpass and on only 12 occasions in two years. These are the only two documented locations of elk using overpasses in North America. An overarching guideline for elk passage is to keep structures as open as possible.

Pronghorn are notoriously wary animals and are perhaps the most difficult large mammal for which to design functional wildlife crossings in North American. In a review of pronghorn movements near roads, Sawyer and Rudd (2005) concluded that either very high and wide bridges or overpasses are suitable structures for pronghorn passage. Little research has been conducted on the crossing features influencing pronghorn passage. U.S. Highway 30 in Nugget Canyon in Wyoming may be the only place where pronghorn have been documented using crossing structures (Sawyer and LeBeau 2011). In this herd, it appears pronghorn learned to use the passage by following mule deer through the structure. Pronghorn overpasses are planned for the Trappers' Point area along US 189 near Pinedale, Wyoming.

Bighorn Sheep were studied in Arizona to ascertain their preferences for crossings. Bristo and Crabb (2008) used radio collars and monitoring cameras to evaluate the effectiveness of three existing bridged underpasses for movement of desert bighorn sheep along Arizona's SR 68. In 25 successful crossing events, only rams used the structures. No marked ewes used the underpasses or crossed over the road at grade. In a separate study along US 93 in Arizona, several bighorn rams were documented using bridged underpasses and ewes and rams crossed across the road at grade (McKinney and Smith 2006). The authors of this study determined that the overpasses were necessary for population-level movement. In November of 2010, three bighorn overpasses, two measuring 50' (15 m) wide, and one measuring 100 feet (30 m) wide, by 202’ (61.6 m) long were completed over four-lanes of US highway 93. Based on the initial success of these overpasses and the above studies, overpasses are the recommended structure type for passing multiple members of both sexes of a bighorn sheep population.

Arboreal Fauna

Species in this guild move primarily through the canopy rather than on the ground surface, such as flying squirrels, arboreal voles, and some bats. The best mechanism for providing safe passages for species in this guild is to construct a canopy-level structure across the roadway, for example, a rope or metal bridge. A second method that is still under investigation is the placement of tall poles alongside a two-lane road to assist gliders over the road and flow of traffic. In North Carolina, several pairs of these tall poles have been placed along two lane roads with trees on both sides of the road. There are platforms toward the top of these poles that are meant as launching and landing pads for the flying squirrels in the area. Cameras mounted on these platforms have recorded successful flying squirrel passage between poles (A. Burroughs NCDOT, personal communication). Researchers in North Carolina are investigating this method further.

Aerial Fauna

Aerial Fauna are flyers and include birds, bats, and flying insects. The primary concern with regards to connectivity across roads is to divert these animals away from flying into the path of traffic. Several mitigation methods can help minimize collisions and also the effects of habitat fragmentation caused by road infrastructure. Crossing structures such as bridges and culverts can assist flying fauna to fly below or over the flow of roadway traffic. High bridges that stand well above natural areas allow flying creatures the ability to maintain flight underneath the road. Such structures include causeways, viaducts and expanded bridges. Overpasses for the wildlife are proved to work in Europe where vegetated overpasses provide safe crossings for woodland bird species (Jacobson 2005). Another alternative is to direct animals above or away from the flow of traffic. Where bridges cross over waterways birds may use the airflow at the bridge to swoop in and gain lift. This behavior has been documented in areas along the coasts of Texas and Florida. The Departments of Transportation in these states have installed either aluminum fence poles (Texas) or poly vinyl chloride (pvc) pipes (Florida) on such bridges to create the appearance of a larger barrier thereby causing the birds to fly higher over the bridge as well as the traffic (Jacobson 2005). Predatory birds such as owls are typically killed along roadways.
when they find a source of rodents within the right-of-way. In Idaho and Oregon along I-84, owl spring migrations occur at the same time farmers are plowing their fields, thus driving out local rodents toward the interstate right of way for cover and forage. While no solutions have been initiated as of yet, it appears the problem could be partially mitigated by keeping rodents out of the right of way, or by preventing owls from accessing the prey through the placement of low fences, or by placing materials that flap in the wind to discourage the owls from approaching the right of way. Another opportunity exists in areas where enough water is present to support the growth of bushes in the median. This would make aerial attacks more difficult from a distance across the lanes of traffic. In Arizona, the first U.S. recorded bird crossing was constructed in Tucson. The burrowing owls nesting along the road were in danger of flying over the road barriers and into traffic. The median area was created as a planter and fast growing trees and shrubs were placed in it. This acted as a diversion device to alter the flight of the owls up and over traffic. Unfortunately, habitat destruction nearby forced the relocation of these birds. Experiments in Oregon were conducted to determine how an endangered species of butterfly could be diverted over the traffic on a highway that bisects their habitat. Efforts are ongoing.

CONCLUSIONS

These Species Movement guilds are meant to better classify an animal of concern near a transportation corridor. Interested biologists may not know if a particular species has been studied for their response to mitigation. By placing that species within its respective Species Movement guild, generalizations can be made as to what mitigation solutions could work for that species. The overview above represents an abbreviated gathering of the current state of the science of wildlife and transportation in the United States and Canada. Further details can be found in Kintsch and Cramer (2011).

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BIOGRAPHICAL SKETCHES

Patricia Cramer is a Research Assistant Professor at Utah State University. She has active research project looking at wildlife and roads in Utah and Montana, and is completing a study in Washington State. Dr. Cramer was co-author with John Bissonette on the National Academies' Research Project, 'Evaluation of the Use and Effectiveness of Wildlife Crossings.' This 4 year study helped us understand the state of the practice and science of mitigating roads for wildlife in North America. She is a member of the Transportation Research Board's Committee on Ecology and Transportation. She received the Denver Zoo's Conservationist Award for 2010.

Julia Kintsch is a conservation ecologist and the founder and owner of ECO-resolutions, LLC ecological resources consulting. She conducts wildlife and habitat assessments, develops road-wildlife mitigation recommendations, and facilitates conservation management for public, private and non-profit clients. Julia holds a Master’s Degree in conservation biology from Duke University and has extensive experience in conservation planning, ecological resource management, and mitigating impacts from infrastructure and human activities on wildlife. Previous roles include conservation scientist at Freedom to Roam, director of programs at the Southern Rockies Ecosystem Project, and conservation planner at the Nature Conservancy.

Sandra Jacobson (USDA Forest Service, Pacific Southwest Research Station) is a wildlife biologist specializing in transportation ecology. She provides technical expertise and training nationally for federal and state public land managers and the transportation community on the interactions of highways and wildlife, emphasizing appropriate issues identification and practical mitigation measures. She uses knowledge of federal land management agency practices and policies based on nearly 30 years of work in both the National Forest System and Research and Development arms of the Forest Service.
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HIGH, WIDE AND HANDSOME – A REVIEW OF WILDLIFE AND AQUATIC CROSSING TECHNOLOGY OVER THE LAST DECADE (2001-2011)

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ABSTRACT

Ten years ago, at the 2001 ICOET Conference in Keystone, Colorado, Ruediger (2001) presented a paper entitled High, Wide and Handsome: Designing More Effective Wildlife and Fish Crossings for Roads and Highways. At the time (2001), the paper provided a biologist's perspective of how wildlife and fish crossing should be designed. Since that time, hundreds of wildlife and aquatic crossings have been built, monitored and researched.

The paper and presentation will explore how wildlife and aquatic organism crossing knowledge has evolved from 2001 to 2011. The authors will explore how monitoring and research information gained over the last decade on structure height and width requirements, bottom material, location and structure type has modified current wildlife and aquatic crossing design. Information on noise impacts, moisture content of soil, light, human activities and vegetation associations relative to structure designs will be updated. Also, use of structures by elk (Cervus elaphus), deer (Odocoileus spp), moose (Alces aces), antelope (Antilocarpra americana), bighorn sheep (Ovis canadensis) and various carnivores will be discussed based on current knowledge. The information presented will help transportation agencies and resource agencies design crossing structures that are effective in reducing animal-vehicle collisions, improving habitat and population connectivity, and are cost-effective.

