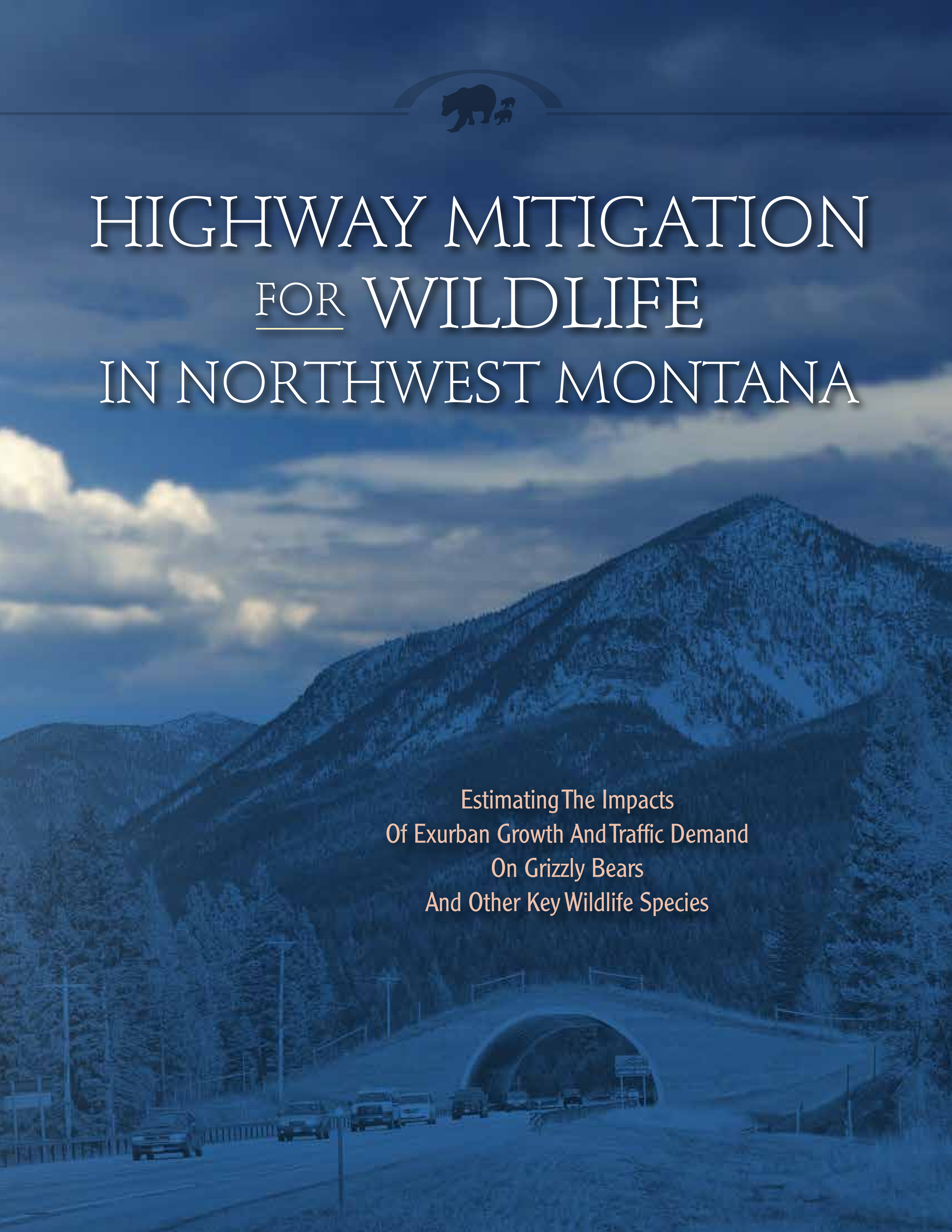
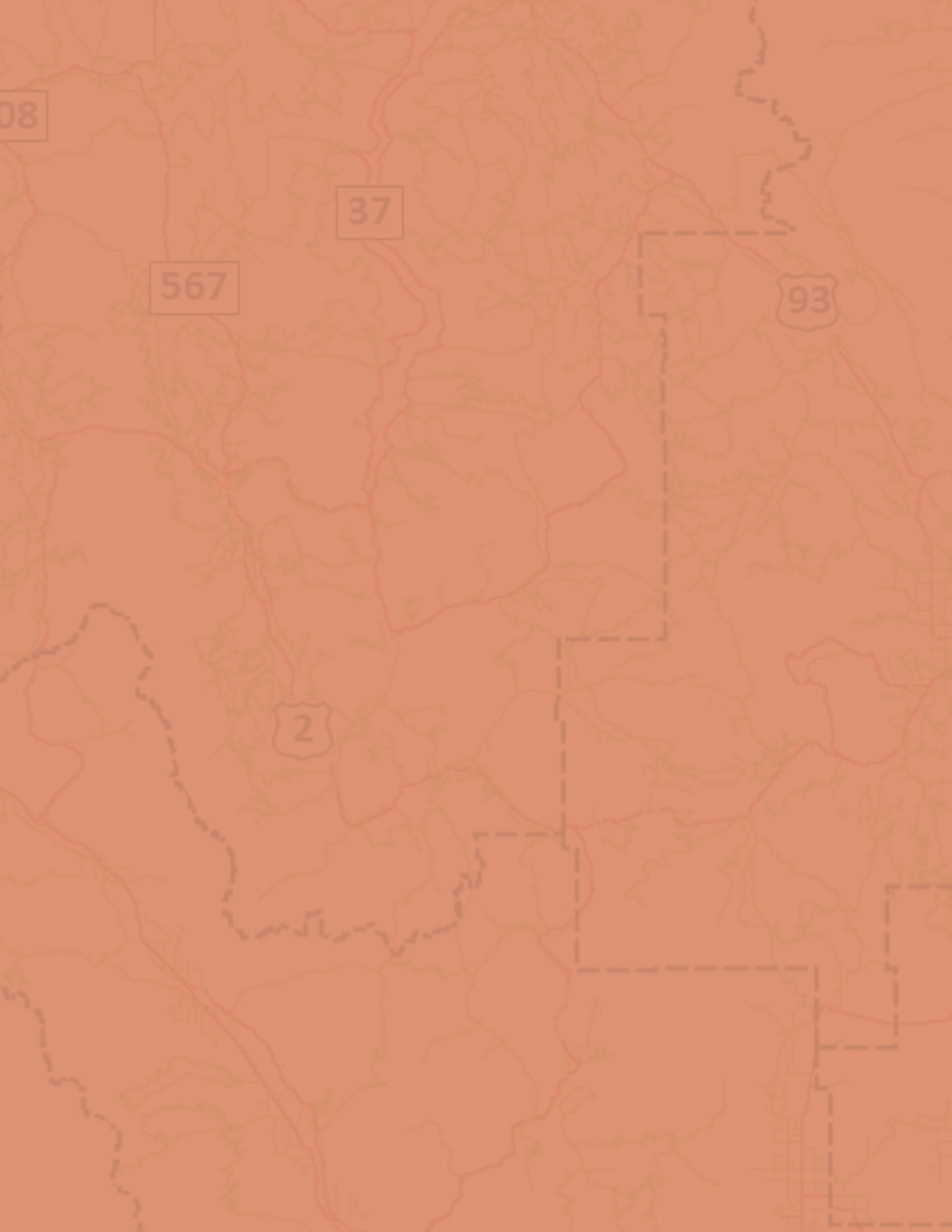


HIGHWAY MITIGATION FOR WILDLIFE IN NORTHWEST MONTANA

Estimating The Impacts
Of Exurban Growth And Traffic Demand
On Grizzly Bears
And Other Key Wildlife Species


37
567
93
2

HIGHWAY MITIGATION FOR WILDLIFE IN NORTHWEST MONTANA

Estimating The Impacts Of Exurban Growth And Traffic Demand On Grizzly Bears And Other Key Wildlife Species

HIGHWAY MITIGATION FOR WILDLIFE
IN NORTHWEST MONTANA

Angie Rutherford, MESc
and Cameron Ellis, MSc

Sonoran Institute
201 S. Wallace Ave., Suite B3C
Bozeman, MT 59715

Pat McGowen, PhD

Western Transportation Institute
College of Engineering, Montana State University
P.O. Box 174250
Bozeman, MT 59717-4250

Meredith McClure, PhD
and Rob Ament, MSc

Center for Large Landscape Conservation
P.O. Box 1587
Bozeman, MT 59771

Jerry Grebenc, MA

Future West
P.O. Box 1253
Bozeman, MT 59771

A report prepared for the
National Fish and Wildlife Foundation

ACKNOWLEDGEMENTS

The authors of this report would like to thank the National Fish and Wildlife Foundation for funding this project. Special thanks are due to the following organizations and individuals who have provided data and other information, attended the field evaluation of the mitigation emphasis sites, and/or reviewed drafts of the final report. Their contributions have been critical to the project's success.

Jeremy Anderson
Wildlife Biologist
Kootenai National Forest, USFS

Linda Dworak
Environmental Science
Missoula District
Montana Department of Transportation

Scott Jackson
National Carnivore Program Leader, USFS

Tom Kahle
Multimodal Planning Bureau
Montana Department of Transportation

Wayne Kasworm
U.S. Fish and Wildlife Service

Reed Kuennen
Wildlife Biologist
Flathead National Forest, USFS

Bill Semmens
Environmental Services–Resources Section Supervisor,
Montana Department of Transportation

Shane Stack
Missoula District Preconstruction Engineer
Montana Department of Transportation

Tim Their
Wildlife Biologist
FWP Region 1
Montana Fish, Wildlife & Parks

John Waller
Wildlife Biologist
Glacier National Park

DISCLAIMER

Suggested Citation: Ament R., P. McGowen, M. McClure, A. Rutherford, C. Ellis, and J. Grebenc. 2014. Highway mitigation for wildlife in northwest Montana. Sonoran Institute, Northern Rockies Office, Bozeman, MT, 84 pp.

