EVALUATION OF WILDLIFE CROSSING STRUCTURES AND FENCING ON US HIGHWAY 93 EVARO TO POLSON

PHASE I: PRECONSTRUCTION DATA COLLECTION AND FINALIZATION OF EVALUATION PLAN

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RESEARCH PROGRAMS

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Evaluation of Wildlife Crossing Structures and Fencing on US Highway 93 Evaro to Polson

Phase I: Preconstruction Data Collection and Finalization of Evaluation Plan

Final Report

by

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16. Abstract

The US 93 reconstruction project on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to occur in the continental United States. The reconstruction will include installations of 42 fish and wildlife crossing structures and approximately 15 miles (24 km) of wildlife exclusion fencing for a total investment of over $9 million. This report documents the success of using a context-sensitive approach to collaboratively redesign a rural highway within a multiple use landscape that accommodates the needs and concerns of different institutions, cultures and priorities. Further, this report introduces baseline field data collection methods and results that are being used to evaluate how the wildlife crossing structures and wildlife fencing affect deer- and bear-vehicle collisions and movements in a multiple-use rural landscape. The preconstruction data summarized here, and in combination with complementary post-construction data, will address the following goals of the evaluation study: 1) determine what effect US 93 wildlife crossing structures and fencing have on the frequency of animal-vehicle collisions and successful animal highway crossings; 2) document the design decision-making processes and lessons learned as a "case study"; and 3) identify best management practices and further research. These issues are addressed via a literature review of important considerations related to locating, designing, and evaluating the effectiveness of wildlife crossings and exclusion fencing; a case study and project history; summary and synthesis of field data collection efforts; overview of other relevant and repeatable field studies; and a discussion about the measures of effectiveness and post-construction data collection recommendations. The ultimate value of the information in this report will be realized when the reconstruction is complete and post-construction field data is collected to comparatively assess the effect of the wildlife mitigation on the parameters of interest identified in the goals. Perhaps one of the most important insights gained from the preconstruction research is that, due to the myriad sources of unquantifiable variation in the environment, many years of monitoring are necessary to make valid inferences. Given the paucity of long-term, before-after field studies assessing the effects of wildlife exclusion fencing and crossing structures on wildlife and driver safety, the US 93 wildlife mitigation evaluation, when completed, will provide useful results, lessons learned, and best management practices to guide other wildlife mitigation efforts in the future.

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Animal-vehicle collision, habitat connectivity, wildlife crossing structures, wildlife fencing, mitigation, road-kill, rural transportation, safety, Wildlife

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CONVERSION CHART

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

FHWA (2004).

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A substantial portion of the funding for this project was subcontracted to Dr. Chris Servheen and Karin McCoy of the University of Montana in Missoula for a research thesis on the movements and genetic connectivity of black bears in the US 93 study area. WTI appreciates their significant efforts to establish focused preconstruction baseline data on black bear movements and genetics relative to the highway. Outside of this project's funded budget, WTI was pleased to collaborate with other researchers focused on preconstruction data collection related to US 93's upcoming reconstruction. Primarily funded by MDT, with additional funding provided by WTI, Dr. Dan Pletscher and Kathy Griffin of the University of Montana conducted an extensive dissertation study on western painted turtle movements relative to US 93 and other roads; WTI appreciates their willingness to share detailed roadkill observations collected during intensive survey efforts.

The WTI Graduate Fellowship Program, in cooperation with the Wildlife Conservation Society (WCS), supported graduate student Whisper Camel, under the direction of Dr. Jodi Hilty of WCS as well as Dr. Sharon Eversman and Dr. David Willey of MSU's Ecology Department, with her research thesis assessing variables that contributed to deer-vehicle collisions and crossings of US 93 prior to reconstruction. Additionally, the WTI Graduate Fellowship Program provided support for Darren Baune, under the supervision of Dr. Otto Stein of MSU's Civil Engineering Department, in his pursuit of a graduate professional paper on existing hydraulic and fish passage conditions at selected culverts to be replaced in the reconstruction of US 93. These efforts provide additional preconstruction baseline data, above and beyond the focus of this study and can provide further insights into the effect of the reconstruction and mitigation efforts for US 93.

Finally, the authors are grateful for WTI's staff and students that contributed administrative, graphical, editorial, technical and field support to the US 93 preconstruction research efforts throughout the years. Specifically, we thank Carla Abrams, Matt Blank, Jeralyn Brodowy, Michael Brown, Robbi Colvin, Chris Dagel, Kacey Diemert, Carol Diffendaffer, Jaime Eidswick, Susan Gallagher, Sonia Germann, Kate Heidkamp, Neil Hetherington, Paris Hodgson, Justin Krohn, Suzy Lassacher, Scott Lee, Jose-Manuel Leon, Carla Little, Virginia Loran, Scott Lowry, Patrick McGowen, Jimmy Mehlos, Megan Powers, Patrick Rainbolt, and Bose Sadagoparamanujam for their time and efforts on this project.

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1. EXECUTIVE SUMMARY

The reconstruction of US Highway 93 (US 93) on the Flathead Indian Reservation in northwestern Montana provides an opportunity to evaluate how wildlife crossing structures and wildlife fencing affect animal-vehicle collisions (AVCs) and wildlife movements in a multiple-use rural landscape. The Confederated Salish and Kootenai Tribes (CSKT), the Federal Highway Administration (FHWA), and the Montana Department of Transportation (MDT) signed a Memorandum of Agreement (MOA; Skillings Connolly 2000) for the reconstruction of 46 miles (74 km) of US 93 from Evaro to Polson. The reconstruction will include installations of 42 fish and wildlife crossing structures and approximately 15 miles (24 km) of wildlife exclusion fencing for a total investment of over $9 million, an unprecedented level of wildlife mitigation efforts on a single reconstruction project in North America.

Additionally, the MOA commits to monitoring and evaluating animal-vehicle collision (AVC) incidents and wildlife movements across the highway before and after the mitigation measures are installed. Funded by FHWA and MDT, the Western Transportation Institute at Montana State University-Bozeman (WTI) was contracted to oversee preconstruction baseline field data collection and to document a "case study" highlighting significant events and decision-making processes that shaped the planning and design of the mitigation measures. Specifically, the objectives of the evaluation study are to:

- Determine what effect US 93 wildlife crossing structures and fencing have on the frequency of AVCs and animal highway crossings;
- Document the design decision-making processes and lessons learned as a "case study"; and
- Identify best management practices and further research.

This report details the preconstruction field study efforts and the history of the reconstruction design process. The summary below recaps each chapter in the main report including the literature review, project history and case study, the preconstruction field study, other US 93 preconstruction road ecology research efforts, measures of effectiveness and post-construction monitoring recommendations, and final conclusions.

Literature Review

The Literature Review focused on published papers, peer-reviewed journal articles and reports regarding locating, designing and evaluating the effectiveness of wildlife crossing structures and exclusion fencing. The review found that there are several methods that can be used to determine optimal locations for wildlife crossing structures. These methods utilize road-kill and AVC data, Geographic Information System-based landscape analysis, expert opinion, and site- and species-specific field studies. Ideally, one would use a combination of these approaches in order to "cross check" their outcomes; e.g., AVC data, coarse-scale GIS analysis and/or expert opinion may be used at a coarse-scale on stretches of road that may be candidates for wildlife mitigation, and then more intensive fine-scale analysis could be performed to determine more precise optimal location.

Although numerous other techniques have been applied in an attempt to reduce AVCs, wildlife fencing, in combination with wildlife passages appears to have the most promise for improving driver safety and maintaining habitat connectivity. Wildlife passages include overpasses and underpasses, with underpasses consisting of bridges or culverts. The literature documents that different species of wildlife prefer different characteristics that may be incorporated into passage structure designs. If the goal of a wildlife mitigation effort was to provide passage for a community of species, several different types of passage designs would likely be required, depending on the suites of species that were to be accommodated. In addition, for wildlife mitigation passages to be most effective, a physical road barrier and funneling system (i.e. wildlife exclusion fencing) should be incorporated into the overall design.

The literature review found that while evaluation of wildlife passage systems is necessary for assessing effectiveness, monitoring is often not performed. The review outlined sequential steps for conducting a comprehensive field evaluation, and identified successful methods, such as collision data, tracking beds, video monitoring, radio monitoring of animal movements, DNA assignment testing, and fecal stress measures. The literature review confirmed the importance of collecting and analyzing data from both before and after installation of wildlife mitigation measures.

Project History and Case Study

Researchers documented the US 93 reconstruction efforts as a case study to highlight the history of the project and its challenges, as well as the different points of view and approaches that shaped the planning and design process. The project dates back to the early 1980s, when the Montana Department of Transportation (MDT), the Confederated Salish Kootenai Tribes (CSKT or "the Tribes") and the Federal Highway Administration (FHWA) recognized the need to increase the level of service and safety for US 93 on the Reservation. Since that time, many challenges were overcome as stakeholders worked together to understand, respect and trust each other through the planning and design process.

Stakeholders adopted a context-sensitive design approach that considered the landscape, people, and cultural values in addition to safety and level of service. Central to the approach was the concept that "The road is a visitor": not only should the highway be safe and accommodate increasing traffic volumes, but US 93 should also respect and reflect the landscape and natural and cultural values of the Tribes. The design concepts agreed upon by the three governments were compiled in a range of documents that were eventually adopted as the US 93 Reconstruction MOA (Skillings Connolly 2000). This document included:

- An overarching Design and Alignment Concepts;
- Design Guidelines and Recommendations;
- Design Components Workbook; and
- Wildlife Crossings Workbook.

A Technical Design Committee (TDC) was formed of members from the three governments to ensure that the design development process proceeded in accordance with the MOA. This TDC worked closely and regularly to steer the project and resolve any disparities by working to achieve consensus and come to reasonable solutions that all three parties could agree upon. The TDC guided the design details for the installation of the 42 fish and wildlife crossing structures and approximately 15 miles (24 km) of wildlife exclusion fencing.

Preconstruction Field Study

The primary goals of the field evaluation are to determine what effect US 93 wildlife crossing structures and wildlife exclusion fencing have on: 1) the frequency of AVCs; and 2) habitat connectivity, specifically in terms of successful wildlife movements across US 93. A "before-after" approach has been adopted and study efforts concentrate on deer species (white-tailed deer [*Odocoileus virginianus*] and mule deer [*Odocoileus hemionus*]) and black bear (*Ursus americanus).*

The first goal of the evaluation will be assessed for the entire 56-miles of US 93 from Evaro to Polson to compare AVCs before and after installation of the mitigation measures. The second goal will be accomplished by assessing wildlife movements across US 93 before and after the installation of the wildlife fencing and crossings. Preconstruction wildlife-highway crossing data collection efforts were focused between Evaro and St. Ignatius, a subsection of the larger study area, with the intention of comparing these data to post-construction data in the same areas. The Evaro, Ravalli Curves and Ravalli Hill areas were the focal study area selected for more intensive wildlife-highway crossing sampling efforts because these areas are slated for the longest continuous stretches of wildlife exclusion fencing with crossing structures.

Researchers used several methods to evaluate deer and black bear behavioral and population ecology in the US 93 highway corridor prior to reconstruction. The documentation of quantity and location of AVCs were analyzed to understand how these data interacted with traffic activity patterns and volume, as well as to quantify statistical limitations with the dataset. Sand track beds were used to sub-sample wildlife movements within the road verge, which provided an estimated total preconstruction crossing rate within the areas that will have the most extensive wildlife fencing. While both the AVC and track bed data provided an index of wildlife population density and road-centric behavior patterns, pellet group data independently indexed local deer population density. Photographic monitoring at an existing bridge indicated what species of animals were using the area and daily patterns of activity in deer and bear moving under the highway.

Used separately, these metrics addressed specific questions regarding preconstruction deer and black bear movements and vehicle-related mortalities within the US 93 corridor. Used together, these indices integrate demographical and behavioral information to better understand trends observed in the parameters of interest as well as what factors may be driving observed trends. This information will be critical in determining the effects of mitigation measures on deer and bear in post-construction years. Preconstruction field study results for the focal species and parameters of interest (deer- and black bear-vehicle collisions and cross-highway movements) are summarized below:

- <u>Deer-vehicle collisions</u>
  - The average annual number of reported deer-vehicle collisions (DVCs) for US 93 from Evaro to Polson during the 2002—2005 preconstruction years was 90 (95% confidence interval [C.I.] = 82, 98). Based on these preconstruction data, it was determined that a 35% decline in DVCs will be detectable after 3 years of post-construction study, and a 22% decline after 5 years of study.
  - The average annual number of DVCs reported in 2002—2005 for the 8.7 miles (14 km) of US 93 where wildlife fencing is proposed was 11.8 (95% C.I. = 4.6,

18.9). This equates to 1.4 deer killed per mile per year (95% C.I. = 0.5, 2.2). These data had high year-to-year variance and only large changes will be statistically detectable in the areas to be fenced; e.g., a 241% change in kills per mile will be detectable after 3 years of post-construction monitoring, while a 151% change will be detectable after 5 years.

  - The annual average number of DVCs for the 44.9 miles (72.3 km) of US 93 that will not have wildlife fencing (including the Ninepipes section where reconstruction design plans have not yet been determined) was 78.3 (95% C.I. = 74.5, 82.0). This equates to 1.7 deer killed per mile per year (95% C.I. = 1.7, 1.8). With significantly more miles of road where no wildlife fencing will be installed, there was less variance in the annual reported DVCs outside the area that will have wildlife fencing such that smaller differences may be detectable in post-construction study. Outside the area that will be fenced, a 19% increase or decline in deer kills per mile would be detectable after 3 years of post-construction study, while a 12% increase or decline would be detectable after 5 years.
  - There were several areas where numbers of DVCs were three standard deviations above the 2002-2005 mean number of DVCs. Two such hotspots were identified at mile markers 33.6 and 34.5; both within 0.1 mile from where wildlife crossing structures will be installed, but the wildlife fencing extending from those structures will not cover those specific locations. An unmitigated hotspot occurred at mile marker 7.4, and several other hotspots (mile markers 37.5, 37.7-37.9, 39.8, and 45.6-45.8) occurred within the final section of US 93 within the Ninepipes National Wildlife Refuge on the Reservation which is planned for reconstruction upon the completion of a Supplemental Environmental Impact Statement

- <u>Bear-vehicle collisions</u>
  - The mean number of black bears killed by vehicles from 1995—2005 on US 93 between Evaro and Polson per year was 2.91 (95% C.I. = 1.15, 4.67). This figure includes data from 2002 and 2003, when 8 and 9 black bear mortalities due to collisions with vehicles were reported for each of these years, respectively; these higher numbers of reports were likely a result of more intensive monitoring for a research study assessing black bear responses to US 93 prior to reconstruction. With small sample sizes, there is little statistical power to detect changes in pre- and post-construction bear-vehicle collisions; this result underscores the importance of repeating the black bear study post-construction in order to obtain more detailed data that will provide a better understanding of the effect of the mitigation on this focal species.

- <u>Cross-highway movements</u>
  - Sand track beds placed parallel to US 93 were used to sample wildlife movements across approximately 30% of three stretches of US 93 that will have extensive lengths of wildlife fencing and crossing structures. Across 4027 m (2.5 miles) of track beds monitored from June through October in the focal study areas over three years (2003—2005), deer species were the most frequently observed tracks,

with medium mammals (including skunks, raccoons, and rabbits/hares) and canines (including domestic dogs and coyotes) as the second- and third-most observed species.

- Deer and black bear track observations classified as "crossings" were used to extrapolate and estimate total crossing activity that occurred along stretches of US 93 planned for extensive fencing. These stretches of highway include approximately 3.2 km (1.9 miles) in Evaro, 5.9 km (3.6 miles) in Ravalli Curves, and 2.1 km (1.3 miles) in Ravalli Hill, for a total of 11.2 km (6.9 miles) to be fenced to exclude wildlife and funnel them toward the crossing structures. An estimated total of 5,196 deer crossed US 93 in these areas over the June-October tracking monitoring seasons in 2003-2005, and while an estimated total of 327 black bear crossings over the same area and same time period.

Other US 93 Road Ecology Preconstruction Research

Researchers reviewed other recent preconstruction research efforts related to various aspects of the reconstruction's effects on black bear, deer, aquatic organism passage, and turtles. Each of these studies provides an opportunity to repeat the research after mitigation is installed to comparatively assess the effects of the reconstruction and mitigation measures. The studies reviewed are described below:

- WTI collaborated with University of Montana to conduct field research focused on black bear density, behavior, population demography, gene flow, and mortality relative to US 93 prior to the reconstruction. Wildlife biology graduate student Karin McCoy's thesis research concluded that US 93 may be a barrier to some segments of the black bear population in the study area, but it is not currently a barrier to overall gene flow. Planned locations of wildlife mitigation passages appear to be aligned with current black bear movements across the highway.
- WTI civil engineering graduate student Darren Baune conducted preconstruction baseline fish passage assessment of several stream crossings planned for replacement. Overall, the passability assessment of the study culverts indicates that each culvert is likely functioning as a fish passage barrier during at least a portion of the year (i.e., each culvert was categorized as a partial barrier).
- WTI and the Wildlife Conservation Society (WCS) collaborated to support graduate student Whisper Camel to study site-specific variables that influenced the occurrence of preconstruction deer-vehicle collisions (DVCs) and deer-highway crossing rates on US 93. Using GIS and other tools, she developed models to help predict DVCs at deer highway crossing locations. Final results are expected early 2007.
- MDT, with additional support from CSKT; the Montana Cooperative Wildlife Research Unit; Montana Fish, Wildlife and Parks; University of Montana; the Salish Kootenai College, and WTI, funded PhD candidate Kathy Griffin to do a three year field study assessing the highway's effects on connectivity, mortality and population parameters for the Ninepipes western painted turtle population prior to the reconstruction of the US 93. Major findings from the draft final report indicate the highway affects the turtle population via direct mortality and reduced connectivity. Considering turtle populations' slow growth and reproductive rates, the conservative estimate of 6-17% of the turtle

population killed on the highway along with additive mortality due to sensitivity to drought conditions could not be sustained if the population were closed (i.e., no emigration or immigration from other populations). However it was evident that temporary and permanent emigration occurs from surrounding reservoirs, underscoring the importance of maintaining landscape connectivity for this species. Given that the Ninepipe/Ronan section of US 93 has not gone through the detailed design phase for reconstruction, specific recommendations for consideration in the design process were made.

Measures of Effectiveness and Post-Construction Monitoring Recommendations

WTI developed complementary post-construction monitoring methods for a "before-after" assessment of the effects of the mitigation and suggested quantitative and qualitative "measures of effectiveness" (MOEs) for the main parameters of interest in this evaluation study: animal-vehicle collisions (AVCs) and wildlife-highway crossings. Considerations for MOEs included the following:

- Recognizing the differences in effect versus effectiveness and that different entities will apply different qualitative and quantitative values to determine whether the mitigation is considered "effective" or not based on their viewpoints;
- Setting a minimum threshold for the MOE related to decreasing deer vehicle collisions (DVCs) at the smallest statistically detectable reduction (35% or greater) determined based on the preconstruction DVC data;
- If the minimum MOE for reducing DVCs by 35% is maintained over 25 years, the estimated costs of the mitigation investments would be repaid in terms reduced property damage, human injuries and fatalities, carcass removal costs, and loss of deer as a resource;
- Setting a minimum MOE for no change or any increase in deer-highway crossings compared to the conservative estimate of total crossings in the areas where the most extensive wildlife crossings are to be installed; and
- Setting an MOE for black bear-highway crossings for at least 10 different individual bears, including at least one female black bear, successfully crossing US 93 annually after the road after mitigation is installed.

Post-construction monitoring recommendations included the following:

- Monitoring post-construction wildlife movements through the wildlife crossing structures, at gaps in the wildlife fencing, and at the wildlife exclusion fence ends through the use of sand tracking beds and remote-trigger IR photo cameras to analyze wildlife movements and habitat connectivity after wildlife fencing is installed, and to compare these data with the preconstruction estimates of deer and bear crossings;
- Using photo monitoring to quantify the accuracy of track beds in reflecting crossing rates;
- Continuing annual pellet transect monitoring to monitor deer populations;
- Monitoring traffic to analyze impact on wildlife-vehicle collisions and crossing behavior;

- Repeating the black bear highway corridor study, fish passage monitoring at newly designed culverts, the western painted turtle study to assess habitat connectivity and road-related mortality after the Ninepipes reconstruction is completed, and the DVC study to comparatively assess the effect of the mitigation measures on DVCs; and
- Maximizing the numbers of years of monitoring to provide better ascertain or reduce the amount of variability in the data while also considering when to initiate post-construction monitoring given the "learning curve" that may be apparent initially after reconstruction is complete.

Conclusions

The US 93 planning and construction represents the culmination of successful and coordinated actions by many involved agencies and interest groups. The case study also is unique in its potential to be one of the most comprehensive and valuable data sets regarding mitigation effects that has yet been collected. It has the potential to provide information about wildlife crossing structures and mitigation measures to engineers, highway departments, and wildlife ecologists that will be useful in guiding future construction projects and creating effective and parsimonious research programs worldwide.

However, all these perceived benefits hinge on rigorous and committed post-construction research. Perhaps one of the most important insights gained from the preconstruction research is that, due to the myriad sources of unquantifiable variation in the environment, several years are required to estimate how much variation can be expected. In turn, several years of post-construction research must be employed to yield useful, applied results, lessons learned, and best management practices that can be applied on other wildlife mitigation efforts in the future.

2. INTRODUCTION

Highways have direct and indirect ecological effects on wildlife. Animal mortality due to collisions with vehicles is also a concern for motorist safety. Indirectly, highways and high traffic volumes bisect wildlife habitat which can impair or prevent wildlife movements to meet daily or seasonal requirements for food, water, secure cover, dispersal of young and reproduction. Animal-vehicle collisions (AVCs) and habitat fragmentation issues deserve consideration in highway infrastructure improvement projects (Evink 2002) for long-term sustainability of wildlife populations and to address the safety issues that wildlife-vehicle interactions may create.

Numerous measures have been applied to mitigate the impacts of highway-wildlife interactions with varying degrees of success (Hedlund et al. 2004, Knapp et al. 2004, Forman et al. 2003, Farrell et al. 2002), but there is a need for more conclusive information about the effectiveness of these methods (Clevenger 2001). Long-term monitoring and research is required to better understand how mitigation deployments affect animal-vehicle collisions and wildlife movements across roads. Evaluation of such deployments will help guide transportation agencies in future mitigation efforts for the benefit of wildlife and motorists.

The reconstruction of US Highway 93 (US 93) on the Flathead Indian Reservation in northwestern Montana provides an opportunity to evaluate how wildlife crossing structures and wildlife fencing affect animal-vehicle collisions and wildlife movements in a multiple-use rural landscape. The Confederated Salish and Kootenai Tribes (CSKT), the Federal Highway Administration (FHWA), and the Montana Department of Transportation (MDT) signed a Memorandum of Agreement (MOA; Skillings Connolly 2000) for the reconstruction of 46 miles (74 km) of US 93 from Evaro to Polson. The reconstruction will include installations of 42 fish and wildlife crossing structures and approximately 15 miles (24 km) of wildlife exclusion fencing for a total investment of over $9 million (Skillings Connolly 2000), an unprecedented level of wildlife mitigation effort on a single reconstruction project in North America.

Additionally, the MOA commits to monitoring and evaluating animal-vehicle collision incidents and wildlife movements across the highway before and after the mitigation measures are installed. Specifically, the objectives of this evaluation study are to:

- Determine what effect US 93 wildlife crossing structures and fencing have on the frequency of animal-vehicle collisions and successful animal highway crossings;
- Document the design decision-making processes and lessons learned as a "case study"; and
- Identify best management practices and further research.

Funded by FHWA and MDT, the Western Transportation Institute at Montana State University-Bozeman (WTI) was contracted to oversee preconstruction baseline field data collection and to document a "case study" highlighting significant events and decision-making processes that shaped the planning and design of the mitigation measures. This report summarizes the preconstruction field study efforts and the history of the design process.

Several components are covered in this preconstruction report. Chapter 3 provides a review of literature on locating and designing wildlife crossing structures and exclusion fencing and addresses methods and considerations for the evaluation of their effectiveness. Chapter 4 outlines the history of US 93 reconstruction efforts as a case study, illustrating the challenges and successes encountered over years of envisioning and negotiating desired outcomes for the highway. A significant portion of this report, Chapter 5, pertains to the preconstruction data collection and field studies carried out by WTI. Chapter 6 summarizes complementary ecological research conducted on US 93 during the preconstruction phase. Chapter 7 provides recommendations for the post-construction monitoring plan including proposed measures of effectiveness, and Chapter 8 summarizes highlights and draws conclusions from the preconstruction monitoring efforts.

The information gathered during the preconstruction phase of the US 93 project provides useful information for transportation and natural resource managers regarding the planning, design, and evaluation of wildlife mitigation deployments. However, it is the comparison of preconstruction and post-construction data that will ultimately yield the most valuable results regarding the performance of wildlife crossing structures and exclusion fencing. Along with lessons learned from the case study, the pre- and post-construction field monitoring and evaluation study will direct the development of “best management practices” to guide future wildlife mitigation deployments.

3. LITERATURE REVIEW

Many authors have documented the effects of roads and vehicles on wildlife (Forman and Alexander 1998, Reijnen and Foppen 1994, Bashore et al. 1985) and several compilations and syntheses of literature related to roads and wildlife exist (Evink 2002, Forman et al. 2003, Irby and Podruzny 2001, Singleton 1998). This literature review does not attempt to exhaustively examine all available information on this topic; rather, this review focuses on published papers, peer-reviewed journal articles and reports regarding locating, designing and evaluating the effectiveness of wildlife crossing structures and exclusion fencing.

In addition to the literature reviewed in this chapter, Chapter 5 summarizes literature related to the field methods used in the preconstruction study. Considerations for the collection and use of animal-vehicle collision data, track bed methods to document animal presence and movements, and pellet transects as an index of population density are specifically addressed and supported with examples in Chapter 5.

3.1. Overview

Animal-vehicle collisions (AVCs) are considered a safety and environmental issue in the United States (US) and around the world. Estimates of 750,000 to 1.5 million automobile collisions with deer (*Odocoileus* sp.) alone occur on US roads each year (Romin and Bissonette 1996, Conover et al. 1995). The annual impact is more than 200 human fatalities, 29,000 injuries and one billion dollars in vehicle damage (Conover 1997 and Conover et al. 1995). Road-killed animals are also an obvious result of AVCs, but the exact magnitude road-related animal mortality is unknown because of inadequate record keeping (Knapp et al. 2004, Barnum 2003, Evink 2002). Roadways intersecting wildlife habitats may act as barriers to dispersal and movement, disrupt migratory routes, limit genetic exchange (Riley et al. 2006, Strasburg 2006, Mills and Conrey 2003, Sunquist and Sunquist 2001, Smith 1999) and impose a range of potential impacts on wildlife habitat (Forman et al. 2003, Evink 2002). As existing roads are reconstructed or expanded and as new roads are being built to accommodate increasing development, the challenge is to minimize the negative and unintended effects to humans, wildlife and ecological systems.

There have been many attempts to reduce AVCs, resulting in varying degrees of success. A number of overviews summarize AVC mitigation measures and corresponding evidence of their effectiveness, or lack thereof (Hedlund et al. 2004, Knapp et al. 2004, Forman et al. 2003, Farrell et al. 2002). Attempted mitigation measures have included techniques and devices to modify animal behavior (e.g., roadside-reflectors, vehicle-mounted whistles, repellents, intercept feeding, and wildlife fencing combined with passages under or over roads) and driver behavior (e.g., educational outreach and public relation campaigns, speed limits and enforcement, increasing driver visibility, and warning signs). The most promising measure for reducing AVCs is to physically limit animals from accessing the roadway with exclusion fencing coupled with wildlife crossing structures which allow animals to pass under or over roadways thereby avoiding passing vehicles (D'Angelo et al. 2005, Knapp 2005, Clevenger et al. 2002b, Evink 2002). Wildlife exclusion fencing used in combination with crossing structures has been shown to reduce AVCs by 80-96% (Clevenger et al. 2001, Lavsund and Sandegren 1991, Ward 1982). Ultimately, if animals are to use a wildlife crossing structure, its location and design features must be preferable to crossing the road itself.

3.2. Locating Wildlife Passages

Wildlife do not cross roads randomly (Barnum 2003; Clevenger et al. 2002b), a factor that must be considered when determining where to place wildlife passages. Animals move to within and between preferred habitats on daily, seasonal, and annual forays as they reproduce, seek shelter, forage, migrate, and disperse (Cramer and Bissonette 2005, Anderson and Gutzwiller 1996). Placing structures at natural crossing points where wildlife prefer to travel will increase the likelihood that animals will find them and use them (Foster and Humphrey 1995). Generalized landscape features found to be most consistently important to the use of passages are the presence of suitable habitat on both sides of the road (Barnum 2003, Gloyne and Clevenger 2001, Veenbaas and Brandjes 1999), the placement of crossing structures at naturally-occurring travel routes and trails (Grist et al 1999, Land and Lotz 1996, Foster and Humphrey 1995), and low levels of human activity (Clevenger and Waltho 2000, Rodriquez et al. 1997). Locating passages in relatively remote or less traveled areas can help reduce the effect of human activity (Iuell et al. 2003).

Beyond generalities, several methods may be used to determine optimal locations for wildlife crossing structures. These methods utilize road-kill and AVC data (Grist et al. 1999), Geographic Information System-based landscape analysis (Ruediger et al. 2004, Craighead et al. 2001, Mietz 1994), expert opinion (Clevenger et al. 2002a), and site- and species-specific field studies (Scheick and Jones 1999, Foster and Humphrey 1995). Ideally, one would use a combination of these approaches in order to “cross check” their outcomes (Clevenger et al. 2002a).

Road kill and AVC data can offer insights for placement of crossing structures if they are spatially accurate and collection methodology is consistent. Typically, however, only a fraction of road kill is reported (Slater 2002, Romin and Bissonette 1996). A study comparing observed road-killed deer and reported AVCs for a particular roadway segment estimated that only 20 percent of AVCs were reported (Messmer et al. 2000). In addition, the lack of reporting standards (Knapp et al. 2004), inadequate spatial precision (Barnum 2003), and opportunistic reporting (rather than systematic monitoring) reduces the usefulness of such data. Relying solely on road-kill data is not advised since it likely under-represents actual numbers (Sielecki 2004, Sullivan and Messmer 2003, Slater 2002). Road kill and AVC rates are useful in determining the general area for mitigation efforts but further analysis is required to determine specific optimal placement (Barnum 2003, Clevenger et al. 2002b).

Geographic Information Systems (GIS) is a computer mapping tool that acts allows for the assessment of spatially-related attributes and has been applied to identify potential highway mitigations sites for wildlife (Kautz et al. 1999, Klein 1999, Singleton and Lehmkuhl 1999). Experienced analysts can readily find or create coarse-scale digital spatial data layers. Public sources of data are often available from state and federal programs (Evink 2002), such as Montana’s National Resource Information System (NRIS 2005) and the US Census Bureau which offers trademarked TIGER (Topologically Integrated Geographic Encoding and Referencing) files. Some examples of spatial data that may be useful, but not necessarily required, to determining optimal locations for mitigation applications include:

- Land cover or habitat types;
- Individual locations or clusters of AVCs;
- Human activity level and building density;
- Locations of potential barriers such as guard rails and median barriers on roads;
- Wildlife home range and movement patterns;
- Linear features of the landscape which may guide wildlife movement;
- Natural wildlife passage sites and locations of wildlife trails; and
- Topography, including slope and complexity of the intended approach to a potential crossing structure location.

Analysts overlay layers of spatial data to relate landscape features to one another, yielding secondary outputs that can be quantitatively and qualitatively analyzed to represent empirical or theoretical relationships. In some cases, the analyst may model these relationships; however, such outputs should be validated through field tests (Johnson and Gillingham 2004, Koeln et al. 1996). The key is to select the most informative data layers, and parameters, and to understand relationships between animal behavior and the landscape, depending on the target species or suites of species and objectives of the project.

Expert opinion may be more accessible and assessable than physical data which may take years to collect and analyze, or spatial models that require time to be validated in the field. Expert opinion can be based on firsthand knowledge of local wildlife populations and landscape attributes or on the insights gained from synthesizing relevant literature. In one study, expert opinion predicting wildlife crossing locations closely approximated an empirical model based on telemetry information (Clevenger et al. 2002a).

After a general area for a wildlife passage is identified via a method or combination of methods described above, more intensive fine-scale analysis will help determine a precise optimal location (Clevenger et al. 2002b, Kautz et al. 1999, Klein 1999). Fine-scale analyses include the ground truthing coarse-scale spatial data and site-specific, and possibly species-specific, field studies (e.g., radio-collar studies of animal movements, track bed monitoring, pellet counts, photo monitoring, traffic monitoring). Each species has specific requirements to consider when locating crossing structures for optimal use (Clevenger and Waltho 2005, Clevenger et al. 2002a, Grist et al. 1999, Foster and Humphrey 1995). Multiple structures in a variety of locations with varying design features may be necessary to meet the requirements of all affected wildlife species in a particular region.

No single technique has been deemed ideal for selecting locations for wildlife passages. Further considerations must also be taken into account to maximize wildlife use of these mitigation measures; for example, design of passages and use of wildlife exclusion fencing to guide animals to these passages will affect wildlife use of a passage, in addition to the location of the passage. An interdisciplinary approach to selecting types of crossings and locations of wildlife passages is useful and practical, as it combines multiple factors such as ecology, engineering, cost, constructability, and social concerns.

3.3. Designing Wildlife Passages

Some studies indicate that passage design may be more important in determining wildlife use than location (Clevenger and Waltho 2005), while others show the opposite (Land and Lotz 1996, Foster and Humphrey 1995). No single passage design has been shown to be appropriate for all wildlife species. Factors that may influence whether an animal use of crossing structures include dimensions of the structure, presence or absence of cover (Clevenger and Waltho 2000), substrate type (Iuell et al. 2003, Clevenger and Waltho 2000, Jackson and Griffin 2000), light, moisture, temperature, noise, fencing, approaches and the potential for species interactions (Jackson and Griffin 2000, Iuell et al. 2003). Species-specific preferences and requirements must be considered when designing wildlife passages (Mata et al. 2005, Clevenger et al. 2002b).

A variety of passage designs may be necessary to meet the needs of multiple species (Clevenger and Waltho 2005, Mata et al. 2005, Barnum 2003, Iuell et al. 2003). One study of monitoring six passage types (circular culverts, adapted box culverts, open span bridges, wildlife underpasses, wildlife overpasses and overpasses designed for human use) revealed that different fauna prefer different crossing types (Mata et al. 2005). Many adaptable species will use more than one type of crossing structure while others have more limited tolerance for artificial passages.

Wildlife mitigation passage designs fall into two general categories: overpasses and underpasses, structural installations that direct animals to cross over or under the roadway and traffic. Wildlife overpasses, also known as “ecoducts” or landscape connectors, are built over a road (similar to a bridge) and vegetated to provide habitats attractive to wildlife (Iuell et al. 2003, Evink 2002, Jackson and Griffin 2000); overpasses may also be created when a roadway tunnels through substrate (Wildlife Crossings Toolkit 2005). Overpasses are generally quieter than underpasses and can offer a more natural and inviting setting (Iuell et al. 2003, Jackson and Griffin 2000). Animals are more likely to use overpasses if the habitat on the opposite side of the road is clearly visible, that is, without a hill that can limit viewing (Clevenger et al. 2002b). Overpasses generally range from 3.4m (3.7 yd) to 870m (0.5 mile) wide at the ends (Evink 2002). Most European overpass designs are 90m (98 yd) wide at the ends reducing to 70m (76.5 yd) at the middle of the structure (Clevenger et al. 2002b, Wieren and Worm 2001, Jackson and Griffin 2000).

A wildlife underpass may consist of a bridge or a culvert. Span bridges, viaducts and causeways across natural features such as rivers or ravines separate traffic from seamless habitat under the roadway, providing an ideal passageway for wildlife. A culvert is a pipe-like structure typically designed and installed to provide water drainage; however, with some thoughtful adaptations, a culvert may also serve as a wildlife passageway. Culverts are often made of corrugated metal or concrete and may have cool, wet conditions (Servheen et al. 2003). Such conditions may be desirable to some animals such as water-dependent amphibians and reptiles, while other animals may be more apt to use a culvert if a dry path, such as a raised bench, is provided through the length of the passage and if there is sufficient vegetation cover inside (if light conditions allow) and at the entrances (Mata et al. 2005, Foresman 2004, McDonald and St. Clair 2004, Barnum 2003, Servheen et al. 2003, Rodriquez et al. 1997).

The size of a crossing structure has a direct relationship to the size of the animals that use it (Clevenger and Waltho 2005, Donaldson 2005, Iuell et al. 2003). Smaller species tend to choose smaller passages while larger species prefer larger passages (Mata et al. 2005 and 2003). Passage width dictates whether or not wildlife will use a crossing structure (Clevenger and

Waltho 2005, Ng et al. 2004, Gordon and Anderson 2003, Iuell et al. 2003, Veenbaas and Brandjes 1999). Structural openness is equal to the product of opening width and opening height divided by the length of the crossing (width x height/length) (Gordon and Anderson 2003, Servheen et al. 2003). Structures with wide, open passages at least 2.1 m (2.2 yd) high with natural bottoms and a clear view of the habitat on the other side are more likely to be used by deer and other ungulates (Clevenger and Waltho 2005, Gagnon et al. 2005, Barnum 2003, Servheen et al. 2003, Foster and Humphrey 1995). Other recommended minimum dimensions for underpasses accommodating deer vary from 3m (3.2 yd) in width and 3.7m (4.0 yd) in height (Donaldson 2005) to 15m (16.4 yd) in width and 3-4m (3.2 – 4.2 yd) in height (Iuell et al. 2003). It should be noted, however, that behavioral differences in deer species (*Odocoileus* sp.) affects the species' tendency to adapt to using crossing structures; e.g., white-tailed deer (*Odocoileus virginianus)* appear to adapt to and use crossing structures more readily than mule deer (*Odocoileus hemoinus)* (Gagnon et al. 2005), although size of the structure may not be the only factor affecting mule deer hesitancy to adapt to using such crossings. Dimensions have a greater impact when the structure is new and animals have not yet adapted to regular use of the structure (Forman et al. 2003, Clevenger and Waltho 2000).

Culverts with narrow openings are heavily used by many small carnivores and other small mammals, amphibians and reptiles that prefer them to more open underpasses (Mata et al. 2005, Foresman 2004, Clevenger and Waltho 1999). Some species, especially large-bodied ones, may find some passages too low or confining without a sufficient view of the habitat on the other side (Donaldson 2005). Smaller species and some carnivores may prefer passages with cover on the approach (Donaldson 2005, Iuell et al. 2003, Evink 2002); some may avoid tunnels if there is insufficient cover throughout (Foresman 2004, Iuell et al. 2003, Evink 2002). Clevenger and Waltho (2005) found that distance to cover was significantly positively correlated to passage use for grizzly bears (*Ursus arctos horribilis*), elk (*Cervus elaphus*) and deer (*Odocoileus* sp.), while the correlation was negative for cougars (*Felis concolor*). Prey species may be discouraged from using a passage if predators also use it, although this is an understudied phenomenon (Little et al. 2002).

Moisture levels are important to consider when planning for moisture-dependent species, and a dry path can encourage use by less moisture-dependent wildlife species (Foresman 2004, Iuell et al. 2003, Evink 2002, Jackson 1999). Noise from traffic or other sources can deter some sensitive species from using a crossing structure (Clevenger and Waltho 2005, Evink 2002).

Singly or in combination, spatial and environmental variables influence wildlife use of crossing structures. Table 1 lists some of the known preferences and avoidances for select species found in Montana. Given the variety of preferences that have been documented, if the goal of a wildlife mitigation effort was to provide passage for a community of species, several different types of passage designs would likely be required, depending on the suites of species that were to be accommodated.

Table 1: Summary of literature assessing northern Rocky Mountain wildlife preferences and features to avoid for designing wildlife crossing structures.

Amphibians

Prefer: Moist conditions (Iuell et al. 2003, Jackson 1996); culverts to open underpasses (Mata et al. 2005, Foresman 2004, Clevenger and Waltho 1999).

Avoid: Dry passages, sudden changes in temperature between the passage and the outside air (Iuell et al. 2003; Jackson 1996).

Black bear (*Ursus americanus*)

No clear preference for overpasses or underpasses (Clevenger et al. 2002b).

Cougar (*Felis concolor*)

Prefer: Underpasses far from human activity with sufficient cover leading to the passage (Clevenger et al. 2002b, Gloyne and Clevenger 2001, Rodriquez et al. 1997).

Avoid: Artificial light might discourage use by mountain lions (Cramer and Bissonette 2005, Jackson 1999, Beier 1995).

Deer (*Odocoileus* sp.) and Elk (*Cervus elaphus)*

Prefer: Overpasses but will also use underpasses (Clevenger et al. 2002b). White-tailed deer (*Odocoileus virginianus)* learn to use underpasses more readily than mule deer (*Odocoileus hemoinus)* (Gagnon et al. 2005).

Grizzly bear (*Ursus arctos horribilis*)

Prefer: Overpasses to underpasses and culverts (Clevenger et al. 2002b).

Wolf (*Canis lupus*)

Prefer: Overpasses to underpasses and culverts (Clevenger et al. 2002b).

3.4. Wildlife Exclusion Fencing

To maximize wildlife mitigation passage effectiveness, a physical road barrier and funneling system should be incorporated into the overall design (Clevenger et al. 2002b, Iuell et al. 2003). Wildlife exclusion fencing prevents animals from accessing the road while channeling them toward crossing structures. Continuous exclusion fencing, in combination with wildlife crossing structures, has been shown to reduce ungulate-vehicle collisions by 96% on controlled access highways (Clevenger et al. 2001, Woods 1990). In some cases, fencing has been necessary for particular species to use a crossing structure. Cougars will not use culverts and ungulates will not use underpasses unless other access is barred (Jackson and Griffin 2000).

Exclusion fencing must be designed to prevent animals from crawling under, climbing over or pushing through to the road surface. Fence height and design must be fitted to the abilities and tendencies of the target species. Fences at least 7.2 feet (2.2m) (Iuell et al. 2003) or 7.9 feet (2.4m) (D'Angelo et al. 2005, Wildlife Crossings Toolkit 2005, Ward 1982) tall will prevent deer from jumping over. Bears and cougars can climb fences but may be prevented from climbing if a 90º lip, or outrigger, is installed at the top of the fencing (Clevenger et al. 2001). Further, these animals climb wooden posts and metal posts may reduce these undesirable behaviors (Clevenger, pers. comm.). Burying the bottom of the fence a few inches or at least ensuring the bottom is absolutely flush with the ground can keep animals from crawling under fences (Clevenger et al. 2001, Boarman and Sazaki 1996, Woods 1990, Feldhamer et al. 1986, Falk et al. 1978). Fine mesh along the bottom section of fencing can keep smaller animals from crawling through the fence and may prevent bears from climbing the fence. Low concrete walls with a lip or small mesh hardware cloth are effective for preventing access by amphibians and reptiles (Griffin and Pletscher 2006, Griffin 2005, Pletscher and Griffin 2003, Iuell et al. 2003, Evink 2002).

No fence is 100% impermeable; some animals will gain access to the highway right-of-way (D'Angelo et al. 2005). If bears and cougars breach a fence by climbing, they can also exit the same way. Ungulates, however, require exit safety features. One-way gates, ramps, and hazing animals through swing gates have all been shown to be effective to some degree (Bissonette and Hammer 2000). One-way gates allow animals to safely exit the roadway, but some animals are reluctant to use them. If gates are not properly lubricated or maintained, they could become stuck in the open position, allowing animals to pass in both directions (Woods 1990, Waters 1988, Ludwig and Bremicker 1983). In Banff National Park, however, cow elk learned how to open these gates to access forage on the right of way; these gates have since been fenced over and large swing gates were installed for ungulates to exit through, with the help of personnel to haze the animal toward the open gates (Clevenger, pers. comm.). Hazing ungulates through swing gates is effective but time-consuming and labor-intensive (Woods 1990). Earthen return, escape, or jump-out ramps are sloped surfaces that lead up to the top of the fence from the roadway, allowing an animal caught inside the fence to "jump out" while not allowing animals to jump inside the fence and right-of-way. Ramps must be maintained so that they are climbable only from the direction of the roadway. These escape routes are most effective when placed at V-shaped funnels in the fence line, and when vegetation provides cover on the ramps (Waters 1988). Ramps ought to be vegetated similarly to the natural surroundings (Bissonette and Hammer 2000). Earthen return ramps cost about $6,000 each (price quoted in 2006; Pat Basting, MDT Missoula District Biologist, pers. comm.) and have been shown to be 8-11 times more effective than one-way gates in allowing ungulates to exit a Utah highway right-of-way (Bissonette and Hammer 2000).

The greatest source of highway intrusion occurs at the ends of wildlife fencing (Wildlife Crossings Toolkit 2005, Pletscher and Griffin 2003, Clevenger et al. 2001, Foster and Humphrey 1995, Woods 1990, Waters 1988, Ludwig and Bremicker 1983, Ward 1982). The terminal points of fencing may result in AVC hotspots if specialized end treatments are not installed to prevent animals from entering the fenced right-of-way (Braden et al. 2005, Iuell et al. 2003, Clevenger et al. 2002b). Fence end treatments are typically applied on the right-of-way, extending from the pavement to the last fence post where wing fencing angles away from the road (Wildlife Crossings Toolkit 2005, Clevenger et al. 2001). Other fence end treatment designs, such as cattle or wildlife guards, electric fences and stone cobble may be somewhat effective, but may not be considered sufficiently safe for motorists, pedestrians and cyclists (Peterson et al. 2003).

There is some disagreement about the effectiveness of end treatments in preventing animals from accessing the right-of-way. One study showed pipe-style cattle guards to be a more effective barrier to ungulates than mesh (Waters 1988), while another study showed mesh to be very effective (Peterson et al. 2003); however the size of the ungulate (elk versus Florida Key deer [*Odocoileus virginianus clavium*], respectively) was likely the influential factor in these two studies outcomes. Cattle guards are effective for mitigating narrow access roads, but small mammals may become trapped if they fall into the well under the guard rails without escape ramps (Iuell et al. 2003). A study of 12, 18 and 24 foot (3.6m, 5.5m, and 7.3m) cattle guards showed extending guard length gained "little advantage" and that a 10 by 12 foot (3.1m by 3.6m) guard is sufficient to deter deer (Reed et al. 1974). Yet another study demonstrated that elk readily jumped across single cattle guards, but that two cattle guards appeared to be wide enough to prevent such breaches (Clevenger et al. 2001).

Highway intrusions can also occur when a fence is not properly maintained. Holes or tears can be created by falling branches, erosion, vehicle collision, direct cutting by people, or as a result of poor construction (D'Angelo et al. 2005, Pletscher and Griffin 2003, Bissonette and Hammer 2000, Boarman and Sazaki 1996, Foster and Humphrey 1995, Woods 1990, Feldhamer et al. 1986, Falk et al. 1978). Ungulates will jump fences which are too low or sag, push through openings, and even crawl under gaps as little as 23 cm (9 in) high (Falk et al. 1978). Coyotes and other small to medium size animals will crawl under gaps and bears will climb wide mesh fencing (Clevenger et al. 2001, Jackson and Griffin 2000). Bears and cougars will also climb support poles. Regular maintenance and repairs are necessary for wildlife exclusion fencing to be most effective.

3.5. Evaluation of Wildlife Passage and Exclusion Fencing

Unfortunately, monitoring of crossing structures is often not performed or is an after-thought resulting in little or no statistically valid data to rigorously investigate effectiveness of the mitigation measures (Clevenger and Waltho 2003). This section summarizes considerations for evaluating wildlife crossing structures to address the inevitable question that follows such installations: "Do these things work?"

Basic steps for planning any scientific evaluation are listed below (Ratti and Garton 1996):

1. Identify research questions and definitions of effectiveness;
2. Identify methods to measure effectiveness;
3. Design monitoring program;
4. Pilot methods, adjust to meet goals, project budgets;
5. Collect data for evaluation;
6. Analyze data to determine effectiveness; and
7. Report results.

There are many research questions that may be of interest in an evaluation of mitigation measures to reduce animal-vehicle collisions and habitat fragmentation. Two key components to address in research questions for such evaluations include: 1) direct impacts to drivers and wildlife as a result of wildlife-vehicle collisions; and 2) indirect impacts of roads and traffic as barriers that may affect wildlife movements and long-term population sustainability. More complex ecological processes and larger-scale landscape functions may also be addressed when evaluating mitigation measures (and there is a need for such research), but the most basic questions should address both animal-vehicle collisions and habitat fragmentation issues.

It is important to structure the research questions to address animal-vehicle collisions and habitat fragmentation issues together. The human safety and economic issues related to animal-vehicle collisions are obvious and are often the impetus for considering mitigation measures; however, it is important to also consider how roads and traffic affect wildlife populations and movements within their habitats. For example, it is possible to reduce animal-vehicle collisions by limiting animal access to the right-of-way (e.g., using wildlife exclusion fencing), or animal-vehicle collisions may be reduced if traffic volumes increase to a level where wildlife no longer approach or attempt to cross the road, but without opportunities for wildlife to move from one side of the road to the other, wildlife habitats will be fragmented potentially resulting in greater vulnerability to disease, natural disasters, genetic inbreeding, ultimately with the potential for negative population effects (Strasburg 2006, Hoffmeister et al. 2005, Puky 2005, Forman et al. 2003, Iuell et al. 2003, Mills and Conrey 2003, Proctor 2003, Bergers and Nieuwenhuizen 1999, Harrison and Bruna 1999).

Goals to measure mitigation effectiveness relate to the research question(s), are supported with applicable literature, and are attainable and measurable. A research question could be, "Do crossing structures and fencing reduce animal-vehicle collisions and allow animals to cross the road?" which could lead to a goal stating that mitigation will be considered effective if there is 1) a 50% reduction in animal-vehicle collisions, and 2) a 25% increase in animal movements across the road.

A common misconception is that mitigation measures for reducing road mortality must be 100% effective. This is not achievable as no fence is a perfect barrier and animals and vehicles will collide even on the most effectively mitigated roads. Further, it is important to know what the statistically detectable changes in animal crossing or animal-vehicle collision rates will be when setting goals for effectiveness. If preconstruction data exist, power analyses can be used to determine minimum statistically detectable changes and set measures of effectiveness. If a the minimum detectable change in animal-vehicle collisions is 75%, then setting a goal of reducing animal-vehicle collisions by 25% would not be appropriate.

With research questions and evaluation goals defined, the parameters of interest will drive the selection of methods to obtain relevant data. The following text summarizes methods used in different monitoring programs to evaluate wildlife mitigation measures:

- *Road-kill or vehicle collision data*. The costs and technical skills required for collecting road-kill or vehicle collision data can be quite low. There are sampling considerations to take into account (see Chapter 5, section 5.2.1 for a more detailed review of these considerations), and other variables to account for (e.g., traffic levels, animal population levels), but overall, this variable is likely the simplest parameter to use in before-after comparisons (Clevenger et al. 2002b). A statistically significant reduction in the number of road-kills pre-mitigation compared to post-mitigation may indicate effectiveness if population changes are accounted for.
- *Snow tracking, tracking beds, tracking plates.* Mammal tracks can be used to document presence and movements relative to roads and mitigation measures, and, potentially, population trends (Mata et al. 2005, Ng et al. 2004, Clevenger et al. 2002b, Barnum 2001, Clevenger and Waltho 2000, Huijser and Bergers 2000, Beier and Cunningham 1996). There are numerous resources that outline tracking techniques and track identification guides for North American mammals (Rezendez 1999, Zielinski and Kucera 1995, Stall 1989, Forrest 1988, Halfpenny and Biesiot 1986, Murie 1974). Numerous media are used to gather tracks, including snow, existing substrates, sand or marble dust, or soot next to contact paper (Mata et al. 2005, Foresman 2004, Ng et al. 2004, Barnum 2001, van Manen et al. 2001, Scheick and Jones 1999, Singleton and Lehmkul 1999). Track beds inside culverts and crossing

structures protect tracking material and tracks from wind and rain, providing fairly reliable data when checked and raked smooth on a regular basis (Clevenger and Waltho 2000, Rosell et al. 1997, Rodriguez et al. 1996, Yanes et al. 1995). Depending on availability of tracking media, this technique is low cost and low tech, although reading and interpreting tracks requires a fair amount of skill.

- *Camera and video monitoring:* Motion and heat-activated remote-trigger cameras capture images of animals, providing occurrence data (Kucera and Barrett 1993). One potential advantage of cameras over tracking is that individuals may be identified if they have unique markings or visible tags (Karanth and Nichols 1998). Most cameras also provide a day and time stamp, so activity patterns can be monitored. With typical triggering ranges from about 10-20 m from the camera, remotely triggered cameras can be set up to capture images of animals moving along a trail or can be set up in arrays to sample larger areas. Costs vary depending on the duration of the study, type of camera, power requirements, and film processing; remotely triggered digital cameras may be more cost efficient than traditional film technology as they require no film processing. Swann et al. (2004) provide an overview of technical considerations for remote-triggered 35mm cameras. Video monitoring further allows the study of animal behavior, including failed crossing attempts (Gagnon et al. 2005), however the technical and cost considerations may be significant.

- *Radio-monitoring animal movements.* Radio telemetry studies can produce comparative data on animal movements relative to roads, wildlife fencing and crossing structures (Chruszcz et al. 2003). Depending on the species and battery life of the equipment, individuals can be followed for years before and after construction (Dodd et al. 2003). There are numerous issues to weigh when considering using radio-telemetry methods, including the permits and approvals required, personnel hours and safety risks involved in capturing, immobilizing animals, and hours and skills required for relocations collared animals (Samuel and Fuller 1996). Collars that use Global Positioning System (GPS) technology can provide data on animal locations at pre-programmed intervals as frequent as 15 minutes, providing an unprecedented level detail in animal locations. These GPS location data are downloadable from a data platform or may be stored on the collar itself, which will be retrieved via VHF signal detection after the collar is released from the animal. Cost of radio-telemetry methods is moderate to high, depending on the technology used, with GPS collars sitting at the more expensive, high-tech end of the spectrum.

- *DNA assignment testing.* This approach typically entails obtaining hair roots, often snagged using barbed wire at remote sampling stations where animals cross the wire, as a source of DNA to identify individual animals by micro satellite markers (i.e., genetically based assignments). These data can detect genetic discontinuities within animal populations at different spatial scales and correlate these with environmental features such as man-made barriers, including highways (Riley et al. 2006, Proctor 2003, Thompson 2003, Conrey and Mills 2001). They can also identify where individual animals have been and test whether mitigation measures aid animal movements, dispersal rates and therefore connectivity between populations (Riley et al. 2006, Proctor 2003, Wills and Vaughan 2001, Luikart and England 1999, Waser and Strobek 1999). Field skills and material costs required for this method are usually low while the lab skills and costs are high.

- *Fecal stress measures.* Fecal stress measures can be used to quantify non-observable physiological responses via non-invasive sampling techniques. Stress measures can be correlated to an animal's proximity to roads and traffic levels over time (Creel et al. 2002, Wasser et al. 1997). Comparison of fecal stress levels for populations proximate and distant from road features, or for populations before and after mitigation measures, can elucidate the extent to which the roads contribute to stress levels and whether crossing structures alleviate this stress. As with other methods, it is important to account for other variables, such as age of the individual (Hardy 2001), hunting levels, human recreation levels, and quality/quantity of food resources; given the extensive variation that has been observed in studies using fecal stress measures, critical interpretation of results is important (Millspaugh and Washburn 2004). Similar to the DNA technique, skills and cost for the lab work are high for this technique, while field sampling is cheap and simple, but this novel technique can address questions related to mitigation effects.
- *Anecdotal information and observational data.* Anecdotal information from scattered observations of animals and their movements can be used as supplemental data or as appendices to a quantitative report (Huijser et al. 2006, Lee et al. 2006, Chruszcz et al. 2003), though these data must be treated differently than data that has been formally sampled. Beier and Noss (1998) discuss the value of observations of dispersing animals when assessing the efficacy of corridors.
- *Accounting for confounding variables.* Numerous variables not of primary interest can affect interpretation of field data results. Identification and quantification of these potential influences can allow compensation for these factors in analyses. Such variables include:
    - Yearly fluctuations in animal populations (Cramer and Bissonette 2005, Puky 2005, Evink 2002);
    - Seasonal fluctuations in animal populations and/or habitat use (Cramer and Bissonette 2005, Puky 2005, Evink 2002);
    - Climatic effects (Evink 2002);
    - Habitat differences along the road corridor (Anderson and Gutzwiller 1996);
    - Differences in human recreation and building density (Clevenger and Waltho 2005);
    - Traffic volume and speed (Smith 1999, Clevenger and Waltho 2000, Clevenger and Waltho 2005).

Changes in animal abundance and distribution can be addressed through various indices (Murray et al. 2002, Krebs et al. 2001, Massei et al. 1998, Lancia et al. 1996, Harestad and Bunnell 1987, Freddy and Bowden 1983, Neff 1968). GIS and satellite imagery can aide in compiling habitat data, including human activity density, although such "remote" techniques require higher skill levels and special computer software (Koeln et al. 1996). Weather data may be collected in the field using special data loggers or regional data may be obtained from National Climatic Data Center (NCDC 2003). Traffic data may be collected at a specific point of interest or from Department of Transportation resources.

The ideal evaluation of wildlife crossing performance will collect data before and after the installation of the mitigation (pre- and post-mitigation). Once a project has committed to installing crossing structures for wildlife, there may be 2-5 years before the construction begins.

Pre-mitigation data collection should begin as soon as possible to maximize the preconstruction sampling effort over time. Long term monitoring captures more data and understanding of patterns through the "noise" of environmental and demographic stochasticity. Small sampling windows of 1 or 2 years may lead to skewed results, misleading managers to shortsighted conclusions (Clevenger et al. 2002b). Further, immediately conducting post-construction monitoring may yield skewed observations because it has been shown that animals need time to "learn" to navigate through landscapes with fencing and crossings (Clevenger et al. 2002b). Understanding the long-term and landscape-level effect of wildlife crossing structures in terms of communities, biodiversity, ecosystem processes, and landscape ecology may take many years (≥10 yrs) before even beginning to suggest results (Clevenger and Waltho 2003, Stephens et al. 2003, Clevenger et al. 2002b), especially if research questions hinge on long-lived, slow-reproducing species that occur in low population densities, such as grizzly bears (Proctor 2003).

In addition to the ideal pre- and post-mitigation comparison study design, incorporating spatial comparisons between mitigated and unmitigated areas that are otherwise similar will further improve the rigor of the study. Before-After, Control-Impact (BACI) designed experiments are being used to evaluate the effects of a road that will be expanded (van Manen et al. 2001). However, randomization and replication of experimental units is difficult with studies of this type, and there are also many confounding factors to contend with even in a replicated study (Underwood 1994). Pre-mitigation data must be comparable to post-mitigation data, so differences between the pre- and post-mitigation conditions should be considered when analyzing the data from these two time periods.

If preconstruction data on animal movements or animal-vehicle collisions are not available, then post-construction study of animal movement behavior is an option. Data on road-kill and animal use of crossing structures can be combined with other wildlife studies to reveal mitigation effects on the studied species (Smith 2005). Null movement models can be developed post-construction to test the effect of roads on animal movement by comparing observed road crossings with hypothetical expected crossings (see Dyer et al. 2002, Whittington 2002, McKelvey et al. 1999, Serrouya 1999). If there is no statistical difference between the two frequencies, then movement patterns are unaffected by roads, and crossing structures are deemed functional.

The final step in the evaluation process is to report results. Sponsors, stakeholders, other transportation agencies, and road ecology researchers will be interested in the outcomes. The most useful and respected reporting is publishing in peer-reviewed journals that can be accessed by the widest audience.

Finally, WTI offers suggestions to improve the evaluation process, data quality, and data analysis, as follows:

- Define the research questions clearly;
- Evaluate research goals to be sure they are obtainable given time and resources available;
- Consult with a statistician early in the planning process;
- Document standardized data collection procedures to ensure consistency of data over time; and
- Enter data into an electronic database promptly and back it up frequently.

4. PROJECT HISTORY AND CASE STUDY

The US 93 reconstruction planning efforts on the Flathead Reservation have encountered and overcome many challenges. In the early 1980s, the Montana Department of Transportation (MDT), the Confederated Salish Kootenai Tribes (CSKT or "the Tribes") and the Federal Highway Administration (FHWA) recognized the need to increase the level of service and safety for US 93 on the Reservation. Differences in opinion and between cultures regarding how the road should be redesigned, however, divided these stakeholders for many years. Only after the three governments built a foundation of trust, respect and mutual understanding was it possible to create a vision for the reconstruction.

The case study presented here highlights the history of the project and its challenges, different points of view, and approaches that shaped the planning and design process. Other resources documenting the history and characteristics of the US 93 reconstruction efforts include Marshik et al. (2001) and Anderson (2003; this paper also includes additional case studies and personal interviews from other wildlife mitigation project efforts).

4.1. Early Challenges

The CSKT is a sovereign nation and governing body that stands on equal ground with MDT and FHWA. The Tribes own and manage the majority of Flathead Reservation land, but the US 93 corridor is owned, managed, and maintained by MDT. As part of the National Highway System, US 93 projects are eligible for Federal-aid funding and support from FHWA. Therefore, US 93 planning and compliance are subject to review under the National Environmental Policy Act (NEPA) process and more than 50 environmental, cultural preservation, and social justice laws included under the NEPA "umbrella."

Early in the conception of the US 93 reconstruction proposals, MDT's approach separated the 56 mile stretch on the Flathead Reservation into four different projects. Each project was to go through an independent Environmental Assessment (EA) process as a part of the NEPA process. The Tribes expressed concern about the cumulative impacts; after extensive discussions, the four projects were combined into one requiring a NEPA Environmental Impact Statement (EIS) process.