The two authors have been involved with over 100 major wildlife and aquatic highway crossings in North America, particularly in the Rocky Mountain States, and have extensive experience in structure location, design, costs and the interagency coordination required to implement effective highway mitigation. The authors experience spans working for state and Federal agencies and private business associated with assessing habitat connectivity, design and placement of wildlife and aquatic structures and coordinating complex projects with a multitude of agencies and publics.

INTRODUCTION

Ten years ago Ruediger (2001) presented a paper at the 2001 International Conference on Ecology and Transportation (ICOET) whereby several factors related to the efficacy of wildlife crossings were explored either from the limited research available at that time or from observations from field reviews. Some of those ecological and design parameters remain firm today and some assumptions and observations proved to be inaccurate based on ten years of research and monitoring over a wide portion of North America. Some of the information contained in this paper can save Departments of Transportation millions of dollars based solely on the size and types of structures we now know will work for many species.

Recent History of Wildlife Crossings in North America

Wildlife crossings in the U.S. and Canada started primarily from two basic needs. The first was as a solution to the serious issue of animal/vehicle (AVC) collisions. Concern for AVC was the primary issue on the TransCanada Highway near Canmore, Alberta (Leeson 1996); on Interstate 70, Interstate 15 and US 6 in Utah, on Highway 260 and Interstate 17 in Arizona and on the southern portion of US 93 that crosses the Bitterroot Valley.

The second concern that influenced the development of wildlife crossings was a conservation concern for large and mid-sized carnivores like Florida panther (Puma concolor coryi), Florida black bear (Ursus americanus), grizzly bears (Ursus arctos), wolves (Canis lupus), lynx (Lynx canadensis), ocelot (Leopardus pardalis), jaguar (Panthera onca) and others. The common concern was that these species required large home ranges, some had low fecundity rates and all but the Florida black bear were Federal or state listed. Also, humans have always had an unwavering fascination with large carnivores. Early concerns were that carnivores were wary and would avoid using crossing structures as compared to more common ungulate and other prey species. Examples of highways where carnivores were a driving force to implement crossing structures include portions of Highway 93 in Montana (grizzly bear, wolf, lynx and other carnivores), I-70 in Colorado (lynx), highways in the McAllen-Brownsville, Texas area for ocelot; and in Southern Arizona where jaguar received a serious highway crossing consideration in the early 2000's. One of the earliest programs in the United States to systematically implement wildlife crossings was in Florida for Florida panther and black bear. The earliest
International Conference on Ecology and Transportation were located in Florida partly because of concerns about Florida panther and Florida black bears and partly because of other carnivore issues elsewhere in the United States and Canada.

Figure 1. Many early wildlife crossing concerns centered on grizzly bear, wolves, lynx, jaguar and Florida panther, Eastern black bear and other carnivores. Photo by Lawrence Urban.

Changing Theories Related to Wildlife Species Use of Crossings

In the 1980’s and 1990’s many highway connectivity concerns focused on large carnivores. Research over the last ten years suggests that most carnivores often use crossings structures more readily than their ungulate prey, particularly elk (*Cervus elaphus*). Black bear and mountain lion (including Florida panther) and other carnivores consistently use wildlife crossings suitable for deer (*Odocoileus* spp.). There is ample evidence that both black bear and mountain lion (*Puma concolor*) will use even smaller crossing widths and heights than recommended for deer. Ocelots and bobcats in Southern Texas have commonly used relatively small culvert pipes (down to 36” diameter) that are much smaller than the small stature native whitetail deer (*Odocoileus virginianus texanus*) will use (Hewitt et al 1998).

Grizzly bear were and are a concern in Western Montana, NE Wyoming and parts of Idaho and Southwest Canada. The issues related to highways are habitat fragmentation, demographic factors, genetic factors and for the role highway mortality can affect overall human related mortality on grizzlies. For many years concern for grizzly bear habitat and population connectivity drove wildlife crossing concerns where the species are present. Also, like elk, grizzly bear are known to be displaced by open roads, particularly in non-park areas. Grizzly bear densities are relatively low compared to prey species and the females usually disperse close to their maternal home-range. In the Northern Rocky Mountains, one of the primary reasons for recommending wildlife overpasses has been to increase the crossing of highways by grizzly bear.

Are wildlife overpasses necessary for grizzly bear and other carnivore species? In most situations, probably not. It is still believed that optimum wildlife connectivity plans should include a variety of sizes and types of wildlife crossings as well as a system based on an adequate number of crossings, particularly in critical wildlife habitat linkages. This will increase the likelihood of use by a broad proportion of species, ages and sexes of animals.
The Role of Species Adaptability and Learned Behavior in Wildlife Crossing Decisions

The following discussion relates to terrestrial wildlife crossings. As recent monitoring has shown, there is often variability within populations as to whether or not a species will use a structure. The size, type and location of the structure will affect its use. Within these parameters there has been some consistent behavioral variability observed in all large and mobile species. The role of learned behavior is also apparent with crossings generally exhibiting more use as time progresses and animals learn where structures are and lose some or much of their apprehension of avoidance. This learning ability exhibits itself for many years and use may increase for a decade or more (Clevenger 2002).

The ability of wildlife to adapt to crossings has not been discussed much in road ecology literature and discussions. Actually, species adaptability, especially for mobile species appears to be greater than many biologist/ecologist have noted. To practicing road ecologists, this implies that the exact location of structures is probably not a precise point, but rather a range of nearby locations which a species has the ability to locate. Also, other factors such as height, width, length and bottom surface also have more amplitude for adjustment than most biologists/ecologists have previously noted.

Structure design and location flexibility become an important consideration in situations where the “perfect crossing” is not possible (which is common). This is NOT meant as a tome to immediately compromise what is commonly known or is thought to be known about wildlife crossing design, location and use. However, when a crossing design must be adjusted it is usually better to alter design criteria or a perfect location than to lose the opportunity to provide a crossing. The more types, sizes and designs of wildlife crossings that are used, the more biologists and engineers will learn about the variability of design criteria we can effectively use.

As retrofit structures are identified, modified and used, the knowledge of wildlife crossings overall is likely to evolve. With retrofits, the height, width, length, type and location of the existing structure is fixed. In these cases the challenge is to adjust non-static components such as fencing, vegetation, bottom surface and other potential discord elements to maximize potential use.

Figure 2. Moose moving through steel arch crossing. Preliminary monitoring suggests that moose will use a variety of crossing structures. Photo by P. Cramer/UDOT.
REVIEW OF THE STRUCTURAL, ECOLOGICAL AND BEHAVIOR PARAMETERS INFLUENCING WILDLIFE USE OF CROSSINGS

Height and Width of Wildlife Crossing Underpasses

There is much more data available now relative to the height and width preferences of most large animals since the original paper presented by Ruediger at the 2001 ICOET (Ruediger 2001). Height and width may determine what species use a structure and the amount of use. Suitable dimensions for wildlife underpasses are generally more understood than dimensions for wildlife overpasses, simply because there has been almost 50 wildlife underpasses built for every overpass constructed (Bissonette 2006). There is still more research and monitoring needed to understand how factors such as width, length and vegetation composition of overpasses affect wildlife movement.

General height recommendations for underpasses for most large and mid-sized mammal species are (Ruediger and DiGiorgio 2007a):

- **Elk and similar sized mammals** – 12’ high x greater than 20’ in width.
- **Deer and most carnivores up to black bear in size** – 10’ high x 20’ or greater in width.
- **Bobcat and coyote sized carnivores** – 4’ high x 4’ wide.
- **Small carnivores and mammals** – 36” high x 36”.

Ungulates such as antelope, bighorn sheep, moose and caribou (*Rangifer tarandus*) have far less information available to base management decisions on height, width and length of structures. Also, in situations such as Alaska where species like moose and brown bears greatly exceed the average stature of similar species to the south, wildlife crossing dimensions may have to be adjusted upward. Also, providing additional width of a crossing may be more effective than adding additional height. Some of the new structure designs such as concrete span arches (used on I-70 in Utah) allow greater flexibility in providing slightly more width to wildlife crossings (see Figure 8).