August 2014

TABLE OF CONTENTS

1. Executive Summary **ix**

2. Introduction **1**

2.1. Project Goals and Objectives 1

2.2. Study Area 3

3. Importance of Wildlife Corridors and Ecological Connectivity **5**

3.1. Focus on Carnivores 5

3.2. Forecasting Needs for Wildlife Connectivity across Major Roads 7

4. Exurban Growth Modeling **8**

4.1. Introduction 8

4.2. Methods 9

4.3. Results 12

4.4. Implications 15

5. Traffic Demand Forecasting Model **16**

5.1. Introduction 16

5.2. Methods for Building Model 16

5.2.1. Basic approach 17

5.2.2. Special generator and seasonal variation 20

5.2.3. Modification for larger rural area 22

5.2.4. Adjusting traffic estimations for Libby, MT area 23

5.3. Application of Model to Forecast Year 23

5.4. Implications 25

6. Synthesis of Wildlife Connectivity Values **28**

6.1. Introduction 28

6.2. Data Sources 28

6.2.1. Grizzly bear movement data and linkage zones 28

6.2.2. Connectivity models for other wide-ranging carnivores 29

6.2.3. Landscape integrity-based connectivity models 29

6.3. Methods 30

6.4. Results 32

6.5. Implications 33

7. Field Evaluation of Highway Mitigation Sites **35**

7.1. Introduction 35

7.2. Ranking Process and Categorical Values 36

7.3. Results 38

8. Mitigation Sites **40**
8.1. Introduction 40
8.2. Existing Structures 40
8.3. Priority Mitigation Sites 41
9. Cooperative Planning Opportunities **52**
9.1. Planning Opportunities 52
9.1.1. Cooperative planning opportunities – local governments 52
9.1.2. Cooperative planning opportunities – state agencies 53
9.1.3. Cooperative planning opportunities – federal land management agencies 54
9.1.4. Other entities 55
9.2. Partnerships Needed for Future Wildlife Mitigation Projects 55
10. References **57**
11. Appendix A: Wildlife Mitigation Measures **62**
11.1. Background 62
11.2. Introduction 62
11.2.1. Wildlife fencing 62
11.2.2. Wildlife overpasses 63
11.2.3. Wildlife underpasses 64
11.2.4. Wildlife crosswalks 64
11.2.5. Vehicle speed reduction 65
11.2.6. Animal detection systems 65
11.2.7. Warning signs and variable message signs 66
11.2.8. Public awareness and education 67
12. Appendix B: Traffic Thresholds for Highway Upgrades **68**
12.1. AASHTO "Green Book" 68
12.2. AASHTO Roadside Design Guide 2006 70
12.3. FHWA Highway Functional Classification Concepts, Criteria, and Procedures 70
12.4. Capacity Analysis 70
12.4.1. Freeways (interstate highways) 71
12.4.2. Multi-lane highways 71
12.4.3. Two-lane highways 72
12.5. Summary 72
13. Appendix C: References for Appendices A and B **73**

LIST OF TABLES

Table 1: Initial density categories and associated annual growth rates. 19
Table 2: Employment data for Lincoln and Flathead counties from the 2010 U.S. Census. 39
Table 3: Traffic thresholds that may instigate road upgrades. 44
Table 4: Summary characteristics of connectivity data sources used to derive wildlife connectivity values. 50
Table 5: Attributes of priority wildlife mitigation sites based on connectivity value and projected traffic volume. 54
Table 6: Values matrix to identify priority wildlife mitigation sites in the study area. 57
Table 7: Prioritization values for the 13 mitigation sites selected in the study area. 62

LIST OF FIGURES

Figure 1: Study area of Lincoln and Flathead counties, Montana. 4
Figure 2: New homes built in the study area from 1970 - 2010. 9
Figure 3: Map showing 2010 census blocks in the study area. 11
Figure 4: Properties removed from the study due to public lands status or other development restrictions. 12
Figure 5: Study area homes per acre in 1970. 14
Figure 6: Study area homes per acre in 2010. 15
Figure 7: Increase in homes per acre 1970 - 2010. 16
Figure 8: Density gain 1970 - 2010 as a function of 1970 density (log scale). 17
Figure 9: Homes added 1970 - 2010 as a function of 1970 density (log scale). 18
Figure 10: *Business as usual* density projection for 2030. 13
Figure 11: Detail of business as usual density projection for 2030 13
Figure 12: *Business as usual* projection for 2030 – new homes displayed as points. 13
Figure 13: *Smart growth* density projection for 2030. 14
Figure 14: Detail of *smart growth* density projection for 2030. 14
Figure 15: *Smart growth* projection for 2030 - new homes displayed as points. 25
Figure 16: Travel demand forecasting model process. 27
Figure 17: Basic transportation network in Flathead and Lincoln counties. 29
Figure 18: Traffic growth for highways entering study area (external stations). 31
Figure 19: Typical travel time distributions (Data Source NCHRP 1998). A different distribution was used for each trip type: home-based work trips (HBW), home-based other trips (HBO), and non-home based trips (NHB). 32
Figure 20: Roads with available traffic flows used for calibration. 33
Figure 21: Typical seasonal variation in the study area (Data Source MDT 2013). 34

Figure 22: Seasonal variation near Glacier National Park (Data Source: Montana Department of Transportation 2013). 35
Figure 23: Annual visitation to Glacier National Park. 36
Figure 24: Housing/job imbalance in the study area. 38
Figure 25: A comparison of current modeled traffic with actual traffic in the study area validated the model. 40
Figure 26: 2030 traffic forecast for major roads in study area. 41
Figure 27: 2030 traffic forecast for *smart growth* land use scenario in study area. 42
Figure 28: Possible relationship between traffic level and impact on wildlife movement. 43
Figure 29: Multispecies connectivity value index based on corridor models for black bear, wolverine, lynx, and forest generalists. 52
Figure 30: Selected road segments and priority sites. Road segments numbered in red correspond to segment numbers in Table 5. Black number ranges indicate projected traffic volume (AADT). 53
Figure 31: Density of wildlife trails observed by Roesch (2006) crossing U.S. 2 between mile markers 153 and 193. 56
Figure 32: Gulley on Highway 2 within Mitigation Site 1a that could be targeted for an underpass structure. 65
Figure 33: Potential crossing mitigation location on Highway 2 in Mitigation Site 2, at the South Fork of the Flathead River Bridge. 68
Figure 34: A view looking south along the gravel road that provides river access for recreationists in Mitigation Site 2 and passes under Highway 2 on the east side of the South Fork of the Flathead River Bridge. 69
Figure 35: Typical road profile within Mitigation Site 3 near milepost 9 on Route 486 (North Fork Road), Flathead County. 70
Figure 36: Highway 93 near milepost 148 at the Lincoln-Flathead county line lies within Mitigation Site 4a of this study. 72
Figure 37: A wildlife-transportation study (unpublished mapping information provided by Montana Department of Fish, Wildlife& Parks) that highlighted important wildlife crossings (numbers 5 and 6 in the image), aligns with the selection of Mitigation Site 4a of this project. 72
Figure 38: Highway 93 south of Dickey Lake in Mitigation Site 4b. 73
Figure 39: A wildlife-transportation study (unpublished mapping data provided by Montana Department of Fish, Wildlife & Parks) that highlighted important wildlife crossings (numbers 10-12 in the image), aligns with this project's selection of Mitigation Site 4b. 74
Figure 40: Viewing the west side of Sutton Creek Bridge on Route 37 in Mitigation Site 5a. 75
Figure 41: Viewing the east side of Sutton Creek Bridge within Mitigation Site 5a on Route 37. 76
Figure 42: Typical road segment of Route 37 in Mitigation Site 5b. 77
Figure 43: View of available terrestrial habitat under the 5 Mile Creek Bridge of Route 37 within Mitigation Site 5b. 78

Figure 44: Highway 2 along the Kootenai River to the north (left in the picture) and steep slopes to the south (right in the picture) within Mitigation Site 6 west of Libby, MT. 79
Figure 45: Typical heavily forested roadsides along Highway 2 northwest of Troy, MT, within Mitigation Site 7. 81
Figure 46: Mix of private and public lands along Highway 2 within Mitigation Site 8a in Lincoln County, MT. 82
Figure 47: Typical road segment within Mitigation Site 8b on Highway 2 south of Libby, MT. 83
Figure 48: The best location for retrofitting a fill slope in a natural drainage with a wildlife underpass (i.e., large culvert, arched bridge) within Mitigation Site 9 on Highway 2. 85