The Notice of Intent to begin the EIS was published in August 1991. The Draft EIS was completed in the fall of 1995. MDT's and FHWA's preferred alternative was based on a four-lane model while the Tribes preferred a two lane design. In the spring of 1996, the stakeholders began serious discussions about their conflicting preferences. Several issues emerged from these talks including safety, traffic operations, commuter related population growth, access management, Ninepipes National Wildlife Refuge, and bypasses of local communities. It also became apparent that the state and federal governments embraced a very different culture than the Tribes.

When the time came for the Final EIS and a Record of Decision (ROD), it was mandatory to attain Tribal support because of the CSKT's status as a sovereign entity. Following cultural traditions, the Tribal elders considered the next seven generations and how a four lane design would affect their home, culture and people. The CSKT Tribal Council voted unanimously against MDT's preferred alternative.

The process failed to find an adequate alternative that met all stakeholder concerns. The three governments drafted a ROD acknowledging their similarities and differences. In August 1996, FHWA published a ROD that stating "This decision does not provide for the physical construction of highway projects with Federal-aid funds until CSKT, MDT, and FHWA agree on the appropriate design and a project level environmental document is completed that addresses social economic and environmental impacts."

Deliberations regarding the reconstruction stagnated until mid-1997 when MDT and FHWA asked what activities the ROD allowed. In February 1998, an amendment to the ROD by FHWA provided for "…acquisition of rights-of way that does not preclude future options…" This allowed MDT to hire Skillings Connolly, Inc. to begin efforts to acquire right-of-way and develop an Access Control Plan. Skillings Connolly approached this task via open and inclusive public involvement guided by a steering committee. The steering committee included representatives from Lake and Missoula Counties and the incorporated cities on US 93 (Polson, Ravalli, and St. Ignatius), all major stakeholders within the US 93 corridor. Critical to the development of the plan was one-on-one meetings with property owners that would be affected by obtaining, removing or purchasing property for highway access. The steering committee played a key role in the public meetings and open houses that were held within the corridor. Monthly meetings were facilitated to arrive at full consensus before moving on to another issue. This inclusive approach illuminated the importance of comprehensive input and collaboration.

In December 1999, the stakeholders agreed to hire a third party consultant to facilitate discussions between the three governments regarding the reconstruction approach. Recognizing the successful outreach efforts with right-of-way acquisition and access management plans, Skillings Connolly was hired as a facilitator and subcontracted three additional consultants to bring information, analyses, and insight to help move the process forward. The Midwest Research Institute was hired to analyze safety and level of service issues associated with the different alignment and lane options; Jones and Jones Architects and Landscape Architects was to resolve disputes and achieve consensus on desired outcomes building on their experience doing similar work for the "Paris Pike" highway project in Kentucky; and Herrera Environmental Consultants was subcontracted to address environmental issues. With upper tier managers, staff and consultants of the three governments committed to a collaborative process, the stakeholders met monthly over the following year to understand each other's concerns, build trust and respect between cultures, and create a vision for the reconstruction of US 93 that satisfied all parties.

4.2. Spirit of Place: A Context-Sensitive Approach

From December 1999 to December 2000, the Tribes, with assistance from Jones and Jones, introduced MDT and FHWA to a holistic approach that considered the landscape, people, and cultural values in addition to safety and level of service. Essentially, this would be considered a "context-sensitive" approach in today's transportation vernacular.

Before design concepts were discussed, the Tribes asked that MDT and FHWA understand the "Spirit of Place". The Spirit of Place "encompasses a broader environmental continuum that includes the surrounding mountains, plains, hills, forest, valley, and sky, and the paths of waters, glaciers, winds, plants, animals, and native peoples. It encompasses the entire Mission Valley, Mission and Salish Mountains, Jocko Valley, and Rattlesnake Divide" (Skillings Connolly 2000). The Tribes emphasized, "The road is a visitor" and that it should respect the Spirit of

Place by responding to the landscape, rather than cutting through the landscape regardless of context. This approach was captured in the following six goals established for the project:

- Develop an understanding of the land and the relationship the Salish and Kootenai people have with the land;
- Find ways the land can shape or influence the road;
- Develop concepts that respect the integrity and character of the place, people, and wildlife;
- Restore habitat areas that have been fragmented by the road and surrounding development;
- Respect and restore the way of life in small communities along the road; and
- Create a better visitor understanding of the place that the Salish and Kootenai people call their homeland.

To address these goals, the Tribes and landscape architects from Jones and Jones characterized different landscapes on the reservation into 14 large outdoor "rooms," each distinguished by unique physical and visual features. The characteristics of these 14 "rooms" or landscapes were summarized to guide the conceptual design phase.

The Tribes wanted assurance that the road would respect and preserve their cultural sacred sites without informing non-Tribal entities of the specific locations of these resources. Recognizing that tribal culture is intertwined with wildlife, the group opted to address cultural and wildlife issues as one and the same, in such a manner that would allow the Tribes to maintain discretion over the release of information that could result in defamation or damage of sacred sites.

Protecting wildlife and cultural resources became an important focal point of the design discussions. The Tribes stressed the importance of minimizing cultural resource and habitat destruction, degradation, fragmentation and wildlife mortality. The incorporation of wildlife passages and wildlife exclusion fencing emerged as a key component early in the conceptual design phase of the project.

Major concerns and priorities were identified on maps, allowing the group to delineate areas of "opportunities and constraints" based on the cultural, natural, and physical landscapes. Opportunities were mapped where scenic, natural and cultural areas could be avoided or where impacts could be mitigated. Constraints were identified in areas where such resources would unavoidably be impacted. All of this information—the major issues, priorities, opportunities, and constraints—served as a framework for developing the initial design concepts.

The stakeholders used an iterative process to suggest and review ideas and concepts for design. To simplify the process, the 14 landscapes identified as "rooms" were pooled into nine separate design segments covering the length of the project. For each segment, design concepts were generated for the following features: road alignment, lane configuration, fish and wildlife crossing structures and exclusion fencing, visitor outreach and interpretive opportunities, and community entry signs. All ideas were considered unless all three governments agreed to discard any from consideration.

The design concepts agreed upon by the three governments were adopted as the US 93 Reconstruction Memorandum of Agreement (MOA; Skillings Connolly 2000) which subsequently amended the EIS ROD as the "final preferred alternative" for the reconstruction effort. This document included "Design and Alignment Concepts" outlining the goals, steps, opportunities, constraints, and priorities agreed to during the design process. The "Design Guidelines and Recommendations" hones those concepts and describes the philosophy and vision for US 93. Specific locations where these concepts would be applied were identified in the "Design Components Workbook". Additionally, the MOA included a "Wildlife Crossings Workbook" with in depth guidance for the design and placement of wildlife crossings and exclusion fencing. Together, these components of the MOA established the model upon which all further design details and decisions hinged upon.

4.3. The Technical Design Committee

Another commitment of the MOA stated that the three governments would work together to achieve consensus throughout the remainder of the project. A "Technical Design Committee" (TDC) was formed to ensure that the designs were developed in accordance with the MOA. Members of the TDC included representatives from CSKT, MDT, FHWA and their consultants. Other representatives from local counties, cities, Montana Department of Fish Wildlife and Parks and the US Fish and Wildlife Service were also invited to participate in TDC discussions as needed. The MOA also stated that if the TDC could not come to consensus on an issue after a reasonable amount of analysis and discourse, it should be reported to the "Project Oversight Group" (POG) consisting of senior-level decision makers from the three agencies to resolve the conflict.

In 2001, prior to beginning the design process, TDC members and Skillings Connolly and their sub-consultants held a "value engineering" workshop; the goal of this effort was to assess the MOA's criteria and, without deviating from the spirit of the MOA, look for opportunities to increase cost-efficiency. For example, many sections of the US 93 reconstruction were considered to be "fill poor" (i.e., earthen fill needed to be transported in from elsewhere); to increase cost-efficiency, a number of the 12 foot by 22 foot (3.7 m by 6.7 m) box culvert wildlife crossings identified in the MOA would be sunk into the ground 2 feet (0.6 m) deeper, reducing the amount of fill (and hence, expense) needed to raise the road to pass over the crossing, with the trade-off of reducing the overall height of the underpass to 10 feet high (Dale Becker, CSKT Biologist, pers. comm.). Decisions approved with consensus among the three governments were documented and carried into the design process.

The TDC began meeting twice a month in 2002, and by 2003, once a month, to collaboratively address the details brought forth during the design process. Eight engineering design firms were awarded individual projects (Table 2). (One final 11.6 mile [18.7 km] section of US 93, in the Ninepipes area, underwent a Supplemental Environmental Impact Statement [SEIS] process and was not yet to the design phase.) Working together, the TDC and their consultants successfully incorporated the concepts in the MOA and the design workbooks into the designs. Any deviations from the MOA were granted only after discussion, negotiations, and consensus occurred between the three governments. All decisions made by the TDC or the POG were documented via meeting minutes, and a matrix of decisions and issues requiring further information or follow-up was continually updated throughout the design process.

Before construction began, FHWA held an Accelerated Construction Technology Transfer (ACTT) workshop. The workshop assembled a diverse group of experts from governmental agencies, academia, and private sector, within and outside of Montana, to discuss potential concerns and possible solutions to avoid pitfalls and delays that can occur on construction projects. Participants focused on issues related to construction, traffic/workzone safety, right-of-way/utilities/railroad, public relations and intelligent transportation system applications, geotechnical and materials, innovative contracting, environment, and structures. The TDC and others involved with the development of the US 93 reconstruction efforts provided context to guide group discussions and sift through ideas to ensure the concepts outlined in the MOA were maintained while different ideas were explored.

Table 2: US 93 reconstruction segments and design consultants.

Road Segments (listed from south to north)	Project Length (miles)	Design Consultant
Evaro - McClure Road	6.4	Entranco
McClure Road - North end of Arlee	5.6	Allied Engineering
North end of Arlee - White Coyote Road	1.5	WGM Group; Frontier-West, L.L.C.
White Coyote Road - South Ravalli	6.7	Robert Peccia and Associates
South Ravalli - Old US 93	4.7	TDH
Old US 93 - Red Horn Road	5.4	Stahly Engineering
Red Horn Road - Spring Creek/Baptiste Road[1]	11.6	Skillings - Connolly
Spring Creek/Baptiste Road - Minesinger Trail	7.3	Carter - Burgess
Mud Creek Structures	0.37	Carter - Burgess
Minesinger Trail - MT 35 (Polson)	2.1	Stelling Engineering; Riverside

[1]Supplemental Environmental Impact Statement expected summer 2006; reconstruction design and wildlife mitigation measures yet to be determined.

Most design projects were completed in 2004, and the first projects were contracted and went to construction in 2004. Not including the highway section undergoing the SEIS, the last projects to go to construction are expected to be completed in 2009. Specific details related to the design of the wildlife mitigation measures are discussed in the next section.

The collaborative approach and the TDC, while requiring a significant commitment of time and staff effort, have successfully developed trust, respect and open communication between the three governments. As a result, the three governments have agreed to continue to address other transportation projects on the Reservation in the future with this collaborative, group effort approach (Ted Burch, FHWA Program Development Engineer, pers. comm.).

4.4. Wildlife Mitigation Measures

The MOA outlined criteria justifying the need for wildlife crossings. The best available information regarding road kill occurrences, winter and summer tracking and trails, habitat, and engineering practicality was used to specify crossing structure location, type, and dimensions for 41 underpasses and one overpass, along with wildlife exclusion fencing. This guidance was compiled in the "Wildlife Crossings Workbook" in the MOA and served as the primary guidance, along with the other tenets of the MOA, for designing the mitigation measures.

In the spring of 2002, at the onset of the TDC meetings and design process, the TDC and the various consultants visited all 42 wildlife crossing structure sites identified in the MOA for group discussions regarding design and final placement of the mitigation measures. Details of these site visits and additional relevant information were compiled into a document distributed to the eight design firms as a reference to help standardize the design process (Jones and Jones 2002a).

In the summer of 2002, considerable time was dedicated to discussing details for designing wildlife mitigation. The TDC and the consultants were guided by the MOA, but each design team had to refine the locations and design of the structures to “fit” the local conditions. However, few, if any, of the consultants had previous experience designing wildlife crossings and exclusion fencing (not surprisingly, given that the incorporation of such measures into highway projects was a somewhat novel concept at that time). To standardize designs across the 8 design segments, a technical memorandum assimilating information from experts and literature provided guidance for the design consultants. Specifications for wildlife exclusion fencing, wildlife-friendly fencing (used at locations where wildlife movement was desired but livestock movements were not), jump-outs, fence placement and connections to bridge abutments or crossing structures, and wildlife guards were developed (Appendix A; Jones and Jones and Western Transportation Institute 2002). The details provided were considered “typicals”; it was expected that these details would be adapted based on specific site conditions without deviating from the design intent laid out in the MOA.

Another technical memorandum provided further guidance for the installation of features related to the post-construction monitoring (Appendix B; Jones and Jones 2002b). Anticipating the use of photo-monitoring and track bed methods, this memorandum included details for designing and installing mounts for remote-triggered cameras inside the underpasses and in an array to cover the wide overpass to capture images of wildlife using these structures. Track bed particulars were also provided so that these features were incorporated into design and reconstruction. The TDC instructed the consultants to create designs for each structure including both concrete and steel options.

The consultants presented their design concepts at TDC meetings incrementally to obtain feedback and ask questions as the designs advanced toward completion. Sub-consultants of the design firms would also interact with the TDC as needed to discuss details related to landscaping and vegetation.

Toward the end of the design process, concerns were raised about the length of wildlife exclusion fencing originally committed to in the MOA for the Evaro and Ravalli Hill areas. At the request of CSKT Wildlife Biologist Dale Becker, WTI reviewed and summarized literature and the best available information regarding the effectiveness of fencing and details that affect the performance of the fencing. Further, WTI analyzed existing track bed data and animal-vehicle collision data in the areas where it was proposed to shorten fencing. Evidence of effectiveness for various techniques to limit wildlife access to the right-of-way through gaps, around the ends of the fencing, by climbing over or burrowing over the fence was presented as well (Hardy and Huijser 2004; Appendix C). Based on the synthesis of this information, WTI emphasized the importance of including measures at gaps to prevent breaches of animals onto the right-of-way, potentially creating a safety situation of greater significance when animals are trapped within the fences versus when no fencing exists.

Ultimately, the TDC opted to shorten the fencing in the Evaro area at the locations where there would have been a preponderance of gaps in the wildlife fencing where driveways and side roads accessed the highway. In addition to installing and maintaining the fencing in this area, the installation and maintenance of wildlife guards and gates at these gaps would require significant additional expense given the number of gaps in these stretches. Further, if multiple gates or wildlife guards failed to prevent wildlife from moving into the right-of-way and this became a frequent occurrence (due to the sheer numbers of gaps in this area with potential to fail to control animal movement), it is possible that this could create a safety situation of greater significance than if the wildlife fencing were not there at all. Such a situation would be difficult to address, short of completely removing the fencing.

Fencing was also shortened in the northern stretches of the Ravalli Hill wildlife mitigation area; the animal-vehicle collision and track bed crossing data indicated these areas had relatively lower wildlife crossing and vehicle-collisions. Additionally, the existing wildlife-exclusion fencing encompassing the National Bison Range adjacent to this stretch of road, in combination with wildlife fencing on the road, could limit wildlife movements with the potential to lead animals between these two fences to the town of Ravalli and the junction of US 93 with MT Highway 200, where conflicts could occur. Although the highway wildlife fencing at the southern end of the Ravalli Hill wildlife mitigation section parallels the Bison Refuge, the funneling effect would be reduced with the shortened fence lengths in this area.

Appendix D summarizes the wildlife mitigation originally outlined in the MOA and the final outcomes of the design process. In summary, seven crossing structures originally included in the MOA were not included in the final design plans, but seven “new” crossing structures were included in the final designs at locations relatively close to where the seven crossings in the MOA were designated and three “new” stock crossings that were not specified in the MOA were included in the final plans.

A single over-crossing, a 150-foot (45.7 m) wide bridge of landscaped wildlife habitat, was strategically placed in the Evaro area for the following reasons: 1) the Evaro Hill area has been modeled as an important habitat to link the Northern Continental Divide Grizzly Bear Recovery Area (including Glacier National Park and the Bob Marshall and Scapegoat Wilderness areas) with the Selway-Bitterroot Grizzly Bear Recovery Area (Mietz 1994); 2) this is one of the few areas of the project that has forested habitat on both sides of the road and is likely to provide cover for many species of wildlife moving through the area, including “more illusive” species (grizzly bears, wolves, lynx, wolverine, fisher) that might move from one mountain range to another; and 3) the CSKT owns much of the land in the area where the over-crossing will be built and the tribes are committed to not developing or selling this land but to conserving the land as a wildlife corridor.

In conjunction with the crossing structures, 16.6 miles (26.7 km) of 7.6 foot (2.3 m) high wildlife exclusion fencing will be installed in the study area. Multiple jump-outs will be installed to allow animals to escape the fenced sections of highway. Final designs include five sections of greater than 0.5 miles (0.8 km) fencing that will direct wildlife to most of the wildlife crossings (Table 3). These five continuous sections of wildlife fencing are not connected to one another, a characteristic different from the Banff Trans-Canada Highway fencing, which has continuous fencing (with passages) along this controlled access highway. With numerous access roads, fencing was not always appropriate or needed; as previously mentioned, the uncertainty of maintaining a barrier to wildlife movements into the right-of-way at these gaps is of particular concern and interest, especially given that such an extensive mitigation effort has not previously been applied in a landscape with multiple uses and anthropogenic influences.

Table 3: Locations and lengths of wildlife exclusion fencing planned for the US 93 reconstruction effort, including numbers of wildlife crossings within each given fencing segment. Fencing lengths were calculated using the west (southbound) stretch and are less than the difference between the mile posts due to the gaps (both mitigated and unmitigated) within each stretch of fencing. Design plans indicate 11 wildlife crossings, including some span bridges, will be installed without adjacent fencing

Type of Fence	Start Mile Post	End Mile Post	Fencing Length (miles)	Fencing Length (km)	# Xings
Continuous Stretches	9.4	11.1	1.2	2.0	6
	18.7	19.2	0.4 [1]	0.6	4
	22.9	26.8	3.4	5.4	5 [2]
	27.7	28.8	0.9	1.5	2
	57.6	58.6	1.0	1.6	1
Short Sections ("Wing Fencing")	31.9	32.1	0.2	0.3	1
	32.6	32.8	0.2	0.4	1
	34.1	34.2	0.1	0.1	1
	34.4	34.4	0.1	0.1	1
	34.7	34.8	0.1	0.2	2
	48.6	48.8	0.2	0.3	1
	49.3	49.4	0.2	0.3	1
	51.0	51.3	0.3	0.4	1

1. This value is less than 0.5 miles because of the mitigated gaps in fencing, largely due to wildlife crossings.

2. Does not include 3 small mammal crossings

In addition to the five extended sections of fencing connecting the numerous crossing structures, 10 additional, independent wildlife passages will have approximately 328.1 feet (100 m) long "wing fences", extending at approximately 45 degree angles from the crossing structure openings to funnel animals to these more "free-standing" crossing structures; these wing fences, for the most part, will not be connected to the next section of fencing. Five of the crossings will not have wildlife fencing, such as bridges, culverts intended for aquatic passage alone or where natural features of the landscape, such as drainages, are expected to lead animals to the crossings without fencing.

There were several locations with no wildlife fencing (Table 4). In many places, these gaps were mitigated with wildlife guards or metal gates. However, assessment of design plans that were available at the time this report was drafted revealed several gaps that did not appear to have such mitigation. Long sections of unmitigated gaps between ends of the fencing were anticipated as some areas were never planned to have any wildlife fencing. Most shorter gaps in the fencing are mitigated according to the design plans; however the handful of shorter, unmitigated gaps where access roads intersect more extensive lengths of fencing are of concern given that this could result in wildlife accessing and becoming trapped in the right-of-way where the risk of an animal-vehicle collision may be higher if the animal can not escape.

Table 4: Gaps in US 93 wildlife exclusion fencing, categorized by the length of the gap and whether gaps included structures (cattle guards, swing gates) to control wildlife passage onto the right-of-way. Longer gaps typically encompass stretches of road where no wildlife mitigation was planned, while shorter gaps usually are indicative of points that intersect sections of wildlife fencing to access US 93.

GAPS	<0.005 miles	>0.005, <0.1 miles	>0.1, <0.5 miles	>0.5 miles
Mitigated	26	19	3	0
Unmitigated	1	3	9	16
Unknown/Partially Mitigated	17	1	3	0
Total	**44**	**23**	**15**	**16**

5. PRECONSTRUCTION FIELD STUDY

Since the inception of reconstruction proposals for US 93 on the Flathead Indian Reservation, concerns about impacts of highway reconstruction on resident wildlife populations have spurred related research efforts. Early in the reconstruction planning process, five alternative lane configurations were proposed by FHWA and MDT. Potential impacts of these alternatives on wetland and riparian habitats and wildlife connectivity across the Reservation, and mitigation measures to alleviate these impacts, were evaluated by Becker (1996). Along US 93 adjacent to Ninepipes National Wildlife Refuge, Fowle (1996a, 1996b) determined road kill rates for western painted turtles (*Chrysemys picta bellii*) were significant, and recommended mitigation measures be implemented to decrease turtle mortality and increase the permeability of the highway. Based on landscape and grizzly bear habitat modeling, the Evaro Hill area on US 93 at the south end of the Reservation has been highlighted as the single corridor and linkage zone connecting the Bitterroot/Selway area to the Mission Mountains/Bob Marshall Wilderness grizzly bear populations (Mietz 1994). Servheen et al. (1998) demonstrated that high-speed highways such as US 93 have adverse effects on grizzly bears, by inhibiting movements, genetic and demographic exchange and increasing mortality. These studies, along with other published research papers addressing transportation impacts on ecological systems in other locations, reinforced concerns about minimizing US 93's impacts on wildlife and habitats.

Reconstruction discussions often centered on these concerns, eventually leading to the incorporation of wildlife mitigation efforts (see Chapter 4 for details). Because these measures were being applied in a mixed-use rural landscape, where it was not clear how animals might respond to the mitigation measures, it was agreed that a field study to evaluate how these mitigation techniques perform in a "real world" rural setting would be conducted. An oversight committee consisting of five representatives from CSKT, FHWA, MDT, and WTI collaboratively established the goals and focus of the evaluation field study.

The oversight committee agreed that a "before-after" approach would be used and while all species of wildlife were of interest, the evaluation was to focus on deer species (white-tailed deer [*Odocoileus virginianus*] and mule deer [*Odocoileus hemionus*]) and black bear (*Ursus americanus).* The primary goals of the field evaluation were to determine what effect US 93 wildlife crossing structures and wildlife exclusion fencing have on: 1) the frequency of animal-vehicle collisions (AVCs); and 2) habitat connectivity, specifically in terms of successful wildlife movements across US 93.

The first goal will be addressed by comparing AVC reports for the 56 miles (90 km) of US 93 to before and after installation of the mitigation measures. Considerations regarding the analyses of these data and a summary of the preconstruction baseline AVC data are detailed in the first subsection of this chapter.

The second goal requires quantifying and comparing wildlife-highway crossing events before and after construction. Preconstruction deer and bear crossings were sampled via sand track beds situated on the highway shoulder to estimate movements across three sections of the road where the longest segments of contiguous fencing will be installed. Post-construction wildlife crossings will be monitored at wildlife crossing structures and at the ends of the fence to compare to the preconstruction crossing rate estimates in the same area (post-construction crossing monitoring will occur at all crossings, not only where preconstruction crossing data was collected; see Chapter 7 post-construction monitoring recommendations for details). The preconstruction tracking methods, crossing data characteristics, resulting estimates of total crossings in the areas to be fenced are detailed in the second subsection of this chapter. Ancillary data collection efforts and results are presented in the following subsections. The final subsection synthesizes the preconstruction field data results, acknowledging the challenges of making inferences given the inherent variability and complexities of the data.

5.1. Study Area

In northwestern Montana, US 93 runs the spine of the Rocky Mountains for 286 miles from the United States-Canada border at Port of Roosville to the Montana-Idaho border at Lost Trail Pass. While many sections of US 93 in Montana have recently undergone or are planned to undergo reconstruction, the US 93 reconstruction project featured in this study spans 56 miles (90 km) of the Flathead Indian Reservation from Evaro, at the southern boundary of the Reservation, to Polson (Figure 1), near the northern boundary of the Reservation.

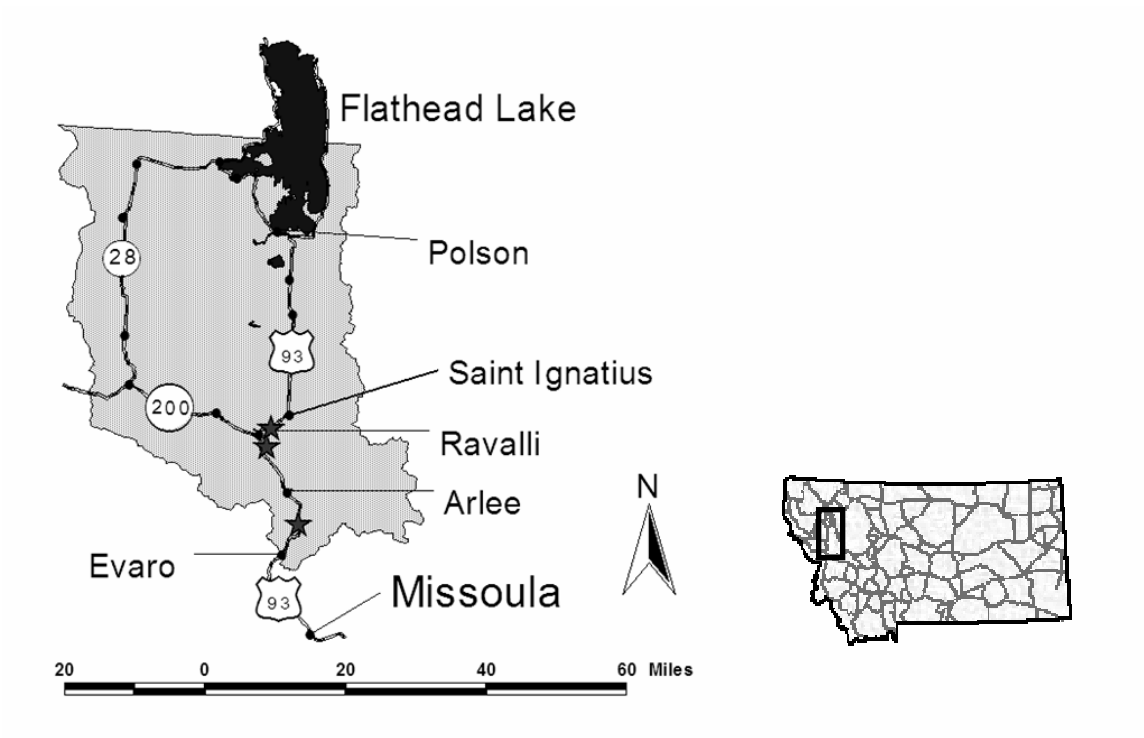


Figure 1: The Flathead Indian Reservation in northwestern Montana including major highway routes. The US 93 reconstruction effort and evaluation study area traverses 56 miles from Evaro to Polson. Stars represent the Evaro, Ravalli Curves and Ravalli Hill study areas from south to north, respectively, where more intensive sampling efforts were focused.

The Flathead Indian Reservation encompasses the west face of the Mission Mountain Range (elevation up to 2993 meters, 9820 feet) along the eastern boundary, the southern end of Flathead Lake at the northern boundary, Rattlesnake Divide Mountain Range along the southern boundary, and valley bottoms transitioning to mountain foothills along the western boundary. The Flathead River and its numerous tributaries flow through the Reservation and form valleys including the Mission Valley, Jocko Valley and the Lower Flathead Valley.

Climate on the Reservation is dominated by Pacific maritime systems. Winters are relatively mild for the northern Rockies but the region is commonly inundated with arctic air originating from the north and east. Precipitation ranges from 12 inches in the less-mountainous west to over 100 inches in the east. Most precipitation is in the form of snow in fall, winter, and spring. Temperatures vary from below 0° F in winter to close to 100° F in the summer. Summers tend to be dry and the growing season ranges from 45 to 120 days.

Habitats on the Reservation range from agricultural lands, shrub and grasslands, and wetland and riparian areas in the valley bottoms to subalpine habitats at the higher elevations. A significant array of wetland complexes and glacial "pothole" lakes and ponds are found on the Reservation as well. These habitats support 309 species of birds, 66 species of mammals, 9 species of amphibians, and 9 species of reptiles (Tribal Wildlife Management Program, unpublished data). Of particular interest, the Reservation supports resident and migrant free-ranging native species such as bull trout (*Salvelinus confluentus*), grizzly bear, Canada lynx (*Lynx canadensis*), bald eagle (*Haliaeetus leucocephalus*), gray wolf (*Canis lupus*), and mountain lion (*Felis concolor*). Black bear, moose, elk, white-tailed deer, mule deer, pronghorn antelope (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*), coyote (*Canis latrans*), and western painted turtles (*Chrysemys picta bellii*) reside on or have been known to pass through the Reservation. In addition, bison (*Bison bison*) have been reestablished as a viable captive population in the 18,500 acre National Bison Range.

The Flathead Indian Reservation is home to the Confederated Salish and Kootenai Tribes (CSKT), which include the Bitterroot Salish, the Pend d'Oreille and the Kootenai tribes. These tribes historically ranged across more than 20 million acres in areas now known as western Montana, Idaho, British Columbia, and Wyoming. The 1855 Hellgate Treaty allocated about 1.25 million acres to these tribes to establish the Flathead Reservation. In the late 1800s, federal legislation set the stage for allotting certain parcels of reservation lands to tribal members. Later, the federal government opened reservation lands to homesteading for non-tribal members on lands that had not been previously allotted to tribal members. The tribes have been reacquiring lands on the reservation since the 1940s; by the mid-1990s, the majority of lands on the reservation were owned by the CSKT and held in trust by the federal government or by tribal members. Reservation landscapes are managed for a variety of uses, with the valleys dominated by agricultural activities such as irrigated farming and livestock production, as well as residences and businesses, and mountain environs supporting forestry, recreation and hunting and fishing for CSKT tribal members.

The US 93 corridor, including the highway and the right-of-way, is owned and managed by the Montana Department of Transportation (MDT) as an easement through the Reservation. As the only major highway between Interstate-90 near Missoula and northwestern Montana, US 93 is a critical route within and beyond the region. Each year, visitors travel US 93 through the Reservation towns of Evaro, Arlee, Ravalli, St. Ignatius, Ronan, Pablo and Polson to destinations such as Glacier National Park, generating an important tourism industry for many businesses in the area. In 2003, prior to reconstruction, the Average Annual Daily Traffic for the reconstruction segments ranged from 7440 to 11,300 (MDT 2006). According to the traffic safety analysis included in the MOA (Skillings Connolly 2000), the proportion of fatal accidents on this section of US 93 (4.8 percent) is higher than the statewide average for National Highway System routes (1.7 percent) and the proportion of nonfatal injury accidents (44.2 percent) is also greater than the statewide average for similar routes (37.1 percent). Thus, high accident severity (i.e., high risk of death or injury when an accident occurs) is a major concern in this corridor. Projections of significant growth in the region call for a significant increase in the level of service for US 93.

As mentioned previously, AVCs and post-construction monitoring of the wildlife crossings, ends of wildlife fencing, and gaps in wildlife fencing will be assessed across the entire length of the reconstruction project, from Evaro to Polson (excluding the 10-mile Ninepipes section between St. Ignatius and Ronan, which will be reconstructed at a later time). Preconstruction crossings will be monitored and compared to post-construction crossings only between Evaro and St. Ignatius, a subsection of the larger study area (Figure 1). The Evaro, Ravalli Curves and Ravalli Hill areas (represented by stars in Figure 1) were selected for more intensive monitoring efforts, because these areas are slated for the longest continuous stretches of wildlife exclusion fencing and crossing structures. The Evaro area is a forested narrow valley that holds high value as habitat amenable to use by grizzly bears and other megafauna of interest (McCoy 2005, Becker 1996, Mietz 1994). The Ravalli Curves area is grassy river valley flanked by steep, rolling hills, and contains some wetland/riparian elements while Ravalli Hill is a high, dry, grassy hill that divides the Mission Valley and Ravalli Canyon (Skillings Connolly 2000, Becker 1996).

5.2. Animal-Vehicle Collisions

The first goal of the evaluation study is to assess AVCs before and after mitigation measures are installed to provide quantifiable evidence of their effect on this parameter. Considerations regarding the analysis of AVC data are outlined below, followed by an account of the sources, methods, and characteristics of the preconstruction baseline AVC data. Extensive details about preconstruction field data collection methods and considerations are documented in the US 93 Field Monitoring Handbook created for this project (Hardy and Huijser 2005).

5.2.1. AVC Data Considerations

Information on what, where, when, and how often species are killed on roads can help assess if and what types of efforts to reduce AVCs may be needed, where these mitigation measures should be located, and whether mitigation was effective in reducing AVCs. However, it is important to understand how AVC data were collected as this affects the assumptions, analytical approaches and interpretation of results (Knapp et al. 2004). The following considerations need to be taken into account when requesting, compiling, analyzing, and applying results from AVC databases:

- Sampling framework: who collected the data & how were the data collected;
- Sampling intent: what was the intent for collecting AVC data;
- Sampling effort: were AVCs reported via systematic monitoring methods or opportunistic observations;
- Sources of error: to what degree has under-reporting, spatial inaccuracies, and observer bias or fatigue affected the dataset;
- Other parameters: what other ancillary information was recorded with each AVC report; and

- Combining AVC datasets: how might differences in sampling areas, time periods or methods affect the combined dataset and is it possible to detect and reduce duplicate observations.

More than 70% of states maintain long-term records of AVCs, but few (20%) actively research the magnitude of the AVC problem (Sullivan and Messmer 2003). Romin and Bissonette (1996) surveyed state natural resource agencies regarding their AVC data collection procedures in 1991. Of 43 responses, 35 reported collecting such data while 8 lacked accurate data.

Motives and methods to document collisions between animals and vehicles can vary, affecting the parameter that is reported; e.g., AVC reports versus road-kill carcass observations. Law enforcement and/or insurance agencies may report only collisions that cause vehicle damage or human injuries or fatalities and in some cases, only AVCs that have caused some minimum damage threshold are reported (IIHS 2004). Departments of transportation may report large animal carcasses removed from the roadway, but not animals that died away from the road edge or small species that pose little threat to traveler safety. State and Federal wildlife management agencies may only document carcasses of species of special interest, such as game animals, rare or unusual observations of wildlife, or threatened/endangered species.

Often, AVCs are documented incidentally or opportunistically, resulting in a dataset that under-represents and inconsistently reports AVCs. Estimates of deer-vehicle collisions based on police reports may be less than half of what might be observed in more intensive field study efforts (Knapp et al. 2004, Sullivan and Messmer 2003) and it's estimated that only 15 to 35% of all AVCs are reported (Sullivan and Messmer 2003, Sielecki 2004). Systematic approaches for reporting road kill carcasses can reduce (but not necessarily eliminate) some of these problems that affect datasets of opportunistically collected data. Even consistent and routine monitoring may underestimate AVCs by a factor of 12-16 times or more for smaller and less visible species (Slater 2002).

Whether using opportunistic or systematic methods to document AVCs or road kills, multiple sources of process and sampling variation will affect AVC or road kill datasets. Sources of process error include the disappearance of carcasses; for example, small carcasses in the lane of travel disintegrate as vehicles pass over the dead animal, or carcasses may be scavenged or removed from the road before researchers document the presence of the kill. Animals may die away from the roadway where road kills may not be detected (Sielecki 2004, Slater 2002, Sielecki 2001, Case 1978). McCaffrey (1973) found that where landscapes were more open, more road-kills may be found (McCaffrey 1973); conversely, Slater (2002) found that the wider the clear zone or verge, the fewer road kill observations were made. Sources of sampling error include non-response error, observer fatigue or observer bias (Thompson 2002). Other causes of underreporting include errors in filling out forms, poor training and lack of motivation (Clevenger et al. 2002b).

Spatially accurate road-kill locations are necessary if mitigation efforts designed to reduce road-kills are to be effective. A study of the spatial error associated with wildlife-vehicle collision reports (Clevenger et al. 2002a) found that the reported location could be off by more than a mile. A low level of spatial precision can locate a general problem area, but may not be spatially explicit enough to provide information on exactly where to locate a crossing structure.

Multiple sources of AVC data may be combined to provide a more comprehensive and accurate picture of the problem; however the user must be aware of the risk of double counting AVCs when datasets cover the same area over the same period of time. Therefore, when pooling datasets from different sources, the collective dataset needs to be systematically screened to eliminate redundant information.

The considerations outlined above limit the use of AVC datasets to varying extents. However, careful assessment, screening, analysis and interpretation of results using such data can provide an indication of areas of AVC concern for more specific study and trends to assess how mitigation measures affect AVCs.

5.2.2. US 93 Preconstruction AVC Data

Given available resources and budgets, WTI opted to work with existing (and future) AVC data from the following three sources:

- MDT Safety Bureau's Montana Highway Patrol (MHP) accident database,
- MDT Maintenance reports of road-killed carcass removals, and
- Montana Fish Wildlife and Parks (MTFWP) supplemental black bear road kill reports.

With a daily presence on US 93, MDT and MHP datasets provided the most consistent AVC and carcass data over the longest period of time (1992—2005). MTFWP has collected supplemental black bear carcass data since 2000. The combined AVC and carcass datasets are the "best available information" that will be used to track general trends in AVC occurrences over time.

Prior to conducting any analyses, the MDT and MHP datasets were combined and systematically screened to eliminate redundant information (i.e., duplicate records). Next, MTFWP bear kill data were added if the date and location of the kills were specific enough to cross-check against MDT and MHP records. The following common variables were included in the final combined dataset:

- Date of occurrence;
- Mile marker (to the 0.1 mile);
- Species of animal;
- Sex of animal (if identified);
- Age of animal (juvenile vs. adult, if identified); and
- Data source (MHP report, MDT carcass removal data, or MTFWP bear kill records).

Rules were established to address potential duplicate records (Hardy and Huijser 2005). If two or more sources report an AVC/carcass record involving the same animal species and sex (if reported) and if these locations are within 0.2 miles and/or within 2 days of each other, the records were assumed to be duplicates, and redundant information was censored. Careful attention was paid to details such as whether two different animals were hit at the same time/place (e.g., when an adult and young of the year cross and are hit together, or if an adult is hit and their young lingers nearby and is hit shortly thereafter) to ensure both animals were accounted for only once and that the second animal was not deleted.

After screening for duplicates, the remaining data were examined (Table 5). Reported AVC or carcass removal events ranged from 4 to 16 per year between 1992 and 1997, a seemingly low number of occurrences for this 56 mile stretch of heavily-traveled rural road. In 1998, MDT Maintenance established carcass removal reporting protocols; presumably as a result of that initiative, the annual number of reported AVCs and carcass removals ranged from 31 to 37 from 1998 to 2001. In 2002, WTI approached the maintenance districts that report carcass removals on US 93 on the Flathead Indian Reservation to explain the importance of these data to this project and asked that they continue to collect these data just as they had been doing since 1998. Additionally, in 2003, an MDT biologist circulated a memorandum to maintenance staff emphasizing the importance of reporting carcass removals (Pat Basting, MDT Missoula District Biologist, pers. comm.). The number of reported AVCs and carcasses in 2002 spiked, with a total of 98 events recorded across the same 56-mile stretch as the previous years. It is possible that more AVCs occurred, or it is perhaps more likely that the maintenance staff inadvertently increased their efforts given their awareness of the significance and purpose of these data.

Table 5: Annual numbers of AVCs and road kill carcass removals reported from 1992 through 2005 by MDT, MHP and MTFWP sources for US 93 from Evaro to Polson, Montana. "Other (Wild)" includes elk, raccoons, turkeys, and coyotes. "Other (Domestic)" includes cattle and horses.

YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Deer	4	7	9	7	10	14	26	30	33	29	98	83	83	96
Black Bear	0	0	0	1	0	1	5	2	3	1	8	9	2	1
Grizzly Bear	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Other (Wild)	0	0	0	0	1	1	0	0	1	0	2	1	2	2
Other (Domestic)	0	0	0	0	0	0	0	0	0	0	0	0	1	2

Based on the observation that reporting efforts were variable over the years, only data from 2002—2005 were used for preconstruction AVC analyses. These data appear to be relatively consistently reported and represent an index of AVC occurrences that happened immediately prior to construction. The majority of observations from 2002—2005 were deer (93%): white-tailed, mule deer, or undetermined deer species (Figure 2). About 5% of reported kills were black bears. The remainder of road kills included grizzly bears and other wild species (e.g., elk, raccoons, turkeys and coyotes).

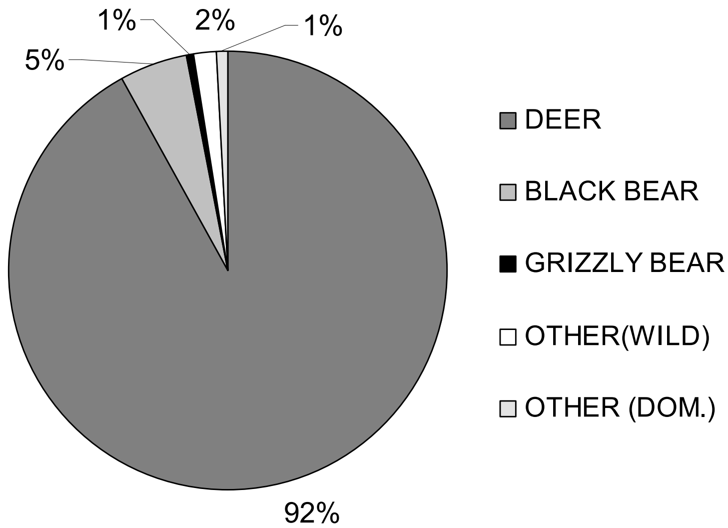


Figure 2: Species ("deer" includes both white-tailed and mule deer) of animal-vehicle collisions and road kill carcass removals from US 93 reported over 2002—2005. Sources: MDT, MHP and MTFWP.

The 2002—2005 AVC dataset was used in the analyses reported below. Although all AVCs are of interest for safety, cultural, economic and resource management reasons, this study focuses on deer and black bear, therefore the analyses only address the vehicle collisions with these species.

5.2.2.1. Preconstruction Deer-Vehicle Collision Data

Although deer-vehicle collisions (DVCs) were recorded from 1992—2005, procedural and sampling changes (described above) appeared to lead to more consistent effort and reporting from 2002—2005 (Figure 3). Hence, the analyses and results below incorporate only the 2002—2005 DVC reports (Note: there were no MDT road kill carcass removal reports for January-May of 2002).

The average annual number of reported DVCs during the 2002—2005 preconstruction years was 90 (95% C.I. = 82, 98). Over the total 52.6 mile study area (mile marker 6 to 58.6), this equates to an average of 1.7 deer killed per mile per year (95% C.I. = 1.6, 1.9).

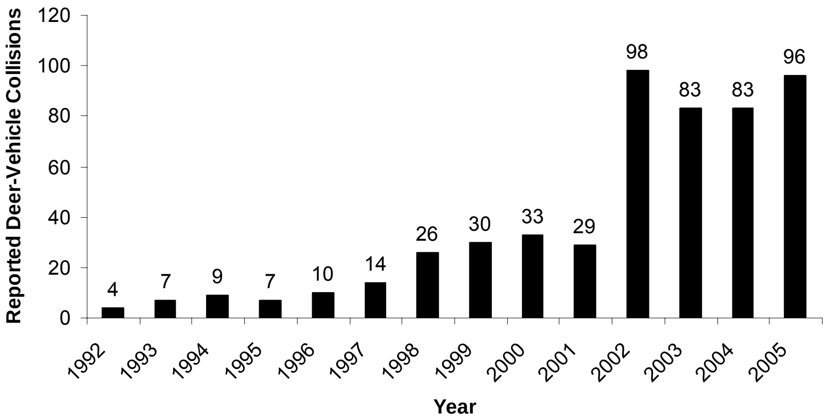


Figure 3: Annual reported deer-vehicle collisions and road-killed deer carcasses removed from Evaro to Polson, 1992-2005. Sources: MDT and MHP.

The 2002—2005 DVC dataset was further divided to assess two specific areas of interest:

1. The 8.7 miles (14 km) where wildlife fence (including long continuous and short wing fence sections) will be installed along both east and west sides of the highway (hereafter referred to as "double fence");
2. The 44.9 miles (72.3 km) outside the proposed double fence, including 3.9 miles where wildlife fencing is planned for only one side of the road and where wildlife fencing sections are less than 0.5 miles (0.8 km) in length (i.e., where short segments of "wing fencing" will be installed immediately adjacent to crossing structures to funnel animals to the passageways under the highway). The 44.9 miles (72.3 km) includes the 11.6 mile (18.7 km) Ninepipes stretch where mitigation and reconstruction design has not yet been determined.

The number of DVCs in each area of interest was divided by the total length of each area to provide a standardized response variable of DVCs per mile. The average annual number of DVCs reported in 2002—2005 where double fence is proposed was 11.8 (95% C.I. = 4.6, 18.9). This equates to 1.4 deer killed per mile per year (95% C.I. = 0.5, 2.2; Figure 4). The annual average number of DVCs outside the area where the double fence will be built was 78.3 (95% C.I. = 74.5, 82.0). This equates to 1.7 deer killed per mile per year (95% C.I. = 1.7, 1.8; Figure 4). The overall reported DVCs in these sections do not statistically differ in the preconstruction period ($P > 0.05$).

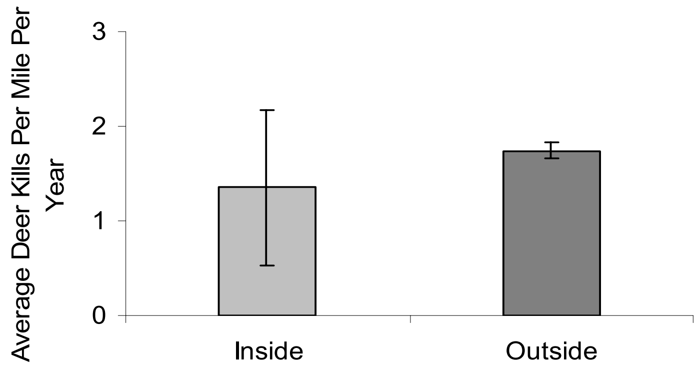


Figure 4: Average number of reported deer-vehicle collisions (DVCs) per mile per year for sections of US 93 inside and outside areas planned for wildlife fencing. Reported DVCs in the Ninepipes stretch were included in areas outside the wildlife fencing; mitigation for this stretch of road has not yet been determined. Bars represent 95% confidence intervals around the mean.

A power analysis was applied to determine what degree of change in DVC rates would be statistically detectable when comparing DVC rates before and after the mitigation is installed, given the sample size, or number of years of DVC data, used in the comparisons. This statistical test determines the probability of detecting differences, or effects, between two groups of data, if an effect actually occurs (Zar 1999). This information is useful when determining appropriate sample sizes (e.g., number of years of post-construction DVC data) that will allow for useful quantitative inferences. The larger the sample size, the more likely one will be able to detect smaller differences with greater precision, but the expense and effort of obtaining such larger samples may be prohibitive; alternatively, with small sample sizes, relevant differences between two sets of data may not be detected and inferences may be limited or inaccurate.

Power analyses are conducted within a hypothesis testing framework where failing to reject the null hypothesis indicates that differences between two estimates were not detected. If the null hypothesis is rejected, indicating that there are differences between the two samples, then the test supports alternative hypotheses of anticipated differences that are likely to be observed in the data. Alternative *a priori* hypotheses may be one-sided or two-sided: a one-sided (i.e., one-tailed) hypothesis tests for an expected change (e.g., a reduction in reported DVCs); a two-sided (i.e., two-tailed) hypothesis tests for an uncertain outcome (e.g., a reduction or an increase in reported DVCs). Power (i.e., the probability of correctly rejecting a false null hypothesis) and significance level or α (i.e., the probability with which one is willing to reject the null when it is in fact correct) can be controlled in these analyses.

The preconstruction sample used in the power analyses (with the power and significance levels set subjectively at 0.80 and 0.05, respectively) consisted of four years of reported DVC observations (n_{pre} = 4). Three power analyses were performed to determine the minimum detectable change in number of deer killed per mile per year given the number of years of post-construction data obtained to be used in the before-after comparison:

1. A one-sided hypothesis test was used to estimate the detectable decline in reported DVCs per mile before and after construction inside areas that will receive double fencing because it is expected that the wildlife fencing will reduce DVCs in these areas.

2. Another one-sided test was used to estimate the detectable reduction in reported DVCs for the study area as a whole; this is the desired, expected effect of the mitigation efforts.
3. For areas that will not have wildlife fencing installed, a two-sided test was used to estimate the detectable increase or decrease in reported DVCs per mile for areas since it is uncertain if a reduction or increase in reported DVCs may occur. If deer do not adapt to the mitigation as desired, they may shift their ranges and cross-highway movements to areas without wildlife fencing, potentially increasing interactions with vehicles or DVCs in the unfenced areas or, of particular interest, near the ends of the fences (related to that potential scenario, it may be possible to test for increases in DVCs along shorter, localized road segments [1 km; 0.6 m] at the ends of the wildlife fencing). It is also feasible that a reduction in DVCs may be observed outside the fenced areas if the reconstructed highway results in increased speeds and traffic volumes become a formidable barrier to wildlife crossing unto itself, subsequently resulting in a decrease in wildlife-vehicle interactions and collisions in these areas.

Ideally an equal number of post-construction years is preferred; power analyses results are reported for a range of 3-5 years post-construction study (n_{post}). Results of these power analyses follow:

1. Deer-vehicle collisions inside the areas that will have double fencing installed had high preconstruction year-to-year variance and therefore only large differences between the pre- and post-construction DVC data will be statistically detectable in these areas. A 241% change in kills per mile would be detectable after 3 years of post-construction study, while a 151% change would be detectable after 5 years (Figure 5).
2. With significantly more miles of road where no wildlife fencing will be installed, there was less preconstruction variance in the annual reported DVCs outside the area that will have wildlife fencing such that smaller differences may be detectable in post-construction study (Figure 5). Outside the area that will have double fencing, a 19% increase or decline in deer kills per mile would be detectable after 3 years of post-construction study, while a 12% increase or decline would be detectable after 5 years. The unfenced stretch analyzed here includes reported DVCs from the Ninepipes section where mitigation measures and reconstruction design plans have not yet been determined. The results relating to the fenced and unfenced sections reported above, therefore, were influenced by the exclusion and inclusion, respectively, of the Ninepipes data; these results will change if these data were shifted from the unfenced dataset and included in the fenced dataset.
3. Detectable differences were relatively small across the entire study area (including fenced and unfenced areas and the Ninepipes stretch), with a 35% decline in DVCs detectable after 3 years of post-construction study, and a 22% decline after 5 years of study (Figure 6).

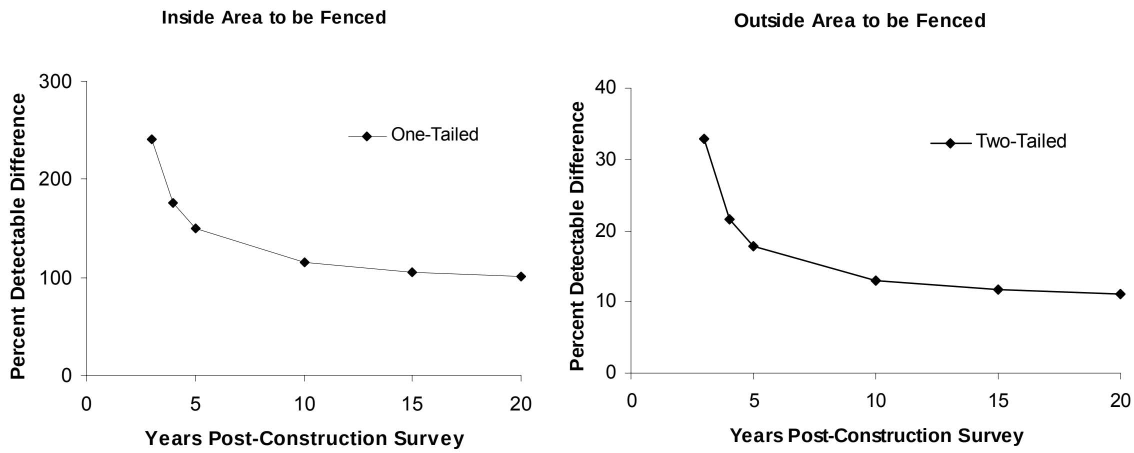


Figure 5: The minimum detectable difference in reported deer-vehicle collisions per mile inside and outside areas (including the Ninepipes section) that will have wildlife fencing installed, given *n* years of post-construction study.

Figure 6: The minimum detectable difference in deer killed per mile across the entire US 93 study area (including the Ninepipes section) given *n* years of post-construction study.

Based on other studies assessing wildlife fencing and crossing effects on AVC rates, it is reasonable to expect that these estimated detectable differences will be obtainable without requiring inordinate number of years of post-construction data. For example, Clevenger et al. (2001) reported an 80% reduction in ungulate-vehicle collisions in Banff National Park where extensive, continuous wildlife fencing limits wildlife access to the Trans-Canada Highway. Lehnert and Bissonette (1997) observed a 37% reduction in deer-vehicle collisions where deer were crossing a rural 2-lane highway at-grade in Utah via an intentional gap in wildlife fencing (i.e., a "deer crosswalk"). While neither example is exactly comparable to the US 93 fencing design and placement, it would not be unreasonable to expect DVC reductions across the entire study area to be within range of these outcomes given that the sections of continuous fencing (where the greatest reductions in DVCs are expected) and unfenced gaps (with lower potential for reductions in DVCs) could balance out to an overall reduction that could be detected in 3-5 years of post-construction monitoring

Locations of deer kills reported in 2002—2005 were plotted by tenths of a mile as were the locations of the planned wildlife fencing and crossing structures (Figure 7). There were several "hotspots" of DVCs across the study area. A "hotspot" was defined as a tenth of a mile with greater than 3 standard deviations more deer kills over 2002—2005 than the mean number of deer kills (average = 0.7 kills per 0.1 mile; standard deviation = 1.4). Based on this definition, two hotspots were identified at mile markers 33.6 and 34.5; both within 0.1 mile (0.16 km) from where wildlife crossing structures will be installed, but wildlife fencing extending from those structures will not cover those specific locations. An unmitigated hotspot occurred at mile marker 7.4, and several other hotspots (mile markers 37.5, 37.7-37.9, 39.8, and 45.6-45.8) occurred within the final section of US 93 within the Ninepipes National Wildlife Refuge on the Reservation which is planned for reconstruction upon the completion of a Supplemental Environmental Impact Statement (Figure 7). It should be noted that DVC locations were reported to the tenth of a mile, and therefore may not have precise spatial locations to where the DVC actually occurred. Hence, some of the peaks and DVC hotspots depicted in Figure 7 may not coincide precisely with the locations of the mitigation measures.

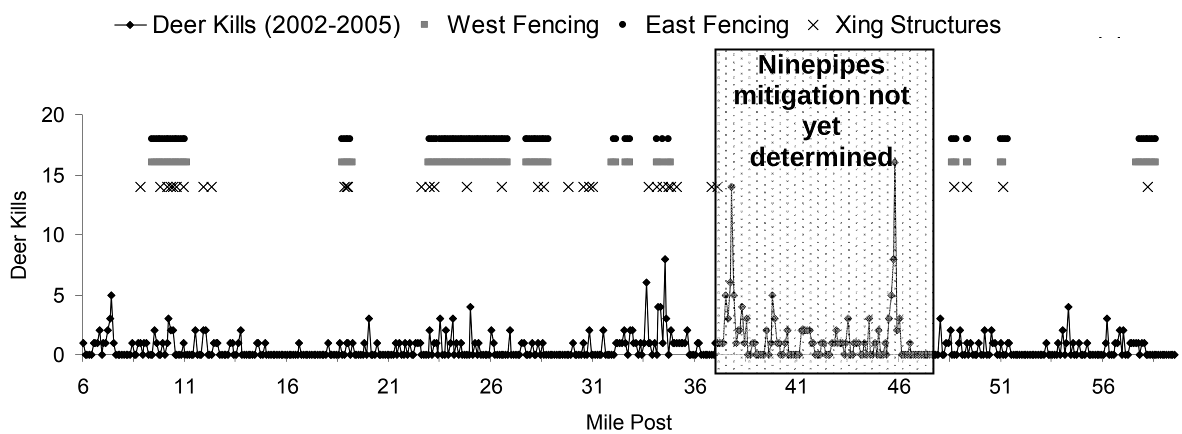


Figure 7: Total reported deer-vehicle collisions over 2002-2005, plotted by 1/10 mile along the US 93 study area, with corresponding mitigation measures across the same area. The Ninepipes section (mileposts 37-48) reconstruction design and mitigation measures will be determined at the conclusion of the Supplemental Environmental Impact Statement in mid- to late-2006.

5.2.2.2. Preconstruction Bear-Vehicle Collision Data

Not surprisingly, black bear-vehicle collision (BVCs) and road-killed carcass reports were rarer than DVCs (Table 6). Over 1995—2005, a total of 32 BVCs over the entire US 93 study area were reported and the mean number of BVCs per year was 2.9 (95% C.I. = 1.2, 4.7). In 2002 and 2003, 8 and 9 black bear mortalities due to collisions with vehicles were reported, respectively; these higher numbers of reports were likely a result of more focused efforts to document such mortalities as a part of a preconstruction black bear research study in the study area (McCoy 2005; see Chapter 6 for an overview of preconstruction black bear field research). With small sample sizes with little statistical power to detect changes, it is difficult to infer if the relatively low numbers of reported BVCs in 2004 and 2005 are an indication of an actual reduction in the bear population or if this is simply indicative of a comparatively less intensive reporting effort compared to 2002 and 2003.

Table 6: Number of black bears reported killed annually as a result of collisions with vehicles on US 93 on the Flathead Indian Reservation from 1995 to 2005. Source: MDT, MHP, and MTFWP data records

Year	Bears Killed	Year	Bears Killed
1995	1	2001	1
1996	0	2002	8
1997	1	2003	9
1998	4	2004	2
1999	2	2005	1
2000	3	-	-

Bear-vehicle collisions were expected to be lower in number than DVCs for several reasons. Primarily, there were fewer black bears than deer in the study area. Additionally, black bear carcasses may be more likely to be removed from the road by people wanting to collect skulls, claws or hides (McCoy 2005). Many black bear road-kills were only incidentally reported, often without spatially-explicit records. Although not unique to only black bears, it may be that bears hit by vehicles moved away from the road before dying, and hence, were not detected and reported.

Because of high variability in the BVC dataset, power analyses were not appropriate. Anticipating this situation, an in-depth preconstruction black bear study (McCoy 2005; see Chapter 6 for further details) was undertaken in order to measure BVCs and other parameters that, collectively, would yield the best inferences regarding bear responses to the mitigation when compared to data obtained using the same methods after construction.

5.3. Habitat Connectivity: Wildlife-Highway Crossings

The second objective of this study is to assess how habitat connectivity may be affected by the wildlife fencing and crossing structures installed on US 93. The term “habitat connectivity” generally refers to a mosaic of habitat patches across the landscape connected by “corridors” that offer favorable conditions for animals to move between individual patches to access resources important to survival and reproduction (e.g., water, cover, food, dispersal and mating opportunities). Roads and traffic can fragment habitats and become barriers to wildlife movements, reducing habitat connectivity (Riley et al. 2006, Strasburg 2006, Proctor 2003, Mills and Conrey 2003, Forman et al. 2003, Sunquist and Sunquist 2001, Smith 1999). Wildlife fencing, with the intent of limiting wildlife access to the roadway in order to reduce AVCs, may reduce habitat connectivity if animals do not find and use passages to move under or over the mitigated road. This study addresses that specific question by monitoring deer and black bear movements across US 93 before the fencing and crossings are installed so that compatible post-construction studies can measure mitigation’s effect on habitat connectivity.

Determining animal movements across landscapes is a challenging aspect of ecological studies. Observer presence may alter animal behaviors, while capturing and radio-collaring animals to remotely monitor their movements can be risky (i.e., animals may accidentally suffer capture myopathy or handling injury, handlers may also be injured). Using relatively inexpensive VHF radio-collars may require many years of intensive field efforts to obtain enough locations to determine species use patterns relative to landscape features of interest. Alternatively, GPS-collars can provide thousands of location "fixes" on a single animal with little effort (beyond collaring and obtaining the data either via retrieving the collar, by wireless downloading of data from close-range or via satellite transmission) allowing researchers to understand how fine-scale features of the environment may influence movements; however, the cost of GPS collars may be prohibitive. In the case of the US 93 evaluation efforts, GPS radio-collars were justified for the in-depth black bear study (McCoy 2005; see Chapter 6 for details) given that black bears are typically inconspicuous and field methods for sampling deer movements probably would not provide adequate data on bear movements given their relative abundance compared to deer.

Radio-collar methods were considered for monitoring deer movements across US 93 but abandoned for several reasons. First, there were no existing deer population estimates available as a reference to determine an appropriate proportion of the population to collar to capture the variation of movements and behaviors occurring within the larger population; a subjectively estimated number of GPS collars (20-40) required was not affordable given the available budget. Further, with no existing data on local deer population group dynamics or movements, there were concerns about collaring animals not representative of the larger population due to the gregarious nature of this species; e.g., if data from ten deer revealed that six consistently moved together as a group, these six animals would not be considered independent and the effective sample would be reduced to five if the location data were used to make inferences about the larger population (bears are not typically gregarious and it is usually apparent when bears are associated with each other, such as a female and her offspring, hence researchers can better control this scenario). Lastly, although locations of deer away from the road corridor are of interest if addressing research questions regarding use of the surrounding landscape, the research question focuses on the road corridor and most of the GPS-collar location data would not be directly relevant to the central question regarding deer-highway crossings.