![Figure 3. A cow elk crossing a steel arch structure on Hwy 93 near Ravalli, Montana. Elk use of crossings is still a challenge, especially cow elk and mixed groups of cows and calves. Photo by CSKT Tribe and Montana Dept. of Transportation](image)
Natural Appearance

The benefits of a “natural appearance” of structures and approaches were mentioned in the 2001 paper by Ruediger (2001). The concept of “naturalness” is subjective. Generally, what the authors consider natural is having similar vegetation as would occur outside of the highway right-of-way and which animals would normally travel when approaching the structures. It would also include the facing of the structure and the structure appearance as the animal approaches and passes through. The behavior of large mammals approaching and passing through wildlife crossings is better understood than when the 2001 paper was published. How the structures fit into the environment still seems extremely relevant to how readily animals adapt to it – especially some ungulate species like elk.

Figure 4. An example of a well-designed box structure in N. Idaho. Natural vegetation extends to the entrance and the facing is a natural earth-tone. Kim Just and Mike Hartz are in the photo (Idaho Trans Dept.). This is one of the earliest wildlife crossings in Idaho designed by ITD and Sandy Jacobson (USFS). Photo by Bill Ruediger

The ideal structure would have natural vegetation approaches leading from the unaffected natural habitat through the right-of-way and directly to the crossing entrance. It would have fencing that allows easy passage of multiple species and age-classes within those species. The facing of the structure would be of an earth-tone that is similar to the soil and vegetation of the surrounding area. The interior of the structure would be ideally a dull surface or earth-tone. Visibility through the structure should allow an animal to clearly see natural habitat on the far side of the crossing. The bottom of the structure would be similar to that found naturally outside the crossing area and highway sounds heard by animals approaching and crossing the structure would be minimal (see following sections on bottom surfaces and noise factors). Recommended fencing at the approaches of wildlife crossings for deer, elk and other large mammals is 3-strand smooth wire, with bottom and top wires at appropriate heights that allow under or over fence movement of adult and young animals. This is in contrast to wildlife fencing to guide animals into a structure and prevent their access on to highway right-of-ways which usually consists of eight-foot high heavy woven wire.

Factors that likely reduce a wildlife crossing’s effectiveness include: any situations that run contrary to the factors that would enhance a structures natural appearance. These include approaches denuded of vegetation so that animals must leave the security of trees and shrubs or other natural habitat prior to entering the structure; the appearance of bright, shiny surfaces on facing or interior of the crossing structure or having to cross on cement or rip-rapped surfaces
leading into or through the crossing. Dog-legs or other factors that do not allow for animals to clearly see natural habitat on the far side of the structures may reduce some target species use of wildlife crossings. Also, fencing that restricts easy access to target species or multiple fences on each side of the structure.

In many situations, some of the factors that affect a natural appearance may have to be compromised due to cost constraints, terrain, construction requirements, adjacent cut-banks, railroads, adjacent roads, power line rights-of-ways or streams.

**Bottom Surfaces of Structures**

A variety of wildlife and aquatic crossing surfaces have been tried. These include concrete walkways, artificial aquatic “jumping pools”, rip-rap (usually by default) and various natural surfaces involving soil and rock mixtures. Engineers may ask for hardened surfaces inside wildlife crossings to contain streams within defined channels to protect expensive structure footings. Very little research has been done in general to document how various bottom surfaces affect wildlife movement.

![Concrete arch structure on US 6 in Utah](image)

**Figure 5.** A concrete arch structure on US 6 in Utah. The bottom material through this arch is well suited for a variety of wildlife use from deer to amphibians. Unfortunately, there is no stream bank on the left side of the arch to encourage wildlife use. Photo by Bill Ruediger.

Providing a natural surface is still recommended by most experienced road ecologists. In fact, if it is possible to have some vegetation within a structure, or debris such as rocks, stumps or logs passage by small animals that find security, cover, moisture and hiding places will likely be increased. For ungulates, providing a soft soil bottom material may enhance a crossing’s use. For most carnivores, a structures bottom material likely does not matter, as long as they can negotiate the crossing.

**Light and Animal Use**

The effects of light or openness on wildlife use of crossings are still poorly understood. As noted by Jacobson (2009), many wildlife species have far more acute vision than humans and do not see low-light situations the same. This is especially true for mammals that commonly travel in twilight or darkness. The ability to see in low light and near darkness is well developed in most carnivores and ungulates. Many wildlife use crossing structures at night or in low-light conditions.
Structures with high openness ratio values are favored by grizzly bear, elk and deer (structures that are high, wide and short). Structures with lower openness ratios are favored by black bear and cougar. However, there are variances in an underpasses openness that will be used by species such as deer and elk and local animals may habituate to structures that are less than ideal. A structure’s openness may filter some species, some age or sex classes and some individuals. Clevenger and Huijser (2011) do not recommend the use of openness indexes or ratios in planning wildlife crossings, rather they recommend using height, width and length factors in conjunction with other highway structural and environment factors.

**Moisture Considerations**

Moisture conditions are likely important for amphibians that have moist skins, or partially breath through their skins, and for invertebrates that live and breed in moist soil (Jackson 1998, Jacobson et al 2007).

A second situation related to moisture is the positive effect of having water within a structure (or on or near an overpass). Bastings (2011) has noted that structures with live streams, spring or other water sources within underpasses have richer species diversity compared to those without water.

![Figure 6. Picture of three river otter (Lutra Canadensis) crossing Hwy 93 north of Evaro, Montana. Note there is a spring in the middle of the new structure. Structures with streams, springs and other water features will likely be used by a greater number of species compared to dry crossings. CSKT/MDT photo.](image)

**Noise Factors**

In general, the effects of highway noises on the efficacies of wildlife crossings are still poorly understood. There are several crossing situations where the effects of highway and traffic noises seem to have adversely affected wildlife use of specific structures. Many existing wildlife crossings have multiple adverse aspects, so teasing out specific problems may be difficult. The following are specific situations that are known or suspected to have adverse noise impacts on wildlife structure use:

1. Bridge noise on some Highway 260 wildlife crossings, Arizona (Gagnon et al 2007). The interfaces between the steel/concrete bridge spans and the concrete abutments make a load noise when traffic crosses the bridge, especially large semi-trucks. The resulting noise has resulted in elk running away from the structures prior to making successful crossings. The noise probably effects use by other wildlife species as well. Correction of these problems is not simple since the noise evolves from a critical structural element (expandable bridge joints).
2. Highway noise on North Wildcat crossing on I-15, Utah (Wildlife Consulting Resources 2007). This was an interesting case where it appeared to several engineers and biologists that highway noise, especially semi-trucks coming down a long hill above the crossing, was concentrated inside or immediately adjacent to the crossings. The result was a load noise that probably would alarm wildlife near or in the crossings. Mule deer (*Odocoileus hemionus*) were readily using this crossings, but elk appeared to avoid it. Mitigation measures recommended to ameliorate the noise included:

   a. Plant the entire median area (between the two structures) with western juniper or other large trees.
   b. Determine if there is a coating that could be applied to the cement walls that reduces noise and also dull the bright surfaces.
   c. Consider noise abatement on the Interstate highway such as tall cement rail (where the trucks come down the hill) to absorb or reflect traffic sounds.

![Figure 7](image-url) This is one of the wildlife crossings on Hwy 260 near Payson, Arizona. The steel girders supporting the highway make a loud noise that scare elk. Elk use over time increased as animals became habituated to the loud noise. Photo by Bill Ruediger.

Clevenger and Waldo (2005) felt noise levels were important to some species of wildlife use, particularly elk, grizzly bear and deer, but often found only small differences in noise levels between most crossings within a given highway.

The effects of noise on birds were studied by Forman et al 2002 and Drooling and Popper 2007. They found some evidence of displacement of nesting, potential hearing loss and other adverse impacts. The effects of noise increase with traffic volume. There are so many variables that could cause specific responses from noise that it is difficult to isolate the impacts of noise on birds or mammals.

**Human Activity**

Human activity near wildlife structures on the Trans-Canada Highway near Banff was determined to reduce wildlife use of some structures (Clevenger 1998). Generally, human use within or adjacent to wildlife crossings is considered a negative environmental factor. Since the original paper published in 2001, there has been a concerted effort to review existing highways to retrofit existing structures for use by various wildlife species. One type retrofit that is commonly encountered is forest road or other low-volume secondary road crossings of larger highways. Wildlife fencing is often incorporated, which funnels animals into and through the crossing. Similar crossings have been used in Europe and other countries for many years (Banks et al. 2002). In Urban areas tunnels crossing highways for bike paths, riding
paths, hiking trails and limited access roads have been recommended for use by wildlife at night or other low-use periods. Since the original structure are built to facilitate human uses a certain amount of activity takes place. In spite of regular human use many of these crossings are used successfully by wildlife.