Black bear emerging from an underpass. Photo: CSKT, MDT, & WTI-MSU

1. EXECUTIVE SUMMARY

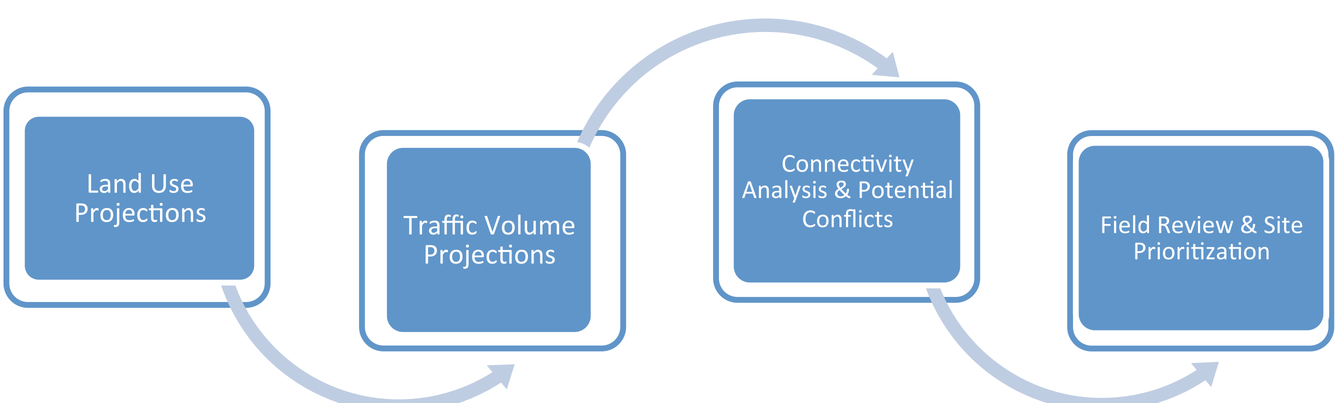
In this report, the Center for Large Landscape Conservation (CLLC), Future West, the Sonoran Institute, and Montana State University's Western Transportation Institute (WTI) investigated the potential impacts of future housing development on traffic to determine where increased traffic from housing development will impact habitat connectivity for large carnivores. The focus of this study was Flathead and Lincoln counties in northwestern Montana. The main goal was to maintain wildlife habitat connectivity across transportation corridors despite the likelihood of future traffic increases. This effort was unique in that it projects development into the future and identifies potential problem sites before the impacts arrive. With foresight and collaborative efforts, the impacts of future development can be mitigated to maintain habitat connectivity within the study area.

Two population projections were modeled. Each model used past population growth and future population estimates to spatially place new homes on the landscape. It was assumed that no new homes would be built on public land or on conservation easements. One model concentrated and biased growth in existing population centers, while the other model used past growth patterns and projected those same patterns into the future. Completed at the census-block level, a block's growth projection was based on the past growth of blocks that started with similar population densities. In this method, more dense areas were projected to grow at a faster rate than less dense areas.

The housing projection models were called the *smart growth model* and the *business as usual model*, respectively. The models produced traffic results that were similar in identifying potential problem areas for wildlife habitat connectivity. To avoid confusion and keep the focus of the study on mitigation opportunities instead of land use planning, this study uses the *business as usual* model.

The main goal was to maintain wildlife habitat connectivity across transportation corridors despite the likelihood of future traffic increases.

Based on the *business as usual* housing projections, future traffic was modeled for the established road network in the two-county study area. Trip generation rates were established based on current research, and the number of trips was then calculated for each new and existing home



in the housing projection. Standard occupancy rates and the shortest route were assumed for all trips. The traffic model was calibrated using existing traffic and adjusted so that future traffic could be predicted. Seasonality of traffic is a factor in the two-county study area, with more traffic during the summer months when carnivores such as grizzly bears, Ursus arctos, are active. These seasonal effects were used in the model calibration. The large scale and rural nature of the study area was somewhat unique, and urban centers were generally ignored in the model calibration, since the main focus of the study was the habitat connectivity in the areas between urban centers.

Increased traffic on certain highways may initiate road expansions and enhancements. These types of changes can increase the likelihood of mortality for wildlife crossing the highways. The thresholds for when these expansions will be needed are not absolute. However, based on previous research, the study identifies annual average daily traffic (AADT) of 200 or above as cause for some concern, and over 3,000 AADT as cause for heavy concern. Using these thresholds, most of the road network was eliminated as areas of concern because there were not more than 200 AADT projected on them. However, all major highways in the study area (i.e., Highway 2, Highway 93 and Highway 37) were identified as segments that were estimated to have over 3,000 AADT by 2030.

The study used the segments of highway identified in the previous step and found where those segments intersected areas with high habitat connectivity. The study identified areas of high habitat connectivity for grizzly bears and other wide-ranging carnivores, using available data sources. Data sets included species-specific data as well as vegetation-driven data. Both the fine-scale species-specific data and the coarse-scale vegetation data were used together to assign a connectivity value to points along the selected road network. Road segments with high connectivity value, and/or those identified as grizzly bear linkage zones, were identified and overlaid with projected traffic. Segments with high increase in traffic or high traffic volumes in the future that were also identified as having high connectivity value were scrutinized further to determine priority sites. Factors such as site-scale peaks in connectivity value, topography, vegetation cover and patterns of human settlement were used to determine priority sites.

Areas immediately surrounding the population centers of Kalispell/Columbia Falls/Whitefish, Eureka and Libby are predicted to increase traffic. However, because, those areas have low connectivity value, they were excluded from the study. Likewise, some areas with high connectivity value are not predicted to increase traffic volumes and were also eliminated as priority areas.

This report has identified potential problem areas years before mitigations will be needed, giving managers time to form partnerships and to cooperatively prepare for safe and wildlife-friendly growth.

Nine high-value road segments, with a total of 13 priority sites, were identified based on their value for wildlife connectivity, topography, and human settlement patterns. Table 5 summarizes the priority sites with their connectivity values and projected traffic.

A team of local experts then field evaluated the 13 priority sites to determine which have the highest potential to detrimentally impact habitat connectivity and the relative importance of each for wildlife mitigation purposes. In the field, each site was given a score (1-5, with 5 as best/most feasible), for a series of values, including its connectivity value, non-modeled species conservation value, highway-wildlife mitigation value, land security value, and traffic threat value. Feedback during the field evaluation confirmed that the priority sites that had been modeled were generally aligned with local knowledge of recognized priority locations.

The priority site with the highest value as a potential mitigation opportunity was east of Essex, MT, on Highway 2 between Glacier National Park and the Great Bear Wilderness. Other important sites lay between Whitefish and Eureka, and between Libby and Troy. Sites were bordered by private land, and those along Lake Koocanusa generally were lower priority due to low traffic threat and low connectivity values.

Potential mitigations options, both short- and long-term, were offered for each mitigation site. Short-term options are relatively inexpensive and can be implemented on a shorter time horizon than long-term options, but they are often less effective than long-term options. Long-term options are often more permanent in nature than short-term options, but they may be expensive and best implemented in conjunction with a reconstruction project.

Short-term mitigation solutions include at-grade options such as cautionary signs and animal detection systems. Long-term options include using existing structures such as bridges and culverts and improving them so that wildlife can pass under a road. More complex options include building new structures such as overpasses or wildlife-specific underpasses. Mitigation options involving structures would require fencing to funnel wildlife to the structure and to give animals caught on the road a jump-out option.

The mitigations offered for each of the suggested sites, if implemented, will help to maintain the connectivity of wildlife habitat in northwestern Montana. These mitigations will not stop all vehicle-wildlife conflicts, but will help to mitigate some and help maintain permeable transportation corridors through suitable wildlife corridors.

These mitigation methods can be quite expensive, so the best chance for successful completion of these projects lies in cooperation among local, state and federal governmental agencies, non-profit organizations whose mission is to protect wildlife habitat, and concerned citizens. This report can be offered as a resource to help plan for continued growth in Flathead and Lincoln counties and to mitigate the effects of that growth on one of the most pristine and important wildlife habitat areas in the nation. This report has identified potential problem areas years before mitigations will be needed, giving managers time to form partnerships and to cooperatively prepare for safe and wildlife-friendly growth.

Grizzly bear in a highway underpass. Photo: CSKT, MDT, & WTI-MSU

2. INTRODUCTION

2.1. Project Goals and Objectives

The Center for Large Landscape Conservation (CLLC), Future West, the Sonoran Institute, and Montana State University's Western Transportation Institute (WTI) partnered to model the impact of future human development, particularly increasing vehicle traffic, on wildlife connectivity. Focused on Lincoln and Flathead counties in northwest Montana, the project was designed to test methods for identifying future road mitigation locations in key wildlife linkage areas between the Crown of the Continent and the Cabinet-Yaak ecosystems. The main goal is to maintain wildlife habitat connectivity across transportation corridors in the region despite the likelihood of future increases in traffic, a factor that exacerbates the barrier effect of roads. Although priority habitat linkage zones and associated highway segments in this area have previously been identified, this effort is unique in the utilization of 20-year forecasts to identify where problems are expected to be in the future, not just where they have been in the past. This type of planning effort will enable local planners, resource managers, transportation agencies, and non-profit organizations to maintain habitat connectivity for wildlife, thus protecting movement patterns, population stability, and genetic diversity.

This planning effort focused on carnivores, particularly grizzly bear, *Ursus arctos*, as an umbrella species. Maintaining movement for species such as grizzly bears, a species sensitive to roads and related human development and activities, is expected to protect many other species' ability to move between and among their preferred habitats. The emphasis of this study is not to stop all animals from being killed on major roads within the study area, but rather to maintain connected habitat and wildlife corridors where they matter most, by proposing mitigation opportunities for the highest priority sites for wildlife connectivity within the region. Additionally, as mitigation measures are provided at critical locations where wildlife corridors traverse busy roads, it is projected wildlife-vehicle collisions (WVCs) will decrease in those locations. Such a decrease will protect wildlife and motorists, alike.

The primary long-term outcome of this project is the protection of critical wildlife corridors and the reduction of habitat fragmentation resulting from road and traffic barriers in the two-county project area. Ultimately, corridor preservation plays a key role in maintaining the landscape connectivity that is crucial for the well-being of many wildlife species that currently thrive within and between the Crown of the Continent and Cabinet-Yaak ecosystems. This report focuses on three threatened or proposed-threatened carnivore species under the Endangered Species Act: the lynx, *Lynx canadensis*; wolverine, *Gulo gulo*; and grizzly bear. As human communities, exurban development, and recreational use continue to expand, transportation infrastructure poses one of the major challenges to maintaining wildlife connectivity. It is essential to identify the intersection between critical wildlife corridors and major roads, in order to recommend priorities and develop workable mitigation solutions for county planners, transportation personnel, wildlife managers, elected officials, and local and regional advocates for wildlife conservation.