Assuming there might be a fair amount of deer movement across US 93, it was presumed that methods concentrated within the road corridor would capture enough data related directly to the research question. Camera or video monitoring of the 6.9 miles (11.1 km) of road corridor where wildlife fencing was planned was deemed too expensive and prone to theft. Eventually, a novel application of animal tracking methods was selected to monitor deer-highway crossings (as well as bear tracks, though, as mentioned above, additional monitoring efforts were taken on to bolster the black bear data).

Animal track observations provide a non-invasive alternative to documenting movements of animals relative to their environment (Turchin 1998). Interpreting animal tracks can reveal the species of animal, gait, direction of travel, and even the approximate time that an animal moved across a patch of ground (Turchin 1998, Halfpenny and Biesiot 1986). Animal tracks may be found opportunistically where animals traveled across loose, pliable substrates or may be methodically sampled at particular locations using "track beds" or "track plates" specifically constructed to non-invasively monitor animals moving across locations of interest.

Track methods alone (without additional measures, such as remote-triggered cameras, to quantify error rates) are an imperfect methodology. Exposure to rain and wind may erase tracks, previously-lain tracks may be obscured by other animals' tracks or other roadside activities (vehicles departing the roadway, precipitation runoff, and activities such as biking or horseback riding; Barnum 2001), and tracking media can freeze such that animals don't leave tracks in the beds (Ward 1982). Despite these recognized short-comings, tracking methods have effectively monitored movements of many different species relative to highways and highway crossings (Mata et al. 2005, Ng et al. 2004, Clevenger and Waltho 2003, Barnum 2001, Clevenger and Waltho 2000, Rosell et al. 1997, Foresman and Pearson 1998, Rodriguez et al. 1996, Yanes et al. 1995, Ludwig & Bremicker 1983, Ward 1982).

Preconstruction deer and black bear crossings (complementing the more in-depth black bear study) of US 93 were estimated via track observations within an array of track beds that sampled the areas planned for the most extensive lengths of double fencing with crossing structures. Track observations documented species presence and animal movements including crossing observations. This sample of crossings identified from track beds was used to extrapolate across the area where the fencing was planned, providing an estimate of total preconstruction crossing rates to compare with post construction crossing data. Additionally, track data were assessed for possible deer or bear avoidance of the track beds. The remainder of this section reviews the methods, analyses and results of the preconstruction track bed monitoring.

5.3.1. Track Bed Methods

Track beds were installed along three discrete stretches of US 93 in the Evaro, Ravalli Curves, and Ravalli Hill areas at the southern end of the Reservation, where the three longest lengths of wildlife exclusion fencing with crossing structures are planned. The following three subsections overview the methods for locating, constructing and maintaining the beds, and the field observer techniques used to record the track observations. Extensive details about preconstruction field data collection methods and considerations are documented in the US 93 Field Monitoring Handbook created for this project (Hardy and Huijser 2005).

5.3.1.1. Track Bed Locations

Using track data from another study (Barnum 2001) that was collected in a manner similar to the approach proposed for the US 93 track bed monitoring, the number of the track beds to be placed in each area was determined by estimating the detectable change in track crossing rates using a two-sided power analysis (as it is uncertain whether crossings may increase or decrease with the installation of the mitigation). Based on these results, it was determined the track beds should cover approximately 33% of the total length of each area to deliver an adequate sample, allowing an 18% or greater change in crossing rates to be statistically detectable.

The extent and location of fencing in each area was determined from the US 93 Reconstruction Memorandum of Agreement (Skillings Connolly 2000); a total of 8100 m (5 miles), 7040 m (4.4 miles), and 5200 m (3.2 miles) of wildlife fencing was originally planned for Evaro, Ravalli Curves, and Ravalli Hill study areas, for a total of 20,340 m (12.6 miles) of fencing across these three areas. Segmenting the length of each area planned for fencing into consecutively-numbered 100 m (109 yd) increments, a random number generator was used to draw numbers representing the 100 m (109 yd) sections where track beds would be placed with respect to the length of the area planned to be fenced. The side of the road (east vs. west) was randomly determined for placing each bed.

Track beds were installed at these predetermined random locations within the areas planned for extensive contiguous fencing with wildlife passages. Each bed was placed parallel to the road in the right-of-way, typically within 1.5 - 3.0 m (5 - 10 feet) of the pavement edge. In a few cases, a random location of a bed fell in an area that was too steep to prevent erosion of the tracking material; such beds were either placed on the other side of the road (if possible), or an alternative site was randomly located within the same focal study area. In 2003, 25, 20, and 17 (62 total) tracking beds were installed in the Evaro, Ravalli Curves and Ravalli Hill areas, respectively, sampling wildlife movements adjacent to the road in approximately one-third of each area.

In 2004, the sections of road originally planned to have contiguous fencing plans were shortened in the Evaro and Ravalli Hill areas. As a result, 24 track beds located outside the newly shortened stretches of road to be fenced in Evaro and Ravalli Hill were dropped from the monitoring effort, leaving 38 of the original 62 track beds within these shorter extents of planned wildlife fencing in the three study areas. Three track beds in the Evaro area that fell outside the stretch planned for fencing were maintained and monitored to provide additional data for the assessment of possible track bed avoidance. Appendix E provides a schematic of the original track bed placements and the reduced set of track beds that were ultimately used to derive the preconstruction estimate of deer and bear crossings. Another two-sided power analysis was performed track data collected in 2003 for the 38 beds within the fenced area, revealing that a 14% or greater decrease or increase in crossing rates would be statistically detectable. These 38 beds, plus the additional 3 beds in Evaro maintained for the track bed avoidance analysis, were monitored in 2003—2005; only data from the 38 beds that were located in the areas to be fenced were used to estimate total crossings within that area of interest.

5.3.1.2. Track Bed Construction & Maintenance

Each track bed consisted of 100 m x 2 m (328 ft x 6.5 ft) of filter fabric covered evenly by about 10 cm (3.9 in) of sandy material deposited onto the fabric via a conveyor belt truck and spread with a grader (Figure 8). The tracking material was a mixture of seven parts sand with one part 1/8 inch crushed aggregate material to provide angular structure to help the sand retain crisp imprints (in dry conditions, sand alone tended to “roll” in from the side wall of an imprint). Hand rakes were used to even out the material (Figure 9) for standard coverage and to prevent the filter fabric from blowing in the wind, potentially deterring crossing animals or distracting drivers.

Figure 8: Rolling filter fabric out while sand material is distributed by a conveyor belt (left) and spreading the sand with a grader (right).

Figure 9: Raking the sand material to evenly cover the track bed fabric.

Each spring after installation, track beds were maintained to provide a consistent track bed surface for each data collection season. Maintenance involved applying herbicides to vegetation that emerged through the filter fabric during the previous growing season. After a few weeks for the vegetation to absorb the herbicide and die off completely, intensive labor to "grub" the dead vegetation from the track beds, followed by raking to "fluff" the sand material that had become compacted over the winter. Additional sand was added as needed where erosion depleted the track bed material.

5.3.1.3. Track Bed Data Collection

Monitoring was initiated in June after the installation or maintenance of the beds was completed and residual tracks were raked out of the sand. Data collection was limited seasonally by the freezing of the sand material during the winter months and lack of regular snowfall for snow track data collection; in October when the track beds froze and passing animals (especially soft padded animals such as bear, canine and feline species) could not leave an imprint in the solid tracking media, monitoring was terminated. Each "year" of track bed field data collection consisted of five months of data collection.

Upon each track bed visit, field technicians recorded several parameters pertaining to track bed and environmental conditions, tracks of species and behavior. The **date** of the visit was recorded along with the observers who visited the beds. The amount of **precipitation** (in mm) that had accumulated since the last visit was recorded in each of the three rain gauges that were established in each area. **Temperature** upon the visit and **bed condition** (e.g., snowy, frozen, wet, dusty, or normal) was also recorded. The **species** that left each set of tracks was recorded (see below for more details on species identification), along with the observers' **certainty** in that designation (*certain*, *probable*, or *possible*). Photographs, with rulers for scale, were taken as needed of prints of special interest or uncertain designation for later analysis or confirmation. **Behavior**, interpreted from the tracks as the animal's apparent movement pattern, was categorized as *crossing*, *parallel*, or simply *presence* (Figure 10). *Crossing* behavior was documented when the trajectory of a set of tracks covered no more than 5m (5.4 yd) of the length of the bed from the entrance to exit point, differentiating these observations from animals traveling *parallel* to the road or animals that merely wandered onto the track bed with no interpretable direction of travel (*presence*). The **direction** of travel relative to the highway was recorded (*approaching* or *leaving*) for all *crossing* observations. The **location** where an animal entered and exited the bed (i.e., two measurements) was measured in meters from the most proximate end of the bed. Finally, if beds were directly across US 93 from one another (which occurred in 5 locations across all three areas), observers recorded whether tracks were likely made by the same animal (i.e., **same track as**) on both beds: for example, where a deer may have crossed the highway from one bed to the other as evidenced in tracks "approaching" the road observed in one bed and "leaving" in the other.

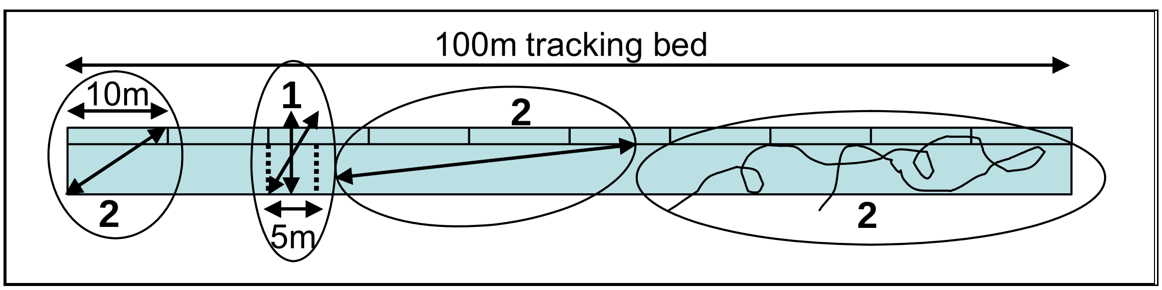


Figure 10: Diagram illustrating categories of animal behavior as interpreted by tracks. A "crossing" observation is depicted in scenario 1 while "parallel" movements are depicted in scenario 2. "Presence" was reported when only a 1-2 prints were observed.

While the focal species were black bear and deer, tracks of all identifiable species or suites of species were recorded. Several publications were consulted for track identification (Rezendez 1999, Zielinski and Kucera 1995, Stall 1989, Forrest 1988, Halfpenny and Biesiot 1986, Murie 1974). Some generalizations were made in the identification of certain species in the field or for purposes of analyzing the data. White-tailed deer and mule deer cannot be told apart with sufficient confidence (Forrest 1988, Halfpenny and Biesiot 1986), therefore these two deer species were recorded as "deer". Black bear and grizzly bear tracks are unique and can be recognized providing the imprints are relatively clear.

Other species not of primary interest or whose tracks may be misidentified were lumped into groups of animals after field data collection to help simplify analyses. For example, because domestic dog tracks may be quite similar to coyote tracks, these tracks were sometimes identified simply as “canine” tracks and not to species. While mountain lion, elk, and moose tracks were identifiable in the field, these were infrequently observed, and lumped into one category (“large mammal”). Skunks, raccoons, and rabbits were generally recorded as “medium mammal”, while smaller mammal tracks observed were generally reported as “small mammal”. Domestic animals, including cattle, horses, and domestic cats, were categorized as “other (domestic)”. Observations of snake crossings, and tracks from other wild species (e.g., geese, insects) were categorized as “other (wild)”.

5.3.2. Calculation of Preconstruction Crossing Estimates

Total preconstruction crossing rates ($\hat{\tau}$) of US 93 by deer and black bears were extrapolated from track bed crossing observations in the three study areas (Evaro, Ravalli Curves, and Ravalli Hill) and across all 3 areas combined. Assuming the randomly located track beds provided a representative sample of all wildlife movements through each area, it follows that the crossings observed in the track beds represent approximately 33% of total deer and bear highway crossings in the areas of inference.

The sample unit (i) was one 100 m (109 yd) track bed, with the sample size (n) being the number of track beds sampled in the pre-mitigation years. For these analyses, only data from the 38 track beds monitored all three years in the areas to be fenced were used. From the number of crossings documented on the tracking beds, the total estimated number of deer and bear crossings ($\hat{\tau}$) for each area of interest (Evaro, Ravalli Curves, Ravalli Hill and the whole study area) in each study year (2003, 2004, and 2005) were calculated using:

$$\hat{\tau} = \frac{N}{n}\sum_{i=1}^{n} y_i \qquad \textbf{Equation 1}$$

from Thompson (2002) where y_i represents the total number of certain deer and bear crossings detected on each bed (i) in a given year, summed over the n 100 m (109 yd) track beds for a given area and year. N represents the total number of 100 m (109 yd) segments in the length of the area of inference. Roughly 33% of the study area was sampled, so N/n approximates 3. The estimated total number of crossings in each highway stretch was thus 3 times the number of crossings detected on the n track beds. Variance in these figures was calculated using:

$$v\hat{a}r(\hat{\tau}) = N^2 (N-n)\frac{s^2}{n} \qquad \textbf{Equation 2}$$

from Thompson (2002) where $v\hat{a}r(\hat{\tau})$ represents the estimated variance, and s^2 represents the sample variance in total number of deer and bear crossings of each study area.

The number of crossings observed in each monitoring season was averaged for each area of interest (Evaro, Ravalli Curves, Ravalli Hill, and the whole study area) in order to run power analyses to determine minimum detectable differences in crossings for preconstruction and post-construction years. The mean number of yearly crossings ($\bar{\hat{\tau}}$) is an average of estimates, and therefore may underestimate true variation in year-to-year crossings. However, post-construction measures will essentially census total crossings in the corridors. In theory, crossings should be detected in track beds inside wildlife crossings or at the ends of the fences. Therefore, the power analyses still yield valuable insight into how much change may be detectable in total wildlife crossings between pre- and post-construction years given ideal survey conditions. The power analyses were for 2-sided t-tests (α=0.05, power =0.80; Zar 1999) because researchers envisioned two possible scenarios: wildlife crossing rates could decline due to disturbance or non-use of the crossing structures, or crossing rates could increase due to the presence of safe passage opportunities provided by the wildlife crossing structures.

5.3.3. Preconstruction Crossing Data Results

In 2003, 62 track beds were monitored weekly from June through October. After the 2003 tracking season, the wildlife fencing plans for the Evaro and Ravalli Hill areas were shortened (Hardy & Huijser 2004, Appendix C), reducing the total number of beds within areas to be fenced to 38. An additional 3 beds in the Evaro area (EV2, EV7 and EV8) located outside the newly shortened wildlife fencing plans were maintained and monitored to provide additional data specifically for investigating potential track bed avoidance by animals. In 2004 and 2005, these 41 track beds were checked twice a week from June through October.

In 2003, monitoring began June 18, 2003, was discontinued for 6 weeks between August 7 and September 25, and was reinitiated from September 26 through October 29. In 2003, these track beds were visited a total of 14 times, every 9.5 days on average, with a total of 1726 track observations of "certain" species designation recorded across all 62 beds.

In 2004 and 2005, monitoring occurred more often as a result of having to visit fewer beds overall. In 2004, monitoring started June 25 and ended October 16. During that time, the track beds were visited a total of 33 times, every 3.47 days on average. Observers recorded a total of 1540 track observations of "certain" species designation across the 41 beds that season. In 2005, track bed monitoring started June 13 and ended October 27, amounting to 40 visits, every 3.49 days on average. A total of 1,325 tracks of "certain" species were observed in the 41 beds monitored in 2005.

Of the 41 track beds that were monitored across all years, only 38 track beds sampled wildlife crossings where mitigation will be installed and these data were used to estimate total wildlife crossings. The other three beds were used to assess species presence and track distribution but were not included in the estimates of preconstruction crossing rates.

Across the 41 track beds (covering a total of 4027 m [13,212 feet] due to measurement error that occurred during installation) sampled in the three study areas over the three years of monitoring, deer species were the most frequently observed tracks in the track beds along US 93, with medium mammals (including skunks, raccoons, and rabbits/hares) and canines (including domestic dogs and coyotes) as the second- and third-most observed species (Figure 11).

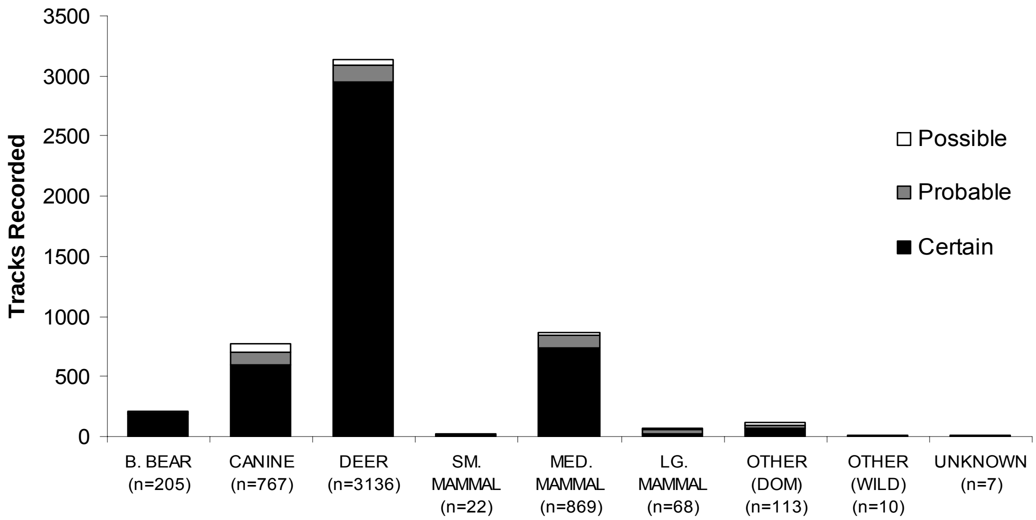
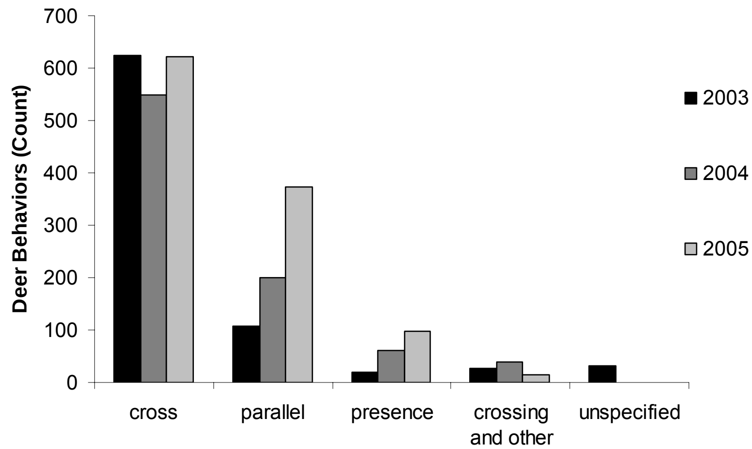


Figure 11: Numbers of species of animal tracks observed in 2003-2005 in 41 track beds sampling a total of 4027 m along US 93 between Evaro and St. Ignatius, Montana. Certainty of the species of observed tracks was reported as "possible," "probable," or "certain".

Analyses of species behavior were restricted to deer and black bear track observations classified as *certain* species designation from the same 41 track beds that were monitored over all 3 monitoring seasons (Figure 12). Deer crossing behavior did not show any apparent decreasing or increasing trend over 2003-2005, but a three-fold increase in parallel behaviors and a five-fold increase in presence behaviors were notable. Black bear crossing behavior sharply decreased from 2003 to 2005 (a 78% decline) and no parallel behavior was documented in 2005.



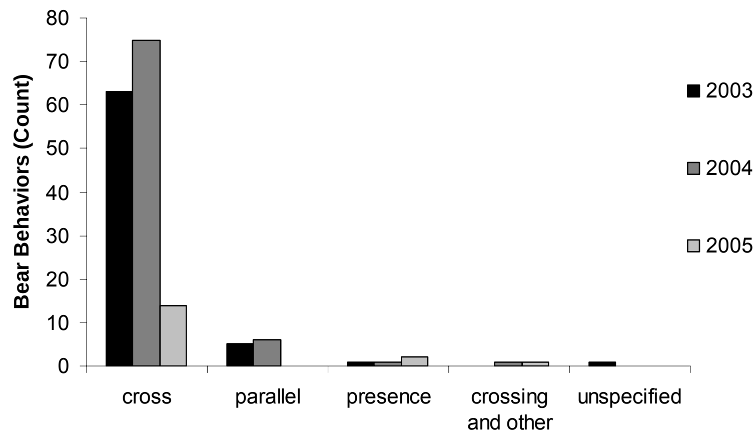


Figure 12: Numbers of deer (top) and black bear (bottom) behaviors interpreted from track observations recorded in 2003-2005 in 41 track beds sampling a total of 4027 m along US 93 between Evaro and St. Ignatius, Montana.

5.3.3.1. Estimated Preconstruction Deer Crossings

Preconstruction estimates of deer highway crossings were established for the areas that will receive wildlife fencing using 38 track beds: 11 track beds in Evaro, 20 track beds in Ravalli Curves, and 7 track beds in Ravalli Hill. A total of 3748 m (2.3 miles) was sampled across all three areas that will receive fencing (this distance was less than the intended 3800 m due to measurement error; true bed length varied by ±13 m (14 yd) from the intended length (100 m). The sample size was therefore not an integer because the sample units were often fractional components of the intended sample, and $n_{Evaro} = 10.96$, $n_{Ravalli\ Curves} = 19.52$, and $n_{Ravalli\ Hill} = 7$.

All certain deer crossings were accumulated for each year (see Appendix F). Using Equation 1 and 2, twelve estimates of total preconstruction deer highway crossings, and the associated variance for each estimate, were calculated for Evaro, Ravalli Hill, Ravalli Curves, and the whole study area (Table 7). The areas of inference were approximately 3.2 km (1.9 miles) for Evaro, 5.9 km (3.6 miles) for Ravalli Curves, and 2.1 km for Ravalli Hill, which totaled 11.2 km (6.9 miles) across all three areas.

Table 7: Preconstruction estimated total deer and bear crossings ($\hat{\tau}$) and associated variance ($v\hat{a}r(\hat{\tau})$) for areas of interest and years of study along the US 93 corridor.

AREA	YEAR	DEER		BEAR	
		$\hat{\tau}$	$v\hat{a}r(\hat{\tau})$	$\hat{\tau}$	$v\hat{a}r(\hat{\tau})$
EVARO (*n* = 10.96)	2003	516	10710	24	122
	2004	603	5935	24	57
	2005	372	4189	3	7
RAVALLI CURVES (*n* = 19.52)	2003	1227	72709	66	231
	2004	657	10729	135	1756
	2005	1035	52100	21	74
RAVALLI HILL (*n* = 7.00)	2003	189	1709	39	444
	2004	261	8177	6	28
	2005	336	15165	9	29
WHOLE AREA (*n* = 37.48)	2003	1932	88991	129	733
	2004	1521	26842	165	1983
	2005	1743	70251	33	107

Ravalli Hill, the shortest section, had a lower estimate of total deer crossings than the other two areas. Ravalli Curves, the longest section, had the highest number of deer crossings (Figure 13). Combining all observed deer crossings observed across the three focal study areas, total estimated number of deer crossings did not change from year to year (P>0.1; Figure 14).

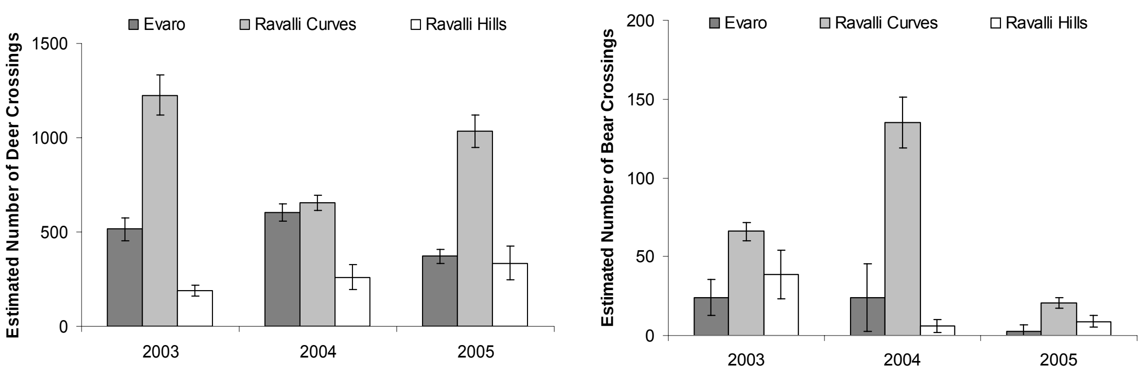


Figure 13: Estimated total deer (left) and bear (right) crossings ($\hat{\tau}$) in each focal study area in each year, based on crossings interpreted from tracks observed in 38 tracking beds. Error bars represent 95% confidence intervals.

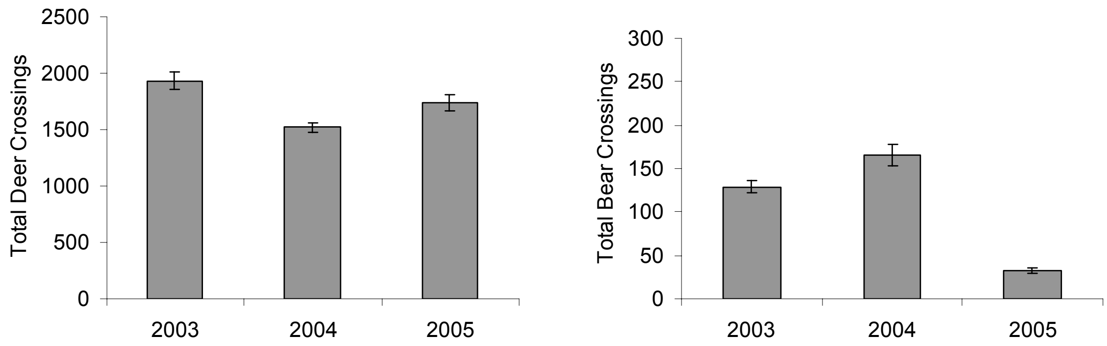


Figure 14: Estimated total deer (left) and bear (right) crossings ($\hat{\tau}$) for the three focal study areas combined in each year, based on crossings interpreted from tracks observed in 38 tracking beds. Error bars represent 95% confidence intervals.

Power analyses indicated the ability to detect a 153% change in deer crossings after 3 years of post-construction study across the three study areas combined (Figure 15). Given 5 years of post-construction study, a change of 60% could be detected in deer crossings. This power analysis was performed using a two-sided hypothesis, assuming that wildlife crossings could increase due to the presence of safe crossing structures, or they could decrease if deer do not adapt and learn to use the crossing structures.

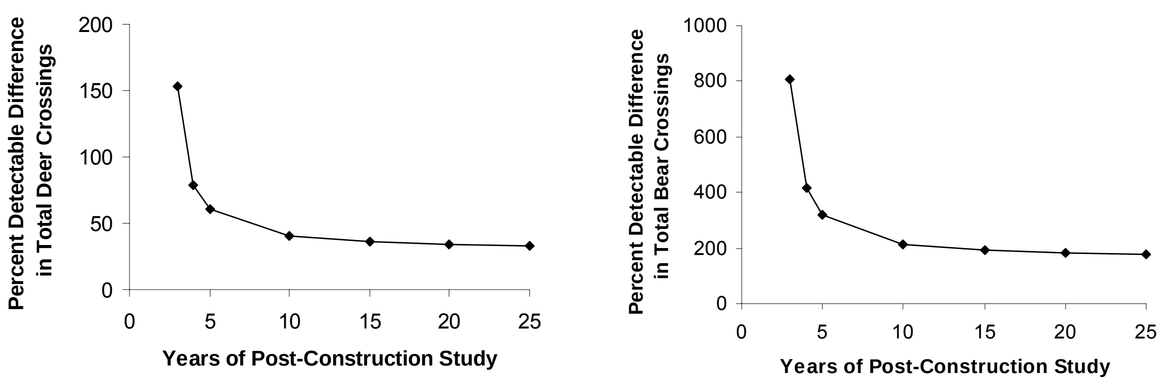


Figure 15: Power analysis of the minimum percent difference statistically detectable in estimated total crossings ($\hat{\tau}$) for deer (left) and bear (right) in the three study areas combined given *t* years of post-construction survey.

5.3.3.2. Estimated Preconstruction Bear Crossings

Preconstruction estimates bear highway crossings were established for the areas that will receive wildlife fencing using 38 track beds: 11 track beds in Evaro, 20 track beds in Ravalli Curves, and 7 track beds in Ravalli Hill. A total of 3748 m (2.3 miles) was sampled across all three areas that will receive fencing (this distance was less than the intended 3800 m due to measurement error; true bed length varied by ±13 m (14 yd) from the intended length (100 m). The sample size was therefore not an integer because the sample units were often fractional components of the intended sample, and $n_{Evaro} = 10.96$, $n_{Ravalli\ Curves} = 19.52$, and $n_{Ravalli\ Hill} = 7$.

All certain bear crossings were accumulated for each year (see Appendix F). Using Equation 1 and 2, twelve estimates of total preconstruction bear highway crossings, and the associated variance for each estimate, were calculated for Evaro, Ravalli Hill, Ravalli Curves, and the whole study area (Table 7). The areas of inference were >3.2 km (1.9 miles) for Evaro, >5.9 km (3.6 miles) for Ravalli Curves, and >2.1 km (1.3 miles) for Ravalli Hill, which totaled 11.2 km (6.9 miles) across all three areas.

The total number of bear crossings showed high variation both within and between years and areas (Figure 13). Ravalli Hill generally had a very low number of bear crossings. The number of bear crossings in Evaro and Ravalli Curves in 2005 was lower than in 2003 and 2004. Combining all observed bear crossings across the three focal study areas, the total number of black bear crossings were significantly lower in 2005 than in 2003 or 2004 ($P<0.01$; Figure 14).

Power analyses indicated the ability to detect an 807% change in bear crossings after 3 years of post-construction study across the three study areas combined (Figure 15). Given 5 years of post-construction study, a change of 318% could be detected in bear crossings. This was using a two-sided hypothesis, assuming that wildlife crossings could increase due to the presence of safe crossing structures, or they could decrease if bear do not adapt and learn to use the crossing structures. These figures were not unexpected given the relatively low population of bear (compared to deer populations) and high variability in datasets with smaller sample sizes; anticipating such an outcome justified the in-depth black bear study (see Chapter 6 for details).

5.3.4. Assessment of Track Bed Avoidance Behaviors

A central assumption in using track beds to non-invasively measure animal movements is that animals do not respond to the presence of the track bed itself. If animals avoid the track bed (e.g., move around the bed rather than crossing the bed) or are attracted to the track bed (e.g., for minerals or salt in the tracking medium) track observations may not be representative of actual animal presence and behaviors. To address this assumption, the distribution of points where animals first entered the track bed, measured in meters from the nearest end of the track bed, were analyzed for deer and bear crossing observations. Uniform distributions of entrance points across the lengths of the beds would suggest animals crossed the track beds as they were encountered, indicating the sampling was unbiased. Non-uniform distributions may imply animals changed their movement behaviors in response to the presence of the track bed, potentially biasing the sample.

There was no reason to expect animals to be attracted to the track beds: to the knowledge of the researchers, the locally-obtained sand and aggregate mixture used in the beds did not contain mineral supplements or salt. If animals were avoiding the track beds, researchers hypothesized that the observed distribution of entry points would assume one of two forms (Figure 16): a preponderance of tracks at the ends of the beds with relatively fewer tracks in the middle of the beds, or more tracks in the middle of the beds with relatively fewer tracks at the ends. The first outcome might be observed if animals approaching the center of the bed moved along the edge of the bed until crossing the bed near the end where the animal might perceive normally vegetated groundcover. The second possible outcome might be observed if animals approaching the bed at the ends walked around the ends of the bed rather than across it, whereas animals approaching the center of the bed continued across it.

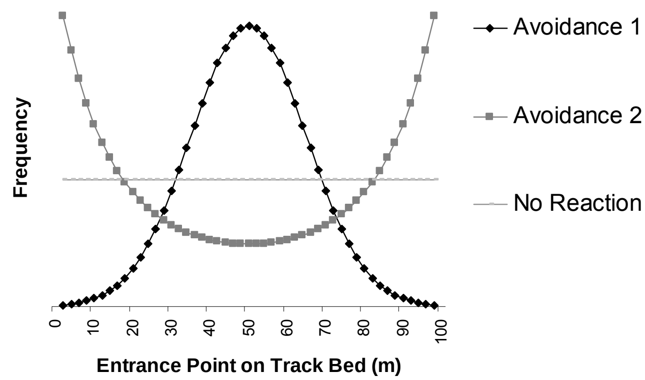


Figure 16: Hypothesized frequency distribution patterns of tracks in track beds given two potential outcomes if animals were avoiding track beds compared to the uniform distribution expected if animals had no reaction and crossed wherever they first encountered the bed.

If the distribution of entry points on the bed was not uniform due to possible avoidance behaviors, it was expected to be symmetrical around the middle of the bed relative to the two ends of the beds (Figure 16), and that a positive or negative relationship between numbers of animal crossings and proximity to the ends of the beds could be detected. Because track beds were not of equal lengths (due to measurement error and because some beds were placed adjacent to one another measuring ~200m), points were standardized by dividing entrance points by the total length of the bed. Thus, the explanatory variable was established as the proportional distance from an end of a bed, with 0.50 representing the exact middle of the bed, and 0.00 representing the two ends of the bed. The response variable was the number of crossings documented at a given proportional distance from the end of the bed. To reduce the effect of small sample size, each entrance point was assigned to one of 25 bins of 0.02 units each, scaled from 0.00-0.02 (the two ends of the bed) to 0.48-0.50 (the middle of the bed), depending on where the entrance point fell along this continuum. Linear regression was used to examine the relationship of entrance points along the length of the beds by testing 1) whether the slope of the regression line significantly differed from zero, 2) whether the slope was positive or negative, and 3) whether the relationship between the number of tracks and the proportional distance from the track bed ends was linear or non-linear.

Data were used from the subset of 62 track beds that were not near structures that may have directed or otherwise influenced animal movement (e.g., guard rails, tall fences, or driveways present on the side of the highway with the track bed). A total of 45 track beds were used in these analyses, four of which were only monitored in the year 2003. Observations of deer and bear crossings were analyzed separately as it is possible these species may respond differently to track beds. Track bed entrance points of animals approaching versus leaving the highway were analyzed separately because animals leaving the highway may respond differently than those approaching the road, being influenced by traffic or the different visual perspective looking down on the track bed from the road versus looking up at the road from the sloped shoulder of the right-of-way.

5.3.4.1. Track Bed Avoidance Assessment Results

After censoring observations from track beds with guard rails, fences, or driveways, and using only certain deer crossing observations from the other track beds, the dataset used to evaluate whether deer altered their movements due to the presence of the track beds included 857 and 655 observations of deer approaching and leaving the highway, respectively. The relationship of entrance points to track bed ends did not differ for deer approaching versus leaving the highway ($P > 0.1$), but there were significantly fewer tracks of deer leaving the highway than entering it ($P < 0.05$). Because the slopes of the regression lines for deer approaching and leaving the highway did not differ, these data were combined for the remaining analyses (n = 1,512). Regression analyses indicated that deer crossed closer to the ends of the beds more often than the middle of the track bed (Figure 17). The slope of this regression line was negative and significantly different from zero (-44.31; 95% CI = -56.42, -32.20; $P < 0.001$), and the regression line explained 62% of the variation in the data ($R^2 = 0.62$).

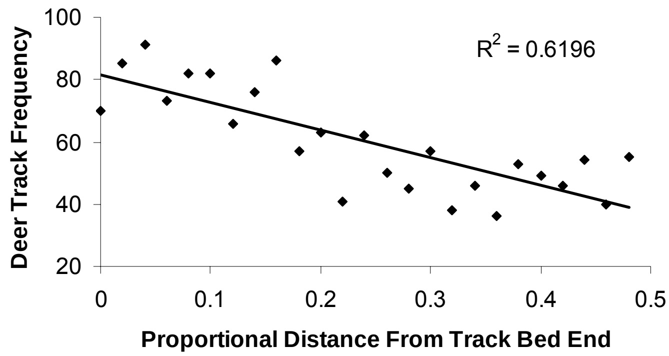


Figure 17: Frequency of deer track bed entrance points relative to the ends of the track beds.

After censoring bear crossing observations from track beds with guard rails, fences, or driveways and using only “certain” bear crossings, the dataset for assessing black bear responses to track beds included 66 and 77 tracks of black bears leaving and approaching the highway, respectively. This relatively low sample size affected the numbers of observations categorized into each bin (0.02), resulting in a rougher-scale picture of bear behavior. Black bears approaching and leaving the highway showed similar distributions of entrance points relative to the ends of the track beds, although inference was difficult due to the small sample size, and behaviors were combined across the three monitoring seasons for the analyses (n = 143).

Regression results indicated that the distribution of entry points for black bear crossing observations tended toward uniformity relative to the length and ends of the track bed (Figure 18). Although the slope of this regression line was significantly different from zero ($P < 0.05$) the strength of the relationship between frequency of crossing closer to the end of the bed was less apparent as the slope was much shallower, at -7.15 (95% C.I. = -13.83, -0.48). Compared to the deer analyses, much less of the variation in track frequency relative to distance to end was explained ($R^2 = 0.16$).

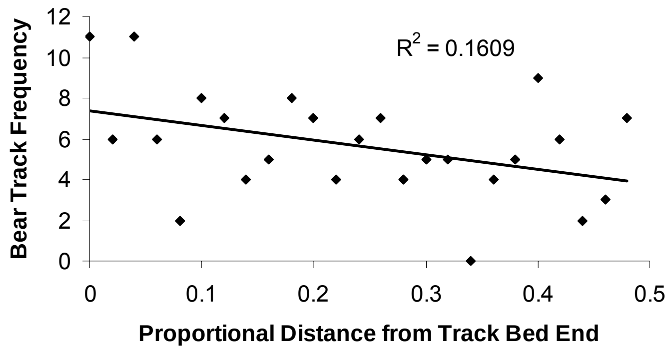


Figure 18: Frequency of black bear track bed entrance points relative to track bed ends.

These results indicate that deer may be exhibiting some track bed avoidance behaviors when confronted with a "free standing" track bed (i.e., a track bed with no features to funnel movements across the bed and animals could chose to walk around the bed). Black bear do not seem to be responding to the same degree that deer were, though it is possible that some bear track bed avoidance may be occurring as well. By understanding that there may have been some avoidance of the beds implies that the estimated preconstruction crossing estimates, especially in the case of deer, may be underestimating the total cross-highway movements.

5.4. Pellet Group Transects

Pellet transects have been used to estimate animal population densities in many biomes (Murray et al. 2002, Krebs et al. 2001, Massei et al. 1998, Harestad and Bunnell 1987, Freddy and Bowden 1983, Neff 1968). Pellet group counts are especially useful to estimate ungulate population abundance, and the utility of this index has been thoroughly reviewed (Mandujano and Gallina 1995, White and Eberhardt 1980, McConnell and Smith 1970, Neff 1968, Eberhardt and Van Etten 1956).

Pellet group surveys are easier to design and implement than methods that directly measure deer density, such as flight surveys or mark-recapture efforts. However, these advantages are offset by multiple assumptions and concerns. Pellet group counts are correlated with deer abundance, but are not directly estimates of deer abundance: thus, researchers must assume a constant functional relationship between number of pellet groups and deer density (Lancia et al. 1996). It follows that several sources of process and sampling variation affect the precision and accuracy of results.

Sources of process variation include:

- Changing deer populations (generally the variable of interest);

- Differential deposition of pellets by habitat, behavior and diet (White and Eberhardt 1980, Neff 1968);
- Yearly variation in climate and its effect on decomposition rates (Harestead and Bunnell 1987); and
- Changes in vegetative cover affecting pellet appearance (i.e., plant growth changes along a transect from year to year due to succession or disturbance, resulting in pellets receiving different exposure to elements; Harestead and Bunnell 1987, Freddy and Bowden 1983).

Sources of sampling variation include:

- Transects run in slightly different places (i.e., a different portion of the landscape was sampled one year to the next);
- Observer fatigue: often related to size of plot, with smaller plots having fewer overlooked pellets (Neff 1968);
- Difficulty in differentiating pellet age (Freddy and Bowden 1983);
- Complete census of groups within a plot (i.e., no groups are missed; Eberhardt and Van Etten 1956); and
- Large sampling variances due to the contagious distribution of pellet groups (i.e., pellet groups tend to be clumped in areas where animals may rest, ruminate and defecate more often than in other places; Mandujano and Gallina 1995, Freddy and Bowden 1983, White and Eberhardt 1980, McConnell and Smith 1970).

Because there were no estimates available of relative changes in the deer population size on the Flathead Reservation (Dale Becker, CSKT Biologist, pers. comm.), pellet group count transects were implemented to provide a time- and cost-effective index to deer abundance in the study areas. Pellet group indices were used to determine whether deer population levels dramatically changed between years, and whether this fluctuation explained some of the year-to-year variation in the associated track bed data and reported DVCs. Black bear population estimates are discussed in the summary of research on preconstruction black bear movements and genetics (Chapter 6).

5.4.1. Pellet Group Transect Field Methods

Surveys for deer pellet groups occurred in 2004 and 2005 in the three focal study areas to ensure the closest possible relationship between deer crossing rate estimates and potential changes in deer population size. Transect starting points were linked to a subset of the randomly-placed tracking beds in order to provide a representative sample of transects on the landscape. A sample size of 25 transects was based on a power analysis using data from the first 15 transects in the three study areas, which indicated that with 25 transects, changes in the deer population greater than 17% should be detectable. While a larger sample size was preferable, this was what was feasible given the budget provided.

Transects were 500 meters long, and consisted of 10 plots 1 meter wide by 50 meters long. Transects were located at the center of a tracking bed and perpendicular to the road. Compass bearings were set at the start point and maintained throughout the transect, which was measured using a measuring tape. If there were obstacles in the path, the original trajectory was maintained with as little deviation from the initial bearing as possible. Permission to access private lands was obtained as needed.

The ten 1x50 m plots were run by placing a meter stick's 0.5 meter mark directly over the measuring tape, creating a 1-meter wide zone. Every pellet group that fell entirely or partly within this zone was counted. A deer pellet group was defined as having at least 10 individual pellets in a cluster. Each pellet group was classified as "fresh black (shiny)", "old black (not shiny)" or "old brown" (for analyses, "fresh black" and "old black" pellet groups were combined for each transect and "old brown" pellet groups were excluded, as these may be from the previous season and may not relate to the deer population of the year in which the survey took place).

At each plot, primary and secondary habitats were recorded generally using the following categories: open grass, open scrub, coniferous forest, deciduous forest, wetland/riparian, residential, agricultural, pasture. The percent of that section that was impassible was recorded (i.e., where it was impossible to census for pellet groups due to thick brush or deadfall).

5.4.2. Pellet Group Data Analyses

Statistical analysis of pellet group data was thoroughly reviewed. The challenges of pellet group analysis include the following factors: 1) pellet group data are count data and therefore represented as integers; 2) pellet groups generally occur at low frequency with high variation; and 3) pellet groups are often distributed contagiously (i.e. clumped or non-randomly) across the landscape (White and Eberhardt 1980, McConnell and Smith 1970). With these non-normally distributed data, options for analysis included 1) transformation to stabilize variance; and 2) use of an alternate statistical distribution to fit the data. Transformation of the data was not the best option in this case, as it assumes the amount of dispersion in pellet groups remains constant across areas and years (White and Eberhardt 1980). Therefore, the use of another statistical distribution was deemed more appropriate. It has been shown that the negative binomial distribution is more flexible than the Poisson (another distribution often used for count data) and best fits pellet group count data in a variety of situations (Mandujano and Gallina 1995, Freddy and Bowden 1983, White and Eberhardt 1980, McConnell and Smith 1970). This distribution is described by two parameters: *m* and *k* as below:

$$P(X = x) = \binom{k + x - 1}{k - 1}\left(\frac{m}{k}\right)^{x}\left(1 + \frac{m}{k}\right)^{-(k+x)} \qquad \textbf{Equation 3}$$

The parameter *m* represents the mean, while *k* is a measure of the contagion (White and Eberhardt 1980). In cases where pellet groups approach random distribution, *k* grows large (>8), and the distribution approaches a Poisson; where pellet groups are more over-dispersed (clumped), *k* approaches 0 (White and Eberhardt 1980, McConnell and Smith 1970).

Using this equation and the "glm.nb" function in program R 2.2.1 (The R Core Development Team 2005), the mean (*m*) and dispersion (*k*) parameters and their associated variance were estimated for the entire pellet group dataset. A suite of generalized linear models was built using the negative binomial distribution to test whether there were differences in pellet group counts between area and/or year of the study.

The functional form of the relationship of the data to the negative binomial distribution was tested using a likelihood ratio test of the model log-likelihoods (White and Eberhardt 1980). The likelihood ratio statistic was computed as:

$$-2(LL(Poisson) - LL(Negative\ Binomial)) \qquad \textbf{Equation 4}$$

This equation tested the null hypothesis that the mean and variance were equal (indicative of a Poisson distribution) against the alternative hypothesis that the variance exceeded the mean (as in the negative binomial distribution). The null hypothesis was tested at $\alpha = 0.05$, with the critical value of the χ^2 distribution corresponding to this significance level with 1 degree of freedom.

5.4.3. Preconstruction Pellet Group Data Summary

Three transects were run in Ravalli Hill, and eleven transects were run in Evaro in 2004 and 2005. Eleven transects were run in Ravalli Curves in 2004, and twelve were run in 2005. A total of 79 pellet groups were documented in Evaro, 25 pellet groups were documented in Ravalli Curves, and no pellet groups were documented in Ravalli Hill in 2004. A total of 60 pellet groups were documented in Evaro, 16 pellet groups were documented in Ravalli Curves, and 2 pellet groups were documented in Ravalli Hill in 2005. Pellet groups for Ravalli Hill were not considered in any of the following analyses due to their low sample size, and because no pellets were found there in 2004. Pellet groups were not evenly distributed across transects, with some transects counting many more pellet groups than others (Table 8).

Table 8: Number of pellet groups found in each area and year, summarized over the total number of transects run.

	OVERALL FREQUENCY		EVARO		RAVALLI CURVES	
# Groups Found per Transect	**2004 (n=25)**	**2005 (n = 26)**	**2004 (n = 11)**	**2005 (n = 11)**	**2004 (n = 11)**	**2005 (n = 12)**
0	9	10	2	2	4	6
1	3	2	0	0	3	2
2	1	3	1	1	0	1
3	0	2	0	1	0	1
4	3	3	0	2	3	1
5	3	1	3	0	0	1
6	1	0	1	0	0	0
7	0	2	0	2	0	0
8	0	1	0	7	0	0
9	0	0	0	0	0	0
10	1	0	0	0	1	0
11+	4	2	4	2	0	0
TOTAL	**104**	**78**	**79**	**60**	**25**	**16**

The negative binomial equation fit the data better than the Poisson distribution. Hypothesis tests using all data were run using Equation 4, and, the pellet group count data were inadequately described by the Poisson compared to the negative binomial distribution.

The dispersion parameter (k) was similarly low across areas, attesting to high clumping of pellet groups across the landscape, and the relative constancy of clumping across areas and years. The similarity in k between areas allowed multiple comparisons between pellet groupings using 4 model structures developed in the "glm.nb" framework in program R 2.2.1 (See Table 9) (The R Core Development Team 2005). The parameter k was not considered in these comparisons, allowing the following:

- One mean pellet group (same # pellet groups regardless of area or year; 1 estimated parameter);
- Mean pellet group by area (2 estimated parameters: EV and RC);
- Mean pellet group by year (2 estimated parameters); and
- Mean pellet group by area and year (4 estimated parameters).

Table 9: Mean number of pellet groups per plot per area per year (m) and the over-dispersion coefficient (k) in each area sampled in each year with their associated error rates as represented by the negative binomial distribution.

	EVARO 2004	RAVALLI CURVES 2004	EVARO 2005	RAVALLI CURVES 2005
m	7.18	2.27	5.46	1.33
Error	2.14	0.95	1.49	0.57
k	1.19	0.68	1.57	0.70
Error	0.67	0.44	0.99	0.56

The mean number of pellet groups per plot differed significantly ($P<0.01$) between areas (Evaro and Ravalli Curves). In both years, Evaro had higher mean number of pellet groups per transect than Ravalli Curves (Figure 19). Although there appeared to be a decrease in the mean number of pellet groups per plot in both areas from 2004 to 2005, these differences were not statistically significant between years ($P > 0.1$).

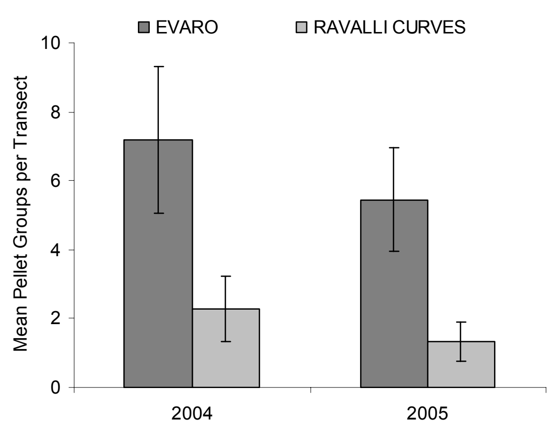


Figure 19: Mean number of pellet groups per plot at each site and year. Bars represent 1 standard deviation from the mean given the negative binomial distribution.

Information theoretic methods and Akaike's Information Criterion (AIC) with small sample size adjustment (AIC_c) were applied to determine model support (Burnham and Anderson 1998). Two models were nearly equally supported: the model estimating pellet group count by area and the model estimating pellet group count by area and year (AIC_c = 217.9 and 218.4, respectively). The other two models, (those estimating just one mean pellet group across all areas and years, and the model estimating mean group counts by year only), received AIC_c values greater than 9 AIC points higher, indicating very low support for these models relative to the other models (Burnham and Anderson 1998).

These results indicated that area was a strong explanatory covariate regarding the mean number of pellet groups observed, and that year added some explanatory power to the function. A closer look at the coefficients on the regression covariates revealed that area was significant at $P<0.001$, while year was only marginally significant at $P = 0.26$ in this equation.

The pellet transect results indicate that the deer population may be declining which may affect observations deer crossing and collisions with vehicles. However, because these results are based on only two seasons of transect observations, these outcomes can not be considered conclusive. Ultimately, the trends should become more apparent as these methods are repeated annually throughout the duration of the study.

5.5. Preconstruction Photo-Monitoring Summary

Early in the piloting of field methods for this study, two 35mm cameras equipped with passive infrared motion and heat sensing triggers were placed under the Montana Rail Link Bridge in the Evaro area (milepost 10.0) to obtain an indication of what species were present in the area and were traveling under US 93. One camera was located south of the railroad and west of US 93 while the other camera was placed north of the railroad and east of US 93. Cameras were placed facing the bridge to photograph movements under the bridge; however, to avoid burning film on passing trains, the tracks were not included in the field of view of either camera. Thus, the photo monitoring data did not completely "census" all movements under the bridge.

Cameras were in place between August 24, 2002 to December 9, 2002 and again from May 20, 2003 to June 4, 2003, and were checked regularly to change film and batteries. A total of 320 photos were taken of 5 different animal species, with humans making up the most-photographed species followed by deer, domestic cats, black bears and domestic dogs (Table 10). Seven of the photos of humans also contained at least one domestic dog in accompaniment. These were the only photos that captured more than one species in the same event. The separate listings for domestic dogs (2 photos, 3 animals) were dogs without human presence. Groups of deer were often photographed. As many as 3 deer were photographed together, generally a doe with two fawns in accompaniment.

Most photographs were printed with the date and time they were taken, although there were several camera malfunctions where date and/or time were not recorded. In total, of the 320 photos taken, 217 photographs were printed only with the date and 287 photographs were printed only with the time of day. For the focal species, deer and black bear, researchers plotted the time of day with the number of pictures taken at that time (Figure 20). Deer activity was highest after 5pm, and movement continued at a relatively high level until about 8am (15 hours; 76 photos). Very few photographs were taken between 8am and 5pm (9 hours; 8 photos). Researchers could make few conclusions from black bear photo data because only 7 photos had time of day documented. Of these 7 photos, only 1 occurred during daylight hours.

Table 10: Species and numbers of animals documented in photos taken from two remote-triggered cameras placed under the Montana Rail Link Bridge near Evaro, Montana from August 24 to December 9, 2002 and May 20 to June 4, 2003.

Species	Count of Photos	Count of Animals
Black Bear	9	9
Cat	29	29
Deer (unknown sp)	2	2
Deer (white-tailed)	99	150
Dog	2	3
Humans	161	216
Train	3	NA
Unknown/Not Animal	15	NA

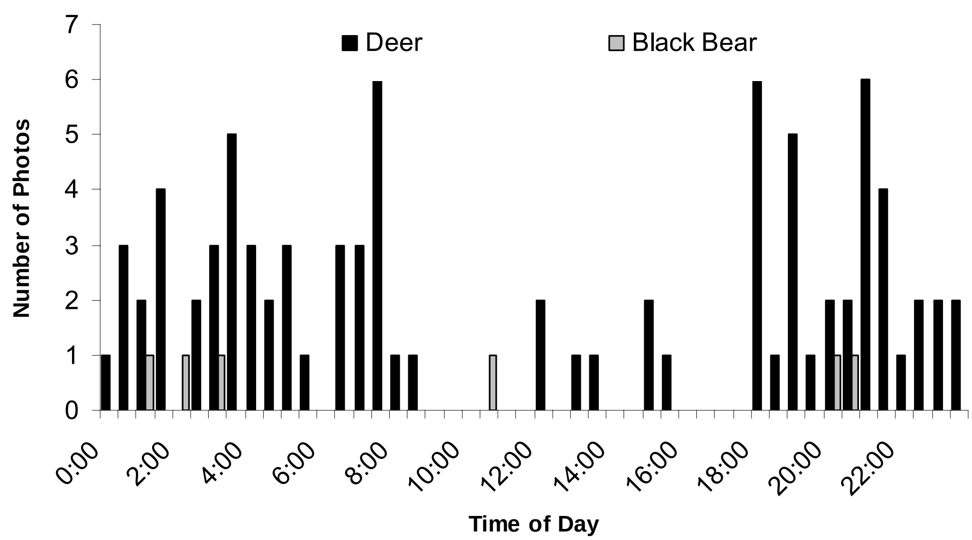


Figure 20: Number of black bear and deer photo events recorded at different times throughout a day (rounded to ½ hour) by two remote-triggered cameras located at the Montana Rail Link bridge near Evaro, Montana from August 24 to December 9, 2002 and May 20 to June 4, 2003.

5.6. Traffic Monitoring

Traffic levels can affect animal-vehicle collisions and animal-highway crossings. Traffic counts were collected to assess how changes in traffic volumes may correspond to changes in crossings and mortalities. While MDT collects traffic volume data from an inductive loop counter north of Arlee (between the Evaro and Ravalli Curves study site), WTI researchers used pneumatic tube road counters (Trax I Traffic Counter/Classifier, Jamar Technologies Inc., Horsham, PA) to collect data within the Evaro and Ravalli Curves areas.

5.6.1. Preconstruction Traffic Data Summary

Traffic counts were monitored from May 22 to July 29, on August 10, and again from August 22 to October 21 in 2003, for a total of 123 days of traffic count collection. Traffic counts were monitored during July 1 and 2, July 9 to 16, and again from August 12 to September 9 in 2004, for a total of 39 days of traffic count collection. Traffic counts were collected from May 12 to 19, July 1 and 2, and July 13 to 28 in 2005, for a total of 26 days of traffic count collection.

Traffic counts increased from year to year (Figure 21). Mean traffic levels were significantly heavier in 2005 than 2004 ($P<0.05$, $t = 7.63$) and traffic was heavier in 2004 than 2003 ($P<0.05$, $t = 3.65$). Due to difficulties in maintaining functional tubes, traffic in 2005 was mainly assessed in July, which could have biased the mean traffic volume high. However, the July average for 2005 was 5,168 and the July average for 2004 was 4,894. Therefore, unless there was a malfunction in the data readers, it seems that traffic volume increased in 2005.

Traffic counts were collected hourly, but deer and bear tracks were only counted on 3-6 day intervals. Tracks documented occurred at an indeterminate time before beds were checked, so the total daily traffic counts were averaged for the interval between track bed checks (Figure 21).

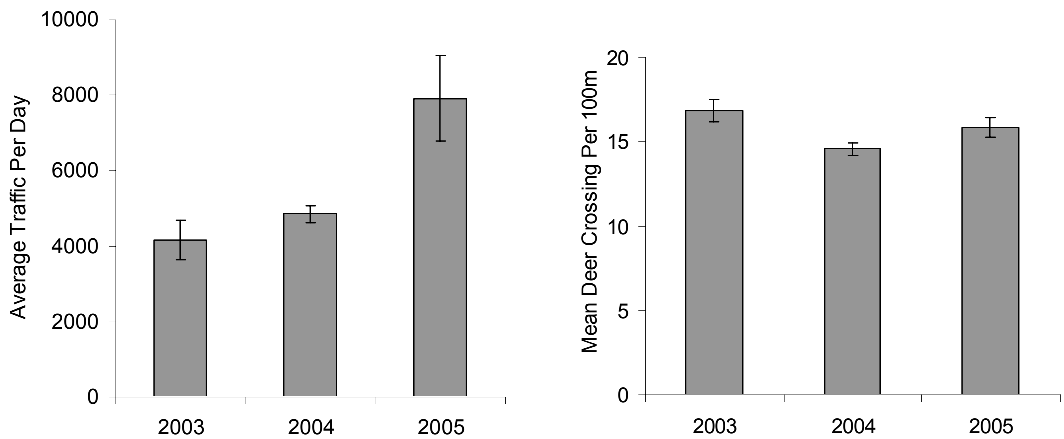


Figure 21: Average daily traffic on US 93 July-October 2003 and 2004 and July 2005 using WTI traffic counters (left) and mean deer crossings per 100m of US 93 highway estimated in 2003, 2004 and 2005.

5.6.1.1. Deer Crossings & Traffic Volume

Deer crossing data from track beds monitored June through October of 2003—2005 (n = 41) were used in this analysis. Although the season-long mean number of deer crossings per 100m (109 yd) track bed did not differ between years (Figure 21; $P > 0.1$), the average number of tracks documented per track bed visit was higher in 2003 (25.59) than in 2004 (17.82) or 2005 (15.95). Visits to the track beds occurred less frequently in 2003 (6.33 days between visits) compared to an average of 3.47 and 3.49 days between visits during 2004 and 2005. With roughly twice (1.82) as much time for tracks to accumulate, it was necessary to adjust the 2003 data to consistently compare average traffic volumes to average number of crossings observed over a similar interval of days between all years. Therefore, a correction factor of 0.549 was used to convert the 2003 deer crossing data to make them compatible with the 2004 and 2005 data. This correction factor resulted in an average of 16.25 tracks/visit across the study area in 2003 which corresponded with the number of tracks/visit throughout the study area in 2004 and 2005 (17.82 and 15.95, respectively).

The relationship between deer crossings observed in the track beds and traffic volume was assessed using the average daily traffic volume over the number of days between track bed visits. For example, if track beds were checked on July 1, 2004 and July 4, 2004, the average traffic daily traffic volume for July 2, 2004 through July 4, 2004 was compared to the average number of observed crossings across all beds. To enhance interpretability of regression coefficients, the traffic volume data were scaled by dividing by 100.

Three relationships between the number of deer crossings and traffic volume were examined. Results from a linear regression model indicated that the variance was non-normally distributed and that there was a curvilinear pattern in residuals. Natural logarithms and square-root transforms of the traffic covariate resulted in slight model improvement. Using the natural-logarithm transform of traffic volume, the traffic covariate reached significance (P=0.05; Table 11) and had a negative slope relating traffic volume to the number of deer crossings. Thus, there may be a slightly negative relationship between traffic volume and deer crossings, with fewer crossings occurring in conjunction with higher traffic volumes.

Table 11: Linear regression results relating traffic volume and deer crossings observed in track beds on US 93. The negative ß estimates represent the decrease in crossings with increasing traffic volume (scaled by traffic volume/100) and is presented with a 95% confidence intervals (LCI and UCI) and associated P-values.

Covariate	β Estimate	95% LCI	95% UCI	P-Value
Traffic/100	-0.51	-1.04	0.02	0.07
Log(Traffic)	-35.38	-68.54	-2.22	0.05
√(Traffic/100)	-8.61	-17.07	-0.15	0.06

Traffic peaks and lulls followed a predictable pattern (Figure 22). Traffic volumes were highest during the daylight hours and lowest in the late night and early morning. However, photo monitoring of cross-highway movements under the Montana Rail Link bridge near Evaro revealed that deer showed a pattern of crossing in the early mornings and late evenings, generally the reverse of the traffic patterns (Figure 22). The 07:00AM hour showed the highest potential for deer-vehicle conflicts, as deer crossings reached a peak as morning traffic increased.