The influences of human uses on crossing use certainly depends of the environment they exist in. In some urban areas, such as Tucson, Arizona; San Diego, California and Boise, Idaho and elsewhere wildlife crossings have been proposed in situations where open space, parks and greenways provide habitat to wildlife adapted to living around humans. These species include coyotes, deer, raccoon and other species often considered highly tolerant of human’s but also include black bear, moose and elk in places like Banff National Park in Canada and Anchorage, Alaska (where even brown bears occasionally follow moose into city limits). There is an increasing trend in some cities and suburban areas to provide wildlife habitat linkages, crossings and other mitigation measures that allow citizens to experience wildlife in or relatively close to urban environments. Urban wildlife also can cause problems such as animal/vehicle collisions, attacks on humans and pets, foraging for food in garbage, bird feeders and other unwelcome issues.

Generally, human activity is considered a negative factor in wildlife use of highway crossings (Clevenger and Waldo 2005 and 2000). Especially in crossings built specifically to provide habitat connectivity or reduce mortality of rare species. In these cases it is essential that wildlife crossings operate at optimum levels and minimizing human activity is one of the primary considerations.

**Wildlife Crossing Location**

This is another situation where wildlife adaptability has shown that crossing location may not be as important as previously stated. Certainly, the general location where wildlife crossings are placed is an important consideration. Many times the perfect location for a crossing is not available because of existing or proposed human developments, terrain factors, high costs or other factors. In fact, such discord elements are often encountered by engineers and biologists when planning crossings, even in the most remote areas. The result is that a crossing may have to be placed in a location that is not ideal. While moving wildlife crossings to secondary locations can be risky, there is also a high probability that many species and individuals will adapt to the structure and it will provide useful service. Care must be taken to ensure that target species can negotiate the terrain to the crossing and that other factors already mentioned are adequately considered.

Of course, use would not be expected if the proposed location moved a structure completely out of a species normal habitat range, such as moving a structure expected to pass riparian species into a dry habitat.

The location of wildlife crossings is still an important decision, but having to place a structure a short distance from the ideal location need not be that critical for many species, especially those that are relatively large and mobile. In general, structures placed in higher quality habitat for target species will receive more use than peripheral or lesser quality habitats (obviously).

**Type and Size of Wildlife Crossings Structures**

Probably more discussions take place related to the type of structure to be built than any other factor. This is because the type and size of structures built directly effects the cost of the project. The basic decisions that engineers and biologists face are: 1. How many structures are needed? 2. What type of structures is recommended? 3. How large do they need to be? 4. What are the specific locations where they will be placed? There are also a myriad of other decisions that will be necessary (such as fencing, maintenance and monitoring), but these four questions usually define most the initial costs.

If costs were not a critical consideration there would undoubtedly be many more eco-passes (overpasses) and multi-span bridges recommended and built. However, the cost of eco-passes and multi-span bridges is so prohibitive that relatively few have actually been constructed specifically for wildlife use. In fact, engineers and biologist often may have to agree on structures that are least-cost for target species. Other considerations that may need to be considered are should fewer high-cost structures be recommended, or would a larger number of lesser-cost structures best meet the overall ecological, highway safety and cost goals?

While the debate still goes on as to the size and type of wildlife structure to be built should be, there now is much more information to base the decisions on compared to ten years ago. The type and size of wildlife crossing structures is and always will be a management decision based on costs, risk, current wildlife structure research, target species and relative importance of the overall wildlife populations involved. The factors involved in making these decisions have previously been discussed by Ruediger (2009) and others.
Luckily, most of the information for carnivores, ungulates and many reptiles, amphibians and smaller animals points to at least some efficacy of lower cost structures and for many species the efficacy is similar to higher cost structures. Usually lower cost structures such as box culverts and concrete or steel arches (for large animals) will provide adequate passage by all targeted species. The two species where some concern still exists is elk and antelope. Use by elk of low-cost steel 4 x 7 meter steel arch structures in Banff Canada is adequate.

![Figure 8. Recent (2010) concrete arch structure on I-70, near Richfield, Utah. The crossing had to be placed slightly to the east of an ideal location. However it is close enough that deer and elk used the structure almost immediately. Patty Cramer/UDOT photo.](image)

![Figure 9. Grizzly bear using steel arch crossing on Hwy 93, Montana. Steel arch wildlife crossings are one of the least-cost types of large wildlife crossing, but will usually be accepted by most species. CSKT/MDT photo.](image)
Cost Considerations of Wildlife Crossings

One of the realities of the 21st Century is that available funding for wildlife crossings and other conservation efforts will be limited. This places engineers and biologists in a position of having to make conservative decisions on how many and what type of crossings will be implemented. If a budget is fixed at $10 million for a segment of highway, do you build one or two wildlife overpasses? Or, three or four single span bridges? Or, twenty concrete box culverts or arches? In 2001 these questions were relevant, as all highway engineers understood. In 2012 the issue of costs is paramount as highway construction and mitigation dollars decline. In today’s political and economic environment the reality is often that if any crossings are provided they must be of the most economical types and sizes.

Since 2001 data about efficacy and costs of structures continues to be assembled. For most species, lower cost structures such as arches, pipes and box culverts work adequately. One of the most cost-effective ways to provide for a wide variety of aquatic and terrestrial passage is to ensure bridges and other stream and water crossings allow for a full spectrum of species passage. This includes both adequate height and width at various flow regimes. Since these structures must be provided to allow stream functions, the incremental costs of making minor changes is often less than providing stand-alone structures. Some DOT’s have found that enlarging bridges and other water crossings reduces maintenance costs and increases the length of time when structures must be replaced.

Another low-cost alternative is using existing structures for wildlife passage (retrofits). Even though these may be substandard in respect to height, width and length many can be functional to many target species. While most current retrofits are designed for large mammals, there are infinite opportunities to use smaller cross-drainage structures for smaller animals like reptiles, amphibians and small mammals.

In general, lower cost crossing designs should be incorporated in most highway crossings unless there is well-documented wildlife or ecological issues involved that require more expensive designs. Examples of situations where higher cost structures should be considered include some threatened or endangered species, migratory populations and ecosystem-scale habitat connectivity issues involving multiple species – often including both plants and animals.

WILDLIFE CROSSINGS – SINGLE SPECIES SOLUTIONS OR CRITICAL ECOLOGICAL MANAGEMENT COMPONENTS

Collisions with large wildlife continue to be a concern of DOT Engineers where these collisions are common, but may not be a major ecological or wildlife management concern. On some highways, such as Utah’s US 6 and I-70 and Arizona’s Highway 260 collisions with deer and elk were a major cause of accidents. In recent years there has been an increasing drum-beat from some biologists/ecologists that wildlife crossings are single species solutions to non-critical ecological issues.

Perhaps wildlife biologists should take a second look at the animal/vehicle collision situation for what they might indicate in terms of overall habitat and population fragmentation, mortality of uncommon or undetected species and of the overall health of the affected natural environment. If highways are causing significant mortality (collisions) with highly mobile species such as deer and elk, there is a significant likelihood that less mobile and less common species are already highly impacted. Also, there is growing information from both Europe and the U.S. that highways evolve from low traffic volumes where collisions with large animals may be infrequently hit, to higher traffic volumes where collisions are more common and eventually to high traffic volumes that even the most mobile species may refuse to cross and mortality drops off again. By the time that frequent collisions with large, mobile species become problematic, many less mobile species may have already experienced greater mortality and complete habitat fragmentation.

If the basic conservation premises for species conservation biology are correct – that most species welfare will depend of the following parameters: 1. The amount of habitat available. 2. The quality of habitat. 3. The interconnectivity of habitat. 4. Controlling human related mortality (including pollution factors). Then, highways have been shown to affect all of the above parameters.