The primary long-term outcome of this project is the protection of critical wildlife corridors and the reduction of habitat fragmentation resulting from road and traffic barriers in the two-county project area.

The ways by which highways and roads

affect wide-ranging species and their populations vary among species depending on the behavior and life-history of each species. Highways are a major influence, but for all species, the location and quality of suitable habitat ultimately determine the species' movements. Highways that intersect with critical wildlife habitat can be an obvious source of mortality or movement restriction, increasing the potential for population decline and isolation. Addressing the threat of larger, faster, busier roads is essential to maintaining northwest Montana's wildlife populations and their ability to move across the landscape.

Using housing density forecasts, travel demand scenarios, wildlife connectivity models, and road ecology science, this study focuses on Flathead and Lincoln counties as a case study to implement a new planning approach to address wildlife connectivity needs. The outcomes of this planning approach are identified areas of opportunity to maintain habitat connectivity and to reduce future wildlife-vehicle conflicts.

The specific steps of this project are to:

- Develop two growth scenarios, each based on past growth patterns that are projected into the future. Each growth scenario will differ based on future development patterns; one will assume more growth near existing population centers and one will model new housing based on historic growth patterns with no accommodation for a potential change in development patterns (i.e., a *business as usual* scenario). (Chapter 4)
- Use the growth scenarios to develop future traffic projections. (Chapter 5)
- Use existing wildlife connectivity data to identify priority linkage areas. (Chapter 6)
- Overlay future traffic projections onto connectivity data to identify areas of potential future wildlife-transportation conflict. (Chapter 6)
- Check model results with local experts and conduct an on-the-ground evaluation. (Chapter 7)

This project identifies key areas where new homes and businesses spur increased traffic and road expansions and enhancements.

- Refine locations and offer mitigation opportunities based on field observations and expert knowledge.(Chapter 8)

Future population growth and associated expansion of highway infrastructure can be expected to impact wildlife habitat in northwest Montana. However, with proper planning, highway expansion and improvement projects can be implemented in a way that minimizes habitat fragmentation for species of conservation concern such as grizzly bear, wolverine, and lynx, as well as many others, such as native ungulates (i.e., bighorn sheep, mountain goat, elk, moose, and deer). This project identifies key areas where new homes and businesses spur increased traffic and road expansions and enhancements. Such changes to the transportation system can adversely affect animal behavior, essentially creating a barrier to their movement as well as increasing potential mortality to individuals at levels that affect populations. Since highway infrastructure can last for 50-75 years, careful consideration of the impacts on wildlife connectivity before the infrastructure is put in place is critical to the future of the affected species. With 20-year projections of needs at the highest priority locations for wildlife connectivity across the project area's highways, this study provides opportunities for highway and wildlife managers to incorporate mitigation in infrastructure projects over the next two decades.

It is important to note that, unlike many existing highway mitigation studies, the focus of this work is not to identify existing problems with wildlife-vehicle collisions, which are primarily driven by conflict with deer, elk, and moose. Instead, we focus on projecting future threats to broad-scale habitat connectivity in order to proactively identify mitigation opportunities that can be addressed early in the planning process of future highway projects in northwest Montana. Our focus on carnivores enables a big-picture perspective on crucial connectivity habitat and how it is impacted by roads. This perspective is often overlooked when focusing on mitigation of collisions with ungulates.

We focus on projecting future threats to broad-scale habitat connectivity in order to proactively identify mitigation opportunities that can be addressed early in the planning process of future highway projects in northwest Montana.

2.2. Study Area

The project is focused on major transportation routes in Flathead and Lincoln counties in northwestern Montana. Lincoln County shares its western border with Idaho, and Flathead County's eastern border is the Continental Divide. Both counties border Canada to the north. The Flathead and Kootenai National Forests are in the study area, as is Glacier National Park. Kalispell, in Flathead County, is the largest city, with an estimated population of 20,487 in 2012. The area immediately surrounding Kalispell is largely developed compared to the rest of the study area. Plum Creek Timber Company owns more private land in the study area than any other single private land owner. As its lands have been

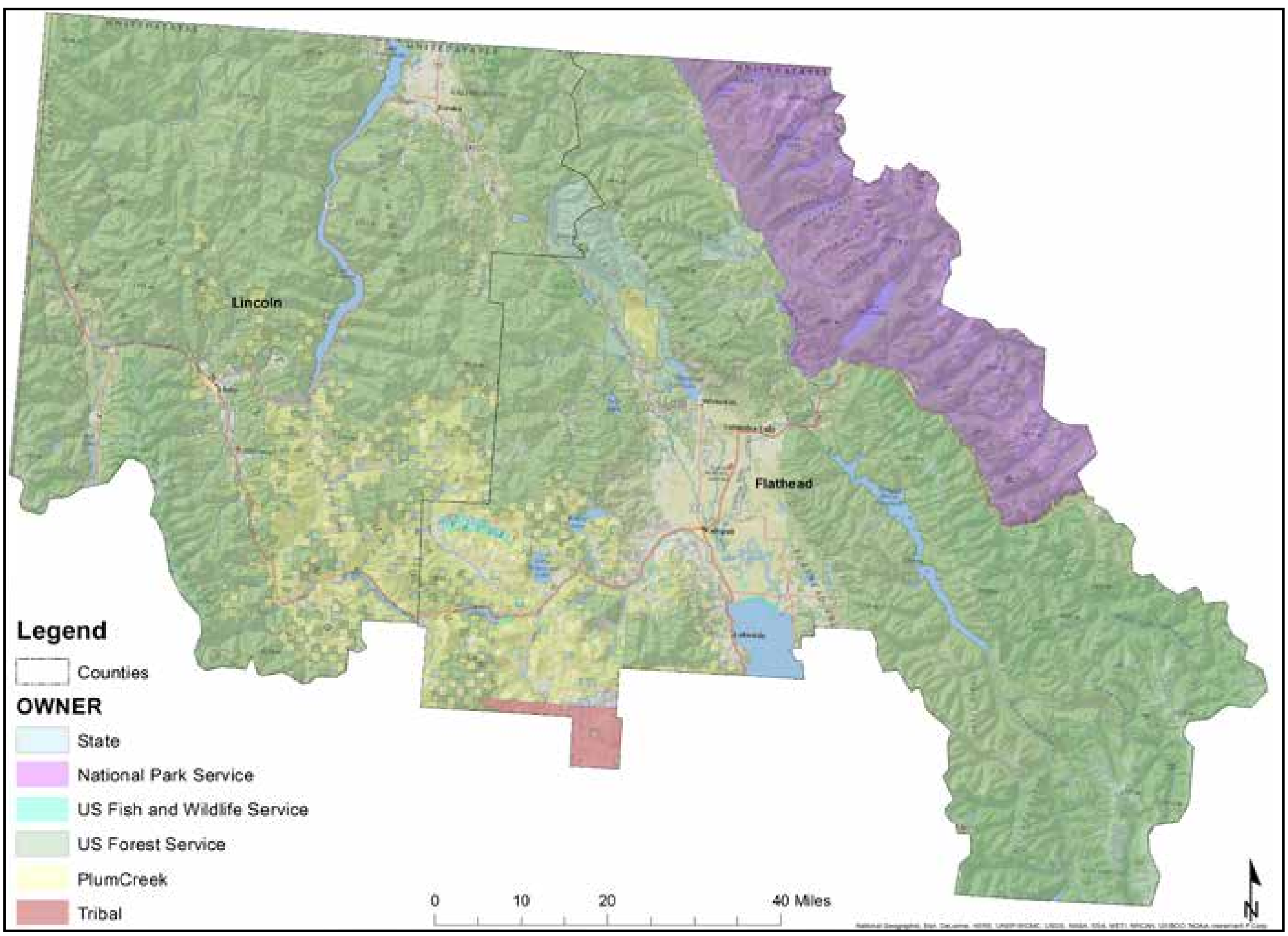


Figure 1: Study area of Lincoln and Flathead counties, Montana.

harvested, the company has been willing to sell some of them to private investors. A large portion of both counties is unavailable to development due to public ownership, conservation easements, or other interests. As a result, only about 20 percent of all lands in the two counties are available for residential development (Figure 4).

The large areas of undeveloped land provide habitat for an array of species, including large carnivores such as grizzly and black bear, mountain lions, and wolverines. Other species also use these areas, including moose, elk, bighorn sheep, deer, and smaller animals such as salamanders and boreal toads. This study focuses on connectivity of habitat in and between these large areas of land, recognizing that animals will likely travel outside of the study area to adjacent habitat and beyond.

Major transportation corridors in the study area include Highway 2, which runs mostly east-west in the southern portion of the counties, and Highway 93, which runs generally north-south through Flathead County to the Canadian border (Figure 1). Traffic in the study area has a large seasonal pulse, with an almost two-fold increase in traffic near Glacier National Park and approximately a 20 percent increase in other areas during the summer tourism season. Tourism is driven by visitation to Glacier National Park, as well as visitors from Canada vacationing in the northern part of the study area. This seasonal increase in traffic corresponds to the seasonality of animal movements, particularly bears, which hibernate during slow-traffic months. In other words, grizzlies are most likely to need to cross roads at the same time traffic volumes are highest.

In other words, grizzlies are most likely to need to cross roads at the same time traffic volumes are highest.