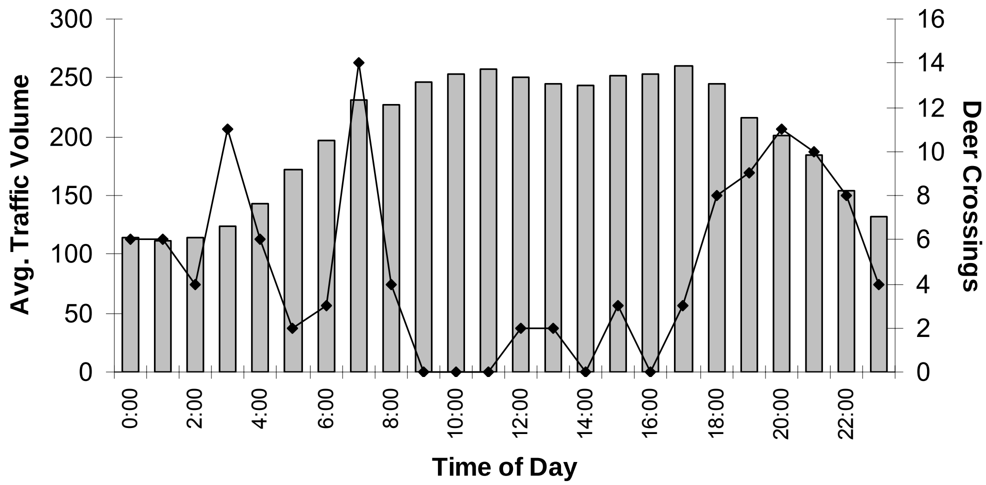


Figure 22: Average hourly traffic volume recorded via WTI traffic counters located on US 93 between Evaro and Ravalli Hill between June-October in 2003 and 2004, and in July 2005, plotted with hourly deer crossings from photo data.

Researchers also monitored the daily fluctuations in traffic across the years and seasons on a larger scale. For each day track beds were checked, and an estimate of deer crossings were made, the previous days' traffic volumes were averaged and the results compared (Figure 23). The results indicated that periods with lower traffic volumes may have higher crossing rates, although results were not conclusive.

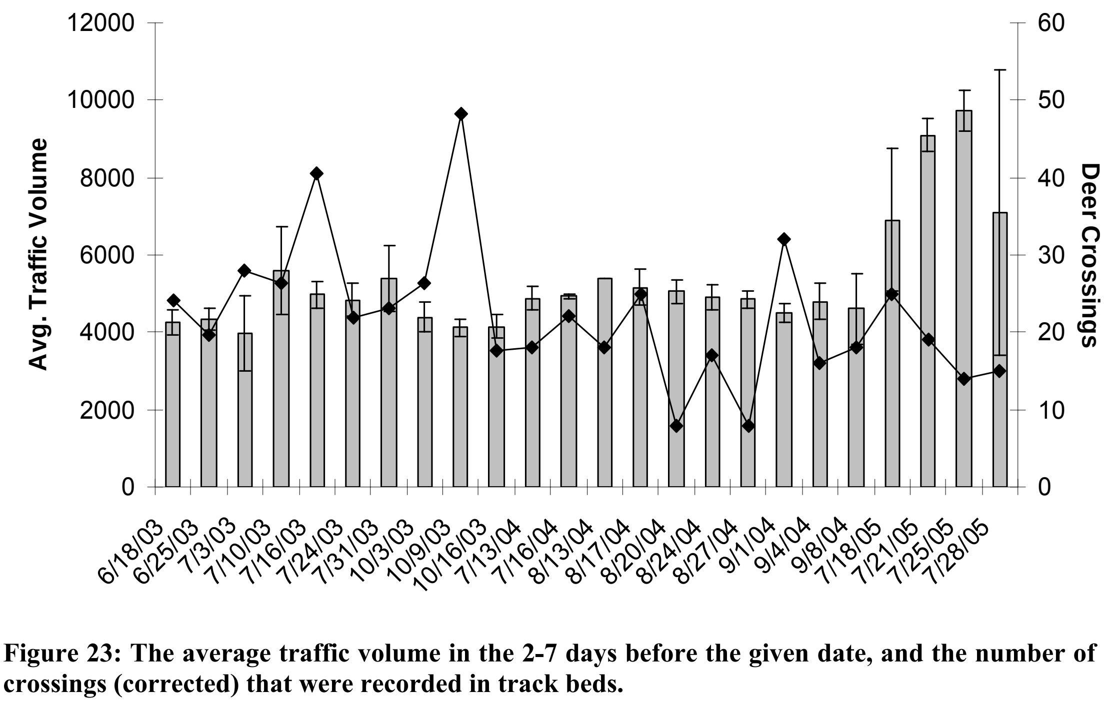


Figure 23: The average traffic volume in the 2-7 days before the given date, and the number of deer crossings (corrected) that were recorded in track beds.

5.6.1.2. Bear Crossings & Traffic Volume

Black bear crossings as interpreted by tracks in track beds were recorded on the same days, and compared to the traffic volume data using the same methodology as deer crossings. Significantly fewer bear crossings were documented in 2005 than in 2004 or 2003 (*P*<0.01; Figure 24). On average, there were 3.55, 2.64, and 0.43 black bear tracks per visit to the track beds in 2003, 2004 and 2005. Like with the deer data, we applied a correction factor of 0.549 to the 2003 data because beds time between monitoring sessions in 2003 was approximately double that of the time between monitoring sessions in 2004 and 2005, and correspondingly, accumulated more tracks.

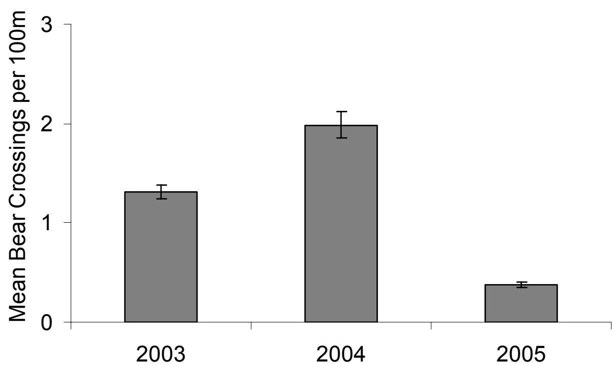


Figure 24: Average number of black bear crossings per 100m observed in track beds (n=41) located parallel to US 93 between Evaro and Ravalli Hill from June to October of 2003, 2004, and 2005.

As with deer data, three forms of traffic volume were used in linear regression with the number of bear crossings: a linear relationship, a square-root transform on traffic, and a $\log_e$ transform on traffic (Table 12). Researchers found a marginal decrease in crossings with the $\log_e$ of traffic (*P* = 0.1), the best-performing model. There was not enough bear crossing data from photo monitoring to determine the activity patterns of bears regarding the highway, but McCoy (2005) found that GPS collared bears had the highest highway crossing rates between 21:00 and 05:00 (see Chapter 6 for a summary of McCoy 2005).

Table 12: Linear regression results relating traffic volume and bear crossings observed in track beds on US 93. The negative ß represents a decrease in crossings with increasing traffic volume (scaled by traffic volume/100), and is presented with a 95% lower and upper confidence interval (LCI and UCI) and associated P-values.

Covariate	β Estimate	95% LCI	95% UCI	P-Value
Traffic/100	-0.07	-0.15	0.02	0.14
Log(Traffic)	-4.57	-9.78	0.65	0.1
√(Traffic/100)	-1.11	-2.43	0.22	0.12

5.7. Synthesis of Preconstruction Field Data Results

Several methods were applied to establish the preconstruction baseline data for deer and black bear behavioral and population ecology in the US 93 highway corridor. The documentation of quantity and location of AVCs indexed wildlife population densities, movement and activity patterns, and how these factors interacted with traffic activity patterns and volume. Track bed data estimated wildlife movements within the road verge, and also served as an index for wildlife population density and road-centric behavior patterns. Pellet group data indexed local deer population density, although deer behavior and habitat selection were determined to affect pellet group deposition. Photographic monitoring established a detailed view of daily patterns of activity in deer and bear, directly recording wildlife behavior during road crossings.

Comparing the multiple indices for the preconstruction years (Table 13) provides a holistic view of roadside ecology in the preconstruction years. Years with more pellets may indicate more deer in an area, which may result in more AVCs and more deer tracks across highways. In Evaro and Ravalli Hill, the indices are in agreement: more AVCs and more tracks occurred in the years when there were more pellets. However, the indices did not agree in Ravalli Curves, with fewer pellet groups counted but more AVCs and tracks in 2005 than in 2004.

This example demonstrates the importance of drawing inference from multiple indices. Indices are useful because they are inexpensive and easy to run, but they naturally contain more variance than the more-expensive population estimators: indices measure something correlated with animal abundance rather than measuring animal abundance directly (Lancia et al. 1996).

Table 13: Comparison of deer-vehicle collisions, crossings, and pellet counts observed in the three study areas in 2003—2005 prior to the reconstruction of US 93.

AREA	YEAR	AVCs	CROSSINGS	PELLETS
EVARO	2003	3	207	N/A
	2004	5	281	79
	2005	4	181	60
RAVALLI CURVES	2003	6	409	N/A
	2004	3	219	25
	2005	6	345	18
RAVALLI HILL	2003	1	63	N/A
	2004	0	87	0
	2005	3	112	2

The main ecological factors of interest in this evaluation related to the population and behavioral ecology of deer and black bear in the US 93 corridor. Specifically, these factors included 1) population densities of deer and bear proximate to US 93, 2) how deer and bear moved across US 93 prior to reconstruction, and 3) how population densities and movements interacted with traffic patterns, resulting in AVCs prior to reconstruction. Methods to quantify these factors will be repeated, with some necessary changes, after the highway is constructed to understand how highway crossings and AVCs will change (see Chapter 7 for post-construction monitoring plan recommendations).

Prior to the installation of extensive lengths of wildlife fencing with wildlife passages under and over the highway, observations of deer and black bear crossings, as interpreted from tracks in track beds along US 93, provided a random sample assumed to be representative of all crossing behaviors across the total length of the three study areas planned for mitigation measures. The baseline variability and estimated total crossings observed prior to mitigation will help interpret year-to-year variation in animal-highway crossings that can be expected after mitigation is installed, as this will affect the overall comparison of pre- and post-mitigation crossings and, ultimately, the final assessment of the effect of the wildlife fencing and crossing structures.

Between the areas of interest (Evaro, Ravalli Curves, and Ravalli Hill), the 2003-2005 estimates of deer crossings varied widely, while across the study area as a whole, overall deer crossings were much less variable. This was an unexpected result. The Evaro area is mostly coniferous forest, while the Ravalli Curves area is more agricultural and the Ravalli Hill area is open grassland. The areas of inference encompass 12 km (7.5 miles), but the areas are separated by gaps of up to 18 kilometers (11 miles). Changes in yearly climate conditions may influence deer migration on a larger scale, influencing movements of up to 13.2 km (8.2 miles) with deer shifting behavior in lighter or heavier winters (D'Eon and Serrouya 2005). Thus, there may be large-scale movements of deer within the study area towards coniferous forests or towards agricultural or open grasslands depending on overall food availability and the previous winter's conditions. If this is the case, then examining changes in the study corridor as a whole may eliminate some of the large-scale variation in crossing rates due to deer population movements between the three areas.

Black bear crossings were variable between study areas and years, with the only noticeable pattern being a substantial decline in all bear activity in the 2005 monitoring season. While it is possible that food availability changed over the spring and summer of 2005, resulting in lower black bear movement, it is also conceivable that black bear populations in the area may have declined. Unfortunately, there is not a supplementary population index with black bear as with deer populations (see section on pellet group indices), and such information could be important in interpreting whether black bear crossing activity was affected by crossing structures or by fluctuations in population numbers.

The estimates of highway crossing rates hinged on the assumption that deer and bear did not respond to the presence of the track beds (i.e., avoidance or attraction). However, track distribution data indicated potential avoidance by deer and black bears. This could result in a conservative estimate of overall wildlife-highway crossings in each area. It is unknown how many deer proceeded around the end of the bed that may have otherwise crossed the highway in the area of the track bed. The preponderance of tracks observed entering the beds closer to the ends as opposed to the middle of the track beds suggests that some deer may have walked around the track bed as they approached or left the roadway.

The potential track bed avoidance is a strong argument for more intensive photographic monitoring systems. There are several camera systems (Reconyx, Recon Talon systems, etc.) that employ silent infrared flashes that cannot be perceived by wildlife (see Chapter 7, Post-Construction Monitoring Recommendations for more details). Further, photographic monitoring can provide information regarding daily activity patterns that can be directly related to traffic patterns, as photos are printed with exact day and time, while track beds cannot register time of day the animal crossed. Finally, photographic monitoring in combination with track beds can confirm whether animals are truly avoiding beds (tracks were not recorded of animals that approached the bed but did not cross it) or whether animals were simply reacting to the presence of the track bed in a manner that did not influence statistical inference from crossings (animals always crossed the bed anyway, just in non-uniform fashion).

Track beds do have recognized limitations that need to be taken into account. The estimated preconstruction estimate of animal activity in the road corridor is likely to be conservative because 1) field researchers used stringent rules to assign “crossing” behavior to a track, 2) track retention on beds may have varied by weather, vehicles driving off roads, cattle drives etc., and 3) there may have been avoidance of track beds. There were significantly fewer tracks of deer leaving the highway than approaching the highway. This may be due to deer jumping over the track beds in a rush to leave the highway and not registering any prints. Highways are positioned above the track beds, so it would be a simple matter for deer to leap the 2 m (2.1 yd) wide track beds, and there were a few anecdotal observations of this behavior reported by local commuters.

Tracks recorded may be influenced by fluctuating population sizes, potentially driving increases or decreases in observed crossings that could confound the interpretation of the effect of the mitigation. This parameter was addressed with mixed success using pellet transect indices to estimate relative changes in local deer populations (see section on pellet group transects). Other behavioral adjustments can occur due to annual fluctuations in climate, which affects growing season temperatures, precipitation and fire cycles that may result in changes in forage abundance. Less abundant forage potentially results in wider animal movements, which may intersect the highway more often. Alternatively, wildlife movements may be shifted to areas away from the road, again blurring the interpretation of the data. Human activities, such as residential development; timber harvesting; game harvesting; prescribed burning; attracting deer and bear (intentionally or not) with trash, orchards, irrigated fields or lawns, or making feed or salt blocks available can affect wildlife movements from year to year. Additionally, track bed techniques and observer interpretation of tracks may introduce variability into the data. Despite these potential shortcomings, the track bed methods employed in this effort offered a useful approximation of deer and black bear behavior regarding US 93 before and after the installation of wildlife fencing and crossings.

Highways alone do not typically block animal movements or directly cause animal mortalities; rather, conflicts arise between animals and the traffic and drivers that travel on highways. Characteristics of the traffic such as total volume and the diurnal pulses and lulls in volume, observed speeds, and types of vehicles (e.g., passenger vehicles, recreational vehicles, semi-trailer trucks) interact with engineered highway features and surrounding landscape potentially resulting in animal-vehicle collisions or an impassable barrier to animal movements.

Traffic volume increased over 2003, 2004 and 2005, but the overall number of deer crossings in each year did not change (see Estimated Preconstruction Deer Crossing). Fluctuations in the true deer population over this time are unknown, but pellet counts in 2004 and 2005 were run to index this parameter (see These results indicate that deer may be exhibiting some track bed avoidance behaviors when confronted with a “free standing” track bed (i.e., a track bed with no features to funnel movements across the bed and animals could chose to walk around the bed). Black bear do not seem to be responding to the same degree that deer were, though it is possible that some bear track bed avoidance may be occurring as well. By understanding that there may have been some avoidance of the beds implies that the estimated preconstruction crossing estimates, especially in the case of deer, may be underestimating the total cross-highway movements.

Pellet Group Transects). Fewer pellets were found in 2005, but the difference was statistically insignificant (P = 0.13).

This simple analysis used a rough scale to determine deer response to differing traffic volumes, but finer-scale data were not available. Regression analysis of average traffic volume and estimated deer crossings revealed a decline in crossings with increasing traffic, but sample sizes were insufficient to determine seasonal differences in crossing rates. Based on the available time stamps on images of wildlife captured using remote-triggered photo monitoring techniques, it appeared that most deer (70%; *n* = 83) and bear (83%; *n* =6) activity occurs at night, while traffic volumes were heaviest during the day. Thus, traffic volume may have had an effect on deer behavior. In post-construction years, once deer adapt to the presence of crossing structures, there should be no relationship between deer crossings and traffic volumes on the daily or weekly scale. However, unless fine-scale deer movement behavior is dictated by traffic volumes, deer would be expected to maintain patterns of higher activity in the morning and evening hours, as in preconstruction years.

Pellet indices were used in an attempt to estimate deer populations in each area in 2004 and 2005. The pellet index complemented, and could only be validated through, the other methods that also indexed deer populations. If deer populations were larger in years when pellet counts were higher, more deer-vehicle collisions and more deer crossings could be expected. Two main conclusions were drawn from pellet data: 1) Evaro had more pellet groups per plot than Ravalli Curves, and 2) more pellet groups were found in 2004 than 2005. While in 2004, Evaro had more pellets and more crossings than in 2005, Ravalli Curves showed an increase in crossings but a decrease in pellet groups over 2004 to 2005 (Figure 25).

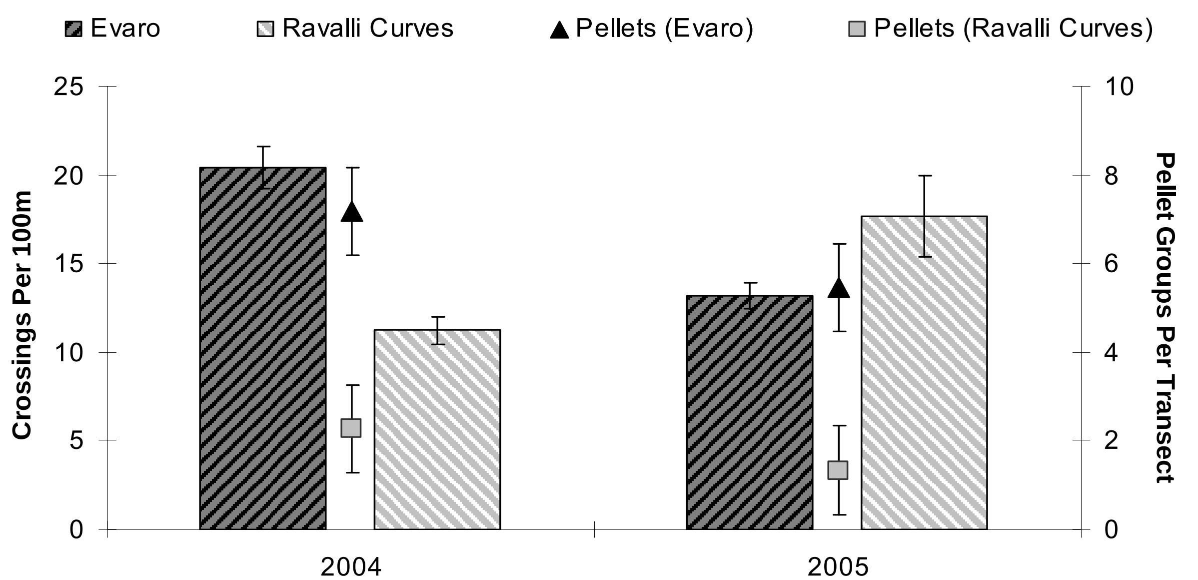


Figure 25: Comparison between crossings per 100m and mean pellet groups per plot in the Evaro and Ravalli Curves areas in 2004 and 2005.

The pellet data were also compared with the 2004 and 2005 deer-vehicle collision (DVC) data for these two areas. Like the crossing counts, researchers found that DVCs were higher in Evaro in 2004 than 2005, but that DVCs were low in Ravalli Curves in 2004 and high in 2005. Thus, track bed counts correlated well with DVCs, but not with the pellet group index.

The discrepancy in deer pellet groups relative to deer tracks and DVCs could be partially explained by the overall habitat in the Evaro and Ravalli Curves areas. The Evaro area was largely coniferous forest, while the Ravalli Curves area was more open habitat, with grassland, wetland, and riparian components. White-tailed deer could behave differently and have different diets in these habitat types, resulting in differential pellet deposition (Neff 1968, Eberhardt and Van Etten 1956).

Used separately, the preconstruction monitoring methods addressed specific questions regarding preconstruction roadside ecology. Used together, these indices help integrate important demographical and behavioral information to understand the current effects of US 93. This information will be critical in determining the effects of mitigation measures on deer and bear in post-construction years. The determination of statistical significance or insignificance in differences between the pre- and post-construction indices will provide some indication of the responses of deer and bear to the mitigation measures. However, power analyses often indicated little ability to detect small changes in certain measures (i.e., AVCs within the area to be fenced). Therefore, examining the trends in all these indices together will effectively provide a more holistic view of deer and bear behavior before and after mitigation is installed in order to evaluate the performance of the mitigation measures.

6. OTHER US 93 ROAD ECOLOGY PRECONSTRUCTION RESEARCH

The previous chapter summarized the preconstruction monitoring methods and baseline data centered on the evaluation study's primary parameters of interest: animal-vehicle collision (AVC) and wildlife-highway crossings for deer and black bear. This chapter highlights other recent preconstruction research efforts related to various aspects of the reconstruction's effects on black bear, deer, aquatic organism passage, and turtles. Although there are inherently valuable outcomes from these projects on their own, each study provides an opportunity to repeat the research after mitigation is installed to comparatively assess the effects of the reconstruction and mitigation measures.

6.1. Black Bear Movements and Genetics Relative to US 93

Black bear and deer are the primary species of interest in this evaluation project. However, compared to deer, black bear observations are relatively rare, making it challenging to obtain sizable datasets feasible for statistical inferences. Additional in-depth black bear research was justified to provide a more comprehensive picture of the baseline preconstruction black bear behaviors and movements relative to the highway prior to construction. To do this, WTI collaborated with University of Montana to conduct field research focused on black bear density, behavior, population demography, gene flow, and mortality relative to US 93 prior to the reconstruction. Karin McCoy conducted this master's thesis research study in 2002-2003 along and beyond the US 93 corridor from the junction of US 93 and Interstate-90 (south of the Flathead Indian Reservation boundary) to St. Ignatius (approximately midway along the reconstruction project; see Figure 1 in previous chapter). McCoy's study had the following objectives (McCoy 2005):

- Estimate black bear preconstruction US 93 highway crossing rates and locations;
- Determine what factors influenced black bear crossings, including food conditioning, age-sex class differences, topographic variables, traffic volume and speed, time of year, time of day, and degree of road-side anthropogenic development;
- Assess spatial relationships between black bear crossing locations, black bear mortality due to vehicle collisions, and the planned locations of wildlife passages;
- Collect DNA samples to estimate black bear density in the highway corridor; and
- Evaluate the heterozygosity of DNA samples to provide preconstruction estimates of genetic variation within the population.

General outcomes are summarized below. For additional details, see McCoy 2005.

6.1.1. Highway Crossings

To document highway crossings, global positioning system (GPS) collars were used to spatially track black bear movements. Eight black bears were captured in August 2002 and 11 bears were captured in May 2003 (including one recapture identified by a tattooed identification number on the underside of the upper lip). Eighteen individuals were monitored in total: 8 adult males, 6 adult females, and 4 subadult males. All collared bears weighed at least 34 kilos and were fitted with VHF radio collars with GPS capability (Telonics Incorporated, Mesa, Arizona, USA) to record hourly locations 24 hours a day. The GPS collars were programmed to release November 1, 2002 and October 15, 2003 for collection and data downloading.

A total of 31,780 locations were obtained for the 18 bears fitted with these collars. With hourly locations of the instrumented bears, it was possible to determine where and when an instrumented bear moved and crossed the highway. However, error associated with GPS location data could result in apparent crossings if collared black bears were simply proximate to the highway. Hence, the following criteria were used to determine true highway crossings: crossings would be greater than 1 hour apart, pre- and post-crossing locations must be on opposite sides of the highway, and post-crossing locations were required to be a minimum distance from the highway to ensure it was an actual crossing, and not a result of GPS error. Following the criteria described above, 187 crossings of US 93 by 10 collared black bears were analyzed.

Of the 10 collared bears that crossed US 93, 5 were determined to be food-conditioned (2 adult females, 2 subadult males, 1 adult male) and 5 were not food-conditioned (2 adult females, 1 subadult male and 2 adult males). Food-conditioned bears crossed highways significantly more frequently than non-food-conditioned bears ($P = 0.009$). This is not unexpected given that the food-conditioned bears had home ranges that were more proximate to the highway; if bears moved randomly throughout their home ranges, bears with home ranges closer to highways would be expected to have a higher crossing rate than bears with home ranges peripheral to the highway. The highway appeared to be “fully permeable” to food-conditioned bears, but posed a possible partial barrier to non-food-conditioned bears.

Adult males seemed to cross less frequently than adult females or subadult males. Most adult males did not cross the highway, and those that did crossed it infrequently. However, these results may be confounded by the effects of food conditioning and home range location relative to the highway. Further, adult males may dominate females, taking the best habitat available, restricting adult females to marginal habitat areas along the highway corridor, which may have contributed to more females crossing than adult males.

Black bear highway crossing frequency differed by time of day and time of year. Crossings occurred most frequently during early morning and evening hours, and most frequently in late summer through early fall. Most (73%) bear crossings occurred when it was dark and traffic volumes were low. Highway crossings were significantly and strongly negatively related to traffic volume ($r = -0.84$, $P < 0.001$). Traffic volume was higher during daylight hours than dusk-dawn hours, and highest in spring-early summer, and declined throughout the summer into fall.

The negative relationship between black bears and traffic volume could be causal (i.e., bears actively avoiding the highway during times of high traffic) or incidental due to bear behavior. Black bears are generally nocturnal, while traffic volumes are highest during daylight hours. However, black bears had high movement rates during spring through early summer, and generally crossed the highway less than expected during these times.

Highway crossings were more likely to occur in areas with dense cover, at night, and near stream crossings. Distance to development was not statistically significant in these models.

6.1.2. Highway Mortality

Highway mortalities of black bears were also documented and assessed. Historic road kills that were documented by MTFWP over 1995-2004 were evaluated, as well as mortalities discovered in the study area (which included a stretch of Highway 200 from its junction with US 93 near the town of Ravalli), in 2002 (n = 10) and in 2003 (n = 11). These findings were considered an underestimate of true highway-related mortality because 1) fatally injured animals may leave the highway side and die where they cannot be easily seen or counted, and 2) human passers-by may drag carcasses off the road to illegally collect hides, skulls and claws. Highway mortality of black bears tended to be highest for subadult bears, making up 68% of known age-sex class bears killed on the highway over 1995-2004.

Road kill locations were closer to planned wildlife passage locations than randomly-selected locations (P = 0.06), indicating wildlife passages may facilitate safe highway crossings for bears. Road kills were more likely to occur nearer stream crossings or riparian areas, and in areas with more dense cover.

6.1.3. Population Density and Genetic Diversity

Lab analysis of DNA extracted from hair can provide insight into genetic relatedness across landscapes and numbers of individuals using an area. Black bear hair was collected from methodical hair snagging efforts, as well as research-trapped bears, highway mortalities, management-trapped bears and other opportunistic hair sampling methods. Hair samples were collected during 2002 and 2003, although sampling effort was more rigorous in 2003.

Preconstruction baseline genetic variation for black bears within the highway corridor was determined from 232 hair samples. DNA could not be extracted from 20 of these samples, and 159 of the remaining samples were successfully genotyped (75%). From these samples and from trapping records, 83 different black bears were identified (48 male and 35 female) in the 148km^2 area that was sampled for hair. This translates to a minimum density of 0.47-0.56 bears per km^2. Using 5 microsatellite DNA markers, baseline genetic variability for this population of black bears was deemed “exceptional”, with observed heterozygosity (degree of genetic variability) averaging greater than 85%.

6.1.4. Conclusions and Recommendations

The highway may be a barrier to some segments of the black bear population in the study area, but it is not currently a barrier to overall gene flow. Planned locations of wildlife mitigation passages appear to be aligned with current black bear movements across the highway.

While the location of the wildlife fencing and passages for the US 93 reconstruction had already been determined, McCoy offered considerations for other efforts to install wildlife fencing and crossings as follows:

- Manage lands adjacent to mitigation passages to minimize human disturbance, including development and access to food sources that could result in habituation;
- Install fencing to direct wildlife to passages and away from areas of high anthropogenic influence;
- Consider high crossing rates associated with streams when placing wildlife crossing structures; and
- Implement companion management focused on securing human foods and attractants to prevent food-conditioning.

McCoy's efforts established a baseline of black bear movement and genetic data that can be further assessed by conducting a similar study after construction is completed. These recommendations are discussed in Chapter 7.

6.2. Preconstruction Hydraulic Profiles and Fish Passage Assessment of Culverts in Evaro Area

Although the larger evaluation study focuses on terrestrial wildlife, reconstruction design efforts also addressed fish passage issues. Outside of the preconstruction evaluation study budget, WTI recruited graduate student Darren Baune to conduct preconstruction baseline fish passage assessment of several stream crossings planned for replacement. The intention is to repeat the same assessment after construction is completed to document hydraulic changes and subsequent effects on fish passage. A summary of Baune's professional paper follows; for more detailed information see Baune (2003).

6.2.1. Methods

Preconstruction data collection was performed at five stream crossings in the Evaro area. Table 14 summarizes existing and planned hydraulic passage structures at each data collection site, as well as the types of data collected and methods used to assess the fish passage conditions at each crossing.

Assessing existing passage conditions at a stream culvert crossing typically utilizes a combination of biological, geomorphic and hydraulic data. Three methods of assessing the "passability" of the existing structures were used on the study sites. Passability refers to the ease in which fish can move through a structure. Culverts are typically categorized as passable, partial barrier (a barrier at some flows but not all) or total barrier (no passage regardless of flow).

The first method was a mark-recapture technique applied at the East Fork Finley Creek Crossing. The method involved separating the stream study site into a control reach (natural stream reach) and a treatment reach that included the existing culvert. The control reach was adjacent to and downstream of the treatment reach. Each reach was blocked at the downstream end with wire mesh supported by stakes driven into the substrate to isolate the study reach from the remainder of the stream. At the upstream end of each reach, a fish trap was placed with wire mesh blocking the remaining portion of the stream.

Electrofishing was used to remove any fish from the two study reaches. These fish were placed downstream of the study reaches. Electrofishing was then used to collect 50 fish from upstream of the study reaches. These fish were randomly divided into two similar groups based on size and species.

Fish in the treatment group had a right pelvic fin clipped for re-identification and fish in the control group had a left pelvic fin clipped for re-identification. Each group of fish was placed in the downstream end of their respective reach. Fish were recaptured in the traps as they moved upstream toward their original capture location. Traps were monitored daily, and physical parameters including stream discharge, water depth in the culvert and velocity in the culvert were collected daily.

The second method utilized comparisons between upstream and downstream fish population characteristics. Researchers collected all fish via electrofishing from a 100 meter reach downstream of the culvert and a 100 meter reach upstream of the culvert on Schley Creek. The fish population characteristics, including average length of fish in each sample and number of fish in each sample were compared to assess the passability of the crossing at Schley creek.

Table 14. Summary of existing stream crossing structures, planned structure and assessment methods.

Stream Crossing Name	Existing Structure	Planned Structure	Data Collected	Fish Passage Assessment
East Fork of Finley Creek	6' x 8' box culvert	12' x 22' corrugated metal culvert or box culvert	• Stream habitat following USFS R1/R4[1]; • Fish movement using mark-recapture; • Stream and culvert hydraulic data; • Topographic data	• Mark-recapture experiment; • Hydraulic modeling with FishXing[2]
Schley Creek	5' diameter reinforced concrete culvert	12' x 22' corrugated metal culvert or box culvert	• Stream habitat following USFS R1/R4[1]; • Fish sampling using upstream and downstream population characteristics; • Stream and culvert hydraulic data; • Topographic data	• Up- and downstream fish population sampling; • Hydraulic modeling with FishXing[2]
Montana Rail Link Fish and Wildlife Crossing	One 5' diameter corrugated steel culvert (north of RR) & one smaller culvert (south of RR)	Open water passage with bridge	Stream and culvert hydraulic data	Hydraulic modeling with FishXing[2]
Finley Creek Tributary #2	4' x 3' box culvert	12' x 22' corrugated metal culvert or box culvert	Stream and culvert hydraulic data	Hydraulic modeling with FishXing[2]
Frog Creek Crossing	2' to 3' diameter concrete culvert	4' x 6' corrugated metal culvert or box culvert	Stream and culvert hydraulic data	Hydraulic modeling with FishXing[2]

[1]Overton, et al. 1997
[2] Version 2.2; http://www.stream.fs.fed.us/fishxing/downloadpage.html; last accessed 5/24/06.

A third method, used at all five crossing structures, involved using FishXing, a publicly-available software (Version 2.2; http://www.stream.fs.fed.us/fishxing/downloadpage.html; last accessed 5/24/06), to assess the passability of the structures. FishXing uses 1-dimensional hydraulic computations to estimate the water depth, velocity and outlet drop height in a given structure for selected flow rates. The software then compares the swimming abilities of "design fish" to assess the passability of the crossing. A 123 mm (4.8 in) adult cutthroat trout (*Onchorynchus clarki*) and a 97 mm (3.8 in) adult cutthroat trout were used as the design fish for the analyses of the East Fork Finley Creek structure and the Schley Creek structure, respectively. The "design fish" size and species were representative of the size and sampled in these two streams during field assessments. For the remaining three crossings, a 100 mm (3.9 in) adult cutthroat trout was selected as the design fish based on the size and species of nearby streams and because cutthroat trout in this size class had been reported to inhabit these study site creeks. Three flow rates were modeled at each crossing: a low flow of 1 cfs, a medium flow equal to that measured in the field at the time of the site visit, and a high flow equal to the estimated 100 year flood flow (Jones and Jones 2002a).

6.2.2. Results

Data were collected in July and August of 2003. Mark-recapture results at the East Fork Finley Creek crossing indicate the structure is a barrier to fish passage at 5 cfs, the flow rate measured during data collection. Fish species found in this stream included brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*) and westslope cutthroat trout (*Onchorynchus clark lewisi*). The average fish length for this study was 123 mm (4.8 in). Eight of 25 fish released in the control reach were captured in the upstream trap of that reach. No marked fish were captured in the trap for the treatment reach. This outcome was not unexpected given that a 1.7 foot drop at the culvert outlet existed during these experiments. Large outlet drops can reduce the passability of a structure or prevent fish passage altogether (Cahoon et al. 2005).

The upstream and downstream fish population characteristics were different at the Schley Creek crossing. The electrofishing census yielded 26 fish downstream and 5 fish upstream of the crossing structure. All fish collected were visually identified as westslope cutthroat trout. The average length of the fish was 97 mm (3.8 in) (n = 31). The difference in the number of fish upstream versus downstream at this site may reflect the passability of the crossing; however, an irrigation diversion located approximately 10 meters downstream of the most downstream extent of the population sample may have affected the fish density in this study. Schley Creek was dry downstream of this diversion. The lack of water and presence of the diversion likely influenced the distribution of fish in the downstream sample and confounded the results of this culvert passability assessment.

Table 15 summarizes results of the FishXing assessment for the five stream crossing sites. All structures were considered passage barriers due to excessive velocity during some portion of the year. Three of the six crossings were estimated as a barrier due to excessive leap heights.

Table 15. Summary of FishXing results for each study site stream culvert based on field measurements collected in July and August of 2003, prior to reconstruction of US 93. Flow rate represents the minimum flow in cubic feet per second that resulted in a barrier to fish passage.

Stream Crossing	Leap Barrier	Velocity Barrier	Flow Rate (cfs)
East Fork of Finley Creek	Yes	Yes	29.3
Schley Creek	Yes	Yes	1.0
Finley Creek Tributary #2	Yes	Yes	5.8
Montana Rail Link (northern crossing)	No	Yes	4.7
Montana Rail Link (southern crossing)	No	Yes	5.9
Frog Creek	No	Yes	4.0

6.2.3. Conclusions and Recommendations

Overall, the passability assessment of the study culverts indicates that each culvert is likely functioning as a fish passage barrier during at least a portion of the year (i.e., each culvert was categorized as a partial barrier). Poorly designed, hastily constructed or improperly maintained culverts can create hydraulic or geomorphic conditions that restrict or prohibit fish movement, with important consequences to fish populations. A literature review of fish passage studies shows that both adult and juvenile salmonids (e.g., trout and salmon species) move frequently and at various times of the year (Kahler and Quinn 1998). Therefore, habitat connectivity is critical to the long-term survival of many fish populations. Characteristics of culverts that impede fish movement include excessive outlet drop heights and velocities, insufficient water depth or debris traps (Robison et al. 1999, Rieman and McIntyre 1995, Votapka 1991, Baker and Votapka 1990).

Much effort is spent today to ensure new culvert designs on fish bearing streams allow fish and other aquatic organisms to pass. These efforts often result in large structures that are embedded into the stream bed or that have a natural stream morphology purposely constructed within them. The cost of crossings generally increases as their size and complexity of the interior increases.

6.3. Landscape and Highway Characteristics Related to Preconstruction Deer-Vehicle Collisions and Deer Crossings of US 93

To better understand site-specific variables that influenced the occurrence of preconstruction deer-vehicle collisions (DVCs) and deer-highway crossing rates on US 93, WTI and the Wildlife Conservations Society (WCS) collaborated to support (outside of the preconstruction evaluation study budget) graduate student Whisper Camel to focus her research thesis on this topic. Working with DVC and deer carcass removal reports from MDT's Traffic Safety Bureau, Camel identified and visited DVC sites and "control sites" where no DVCs had been reported as well as each track bed site and measured numerous habitat, landscape, and highway variables locally. Using GIS, Camel measured additional variables at the landscape-scale associated with these same sites. She identified *a priori* candidate models of combinations of local and landscape variables that were hypothesized, based on relevant literature and expert opinion, to be correlated with DVC and highway crossing events at local, half-mile, mile and two mile scales. Each model was then analyzed using logistic (for DVC versus non-DVC control sites) and multiple (for deer-highway crossing rates) regression techniques. Models were comparatively ranked using an information-theoretic approach (Aikake's Information Criterion or AIC; Burnum and Anderson 1998) to select the model that "best" predicted DVC and deer-highway crossings.

Final results are expected early 2007. A follow-up analysis incorporating variables related to the mitigation measures could be undertaken after construction is complete and a sufficient sample of DVCs reports is compiled to further assess the wildlife fencing and crossing structure installation effects on DVCs.

6.4. US 93 Preconstruction Effects on Western Painted Turtle Movements and Population Structure in the Ninepipes Area

Numerous stakeholders, including a wildlife biologist, CSKT tribal members and the general public have raised concerns about US 93's impacts on the western painted turtle (*Chrysemys picta bellii*) population in the Ninepipes area. Bisecting the prairie-pothole wetland habitats that these turtles depend upon, US 93 has been identified as a potential barrier to movement between ponds across the highway from each other, as well as a source of mortality for turtles, with potential to fragment this population and lower population viability. Further, safety concerns have been raised due to drivers braking and swerving to avoid turtles on the highway.

Fowle (1996a, 1996b) determined road kill rates for western painted turtles in this region were significant, and recommended mitigation measures be implemented to decrease turtle mortality and increase the permeability of the highway. Building on this effort, the MDT, with additional support from CSKT; the Montana Cooperative Wildlife Research Unit; Montana Fish, Wildlife and Parks; University of Montana; the Salish Kootenai College, and WTI, funded a three year field study assessing the highway's effects on connectivity and population parameters for the Ninepipes western painted turtle population prior to the reconstruction of the US 93.

The primary goal of this research was to understand landscape-level connectivity and potential effects of the highway on the western painted turtle population that straddles an 18 km (11.2 mile) section of the road in the Ninepipe/Ronan area (Griffin and Pletscher 2006). Objectives of the research included the following (Griffin and Pletscher 2006):

- To determine demographic rates of survival in and movement between ponds;
- To determine the extent to which the highway obstructs movements;
- To examine potential effects of road mortality on the population;
- To compare available fencing methods used in herpetofauna-highway interaction projects and assess their effectiveness at minimizing turtle road kill and directing turtles to wildlife crossing structures; and
- To test flashing material as a barricade on fences to keep turtles from breaching barriers or directional fencing.

To accomplish the objectives relating to demographics and movements, a capture-mark-recapture study and road mortality study were conducted. Initial results follow; further details can be found in Griffin and Pletscher 2006.

6.4.1. Highway Mortality

Thirty-three road mortality surveys were performed approximately once a week from mid-May through late August 2003-2005 along a 6.4 km (4 mile) section of US 93 and 4 km (2.5 miles) of two low-volume side roads. A total of 1,040 western painted turtles were killed on US 93 while 19 turtles were found on the low-volume side roads. Of the turtles killed on the highway, 43.3% (451) were adults and 21.3% (221) were juveniles, while the remaining individuals age class could not be determined. Sex could not be identified for 61% (639) of road mortalities, but of the turtles that sex could be determined, no sex bias was found as approximately an equal number of males and females (99 and 81, respectively) were found.

Most mortality occurred in June and more individuals were killed on roads prior to mid-July than later in the summer. More adults were killed in early summer although males experienced more mortality than females later in the summer, while juveniles were killed more consistently throughout the summer with a spike of juvenile mortality occurring in August.

Mortality was greatest where large ponds were adjacent to both sides of the highway. Most turtle kills that could be identified were from these proximate ponds while only 3 turtles from the furthest study pond were found killed on the road. More road mortality turtles were counted than natural over-winter mortalities.

6.4.2. Capture-Mark-Recapture Study

A total of 2,335 individual turtles were identified in 8,520 captures from 2002-2004. With 873 and 803 males and females identified, no sex bias was indicated overall, although two pond complexes had statistically significant deviations from 50:50 sex ratios where more males than females were found in one pond and more females than males in another. A total of 659 juveniles were marked.

Movements of marked turtles typically occurred between permanent and temporary ponds with the longest movement of 2,400 meters made by a juvenile. No significant difference was detected between numbers of males and females that made inter-pond movements, however it is possible that females may have moved away from and back to an individual pond to nest which would not be detected with the capture-mark-recapture techniques.

Fine-scale movements between ponds bisected by the highway indicated that 106 and 78 turtles moved away from the two ponds without crossing the highway, while 40 turtles successfully crossed the highway. However, 150 mortalities were recorded between these ponds with 69 identified as adults and of these 36 (52%) were marked, indicating that about half (47%) of the turtle crossing attempts resulted in mortalities, however this estimate may be low given that 19 turtles found dead on the road could not be confirmed if they were marked.

Deep ponds had most consistent abundance estimates while shallower ponds showed dramatic reductions in abundance estimates as these ponds were affected by drought conditions and water depth decreased as summer advanced. For the study area and years, the regional adult abundance estimate peaked in spring 2003 at 854 and fell to 372 in fall 2004. Based on these estimates, road mortality counts conservatively estimated 6.0% and 7.9% (in 2003 and 2004, respectively) to 16.9% and 13.0% (in 2003 and 2004, respectively) of the population was killed on the highway during this study.

6.4.3. Survival, Population and Movement Modeling

Using the capture-mark-recapture data, modeling survival probabilities indicated that the pond, season, and drought conditions had the greatest influence on survival rates. Distance to road was not a significant factor given that ponds far away from the highway were still affected by road mortality. In one case, from the study pond second furthest from the road (881 m [0.5 mile]) incurred the highest numbers of road mortality turtles when that pond began to dry and turtles moved over the road to another pond. Two study ponds that retained water experienced higher survival rates than other ponds; ponds that lost significant water had lower survival rates due to the fact that moving makes them more susceptible to road mortality. The population structure did not appear to be affected by the highway given that the living turtle sex ratio was not significantly different than a 50:50 male to female ratio and there appeared to be no sex bias in recorded road mortalities.

Only 1-2% of annual movements occurred between pond complexes indicating that the movement that does occur is important to providing connectivity to local populations in these pond complexes. Modeling showed that 7-10% of movements were temporary departures from the pond complexes and considerable temporary emigration outside the complexes indicated that western painted turtles may use larger areas seasonally than previously thought. Movements may be limited by the highway as the models showed that road reduced turtle movement rates and turtles were less likely to move long distances if a road intervened.

The highway affects the turtle population via direct mortality and reduced connectivity. Considering turtle populations' slow growth and reproductive rates, a conservative estimate of 6-17% of the population killed on the highway, and additive mortality due to sensitivity to drought conditions, the observed mortality could not be sustained if the population were closed (i.e., no emigration or immigration from other populations). However it was evident that temporary and permanent emigration occurs from surrounding reservoirs, underscoring the importance of maintaining landscape connectivity for this species.

6.4.4. Recommendations

Three priority areas of the highway include two locations where the road splits two kettle ponds and another location (immediately south of the scenic turnout at Beaverhead Lane) where the road lies between two semi-permanent ponds on one side of the road and a permanent pond on the other. Culverts and fencing are recommended based on findings from the final two objectives related to research on mitigation measures, with references to specific dimensions, design and placement based on previous turtle-road studies elsewhere (Dodd et al. 2004, Aresco 2005). Given that the Ninepipe/Ronan section of US 93 has not gone through the detailed design phase for reconstruction, specific recommendations for consideration in the design process include the following (see Griffin and Pletscher 2006 for additional details):

- Construct bridges or oversized culverts in priority areas (between kettle ponds) where water crossings occur;
- Construct oversized box culverts with flat bottoms and earthen substrate in dry crossing areas;
- Minimize construction activities in the priority areas from mid-May to mid-July when movement activity is highest in order to reduce disturbance and mortality;

- Monitor construction and in kettle pond priority areas and provide safe passage opportunities around the construction detours;
- Install wing or directional fencing to funnel turtles to culverts;
- Post "Turtle Crossing" warning signs May-September to increase motorist awareness during the season they are most likely to encounter turtles (so as to not habituate drivers to the message); and
- Conduct a post-construction study to evaluate the efficacy of the crossings in providing landscape connectivity. It is noted that only two studies (Dodd et al. 2004, Aresco 2005) have pre- and post-construction data evaluating construction effects on connectivity and that this study is the only study known to include preconstruction population data, underscoring the importance of this effort in providing unique and valuable insights into long-term effects of roads on turtle population dynamics and connectivity.

7. MEASURES OF EFFECTIVENESS AND POST-CONSTRUCTION MONITORING RECOMMENDATIONS

In conjunction with developing the preconstruction monitoring methods, WTI developed complementary post-construction monitoring methods for recommendation and suggested quantitative "measures of effectiveness" (MOEs) for the main parameters of interest in this evaluation study: animal-vehicle collisions (AVCs) and wildlife-highway crossings. After an overview of the complexities of determining "effectiveness", post-construction monitoring recommendations and MOEs are outlined below.

7.1. Determining "Effectiveness"

Determinations of effectiveness are based on biological, social, economic, political, safety, and/or other *values* (Table 16). For example, although monetary value has been placed on human life (Sielecki 2004, Schwabe et al. 2002, U.S. Department of Transportation 2002, Romin and Bissonette, 1996), many would argue that a human life is priceless based on their personal values. Increasing wildlife habitat connectivity is difficult to quantify monetarily, but known to be biologically important; improved connectivity is highly valued for some people, but others may not be concerned about connectivity. While it is possible to present measures of effectiveness, effectiveness is ultimately determined by an individual's or agency's values.

Table 16: Possible "effective" outcomes of management actions to maintain wildlife linkage zones (i.e., habitat connectivity corridors) where wildlife move across landscapes between core areas of habitat (Servheen 2006).

Biological	• Wildlife movement across the landscape • Gene flow • Dispersal success • Female movement • Access to resources • Reduction of wildlife mortality • Reduction of wildlife-human conflicts in linkage areas
Economic	• Improved efficiency in project planning • Road or bridge designs that don't have to be rebuilt for wildlife needs • Minimal environmental review and court challenge • Reduced safety liability risk due to highway design and planned wildlife crossing/fencing in likely wildlife crossing areas • Property value increases due to perceived value of adjacency to wildlife linkage areas
Public Safety	• Reductions in AVCs
Social	• "Buy in" by local people to build support for concept of mitigation measures • Acceptance of linkage by local public/political interest • Involvement of local people in refinement of linkage area locations • Involvement of local people in linkage area management design
Political	• Support for linkage planning by mgmt in budget and personnel decisions by DOT • County planning board considerations of wildlife linkage in long-term planning and subdivision approval considerations • Congressional support for linkage area identification, management, monitoring and evaluation in federal agency budgets • County commissioner support for linage planning and implementations

The CSKT, MDT, and FHWA have a variety of viewpoints about what "success" or "effectiveness" may look like once the mitigation measures are established. To understand the range of views from agency personnel, WTI sent out a survey to the US 93 Technical Design Committee members, as well as other key staff involved in the US 93 reconstruction efforts. Three people from MDT, two from CSKT, and one from FHWA provided feedback to the survey. Responses to the open-ended question: "*Are there other ways you might deem (the wildlife mitigation efforts) "effective" (or not)?*" reflected a range of viewpoints, as follows:

- "…individual crossing areas should be viewed independently based not only on effectiveness from a safety standpoint but also biological standpoint. Effectiveness based upon what is necessary to maintain local populations and structure over time. But if the local populations are already healthy and functional, then it may be necessary to consider the effectiveness of the structure purely on animal-vehicle collision reduction basis. Bottom Line, from my standpoint, I feel effectiveness should not only be based upon safety issues (reductions in animal-vehicle collisions) but also, are we allowing for connectivity of local populations so that they can maintain or increase in numbers and have stable structure without adverse effects to available habitat";
- "As long as we learn better ways to handle animals and vehicles and can apply what we learn on other projects both within and outside Montana it will be an effective experiment";
- "I believe that any change is worth the investment. While not a wildlife expert, I believe any change, no matter how long it takes is worth the investment. I feel it's about time we construct human transportation corridors that respect wildlife transportation corridors, especially when we superficially enhance the ability for human to travel at break neck speeds, burning finite resources and altering out global climate and local ecosystems";
- "A benefit / cost ratio of greater than 1 ($ value of benefit divided by $ value of costs). It will be very important to determine this value by using benefits and costs as measured in dollars. Utilizing or developing various methodologies for conducting a true benefit/cost analysis for these types of measures is essential to be able to justify the expenditure of public funds";
- "Acceptance by CSKT. The main intent of these crossings is to support cultural values held by CSKT and others. Any decrease in mortality or increase in wildlife usage will be considered a success"; and
- "We need to be open to the idea that effectiveness will likely increase as time passes after construction. Initial results may not tell us much. Additionally, time for habitat and cover development must be included into the equation -- these factors will also require time".

Recognizing that different viewpoints and values are equally valid, the raw results, with no judgment of the outcome, need to be presented to allow independent assessments of effectiveness based on individual values. However, it is equally important to set reasonable and measurable targets defining desirable or undesirable outcomes that justify and defend management decisions in order to be accountable to the public.

Effectiveness relates to some "desired outcome" based on values; however, determining if there is an *effect* that may be attributable to a specific change (e.g., the installation of mitigation measures) is an important component of determining effectiveness. Effect in this context refers to a change that may be measured statistically and/or biologically. A statistical *effect* (e.g., a detectable reduction of deer-vehicle collisions by 35%) may not be considered *effective* by parties wanting to see a reduction by 50% or greater. Other parties may consider an *effect* of a reduction in deer-vehicle collisions by just 1% *effective* if they highly prize the value of the animals and/or human safety risks. A statistically detectable effect may or may not be biologically significant; i.e., just because a change was measured does not necessarily mean it will have biological impacts on the population or community of interest. Conversely, it is possible to have biologically significant effects or changes within the population of interest that are not statistically detectable, an unfortunate outcome for imperiled populations if managers do not recognize the potential for this outcome.

Many factors influence whether actual effects may be detectable. With large sample sizes, applied statistics may detect significant effects to a fraction of a percent – an effect size that may be too small to be biologically significant. On the other hand, in cases with small sample sizes (i.e., rare or elusive species), a statistical effect may only be determined after very large changes, and a statistically insignificant change may be very biologically significant (Taylor and Gerodette 1993). As more data is amassed, variability in the dataset may decrease, which increases the ability to detect statistical differences in the response variable. Additionally, as one agency respondent mentioned above, time will likely affect the outcomes observed as animals adjust their navigation patterns to a landscape with wildlife fencing and crossings. Hence, the data may reveal different outcomes at several different points in time.

Finally, no matter what effect may be measured, especially in ecological field studies, it can not be considered "proof" of a simple "cause and effect" relationship (Neter et al. 1996). Other variables such as population fluxes, unusual weather events, increases in traffic volumes or changes in observed speeds need to be assessed to understand how these factors may contribute to observed changes in the response variable. In the case of the US 93 evaluation, routine evaluation of the parameters of interest along with a handful of other potentially influential variables will help interpret how the mitigation measures influence local deer and black bear populations over time.

In the context of the parameters of interest for the US 93 evaluation study, effects pertain to a measurable change in deer- and bear-vehicle collisions and deer and bear highway crossings. Differences in sample sizes for these two species allows for quantitative considerations when determining MOEs for deer-vehicle collisions and highway crossings, but bear MOEs for these parameters of interest are limited because of small sample sizes. Three measures of effectiveness are assessed relating to biological, economical, and public safety interests. The following sections discuss recommendations for post-construction monitoring and suggested measures of effectiveness for the primary parameters of interest. Additional post-construction monitoring recommendations for other confounding variables that need to be accounted for are also outlined.

7.2. Animal-Vehicle Collision Post-Construction Monitoring

The preconstruction AVC data were obtained from MDT's Traffic Safety Bureau, including AVC reports from the Montana Highway Patrol (MHP) and carcass removal reports from MDT's Maintenance Division. Additional data on black bear road kill were obtained from Montana Fish, Wildlife and Parks. Although there are recognized limitations to using these data, they were consistently collected over the years immediately prior to reconstruction, they did not expose field staff to additional safety risks, and MDT and MHP made these data readily available for the purposes of this evaluation study. Additionally, the reporting systems used to compile these data will continue to be used during and after reconstruction. Therefore, it logically follows that the post-construction AVC dataset including MHP AVC and MDT carcass removal reports should be used for assessing potential changes in AVCs.

Maintaining current level of effort in AVC and carcass removal reporting will be vital to effectively compare the pre and post-construction dataset. Increasing effort will bias the post-construction road-kill counts high, while decreasing search effort could result in “false success.” An annual memorandum from MDT Maintenance Division reminding maintenance crews to continue to report carcass removals *with the same effort as has been applied since 2002* may help maintain consistency (there is also the valid concern that such “reminders” cause an inadvertent increase in reporting; it is difficult to say what might be the best technique to continue uniform effort over time).

One concern with measuring effectiveness based on trends of AVCs is that animal populations fluctuate, and AVCs may be correlated with such fluctuations. A sharp increase or decrease in animal populations could therefore result in more or fewer AVCs independently of the effects of crossing structures. This potential confounding factor was not unrecognized. When analyzing deer-vehicle collisions, the post-construction data must be at least qualitatively compared to concurrently-collected pellet data, as pellet data provide an index to population fluctuation (Murray et al. 2002, Krebs et al. 2001, Massei et al.1998, Harestad and Bunnell 1987). Although there was no corresponding index for black bears, this again underscores the importance of collecting more detailed data through a companion telemetry study.

7.2.1. Deer-Vehicle Collisions

Measures of effectiveness regarding deer-vehicle collision (DVC) data depend on two factors: the perceived change in DVCs together with the change in local deer populations. It is possible that an increase in deer populations could result in an increase in DVCs, even if crossing structures are effective, resulting in the false conclusion that crossing structures did not work. The reverse conclusion could also apply. Therefore, it is insufficient to draw measures of effectiveness from trend in DVCs alone. The below measures based on DVCs should be compared to the pellet transects to provide the vital link to population numbers. All post-construction analysis of DVCs should be compared to pellet data to interpret changes.

Preconstruction power analyses of the deer-vehicle collision (DVC) data for the entire study area indicated that a 35% change in DVCs per mile per year would be detectable after 3 years of post-construction data collection, and a 22% change would be detectable after 5 years of post-construction data collection. These power analyses assumed equal variance in year-to-year DVCs in the before and after construction years. Greater variability in the post-construction AVC dataset would require a greater change in AVC rates and/or longer monitoring to statistically detect this change while less variability would result in smaller detectable changes or fewer monitoring years required to detect such a change.

7.2.1.1. Determining Statistically Significant Effects

To determine the effectiveness of the proposed mitigation measures on the safety, economic, and biological impacts of DVCs, a helpful first step is to quantify the effect of mitigation on DVCs. The most straightforward approach would be to use a one-sided t-test to compare pre and post-construction DVCs across the entire study area to determine whether a decline occurred. Additional analyses to account for other variables (e.g., population fluctuations, extreme weather events, habitat reduction, increases in traffic volume) will be important, as a statistical difference in DVCs between the pre and post-construction years does not necessarily imply a cause-and-effect relationship. The framework for hypothesis testing is outlined below:

- Null hypothesis: $(\text{DVCs/mile/year})_{pre} = (\text{DVCs/mile/year})_{post}$
    - If test fails to reject the null hypothesis, there is no statistically detectable change in DVCs before and after mitigation.
    - This outcome does not necessarily mean that there was no change in DVCs; it only means that the level of change was not statistically detectable given the variability of the data. Assuming variability in the post-construction data is the same as preconstruction variability, the power analyses using the preconstruction DVC data indicated the following:
        - If test is based on 3 years of post-construction data, a statistically undetectable change less than 35% may have occurred;
        - If test is based on 5 years of post-construction data, a statistically undetectable change less than 22% may have occurred; and
        - Additional assessment of the datasets may reveal outliers of DVCs before and after mitigation, and researchers can infer how these outliers may affect the means that were compared.
- Alternative hypothesis 1: $(\text{DVCs/mile/year})_{pre} > (\text{DVCs/mile/year})_{post}$
    - If the test supports this hypothesis, *fewer* DVCs occurred after mitigation than prior to mitigation
    - Assuming variability in the post-construction data is similar to preconstruction, the power analyses conducted with the preconstruction data indicated the following outcomes:
        - If test is based on 3 years of post-construction data, post-construction DVCs will have decreased by greater than 35% and
        - If test is based on 5 years of post-construction data, post-construction DVCs will have decreased by greater than 22%.

These tests will determine whether there was a statistically detectable effect and do not relate to biological or safety effectiveness. However, this information determines a lower boundary for designating MOEs. For example, a greater than 25% reduction in DVCs after three years would not be an appropriate MOE given that the smallest change detectable would have to be greater than 35%. If a 30% reduction in DVCs occurred, which would be considered effective based on the MOE, a false conclusion would be made saying the mitigation did not meet the MOE standards when, it actually did, simply because the test was unable to detect the change statistically. Therefore, based on statistical analyses, WTI suggests the lowest level of effectiveness considered for DVCs be based on a minimum of a statistically-detectable 35% reduction in DVCs.

7.2.1.2. Economic Measures of Effectiveness

These tests provided a framework to relate observed effects to economic measures of effectiveness. There was an average of 90 deer killed per year, as assessed over 4 years, with a minimum detectable difference of a 35% reduction in DVCs. Costs of the mitigation structures were assessed (Skillings and Connolly 2000) and monetary values of property damage, costs of human injuries and fatalities, costs of the deer as a hunted species, and costs of carcass disposal have been quantified in numerous sources. Synthesizing this information, it can be determined how much of a reduction in DVCs per year would pay for the cost of implementing the mitigation measures after how many years.

To lay the framework for an economic MOE, it is necessary to briefly recapitulate how the average costs for a deer-vehicle collision were calculated. The citations below were originally summarized in Huijser (2006).

- Costs of Property Damage:

  In Nova Scotia, the minimum percentage of white-tailed deer-vehicle collisions (*Odocoileus virginianus*) resulting in property damage was estimated at 90.2% (3524 collisions with property damage from 3905 collisions [Tardif & Associates Inc. 2003]). In Utah, this percentage was estimated at 94% (Romin and Bissonette 1996). For this analysis it was assumed the percentage of all collisions resulting in property damage to be 92% for deer.

  The property damage (repair costs for vehicle) was estimated at $1,200-$1,881 for deer in Utah and Vermont, in 1992 (Romin and Bissonette 1996), $1577 on average for different regions in the United States in 1993 (Conover et al. 1995), and $1,700 for deer in the Midwest, in 2002 and 2003. For this analysis it was assumed that the average vehicle repair costs as a result of deer-vehicle collisions were $2,000. Combined with the percentage chance that a collision indeed results in property damage, the average vehicle repair cost per deer-vehicle collision was estimated at $1,840.

- Costs of Human Injuries:

  An estimated 19,551 deer-vehicle collisions result in human injuries each year (average for 2001-2002; Conn et al. 2004). The percentage of white-tailed deer-vehicle collisions resulting in human injuries was estimated at 1.3% (Finland; Haikonen and Summala 2001), 3.8% (Midwest; 4,724 collisions with human injuries from 125,608 collisions [Knapp et al. 2004]), 4% (Ohio; review in Schwabe et al. 2002), 7.7% (Ohio; 10,997 collisions with human injuries from 143,016 collisions [Schwabe et al. 2002]), and 9.7% (Nova Scotia; 378 collisions with human injuries from 3905 collisions [Tardif & Associates Inc. 2003]). For this analysis it was assumed that a deer-vehicle collision resulted in an average of 0.05 human injuries.

In Canada, the costs to society of a human injury as a result of a traffic accident was estimated at CAN $97,000 (Sielecki 2004). In Alberta, the average net cost per human injury was estimates at CAN $22,961 (hospitalized) and $3,466 (emergency room only) (Jacobs et al. 2004). In the United States, the cost of a serious injury was estimated at $170,000 for a severe injury and $33,000 for a minor injury (Schwabe et al. 2002), $206,000 for an incapacitating injury, $41,000 for an evidential injury, and $22,000 for a possible injury (U.S. Department of Transportation, 2002). In New Mexico, Biggs et al. (2004) assumed an average cost of $10,000 per human injury, including medical expenses and lost work time. In Ohio, Wu (1998) estimated these costs at $34,000 for 1996. For this analysis it was assumed that costs of human injuries would average at a conservative $2,500 per DVC.

- Costs of Human Fatalities:

A study that used data from nine states (Colorado, Georgia, Minnesota, Missouri, North Carolina, Ohio, Pennsylvania, South Carolina and Wisconsin) found that 77% of all animal-vehicle accidents with human fatalities involved deer (Williams and Wells 2004). The percentage of white-tailed deer-vehicle collisions resulting in human fatalities was estimated at 0.009% (Ohio; 14 collisions with human fatalities from 143,016 collisions [Schwabe et al. 2002]); 0.029% (North America; review in [Schwabe et al. 2002]), 0.03% (Midwest; 33 collisions with human fatalities from 125,608 collisions [Knapp et al. 2004]), 0.05% (Nova Scotia; 2 collisions with human fatalities from 3905 collisions [Tardif & Associates Inc. 2003]). For this analysis it was assumed that a deer vehicle collision resulted in an average of 0.0005 human fatalities.