Highways and roads continue to be one of the most serious adverse impacts to wildlife, wildlife habitat and natural environments. The most effective solutions involve engineers and biologists working together to avoid or mitigate adverse impacts to species and their habitat. The results of collaborative work between agencies, NGO’s, the public and between various professions such as engineering, ecology, wildlife management, fisheries and planning can be new and modified highways that are surely improvements over the existing conditions. Finding these solutions at a cost that society will accept is a challenge that is both difficult and rewarding. Let’s roll up our sleeves and do something good for the planet!
BIOGRAPHICAL SKETCHES

Bill Ruediger is a wildlife biologist and operates a transportation/wildlife consulting business called Wildlife Consulting Resources (WCR). Bill has worked with numerous State Departments of Transportation and resource agencies on wildlife habitat linkage analysis and designing effective wildlife crossings. Some of the DOT’s Bill has worked with include Alaska, Arizona, California, Colorado, Florida, Idaho, Montana, New Mexico, New York, Oregon, Tennessee, Utah and Wyoming. Bill has successfully completed over 35 transportation/ecology projects since starting his business. He has also worked with agencies or groups in Canada, Europe and Africa on wildlife crossings and transportation issues. Bill has authored or co-authored over 30 published papers on wildlife, carnivores, fish and/or highways. He was a co-author on the FHWA Eco-Logical and Wildlife Habitat Connectivity Across European Highways documents. Bill has received nineteen National and Regional awards including the Forest Service Chief’s Award for Excellence in Endangered Species Management and the Forest Service/BLM Combined Award for Best Project Leader of the Year (2000 - Lynx Conservation Assessment and Strategy). In April, 2005 he will receive “Environmental Leadership Award” from FHWA, the first time this award has been presented to a non-transportation agency person. He also served or headed teams that won three FHWA “Environmental Stewardship Awards” for years 2006, 2009 and 2009. He has a BS in wildlife management from Utah State University and a Master’s degree in Forestry from University of Idaho. Bill retired in December 2005 after 35 years with the US Forest Service. Bill’s last position was that of Ecology Program Leader for Highways, a National level position. In this position, Bill worked throughout the US and in other countries on trouble-shooting difficult highway projects with wildlife and fish coordination issues, helping states organize and establish wildlife habitat linkage programs, developing processes to assess and mitigate wildlife and fish habitat with roads and highways and worked with State DOT’s on wildlife crossings. He also was a founder and chairperson of the Western Forest Carnivore Committee and a co-founder of the International Conference on Ecology and Transportation.

Patrick B. Basting received his B.S. in Forestry at the University of Montana in 1987. For the past 20 years Pat has been a district biologist with the Montana Department of Transportation. In the mid-late 90’s he wrote and submitted the first wetland mitigation banking prospectus in Montana to the Corps of Engineers, worked on several stream and river restoration projects, and has been involved in various aspects of stream (new to Montana – COE Stream Mitigation Requirements) and wetland mitigation. When Pat transferred into the Missoula District in the summer of 2000, wildlife connectivity issues were beginning to gain momentum and recognition. Since that time Pat has been heavily involved in the entire spectrum of transportation/wildlife issues working on placement, design, construction and/or monitoring of over 100 wildlife crossings in western Montana, inter-acting with agency and citizen wildlife groups, sponsoring and chairing multiple road ecology related research projects, and served as a panel member for transportation segment of the Western Governors Associations ‘Crucial Habitats and Corridors Initiative’. Pat has also co-authored a paper “Measuring the Success of Wildlife Linkage Efforts” for the 2007 ICOET Conference and Co-authored chapter in the recent book “Safe Passages: Highways, Wildlife and Habitat Connectivity” Island Press – 2010.

LITERATURE CITED


Basting, Pat. 2011. Personal communication.


**ABSTRACT**

The OTIA III State Bridge Delivery Program is part of the Oregon Department of Transportation's (ODOT) 10-year, $3 billion Oregon Transportation Investment Act program. OTIA funds were utilized to repair or replace hundreds of bridges, pave and maintain city and county roads, improve and expand interchanges, add new capacity to Oregon's highway system, and remove freight bottlenecks statewide. About 17 family-wage jobs are sustained for every $1 million spent on transportation construction in Oregon. Each year during the OTIA program, construction projects will sustain about 5,000 family-wage jobs.

Oregon Bridge Delivery Partners (OBDP) is a private-sector firm that has contracted with the Oregon Department of Transportation to manage the $1.3 billion state bridge program. OBDP, a joint venture formed by HDR Engineering Inc. and Fluor Enterprises Inc., will ensure quality projects at least cost and manage engineering, environmental, financial, safety, and other aspects of the state bridge program.

The environmental framework developed for the OTIA III State Bridge Delivery Program is founded on a series of Environmental Performance Standards (EPS). These EPS outline pre-approved processes for avoidance, minimization, and mitigation measures. Regulatory concurrence was received during the development of the EPS rather than during the design of the project.

Seven years into the OTIA III program, all projects have been designed and permitted and construction is fully underway with 62 bridges (out of 365) left to finish construction.

Innovative and creative use of technology has been a keystone for these accomplishments. Environmental professionals input the relevant environmental data for a project in a comprehensive, on-line Pre-Construction Assessment (PCA). The data was used to identify project challenges (e.g., archaeological sites or wetlands within the project footprint) and compile electronic reports to the regulatory agencies that are provided each year to show how the required metrics are being met. Environmental metrics, such as exempted T&E species “take” and wetland fill quantities are tracked using the GIS database. One framework meets the needs of many stakeholders.

Now with almost seven years of execution, we have some great successes and lessons learned to share. We have continued to adapt and develop tools to be successful – as well as shift our operating structure. The focus of this presentation will be on how well the metrics were met using the EPS, gauge the program success and look at how the EPS are being updated for use in the future on other programs.

Now what: The future of EPS: This early environmental target identification allows the project to be designed with low risk to costly redesign. This has been successfully implemented on multiple projects in Oregon and is now being utilized on other programs across the country including work on the Jobs in Transportation Act (JTA).

**INTRODUCTION AND BACKGROUND**

ODOT pioneered a collaborative process a decade ago beginning when Northwest salmon runs were listed under the Federal Endangered Species Act (ESA). As a result of the salmon listing, the permitting process became more complicated and seeking approval one agency at a time was leading to project delays and inefficiencies. ODOT was also encountering issues with integrating National Environmental Policy Act (NEPA) requirements into its Clean Water Act permitting process. At the same time, ODOT projects doubled due to an influx of funding from the newly allowed sale of state transportation bonds.

In 2001, the Oregon Legislature passed the Oregon Transportation Investment Act (OTIA I), which increased a number of driver and motor vehicle fees to secure $400 million in bonds to finance a range of road infrastructure improvements. In 2002, OTIA II was passed thereby adding another $100 million for additional work. Combined with
matching funds from local government, OTIA I and OTIA II provided funding for 160 projects across Oregon aimed at increasing lane capacity, improving interchanges, repairing and replacing bridges, and preserving road pavement. These two phases of OTIA were permitted utilizing standard permitting processes.

In 2003, the State’s focus turned toward the hundreds of aging concrete bridges, causing ODOT to impose weight restrictions. The Economic and Bridge Options Report, produced by ODOT with the trucking industry and other stakeholders, estimated that Oregon’s deteriorating bridges could cost the state more than 88,000 jobs and $123 billion in lost productivity over the next 20 years if the situation were not rectified.

The Oregon Legislature responded to this by passing House Bill 2041 in July 2003, which enacted OTIA III. The third phase of OTIA provided $2.46 billion for Oregon transportation infrastructure over a 10-year period, including $1.3 billion for repair or replacement of the state highway system’s aging bridges. The OTIA III State Bridge Delivery Program (Program) was promoted as serving a dual purpose: road infrastructure improvement and job creation.

ODOT also understood to meet the deadlines of the OTIA III program (10 years) they would need to work closely with the regulatory community and other stakeholders to develop a new permitting process and improve partnerships.

The OTIA III Program is part of the ODOT’s 10-year, $3 billion Oregon Transportation Investment Act (OTIA) program. OTIA funds will repair or replace hundreds of bridges; pave and maintain city and county roads; improve and expand interchanges; add new capacity to Oregon’s highway system; and remove freight bottlenecks statewide. The Program is also expected to decrease unemployment and increase economic development. About 17 family-wage jobs are sustained for every $1 million spent on transportation construction in Oregon. Each year during the OTIA program, construction projects will sustain about 5,000 family-wage jobs.