Grizzly bear on a highway overpass. Photo: WTI-Parks Canada

3. IMPORTANCE OF WILDLIFE CORRIDORS AND ECOLOGICAL CONNECTIVITY

Connectivity is most often and most inclusively defined as "the degree to which the landscape facilitates or impedes movement" (Taylor et al. 1993). It is an essential component of intact, healthy landscapes that supports wildlife movement and functional ecological processes. More specifically, connectivity can be described as "ecological conditions that exist at several spatial and temporal scales, providing landscape linkages that permit the exchange of flow, sediments, and nutrients; the daily and seasonal movements of animals within home ranges; the dispersal and genetic interchange between populations; and the long distance range shifts of species, such as in response to climate change" (36 Code of Federal Regulations, Section 219.19). ***Corridors*** have been defined in a variety of ways, but are generally agreed to constitute distinct components of the landscape that provide connectivity. ***Wildlife crossings*** are more narrowly defined as structures that allow animals to cross barriers (including roads) safely, and can be an important component of corridors.

In this study, we focus on the importance of corridors for maintaining wildlife movement. The long-term viability of wildlife populations is dependent upon movement processes spanning multiple spatial and temporal scales, including daily foraging bouts among patchy local resources, seasonal migrations between summer and winter ranges, and long-range dispersal in search of new territories. These movements ensure access to resources and mates, healthy levels of genetic diversity, demographic rescue effects following local extinction events, and the capacity to adapt to changing conditions.

Maintaining functional corridors supporting animal movement also contributes to ecological integrity more generally, sustaining ecological processes such as water, energy, and nutrient flows. Corridors also maintain the adaptive capacity of entire communities to recover from acute disturbances (e.g., fire) or to shift in response to chronic disturbances such as climate change. Climate change alters seasonal patterns of temperature and precipitation, and also affects long-term patterns of fire, drought, and flood. To adapt and persist, many wildlife species will need to shift their ranges and movement patterns.

In this study, we focus on the importance of corridors for maintaining wildlife movement.

Fragmentation may impede such adaptation, potentially resulting in isolated wildlife populations that will be highly vulnerable to extinction.

Maintaining connectivity across highways will allow wildlife to find refuge by moving away from habitats that have experienced detrimental change and toward habitats that have acquired the conditions to which a given species is adapted. A review of 25 years of peer-reviewed publications indicated that the most-recommended action for the long-term protection of biodiversity was maintenance of landscape connectivity that will support movement in response to climate change (Heller & Zavaleta 2009). Since highway infrastructure and mitigation measures are designed to exist for many decades into the future, increasing permeability across that infrastructure today increases the probability of animals successfully adjusting to changing environmental conditions far into the future.

3.1. Focus on Carnivores

The focus of our case study in Flathead and Lincoln counties is on habitat connectivity for carnivores occurring in this area, including Canada lynx, wolverine, black bear (*Ursus americanus)*, and particularly grizzly bear.

These species utilize large territories and thus require large areas of suitable habitat to support viable populations long term. These species exhibit dispersal movements typically ranging from 10 km to well over 100 km (Proctor et al. 2004, Costello et al. 2008, Inman et al. 2012), with extreme dispersal events of 900-1,100 km (Inman et al. 2009, Poole 1997). All are associated with forest habitat, yet represent different degrees of habitat specialization (grizzly and black bears are considered forest generalists, while lynx and wolverine have more stringent habitat requirements and are considered forest specialists). Together, these characteristics make it likely that providing for the habitat and connectivity needs of these species will serve as an umbrella for the needs of many other forest-dwelling species, and will provide broad-scale ecological connectivity supporting functional ecosystems and ecological processes.

Grizzly bears and Canada lynx are listed as threatened under the Endangered Species Act, and a decision to list wolverines as threatened is currently pending. All of these species have known sensitivity to highways and vehicle traffic, which may negatively impact wildlife populations through direct mortality; road avoidance behavior; and habitat loss, degradation, and fragmentation (Andrews, 1990, Bennett, 1991, Forman & Alexander 1998, Mumme et al. 2000). A national study identified 21 federally listed threatened or endangered species, including lynx, for which road mortality is among the major threats to survival of the species (Huijser et al. 2007). Loss of connectivity due to highways may also pose a threat to the long-term persistence of some wildlife populations (Noss et al. 1996, Sweanor et al. 2000, Gibbs & Shriver 2002, Epps et al. 2005) or may otherwise have significant detrimental impacts on wildlife population demographics (Gibbs & Steen 2005).

This report focuses particularly on grizzly bears because of their forest generalist characteristics, their threatened status, the well-documented impacts of roads on their behavior and demographics, and the documented benefits of highway mitigation to grizzly populations.

Grizzlies' response to roads has been fairly well studied since the 1980s, with new information on their use of highway mitigation structures (i.e., overpasses and underpasses) being published more recently. They are quite sensitive to the presence of roads, avoiding those with traffic levels as low as 10 vehicles per day in the Northern Continental Divide Recovery Area (Mace et al. 1996). In Alberta, grizzlies were found to avoid roads with moderate traffic (20–100 vehicles per day) and strongly avoid higher traffic volume roads (>100 vehicles per day) at all times (Northrup et al. 2012). High volume, high speed roads have been shown to reduce permeability across the road or become barriers to grizzly bear movement (Chruszcz et al. 2003, Waller and Servheen 2005, Alexander et al. 2005, Proctor et al. 2012). Roads can also be a source of direct mortality (Gunther et al. 2004).

Despite their sensitivity to traffic and other human-caused highway stimuli (i.e., light, noise), grizzly bears have fortunately demonstrated a willingness to use highway mitigation infrastructure such as overpasses or underpasses to cross busy roads (Clevenger et al. 2009, Sawaya et al. 2013). Furthermore, a system of overpasses and underpasses with fencing has been demonstrated to maintain their gene flow (Sawaya et al. 2014), confirming the value of mitigation for supporting the long-term health of grizzly populations (as well as black bears). Other findings further suggest that grizzlies may be able to adjust their patterns of use to avoid human conflicts at these engineered structures (Barrueto et al. 2014). Black bears are also known to use wildlife crossing structures, and while not studied as extensively, lynx and wolverines have been observed via camera traps using crossing

The mitigation opportunities highlighted in this report are priority sites for maintaining wildlife habitat connectivity where it matters most.

structures in Banff National Park (Clevenger et al., 2009).

This analysis offers an important complement to standard road mitigation studies. To fully mitigate the effects of a highway on wildlife habitat and wildlife-vehicle collision risk, more comprehensive mitigation would be needed. Instead, the mitigation opportunities highlighted in this report are *priority sites for maintaining wildlife habitat connectivity where it matters most*. Mitigation at these sites should be considered in conjunction with mitigation efforts aimed at reducing WVCs from a human safety perspective.

Grizzly bears have fortunately demonstrated a willingness to use highway mitigation infrastructure such as overpasses or underpasses to cross busy roads.

3.2. Forecasting Needs for Wildlife Connectivity across Major Roads

The mechanisms by which highways fragment wildlife habitat and inhibit animal movements are intuitive and predictable. First, highways themselves create physical obstacles. The wider the highway, and the more substantial the associated fencing, median barriers, or guardrails, the less likely an animal is to be able or willing to cross. As highways carry increasing levels of traffic at higher speeds, animals must navigate this additional hazard, and choose a time and place to safely cross. Crossings by wildlife are expected to become less successful with increasing traffic and/or increasing speeds, until eventually animals may be deterred from the road completely and choose not to cross (e.g., as suggested by Northrup et al. 2012, Dodd et al. 2011). When animals no longer attempt to cross the road or are consistently unsuccessful in doing so—whether due to traffic or the effects of the road's physical infrastructure --the road has become a complete barrier to movement, the landscape has been effectively fragmented, and demographic and genetic connectivity across the road has been lost.

Generally, increased human development will produce increased traffic. While areas such as Lincoln and Flathead counties today continue to host the full spectrum of wildlife species historically occupying the Northern Rockies, these species are experiencing increased impacts due to development pressures. As population and traffic numbers increase, traffic and wildlife managers can save lives and money by considering the effects of road improvements on wildlife habitat and mitigating those impacts before they become barriers. By forecasting the impacts of increased development on traffic, this study allows traffic and highway managers to start planning to mitigate those impacts long before they are needed, in a manner that is most cost-effective and that focuses limited resources where they will benefit habitat connectivity the most.

The mechanisms by which highways fragment wildlife habitat and inhibit animal movements are intuitive and predictable.

4. EXURBAN GROWTH MODELING

4.1. Introduction

Estimating the location of future housing and employment growth in Lincoln and Flathead counties was the first step in the larger modeling process. The purpose of the housing and employment growth projections was to provide a spatially explicit estimation of future housing density in the study area, such that subsequent models could predict traffic volumes on specific segments of roadway.

Traffic modeling (described in Chapter 5) was based on census-block-level housing and employment data, so the same scale was used for the growth model. Information about past development in the study area was used to predict future growth. Specifically, past growth from 1970 to 2010 was used to estimate the location and density of future housing and employment developments through the year 2030.

The period between 1970 and 2010 was characterized by residential growth occurring in suburban and exurban environments surrounding urban areas, with comparatively less growth in urban cores and in the isolated or remote regions of the study area.