In the United States the monetary loss of a human fatality was estimated at $1,500,000 (Romin and Bissonette 1996), $2,393,000 (Schwabe et al. 2002), and $2,981,000 (U.S. Department of Transportation 2002). In Canada, the costs to society of a human fatality as a result of a traffic accident was estimated at CAN $4,170,000 (Sielecki 2004). In a review study Trawén et al. (2002) calculated the costs of a fatal casualty of road accidents in a wide range of countries, including the United States. They calculated the costs at about $3,600,000 for the United States in 1999. For this analysis it was assumed that a human fatality as a result of a deer-vehicle collision averaged $3,000,000 in costs to society, resulting in an average cost of $1,500 in human fatalities per deer collision.

- Costs of Deer Fatalities:

Animals usually die immediately or shortly after having been hit by a vehicle. In Michigan, Allen and McCullough (1976) estimated that a minimum of 91.5% of all white-tailed deer that were hit by a vehicle died at the scene or later. For this analysis we assumed that a deer-vehicle collision always resulted in the eventual death of the deer.

The monetary value of deer has many different components, including license fees, costs associated with hunting (materials, transport, lodging, meals), and recreational wildlife viewing. Hunting license fees in British Columbia were CAN $15-125 for deer for residents and non-residents respectively (Sielecki 2004). The net return to the economy of British Columbia from hunting was estimated at CAN $1,270-7,450 per deer (Sielecki

2004). The value of recreational wildlife viewing may be more difficult to quantify. The total net return to economy of British Columbia from recreational wildlife viewing was estimated at CAN $174,000,000 per year, but this included 681,000 individuals of various large mammal species, translating to an average value of CAN $255 per large mammal for recreational wildlife viewing (Sielecki 2004). In New Mexico, the minimum estimated income to the state as a result of hunting was estimated at $250 per deer, excluding hunter expenditures and associated economic benefits (Biggs et al. 2004). In Utah, Romin and Bissonette (1996) estimated the economic value of a deer at $1,313 in 1992. Bissonette and Hammer (2000) estimated the value of deer in Utah in 1999 at $2420. For this analysis we assumed that the total monetary value was $2,000 per deer.

- Removal and Disposal Costs of Deer Carcasses

  In Canada, carcass removal and disposal costs for animal carcasses were estimated at CAN $100 per deer (Sielecki 2004). In Pennsylvania, the average for deer carcass removal and disposal in a certified facility was $30.50 per deer for contractors and $52.46 per deer for the Pennsylvania Department of Transportation in 2003-2004 (Pers. com. Jon Fleming, Pennsylvania Department of Transportation). For this analysis we assumed that the removal and disposal costs of animal carcasses to be $50 per deer.

- Construction Costs

  Estimates of crossing structure and fence costs were prepared in the MOA by Skillings Connolly (2000). In several cases, crossing structures did not occur where the MOA recommended, and alternate structures appeared in preliminary and final plans. For these purposes, costs were estimated from measures of similar size and structure. Fish passages and small mammal passages (those measuring approximately 4' by 6') were not included, nor were mitigation measures on side roads off US 93. Bridges were considered multi-use, and not specifically to be installed for wildlife, so 1/3 of the total construction cost for bridges was considered. The total cost for mitigation construction was then $6.1 million dollars. This does not include upkeep or maintenance fees, or increases in construction costs.

The total value of an average deer-vehicle collision was estimated at $7,890 from the above information. The total construction costs relevant to deer crossing structures were approximately $6.1 million dollars. Given a current average of 90 DVCs per year, and a given reduction in DVCs (from 35% to 100%), yearly savings (in millions of dollars) was calculated for varying times post-construction (Table 17).

Table 17: Reduction in DVCs and corresponding savings in millions of dollars considering an average of 90 deer killed in the study area yearly and the average cost of 1 collision being $7,890. Grey shaded areas represent savings exceeding construction costs.

		SAVINGS					
% Reduction in DVCs	# Fewer DVCs	1 year	5 years	10 years	15 years	20 years	25 years
35%	31.5	$0.2	$1.2	$2.5	$3.7	$5.0	$6.2
40%	36.0	$0.3	$1.4	$2.8	$4.3	$5.7	$7.1
45%	40.5	$0.3	$1.6	$3.2	$4.8	$6.4	$8.0
50%	45.0	$0.4	$1.8	$3.6	$5.3	$7.1	$8.9
55%	49.5	$0.4	$2.0	$3.9	$5.9	$7.8	$9.8
60%	54.0	$0.4	$2.1	$4.3	$6.4	$8.5	$10.7
65%	58.5	$0.5	$2.3	$4.6	$6.9	$9.2	$11.5
70%	63.0	$0.5	$2.5	$5.0	$7.5	$9.9	$12.4
75%	67.5	$0.5	$2.7	$5.3	$8.0	$10.7	$13.3
80%	72.0	$0.6	$2.8	$5.7	$8.5	$11.4	$14.2
85%	76.5	$0.6	$3.0	$6.0	$9.1	$12.1	$15.1
90%	81.0	$0.6	$3.2	$6.4	$9.6	$12.8	$16.0
95%	85.5	$0.7	$3.4	$6.7	$10.1	$13.5	$16.9
100%	90.0	$0.7	$3.6	$7.1	$10.7	$14.2	$17.8

The structures that will be built vary greatly in size, construction and maintenance needs. Based on the MDT Road Design Manual (2000), mainline pipes (culverts) should have design lives of approximately 75 years. WTI economic projections extend only 25 years, after which even the lowest detectable level of DVC reduction essentially pays for the construction costs of the mitigation structures. Note this analysis relates only to expenses associated with deer-vehicle collisions; larger mammals such as moose and elk incur greater expenses per collision, therefore it would be expected that an even smaller reduction in collisions could pay of the expense of the mitigation sooner than what is reported above.

7.2.1.3. Other Measures of Effectiveness

Determining biological effectiveness is not always as simple as determining a minimum detectable effect. If the focal species were threatened or endangered, population viability analyses could be run to determine population sizes and requirements for genetic exchange with adjacent populations. However, US 93 highway is not considered to be a significant threat to the long-term viability of local deer populations, which are numerous enough to sustain hunting harvest. To prevent US 93 from becoming a threat as the road is widened and traffic levels increase, biological effectiveness for deer can be inferred as long as two factors are met. First, and most importantly, safe deer movement across the highway must not be impeded; rather, such movement should be encouraged. Secondly, any reduction in DVCs could be considered effective as long as some level of movement across the highway is maintained.

Based on other data (see above), this analysis assumed that 5% of deer-vehicle collisions resulted in human injury. Such injuries ranged in severity from $10,000 to $206,000 in hospital costs and lost work time (Biggs et al. 2004, Schwabe et al. 2002). This translates to 4.5 human injuries of varying severity each year. If DVCs were reduced by 35%, 3.0 human injuries would occur each year on average. A 75% reduction in DVCs reduces the number of human injuries to 1.0 each year on average (Figure 26). For this analysis, it was assumed that 0.05% of all deer-vehicle collisions would result in one human fatality. This translates to one human fatality due to a DVC every 20-25 years. A 35% reduction in DVCs reduces this to 1 fatality every 30-35 years. A 75% reduction in DVCs would reduce this further to 1 fatality every 85-90 years.

7.2.2. Bear-Vehicle Collisions

Quantifying measures of effectiveness for black bear ecology is more challenging compared to establishing MOEs for deer. It is difficult to demonstrate statistical significance in situations where populations are small or dispersed (Taylor and Gerrodette 1993), but these are often the populations most in need of conservation attention. Large-bodied carnivores tend to have larger home range sizes, and can be especially susceptible to habitat fragmentation (Proctor 2003, Noss et al. 1996). Species with low population growth rates, like black and grizzly bears, are highly sensitive to survival of adult females (Heppell et al. 2000). Often, the loss of just a few adult females can be the difference between a growing or declining black or grizzly bear population (Hebblewhite et al. 2003, Freedman et al. 2003, Kasworm et al. 1998).

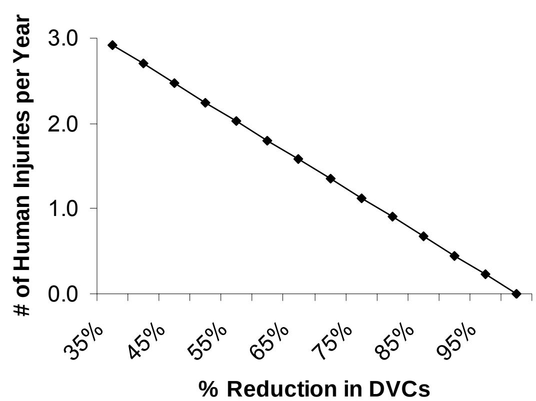


Figure 26: Hypothetical estimated reduction in human injuries per year associated with different levels of reduction in deer-vehicle collisions along US 93.

Given these concerns, promoting safe passageway across US 93 is especially important for black bears. However, measuring change between pre and post-construction bear-vehicle collisions (BVCs), bear-highway crossings, and levels of genetic variability will be difficult. Over 1995—2005 (using data from MTFWP, MDT and MHP), the mean number of black bears killed by vehicles over the entire US 93 study area per year was 2.91 (95% C.I. = 1.15, 4.67). These scant occurrences, and this wide variance, did not provide a dataset appropriate for power analyses. In such a case, statistical significance regarding a decline in black bear collisions is not likely to be achieved.

The preferred approach to assessing effect and effectiveness of mitigation structures on decreasing black bear kills is to repeat the intensive study run by McCoy (2005). McCoy used genetic methods to count a minimum of 83 individual black bears in the US 93 corridor in 2003 and found 10 and 11 road killed black bears in 2002 and 2003, respectively. The majority of these mortalities were sub-adult males, which have less effect on population growth rate than females. Nonetheless, a closed black bear population (i.e., an isolated population with no immigration or emigration of bears) of 83 would have to grow at more than 14% a year to offset these mortalities in order to maintain a similar number of bears in the population over time. It is theoretically possible for black bear populations to grow at 20% a year (Freedman et al. 2003), but this rate is exceptionally high, and realization of such a rate would occur only in ideal conditions without highway mortality, management mortality, hunting mortality, or competition with grizzly bears.

Using these figures to consider the biological significance of road kill bear mortalities, if road kill rates similar to McCoy's (2005) observations continue in combination with mortalities associated with management removals, hunting and conflicts with grizzly bears, a population decline could result, unless the population is bolstered by immigration of black bears from other populations or if the reproductive rates exceed a 14% increase a year. With the goal of sustaining the black bear population, reducing black bear mortality due to road kill is a necessity, unless all other mortalities are eliminated, an unrealistic scenario. With only 2 years of observations, the lack of degrees of freedom eliminates the ability to statistically compare preconstruction to post-construction road kill bear mortalities. However, the assumption that a 50% reduction in bear kills would benefit the population can be justified as a reasonable measure of effectiveness that could help sustain this population. Therefore, if post-construction bear-vehicle collision search efforts similar to McCoy (2005) find an average of 5 or less bear-vehicle collisions per year, assuming the population hasn't plummeted and is not imperiled, the mitigation could be deemed effective with the knowledge that the reduced mortality will help sustain this population over time. If post-construction bear counts appear to be significantly lower than preconstruction counts, it may be appropriate to set a measure of effectiveness for fewer black bear road kill mortalities since the biological implications of any road kill mortalities could have a significant additive effect on these population reductions, especially if any females are hit by vehicles.

This is a simple and ultimately qualitative and subjective approach to establishing measures of effectiveness for black bears, but the basic logic behind this goal is reasonable and justifiable. More complex quantitative measures of effectiveness could be explored via population viability analyses and more intensive data collection to assess what other parameters may affect the bear population in order to understand how the reduction of road kill fits into a complex relationship of many variables that influence this population of black bears that reside in and around the US 93 highway corridor.

7.3. Habitat Connectivity: Wildlife-Highway Crossing Post-Construction Monitoring

For post-construction monitoring, WTI collaborated with the US 93 Technical Design Team to incorporate track beds both inside and just outside of each crossing structure as well as at the ends of the long sections of fencing and on the jump-outs. Track beds outside crossing structures will provide data that are comparable to the preconstruction track bed data because the exposed track beds are subject to environmental conditions that likely result in the loss of legible tracks if rain or wind obliterate the imprints, and can be compared to track observations from the sheltered track bed inside the crossing structure to determine average error rates to fine tune the preconstruction track observations.

Theoretically, post-construction track beds inside the crossing structures will capture tracks of all deer and bear movements through crossing structures. In combination with observations of deer movements around the ends of the fence, the track data will essentially "census" all movements from one side of the road to the other, with the exception of deer and bear that breach the fence and escape from the fenced right-of-way without using the jump-outs. Total crossings measured via post-construction tracking methods will be compared to the estimated total preconstruction crossings extrapolated across the stretches of roads that will have contiguous fencing installed. Additionally, wildlife movements around the ends of the fences will be taken into account in conjunction with an assessment of post-construction deer-vehicle collisions when determining the effect of the mitigation measures. Although these observations indicate deer are moving from one side of the road to the other, fence end crossings could result in hotspots of wildlife-vehicle collisions at the ends of the fences.

Power analyses indicated the ability to detect a 153% change in deer crossings and an 807% change in bear crossings after 3 years of post-construction study across the three study areas combined. With 5 years of post-construction study, a change of 60% could be detected in deer crossings, and 318% could be detected in bear crossings. This was using a two-sided hypothesis, assuming that wildlife crossings could increase due to the presence of safe crossing structures or decrease if deer and bear do not adapt and learn to use the crossing structures.

It is possible that smaller changes in deer crossings may be detectable if the variance is reduced from what was observed in the preconstruction crossing estimates. However, a 60% detectable reduction in deer crossings may be considered a biologically significant, negative impact, even for a population that is not imperiled or threatened. Therefore, given the preconstruction power analyses results, WTI proposes that 1) no change or b) any increase in deer crossings be deemed a success; if a reduction in deer crossings is detected, the mitigation measures will not have achieved the desired effect of maintaining habitat connectivity for deer. Five years of monitoring are required to measure this.

Estimating changes in highway crossings by black bears will require more detailed attention due to low frequency and high variability in crossing rates as observed by the tracking index. McCoy (2005) used GPS collars (taking hourly fixes) to monitor black bear movements through the highway corridor and to quantify individual highway crossing rates and the proportion of collared black bears that crossed the highway. Of the collared bears monitored in that study, McCoy (2005) found 187 highway crossings of US 93 by 10 of 18 collared bears (55%). She also found that age, sex, and whether bears were habituated or food-conditioned contributed to observed highway crossings. Again, WTI recommends that a companion study to McCoy (2005) be conducted after construction to measure post-mitigation bear movements to compare to McCoy's (2005) preconstruction findings to infer effects of the mitigation. Taking into account changes in the population (another metric to be measured post-construction via genetic hair sampling to determine a minimum number of bears in the study area), one measure of mitigation structure effectiveness may be if post-construction crossings are similar to preconstruction crossings. Greater success could be inferred if crossing rates increase.

Habitat connectivity is vital for maintaining genetic flow between populations and preventing isolation. Statistical assessment of genetic difference between black bear populations on either side of US 93 will also be challenged by low power to detect changes. Although McCoy (2005) established a baseline heterzygosity (genetic variability), at the time of study, there were only 6 locations (called microsatellites) that used to detect variability. This, combined with the long generation time of black bears, will result in statistical difficulties to determine trends. However, to determine effectiveness based on genetic data only, the "one migrant per generation" rule may be sufficient in many scenarios (Mills and Allendorf 1996). For fluctuating populations or those violating the assumptions of Hardy-Weinberg equilibrium (i.e., population is not closed, mating is non-random, etc.), up to 10 animals may be needed to maintain current levels of genetic diversity (Vucetich and Waite 2000, Mills and Allendorf 1996). Therefore, WTI recommends that one measure of effectiveness be set at a minimum of at least 10 different individual bears, including at least one female bear, successfully crossing US 93 annually after the road mitigation is installed. However, the minimum amount of movement to maintain genetic viability is not necessarily enough for some metapopulations to persist (Akçakaya et al. 1999); therefore this measure of effectiveness must be interpreted with caution.

Waiting for a period of time (at least 2-3 years) after the mitigation is installed to repeat the black bear study is advised to give bears time to acclimate to the mitigation. Bear crossings are likely to decrease immediately after the construction as bears have yet to learn how to navigate through this new landscape with fencing and crossing structures. After a few years, bears will likely have adjusted their travel routes and study results will be more representative of the long-term effects that the mitigation may have on this bear population.

7.4. Post-Construction Photo-Monitoring Recommendations

Photo monitoring of the crossing structures will be used to quantify wildlife movements through crossing structures and to estimate potential error rates of track bed observations, which may occur if numerous animals move through a structure and obliterate previous tracks. Additionally, photo monitoring can allow for identification of individual animals that may have unique marks or patterns on their coats (Karanth and Nichols 1998). One animal crossing 100 times is less desirable than 10 individuals crossing 10 times; photo monitoring may allow researchers to determine to what degree the data are influenced by repeated crossings by individual animals.

Photo monitoring also is advantageous because species confirmation is more reliable than on track or sign only (Swann et al. 2004). Photo monitoring would allow differentiation of mule deer and white-tailed deer, while tracking surveys cannot. If remote cameras are carefully selected and placed, they ought not to alter animal behavior.

Remote cameras are available with a wide variety of features and abilities, and careful selection of cameras is necessary to ensure that the data will be usable and meet the objectives. For these purposes, the following criteria are most important:

- Reliable time and date stamps captured on all photos;
- Theft-resistance, as cameras will be in high-use areas;
- Flash and sound that do not alter animal behavior;
- Fast trigger time to capture quick-moving animals;
- High storage capacity so that data are not lost between visits;

- Long battery life so that data are not lost between visits; and
- High durability and weatherproofing so that units can be used for years.

In the context of this project, digital cameras are preferable to 35mm film models for several reasons. Digital cameras can store up to 1,500 images while 35mm cameras are limited to 36 exposures. Digital cameras store photos on re-usable memory cards, which can be downloaded onto a computer and catalogued without any additional processing costs, while 35mm cameras require film canisters and high development costs. Price differences between comparable digital and 35mm units range from $50-$200. The higher initial costs of digital cameras are quickly offset by their low maintenance costs, not having to purchase and develop film, and their expanded storage abilities.

A number of available camera systems were researched based on the above criteria by interviewing five wildlife biologists who have employed various camera systems and reading web-logs and websites dedicated to game cameras and reviews by users. The camera system that received the strongest recommendations from other researchers was the Reconyx digital camera. This system offers infrared flash, silent operation, very fast trigger time, long-battery life (although an upgrade to rechargeable batteries was recommended), quality weatherproofing, a wide range of operating temperatures (-20F to >100F), and easily modification to lock it securely and prevent theft. This system comes with software that allows easy downloading, categorization and filing of a large number of photos, a very desirable feature for a long-term study. Reconyx cameras are used by University of Montana and Dr. Anthony Clevenger in Banff National Park wildlife-highway research projects and predator exclusion studies. These camera systems cost $1,199.99, and are offered at 10% discount with a purchase of 10 or more.

Although fewer researchers supported the mid-range units, several received good reviews by on-line web logs and websites devoted to game cameras. The Cuddeback and Recon Talon are two models that are comparable in cost at $399 each. The Cuddeback offers a faster trigger time, but does not have the IR flash. The Recon Talon does have the IR flash, and its software may allow updates to have a faster trigger time. A University of Montana researcher used the Recon cameras with good success, but noted that they did not perform as highly as the Reconyx cameras. A Colorado lynx biologist used Cuddeback cameras, and was pleased with the unit except that it would occasionally fail in cold temperatures. Both the Cuddeback and Recon use memory cards (up to 512mb) that allow fast and easy download of pictures onto a PC or laptop.

An optimal photo monitoring sampling design would include using digital cameras in each wildlife crossing structure for the duration of the post-construction study. Rotating cameras between crossing structures would result in less data gathered overall, and therefore higher variance and lower power to detect differences. Further, rotating cameras could result in a seasonal bias in data collection, and would require more personnel time to move the cameras. WTI recommends using higher-quality digital cameras to ensure accurate results. Using high-quality cameras at all crossings may also allow field personnel to dedicate more time to track monitoring at the ends of the fences and on the jump-outs.

7.5. Pellet Transect Population Monitoring

Population monitoring is intended only to track trends in deer population numbers; therefore, there are no associated MOEs for this parameter. However, for the method to yield effective data that can be used to understand how population fluctuations may affect what is observed in the parameters of interest, post-construction monitoring is essential.

It is important to monitor deer population trends to understand what changes in deer-vehicle collisions and highway crossings might be attributable to the mitigation versus changes in the population. Unless there are adequate post-construction monitoring funds to conduct a mark-resight population estimate study for deer, it is recommended that pellet transect monitoring be continued on an annual basis. While recognized as a crude index, it can detect relative changes in the deer population over time, an important consideration when determining whether changes in deer-vehicle collisions or deer crossings are due to the mitigation or changes in the population.

7.6. Traffic Monitoring

Similar to population monitoring, defining an MOE for traffic levels is not appropriate. It is expected that traffic levels will increase given that the reconstruction aims to increase traffic capacity. Further, speeds may increase with the reconstructed road that includes passing lanes and wider shoulders. Traffic levels and speeds may affect focal species movements, but with the introduction of measures that separate crossing movements from traffic, it is possible that the influence of this variable is reduced. Continued traffic monitoring either using pneumatic tube traffic counters or using MDT automatic traffic recorder data is recommended throughout the post-construction monitoring study in order to assess this relationship.

7.7. Recommendations for Crossing Structures on Fish Bearing Streams

A generalized MOE for fish passage is recommended. If post-construction monitoring reveals no leap or velocity barriers and fish passage is attained, it is suggested that the reconstruction of these culverts be considered effective.

Monitoring new culvert installations will provide information about how these crossings maintain conditions that promote and ensure fish and other aquatic organism passage. How new crossings perform over time, especially through a large flow event, will provide invaluable insight towards future design, construction and maintenance practices. Monitoring of these structures can be accomplished in several ways. Table 18 summarizes several monitoring options that exhibit a range of complexity, cost and effort.

Table 18: Potential post-construction monitoring scenarios to assess fish passage performance at newly constructed water passageways.

Monitoring Scenario	Activities	Level of Effort	Quality of Information	Estimated Cost per monitoring year*
1	Standard inspections by MDT maintenance or equivalent crews	Low	Low	Standard Operating Procedures (no additional cost)
2	Hydraulic and geomorphic data	Medium	Medium to High	$20,000 to $40,000 annually
3	Hydraulic, geomorphic, and biological data	High	High	$40,000 to $80,000 annually

*Estimated cost based on two people monitoring at 30 crossing structures on the U.S. 93 corridor.

The first monitoring scenario involves qualitative reporting of culvert performance based on standard inspections and maintenance by MDT personnel along roads. This scenario does not include any additional effort beyond that which the MDT maintenance personnel already perform.

The second monitoring scenario suggested above includes collection of basic geomorphic data that can be compared to the same metrics measured prior to reconstruction. Monitoring should be performed at low flow, after each spring runoff cycle, on an annual basis at each crossing. Data collection should include consistent measurements of the downstream outlet area of each culvert (treatment reach) and a minimum of two areas in the natural stream outside the hydraulic influence of the culvert (control reaches). Benchmarks on either side of the stream in all reaches should be constructed, and a stream cross section should be measured between these bench marks. The performance of the culvert over time will be assessed by comparing the rate of geomorphic change from one year to the next between the control and treatment reaches.

The third monitoring scenario includes collection of a larger suite of hydraulic, geomorphic and biological data. Monitoring should be performed on an annual basis at each crossing when the flow allows easy and safe access to the stream and crossing. Data collection should include hydraulic/geomorphic data and biological data including the same sampling methods as detailed in the second monitoring scenario. Additionally, a longitudinal stream profile should be collected upstream and downstream of the culvert crossing. Each reach for the longitudinal profile should extend a minimum of two culvert lengths. Sediment samples following Wolman's pebble count method should be collected in the upstream and downstream reaches. The biological data set should include an annual mark-recapture assessment following the methods used in the preconstruction study. The performance of the crossing over time will be assessed by comparing the suite of hydraulic/geomorphic data between reaches and by the results of the mark-recapture assessment. These data will provide complementary information about the crossing performance over time.

7.8. Post-Construction Monitoring Schedule

The collection of AVC data will occur throughout construction and after construction. Other monitoring efforts will need to be initiated at an appropriate time after the mitigation is installed. Considerations should be given to *when* the collection of monitoring data will represent wildlife responses characteristic of what might be seen over the long term. If sampling of some variables, such as wildlife crossing structure use, were to occur immediately after the construction, there may appear to be a lack of effectiveness given that animals may take some time to learn how to navigate across the landscape with new fencing and crossings. However, if the resources are available to initiate wildlife crossing structure monitoring immediately after construction and continue regular monitoring for at least five years, it would be informative to see what the "learning curve" may be for wildlife to adapt to the mitigation.

Because the US 93 project is being constructed in phases, monitoring may also need to be initiated in phases. Appendix G provides an overview of the construction schedule, along with a proposed schedule for the various recommended post-construction monitoring methods. In summary, the WTI recommends the following schedule for post-construction monitoring:

- Continued, consistent AVC and road kill carcass removal reporting by Montana Highway Patrol and Montana Department of Transportation maintenance staffs throughout the construction and for at least 5 years post-construction;
- Consider an initial analysis of effects of the mitigation on deer-vehicle collisions only after all reconstruction across the entire area (excluding the Ninepipes reconstruction section) have been completed for at least three years;
- Annual pellet transect monitoring throughout construction and post-construction monitoring years to establish an index that will show long-term trends in the deer populations in the highway corridor;
- As wildlife crossings are installed and completed, photo-monitor crossings to document what and how quickly different species of animals learn to use the structures in order to:
    - o Pilot the camera equipment set-ups to ensure methods are fine-tuned for the long-term monitoring and
    - o Provide initial feedback to the public in an effort to be accountable to the inevitable queries regarding this high-profile project;
- Once all structures and fencing are installed, step up monitoring efforts to include track bed monitoring to complement the photo-monitoring for at least 3 years;
- At the earliest, repeat the fish passage hydraulic assessments one year after construction of these crossings is completed;
- At the earliest, repeat the bear study two years after construction is completed in the three focal study areas (Evaro, Ravalli Curves, Ravalli Hill);
- At the earliest, repeat the turtle study in the Ninepipes two years after that section has been completely reconstructed;
- At the earliest, repeat the in-depth deer-vehicle collisions study to assess what road, mitigation, and landscape features influence deer-vehicle collisions after all sections of

the reconstruction (excluding the Ninepipes section) have been completed for five years, in order to be comparable to the preconstruction analyses and dataset; and

- Monitor traffic speeds and volumes after construction is completed for each section for the same amount of time that monitoring of other parameters is occurring.

8. CONCLUSIONS

The US 93 reconstruction project on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to occur in the continental United States. The reconstruction will include installations of 42 fish and wildlife crossing structures and approximately 15 miles (24 km) of wildlife exclusion fencing for a total investment of over $9 million. This report documents the success of using a context-sensitive approach to collaboratively redesign a rural highway that accommodates the needs and concerns of different institutions, cultures and priorities. Further, this report introduces baseline field data collection methods and results that are being used to evaluate how the wildlife crossing structures and wildlife fencing affect animal-vehicle collisions (AVCs) and wildlife movements in a multiple-use rural landscape. The preconstruction data summarized here, and in combination with complementary post-construction data, address the following goals of the evaluation study:

- Determine what effect US 93 wildlife crossing structures and fencing have on the frequency of animal-vehicle collisions and successful animal highway crossings;
- Document the design decision-making processes and lessons learned as a "case study"; and
- Identify best management practices and further research.

The ultimate value of the information in this report will be realized when the reconstruction is complete and post-construction field data is collected to comparatively assess the effect of the wildlife mitigation on the parameters of interest identified in the goals. As a stand-alone document, this report provides an overview of important considerations related to locating, designing, and evaluating the effectiveness of wildlife crossings and exclusion fencing. These issues are addressed via a literature review, case study and project history, summary and synthesis of field data collection efforts, overview of other relevant and repeatable field studies, and a discussion about the measures of effectiveness and post-construction data collection recommendations.

8.1. Literature Review

General conclusions from the literature review include:

- Wildlife exclusion fencing is a promising method for improving driver safety and reducing AVCs;
- Wildlife exclusion fencing in conjunction with wildlife under- and over-passes may restore, sustain, or even improve, habitat connectivity;
- A combination of methods (e.g., road-kill locations, habitat evaluation, radio-telemetry monitoring, multiple-species monitoring) should be used to determine optimal locations for wildlife crossing structures;
- A variety of methods can be used to conduct a successful field evaluations, including collision data, tracking beds, video monitoring, radio-telemetry,, DNA assignment testing, and fecal stress measures; and

- The need to conduct preconstruction as well as postconstruction data collection was apparent.

The Literature Review focused on published papers addressing methods and considerations for locating, designing and evaluating the effectiveness of wildlife crossing structures and exclusion fencing. Although numerous techniques have been applied in an attempt to reduce AVCs, wildlife fencing appears to have the most promise for improving driver safety; equally important, when appropriately designed and placed wildlife under- and overpasses are used in conjunction with wildlife fencing, habitat connectivity may be sustained, restored or improved for long-term sustainability of wildlife populations.

Different species of wildlife prefer different characteristics that may be incorporated into passage structure designs and wildlife exclusion fencing further ensures animals will be prevented from crossing the road at-grade while simultaneously guiding or funneling wildlife movements to the crossing structures. Several methods can be used to determine optimal locations for wildlife crossing structures; using a combination of these approaches in order to "cross check" outcomes and defend decisions to install wildlife mitigation on highway reconstruction projects is advised.

Monitoring of wildlife passage systems is necessary for assessing effectiveness and to build understanding of and evidence for efficient and effective approaches to reducing animal-vehicle collisions and maintaining wildlife habitat connectivity across landscapes. Steps for conducting field evaluations, including identified successful methods, such as collision data, tracking beds, video monitoring, radio monitoring of animal movements, DNA assignment testing, and fecal stress measures, were reviewed; the need to conduct more pre- and post-construction comparative studies was emphasized in the literature.

8.2. The U.S. 93 Planning Process Case Study

General conclusions from the U.S. 93 planning process include:

- This level of wildlife-sensitive highway design effort is unprecedented in the continental U.S.;
- A context-sensitive approach was vital for planning between the Tribes, the state, and the federal governments; and
- The TDC provided cohesive efforts to steer the project and achieve consensus on areas of dispute.

Researchers documented the US 93 reconstruction efforts as a case study to highlight the history of the project and its challenges, as well as the different points of view and approaches that shaped the planning and design process. In the early 1980s, the Montana Department of Transportation (MDT), the Confederated Salish Kootenai Tribes (CSKT or "the Tribes") and the Federal Highway Administration (FHWA) recognized the need to increase the level of service and safety for US 93 on the Reservation. The three governments did not, however, initially agree on the design concepts for reconstructing the road. After a long planning process, many challenges were overcome as stakeholders worked together to understand, respect and trust each other, ultimately a key to the success of this project.

Stakeholders adopted a context-sensitive approach that considered the landscape, people, and cultural values in addition to safety and level of service. Central to the approach was the concept that "The road is a visitor": not only should the highway be safe and accommodate increasing traffic volumes, but US 93 should also respect and reflect the landscape and natural and cultural values of the Tribes.

These concepts and philosophies were documented as design concepts that made up the tenets of a Memorandum of Agreement (MOA) that the three governments collaboratively followed through the design process. A Technical Design Committee (TDC) was formed of members of the three governments to ensure that the design development process proceeded in accordance with the MOA. This TDC worked closely and regularly to steer the project and resolve any disparities by working to achieve consensus by finding reasonable solutions that all three parties could agree upon. The TDC guided the design details for the installation of the 42 fish and wildlife crossing structures and approximately 15 miles (24 km) of wildlife exclusion fencing.

8.3. Preconstruction Data Collection

General conclusions from the preconstruction monitoring include:

- The average annual number of reported deer-vehicle collisions (DVCs) for US 93 from Evaro to Polson during the 2002—2005 preconstruction years was 90 (95% confidence interval [C.I.] = 82, 98);
- A 35% decline in DVCs will be detectable after 3 years of post-construction study, and a 22% decline after 5 years of study;
- The mean number of black bears killed by vehicles from 1995—2005 on US 93 between Evaro and Polson per year was 2.91 (95% C.I. = 1.15, 4.67);
- With small sample sizes, there is little statistical power to detect changes in pre- and post-construction bear-vehicle collisions;
- The estimated total number of deer crossings of US 93 between June and October 2003—2005 in the areas that will receive wildlife fencing ranged from 1521 to 1932;
- The estimated total black bear crossings in the same area ranged from 33 to 165;
- The Evaro study area had significantly more deer pellet groups than the Ravalli Curves or Ravalli Hill study areas in both 2004 and 2005;
- The black bear radio telemetry and DNA study indicated the highway may be a barrier to some segments of the black bear population, but it is not currently a barrier to gene flow; and
- Each culvert was a partial fish passage barrier at certain times of year.

The MOA also included a directive to evaluate the effect and effectiveness of the wildlife mitigation investments. To meet this directive, the preconstruction monitoring study documented in this report was initiated in 2002 and post-construction monitoring would complement these efforts to comparatively analyze the effects of the wildlife crossings and fencing, with a specific focus on deer- and black bear-vehicle collisions and movements across the highway.

Preconstruction field data collection efforts focused on deer and black bear movements in the Evaro, Ravalli Curves and Ravalli Hill areas where the longest continuous stretches of wildlife exclusion fencing and crossing structures are planned. These data ought to be compared with post-construction monitoring of wildlife movements through the wildlife crossings and around the ends of the exclusion fences in these specific study areas; additional information may be gleaned from post-construction monitoring of movements through all crossing structures across the entire length of the project to address how other configurations of crossings with shorter segments of fencing may affect wildlife movements and AVCs. AVCs have been and continue to be reported across the entire US 93 corridor from Evaro to Polson, providing pre- and post-construction data that could form the basis for analyzing the mitigation effects on driver safety and wildlife-vehicle mortalities.

Researchers used several methods to establish the primary monitoring techniques applied to obtain baseline preconstruction deer and black bear behavioral and population data for the US 93 highway corridor. The documentation of quantity and location of AVCs were analyzed to understand how these data interacted with traffic activity patterns and volume, as well as to quantify statistical limitations of these datasets in order to determine appropriate measures of effectiveness and post-construction monitoring recommendations. Sand track beds were used to randomly sub-sample wildlife movements within the road verge in the Evaro, Ravalli Curves and Ravalli Hill areas. These observations provided representative observations of deer and bear crossings of the highway that were used to estimate total preconstruction crossing rates within the areas that will have the most extensive wildlife fencing. Results for the focal species and parameters of interest (deer- and black bear-vehicle collisions and cross-highway movements) are summarized below:

- <u>Deer-vehicle collisions:</u>
    - The average annual number of reported deer-vehicle collisions (DVCs) for US 93 from Evaro to Polson during the 2002—2005 preconstruction years was 90 (95% confidence interval [C.I.] = 82, 98). Based on these preconstruction data, it was determined that a 35% decline in DVCs may be detectable after 3 years of post-construction study, and a 22% decline after 5 years of study;
    - The average annual number of DVCs reported in 2002—2005 for the 8.7 miles (14 km) of US 93 where wildlife fencing is proposed was 11.8 (95% C.I. = 4.6, 18.9). This equates to 1.4 deer killed per mile per year (95% C.I. = 0.5, 2.2). These data had high year-to-year variance and only large changes may be statistically detectable in the areas to be fenced; e.g., a 241% change in kills per mile may be detectable after 3 years of post-construction monitoring, while a 151% change may be detectable after 5 years;
    - The annual average number of DVCs for the 44.9 miles (72.3 km) of US 93 that will not have wildlife fencing (including the Ninepipes section where reconstruction design plans have not yet been determined) was 78.3 (95% C.I. = 74.5, 82.0). This equates to 1.7 deer killed per mile per year (95% C.I. = 1.7, 1.8). With significantly more miles of road where no wildlife fencing will be installed, there was less variance in the annual reported DVCs outside the area that will have wildlife fencing such that smaller differences may be detectable in post-construction study. Outside the area that will be fenced, a 19% increase or decline in deer kills per mile would be detectable after 3 years of post-construction study, while a 12% increase or decline would be detectable after 5 years; and

    - There were several "hotspots" of DVCs across the study area. Two hotspots were identified at mile markers 33.6 and 34.5; both within 0.1 mile from where wildlife crossing structures will be installed, but the wildlife fencing extending from those structures will not cover those specific locations. An unmitigated hotspot occurred at mile marker 7.4, and several other hotspots (mile markers 37.5, 37.7-37.9, 39.8, and 45.6-45.8) occurred within the final section of US 93 within the Ninepipes National Wildlife Refuge on the Reservation which is planned for reconstruction upon the completion of a Supplemental Environmental Impact Statement.

- <u>Bear-vehicle collisions:</u>
    - The mean number of black bears killed by vehicles from 1995—2005 on US 93 between Evaro and Polson per year was 2.91 (95% C.I. = 1.15, 4.67). This figure includes data from 2002 and 2003, when 8 and 9 black bear mortalities due to collisions with vehicles were reported for each of these years, respectively; these higher numbers of reports were likely a result of more intensive monitoring for a research study assessing black bear responses to US 93 prior to reconstruction. With small sample sizes, there is little statistical power to detect changes in pre- and post-construction bear-vehicle collisions; this result underscores the importance of repeating the black bear study post-construction in order to obtain more detailed data that would provide a better understanding of the effect of the mitigation on this focal species.

- <u>Cross-highway movements:</u>
    - Sand track beds placed parallel to US 93 were used to sample wildlife movements across approximately 30% of three stretches of US 93 that will have extensive lengths of wildlife fencing and crossing structures. Across 4027 m (2.5 miles) of track beds monitored from June through October in the focal study areas over three years (2003—2005), deer species were the most frequently observed tracks, with medium mammals (including skunks, raccoons, and rabbits/hares) and canines (including domestic dogs and coyotes) as the second- and third-most observed species and
    - Deer and black bear track observations classified as "crossings" were used to extrapolate and estimate total crossing activity that occurred along the stretches if US 93 planned for extensive fencing (approximately 3.2 km in Evaro, 5.9 km in Ravalli Curves, and 2.1 km in Ravalli Hill, a total of 11.2 km will be fenced to exclude wildlife and funnel them toward the crossing structures). The estimated total number of deer that crossed US 93 between June and October 2003—2005 in these areas prior to the installation of the fence ranged from 1521 to 1932 and the estimated total black bear crossings in the same area ranged from 33 to 165.

While both the AVC and track bed data provided an index of wildlife population density and road-centric behavior patterns, pellet group transects were established to independently index local deer population densities in a one kilometer buffer zone around the highway in the three focal study areas. Photographic monitoring at a railway underpass in the Evaro area documented what animals were using this passage to move under the existing highway and to understand the daily patterns of activity for deer and bear moving within the highway corridor. Used separately, these tools addressed specific questions regarding preconstruction roadside ecology. Used together, these indices help integrate important demographical and behavioral information to understand the current effects of US 93. This information would be critical in determining the effects of mitigation measures on deer and bear in post-construction years.

Following that thread, it was noteworthy to mention the high variability observed in the preconstruction datasets, an anticipated phenomenon commonly seen in ecological studies where there is little to no control over parameters that may influence the focal parameters of interest, other than the focal treatment. This important point underscores the need for extensive (at a minimum, three years) of post-construction monitoring if rigorous results are desired.

In addition to the primary preconstruction data collection efforts described above, this report also documented and reviewed other recent, relevant preconstruction field research efforts. Each of these studies (including research on black bears, western painted turtles, characteristics associated with the deer-vehicle collision occurrences, and hydraulic assessments of aquatic passage structures) provides an opportunity to repeat the research after mitigation is installed to comparatively assess the effects of the reconstruction and mitigation measures.

Based on established methods for and characteristics of the primary preconstruction data collection, "measures of effectiveness" (MOEs) for the main parameters of interest in this evaluation study were outlined. Discussion about the differences in *effect* versus *effectiveness* lead to suggested minimum MOE of a 35% reduction in deer-vehicle collisions (DVCs) based the smallest statistically-detectable change established via a power analysis using the preconstruction DVC data. Other methods for defining effectiveness included conducting a simple cost-benefit analysis based the expense of the mitigation investments versus the potential monetary savings of reduced DVCs over time and subsequently reduced property damage, human injuries and fatalities, deer fatalities, and carcass removal burdens. If the smallest detectable reduction in DVCs were to be achieved and sustained, the investment would be repaid within 25 years; greater reductions in DVCs can offset the costs of the mitigation over a shorter period of time.

Determining appropriate MOEs for reductions in bear vehicle collisions were more challenging given that the primary data collection techniques (standard reporting of AVCs and track bed monitoring sub-sampling wildlife movements across US 93 in the three focal study areas) predictably yielded sample sizes too small to make statistical inferences. Anticipating this situation, the preconstruction black bear study was undertaken to provide more in-depth preconstruction data to be compared to similar intensive black bear data collected after construction is completed. If post-mitigation bear movements across the highway observed via the variety of metrics (e.g., tracking and photo monitoring at the crossing structures, GPS-collar movement monitoring and/or genetic sampling) document approximately the same level of crossing events as observed prior to the installation of the fencing and crossing structures, it is recommended that the mitigation be considered effective given that the preconstruction condition of US 93 does not appear to be a significant barrier to the passage of black bears.

It was determined that a population growth rate of approximately 14% (a relatively high growth rate for slow-growing and reproducing species such as black bears) would theoretically offset the ten or eleven black bear road kills reported during the two-year intensive bear study, along with other additive sources of mortality. Although immigration of other black bears into the area could reduce this requirement, it was proposed that reducing the number of road kill by half might be considered the minimum threshold for defining effectiveness of the mitigation relative to reducing black bear mortalities, providing the population is not threatened by other significant sources of mortality.

Specific considerations for post-construction monitoring were recommended. It is critical that continued, consistent AVC and road kill carcass removal reporting by Montana Highway Patrol and Montana Department of Transportation maintenance staffs occur throughout the construction and for at least 5 years post-construction. After reconstruction across the entire area (excluding the Ninepipes reconstruction section) has been completed, initial analyses of effects of the mitigation on DVCs should not be considered until after a minimum of three years (more ideally five years) has passed to provide a sample size similar to the preconstruction DVC dataset. Post-construction wildlife movements through the wildlife crossing structures, at gaps in the wildlife fencing, and at the wildlife exclusion fence ends should be monitored using a combination of sand tracking beds in combination with remote-trigger IR photo cameras to quantify the accuracy of track beds was recommended to improve the overall confidence in the pre-post comparisons of the track bed data.

Monitoring other parameters that can affect the interpretation of the observed outcomes should be accommodated in the post-construction monitoring plan as well. Annual pellet transect monitoring would be important to understanding trends in the deer population that may affect the observed DVCs and use of the crossing structures. Monitoring traffic to analyze impact on wildlife crossing behavior would help further understand how such variables may influence wildlife responses to the mitigation.

8.4. Recommendations

A general summary of recommendations includes:

- The importance of at least 3, and preferably 5 or more, years of post construction data collection;
- Timing of data collection relative to construction phase completion is important, and at least 3 years of monitoring should occur after the last phase is completed;
- Photo monitoring is recommended to gain insights into activity patterns and to validate the tracking indices; and
- Repeating the wildlife studies from the preconstruction years (black bear movements, fish passage, western painted turtle mortality and movements, and characteristics contributing to DVCs) is necessary to understanding the effects of construction.

As mentioned previously, variability revealed in the preconstruction datasets illustrates the need for a bare minimum of three years of post-construction data collection from the time the mitigation installation is complete within a given area; ultimately, five or more years from the conclusion of construction would be better. Given that the eight reconstruction segments are being completed in phases, the scheduling of post-construction monitoring efforts may be gradually increased as each area is finished, but it is recommended that there be at east 3 years of post-construction monitoring after the last segment (excluding the Ninepipes area) is completed. Further, the post-construction monitoring schedule should consider the biotic and abiotic conditions that evolve after construction is completed, vegetation recolonizes the disturbed areas, and wildlife adapt to their new landscape with fencing and crossings that will affect their navigation, movements and behaviors. During the period when an increasing number of mitigation measures are finished but others are either underway or planned to begin, photo-monitoring could begin at the completed wildlife crossings to document what and how quickly different species of animals use the structures. This exercise would pilot the camera equipment set-ups to ensure methods are fine-tuned for the more intensive long-term monitoring efforts. Further, these photos would provide initial feedback to the stakeholders and public before the more quantitative data can be reported on after several years of more extensive post-construction data collection. Once all structures and fencing are installed, it is recommended that the more intensive track bed monitoring be used to complement the photo-monitoring, which would then initiate the beginning of the intensive monitoring efforts that should be continued for a minimum of three years.

Repeating the other intensive field study efforts post-construction would provide additional focused data to document the effects of the mitigation on black bear, fish passage, western painted turtles and characteristics that contribute to DVCs in the US 93 corridor. Other than repeating the hydraulic assessments, which could be done one year after construction is completed at those particular sites, the wildlife studies should not begin until at least two years (preferably more) post-construction have passed in the study areas where these projects would be replicated.

Based on the pre- and post-construction comparative analyses, lessons learned and best management practices will be used to guide other institutions considering incorporating wildlife crossing structures and mitigation measures in future construction projects. Due to the myriad sources of unquantifiable variation in the environment, several years of committed post-construction monitoring must be employed to meet these goals of the evaluation study. The US 93 context-sensitive approach to redesigning a road that fits with the surrounding physical, natural, and cultural landscapes is establishing a higher standard for highway reconstruction efforts; with numerous entities interested in this high-profile reconstruction efforts outcomes, the analysis of the pre- and post-construction data and case study will provide insights and accountability with regards to the investments dedicated to improving driver safety and reducing impacts on wildlife.

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10. APPENDIX A: WILDLIFE MITIGATION DESIGN GUIDANCE

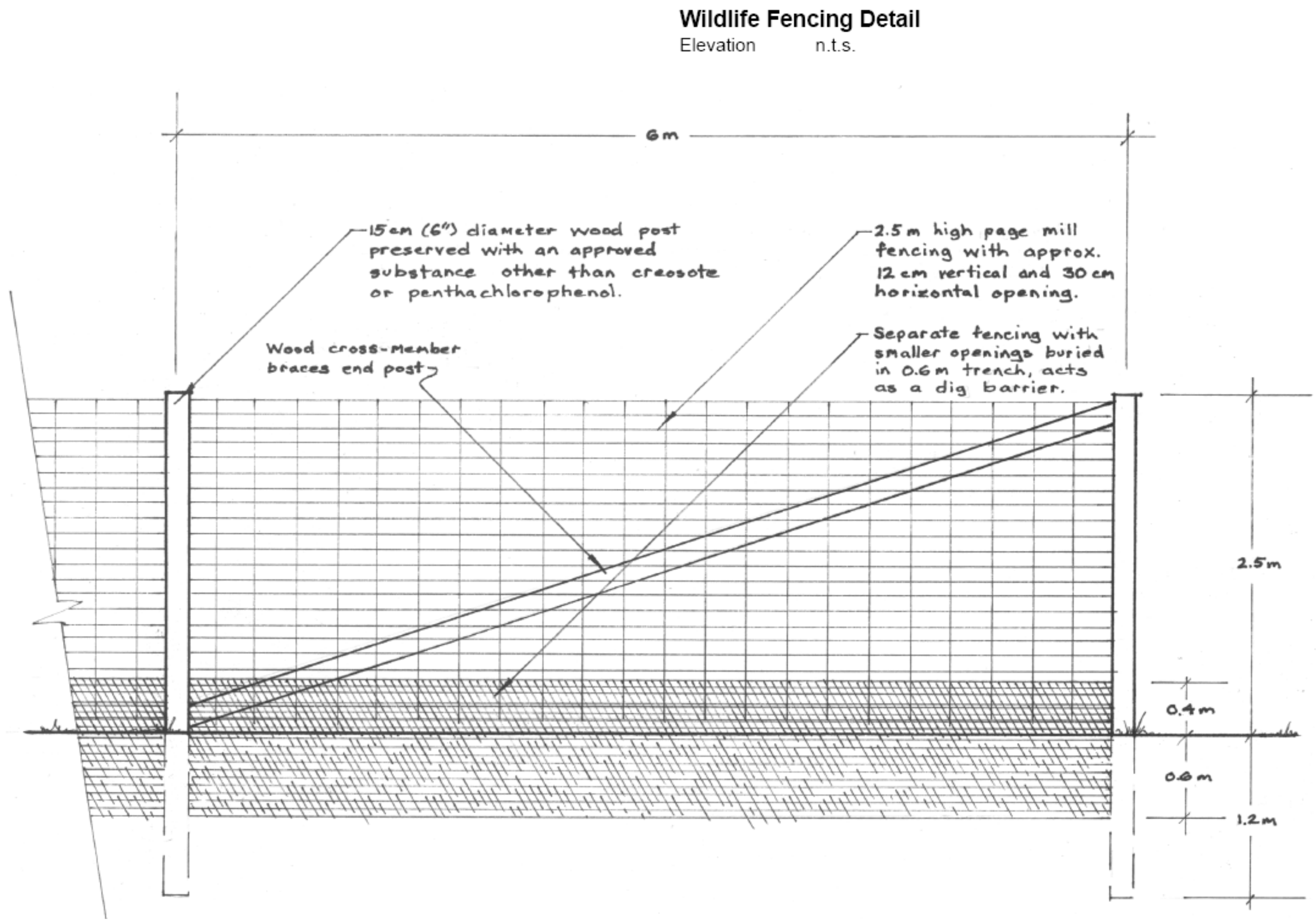


Figure A-1: Fencing typical details provided to US 93 design consultants (Jones and Jones 2002b)

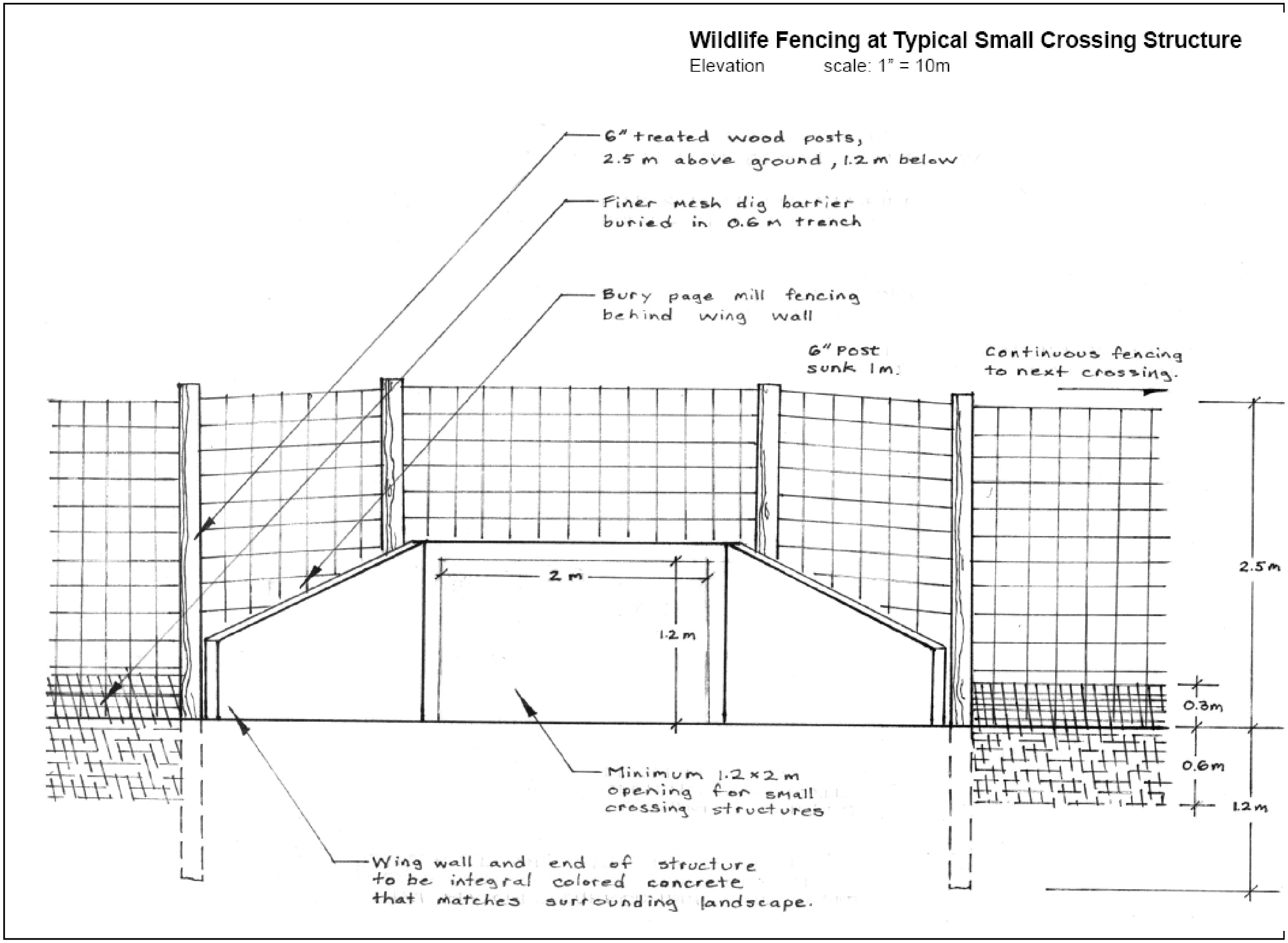


Figure A-2: Fencing typical details provided to US 93 design consultants (Jones and Jones 2002b)

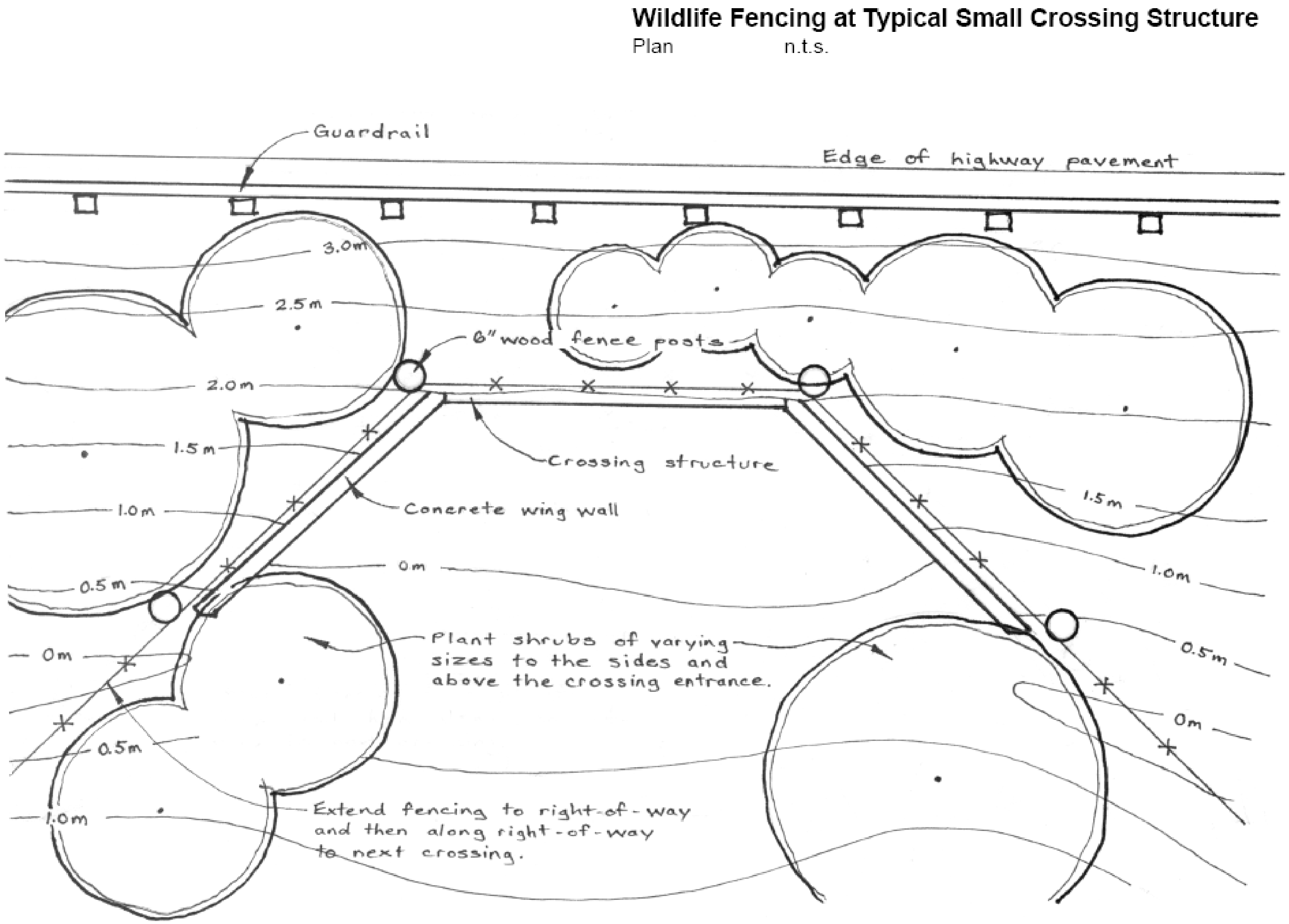


Figure A-3: Fencing typical details provided to US 93 design consultants (Jones and Jones 2002b)

Wildlife-friendly Livestock Fencing

Elevation n.t.s.

For situations where the wildlife fencing ties in to livestock fencing the livestock fencing will need to be modified to the following specifications for deer: (1) Bottom wire up 40.6 cm from ground – thus allowing for movement of fawns. (2) Only 3 strands of wire are required. (3) Top wire is smooth and 91.4 cm from ground – thus allowing deer greater ease in jumping over the fence. (4) Stays (extending over all three wires) are placed between fence posts. Since deer frequently become entangled when the top 2 wires twist around the legs, the stays make a more rigid fence, thereby allowing the animal a better chance to wiggle out of the fence.

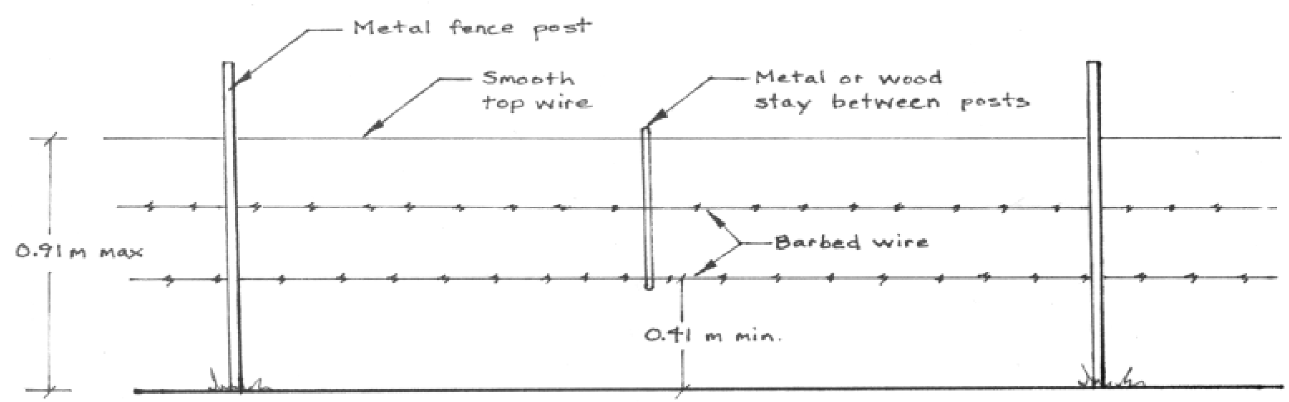


Figure A-4: Fencing typical details provided to US 93 design consultants (Jones and Jones 2002b).