Oregonians have not seen an investment of this magnitude in highway and bridge construction since the state’s interstate freeway system was built in the 1950s and 1960s. The sheer size and scope of the bridge program means that the ODOT must change how it does business. The agency hired Oregon Bridge Delivery Partners (OBDP), a joint venture formed by HDR Engineering Inc. and Fluor Enterprises Inc., to assist in the management of the program. The ODOT is making a historic shift from an agency that self-performs its design and construction projects to one that manages the transportation system.

Many of the bridges slated for repair or replacement are on Interstate 5 and Interstate 84, which are the state’s economic lifeline routes. These interstate highways carry most of Oregon’s commercial truck traffic. If the hundreds of aging bridges on these routes and others are not repaired or replaced, the ODOT will soon be forced to place weight limits on highway bridges that would impair Oregon’s economy.

The ODOT and OBDP are utilizing this program to implement a new decision-making framework called CS\textsuperscript{3}, or Context Sensitive and Sustainable Solutions. CS\textsuperscript{3} helps to preserve Oregon’s scenic, aesthetic, historical, cultural, economic, environmental, and other values while building safe and enduring projects. It is community values shaping a new generation of bridges. CS\textsuperscript{3} puts communities at the heart of important project decision-making.

Through the CS\textsuperscript{3} initiatives, the bridge program helped to produce a better trained workforce, prosperous communities, a stronger state economy, and bridges that take into account their impact on the natural environment.

**COLLABORATIVE APPROACH – OTIA III AND JTA**

The collaborative approach from CS\textsuperscript{3} continued through the addition of the Jobs in Transportation Act (JTA) work. The Governor’s Transportation Vision Committee (Vision Committee), comprised of representatives from state government, the Oregon Legislature, the private sector, public agencies, nonprofit organizations and local government, worked together for over a year to develop the 2008 Transportation Vision Committee Report to Governor Ted Kulongoski [link](#) with recommendations to focus on how to make a new investment in the transportation system that creates jobs for Oregon’s workers, a sustainable environment for our children, and expand transportation choices for Oregonians. These recommendations helped to develop the JTA.

The Vision Committee made several recommendations pertinent to Section 18. The Vision Committee recommended broadening the use of environmental standards to all transportation construction projects funded with state funds. The Vision Committee also recommended that ODOT expand the use of performance-based permitting beyond OTIA III to permit significant portions of the STIP such as bridge and modernization projects.
The ODOT has been working collaboratively with federal and state agencies to integrate and coordinate environmental protection, permitting, enhancements, and reuse and recycling into the overall Program. The EPS have been developed to ensure safe practices with regard to hazardous materials, to protect Oregon's natural resources, and to provide economic stimulus by expediting the Program.

In 2004 and 2005, multi-disciplinary teams representing key federal and state agencies developed the OTIA III EPS with the goal of creating well-integrated and consistent terms and conditions for each agency's respective regulatory process. The EPS provide consistent expectations and guidelines for design and construction teams to meet ODOT and regulatory agency requirements for completion of the bridge program, and cover expectations for the program ranging from habitat and species protection through materials reuse and recycle.

The ODOT also realized that successful program management means sustained collaboration. The regulatory partnerships needed to be maintained on the program and open communication regarding all project elements was vital. To facilitate this effort, two key regulatory partner teams have been established. The first team is the Programmatic Agreements Reporting and Implementation Team (PARIT), made up of regulatory partners from Oregon Department of State Lands (DSL), U.S. Army Corps of Engineers (ACOE), Oregon Department of Fish and Wildlife (ODFW), US Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), Oregon Department of Environmental Quality (DEQ), Federal Highway Administration (FHWA), State Historic Preservation Office (SHPO), ODOT and OBDP, meets twice a month. The second team is the Materials and Contamination team, made up of members from ODOT, DEQ, and OBDP, which meets monthly. The teams provide an avenue for open communication that allows all the agencies to work through project questions/concerns.

**THE NOW: OTIA III UPDATE**

**PERMITTING**

The new approach to permitting for the Program included a batched, programmatic Biological Opinion (BO), a Regional General Permit (RGP), and 401 Water Quality Certification. The EPS are the guidance to the design and construction teams to show that the intent of the programmatic permits is being met. The EPS present the intent and goals of the regulatory consultation and provides guidance on acceptable implementation methods to achieve the performance criteria. However, the permits were created for the entire State and cross many different ecological systems (ecoregions). When developing the Program, it was understood that variances to the EPS and the permits may be required. The BO outlines the required variance process to be followed if these circumstances are determined on the Program projects. Design and permitting of the projects was finalized in 2010, with 95% of the Program bridges utilizing the programmatic permitting approach.

**Variance**

Successful program implementation and stewardship means the continued collaboration with the regulatory partners when it is noticed that the EPS and permits may need to be varied from (for items such as in water work extensions). There have been projects that have shown that variances can be beneficial. The variances still meet the intent of the programmatic and CS3 approach, but due to on site conditions or certain construction methods, a variation to what was outlined in the EPS was needed. The variances are negotiated with the regulatory partners and end in a win-win for all partners.

In 2010, there were eleven (11) variance requests for fifteen (15) water crossings. All of the variances were accepted by the agencies. One in-water work window variance was initially requested by the design-build contractor, but was retracted after further discussions. Early in the Program, ODOT/OBDP changed construction specifications so that the contractor was responsible for extension requests (providing all necessary documentation and justification). What has been seen since this was made a requirement is a decrease in the number of requests as contractors are determining better ways to stay on schedule.

**Avoidance and Minimization**

Building projects sensitive to their communities and landscape is one of the five OTIA III Program Goals. This goal, at the heart of the OTIA III Environmental Stewardship Program, prioritizes avoidance and minimization efforts. After three years, implementation of the avoidance and minimization philosophy has been highly successful.

Ninety-five percent (95%) of eligible bridge delivered through OBDP have used the programmatic permitting strategy. At the end of 2010, more than 209 bridges had been constructed and almost 60 more are in construction, with an additional two (2) bridges approaching the construction stage. The ODOT/OBDP environmental staff has, to date,
conducted approximately 1,300 construction monitoring/inspection visits. There has been one permit violation during the seven years of construction. Due to the collaborative approach, ODOT/OBDP self-reported the permit violation and the violation were quickly negotiated with the affected agencies.

Less than 10 percent of the program exempted “take” has been allocated for any species. The Program has had equal successes implementing this framework with design-build and design-bid-build delivery. OBDP/ODOT looks forward to continued success as we maintain our most effective tool – collaboration.

Wetlands and waterways are within the “Area of Potential Impact” (API) of nearly 80% of the 365 program bridges; however, less than 20% of the projects have impacted aquatic resources to date. To date, there has been no observed lethal take on the Program. Many of those impacts are associated with temporary structures (e.g., work area isolation, detour bridges, work platforms, containment structures) or enhancements (removal of existing fill within the floodplain or riparian corridor). To date, there has been less than 2.3 acres of temporary fill and 1.0 acre of permanent fill in waterways. There has also been 5,450 cubic yards of fill removed from the functional floodplain at 58 bridge sites to improve fluvial processes. There has been 9.1 acres of temporary and permanent riparian impacts to date and 8,280 linear feet of streambank habitat has been disturbed, which is significantly less than originally expected. The Program originally identified the need to construct wetland mitigation banks that now are not needed due to the avoidance measures.

Nearly every bridge within the Program has habitat for some sensitive species – from birds (marbled murrelets, northern spotted owl, etc.) to fish (salmon, suckers, etc.) to invertebrates (vernal pool fairy shrimp, Fender’s blue butterfly, etc.) to plants (Kincaid’s lupine, Bradshaw’s lomatium, etc.). The Program has a batched-programmatic biological opinion that allocated incidental “take” for 22 threatened or endangered species. To date, OBDP have determined the amount and extent of take for over 30% of the bridges, and assigned less than 1% of the “take” allocated in the BO for the Program. Looking forward, it is possible that OBDP will complete the program with less than 10% of the entire take allocation being used. After six construction seasons, there has not been any lethal take on the Program. Overall, the Program is exceeding avoidance expectations.