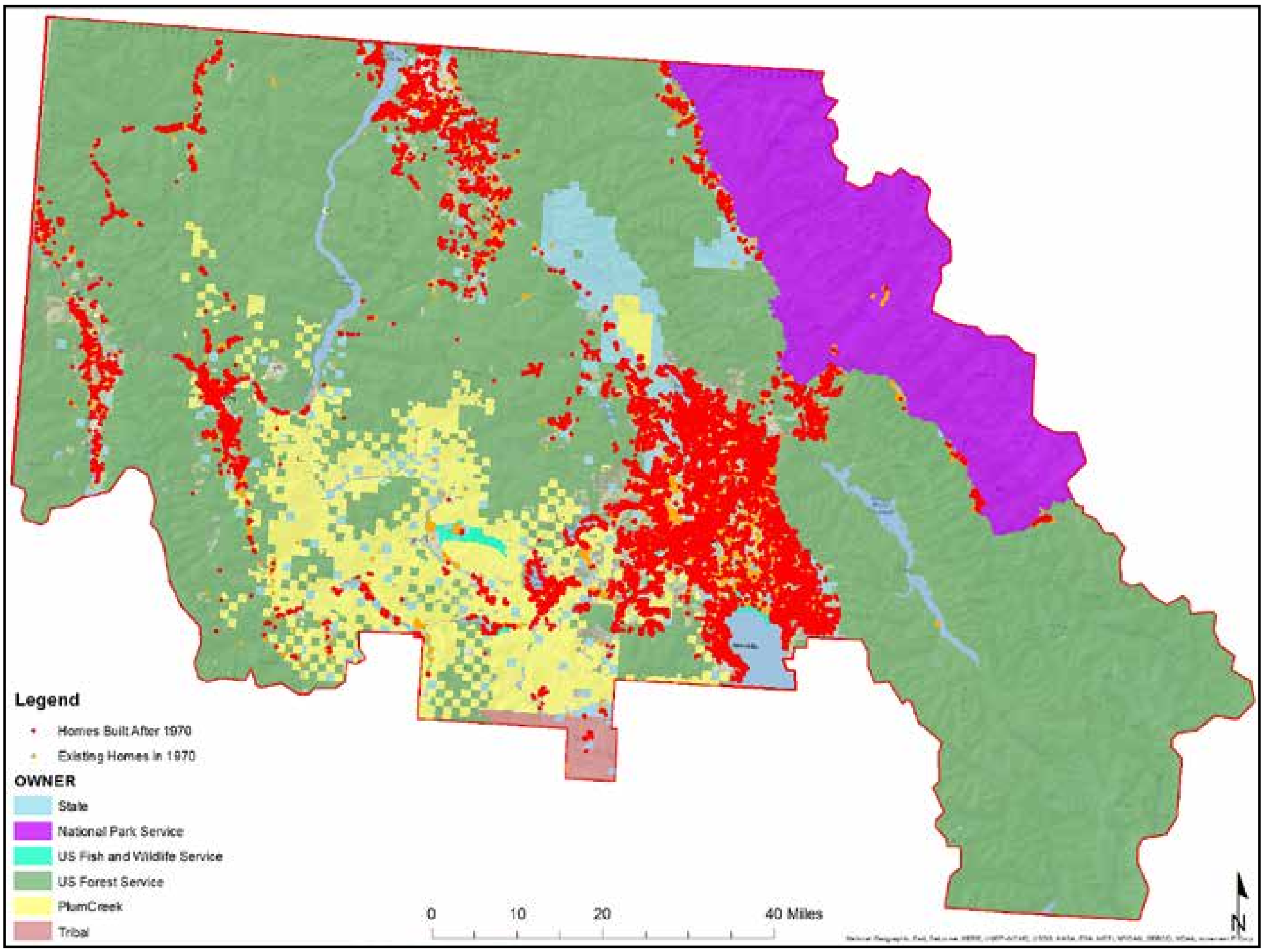


Figure 2: New homes built in the study area from 1970 - 2010.

Our goal was to produce two future growth scenarios for the study area:

- The *business as usual* model carries growth forward in a pattern similar to the growth experienced between 1970 and 2010.
- A *smart growth* model estimated growth based on slightly higher than experienced density in urban and suburban areas, with fewer new developments in exurban and rural areas.

Although both scenarios were used for the traffic and wildlife modeling, the *business as usual* model was used for the final prioritization and field evaluation. The *business as usual* model, which predicts more dispersed growth, is the estimation of future growth that most closely matches the growth patterns from the past several decades. It is worth noting that the traffic projections resulting from both scenarios are similar. This similarity is likely caused by travel between towns. Kalispell, as a major employment center, generates work traffic on highways whether someone lives in town or in a suburb of town. In other words, compact development patterns alone are insufficient to mitigate traffic on rural highways or significantly reduce wildlife vehicle conflicts.

4.2. Methods

Woods & Poole Economics (Woods & Poole Economics, Inc. 2013) estimates growth rates in the region through 2030 will be roughly 1.8 percent annually, resulting in approximately 26,900 new homes built in the region by 2030. The growth model was calibrated to add this many houses in the study area by 2030. In the period from 1970-2010, all census blocks did not grow at the same rate. That time period experienced an explosion in growth in suburban and exurban

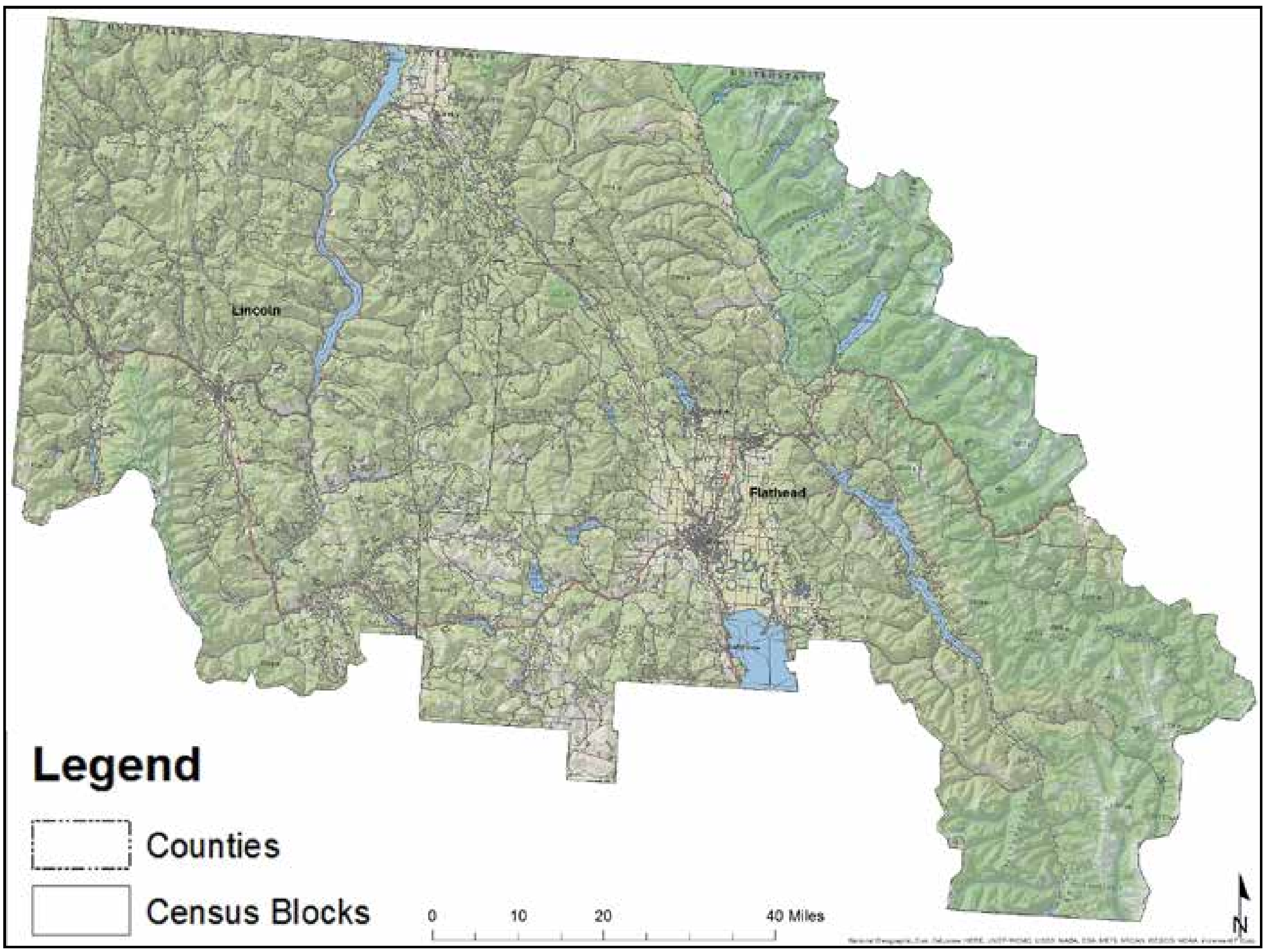


Figure 3: Map showing 2010 census blocks in the study area.