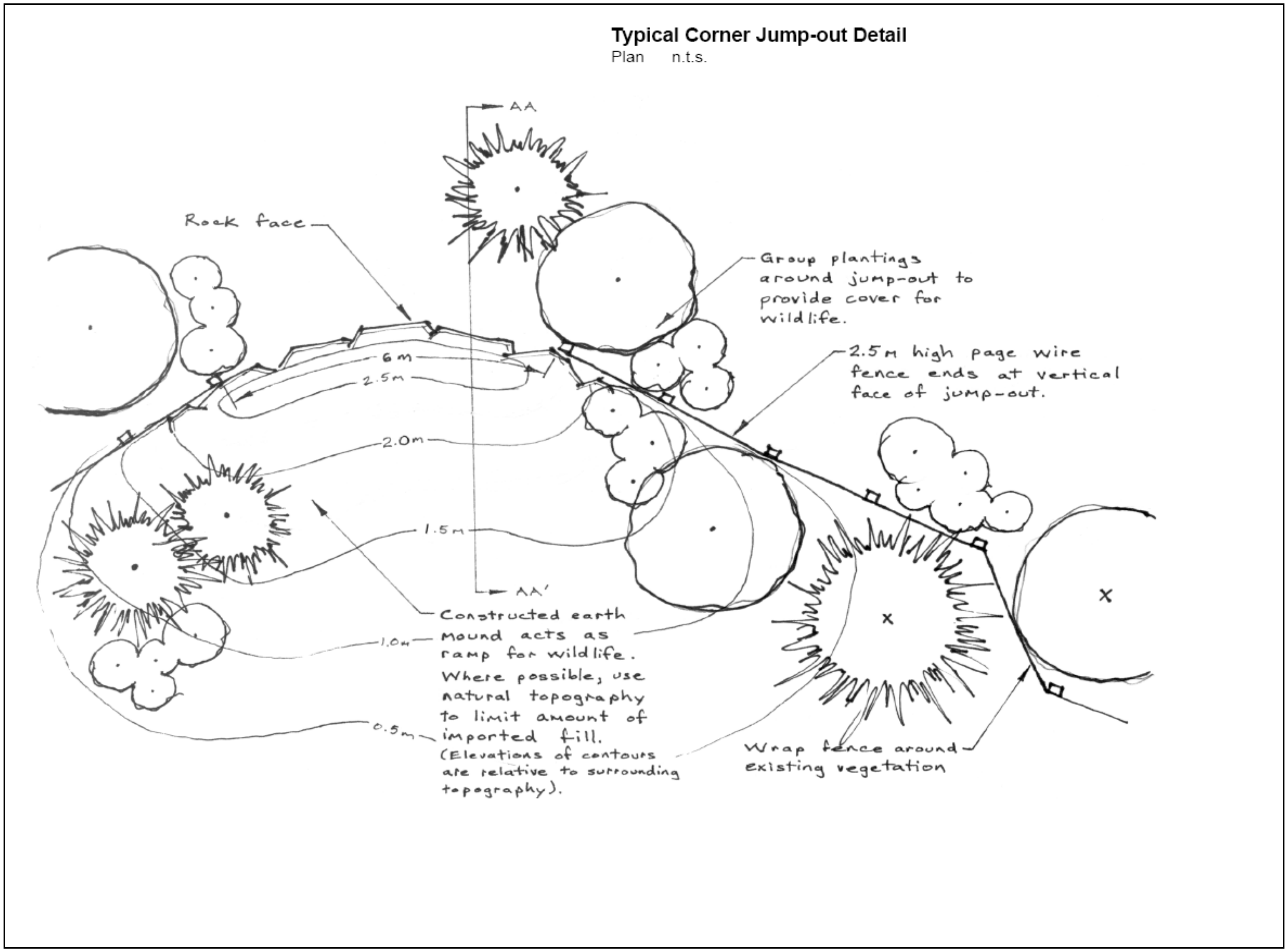


Figure A-5: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

Figure A-6: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

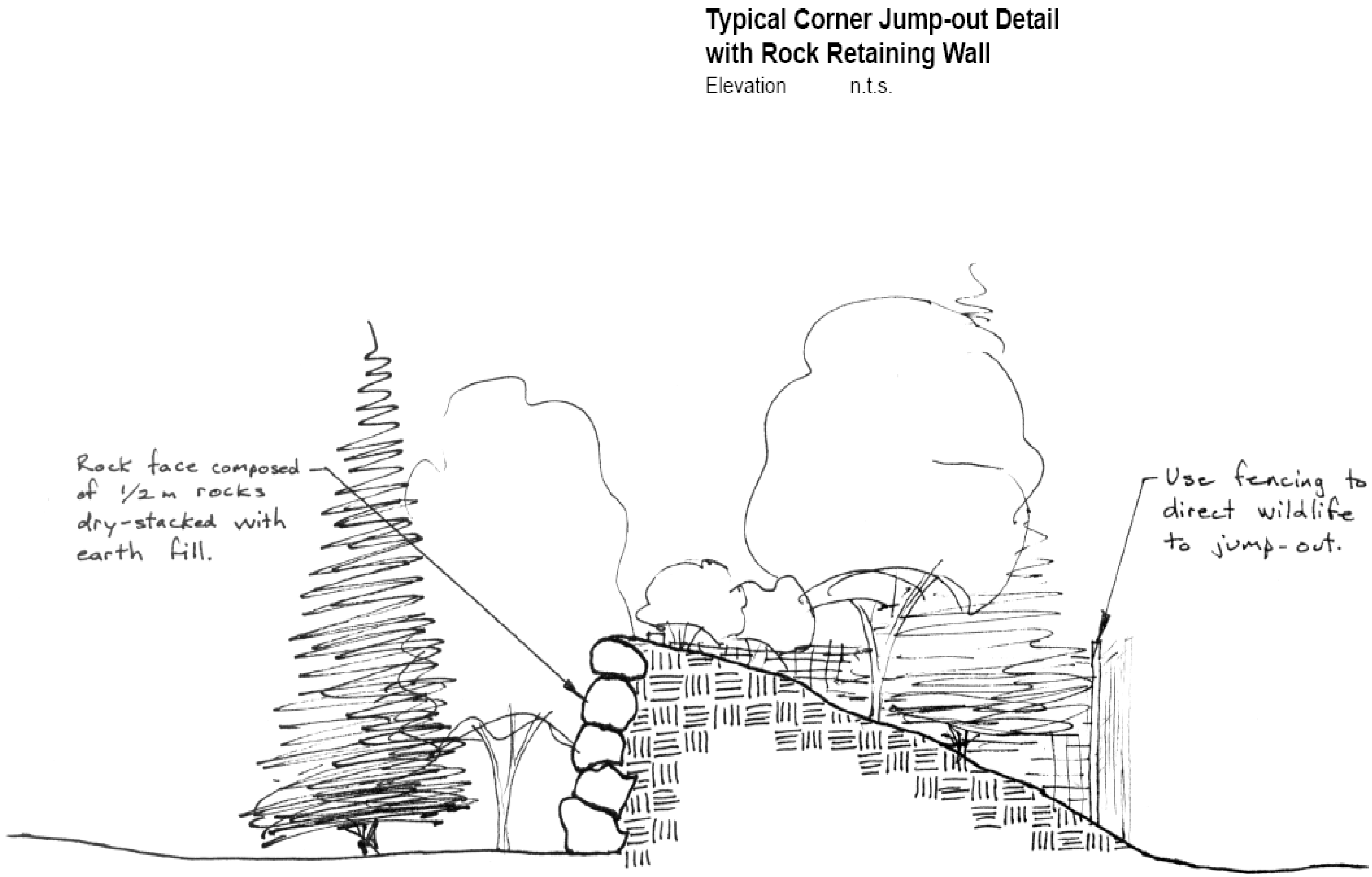


Figure A-7: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

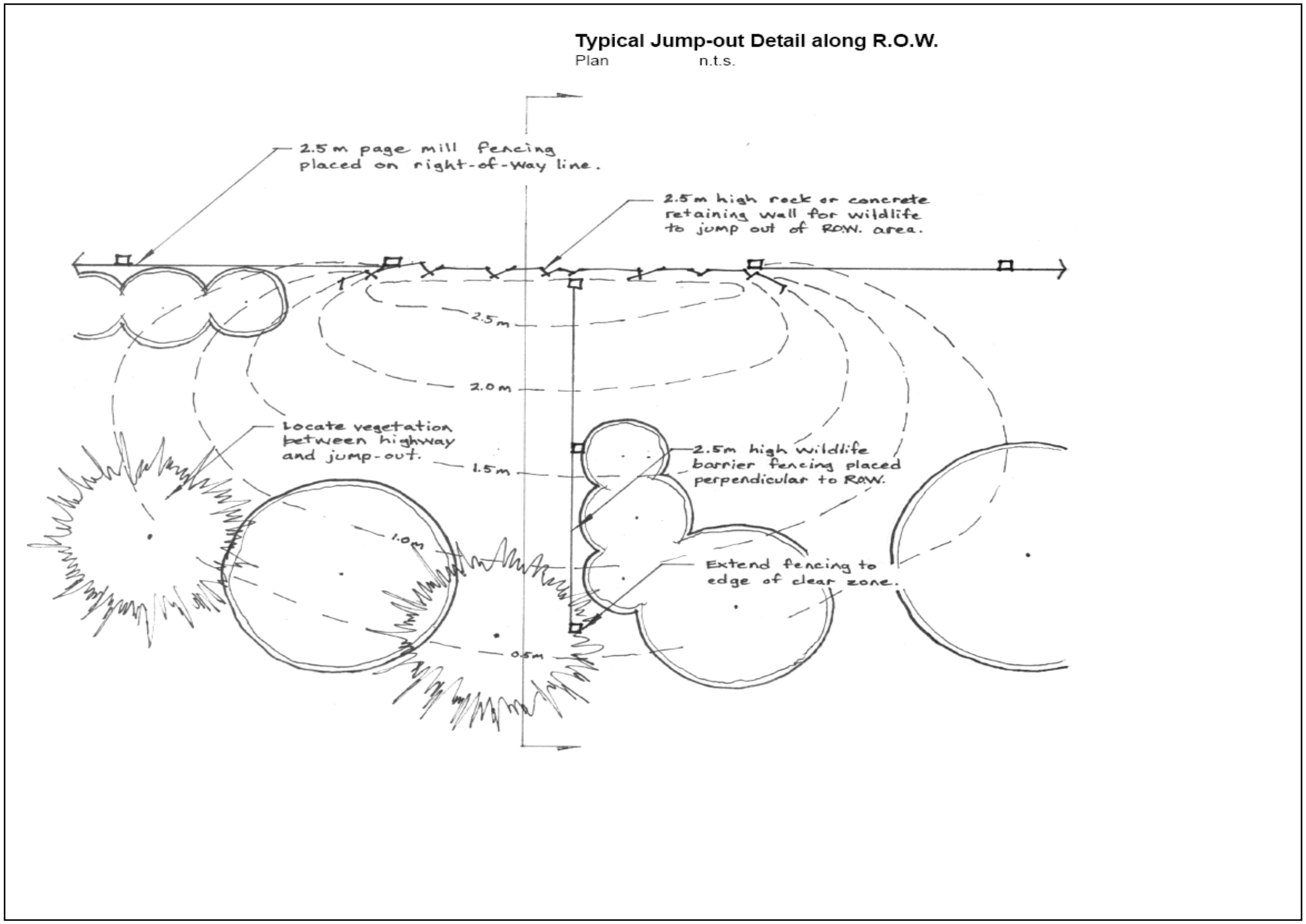


Figure A-8: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

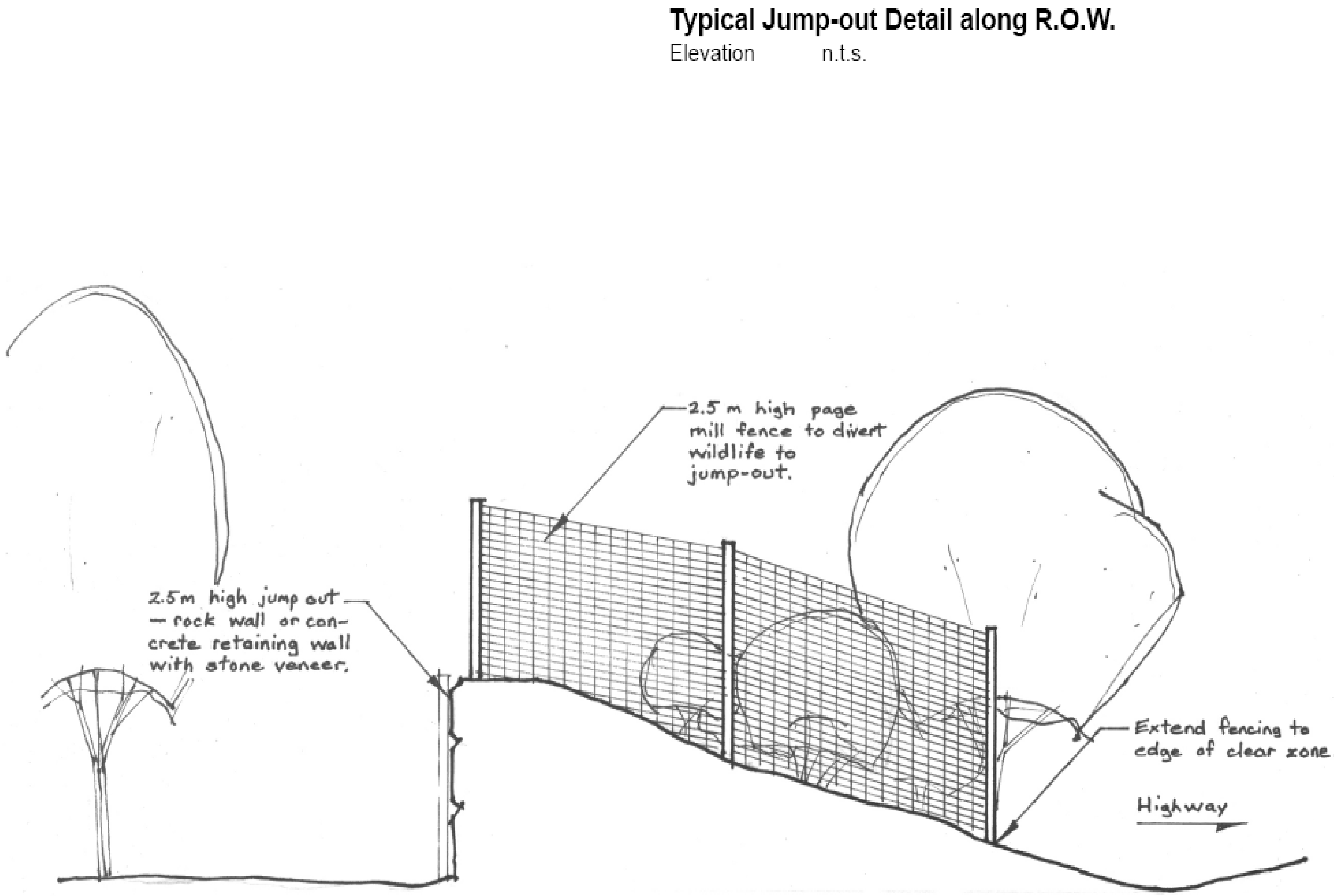


Figure A-9: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

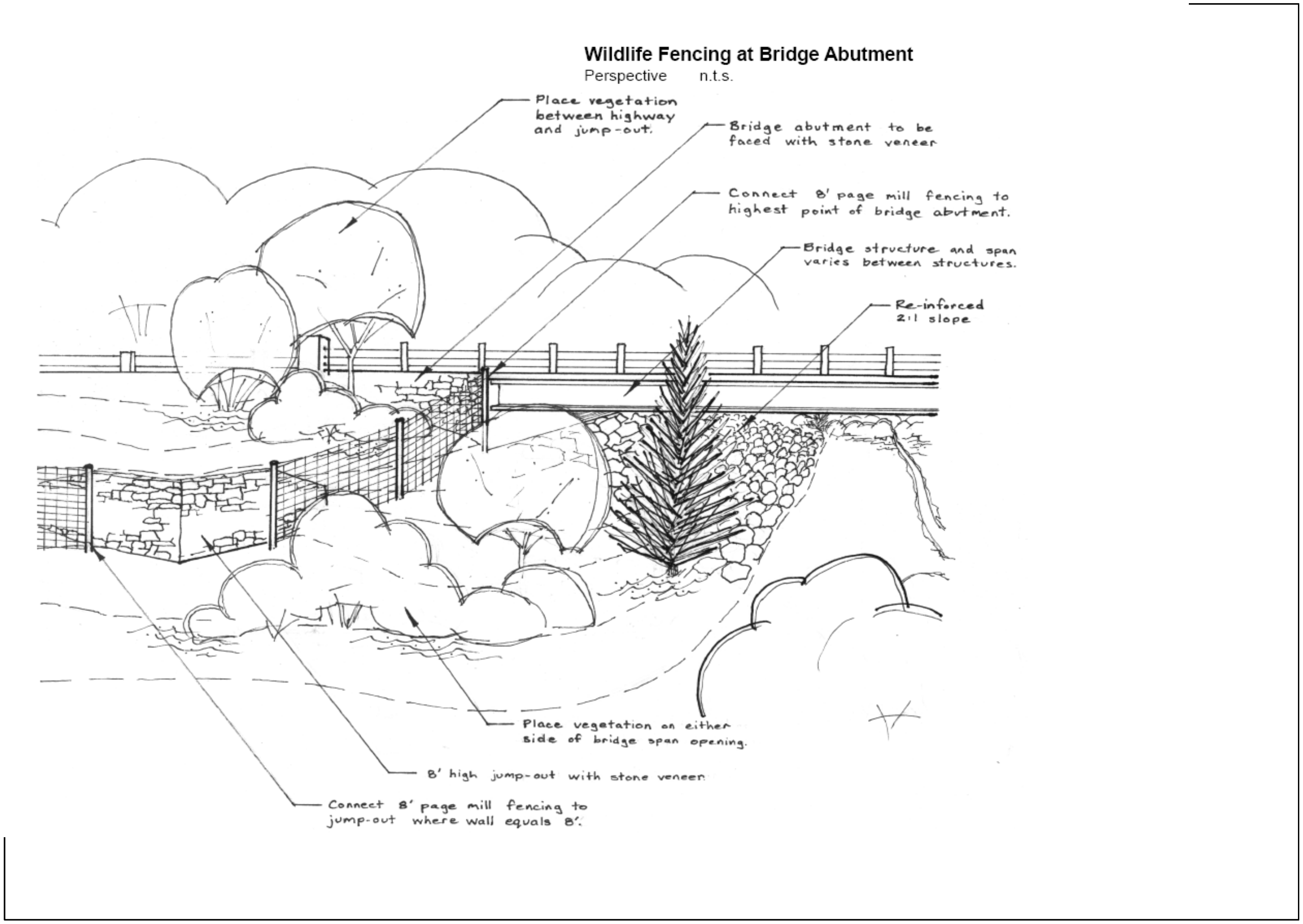
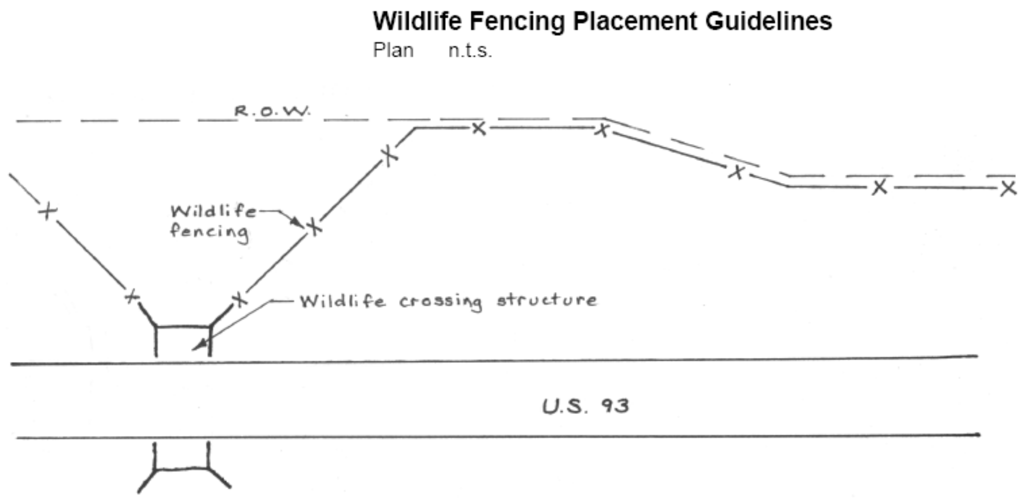


Figure A-10: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

In landscapes without trees or large shrubs, continuous fencing should be installed along the right-of-way (R.O.W.) line replacing the exisitng livestock fencing.



In forested landscapes, continuous fencing should be installed along the R.O.W. line, except where there are mature trees or vegetation to be preserved at the R.O.W. If mature vegetation is in the way, run fencing around the trees' driplines on the highway side of the R.O.W.

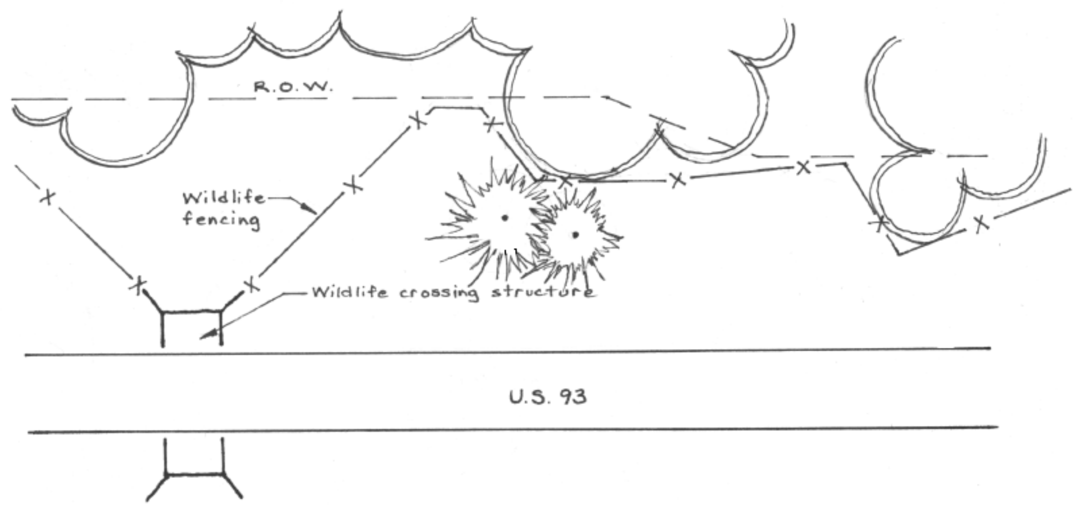
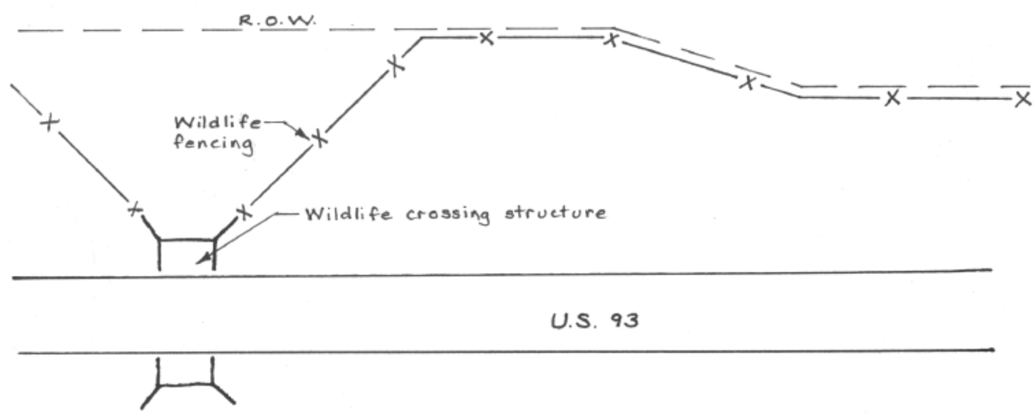


Figure A-11: Wildlife jump-out typical details provided to US 93 design consultants (Jones and Jones 2002b).

Wildlife Fencing Placement Guidelines

Plan n.t.s.

In landscapes without trees or large shrubs, continuous fencing should be installed along the right-of-way (R.O.W.) line replacing the exisitng livestock fencing.



In forested landscapes, continuous fencing should be installed along the R.O.W. line, except where there are mature trees or vegetation to be preserved at the R.O.W. If mature vegetation is in the way, run fencing around the trees' driplines on the highway side of the R.O.W.

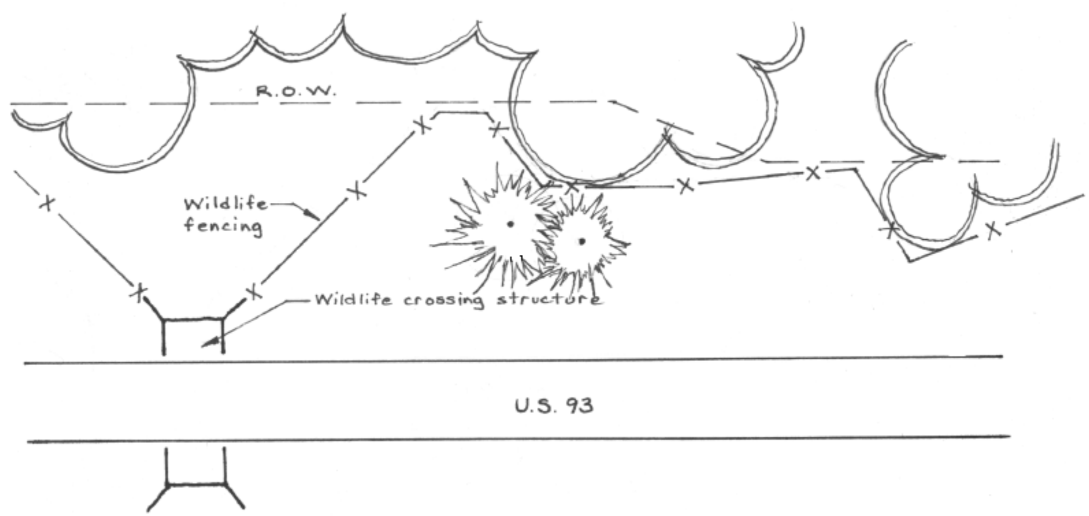


Figure A-12: Fencing placement and wildlife guard typical details provided to US 93 design consultants (Jones and Jones 2002b)

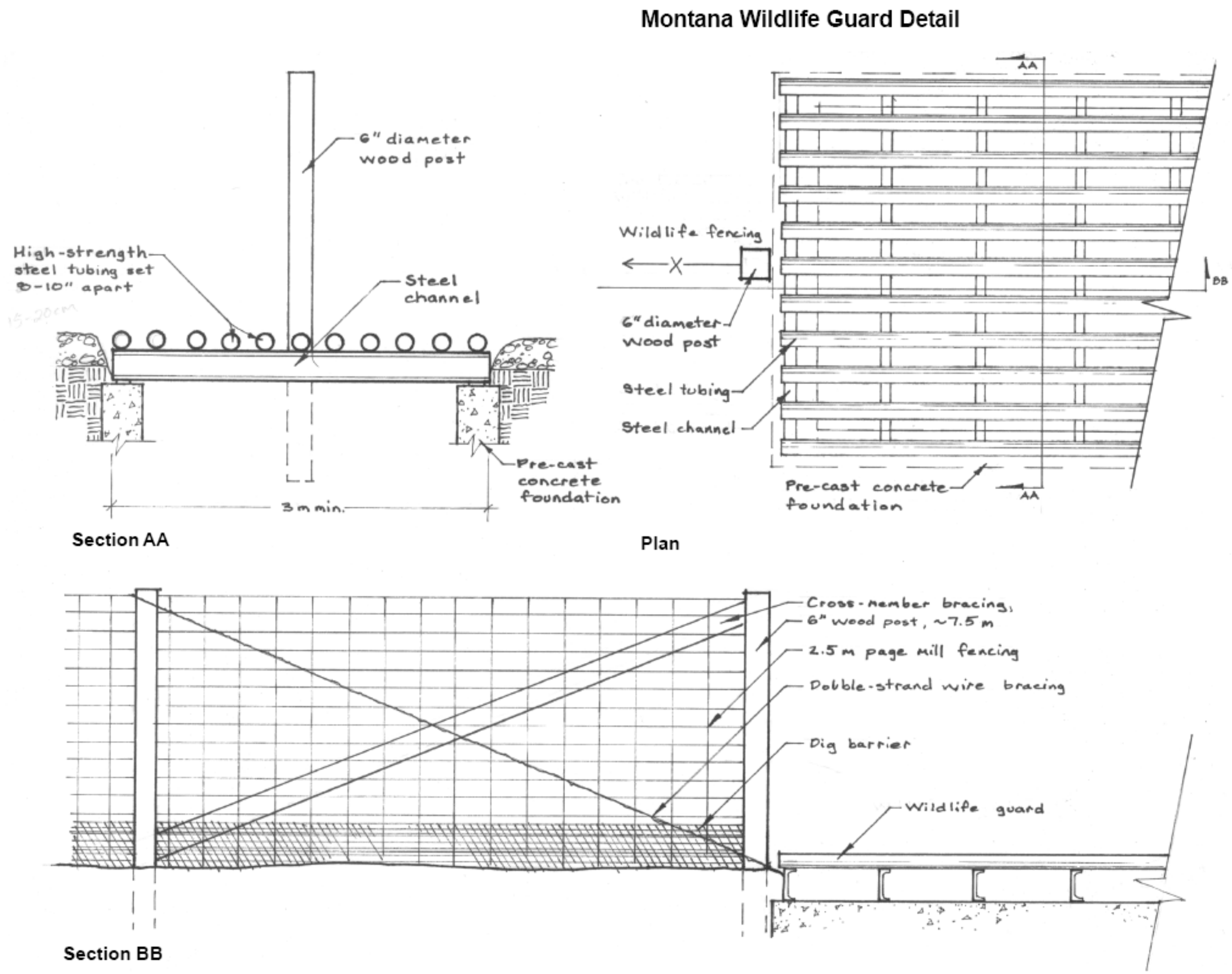


Figure A-13: Fencing placement and wildlife guard typical details provided to US 93 design consultants (Jones and Jones 2002b)

11. APPENDIX B: MONITORING FEATURES DESIGN DETAILS

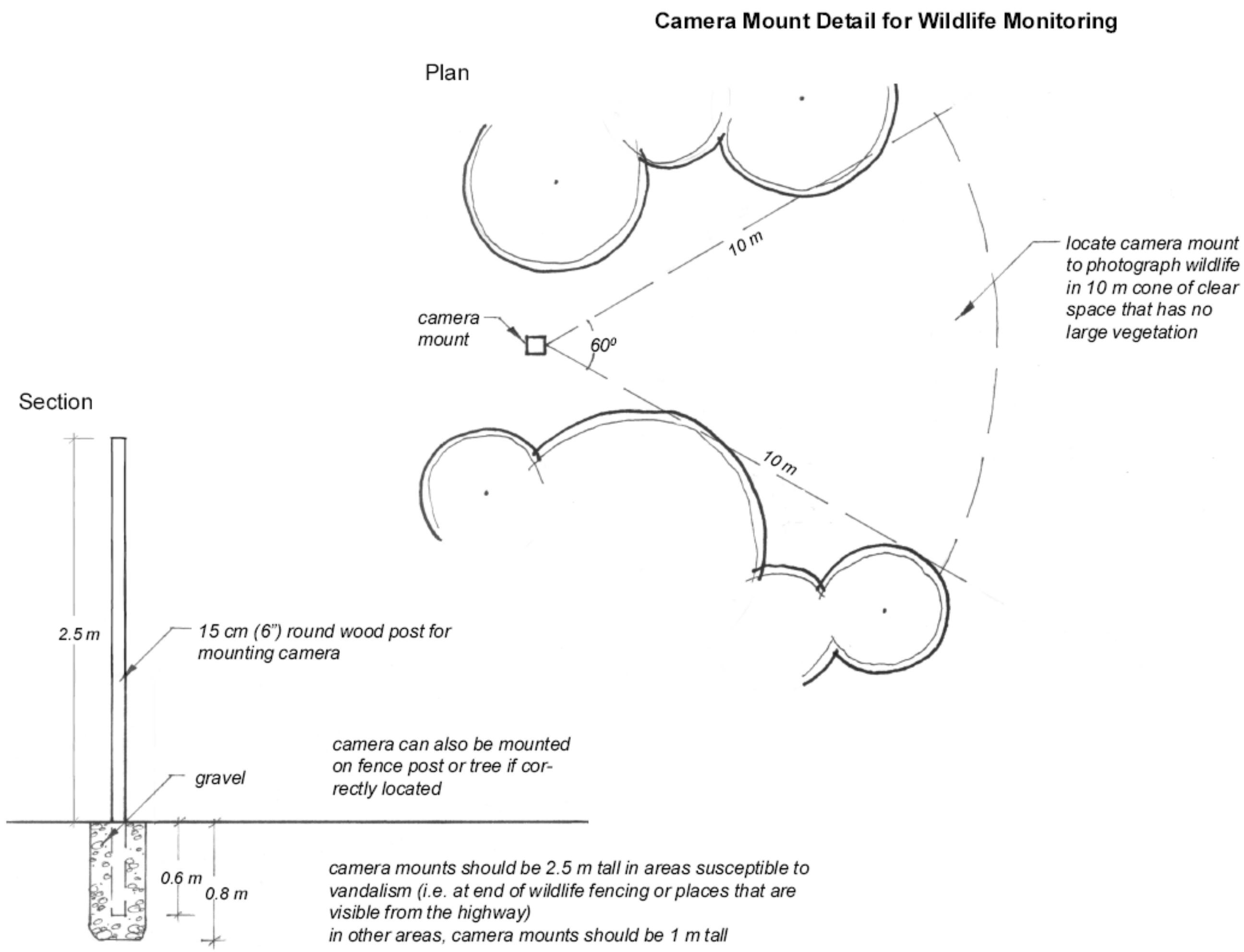


Figure B-1: Remote-trigger camera mount typical design details provided to US 93 design consultants (Jones and Jones 2002b).

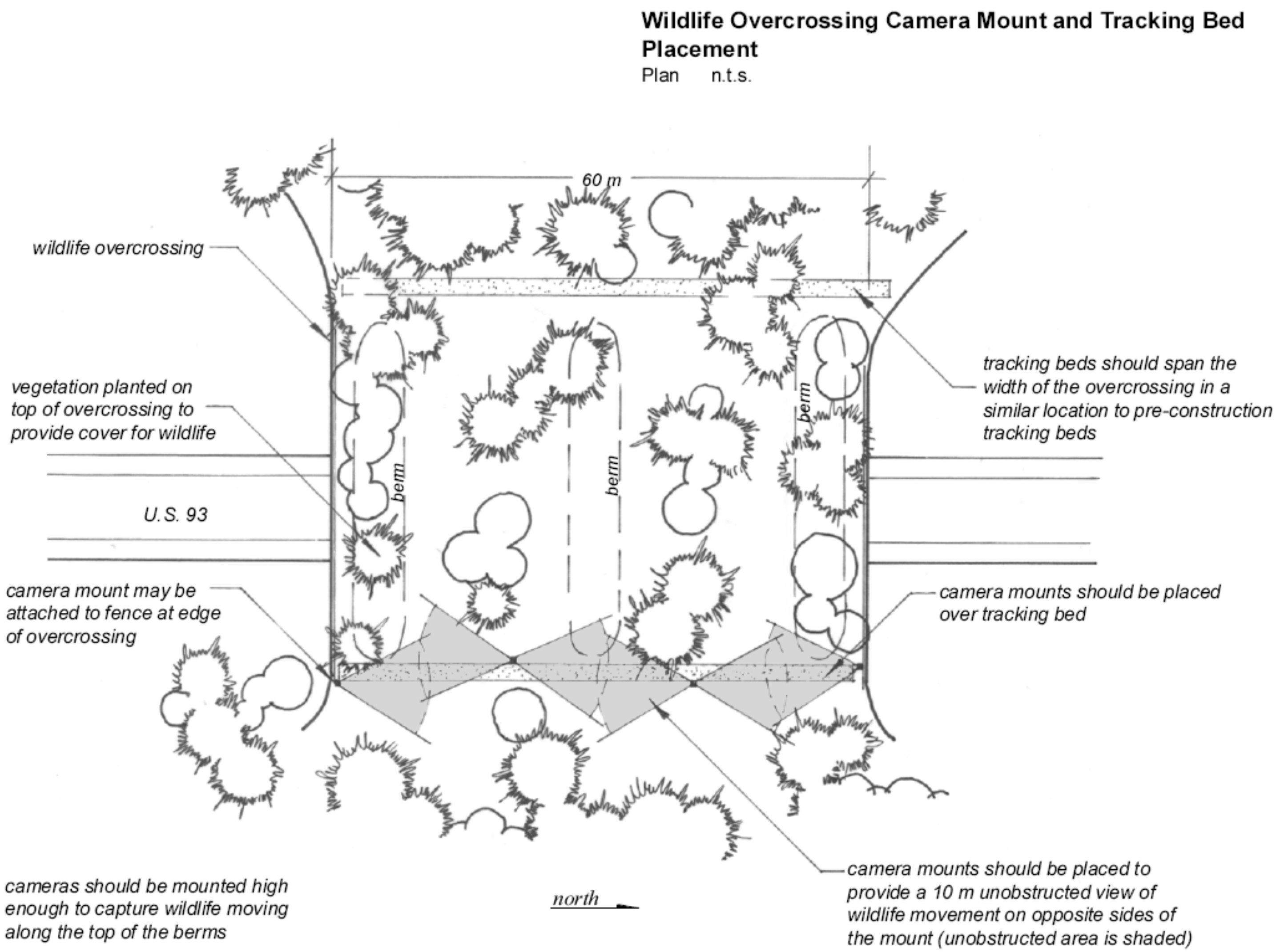


Figure B-2: Remote-trigger camera mount typical design details provided to US 93 design consultants (Jones and Jones 2002b).

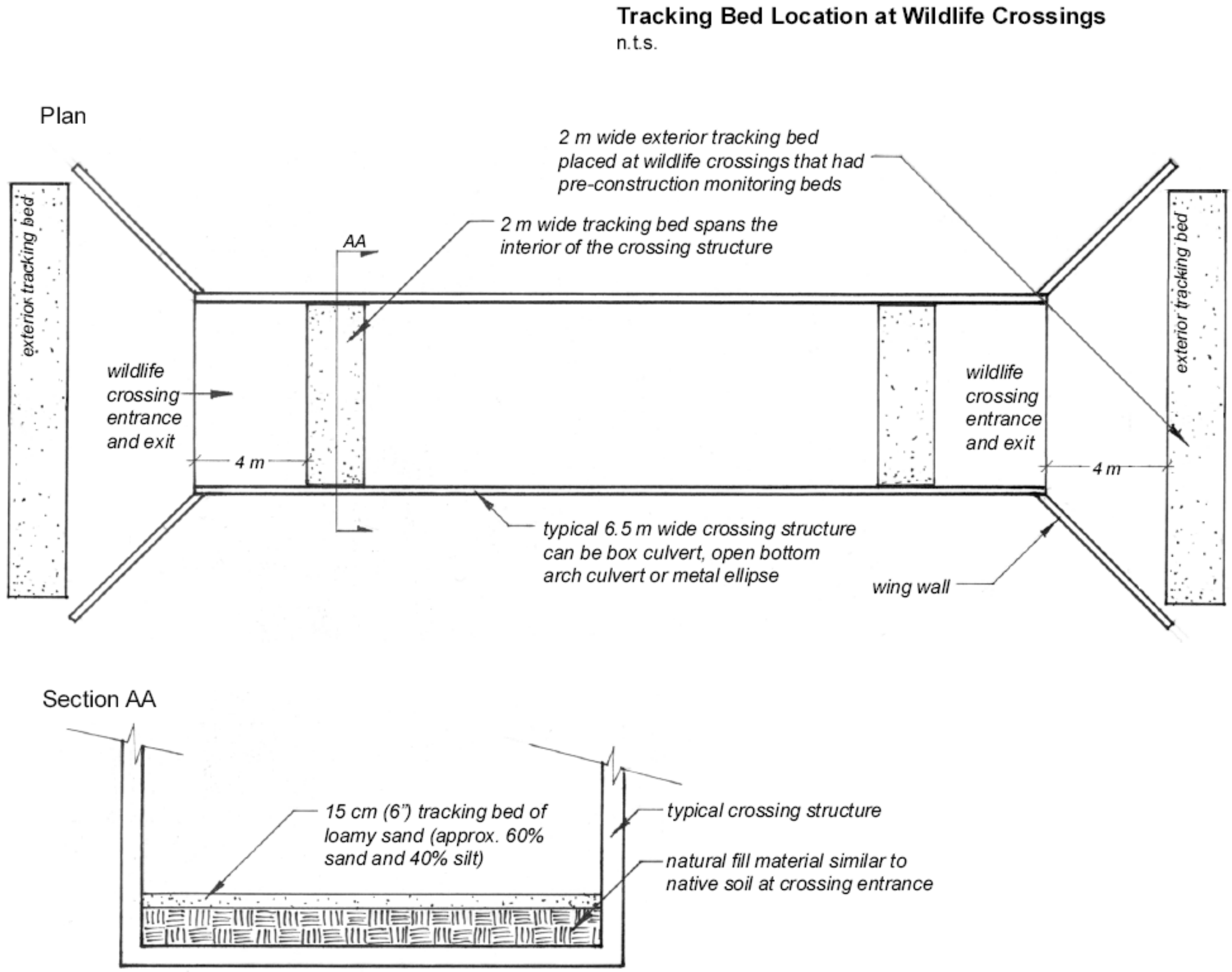


Figure B-3: Tracking bed design details provided to US 93 design consultants (Jones and Jones 2002b).

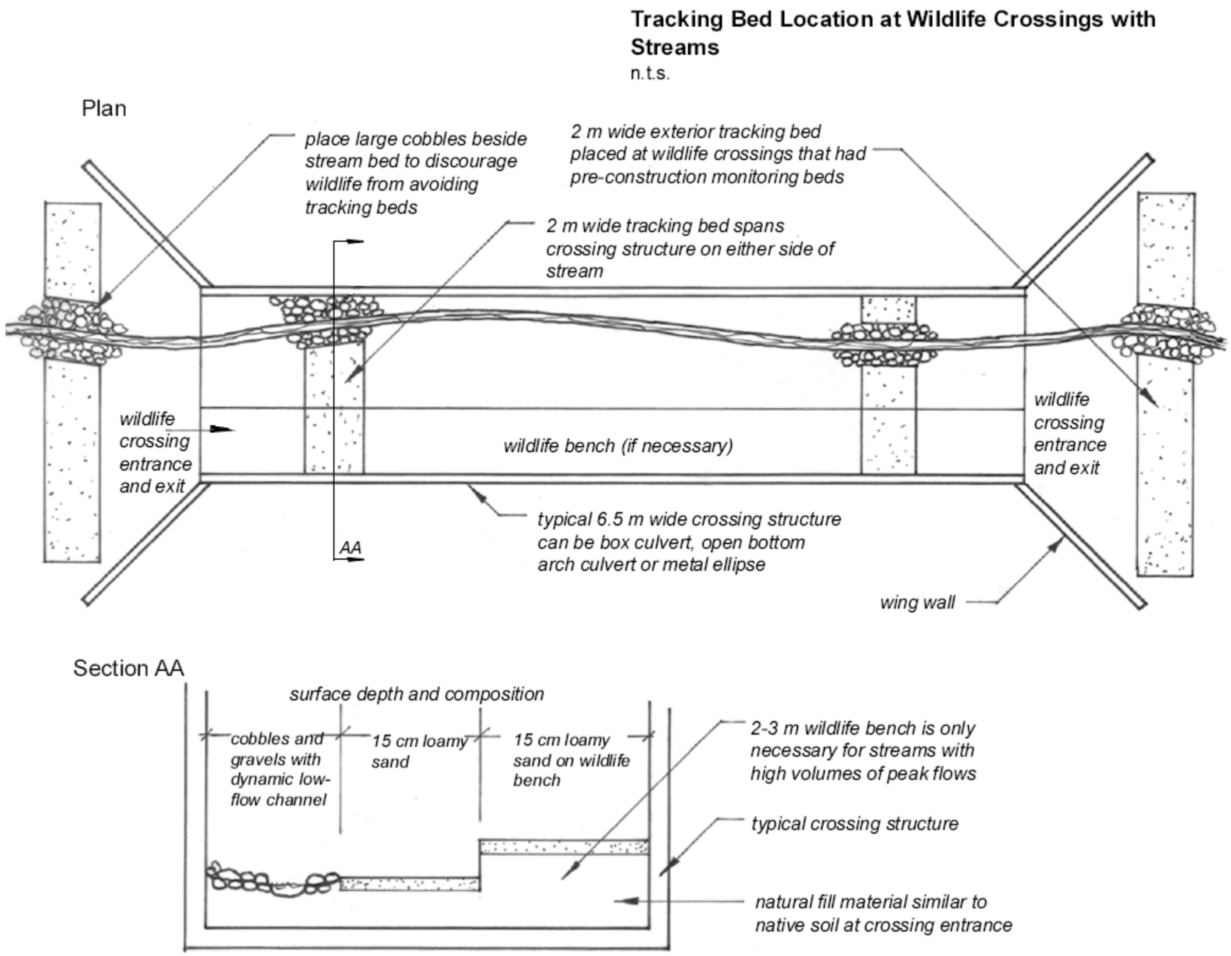


Figure B-4: Tracking bed design details provided to US 93 design consultants (Jones and Jones 2002b).

12. APPENDIX C:

EFFECTS OF PROPOSED FENCING CHANGES ON ANIMAL-VEHICLE COLLISIONS, HABITAT CONNECTIVITY AND STUDY DESIGN FOR US 93 WILDLIFE MITIGATION ON THE FLATHEAD RESERVATION

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REVISED February 10, 2004

EXECUTIVE SUMMARY

Over the coming years US Highway 93 (US 93) will be reconstructed on the Flathead Indian Reservation between Evaro and Polson, Montana. The reconstruction will include the installation of wildlife crossing structures and fencing. In December 2003, it was proposed that two of the three areas (Evaro and Ravalli Hill) may have less wildlife fencing than originally planned.

The Western Transportation Institute has prepared this report to help the US 93 Technical Design Committee (TDC) make an informed decision with regard to how the changes in fencing may affect the goals of the wildlife mitigation and the evaluation study. This report summarizes recommendations regarding fencing design details. Recommendations are based on the synthesis of the field data collected thus far, relevant literature and prior experience with fencing issues as they relate to the goals of reducing animal-vehicle collisions and maintaining habitat connectivity. WTI also addresses the effects that the fencing changes may impose on the evaluation study design.

WTI has produced this report to complement the specific fencing recommendations drafted by Dale Becker, Confederated Salish and Kootenai Wildlife Biologist. WTI is providing the TDC with the best available data and information regarding the effectiveness of wildlife mitigation. WTI does not claim to have incorporated all issues that the TDC will have to consider balancing with the goals of the mitigation, although issues that may affect the mitigation success have been addressed. WTI respectively submits these considerations to aide the TDC with making informed decisions.

Impact of Proposal on Animal Vehicle Collisions and Animal Crossings

WTI documented and analyzed available data on AVCs and animal crossings detected in sand track beds along US 93 to identify potential effects of proposed fencing changes in the Ravalli Hill and Evaro areas as they relate to the goals of the mitigation efforts. In the Ravalli Hill area, it does not appear that decreasing the fencing at the north end of this area will have major implications in terms of AVCs. However, the following recommendations are proposed for the rest of Ravalli Hill to limit AVCs:

- do not shorten the fence at the south end of Ravalli Hill; keep the original southern fence end that extends down to the MT 200 intersection; and
- extend the north end of the fence near Ravalli Hill Wildlife Crossing #2 further (300-500 meters) than proposed in December 2003.

In the Evaro area, the elimination of wildlife fencing from Whispering Pines Road south to the reservation border is concerning relative to reducing AVCs. The authors have specific concerns about the area just north of the Reservation boundary where tracking bed data show relatively high numbers of black bear and deer crossings. The authors are also concerned about numerous black bear AVCs at the northern end of the Evaro study area, near East Fork of Finley Creek, some of which have recently occurred north of the original fencing proposal's northern termination point.

Fencing from Whispering Pines Road to the Reservation border or from the Schley Homesites northward may not be favored for a variety of reasons; however, the authors recommend the TDC take a hard look at alternative mitigation measures for this stretch. The authors list and describe other mitigation measures for consideration in “Alternatives to Wildlife Exclusion Fencing.”

Impact of Proposal on Wildlife Monitoring Methods

WTI has been documenting wildlife crossings of US 93 through the monitoring of 62 tracking beds throughout summer and autumn 2003. These beds were located in areas that were planned to have the longest sections wildlife fencing with crossing structures. The tracking beds are used to obtain an estimate of preconstruction animal crossing rates. This estimate will be compared to post-construction crossing measurements of animal movements through the crossing structures, to quantify possible changes in habitat connectivity. The sample size of 62 beds was determined based on a power analysis conducted with similar crossing rate data for deer from another study. With the proposal to reduce the wildlife fencing lengths in the Evaro and Ravalli Hill areas, 20 of the 62 tracking beds are now in areas that will not have wildlife fencing. These 20 tracking beds can no longer be used to estimate the number of wildlife crossings which reduces the sample size of the study by 32%.

A new power analysis was conducted using the study’s 2003 deer crossing observations to assess the impact that the fencing changes impose on the monitoring of the remaining 42 tracking beds. The results indicated that the sample size reduction does not substantially affect the ability to detect an overall difference in deer crossings before and after construction. However, if one is not only interested in a potential change in deer crossings in the three areas combined, but also in a potential change in deer crossings in the individual study areas, the authors reach a different conclusion, particularly for Ravalli Hill.

WTI learned there have been further changes in the fencing plan and an additional 5 beds will be lost in the northern end of Evaro. This is unlikely to dramatically change the conclusions; therefore the decision was made to not conduct a new power analyses.

Fencing design considerations and details

The purpose of the wildlife exclusion fencing is two-fold: to funnel animals toward crossing structures and to prevent animals accessing the road where collisions can occur. No wildlife exclusion fencing design has been found to be 100% effective and completely impermeable to all animal species; however, several techniques have been used to deter animals from accessing the area between the fences. For those animals that breach the fence and are trapped on the right-of-way between the fences, there are methods that can expedite the animals’ exit from this unsafe situation.

Fence end treatments

Fence end treatments can limit the numbers of animals becoming trapped between the fences. Fence end treatments are typically applied on the right-of-way, extending from the pavement to the last fence post where the wing fencing angles away from the road. Thus far, the TDC has concluded that current fence end treatment designs (cattle or wildlife guards, electric fence, cobbles) are not sufficiently safe for motorists, pedestrians and cyclists that travel along the road or in the right-of-way.

With no other alternatives proposed, there will be no fence end treatments to prevent animals from accessing the right-of-way between the wildlife exclusion fencing. ***Without fence end***

treatments, the effectiveness of the fencing will be reduced as animals will not be deterred from accessing the right of way between the fences. If there are numerous incidents of animals becoming trapped between the fences, animal-vehicle collision rates may increase.

Treatments for access points or fence gaps

Access roads result in openings in the wildlife fencing. Without additional mitigation measures for those openings, animals have access to the right-of-way and the road. This jeopardizes the effectiveness of all other mitigation measures (i.e. the wildlife fencing and wildlife crossing structures), both with regard to animal-vehicle collisions and providing animals with safe crossing locations. The authors reviewed the following options for the TDC's consideration:

No additional measures: The effectiveness of the wildlife fencing and wildlife crossing structures with regard to animal-vehicle collisions could be reduced from about 96% to less than 40%.

Mitigation measures that discourage animals from crossing:

- **Gates:** Access points that are infrequently used by only one or several people or official organizations could be gated (preferably with a lock). This could potentially result in a barrier that is close to 100% effective, similar to having no gaps in the wildlife fencing;
- **Cattle guards or wildlife grates:** The literature on the effectiveness of cattle guards as a means to deter wildlife movements is limited with varying conclusions. Based on the authors' literature review, bridge grating could reduce key deer access to feed by 75-99.5%, depending on the design of the grates. Others have found that deer will pass over cattle guards and have deemed this measure ineffective. Despite these conflicting results, ***the authors recommend that the TDC consider modified bridge grating or cattle guards at gaps in the wildlife fencing. Modified bridge grating or cattle guards should be combined with jump-outs on either side of the road to provide an escape for animals that do succeed in crossing modified bridge grating or cattle guards.*** Modified bridge grating could potentially result in a barrier that is 99% effective, similar to having no gaps in the wildlife fencing.

Mitigation measures that promote animals to cross:

- **Crosswalks:** If there are two access roads directly opposite of each other, one may choose not to install barriers, but to promote animals to cross at that location. If there is only one access road, then one may choose to simply create a gap in the wildlife fencing on the other side of the road. If these gaps are combined with jump-outs and unique signing to warn drivers that animals may cross at that particular location, similar to pedestrian crossings, animal-vehicle collisions may be reduced by potentially about 40% (compared to 96% for wildlife fencing combined with wildlife crossing structures).
- **Crosswalks combined with animal-detection & driver warning systems:** See above. If the crosswalks and jump-outs are combined with an animal-detection and driver warning system, the number of animal-vehicle collisions could potentially be reduced by about 80% (compared to 96% for continuous wildlife fencing combined with wildlife crossing structures).

Similar to fence end treatments, if no additional mitigation measures are applied at gaps in the wildlife fencing, the effectiveness of the wildlife fencing will be reduced, and the return on the

investments in wildlife fencing and crossing structures will be jeopardized. It is the author's recommendation that modified bridge grates are installed at gaps in the fencing, perhaps even at (locked) gates. This measure is potentially 99% effective. If modified bridge grates are not an option, then it is recommended that openings are placed on both sides of the road, in combination with an animal-detection and driver warning system (potentially 80% effective). The authors strongly caution the TDC against having gaps without additional mitigation measures.

Escape routes

Escape routes allow animals to exit the right of way if they are caught between wildlife fencing along the road. It is important to have escape routes, with or without fence end or gap treatments and such escape routes are especially important if there is no barrier at fence ends or at gaps in the wildlife fencing.

In Banff National Park, one-way gates were unsuccessful as elk learned how to move through these in both directions. The solution to this issue, in areas where there were no jump outs, was to install gates that rangers would open in order to haze animals off the right of way.

The current plan is to install jump outs where the fencing changes angle to funnel in to the wildlife crossing structures. The authors recommend installing additional jump-outs, spacing the jump outs at quarter mile intervals along the first mile of fencing from each fence end or fence gap. In other fenced areas that have less deer road kill and that are not near the end of the fence, jump outs may be placed at half mile intervals (800 m).

Deterring fence climbers and burrowers

Specific strategies to discourage wildlife from climbing over or digging under the fence include:

- provide a 90 degree barbed wire outrigger (i.e. overhang) that extends out ~3 feet;
- use finer mesh fence to prevent bears from getting their feet in the mesh openings to use as a step (they climb the fence using mesh openings just like humans would);
- use metal poles instead of wooden poles, or design a treatment or a pole that discourages black bears from climbing the wooden poles; and
- attach a skirt of smaller-meshed fencing that extends from the exclusion fencing to bury in the ground.

Alternatives to wildlife exclusion fencing

While the standard page wire wildlife exclusion fencing is considered the most effective means to reduce AVCs, alternatives are summarized below for the TDCs consideration.

Electric fencing alternative

When used to exclude deer from airports, electric fence was shown to be 80% effective. Success rate may be reduced if (1) maintenance was inconsistent; (2) lines were short-circuited by weed growth or snow cover; or (3) when deer are highly motivated to cross the fence.

At the December 2003 US 93 Technical Design Committee (TDC) meeting, the group discussed installing ElectroBraid fencing in selected areas, in place of the wildlife exclusion fencing. Richard Lampman, an ElectroBraid representative, has met with WTI and MDT and has offered a trial of ElectroBraid at no cost, with the agreement that if satisfied, then MDT purchases the fence.

If the TDC supports installing this alternative fencing, WTI would like to evaluate the Electrobraid fencing with regard to the following criteria:

- Effectiveness: what percentages of animals (specifically deer and black bear) that approach the electric fence are effectively repelled or breach the fence line? Standard wildlife fencing would be used as a control.
- Costs for operation (e.g. electricity) and maintenance (e.g. fence repairs). Standard wildlife fencing would be used as a control.

Signage / Driver warning techniques

Fencing attempts to modify animal behavior and movements; signage attempts to modify driver behavior. It has been shown that the static wildlife silhouette warning signs are ineffective at reducing animal-vehicle collisions. The authors believe signs need to be applied in such a manner to impress upon the drivers to understand the message and drive more cautiously. The following measures may be used to warn drivers of potential animal-vehicle conflicts.

- **Speed reductions:** Reduction in speed provides drivers with more time to see and respond to hazards and increase their breaking distance. This logical premise has not been extensively studied in relation to animal-vehicle collisions but there are data that support this idea. If drivers could be impressed upon to obey speed reductions (dynamic signs that show the driver their actual speed; additional enforcement of posted lower speed limits), there is a chance that AVCs will be reduced.
- **Animal-detection/driver warning systems:** Animal-detection/driver warning systems detect animals approaching the road and then activate a sign to warn drivers that a large animal is on or near the road at that time. Animal-detection systems in Switzerland led to 80% reduction in ungulate - vehicle collisions. Used in combination with fencing, detection sections can be installed at the access roads to warn drivers that animals or vehicles may be entering the road so that drivers accessing the highway do not trigger the system. There are numerous technologies used to detect animals and the most appropriate system should be selected to fit the specific situation. If the TDC opts for

this alternative, WTI would be pleased to work on this particular aspect of mitigation design, installation, maintenance, and monitoring its reliability and effectiveness.

- **Pavement markings:** Another potential alternative is to apply reflective strips that are used to mark the stripes on the road (white and yellow) in such a way that when a large animal enters the road, the animal's body simply blocks some of the reflectors so that drivers see a break in the linear pattern of reflected light and then slow down and proceed with increased vigilance. To date there are no hard data on the effectiveness of this mitigation measure, but considering the minimal investment required, it may be worth evaluating this technique. WTI is beginning a review of pavement markers and may be able to provide general technical advice on the topic.

Monitoring

The two main objectives for the monitoring study are to quantify pre- and post-construction AVCs and animals crossing US 93. WTI has worked with the TDC on the design specifications for tracking beds both inside and outside the crossing structures, as well as brackets for mounting cameras to monitor activities at the crossing structures. In addition, WTI would like the following design details incorporated into the reconstruction plans:

- To document potential “end run” wildlife movements, WTI would like 50 meter long sand tracking beds installed at fence ends, parallel to the road;
- WTI would also like sand tracking beds perpendicular to the road and extending to the post where the wing fence section angles away from the road to the pavement and on either side of access road gaps. Data from these track beds will help WTI estimate the numbers and types of animals that may be getting trapped between the fences; and
- Sand tracking beds on top of and at the base of each jump out will allow WTI to monitor which wildlife species are using the jump outs and if wildlife may be approaching and jumping in to the right-of-way via these breaks in the fencing.

In summary, shortening the fencing affects WTI’s ability to evaluate the effectiveness of the mitigation as noted below:

- Despite the fact that shortening wildlife fencing in Evaro and Ravalli Hill will reduce the tracking bed sample size from 62 to 42, WTI will still be able to sufficiently detect changes in deer (mule and white-tailed) crossings before and after construction. With a very recent (February 2004) proposal for additional shortening of the fence at the north side of Evaro, the sample size is reduced to 37. A dramatic change in conclusions was not expected; therefore, a new power analyses was not conducted;
- If similar power analysis is to be obtained for other species, the authors would have to restore the sample size, perhaps to much more than 62 track beds;
- The power analysis for deer crossings is maintained for the three areas combined (Evaro, Ravalli Curves and Ravalli Hill). However, the power for the individual areas or Evaro and Ravalli Hill are severely affected. As a consequence WTI cannot expect to analyze the effectiveness of the mitigation measures for each area individually, nor can the effectiveness between these areas be compared. WTI can only analyze this for the three areas combined;

- WTI will discontinue preconstruction animal crossing track bed monitoring efforts in the areas that have continuous fencing for less than 1500 m in road length (i.e. within the Evaro, Ravalli Curves and Ravalli Hill areas);
- WTI will continue our preconstruction monitoring at the remaining fenced areas of Evaro, Ravalli Curves and Ravalli Hill that have fencing for at least 1500 m; and
- The resources that would have been applied to tracking the 20 beds that will no longer be included in the monitoring effort will be rebudgeted for unexpected events, such as tracking bed maintenance (grading to loosen sand media after winter compaction, weeding/spraying).

Final Summary of Fencing Design Details

Wildlife exclusion fencing effectiveness increases when the chances of animals breaching the fence are minimized. There are mitigation options to decrease animals entering the right-of way and becoming trapped between the fences. Applying mitigation at the gaps in the fence and providing escape routes will be critical on this project. In addition, maintenance is an important factor to keeping animals outside the right of way.

Continuous wildlife fencing in combination with wildlife crossing structures on controlled access highways has been shown to reduce ungulate-vehicle collisions by 96%. In a decreasing continuum from this "ideal" situation, animal-detection/driver warning systems in combination with fencing have been shown to reduce animal-vehicle collisions by 80% while "wildlife crosswalks" with unique signage only reduced ungulate vehicle collisions by about 40%.

Deterring animals from entering gaps by using cattle guards or modified bridge grates across the gaps has seen varying results, from 99.5% to 75% exclusion for Key deer approaching two different grate patterns, to some studies claiming that cattle guards are ineffective for deer exclusion. Following this logical continuum, openings with no mitigation to deter animal movements are likely to be even less effective. Combinations of these techniques may increase effectiveness beyond the effectiveness of their individual applications. ***To maximize the wildlife mitigation investments, WTI stresses that the TDC seriously consider additional mitigation measures at the gaps in the wildlife fencing with cattle guards or modified bridge grates. If these are not an option, gaps on either side of the road in combination with animal-detection and driver warning systems are recommended. In addition, wildlife fences need to be designed with adequate jump outs and escape routes***.

The US 93 reconstruction project is in the unique position to pioneer the way for future mitigation projects that must accommodate numerous access points through wildlife fencing. Given the number of gaps in the fence on this project, it is possible to install various mitigation measures deemed appropriate and monitor each for effectiveness. Measures that do not meet the performance standards that are recommended may need to be replaced in the future. This approach can be difficult to budget for, but is worth consideration.

INTRODUCTION

Over the coming years US Highway 93 (US 93) will be reconstructed on the Flathead Indian Reservation, between Evaro and Polson, Montana. The reconstruction will include the installation of wildlife crossing structures and wildlife fencing that limits animals' access to the road. The goals of this mitigation are to increase driver safety by reducing animal-vehicle collisions and provide habitat connectivity for wildlife to move safely under or over the road.

The Western Transportation Institute (WTI) at Montana State University is evaluating the effectiveness of these wildlife crossing structures and fencing, focusing on deer (white-tailed deer and mule deer combined) and black bears and two main parameters: 1. animal-vehicle collision (AVC) rates (safety); and 2. animal movements across the road (habitat connectivity). The evaluation research methods have been designed to compare animal crossings and road kill rates before and after the reconstruction. Road kill data have been and continue to be collected by MDT maintenance staff and these data will be used for the evaluation. After a pilot study in winter 2002-2003, WTI moved forward with a study design that will yield comparable pre- and post-construction animal crossing data. The preconstruction sampling regime is based on sub-sampling animal crossings of US 93 in areas that are planned to have long sections of wildlife fencing.