Conservation and Mitigation Strategies

The BO also has a requirement for conservation and mitigation of specific species of concern. To date, conservation strategies have been completed for Bull Trout and Oregon Chub and are underway for Fender’s blue butterfly, Northern Spotted Owl and Marbled Murrelet. Other species identified were not impacted.

MATERIALS AND CONTAMINATION

The Materials and Contamination performance standards were added to the EPS in September 2005. The Materials and Contamination Environmental Performance Standards include three primary environmental areas: 1) Management, 2) Materials Management, and 3) Contamination Discovery and Management. In an effort to meet requirements of the Governor’s Executive Order on Sustainability, the ODOT is tracking information on construction and demolition waste management, recycled materials use, fuel selection, and equipment retrofitting for particulate emissions, in order to report on success in meeting Program goals.

This particular EPS identifies reuse and recycling goals for the Program as well as identifies safe handling practices for materials. Use hierarchies are discussed for all materials and outlines preferred reuse methods including on-site use all the way down to landfilling. The EPS provides guidance to the construction contractor for managing material waste streams.

DESIGN

Part of the success of the stewardship process is how well the program expectations were encompassed into the bridge designs. To assist in this, a series of tools were used in the design stage of the projects. These tools helped to create the CS³ projects that the regulatory agencies and state partners were expecting. The ODOT created Engineering and Environmental Baseline Reports to provide an early evaluation of the project areas and identify potential areas of concern. The baseline reports help to identify resources within the project area that may be affected by the bridge construction. The resources include natural resources, wetlands, cultural and historic, materials and contamination sites, and Environmental Justice populations, among others. Engineers and designers utilize this information to aid in the design of a bridge that is not only structurally sound and safe, but also avoids or minimizes the impacts to resources near the bridge area.

The design teams utilized the EPS to determine the best path forward in creating a CS³ project package. Innovative and creative use of technology has been a keystone to the framework. Environmental professionals input the relevant
environmental data for a project in a comprehensive, on-line Pre-Construction Assessment (PCA) database. The design team utilizes the baseline information, EPS, and site visit data to complete the PCA requirements.

The data was used to identify project challenges (e.g., archaeological sites or wetlands within the project footprint) and compile electronic reports to the regulatory agencies. Environmental metrics, such as exempted T&E species “take” and wetland fill quantities are tracked using the GIS database. Thus, one framework met the needs of many stakeholders.

How to successfully implement the permits into construction contracts was a key lesson learned in the design portion of our projects. The permit and EPS requirements needed to be translated into specification language. OBDP started to receive specifications from the design A&E firms that varied widely on how they wrote up the commitments and tried to make them enforceable. At that time, OBDP determined it would be better and more cost and time efficient, and help verify that the commitments were being incorporated into the specifications if a template specification was created.

The tools used in design provide more consistent construction documents (plans and specifications) to ensure the Program permits and regulatory commitments are transferred to the construction phase of the projects.

CONSTRUCTION

OBDP and the ODOT have set up a number of contractual requirements which promote environmental stewardship and collaboration with the construction sector. One such requirement is providing an environmental stewardship training session to the construction contractor’s staff. In the environmental stewardship training, the basis of the Program is explained. The training includes the biological opinion, the streamlined permitting process through the PCA, and the EPS are discussed along with erosion and pollution control requirements, incident response / violation procedures, communication procedures, and project specific environmental concerns. This training lays out the roadmap construction contractors need to follow in order to remain in compliance with the program permits and the overall program goal, and lays out in detail the implications of failure to maintain compliance with the program permits. Expectations for environmental compliance are outlined: how will a site be assessed? What would a compliant item look like? What is non-compliant? Recurring issues are discussed, and the environmental stewardship training provides a forum for training and guidance to limit or prevent future recurrences. This is part of the outreach to construction contractors. To date, all construction stewardship trainings have been completed, but are refreshed/renewed as construction staff changes or as issues arise on projects.

During construction the environmental stewardship framework is implemented through environmental compliance inspections. The objective of environmental compliance inspection is to document the project compliance with respect to the program permits and the construction contract and aid construction contractors in understanding the environmental concerns. A large portion of our construction compliance is to teach contractors about the Program and environmental stewardship and to grow everyone’s ownership in the Oregon environment. Compliant and non-compliant items are documented as well as the corrective action and associated timelines necessary to get a project back into compliance with the project permits. Since program inception, OBDP has completed almost 1,300 environmental compliance inspections.

Most inspections are completed in conjunction with the construction contractor, and findings are shared with the contractor, OBDP, ODOT, and regulatory agencies through an online document management system. The most commonly observed items requiring correction are associated with erosion control and pollution control, such as improper installation of erosion control materials or minor fuel spillages. Contractors were able to quickly repair or remediate the situations before the issue resulted in a permit violation, demonstrating an increasing initiative in preventing environmental permit violations.

The inspections allow OBDP staff members to identify areas where improvement may be necessary and/or required to improve compliance with permits and to provide a larger overall benefit to terrestrial and aquatic species and habitats. Periodic inspections help the environmental staff identify problems so they can be fixed before becoming more serious and potentially result in a formal violation from a regulatory or resource agency.

Annual refresher training is provided to all OBDP and ODOT construction staff, prior to the start of the in-water work season. The refresher includes reminders of what to watch for during construction, what is important to regulatory agencies, and what is critical to maintaining environmental success and stewardship. It incorporates lessons learned from the previous construction season.

The result of this collaborative environmental stewardship framework is that, to date, one formal violation of an environmental permit has been issued. Additionally, this collaborative approach to environmental compliance
inspection is changing the construction culture; construction contractors, taking a more proactive approach to environmental stewardship, are recognizing the benefit of the programmatic permits. Lessons learned during environmental compliance inspection will continue to be incorporated into future contracts for both the Program projects as well as other ODOT projects.

CONSTRUCTION WASTE REUSE AND RECYCLING STEWARDSHIP

As part of our stewardship goals and the implementation of the Materials and Contamination EPS in construction, OBDP has requested that construction contractors report on the reuse and recycling efforts on their projects. There will eventually be a contractual requirement for such reporting, but for the moment, ODOT and OBDP are working with the construction contractors to raise awareness of reuse and recycling. As part of that effort, the contractors have voluntarily documented and reported on their projects.

In 2010, construction contractors reported an estimated weight in tons of recycled material at approximately 262,000 tons with a savings over $9,434,000 on reuse and recycling of project materials; however, the savings are expected to be much higher as a result of substantial unreported cost savings. To date, there is an estimated $14 million in saving reported.

Off-road diesel is not allowed on the OTIA III Program and per construction specifications “Use highway grade diesel fuel in all pieces of equipment where clean-burning fuels cannot be used.” In 2010, contractors reported utilizing over 169,700 gallons of ultra low sulfur diesel (ULSD) and over 58,200 gallons of biodiesel. Regular unleaded gasoline, highway-grade diesel, and off-road diesel are also reported. In 2010, off-road diesel was utilized, but was used oil used in asphalt paving operations. The use of the ULSD fuel results in an approximate 15% reduction of particulate matter emission when compared to the use of off-road diesel fuel.

LESSONS LEARNED

As part of our continued commitment to our environmental stewardship goals, program updates based on our design and construction lessons learned are continually being incorporated into our projects.

OBDP are continuing to try new products and processes with the potential to provide a benefit to the owner and resources, at the same time recognizing that we can and probably will encounter the failures which are intrinsic to the experimentation process. Experimentation and innovation have the potential to provide more cost-effective solutions to common issues, but the potential benefits must always be weighed against the cost of failure and its ramifications.

GIS, databases, template report outputs, online interfaces and program-dedicated emails and portals were undoubtedly central to the success of the environmental program because they helped develop transparency and accountability that was critical to developing trust with participating agencies. Developing these program-specific tools for a dynamic program is a challenge. Development of most IT systems works best with a static program. You know how it should work, there is a set user with a set need, you build it once and it’s done. That was not the situation for this program. Environmental regulations and permitting processes change, even on a program with established agreements. And the needs of the users change. That meant ODOT’s systems had to be adaptable.