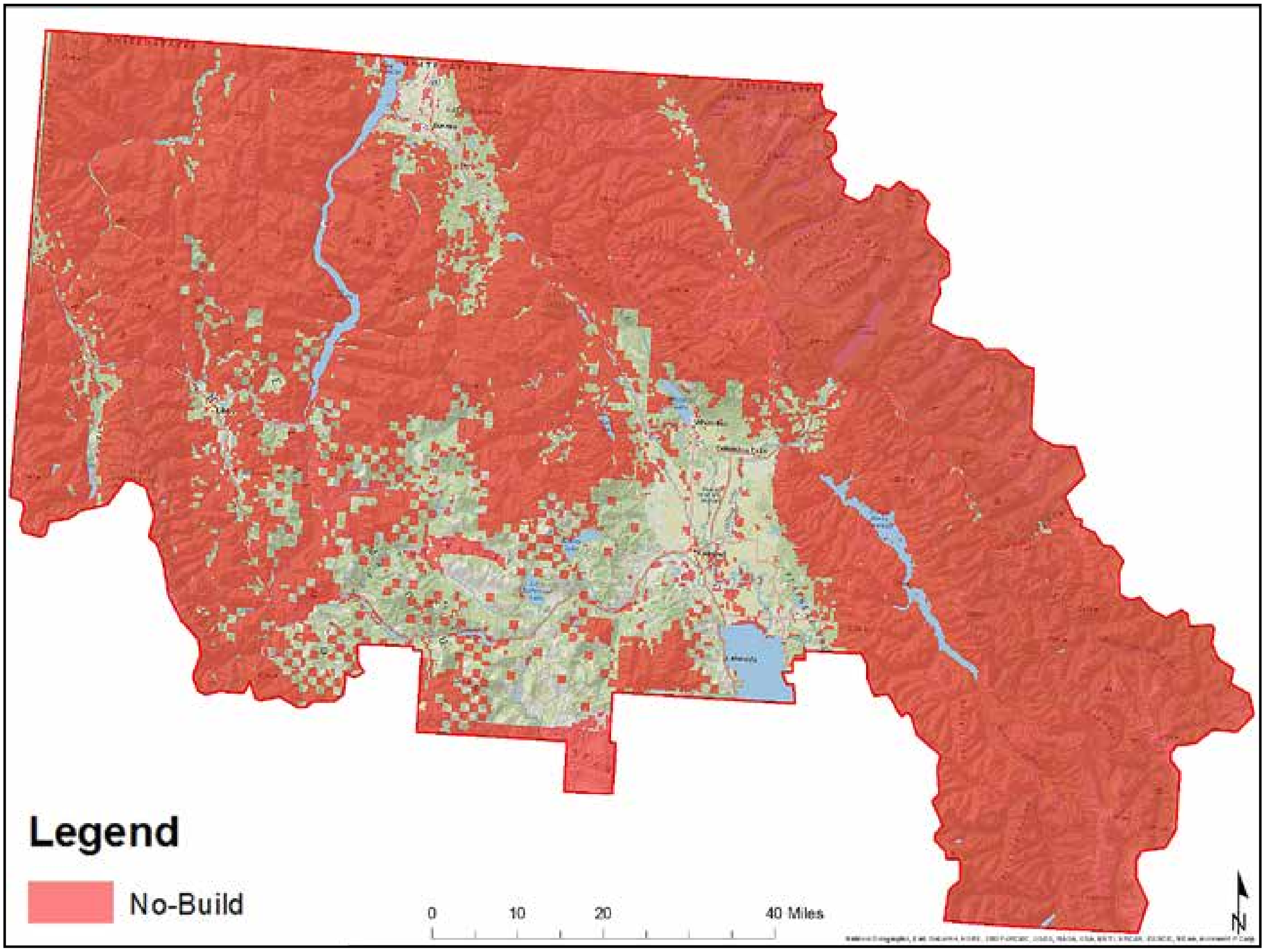


Figure 4: Properties removed from the study due to public lands status or other development restrictions.

areas, with less extensive growth in the urban cores. Our methods were designed to carry those growth patterns forward through 2030.

Housing data for 1970 was determined using the Montana Statewide Cadastral (CAMA), which identifies a "year built" for each residential parcel. All parcels with a "year built" prior to 1970 were assigned to a census block and totals were cross-checked with 1970 census data.

Housing in 2010 was determined similarly, by selecting and assigning all parcels with residential structures built between 1970 and 2010 to a census block.

Census blocks in the study area range widely in size, from small urban blocks (1 acre) to very large and sparsely populated rural blocks (457,273 acres). Montana Statewide Cadastral data was used because of spatially and temporally explicit information on housing development in the study area. Housing data for the 1970 census was not readily available in digital format, and census blocks have shifted, making comparison between large rural blocks more difficult and less accurate.

DEVELOPMENT RESTRICTIONS - Portions of the study area were removed from the study due to their status as public lands or due to other development restrictions, such as conservation easements. No future growth was assigned to these locations. Removed areas included federal lands (i.e., USFS, BLM, etc.), state land, tribal land, open water, and conservation easements. Due to the large amount of public lands in the study area, the total area removed from future development was 4,575,616 acres, or roughly 80 percent of the study area.

Spatially explicit growth was calculated by dividing the study area into polygons based on

2010 census blocks. Census blocks larger than one square kilometer were divided into square kilometer polygons, while smaller census blocks were left intact. Housing densities in the 1970 sample and the 2010 sample were determined for each polygon by dividing the number of homes in the polygon by the area of the cell.

Housing growth in the study area was divided into nine categories, from very low-density development (fewer than two homes per square mile) to the highest density category (more than four homes per acre) (Table 1). Given the largely rural landscape, the majority of the study area fell into low-density categories, while the highest density areas occurred only in the urban cores of the larger population centers.

In the period between 1970 and 2010, the lower density categories added the most homes, while the highest density areas added comparatively few new homes (Figure 9). However, due to the very large size of the low-density areas, the more relevant metric for housing growth in the study area is the increase in density between 1970 and 2010 within each category (i.e., new homes proportional to the geographic area of the category). In this analysis, density increased most rapidly in the polygons with an original (1970) density of between *one home per four acres* and *one home per half acre* (Figure 8). In other words, in the period between 1970 and 2010, density increased most rapidly in areas with existing homes and infrastructure, but at exurban densities.

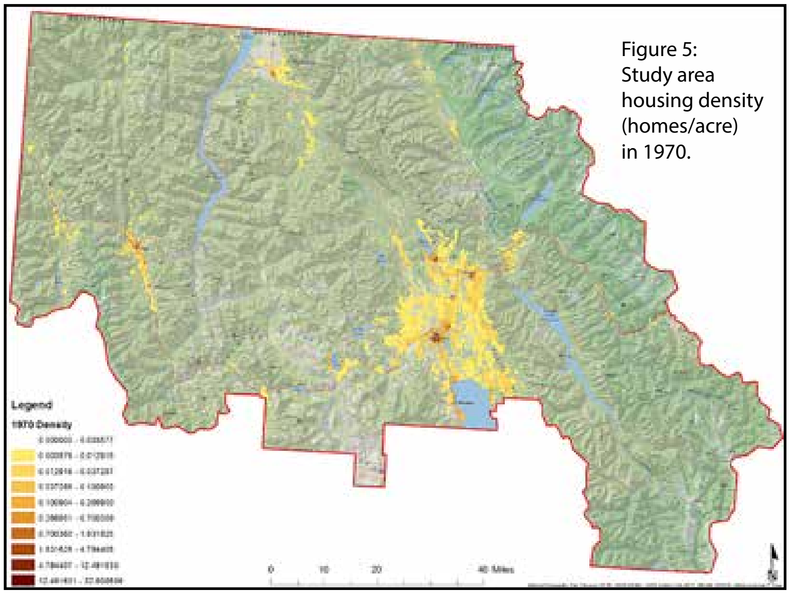


Figure 5: Study area housing density (homes/acre) in 1970.

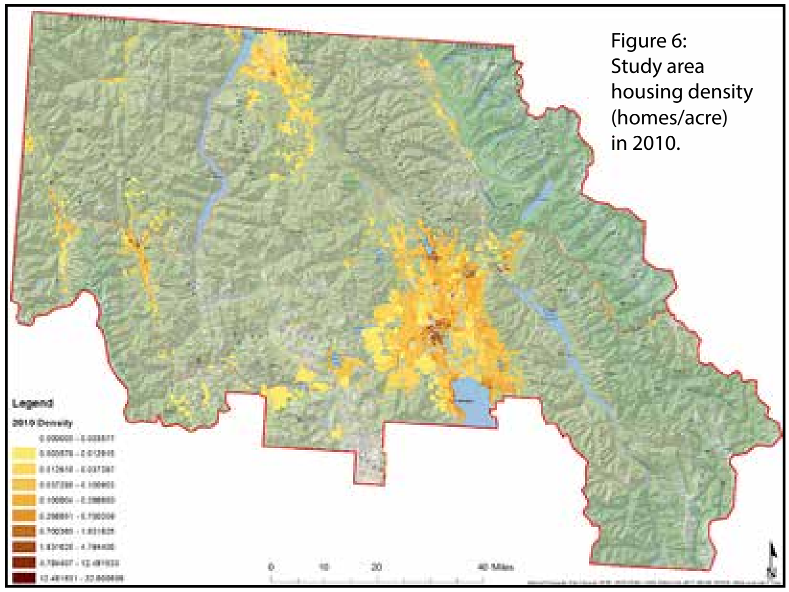


Figure 6: Study area housing density (homes/acre) in 2010.

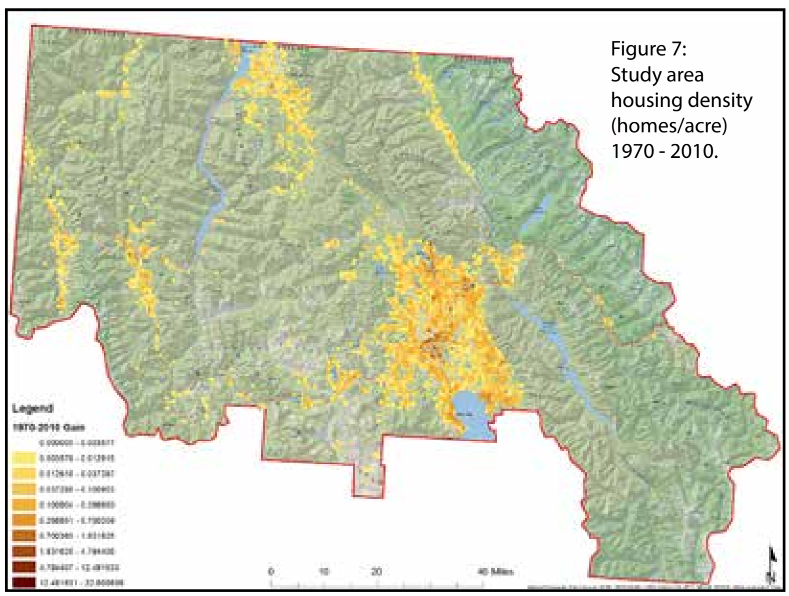


Figure 7: Study area housing density (homes/acre) 1970 - 2010.