In December 2003, it was proposed to the US 93 Technical Design Committee that two of the three areas (Evaro and Ravalli Hill) have less wildlife fencing than originally planned. Because this proposal departs from the US 03 Memorandum of Agreement, it will be important for the Technical Design Committee (TDC) to make an informed decision with regard to how this proposal may affect the goals of the wildlife mitigation and the evaluation study.

This report summarizes AVC data, preconstruction crossing data, and concerns and recommendations regarding fencing design details. In addition, the report also addresses the effects that the fencing changes may impose on the evaluation study design. Recommendations in this report are based on the synthesis of the field data collected thus far, relevant literature and prior experience with fencing issues as they relate to the goals of reducing animal-vehicle collisions and maintaining habitat connectivity. Through discussions with Dale Becker, Confederated Salish and Kootenai Wildlife Biologist, and Pat Basting, Montana Department of Transportation Missoula District Biologist, limitations of some applications in the US 93 environment are integrated, and provide logic for our final recommendations. Dale Becker is providing specific recommendations relative to the stationing in a separate report.

One final consideration for readers of this report: WTI is providing the TDC with the best available data and information regarding the effectiveness of wildlife mitigation. The authors do not claim to have incorporated all the non-biological issues that the TDC will have to consider balancing with the goals of the mitigation, although issues that may affect the mitigation success are addressed. WTI would like to note that the current contract to collect preconstruction data for the evaluation of these mitigation measures does not include producing this paper; however, the authors are pleased to objectively report on this topic to the TDC. WTI respectively submits these considerations to aide the TDC with making informed decisions.

PRECONSTRUCTION ANIMAL-VEHICLE COLLISIONS AND ANIMAL CROSSINGS OF US 93 RELATIVE TO WILDLIFE FENCING PLANS

A summary of available animal-vehicle collision and crossing data from the Evaro and Ravalli Hill areas as they relate to the goals of the mitigation efforts are noted below. Following the review of the existing data, potential effects for consideration are outlined regarding proposed fencing changes. This report does not discuss the Ravalli Curves wildlife mitigation area since there are no proposed changes for Ravalli Curves.

Animal-vehicle collisions

One of the goals of the evaluation of the wildlife mitigation is to compare preconstruction animal-vehicle collisions (AVCs) to post-construction AVC occurrences. Given US 93's safety record, it was felt the amount of time that field observers would have to spend surveying the corridor for road killed animals exposed them to a high safety risk. Also, such a survey requires a driver, an observer, a vehicle and gas, and with a limited budget other evaluation tasks, such as quantifying animal crossings before construction would be a better allocation. After careful thought, WTI opted to work with AVC monitoring data collected by Montana Department of Transportation's (MDT).

Based on data provided by the MDT Safety Bureau, between 1992 and 2002, MDT Maintenance crews and Montana Highway Patrol (MHP) recorded a total of 279 AVC and/or road kill occurrences on US 93 between Evaro and Polson (for this report, "animal-vehicle collisions" and "road kill" are synonymous). The 2003 data were incomplete at the time this report was drafted. Figure C-1 displays the annual AVC reports from 1992-2002.

Data is used cautiously for several reasons. First, these data were collected opportunistically rather than systematically and therefore are not statistically reliable. Second, the database is a combination of two data sources; despite efforts to eliminate double counts, it may not be obvious that a record is a repeat of a single occurrence (e.g., if MHP records an incident, then MDT maintenance picks up the carcass at a later date with a slightly different odometer reading, the data may not appear to be duplicate information and could be double counted).

Apparent increases in AVC reports seen in Figure C-1 could be due to an actual increase AVCs or may be a result of indistinguishable double counts. It may also be due to inconsistencies in reporting efforts. For example, MDT formalized the collection of these data in 1998, whereas prior to 1998 there were no initiatives to formally collect these data. The jump in reporting in 2002 may be due to WTI emphasizing the importance of these data to MDT maintenance staff that remove carcasses from US 93; WTI requested staff not to change their level of effort but this may have occurred inadvertently with increased awareness of the significance and purpose of these data.

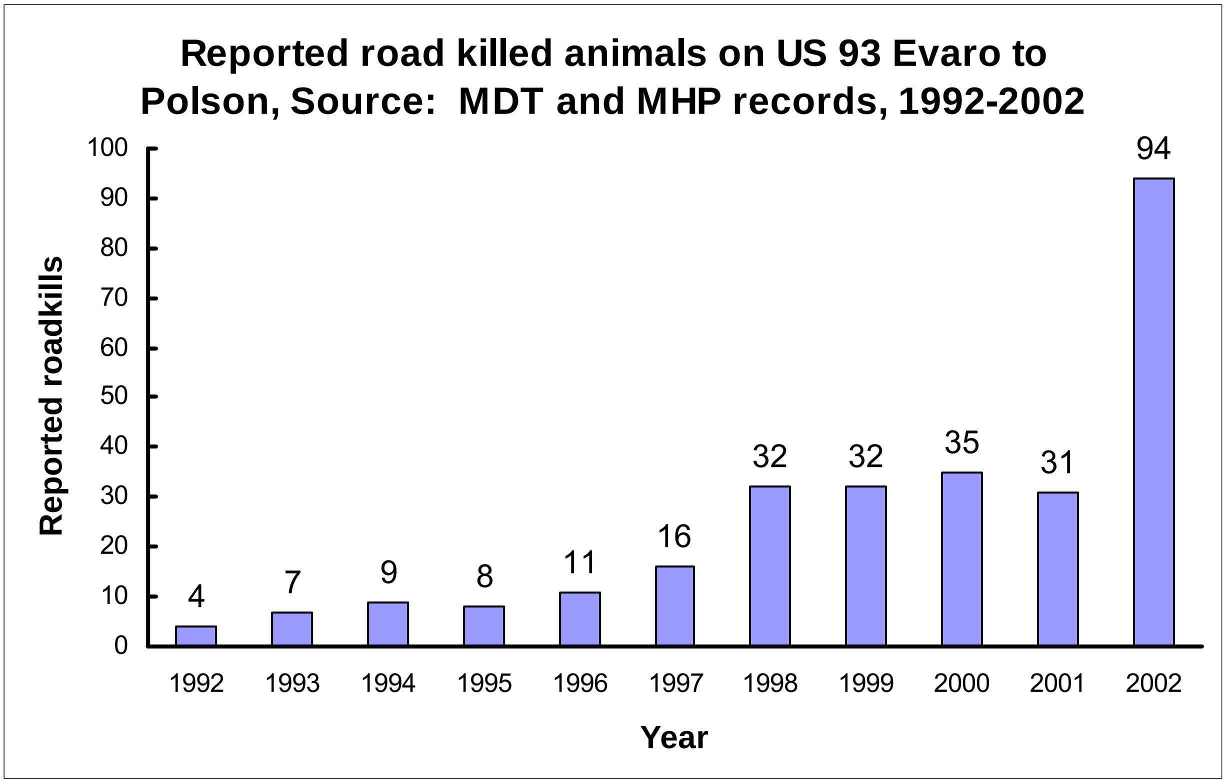

Figure C-1: Annual reported roadkills on US 93 Evaro to Polson from 1992 to 2002. Source: Montana Department of Transportation and Montana Highway Patrol records.

Despite potential double counts or increased reporting, it is likely these data underestimate the numbers of animals hit by vehicles. This is probably due to the following compounding reasons: 1) not all animal-vehicle collisions are reported by the drivers; 2) animals hit by vehicles don't always die on or near the road but could die away from the road, undetected; and 3) not all animals killed by vehicles on or near the road are seen or reported and in some cases, people pick up carcasses without reporting the occurrence.

The authors are cautious in making any definitive conclusions with this dataset but rather use these data as the "best available information". For this report, three sets of data are presented: 1) the entire data set from 1992 to 2002; 2) a subset of data from 1998 to 2001; and 3) the 2002 data subset alone in an attempt to control sampling differences between years. Road kill locations were recorded by mile markers to the tenth of a mile; therefore the authors refer to mile markers rather than metric stationing.

Evaro

The original plan for the Evaro area included wildlife fencing from mile marker 7.2 to 12.2. Between 1992 and 2002 there were a total of 38 reported ungulate (deer and elk) road kill along this stretch of road, ranging from 0 to 4 and averaging 0.88 (SD = 1.03) reported road kills per tenth mile. Figure C-2 shows how the Evaro road kill data from 1992 to 2002 breaks down for ungulates and bear, per tenth mile. Figure C-3 shows the same with the subset of data from 1998 to 2001 and Figure C-4 shows the 2002 data alone.

It has been proposed to not install wildlife fencing from the Reservation boundary to Whispering Pines Road (mile markers 7.2 to 9.3). This area averaged 1 (SD = 1.05) reported road kills per tenth mile while the areas that will be fenced as originally planned averaged 0.8 (SD = 1.03) reported road kills per tenth mile (Table C-1). Similar trends are seen in the 1998-2001 and 2002 data subsets, with the average road kills per tenth mile in the unfenced areas slightly exceeding means for the fenced area and the entire Evaro stretch; though there was no statistical difference between fenced and unfenced means.

Note: these calculations and graphs do not include the most recent proposal changes to shorten the fence at the north end of Evaro.

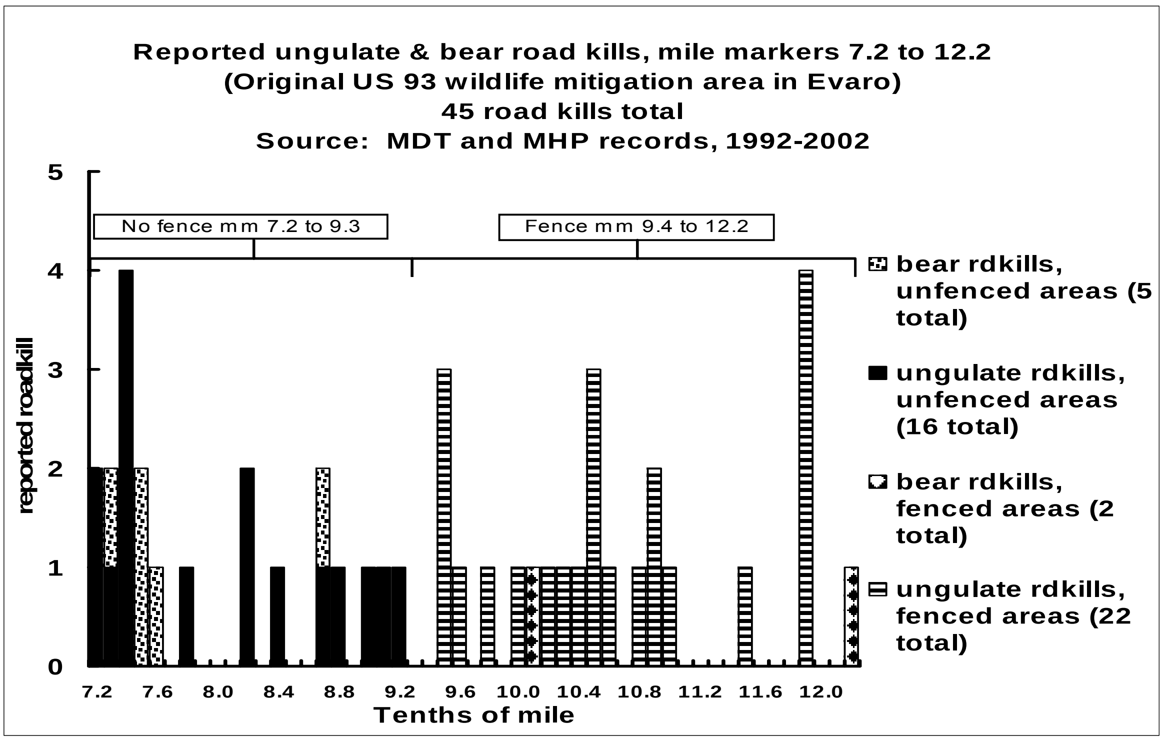

Figure C-2: Reported ungulate and bear road kills from 1992-2002 per tenth mile from mile marker 7.2 to 12.2 on US 93 in the Evaro area. The graph distinguishes areas that will and areas that may not include wildlife fencing in the reconstruction.

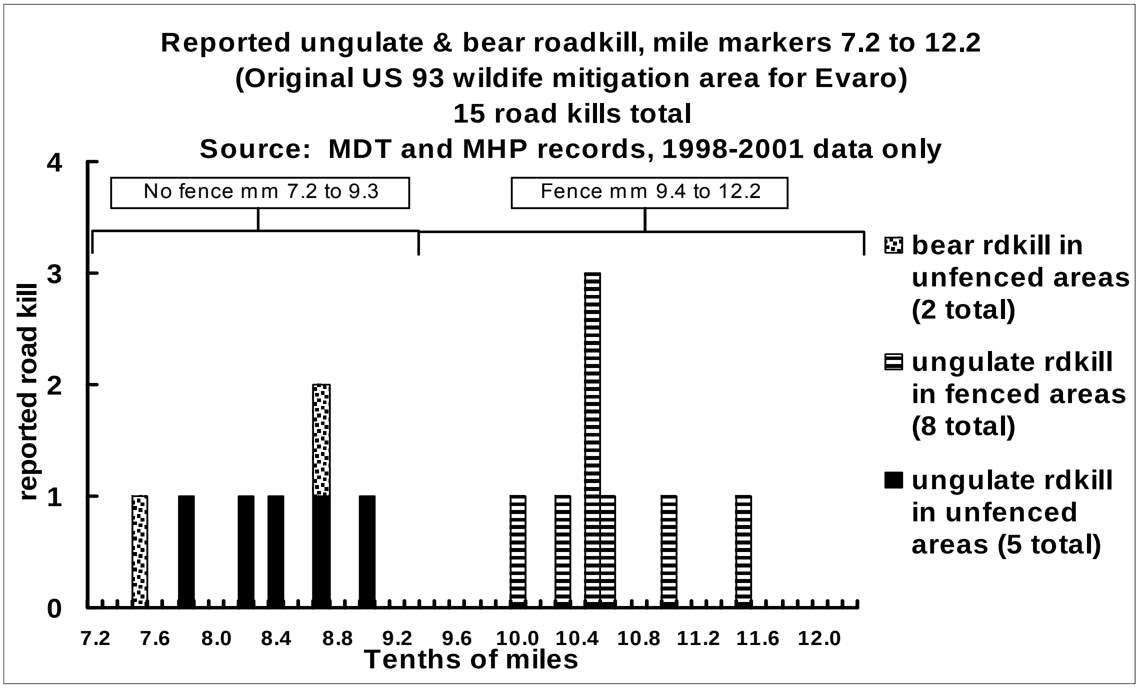

Figure C-3: Reported ungulate and bear road kills from 1998 – 2001 per tenth mile from mile marker 7.2 to 12.2 on US 93 in Evaro area. The graph distinguishes areas that will and areas that may not include wildlife fencing in the reconstruction

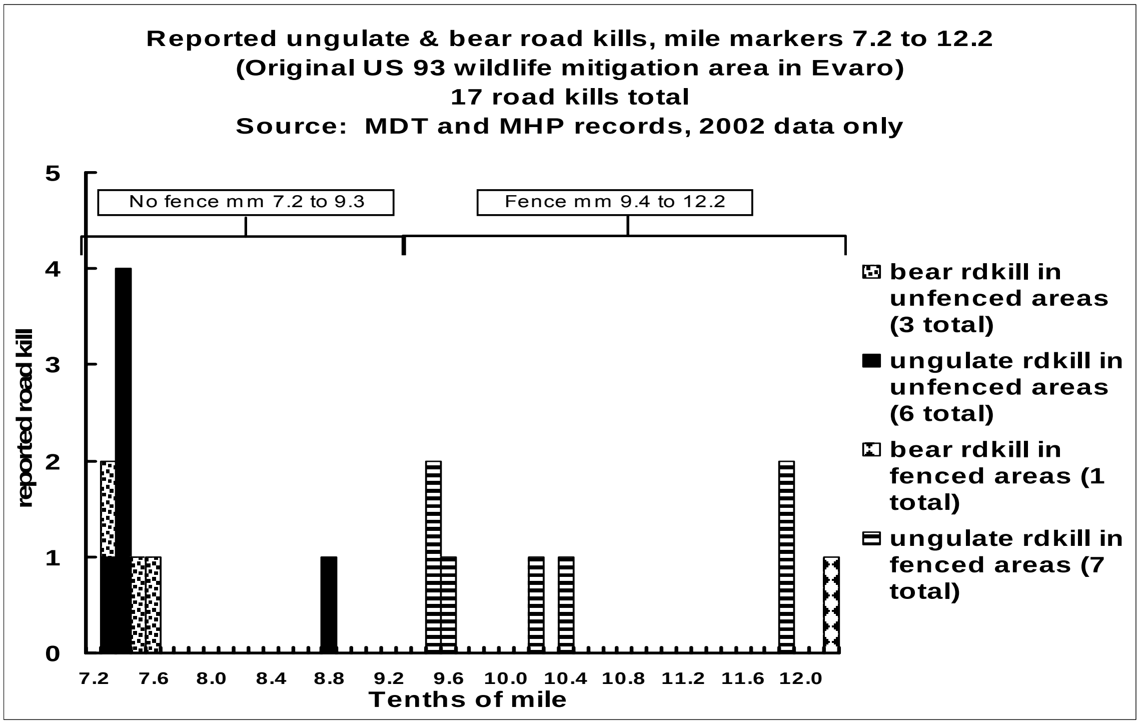

Figure C-4: Reported ungulate and bear road kills from 2002 per tenth mile from mile marker 7.2 to 12.2 on US 93 in the Evaro area. This is the most recent available road kill data. The graph distinguishes areas that will and areas that may not include wildlife

Table C-1: Summary statistics for reported road kills per tenth mile on US 93 in the Evaro area from 1992-2002, 1998-2001, and 2002 alone. Subsets of data were summarized in an effort to control probable differences in sampling efforts.

Reported Evaro roadkills per 10th mile	**1992-2002 data (45 road kills)**			**1998-2001 data (15 road kills)**			**2002 data (17 road kills)**		
	entire area	fenced	unfenced	entire area	fenced	unfenced	entire area	fenced	unfenced
N (10ths of miles)	51	30	21	51	30	21	51	30	21
Mean # rdkill / 0.1 mile	0.882	0.8	1	0.294	0.267	0.333	0.333	0.267	0.429
StDev	1.032	1.031	1.049	0.6097	0.64	0.577	0.766	0.583	0.978
SE Mean	0.145	0.188	0.229	0.0854	0.117	0.126	0.107	0.106	0.213

Ravalli Hill

The original plan in the Ravalli Hill area was install wildlife fencing from mile marker 27.5 to 30.9. Across this stretch, a total of 8 deer road kill and no bear road kill were reported from 1992-2002 (Figure C-5), ranging from 0 to 1 per tenth mile. Fencing will be installed from the northern end of the town of Ravalli and the MT 200 junction to mile marker 28.5, but it is proposed to not fence from mile 28.6 northward. Of the 8 reported road kills, 4 occurred in the fenced area while the other 4 were in the proposed unfenced area. Summarizing the data from 1992 to 2002, the entire Ravalli Hill area averaged 0.2 (SD = 0.19) road kill per tenth mile; while an average 0.36 (SD = 0.5) and 0.17 road kill per tenth mile were reported for fenced and unfenced Ravalli Curves areas, respectively. Because of the low numbers of reported road kills, WTI did not analyze the subsets of data to compare to the larger set of data.

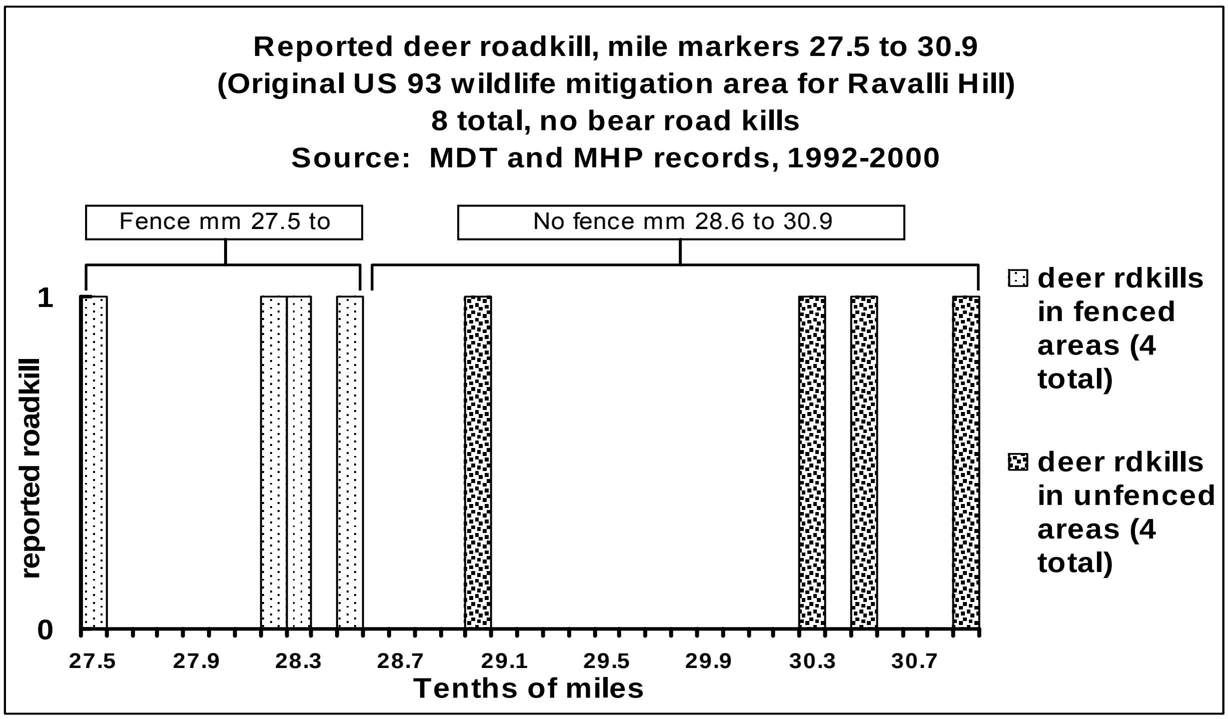

Figure C-5: Reported deer road kills from 1992-2002 per tenth mile from mile marker 27.5 to 30.9 on US 93 in the Ravalli Hill area. The graph distinguishes areas that will and areas that may not include wildlife fencing in the reconstruction.

Animal crossings of US 93

To evaluate the wildlife mitigation measures in terms of maintaining connectivity across US 93, WTI is comparing pre- and post-construction animal movements across the road in areas originally planned to have the longest sections of wildlife fencing with crossing structures installed (Evaro, Ravalli Curves, and Ravalli Hill). To estimate animal crossings prior to the reconstruction, WTI installed 62 sand tracking beds, each 100 meters long, at random locations parallel to the road. This method randomly sub-samples animal activities, as interpreted by tracks, next to US 93, for approximately 30% (6200 meters total) of the total length of road that was planned for wildlife fencing. The resulting extrapolated preconstruction crossing rate for those lengths of road will be compared to post-construction tracking bed data that quantify animals crossing under or over US 93 via the crossing structures and animals that cross the road, at grade, at the ends of the fence.

WTI documented tracking observations from these 62 tracking beds for 9 and 6 weeks in the summer and fall, respectively, until the tracking medium froze. During that time, the 25 tracking beds in Evaro and the 20 tracking beds in Ravalli Curves were visited once a week for a total of 15 visits. The 17 tracking beds in Ravalli Hills stretch were visited once a week for 10 visits due to the fact that these tracking beds were installed later than the Evaro and Ravalli Curves tracking beds.

Across all three study areas, WTI recorded a total of 2193 track observations. These observations included interpreted behaviors of animals approaching, leaving, and moving parallel to the road. It was assumed an animal crossed the road if the animal's trajectory spanned 5 meters or less of the tracking bed length as they approached or left the road. Presence was recorded when behaviors or directional movements were indiscernible. Tracks of black bear (no grizzly bear; hereafter we refer to black bear simply as "bear"), elk, deer (white-tailed and mule combined), moose, mountain lion, coyotes, raccoon, rabbit, skunk, snakes, geese, and porcupine, as well as domestic cats and dogs, cattle and horses, and humans (and presumably a human entity stepping across the bed on roller-blades) were found. Numerous automobile, 4-wheeler, and bicycle tracks that moved through the beds were also found. Regarding WTI's study focal animals, 1115 and 94 observations of deer and black bear tracks, respectively, across the three study areas (Figures C-6 & C-7) were recorded. Most of these track observations were interpreted as crossings of the road (Figures C-8 & C-9).

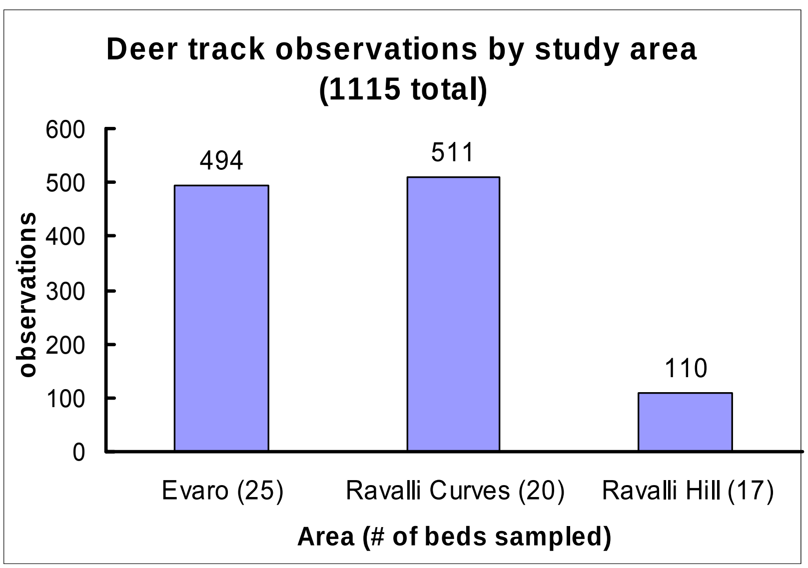

Figure C-6: Deer track observations recoded in the Evaro, Ravalli Curves and Ravalli Hill track beds during the 2003 summer and fall seasons. The track beds randomly sub-sample approximately ately 30% of the total length of the US 93 originally planned for the wildlife fencing with crossing structures; hence, each area had varying numbers of 100 m tracking beds, as noted parenthetically on the x-axis.

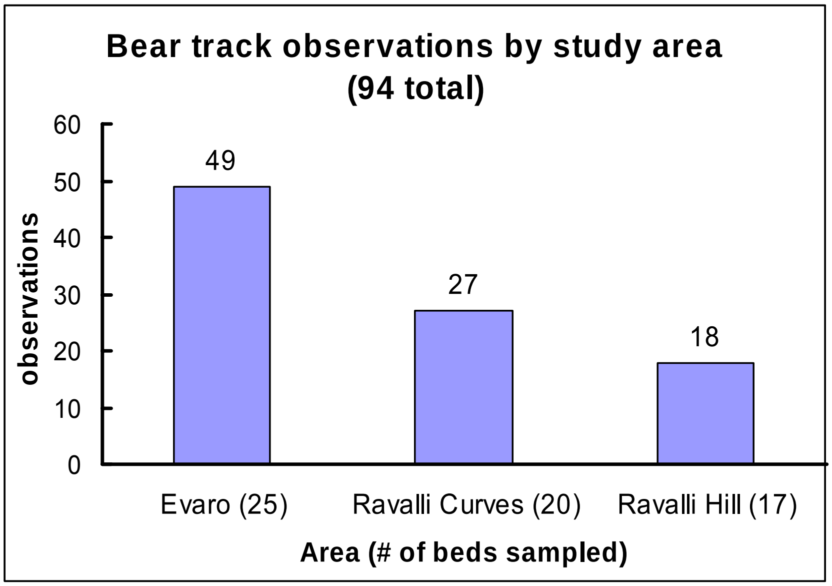

Figure C-7: Bear track observations recorded in the Evaro, Ravalli Curves and Ravalli Hill track beds during the 2003. The track beds randomly sub-sample approximately 30% of the total length of US 93 originally planned for wildlife fencing with crossing structures; hence, each area had varying numbers of 100m tracking beds, as noted parenthetically on the x-axis.

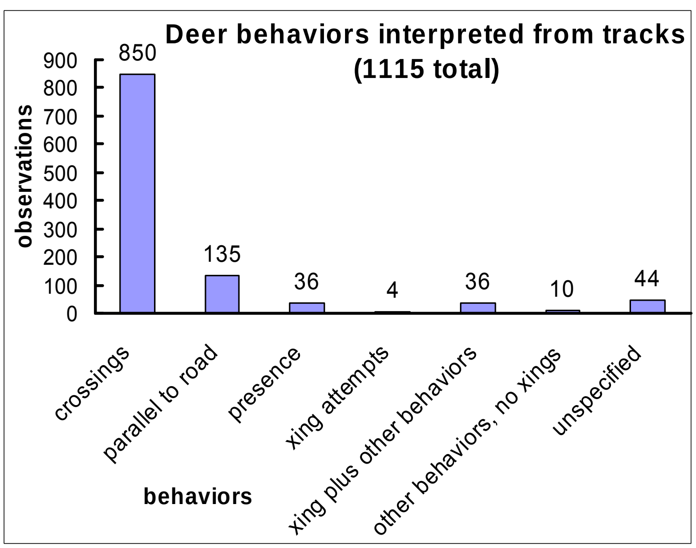

Figure C-8: Deer behavioral observations as interpreted from tracks recorded in 2003 along a sub-sample of approximately 6200 meters of US 93 originally planned for wildlife fencing and crossing structures in the Evaro, Ravalli Curves and Ravalli Hill areas.

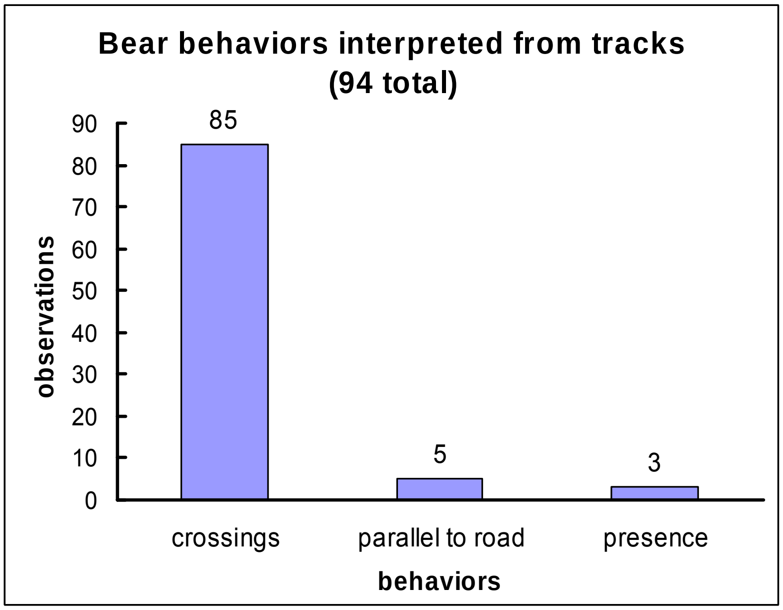

Figure C-9: Bear behavioral observations as interpreted from tracks recorded in 2003 along a sub-sample of approximately 6200 meters of US 93 originally planned for wildlife fencing and crossing structures in the Evaro, Ravalli Curves and Ravalli Hill areas.

Evaro

WTI visited the 25 Evaro track beds 15 times and recorded a total of 494 deer and 49 bear tracks. Of these observations, deer crossed the road 219 times (44%) and bears crossed 46 times (94%). A total of 208 (42%) deer and 33 (67%) bear track observations occurred in track beds 1-9, the area proposed to have no fencing (Figures C-10 & C-11). Researchers calculated deer crossing rates as the number of deer crossing observations per tracking bed per visit (crossing rates for bears were not calculated due to small sample size). Mean crossing rates for all 25 beds, 16 beds in the fenced area, and 9 beds in the unfenced area were compared (Table C-2) and are displayed graphically for fenced and unfenced areas as well (Figure C-12).

Deer crossing rates across all 25 track beds in Evaro ranged from 0 to 2.3 crossings per bed per visit. The range of rates in the fenced areas was 0 to 1.7 with the highest deer crossing rates of 1 and 1.7 found in the track beds located at the proposed southern terminus of the fence, near Whispering Pines Road. Deer crossing rates in the proposed unfenced areas ranged from 0.3 to 2.3, with the highest crossing rate recorded in the southern most track bed near the Reservation boundary and the south end of the original fencing plan. When a 2-sample t-test to compare mean deer crossing observations per bed per visit between the fenced and unfenced areas was applied, the crossing rate in the unfenced area was higher, but not quite significant ($P<0.05$) (Figure C-11; n = 20, $t_{12} = 1.85$, $P = 0.089$).

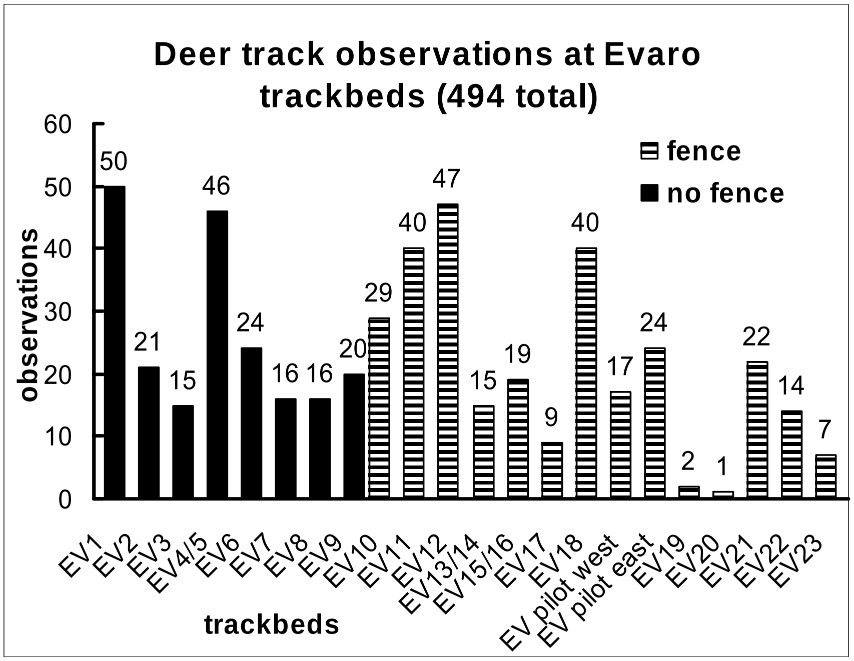

Figure C-10: Deer track observations from 15 weekly visits of 25 100-meter sand track beds randomly placed parallel to US 93 in the Evaro area. The graph distinguishes between areas that will and areas that may not include wildlife fencing in the reconstruction.

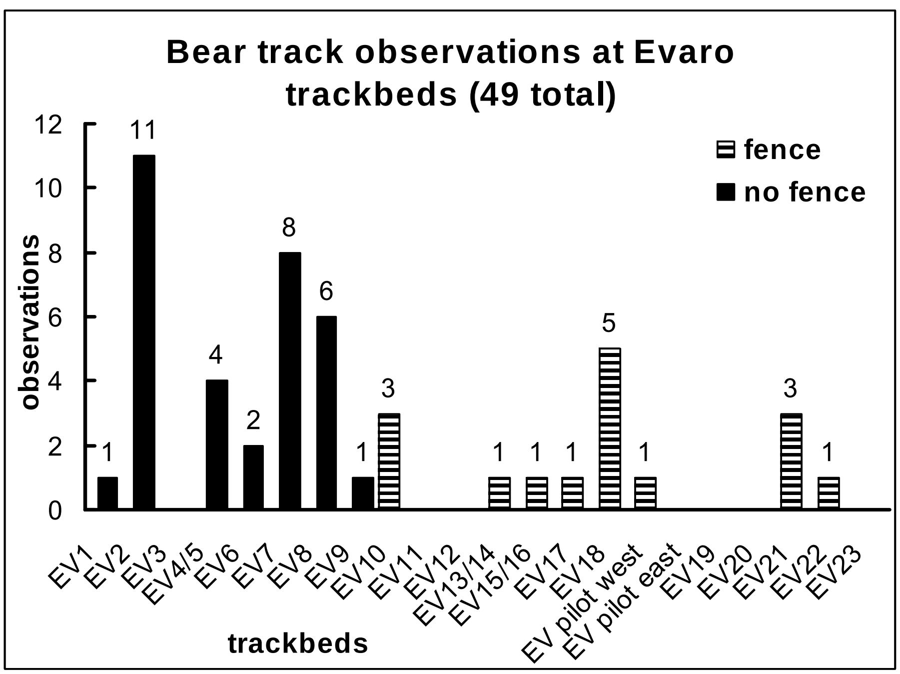

Figure C-11: Bear track observations from 15 weekly visits of 25 100-meter sand track beds randomly placed along and parallel to US 93 in the Evaro area. The graph distinguishes between areas that will and areas that may not include wildlife fencing in the reconstruction.

Table C-2: Average deer crossings rates (crossings per track bed per weekly visit) from 15 visits of the 25 100-meter sand track beds randomly placed along and parallel to US 93 in the Evaro area. Mean deer crossing rates were greater in the areas proposed to not have wildlife fencing (n = 20, t 12 = 1.85, P = 0.089, α = 0.1).

Average deer crossing rates (xings per bed per visit)	**Evaro**		
	entire area	fenced	unfenced
total meters sampled	2500 m	1600 m	900 m
Mean rate of deer xings/bed/visit	0.773	0.583	1.058
StDev	0.571	0.527	0.616
SE Mean	0.128	0.137	0.218

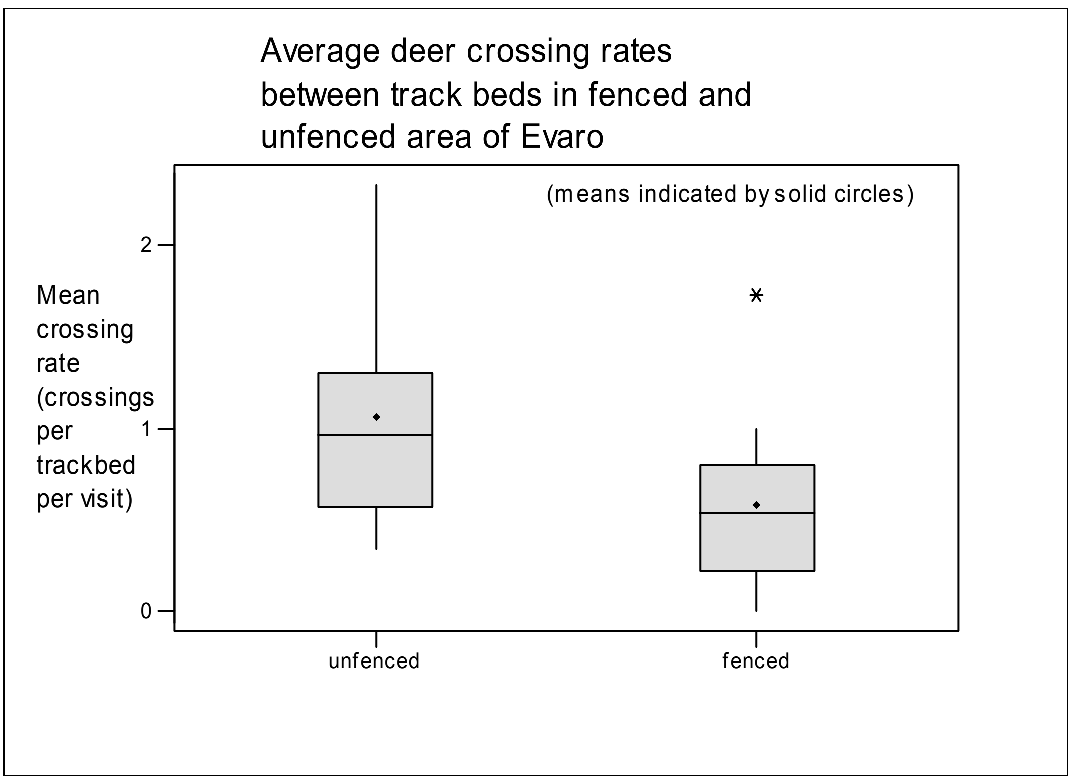

Figure C-12: Average deer crossing rates (crossings per track bed per weekly visit) from 15 visit of 9 and 16, 100 m sand track beds in unfenced and fenced areas, respectively, along US 93 in the Evaro area. Mean deer crossing rates were greater in the areas proposed to not have wildlife fencing was higher, but not significant (*P*<0.05; n = 20, t_{12} = 1.85, *P* = 0.089). The box represents the middle 50% of the data. The line through the box represents the median. The lines extending from the box represent the upper and lower 25% of the data (excluding outliers). Outliers are represented by asterisks (*).

Ravalli Hill

Of the 110 deer tracks detected during 10 visits of the 17 track beds in the Ravalli Hill area, only 20 (18.2%) occurred in the proposed unfenced area (Figure C-13) along with 3 (17%) of the 18 bear track observations (Figure C-14). Most bear observations were found in track beds at the base of Ravalli Hill, where the road leaves the town of Ravalli and heads north, ascending the hill.

Deer crossings per bed per visit ranged from 0 to 1.9; no deer were recorded crossing in the 8 track beds located in the proposed unfenced area, while crossing rates observed in the track beds located in the fenced area spanned from 0.2 to 1.9 deer crossings per bed per visits. WTI did not conduct any tests for statistically significant differences between deer crossing rates in the fenced and unfenced areas of Ravalli Hill.

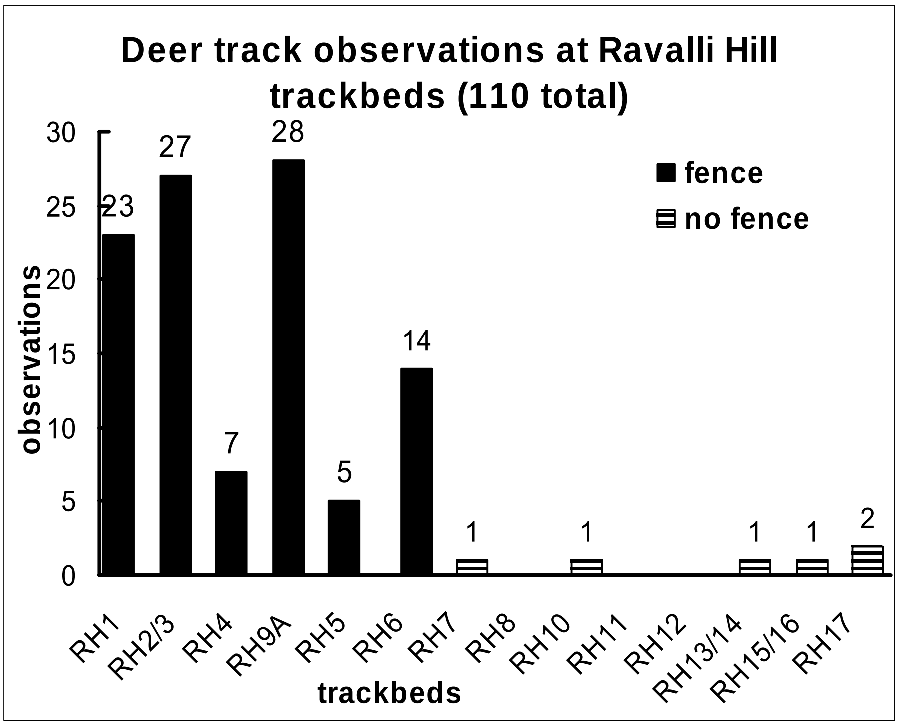

Figure C-13: Deer track observations from 15 weekly visits of 25 100-meter sand track beds randomly placed along and parallel to US 93 in the Ravalli Hill area. The graph distinguishes areas that will and areas that may not include wildlife fencing in the reconstruction.

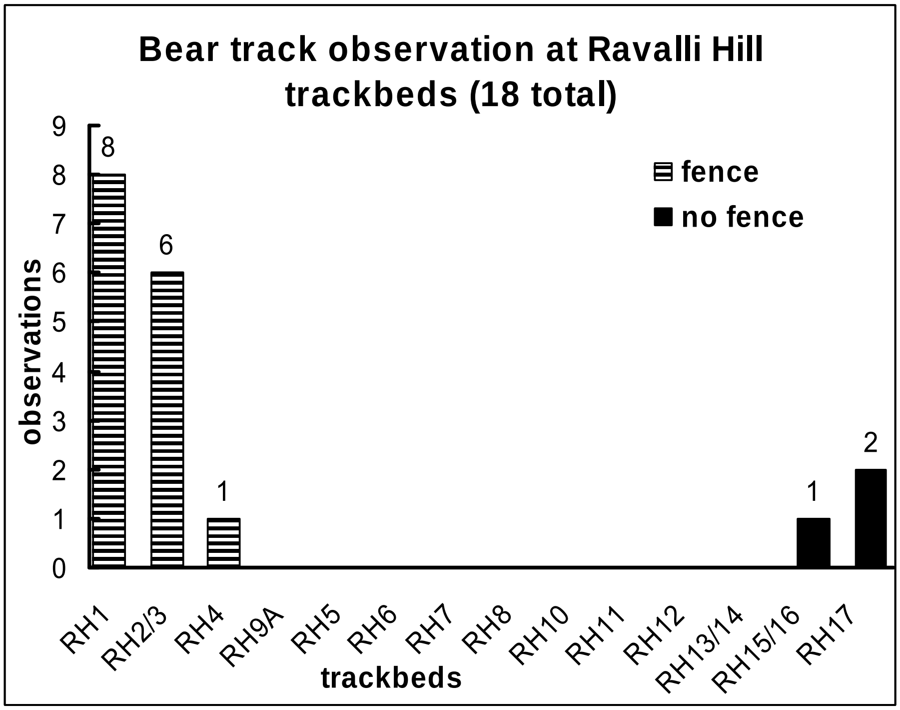

Figure C-14: Bear track observations from 15 weekly visits of 25 100-meter sand track beds randomly placed along and parallel to US 93 in the Ravalli Hill area. The graph distinguishes areas that will and areas that may not include wildlife fencing in the reconstruction.

Discussion of Animal-Vehicle Collision and Animal Crossing Data Relative to Proposed Wildlife Fencing Changes

While far from conclusive due to the limitations of the AVC data mentioned earlier, no statistical difference between the reported animal-vehicle collisions in fenced versus unfenced areas overall were found. The crossing rate data prompts some considerations as fencing plans are revised.

Evaro

The elimination of wildlife fencing from Whispering Pines Road south to the reservation border is concerning relative to reducing AVCs. In this area, 21 reported AVCs occurred between 1992 and 2002. In addition, track bed data indicate higher rates of deer and bear activity in the unfenced area compared to the fenced area, with 42% of the deer and 67% of the bear track observations recorded in the 9 beds in the unfenced area (36% of all track beds in the Evaro study area).

WTI has specific concerns about the area just north of the Reservation boundary. Bears and deer cross frequently at the southern end of the Evaro area, just north of the town site. The stretch north of Evaro transitions from 2 to 4 lanes and just a ways further north there is a curve. Short sight distances on the curve, vehicles turning on or off the highway from access points near the Reservation boundary and the lane transition may affect drivers' abilities to see and avoid animals in this area. Reconstruction will reduce access points in Evaro "proper", but the footprint of the road will not be much different than it is currently. ***Numerous black bear AVCs at the northern end of the Evaro study area, near East Fork of Finley Creek have occurred,***

some of which have recently occurred north of the original fencing proposal's northern termination point. Without mitigation, the southern and northern stretches of the Evaro area originally proposed to be fenced, AVCs may continue to be an issue in this area.

Fencing from Whispering Pines Road to the Reservation border may not be favored for a variety of reasons, but the authors recommend the TDC look at alternative mitigation measures for this stretch. Such alternative measures are listed and described in "Alternatives to Wildlife Exclusion Fencing".

Ravalli Hill

The AVC reports on the top of Ravalli Hill, the proposed unfenced stretch, are not of concern and there are only a few deer and black bear tracks recorded in that area along with occasional coyote, skunk, and snake tracks. It does not appear that there will be major implications in terms of AVCs if the top of Ravalli Hill is unfenced.

If the fencing in Ravalli Hill is reduced as proposed, the authors recommend that the new north end of the fence extend further beyond Ravalli Hill wildlife crossing #2 than originally proposed, tying the eastern fence in to the rocky slopes on that side of the highway. It will also be important to consider the wing fencing angle and length for the western fence's north end, paying attention to the potential constriction that could occur between the wing fence and the Bison Range fence.

However, ***shortening the fence at the south end of Ravalli Hill is not recommended..*** Although existing AVC data indicate the southern most stretch of Ravalli Hill is not currently a high kill area, ***researchers recorded many deer and black bear tracks and crossings in our first three track beds in this area.*** While this is currently an ideal scenario (i.e., animals moving across the road without getting hit), the new road with increased capacity and larger radius for the curve just north of Ravalli may result in faster moving traffic and more animal-vehicle conflicts. Currently, northbound drivers accelerate from the 45 mile per hour speed zone in Ravalli to ascend the hill and southbound drivers are breaking as they descend the hill and curve into the town of Ravalli. ***Given the curve, hill, high rate of crossing in this area, and increased traffic levels in the future, the authors recommend that the southern end of the Ravalli Hill fencing begin near the town of Ravalli as originally planned.***

WTI acknowledges other issues regarding this southern stretch of fencing in Ravalli Hill. The majority of the track observations in the Ravalli Hill area were recorded in track beds just north of the town of Ravalli, about 300-500 m south of the planned wildlife crossing. Until animals adapt to the fence and use the under-crossing, animals may "end run" around the southern fence termini which could result in increased human-wildlife interactions in Ravalli.

EFFECTS OF WILDLIFE FENCING CHANGES ON WILDLIFE MONITORING METHODS

This section outlines potential effects of proposed fencing changes as they relate to monitoring and evaluating effectiveness of the mitigation efforts. Animal crossing methodologies is the focus since this is the component of the evaluation that will be affected by any changes in the fencing. Animal-vehicle collision data collection will not be affected by fencing changes. Again, there is no reference to the Ravalli Curves wildlife mitigation area in this report as there are no proposed changes for this area.

Animal crossing tracking bed study design

WTI has been documenting tracking observations of animals crossing the road from 62 tracking beds since their installation, throughout summer and autumn 2003 (see previous description of methods). The sample size of 62 beds was determined based on a power analysis conducted with similar crossing rate data from another study (Barnum 2001). Through this power analysis, WTI determined that a sample size of 62 track beds (each tracking bed is a sample unit) would enable detection of differences of ±13% and greater between the pre- and post-construction crossing rates.

With the proposal to reduce the wildlife fencing lengths in the Evaro and Ravalli Hill areas, 20 of the 62 tracking beds are now in areas that will not have wildlife fencing (Table C-3). These 20 tracking beds can no longer be used to estimate the number of wildlife crossings to compare to post-construction crossing data in areas with wildlife crossing structures and fencing. This means that the sample size of the study is reduced by 32%.

A reduction in sample size makes it harder to show possible changes in animal crossing rates before and after construction. Figure C-15 demonstrates how sample size affects the ability to detect a difference between pre- and post construction deer crossing rates. Based on a power analysis conducted before installation of the tracking beds investigators estimated that with 62 beds differences in pre- and post-construction crossing rates of ±13% and greater would be detected. Looking at that same analysis, the loss of 20 tracking beds indicates investigators would only be able to detect differences of ±14% and greater, which will not severely affect the evaluation study, but with fewer tracking beds it becomes exponentially harder to detect differences between treatments, as Figure C-15 exemplifies, for example, when sample size is reduced from 20 to 10. These power analyses were based on data from another study (Barnum 2001) and were translated to the WTI study design. This situation may be different, and the loss of the 20 tracking beds may affect the investigators ability to detect differences more than is understood based on Barnum’s (2001) data. To further explore this situation, investigators did a new power analyses based on the data collected from the sand tracking beds in summer and autumn 2003.

Table C-3: Stationing and tracking bed (sampling unit) changes for original and proposed fencing plans.

Study Area	Stationing for original fencing plans	Number of original tracking beds (n)	Stationing for proposed fencing plan	Tracking beds (n) under proposed fencing plan
Evaro	±123 to ±205	25	157 (Whispering Pines rd) to ± 205	16 (9 beds lost: beds 1-9)
Ravalli Curves	±374 to ±437	20	No changes	20 (no changes)
Ravalli Hill	± 451 to ±503	17	±451 to ± 465 & ±497 to ±503?	6 (11 beds lost; beds 6, 7, 8, 10, 11, 12, 13, 14, 15, 16, and 17)
Totals	*19,700 meters of fencing*	*62 tracking beds*	*13,100 meters of fencing*	*Sum: 42 tracking beds remaining, 20 lost*

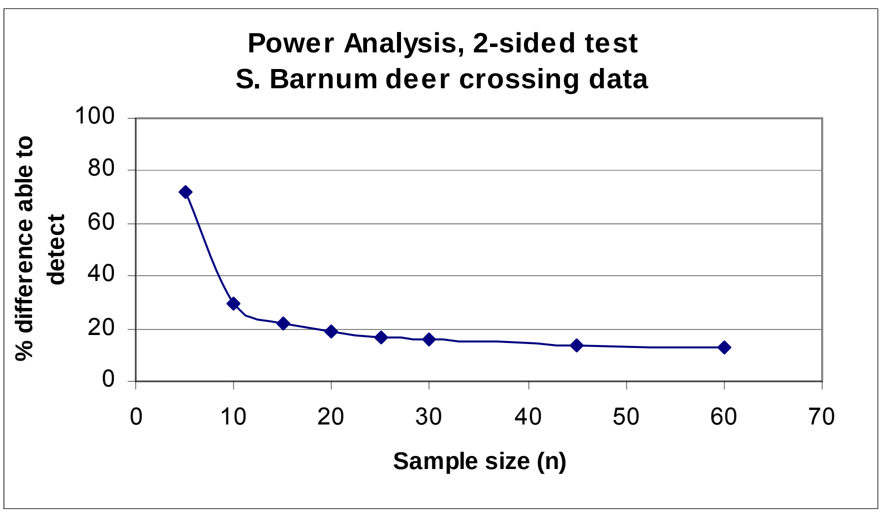

Figure C-15: Power analysis for a 2-sided test based on Barnum's deer crossing data, translated to the study design of the Hwy 93 study. Power = 0.80, α = 0.05 (Barnum 2001).

Power analyses with 2003 US 93 tracking data

WTI conducted the power analyses using tracking data observations of deer crossings only (white-tailed deer and mule deer combined). The average number of deer tracks encountered per visit per sand tracking bed (100 m long) (TRX/VISIT) were calculated. The beds were visited 9 times (Evaro and Ravalli Curves) and 4 times (Ravalli Hill) in summer and 6 times in autumn (all three areas).

For this analysis investigators assumed to have one years worth of data before construction, and one years worth of data after construction. It was assumed that the tracking beds would be visited once a week during three six week periods (spring, summer and fall), 15 times per year in total. Therefore, TRX/VISIT by 15 was multiplied ((TRX/VISIT) x 15). The average number of deer tracks per 15 visits was 12.6 (based on 62 beds). This variable is a “count” variable that typically has a positively skewed distribution. In order to conduct a t-test this variable must be transformed into one that has a normal distribution. Taking the natural logarithm typically does this. However, there were 13 sites that had 0 deer tracks (out of a total of 62 sites), and this causes problems when the natural logarithm (Ln) is taken. Therefore a relatively small value; 0.1 (Ln((TRX/VISIT)x18+0.1)) was added.

Four power analyses were performed. The first two were based on all 62 tracking beds, whereas the 3rd and 4th analyses were based on the 42 remaining tracking beds only (average number of deer tracks was 14.63 with 3 sites that had 0 deer tracks). The first and third analyses are based on the alternative hypothesis that investigators do not know whether the mitigation measures will result in more or fewer animal crossings (2-sided). The second and fourth analyses are based on the alternative hypothesis that if there is a difference investigators expect the mitigation measures to result in more animal crossings (1-sided).

Figure C-16 shows the results for a 2-sided test. Based on the data from all 62 tracking beds the percentage difference investigators would be able to detect was increased from ≥16.9% to ≥20.0% (a loss of 3.1%). Based on the data from the 42 remaining tracking beds the percentage difference investigators would be able to detect was increased from ≥11.8% to ≥13.4% (a loss of 1.6%). With only 42 tracking beds remaining investigators are still far off from the steep sections of the two curves on Figure C-16 where a very rapid loss of power occurs.

Figure C-17 shows the results for a 1-sided test. Based on the data from all 62 tracking beds the percentage difference investigators would be able to detect was increased from ≥15.4% to ≥17.9% (a loss of 2.5%). Based on the data from the 42 remaining tracking beds the percentage difference investigators would be able to detect was increased from ≥11.1% to ≥12.4% (a loss of 1.3%). With only 42 tracking beds remaining investigators are still far off from the steep sections of the two curves on Figure C-16 where a very rapid loss of power occurs.

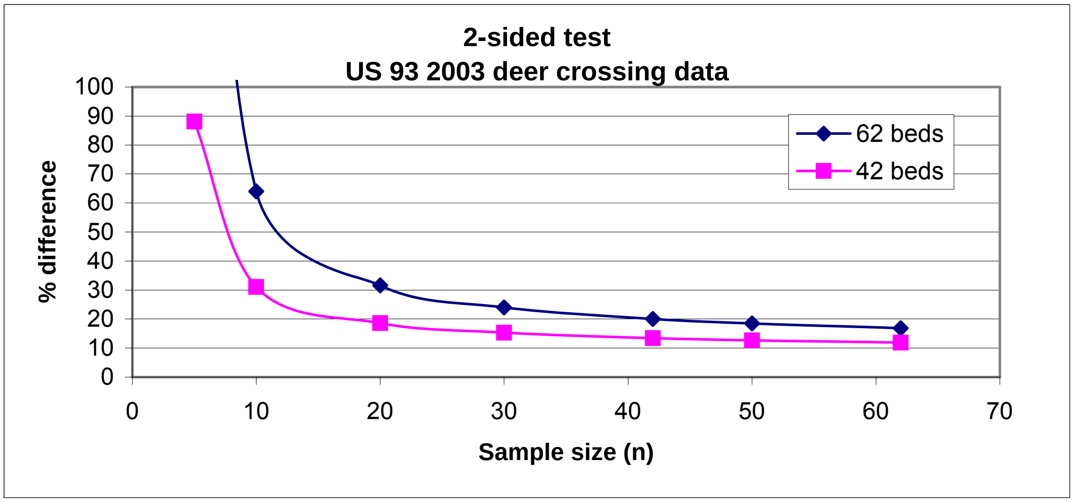

Figure C-16: Power analyses for a 2-sided test for two data sources: one based on all 62 tracking beds, and one based on the 42 remaining tracking beds only. Power = 0.80, α = 0.05.

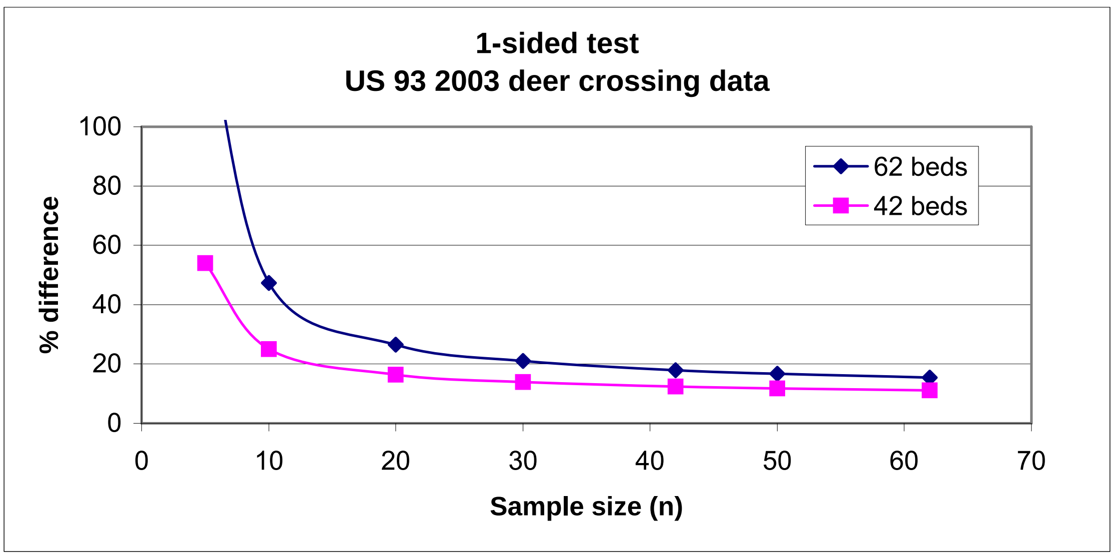

Figure C-17: Power analyses for a 1-sided test for two data sources: one based on all 62 tracking beds, and one based on the 42 remaining tracking beds only. Power =0.80, α = 0.05.

Power analyses results

There is great similarity between the power analyses based on Barnum's (2001) data and the data based on the 42 remaining tracking beds. This indicates that the original power analysis described the situation for Hwy 93 quite well.

Ten of the 11 beds that were lost on Ravalli Hill had 0 deer tracks. This resulted in a relatively low standard deviation for the 42 remaining tracking beds. As a result the 42 remaining tracking beds had better power than the 62 tracking beds. The standard deviation will be based on the fenced areas only, and not on the areas that are no longer scheduled to be fenced.

Although a 1-sided test seems to makes sense, it is not really appropriate. The wildlife crossing structures and fencing may make road crossings safer for the animals, but they do not necessarily result in an increase of crossings. The road will be wider than before and the animals can now only cross at the wildlife crossing structures. Therefore a 2-sided test is far more appropriate than a 1-sided test. The conclusion should be based on the power analysis for a 2-sided test that is based on the data from the 42 remaining tracking beds only.