ODOT and OBDP also had to recognize that each agency had its own administrative process that had to be followed. One of the earliest challenges that also required time and attention was the routing of project materials, such as preconstruction agreements and wetland delineations. Discussing submission processes, format, layout, file size and content kept our Programmatic Agreements Reporting and Implementation Team (PARIT) discussions relevant and necessary. The way this was resolved, was the permitting document was broken down into the “hard copy” elements required by two agencies and left as a whole document and uploaded to the document control system for the remaining agencies.

As part of the lessons learned process, OBDP incorporates observations of successful and unsuccessful construction materials and practices into future projects. Some of the biggest lessons learned helped during construction on means and methods for creative solutions to prevent permit modifications.

Unless commitments made in the permitting packages are transferred into the construction contract, a construction change order might have to be requested or a permit modification pursued. Change orders, even ones which result in a net savings or in no additional cost, have the potential to delay a project. Permit modifications can result in more impact (within the terms of the BO) to sensitive environmental resources or additional cost to the construction contract for additional protective measures required by resource or regulatory agencies as a condition of the permit modification.
Recognizing that continued minor inconsistencies in construction contracts could result in major issues during construction, specification templates were developed to help streamline the design process with regard to environmental requirements as well as to increase the consistency of EPS incorporation into the construction contracts. In addition, the specification templates incorporate enforceable language proposed from design firms and internal sources as well as lessons learned during previous construction seasons.

Other lessons learned seem like smaller issues to work through, but are far more important than most people realize, especially when working with such a collaborative approach. People want to contribute and they need to be listened to. A key difference between this program and standard practice, as explained to ODOT by nearly every regulatory agency liaison, is that ODOT listened to all participants, regardless of regulatory authority on a specific project or project element. Without question, this put the development of trust in the fast lane.

Details matter. If the program were to start over tomorrow, one item to change would be how certain data which was both influential in project costs and prone to conflicting opinions, would be collected in the field. In particular, the functional floodplain, a zone developed for the program, would be determined with the PARIT in the field, rather than with consultants. Too many hours were spent in strong disagreement as to whether the proper cross-sections were selected, the methods adequately followed or the report sufficiently prepared.

Documenting the decision is not enough; the reasons behind the decision also need to be documented. Documenting and regularly revisiting the reasoning for decisions helps manage staff turnover, forgetfulness and time. Each agency that OBDP and ODOT worked with had some staff turnover, being able to pull out the record and revisit what the team did together builds and strengthens the trust of the participants.

A program is only as strong as the people who participate. The strongest, most logical framework will crumble if there is not trust, collaboration and the spirit that we all get there together. Combative, disrespectful, secretive, manipulative communication will erode the strongest foundations of any program. This is why the frequency of meeting, duration of discussions and large membership of the PARIT were so critical to success. Many outsiders thought we met too often, for too long and with too many liaisons. However, if the PARIT’s makeup were determined solely by the topic that day, then trust would erode. It also slows the process. By having everyone in the room at the same time, the meeting itself may have lost a small percentage of efficiency; however, that 15 minutes lost in the meeting more than made up for the weeks or months of time that would be lost on the overall project schedule.

THE FUTURE: JOBS IN TRANSPORTATION ACT

As discussed earlier, following the success of the OTIA III Program, the Jobs in Transportation Act (JTA) was enacted. Section 18 of the JTA placed requirements to expand upon the permitting successes of OTIA III as well as the lessons learned, including some of those reported above. The JTA is taking into consideration the EPS for all state highway construction projects and local government projects funded by ODOT. The intent of the new EPS will be to improve the environmental permitting process for highway construction projects.

The key to the JTA is that it will help move all of ODOT further towards outcome based permitting versus traditional environmental permitting process and not just a specific program such as the bridge repairs and replacements. The key for this to work is the continued collaboration and to build upon the solid relationships with regulatory agencies developed through OTIA III and other outreach efforts over the past decade.

The new EPS are being developed utilizing stakeholder groups. The first step was to obtain feedback from A&E firms, contractors and the regulatory community on how the OTIA III and other programmatic permitting have worked in the past. A good baseline on what worked well and what improvements would be needed was created.

New EPS are being developed through established working groups populated by environmental staff, designers and regulatory agency staff to develop EPS and build upon the existing programmatic agreements and permitting requirements. There also needs to be appropriate guidance documents developed to communicate design level specifics to designers regarding how to meet EPS.

The collaborative portion of this process is going to be critical because these EPS will be managed differently than those of OTIA III. There will not be a single “governing” body such as the PARIT that reviews each project and verifies commitments of the EPS. Also, compliance with EPS and associated accelerated permitting vehicles will be optional. This process allows ODOT to follow traditional permitting processes if project scope does not fit within EPS framework.
CONCLUSION

Through continued collaboration and a high level of communication with Federal and State partners, ODOT and OBDP have continued to have a successful environmental stewardship program on the OTIA III Program. As design has completed and construction continues to ramp up, these principles are going to be critical for continued success. These successes have also helped create the basis to a new program for ODOT through the JTA process. Improved environmental stewardship will continue through this program and keep ODOT as a forerunner in environmental stewardship.

The construction inspection team set up on the Program continues to work with construction contractors as a “training” opportunity, not as an enforcement opportunity. The inspection team works as a partnering team with the construction community to raise awareness of the important environmental issues and find solutions to critical path construction details. This benefit is starting to be seen on non-Program projects and will continue to be the legacy of the success of the Program’s environmental stewardship program.

The environmental stewardship framework developed for the Program facilitates design and construction of projects that are sensitive to their communities and landscape while streamlining the permitting process. The collaborative approach with regulatory partners has been a key success in the avoidance and minimization of project impacts and the sixth year of successful environmental stewardship for the Program.

This success is measured by the numbers and results to date. The application-to-permit timeframe was reduced from roughly six months to less than 30 days. More than 95 percent of all eligible bridges (206 bridges) followed the programmatic permits. Zero construction let dates were missed due to environmental permitting and zero redesigns were required due to environmental conflicts. A cost-benefit analysis showed a $3.19 return on investment for each dollar spent on permitting (approximate $75 million in Program savings).

Following the success of the Bridge Program, the Oregon Legislature appropriated funds to new transportation funding, the Jobs and Transportation Act, that effectively requires use of the key elements of the OTIA III environmental program, such as EPS and collaborating with resource and regulatory agencies. The benefits of the EPS that helped move the JTA program forward include defining how ODOT will meet regulatory requirements upfront in the design process, taking the guesswork out of the design process, removes environmental from the critical path and improves reliability for project delivery.

BIOGRAPHICAL SKETCHES

Shelley D. Richards, P.E., HDR Engineering. Shelley has 15 years of experience in the environmental and transportation fields and has been with HDR for nine years and was at ODOT prior to that. As the Environmental Manager for the Oregon Bridge Delivery Partners (OBDP), Shelley oversees program, design and construction oversight staff – operating throughout the State. Prior to the Program, Shelley was a Project Manager for challenging transportation projects, including rail and highway for design and construction. In her role with HDR’s OBDP, she manages the environmental design and construction portions of the program and maintains the environmental requirements on the projects. She works closely with all the local, state and Federal regulatory agencies. Shelley is a Registered Professional Engineer (PE) in Oregon and Washington and holds a Bachelor’s of Science degree from Washington State University in Civil Engineering, a Master’s of Science degree from Portland State University in Civil (Geotechnical) Engineering as well as an International MBA.

Howard (Hal) Gard, Oregon Department of Transportation. Hal Gard manages the Geo-Environmental Section (ODOT’s Chief Environmental Officer) within ODOT’s Technical Services Branch. The Section is composed of four Units; Engineering and Asset Management, Natural Resources, Environmental Planning, and Program Support. Hal has worked for ODOT since 1994 when he was hired as the department’s first archaeologist. After having developed and managed that program for 8 years, he joined the newly formed Bridge Delivery Unit to work on new environmental streamlining opportunities presented by the OTIA III program before joining Technical Services. Hal is a Registered Professional Archaeologist and holds a Bachelor’s Degree from the University of California in Anthropology, and a Master’s Degree from Oregon State University in the co-fields of Archaeology, Fish and Wildlife, and Geo-science.

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