Conclusions on Fencing Reduction Effects on Monitoring Methods

The new power analysis for a 2-sided test based on the data from the remaining 42 tracking beds indicates that the percentage difference we would be able to detect would increase from ≥11.8% to ≥13.4% (a loss of 1.6%). This does not substantially affect our ability to detect a difference in animal crossings before and after construction. In addition, according to the line in Figure C-1 investigators are still well on the horizontal part of the curve, which indicates that the study still has a substantial safety margin for the power of the analyses. As a whole, the loss of the 20 tracking beds has increased the investigators ability to detect a difference in animal crossings before and after construction (from ≥16.9% to ≥13.4%), largely due to the reduction in "0-observations" from the tracking beds on Ravalli Hill. Based on these three arguments (only 1.6% loss, acceptable safety margin, better power than before) the authors cannot justify asking for compensation for the loss of the 20 tracking beds.

However, if one is not only interested in a potential change in animal crossings in the three areas combined, but also in a potential change in animal crossings in the individual areas, a different conclusion would be reached. For Evaro, the number of tracking beds is reduced from 25 to 16. The investigators ability to detect a difference in animal crossings before and after construction in this area was substantially reduced (from ≥16.6% to 21.4%, a loss of 4.8%). Perhaps more importantly, the authors now find themselves on the steep part of the curve. This means that if the power analysis is only slightly off, the ability to detect a difference in animal crossings before and after construction in only the Evaro area could be exponentially reduced. This is even worse for Ravalli Hill (tracking beds from 17 reduced to 6; ability to detect difference reduced from ≥20.5% to ≥60.5%, a loss of 40%).

To summarize, the reduction in tracking bed sample size will not significantly affect the authors' ability to detect changes between pre- and post-construction deer crossing rates across all three focus study areas, but WTI will not be able to compare crossing rates between the three focus study areas.

Note: The latest proposal is to shorten fence at the northern end of Evaro. This results in the loss of 5 more beds. While this is not ideal for the study design, it is unlikely to change the conclusions dramatically.

FENCING DESIGN CONSIDERATIONS AND DETAILS

Deterring Animals from Accessing Areas Between the Fences

The purpose of the wildlife exclusion fencing is two-fold: to funnel animals toward crossing structures and to prevent animals accessing the road where collisions can occur. No wildlife exclusion fencing design has been found to be 100% effective and completely impermeable to all animals, but several techniques have been used to deter animals from accessing the area between the fences. For those animals that breach the fence and are trapped on the right-of-way between the fences, there are methods that can expedite the animals' exit from this unsafe situation.

Fence end treatments

Fence end treatments can limit the numbers of animals becoming trapped between the fences. Fence end treatments are typically applied on the right-of-way, extending from the pavement to the last fence post where the wing fencing angles away from the road. Thus far, the TDC has concluded that current fence end treatment designs are not sufficiently safe for motorists, pedestrians and cyclists that travel along the road or in the right-of-way. The following fence end treatments were discussed at the December 2003 US 93 Technical Design Committee (TDC) meeting.

- **Cattle guards or wildlife grates***:* Cattle guards could be used between the fence and the pavement, although WTI is not aware of any projects applying cattle guards in this manner. Cattle guards could also be installed in the road itself, but there may be safety issues related to the high speeds on US 93. The TDC considered cattle guards potentially dangerous for people, especially children, and may divert people onto the road if they were avoiding stepping across the cattle guard. Further examination of the application and effectiveness of cattle guards at fence gaps is described in the next section).
- **Electrobraid fencing***:* The TDC felt that using electric fencing for this particular application to be potentially dangerous for the public as it would likely divert people onto the road. Further examination of the application and effectiveness of electric fencing is described in the "Alternatives to wildlife fencing," section.
- **Cobbles***:* This technique creates a surface that is difficult for animals to walk across. While this has been applied on the Trans-Canada Highway near the town of Canmore, Alberta, FHWA and MDT consider cobbles as obstacles in the clear zone, and therefore this alternative is not acceptable with regards to driver safety.

With no other alternatives proposed, there will be no fence end treatments to prevent animals from accessing the right-of-way between the wildlife exclusion fencing. ***Without fence end treatments, the effectiveness of the fencing will be reduced as animals will not be deterred from accessing the right of way between the fence. If there are numerous incidents of animals becoming trapped between the fences, animal-vehicle collision rates may increase.***

Treatments for access points or fence gaps

Access roads that intersect US 93 in areas where wildlife fencing is planned are problematic. These access points create gaps in the wildlife fence that must safely pass vehicles, pedestrians and cyclists. ***It will be important to apply mitigation where there are gaps in the wildlife fencing to deter animals from walking into the right-of-way.*** Options for the TDC's consideration follow:

No additional measures: The effectiveness of the wildlife fencing and wildlife crossing structures with regard to animal-vehicle collisions could be reduced from about 96% to less than 40%.

Mitigation measures that discourage animals from crossing:

- **Gates:** Access points that are infrequently used by only one or several people or official organizations could be gated (preferably with a lock). This could potentially result in a barrier that is close to 100% effective, similar to having no gaps in the wildlife fencing.
- **Cattle guards or wildlife grates:** The literature on the effectiveness of cattle guards as a means to deter wildlife movements is limited with varying conclusions. In an extensive and comprehensive review of deer deterrent techniques for airports, Katona et al (2000) recommend cattle guards longer than 4.6 meters as an effective means of deterring deer from entering at fence openings that must remain open for vehicle passage. Peterson et al (2003) mentions papers with conflicting results:

> "Reed et al (1974) found in field tests that mule deer and elk walked 3.7 meters long guards (10.2cm spacing between rails) but would not jump them. Conversely, Sebesta (2000) found in field tests that white-tailed deer would jump 3.7 meters long guards (10.2cm spacing between rails) but would not walk across them."

In the case of the Reed et al. (1974) paper, investigators individually released 18 deer from captivity and found that 16 deer crossed the guard; the incentive to flee may have influenced these results. Peterson et al. (2003) suggests that there are sufficient incentives to cross (e.g., higher quality forage in the right-of-way) deer may attempt or succeed crossing these guards but if there is forage of equal quality both inside and outside of the fence, there may not be an incentive for deer to cross.

Peterson et al (2003) evaluated how well 3 types of bridge grating material excluded Key deer from an attractant (food) (Figure C-18). The 3 different bridge grates were approved by Florida DOT with regards to pedestrian, cyclist and motorist safety (Figures C-19-21). Grate 1 was 99.5% effective in excluding Key deer and grates 2 and 3 were determined to have similar levels of effectiveness, preventing approximately 75% of the Key deer crossing attempts. The authors recommend grate 1 for deterring Key deer but suggest that the grates be selected according to the hoof size and jumping ability or agility of the target species. Larger openings in the pattern may be required for mule deer or elk); at the same time, they acknowledge that the smaller pattern with the diagonal cross member may be preferred by pedestrians and cyclists. Peterson et al. (2003) estimate bridge decking costs at $40-$130 per square meter.

The authors recommend that the TDC considers modified bridge grating or cattle guards at gaps in the wildlife fencing. Modified bridge grating or cattle guards should be combined with jump-outs on either side of the road to provide an escape for animals

that do succeed in crossing modified bridge grating or cattle guards. Modified bridge grating could potentially result in a barrier that is 99% effective, similar to having to gaps in the wildlife fencing.

Mitigation measures that promote animals to cross:

- **Crosswalks:** When there are two gaps in wildlife fencing across from each other, such that animals can cross at those gaps, it is possible to use unique signing to warn drivers that animals may cross at that particular location, similar to pedestrian crossings. Lehnert and Bissonette (1997) evaluated such "wildlife crosswalks" in Utah and found mule deer (*Odocoileus hemionus*) mortality declined 42.3% and 36.8% along their 4-lane and 2-lane highway study sites, respectively. Although they were not able to statistically correlate the mortality reduction to the crosswalk installation, it was noted that deer used the right-of-way less and were observed crossing within the crosswalk, indicating that fencing combined with crosswalks may have contributed the reduction in mortality. Lehnert and Bissonette (1997) attributed mortalities to lack of driver responses to crosswalk warning signs, and the fact that animals would leave the crosswalk and become trapped between the fences. Their article offers design suggestion to improve this application.
- **Crosswalks combined with animal-detection & driver warning systems:** See above. If the crosswalks and jump-outs are combined with an animal-detection and driver warning system, the number of animal-vehicle collisions could potentially be reduced by about 80% (compared to 96% for continuous wildlife fencing combined with wildlife crossing structures).

Similar to fence end treatments, if no additional mitigation measures are applied at gaps in the wildlife fencing, the effectiveness of the wildlife fencing will be reduced, and the return on the investments in wildlife fencing and crossing structures will be jeopardized. The authors recommend that modified bridge grates are installed at gaps in the fencing, perhaps even at (locked) gates. This measure is potentially 99% effective. If modified bridge grates are not an option, then openings on both sides of the road, in combination with an animal-detection and driver warning system (potentially 80% effective) is recommended. The authors strongly caution the TDC against having gaps without additional mitigation measures.

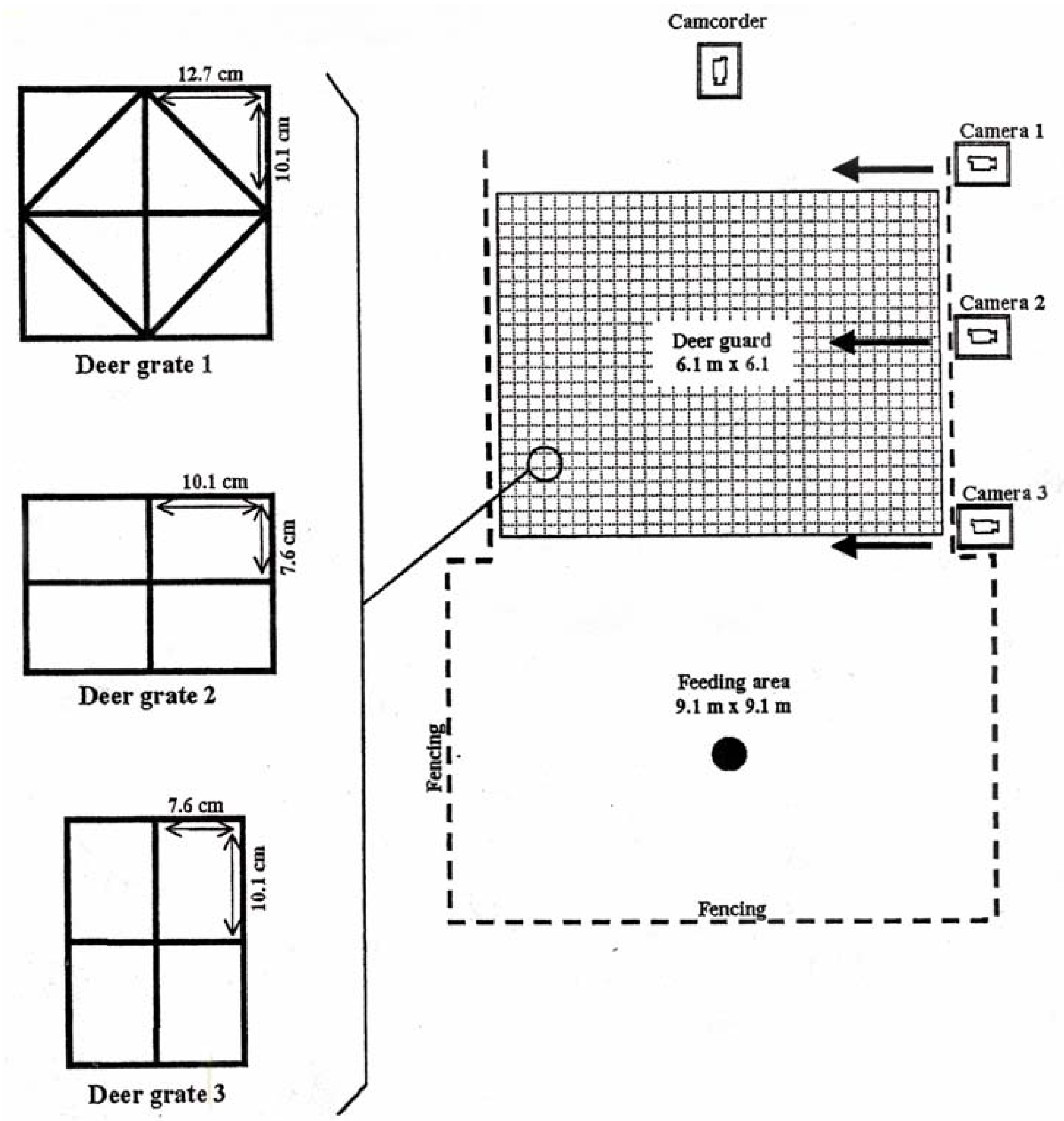

Figure C-18: Deer (bridge) grate patterns tested (grates 2 and 3 differ only in the orientation of the grate openings) and the test site layout for evaluating the effectiveness of the different grates in excluding Key deer from food, Big Pine Key, Florida, 2001-2002 (Peterson et al. 2003).

Figure C-19: Installation of deer (bridge) grate used in deterrence tests for Key Deer, Big Pine Key, FL 2001-2002 (Peterson et al. 2003).

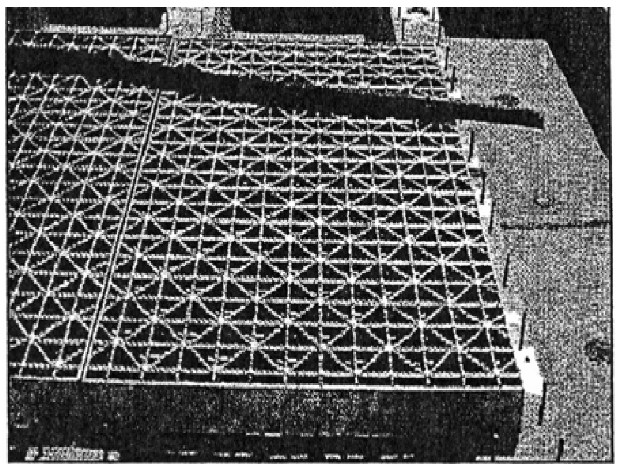

Figure C-20: Grate design used in deterrence tests for Key deer, Big Pine Key, FL 2001-2002 (Peterson et al. 2003).

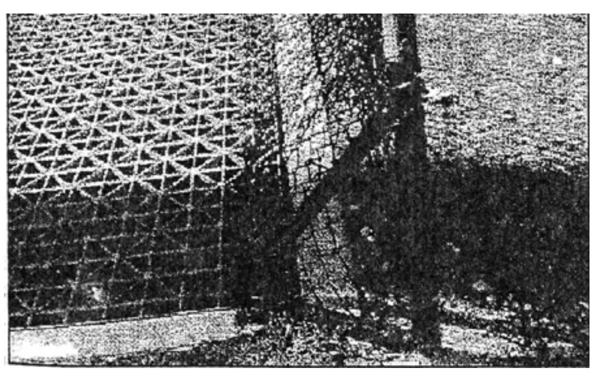

Figure C-21: Exclusion fencing tied into grate design used in deterrence tests for Key Deer, Big Pine Key, FL, 2001-2002 (Peterson et al. 2003).

Escape routes

Escape routes allow animals to exit the right of way if they are caught between wildlife fencing along the road. It is important to have escape routes, with or without fence end or gap treatments and such escape routes are especially important if there is no barrier at fence ends or at gaps in the wildlife fencing.

In Banff National Park, one-way gates were unsuccessful as elk learned how to move through these in both directions. The solution to this issue, in areas where there were no jump outs, was to install gates that could opened by rangers to haze animals off the right of way (A.P. Clevenger, pers. comm.; T. Hurd, pers. comm.).

The current plan is to install jump outs where the fencing changes angle to funnel in to the wildlife crossing structures. The authors recommend that more jump outs be installed at the intervals recommended by Bissonette and Hammer (2000). In areas with high deer road kill, Bissonette and Hammer (2000) recommend placing jump outs at quarter mile intervals (400 m) on both sides of the road. When installing many miles of continuous fencing, Bissonette and Hammer (2000) recommend spacing the jump outs at quarter mile intervals along the first mile of fencing from each fence end. In other fenced areas that have less deer road kill and that are not near the end of the fence, they recommend placing jump outs at half mile intervals (800 m). In addition, jump out design and placement details are listed below:

- Locate jump outs in areas as far from the highway as possible. These are areas animals are likely to flee to and it gives them "space" to calm down;
- Locate jump outs in areas with natural cover such as trees to shield animals from road disturbance;
- Install a short section of fence on the earthen ramp, perpendicular to the fence line and bisecting the jump out opening, in order to direct animals to and off the jump out;
- Another alternative to the last point to help animals find and use the jump out is to extend the earthen ramp beyond the fence to a right angle so that it forms an equilateral triangle with the hypotenuse following the line where the fence would have been; and
- To reduce the amount of fill needed for the ramp, it may be possible to use fill from the area outside the fence where the jump out is to be placed to simultaneously raise the ground inside the fence and create a depression on the outside of the fence so that the vertical face of the jump out is partially below original ground level. The depression outside the fence should be landscaped to extend ~8 feet away from the vertical face and so that the top-to-bottom height of the vertical face is 8 ft to deter animals on the outside of the fence from jumping in. This design has been applied along western border of the National Elk Refuge in Jackson Hole, Wyoming. In response to WTI's inquiry about these jumputs, Don Cushman (pers. comm.), one of the refuge managers, comments:

> "Our fence on the west side of the refuge (for about 5 1/2 miles north of Jackson) is 8 feet high, comprised of two stacked rows of standard 4-foot fencing. Where the jumps are located, we've taken out a section of the upper portion, and we've just built a tapered berm on the highway side of the fence. A vertical wooden wall against the fence provides the eastern edge of the berms. At the middle of the top of the berm we have a fence that is perpendicular to the main fence (in the center of the opening), so that the elk can't just run up and over the berm and continue

outside the fence--they need to turn and jump into the refuge. We did not build any depression on the inside of the fence, although there may be slight ones now as a result of elk jumping repeatedly into the landing zone. This has worked very well for access for elk that migrate from the west into the refuge, but this year (for the first time, to my knowledge) we've had a few elk do the reverse and jump out. To stop that, we built the berm a little higher, and that seems to have solved the problem for now."

He continues: "We do not have assigned monitoring routines, but due to the locations, we have a good, consistent picture of what happens. There's a lot of traffic on that road, including refuge employees commuting, and we know that most of the elk are not intimidated by the jump, and the perpendicular fence usually turns them into the refuge. Occasionally some will turn and go back across the road and back up the butte, but this is not the majority of elk. I think it's safe to say that we would recommend this design, since we did not build all of them at the same time. We've continued to use the same design as we've added the most recent couple of jumps."

Deterring fence climbers

Observations from Banff NP show that black bear, cougar, and (rarely) lynx can climb fences as well as wooden poles (A.P. Clevenger, pers. comm). Grizzly bears have not been witnessed climbing the fence, and they rarely dig under the fence, so are not causing problems with fencing in Banff. Cougars tend to jump to pole-tops rather than climbing the mesh fence. Most animals that climb the fences appear to exit the same way they came in and are rarely killed by cars; approximately one black bear per year and one cougar every 5 years are killed by vehicles after climbing the fence. One possible explanation that the black bear intrusions do not typically result in mortalities due to vehicle collisions is that many bears breach the fence to eat dandelions in the right-of-way. Once finished eating or if they are scared away, most simply climb back over the fence without attempting to cross the road (A.P. Clevenger, pers. comm.)

The situation on Hwy 93 may be different. The right-of-way may not offer attractive food and US93 is (and will be reconstructed) narrower and will have less traffic than the Trans Canada Highway. As a consequence black bears that climb the fence may do so to cross the road, with the potential of a collision with a car. Possible strategies to discourage black bears from climbing the fence follow:

- Provide a 90 degree barbed wire outrigger (i.e. overhang) that extends out ~3 feet:
    - Tests were done with outriggers at 90 and 45 degree angles in Banff NP, but the results were never published, possibly because of too small sample size (T. Hurd, pers. comm.);
    - A 10 ft chain link fence and barbed wire outrigger was used on SR 29 and SR 46 in Florida. This was found to be effective (Roof & Wooding 1996), though part of this success may be due the fact that the fencing is a cyclone fence with tighter mesh.
- Use finer mesh fence to prevent bears from getting their feet in the mesh openings to use as a step (they climb the fence using mesh openings just like humans would); and

- Use metal poles in stead of wooden poles, or design a treatment or a pole that discourages black bears from climbing the wooden poles. Regarding aesthetics, it may be possible to paint or treat metal poles dark brown.

Deterring Fence Burrowers

To prevent animals from burrowing under the fence the authors recommend attaching a skirt of smaller-meshed fencing to the exclusion fencing and burying it in the ground. Specific details such as the following should be considered:

- Skirt width (which will be determined by how much to bury and how high above ground level to attach the top of the skirt to the larger fence) and
- Mesh size of the lower larger mesh fence and the skirt fence.

Alternatives to Wildlife Exclusion Fencing

While the standard page wire wildlife exclusion fencing is considered the most effective means to reduce AVCs, there are alternatives to using this type of fencing for mitigating for this safety problem. Alternatives for the TDCs consideration are summarized below.

Electric fencing alternative

In their comprehensive report on methods to deter deer from airports, Katona et al (2000) summarizes their research in their executive report, as follows:

> "[Electric fence] provides about 80% exclusion of deer that attempt to cross the fence by conditioning them to associate electric shocks with the fence. This effectiveness declines when (1) maintenance is inconsistent; (2) when lines are short-circuited by weed growth or snow cover; or (3) when deer are highly motivated to cross the fence when populations are high, during the rutting season in the fall, or when frightened by hunters."

At the December 2003 US 93 Technical Design Committee (TDC) meeting, the group discussed installing ElectroBraid fencing in selected areas, in place of the wildlife exclusion fencing. Katona et al (2000) offer these observations on ElectroBraid (the authors are uncertain if they refer to Canadian or US dollars):

> "A six-month evaluation of an ElectroBraid™ electric fence installation at Little Rock AFB has been judged to be a success. The 1.8-m high vertical electric fence design used nine strands of ElectroBraid™ cord spaced 22.8 cm apart (the bottom three cords were spaced 15.2 cm apart to deter small animals). The fence was installed in September of 1999 and has reduced deer sightings on the airfield from an average of 19 deer per night to one per night and 80% of nights have been deer-free. Most deer that were spotted on the field were traced to entering through an open gate. Deer that had jumped the fence were running from hunters. The fence 9,266-m perimeter installation cost of $82,200 was significantly lower than the cost of a conventional 2.44-m chain-link fence with three barbed wires on angle extensions ($400,000) with an equivalent effectiveness. Snow accumulation should be ploughed away from the fence to maintain winter effectiveness.

Richard Lampan, an ElectroBraid representative, has met with WTI and MDT and has offered a trial of ElectroBraid at no cost, with the agreement that if satisfied, WTI will purchase the fence.

If the TDC supports installing this alternative fencing, WTI would like to evaluate the Electrobraid fencing with regard to the following criteria:

- Effectiveness: What percentages of animals (specifically deer and black bear) that approach the electric fence are effectively repelled or breach the fence line?
- Costs for operation (e.g. electricity) and maintenance (e.g. fence repairs).

WTI proposes a pairwise comparison of sections with Electrobraid fencing and sections with standard fencing. The length of the sections should be meaningful to wildlife, and it should be long enough for certain events to take place (e.g. falling trees). WTI proposes lengths of 250 meters of Electrobraid fencing situated next to 250 meters of standard fencing. WTI proposes a minimum sample size of five (i.e. 5 pairs). To do this, 5 road sections of 2*250 m (=500 m) each that meet the following criteria would need to be identified:

- The 500 m long road sections should be located in homogenous sections; i.e. no major changes in the road, right-of-way or adjacent habitat / land use. The other side of the road should be homogenous as well;
- The 500 m long sections should be located in areas that do not have access roads;
- The 500 m long sections should be located in areas that have no or very few people living in the direct vicinity;
- The 500 m long sections should preferably be located adjacent to tribal or other government land; and
- The 500 m long sections should be located on sections where small animals are not of concern. Small animals may crawl underneath the electrified fence.

The power source may depend on local situation, but should preferably be equal for all five road sections. The fencing may be powered through solar panel or 110 V, depending on the accessible power at each Electrobraid installation. It would be acceptable to apply Electrobraid fencing on one side of the road only. If the other side of the road has Electrobraid fencing too, they will be treated as 1 experimental unit, not 2.

Signage / Driver warning techniques

Fencing attempts to modify animal behavior and movements; signage attempts to modify driver behavior. It has been shown that the static wildlife silhouette warning signs are ineffective at reducing animal-vehicle collisions. Signs need to be applied in such a manner to impress upon the drivers to understand the message and drive more cautiously. Information on measures used to warn drivers of potential animal-vehicle conflicts is provided in the following sections.

Speed reductions

Reduction in speed provides drivers with more time to see and respond to hazards and increase their breaking distance. This logical premise has not been extensively studied in relation to animal-vehicle collisions. Gunther et al (1998) found higher road-kill rates on Yellowstone National Park roads with 55 mph posted speed limits compared to 45 mph or lower and they concluded that increased speed was the primary factor contributing to wildlife-vehicle collisions. They also noted that as park roads were reconstructed with wider (30 feet) paved widths, shoulders, and smooth driving surfaces, motorists increased their speeds an average 5 mph and some sections of reconstructed roads had an increase road kills.

Animal-detection/driver warning systems

Animal-detection/driver warning systems dynamically detect animals approaching the road and then activate a sign to warn drivers. Dr. Huijser has been conducting research on animal-detection/driver-warning systems since joining WTI in August 2002. Dr. Huijser is currently overseeing research on the effectiveness of these systems and has extensive experience with the issues involved in the installation, maintenance, reliability and effectiveness of such systems. His summary papers were included (Huijser and McGowen 2003, Huijser 2003) on animal-detection/driver-warning systems in North America and Europe with our previous submission of this report.

Animal-detection systems in Switzerland led to 80% reduction in ungulate - vehicle collisions (Kistler 1998, Romer et al. 2003). Detection sections can be installed to begin and end at the access roads, excluding the road itself, so that drivers accessing the highway do not trigger the system. However, this leaves unmitigated gaps in the system. In the case of US 93, animal-etection systems may be combined with fencing to detect animals or other movement through the gap to flash warning lights to watch for hazards entering the road ahead. Vandalism and theft may be an issue as these systems are usually exposed to the public eye, but buried geophones in combination with infrared sensors have been applied successfully in Nugget Canyon, Wyoming. There are numerous technologies used to detect animals and the most appropriate system should be selected to fit the specific situation. If the TDC opts for this alternative, WTI would be pleased to work on this particular aspect of mitigation design, installation, maintenance, reliability and effectiveness.

Pavement markings

Another potential alternative is to apply reflective strips that are used to mark the stripes on the road (white and yellow) in such a way that when a large animal enters the road, the animal's body simply blocks some of the reflectors so that drivers see a break in the linear pattern of reflected light and then slow down and proceed with increased vigilance. Maine DOT is experimenting with smaller intervals of these standard reflective strips (R. Van Riper, pers. comm.). This could be a low tech, low cost, vandalism and theft proof solution, but as to date there are no hard data on the effectiveness of this mitigation measure. Nevertheless, WTI recommends getting more information on this and stress that this technique has had no quantitative evaluation to date. WTI is beginning a review of pavement markers and may be able to provide general technical advice on the topic.

Monitoring

The two main objectives for the monitoring study are to quantify pre- and post-construction AVCs and animals crossing US 93. WTI has worked with the TDC on the design specifications for tracking beds both inside and outside the crossing structures, as well as brackets for mounting cameras to monitor activities at the crossing structures.

In addition to monitoring the activity at the crossing structures, it will be important to monitor animals' responses to fencing as it relates to possible changes in AVC and animal crossing rates before and after the construction. While the crossing structures are our preferred routes for animals to move from one side of the road to the other**,** it is inevitable that wildlife will travel around the ends of the fencing. ***To document these "end run" wildlife movements, WTI would like 50 meter long sand tracking beds installed at fence ends, parallel to the road.***

WTI would also like sand tracking beds perpendicular to the road and extending the post where the wing fence section angles away from the road to the pavement and on either side of access road gaps. Data from these track beds will help WTI estimate the numbers and types of animals that may be getting trapped between the fences. WTI is looking into using heat- and motion-detecting cameras or video, but have not committed to a particular design as the authors are searching for a "low profile" system to avoid vandalism and theft.

Finally, it is important to monitor activity at the jump outs. ***Sand tracking beds on top of and at the base of each jump out will allow investigators to monitor which wildlife species are using the jump outs and if wildlife may be approaching and jumping in to the right-of-way via these breaks in the fencing.***

Below is a summary of how shortening the fencing affects WTI's ability to evaluate the effectiveness of the mitigation with the following points:

- Despite the fact that shortening wildlife fencing in Evaro and Ravalli Hill will reduce the tracking bed sample size from 62 to 42, and now to 37, investigators will still be able to do the research well. This is mostly due to the exclusion of the tracking beds on Ravalli Hill that had 0 deer tracks. This resulted in a smaller standard deviation, and better power, not less (see the earlier power analyses section for details). This only relates to deer (mule and white-tailed). If similar power is to be obtained for other species, investigators would have to restore the sample size, perhaps to much more than 62 track beds. For example, black bear crossings are about 10-15 times rarer than deer crossings and the standard deviation is also likely to be larger. Compensation for the loss of 20 beds will probably still be inadequate to detect differences in pre- and post-construction bear crossings and is likely to be substantially "out of our budget". Therefore, the authors don't think it is reasonable to try to set the same objectives for black bear as for deer.
- The power for deer crossings is sufficiently maintained for the three areas combined (Evaro, Ravalli Curves and Ravalli Hill). However, the power for the individual areas or Evaro and Ravalli Hill are severely affected. As a consequence the authors cannot expect to analyze the effectiveness of the mitigation measures for each area individually, only for the three areas combined.
- WTI will discontinue preconstruction animal crossing track bed monitoring efforts for the Pistol Creek wildlife area of Ravalli Hill. It is of similar size to other small sections of fencing. Rather, the decision was made not to focus preconstruction crossing rate estimation efforts on. The same is true for the isolated Frog Creek wildlife crossing with short fencing at the south end of Evaro (if the fencing was extended south to the Reservation border as WTI recommended earlier, investigators would likely continue monitoring this area as the length of installed fencing will affect more of the landscape and animal movements in that area).
- WTI will continue preconstruction monitoring at the remaining fenced areas of Evaro, Ravalli Curves and Ravalli Hill.
- WTI recommends discontinuation of preconstruction animal crossing monitoring for track beds in areas that will no longer be fenced. Data from these areas will no longer relate to the main research question. Furthermore, the sample size would be insufficient

to be able to conclude whether more or less animals cross at the unfenced sections once the fence has been installed. WTI recommends that the resources that would have been applied to this effort be saved for unexpected events, such as tracking bed maintenance (grading to loosen sand media after winter compaction, weeding/spraying).

Final Summary of Fencing Design Considerations

Wildlife exclusion fencing effectiveness increases when the chances of animals breaching the fence are minimized. There are mitigation options to decrease animals entering the right-of way and becoming trapped between the fences. Applying mitigation at the gaps in the fence and providing escape routes will be critical on this project. In addition, maintenance is an important factor to keeping animals outside the right of way.

Continuous wildlife fencing on controlled access highways has been shown to reduce ungulate-vehicle collisions by 96%. In a decreasing continuum from this "ideal" situation, animal-detection/driver warning systems in combination with fencing have been shown to reduce animal-vehicle collisions by 80% while "wildlife crosswalks" with unique signage only reduced ungulate vehicle collisions by about 40%. Deterring animals from entering gaps by using cattle guards or bridge grates across the gaps has seen varying results, from 99.5% to 75% exclusion for Key deer approaching two different grate patterns, to some studies claiming that cattle guards are ineffective for deer exclusion. Following this logical continuum, openings with no mitigation to deter animal movements are likely to be even less effective. Combinations of these techniques may increase effectiveness beyond the effectiveness of their individual applications.

It will be crucial to mitigate where there are single openings on one side of the fence but not the other as this could be a significant trapping point for animals. Gates or wildlife guards may be the best solution in these situations.

Where there are two gaps across from each other, wildlife guards with animal-detection systems could both deter animals and warn drivers when animals or cars are entering the roadway. If wildlife crosswalks were used, care would have to be taken with landscaping (that is unpalatable to deer and bear) or other methods in the right-of-way to encourage straight crossing to the opening on the other side of the road.

The US 93 reconstruction project is in the unique position to pioneer the way for future mitigation projects that must accommodate numerous access points through wildlife fencing. Given the number of gaps in the fence on this project, it is possible to install various mitigation measures deemed appropriate and monitor each for effectiveness. Measures that do not meet the performance standards that are set forth may need to be replaced in the future. This approach can be difficult to budget for, but it worth consideration.

To maximize the fencing investment, WTI stresses that the TDC seriously consider these measures and reemphasizes that there is a chance that unmitigated gaps are likely to result in a serious reduction of the effectiveness of the wildlife fencing and wildlife crossing structures, jeopardizing both safety and habitat connectivity.

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13. APPENDIX D: INVENTORY OF WILDLIFE CROSSINGS

Table D-1: Inventory of wildlife crossing structure types with dimensions to be installed on US 93 from Evaro to Polson, Montana. List includes crossings identified for inclusion in reconstruction efforts in the US 93 Reconstruction Memorandum of Agreement (MOA; Skillings Connolly 2000), as well as "new" or alternate crossing structures in lieu of structures originally listed in the MOA. Table continues on following pages; key and sources are included at bottom of table.

# IN MOA	Crossing name	MOA Station ID	Design Plans Station ID	TYPE						Dimensions
				CSP or RCB	Multi-Span bridge (exisiting)	Wildlife Overcrossing	Open Span or Multispan bridge	Open Span Bridge	CSPA or RCPA	
1	Frog Creek Fish Crossing	13140	13287.6	M,P						1219 mm (1.3 yd) x 1829 mm (2 yd) (estimated)
2	North Evaro Wildlife Crossing	14340	14802.3	M,P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)
3	Rail Link Fish and Wildlife crossing	16280	16305		M,P					Not Available
4	Finley Creek Tributary #1 Wildlife Crossing	16960	16862.5	M,P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)
5	Finley Creek Tributary #2 Wildlife Crossing	17200	17245.1	M,P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)
6	Evaro Hill OverCrossing	17440	17340			M,P				45720 mm (50 yd) to 60960 mm (66.6 yd) (recommended width)
7	Finley Creek Tributary #3 Wildlife Crossing	17700	17639.2	M,P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)
	NEW STRUCTURE (NOT IN MOA)	-	18121.3	P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)
8	Schley Creek Fish & Wildlife Crossing	19860	19840	M,P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)
9	East Fork Finley Fish & Wildlife Crossing	20420	20409	M,P						3658 mm (4 yd) x 6706 mm (7.3 yd) (estimated)

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F = in the Final Plans

# IN MOA	Crossing name	MOA Station ID	Design Plans Station ID	TYPE						Dimensions
				CSP or RCB	Multi-Span bridge (exisiting)	Wildlife Overcrossing	Open Span or Multispan bridge	Open Span Bridge	CSPA or RCPA	
10	Agency Creek Fish Crossing	25860	25825	M,P						1219 mm (1.3 yd) x 1829 mm (2 yd) (estimated)
	NEW STRUCTURE (NOT IN MOA)	-	30976	F						42000 mm (45.9 yd) x 2100 mm (2.2 yd) x 2100mm (2.2 yd)
	NEW STRUCTURE (NOT IN MOA)	-	31026	F						41000 mm (44.8 yd) x 2100 mm (2.2 yd) x 2100mm (2.2 yd)
	NEW STRUCTURE (NOT IN MOA)	-	31086	F						48000 mm (52.4 yd) x 2100 mm (2.2 yd) x 2100mm (2.2 yd)
11	Jocko River Fish & Wildlife Crossing	31200	31200				M,F			135000 mm (147.6 yd) x 320000 mm (349.9 yd) (MOA recommends 12' min. height)
12	Schall Flats #1 Wildlife Crossing	33850	*Not in Plans*	M						
13	Schall Flats #2 Wildlife Crossing	35100	*Not in Plans*	M						
14	Schall Flats #3 Wildlife Crossing	36150	*Not in Plans*	M						
15	Schall Flats #4 Wildlife Crossing	37400	*Not in Plans*	M						
	STOCK PASS (NOT IN MOA)	-	37600	F						37500 mm (41 yd) x 2400 mm (2.6 yd) x 2400 mm (2.6 yd)
16	Jocko/Spring creek Fish & Wildlife Crossing	38100	38000					M,F		12000 mm (13.1 yd) x 30000 mm (32.8 yd) (MOA recommends 12' min. height)

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# IN MOA	Crossing name	MOA Station ID	Design Plans Station ID	TYPE						Dimensions
				CSP or RCB	Multi-Span bridge (exisiting)	Wildlife Overcrossing	Open Span or Multispan bridge	Open Span Bridge	CSPA or RCPA	
17	Ravalli Curves #1 Wildlife Crossing	41150	*Not in Plans*	M						
18	Ravalli Curves #2 Wildlife Crossing	41200	*Not in Plans*	M						
	NEW STRUCTURE (NOT IN MOA)	-	39609						F	21950 mm (24 yd) x 7315 mm (8 yd) x 3048 mm (3.7 yd) (concrete) 21950 mm (24 yd) x 6858 mm (7.5 yd) x 4775 mm (5.2 yd) (steel)
	NEW STRUCTURE (NOT IN MOA)	-	40520						F	25610 mm (28 yd) x 7315 mm (8 yd) x 3048 mm (3.3 yd) (conctrete) 25610 mm (28 yd) x 6858 mm (7.5 yd) x 4775 mm (5.2 yd) (steel)
19	Jocko Side Channel Fish & Wildlife Crossing	42460	42123					M,F		12000 mm (13.1 yd) x 30000 mm (32.8 yd) (MOA recommends 12' min. height)
20	Ravalli Curves #3 SMALL MAMMAL Crossing	42600	42600	M,F						27500 mm (30 yd) x 1200 mm (1.3 yd) x 1800 mm(1.9 yd)
21	Ravalli Curves #4 SMALL MAMMAL Crossing	42730	42700	M					F	24000 mm (26.2 yd) x 2050 mm (2.2 yd) x 1500 mm(1.6 yd)
22	Ravalli Curves #5 SMALL MAMMAL Crossing	43050	42940	M,F						27500 mm (30 yd) x 1800 mm (1.9 yd) x1200 mm(1.3 yd)
23	Copper Creek Fish & Wildlife Crossing	43200	43123					M	F	18290 mm (20 yd) x 7315 mm (8 yd) x 3048 mm (3.3 yd) (concrete) 18290 mm (20 yd) x 7747 mm (8.4 yd) x 5105 mm (5.5 yd) (steel)

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# IN MOA	Crossing name	MOA Station ID	Design Plans Station ID	TYPE						Dimensions
				CSP or RCB	Multi-Span bridge (exisiting)	Wildlife Overcrossing	Open Span or Multispan bridge	Open Span Bridge	CSPA or RCPA	
24	Ravalli Hill Wildlife Crossing (x2)	45955	45946.8	M					P	31200 mm (43.1 yd) x 3500 mm (3.8 yd) x 7315 mm (8 yd) (concrete) 31200 mm (34.1 yd) x 7417 mm (8.1 yd) x 5156 mm (5.6 yd) (steel)
	NEW STRUCTURE (NOT IN MOA)	-	46371						P	39000 mm (42.6 yd) x 3500 mm (3.8 yd) x 7315 mm (8 yd) (concrete) 39000 mm (42.6 yd) x 7417 mm (8.1 yd) x 5156 mm (5.6 yd) (steel)
25	Pistol Creek #1 Wildlife Crossing	49800	49855.7	M					P	40000 mm (43.7 yd) x 3500 mm (3.8 yd) x 7315 mm (8 yd) (concrete) 40000 mm (43.7 yd) x 7417 mm (8.1 yd) x 5156 mm (5.6 yd) (steel)
26	Pistol Creek #2 Wildlife Crossing	50100	50163	M					P	40000 mm (43.7 yd) x 3500 mm (3.8 yd) x 7315 mm (8 yd) (concrete) 40000 (43.7 yd) x 7417 mm (8.1 yd) x 5156 mm (5.6 yd) (steel)
27	Sabine Creek Fish and Wildlife Crossing	51760	51784.7	M,P						14700 mm (16 yd) x 7320 mm (8 yd) x 3905 mm (4.2 yd)
28	Mission Creek Crossing	52890	52864					M,P		40000 mm (43.7 yd) width unk. MOA recommends min. 12' height
29	Post Creek Drainage # small mammal crossing	54400	54443.2	M,P						31000 mm (33.9 yd) x 2100 mm (2.2 yd)
30	Post Creek Drainage #2 Fish & Small Mammal Crossing	55000	55056.6	M,P						19600 mm (21.4 yd) x 7320 mm (8 yd) x 4750 mm (5.1 yd)

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RCPA = Reinforced Concrete Pipe Arch M = in the Memorandum of Agreement P = in the Preliminary Plans
F = in the Final Plans

# IN MOA	Crossing name	MOA Station ID	Design Plans Station ID	TYPE						Dimensions
				CSP or RCB	Multi-Span bridge (exisiting)	Wildlife Overcrossing	Open Span or Multispan bridge	Open Span Bridge	CSPA or RCPA	
31	Post Creek Drainage #3 Fish & Small Mammal Crossing	55500	55506	M,P						22100 mm (24.1 yd) x 7320 mm (8 yd) x 4750 mm (5.1 yd)
32	Post Creek Drainage #4 Fish & Small Mammal Crossing	55900	55998.4	M,P						19600 mm (21.4 yd) x 7320 mm (8 yd) x 3905 mm (4.2 yd)
33	Post Creek Drainage #5 Fish & Wildlife Crossing	56160	56183.1	M,P						39500 mm (43.1 yd) x 1800 mm (1.9 yd) x 1200 mm (1.3 yd)
34	Post Creek Drainage #6 Fish & Wildlife Crossing	56520	56556.6	M,P						31500 mm (34.4 yd) x 2400 mm (2.6 yd) x 2400 mm(2.6 yd)
35	Post Creek Drainage #7 Fish & Wildlife Crossing	59180	59212.2	M,P						29500 mm (32.2 yd) x 1800 mm (1.9 yd) x 1200 mm (1.3 yd)
36	Post Creek Drainage #8 Fish & Wildlife Crossing	59740	59755.5	M,P						31500 mm (34.4 yd) x 1800 mm (1.9 yd) x 1200 mm (1.3 yd)
37	Ronan Canal #1 Fish & Wildlife Crosssing	77300	77400	M,P						8500 mm (9.2 yd) x 3000 mm (3.2 yd)
38	Ronan Canal #2 Fish & Wildlife Crosssing	78300	78365	M,P						8500 mm (9.2 yd) x 3000 mm(3.2 yd)
39	Mud Creek Tributary Fish & Wildlife Xing	80160	*Not in Plans*	M						
40	Mud Creek #1 Fish & Wildlife Crossing	80950	80954 & 80960					M, P		12800 mm (13.9 yd) x 4200 mm (4.5 yd) (x 2 xings)

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# IN MOA	Crossing name	MOA Station ID	Design Plans Station ID	TYPE						Dimensions
				CSP or RCB	Multi-Span bridge (exisiting)	Wildlife Overcrossing	Open Span or Multispan bridge	Open Span Bridge	CSPA or RCPA	
41	Mud Creek #2 Fish & Wildlife Crossing	old hwy 93	*UNKNOWN*					M, P		12800 mm (13.9 yd) x 4200 mm (4.5 yd)
42	Polson Hill Wildlife Crossing	91700	91670	M					F	31700 mm (34.6 yd) x 3658 mm (4 yd) x 7315 mm (8 yd) (concrete) or 31700 mm (34.6 yd) x 4191 mm (4.5 yd) x 7468 mm (8.1 yd) (steel)

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14. APPENDIX E: TRACK BED LOCATIONS

The figure below shows approximate locations of sand track beds installed in 2003 in the Evaro region of the US 93 study area. The continuous black line represents the highway, while each short black line represents a 100 m long bed that was placed randomly (with respect to the length and either side of the stretch of road originally planned for contiguous fencing with crossing structures) to obtain a representative sample of deer and bear movements across the area to be fenced. Brackets encompass track beds monitored in 2003-2005; data from this subset of track beds were extrapolated across the area to be fenced to estimate total preconstruction crossings. Beds outside the brackets were dropped from monitoring after 2003 when fencing plans were shortened and data from these beds no longer pertained to deer and bear movements within the area to be fenced (however beds EV2, EV7 and EV8 outside the white brackets were monitored in order to bolster the dataset used to assess possible track bed avoidance behaviors). Original map source: Jones and Jones (2002a).

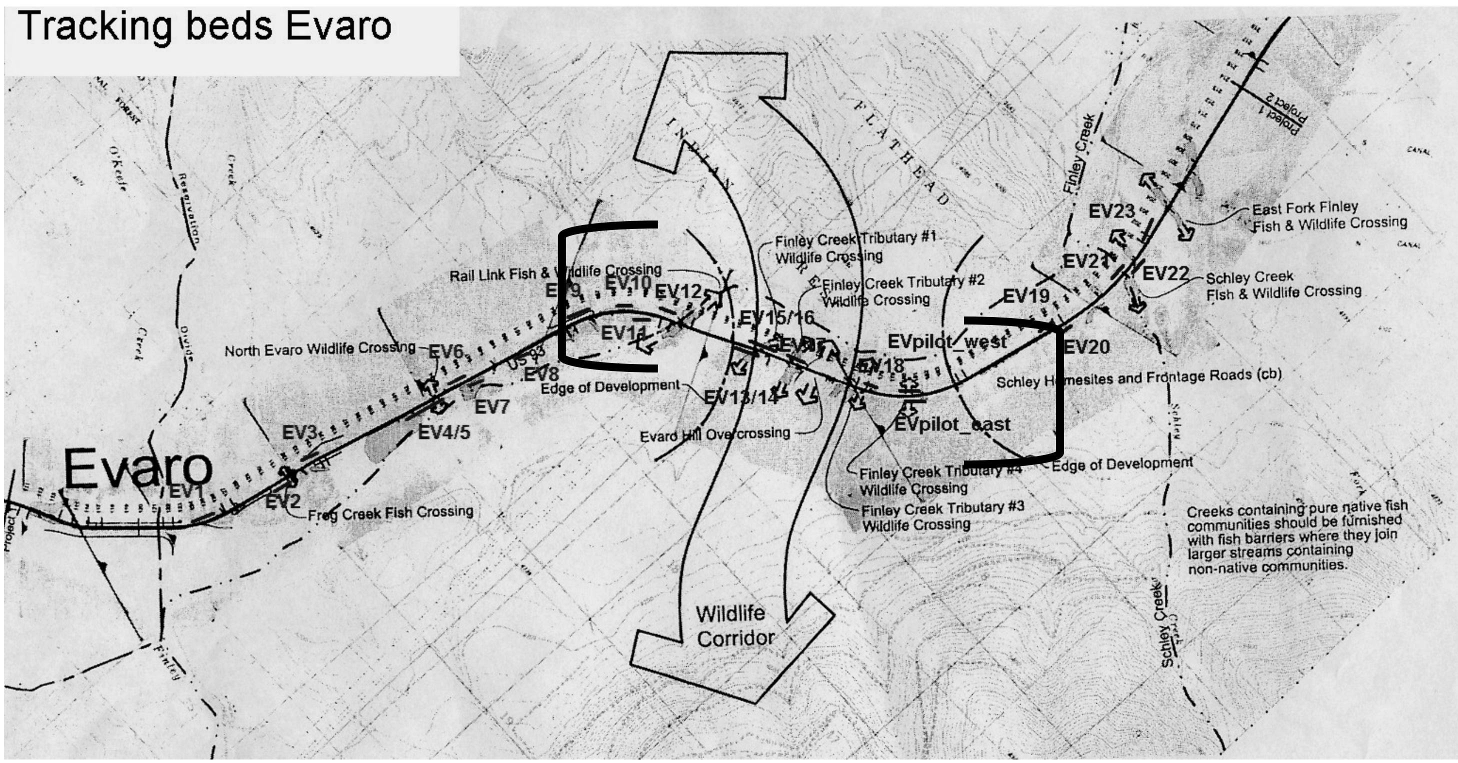


Figure E-1

The figure below shows approximate locations of sand track beds installed in 2003 in the Ravalli Curves region of the US 93 study area. Each short black line represents a 100 m long bed that was placed randomly (with respect to the length and either side of the stretch of road originally planned for contiguous fencing with crossing structures) to obtain a representative sample of deer and bear movements across the area to be fenced. These data were then extrapolated across the entire area to estimate total preconstruction crossings. Original map source: Jones and Jones (2002a).

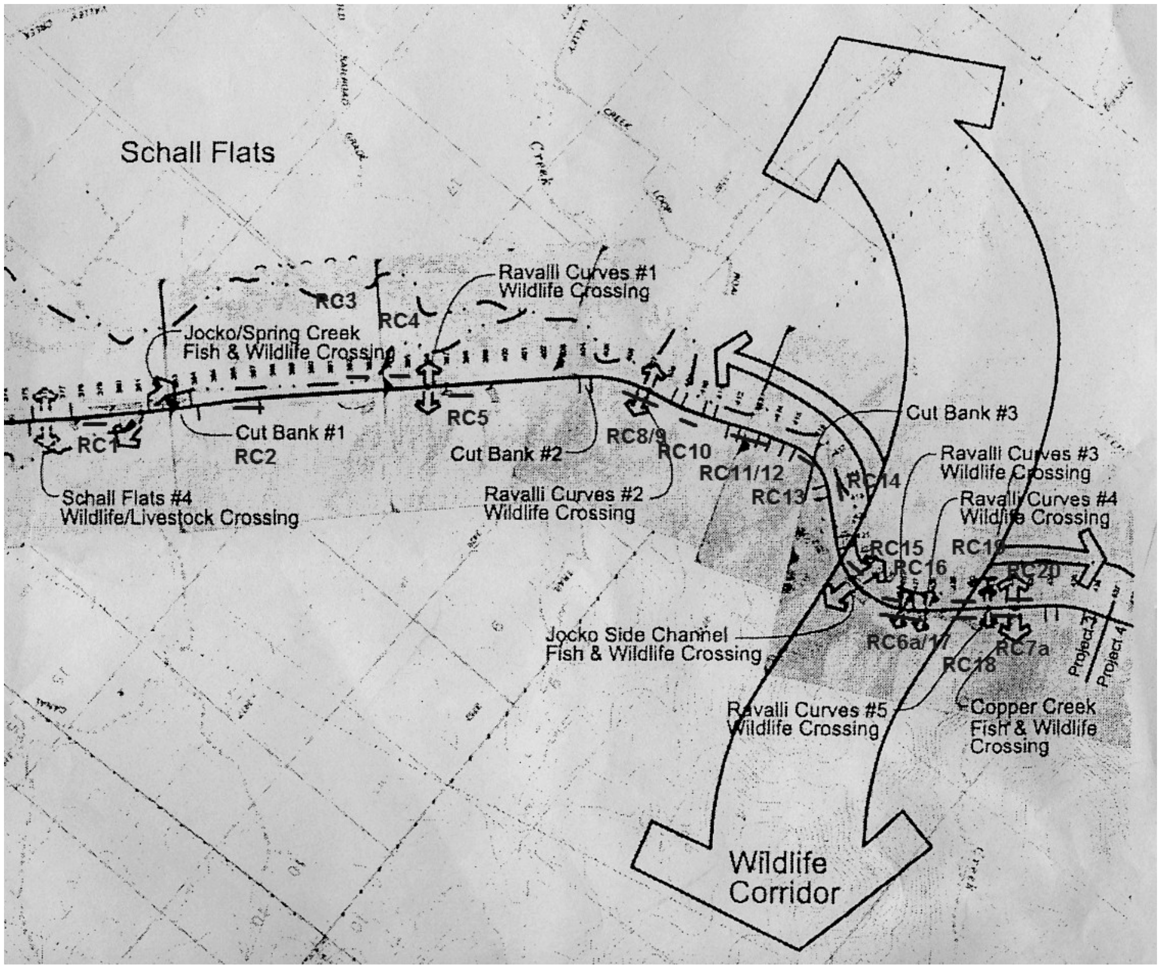
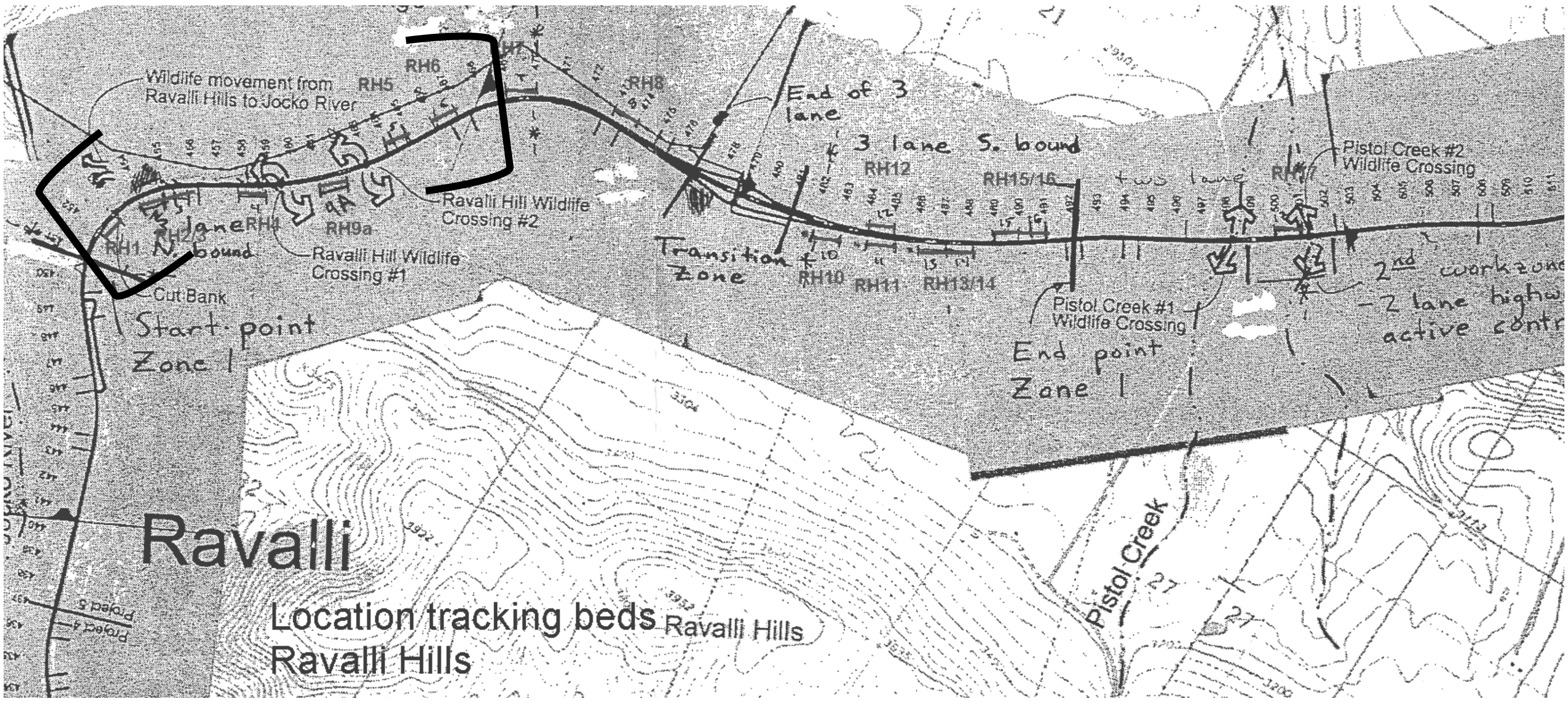


Figure E-2

The figure below shows approximate locations of sand track beds installed in 2003 in the Ravalli Hill region of the US 93 study area. Each short black line represents a 100 m long bed that was placed randomly (with respect to the length and either side of the stretch of road originally planned for contiguous fencing with crossing structures) to obtain a representative sample of deer and bear movements across the area to be fenced. Brackets encompass track beds monitored in 2003-2005; data from this subset of track beds were extrapolated across the area to be fenced to estimate total preconstruction crossings; these data were then extrapolated across the entire area to estimate total preconstruction crossings. Beds outside the white brackets were dropped from monitoring after 2003 when fencing plans were shortened and data from these beds no longer pertained to movements within the area to be fenced. Original map source: Jones and Jones (2002a).



FigureE-3

15. APPENDIX F: DEER AND BEAR TRACKING DATA SUMMARY

Table F-1: Track beds monitored in each area and each year, the actual length of each bed in meters, and the total number of "certain" deer crossings recorded each year of track bed monitoring.

Table 19

Evaro					Ravalli Curves					Ravalli Hill				
BED	**LENGTH**	**2003**	**2004**	**2005**	**BED**	**LENGTH**	**2003**	**2004**	**2005**	**BED**	**LENGTH**	**2003**	**2004**	**2005**
EV10	87	20	15	17	RC1	87	21	18	20	RH1	100	16	26	9
EV11	98	33	22	24	RC10	99	10	6	2	RH2/3	200	12	15	18
EV12	97	40	33	20	RC11/12	194	60	24	31	RH4	100	6	3	3
EV13/14	218	8	37	23	RC13	99	18	1	0	RH5	100	2	5	11
EV15/16	216	10	23	15	RC14	100	11	0	10	RH6	100	8	36	56
EV17	99	2	12	2	RC15	100	5	9	6	RH9A	100	19	2	15
EV18	99	30	31	7	RC16	96	5	13	8					
EV2	101	15	40	22	RC17/6A	207	12	11	15					
EV7	87	9	11	11	RC18	99.2	18	15	4					
EV8	91	11	29	24	RC19	103	8	9	2					
EVPE	91	12	11	5	RC2	101	21	14	35					
EVPW	91	17	17	11	RC20	97.8	3	3	5					
					RC3	89	23	7	47					
					RC4	93	50	35	68					
					RC5	101	41	19	57					
					RC7A	87	6	7	4					
					RC8/9	199	97	28	31					
TOTAL	1375	207	281	181	TOTAL	1952	409	219	345	TOTAL	700	63	87	112

Table F-2: Track beds monitored in each area and each year, the actual length of each bed in meters, and the total number of "certain" black bear crossings recorded each year of track bed monitoring.

Evaro					Ravalli Curves					Ravalli Hill				
BED	**LENGTH**	**2003**	**2004**	**2005**	**BED**	**LENGTH**	**2003**	**2004**	**2005**	**BED**	**LENGTH**	**2003**	**2004**	**2005**
EV10	87	2	1	0	RC1	87	0	1	0	RH1	100	8	0	1
EV11	98	0	0	1	RC10	99	1	1	0	RH2/3	200	4	0	2
EV12	97	0	3	0	RC11/12	194	1	3	1	RH4	100	1	2	0
EV13/14	218	1	1	0	RC13	99	0	0	0	RH5	100	0	0	0
EV15/16	216	0	1	0	RC14	100	1	1	0	RH6	100	0	0	0
EV17	99	1	0	0	RC15	100	3	7	0	RH9A	100	0	0	0
EV18	99	4	0	0	RC16	96	4	3	0					
EV2	101	8	3	3	RC17/6A	207	4	7	0					
EV7	87	5	4	1	RC18	99.2	1	3	0					
EV8	91	5	18	0	RC19	103	1	15	0					
EVPE	91	0	1	0	RC2	101	0	0	1					
EVPW	91	0	1	0	RC20	97.8	3	2	1					
					RC3	89	0	0	0					
					RC4	93	0	0	1					
					RC5	101	0	0	0					
					RC7A	87	2	1	3					
					RC8/9	199	1	1	0					
TOTAL	1375	26	33	5	TOTAL	1952	22	45	7	TOTAL	700	13	2	3

16. APPENDIX G: CONSTRUCTION AND MONITORING SCHEDULE

Table G-1: Construction and Monitoring Schedule.

		XINGS	Summer 2006	Fall 2006	Winter 2006	Spring 2007	Summer 2007	Fall 2007	Winter 2007	Spring 2008	Summer 2008	Fall 2008	Winter 2008	Spring 2009	Summer 2009	Fall 2009	Winter 2009	Spring 2010	Summer 2010	Fall 2010	Winter 2010	Spring 2011	Summer 2011	Fall 2011	Winter 2011	Spring 2012	Summer 2012	Fall 2012	Winter 2012	Spring 2013	Summer 2013	Fall 2013
CONSTRUCTION	Evaro to McClure	9[a]		■	■	■	■	■	■	■	■	■																				
	McClure to N. Arlee	0[a]						■	■	■	■	■	■	■	■	■																
	N. Arlee to White Coyote Rd.	4	■	■	■	■	■	■																								
	White Coyote Rd. to S. Ravalli	7[b]			■	■	■	■	■	■	■	■	■																			
	S. Ravalli to Old US 93	6	■	■	■	■	■	■	■	■																						
	Old US 93 to Red Horn Rd	10	■	■	■	■	■	■	■	■	■	■	■																			
	Red Horn Rd to Spring Creek		*SEIS to be completed 2006 (undetermined construction dates)*																													
	Spring Creek to Minesinger Tr	4		■	■	■	■	■	■	■	■	■																				
	Minesinger Tr to MT 35	1	■	■	■	■																										
MONITORING	AVC Documentation		▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
	Pellet Group Survey		▒				▒				▒				▒				▒				▒				▒					
	Track Survey (option 1)						▒	▒			▒	▒			▒	▒			▒	▒			▒	▒			▒	▒			▒	▒
	Track Survey (option 2)																		▒	▒			▒	▒			▒	▒			▒	▒
	Photo Monitoring		▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
	Traffic Survey															▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒	▒
	Repeat Black Bear Study																										▒	▒			▒	▒
	Repeat Deer Study																			▒	▒	▒	▒	▒	▒	▒	▒	▒	▒			
	Creek Profiles													▒	▒																	

[a] Plus 1 fish crossing

[b] Plus 3 small mammal crossings

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