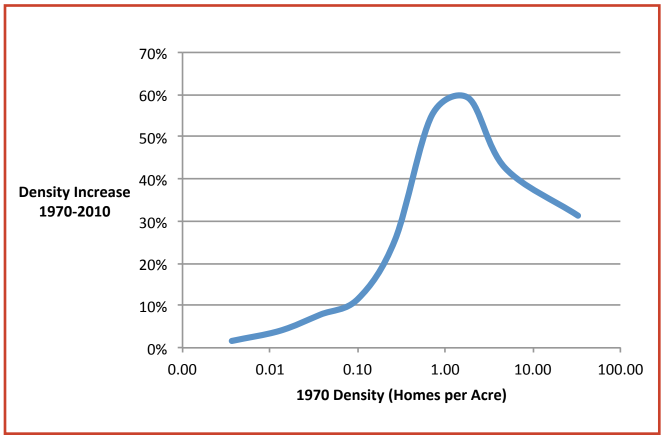


Figure 8: Density gain 1970 - 2010 as a function of 1970 density (log scale).

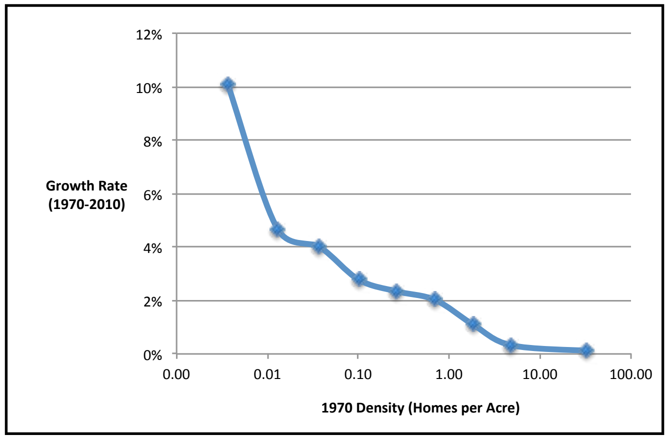


Figure 9: Homes added 1970 - 2010 as a function of 1970 density (log scale).

Future growth was determined by linking the annual growth rate experienced in the 1970-2010 time-step, and carrying it forward 20 years, resulting in an absolute number of new houses for each density category.

The *smart growth* projection was created similarly, although rather than carrying the same density-dependent growth rates forward unchanged, cell-specific density gains were squared and then rescaled to our target new-housing gain (~26,500 homes) across the study area, resulting in higher density development closer to the larger population centers, and no new development in grid cells without existing homes.

Results from each of the models were joined to their respective polygons. In instances where the polygon was smaller than the census block that contained it, the new homes were aggregated to the census-block level.

4.3. Results

The *business as usual* growth projection resulted in a pattern of growth that was very similar to the patterns of growth experienced between 1970 and 2010. Density increased across the entire developable study area, particularly on the peripheries of developed areas such as Whitefish and Kalispell. Density also increased along highways and transportation infrastructure between urban centers.

Table 1: Initial density categories and associated annual growth rates.

DENSITY CATEGORY			1970-2010			BUSINESS AS USUAL			SMART GROWTH		
Homes Per Acre			1970 Homes	Annual Growth Rate	2010 Homes	Reclassified Annual Growth Rate	New Homes	2030 Total Homes	Reclassified Annual Growth Rate	New Homes	2030 Total Homes
0	to	0.0036	349	10.08%	16237	2.28%	9263	25500	1.96%	7699	23936
0.0037	to	0.0129	1282	4.68%	7982	2.65%	5480	13462	0.79%	1367	9349
0.013	to	0.0373	1647	4.01%	7933	2.78%	5807	13740	1.77%	3324	11257
0.0374	to	0.1009	1040	3.73%	4500	2.54%	2929	7429	2.43%	2771	7271
0.101	to	0.267	1819	2.34%	4586	1.76%	1916	6502	3.22%	4059	8645
0.2671	to	0.7004	1627	2.02%	3621	1.00%	793	4414	3.68%	3841	7462
0.7005	to	1.8316	2308	1.08%	3545	0.37%	272	3817	2.13%	1860	5405
1.8317	to	4.7844	4880	0.33%	5560	0.11%	120	5680	1.11%	1377	6937
4.7845	to	32.6087	1609	0.10%	1674	0.04%	14	1688	0.66%	236	1910

Business as Usual growth projection

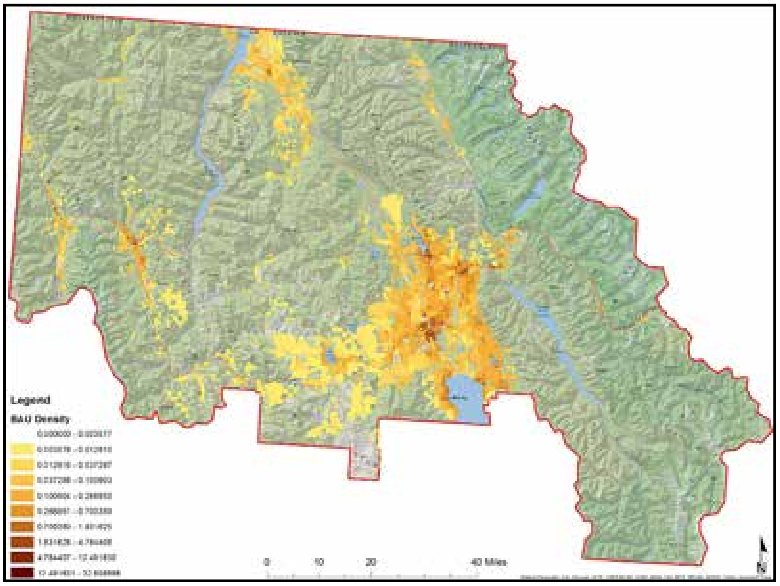


Figure 10: *Business as usual* housing density projection for 2030.

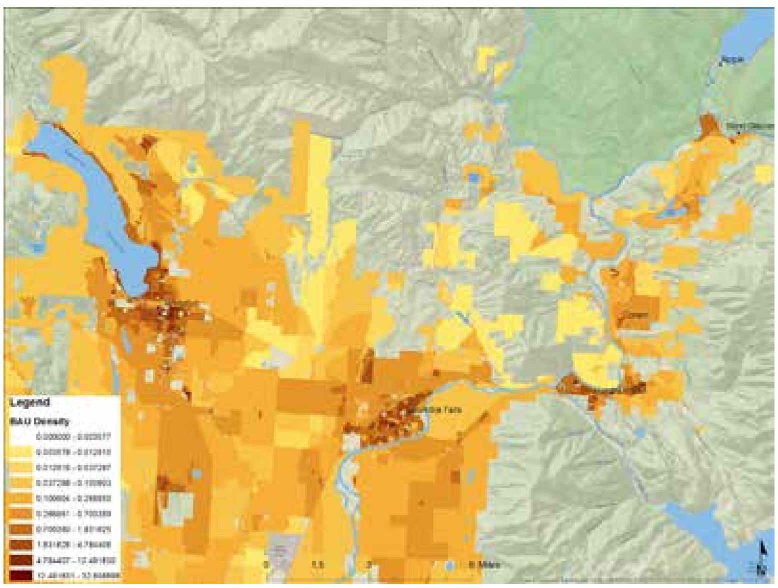


Figure 11: Detail of *business as usual* housing density projection for 2030

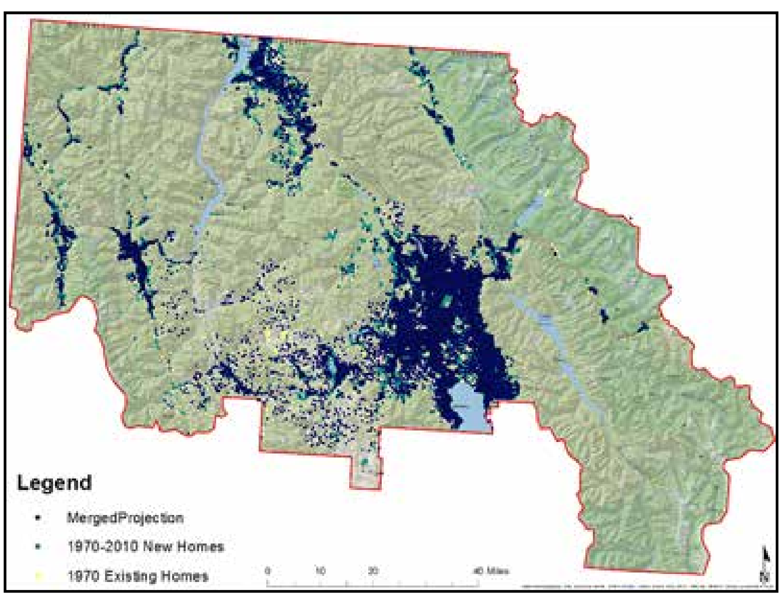


Figure 12: *Business as usual* projection for 2030 - new homes displayed as points.

Smart Growth projection

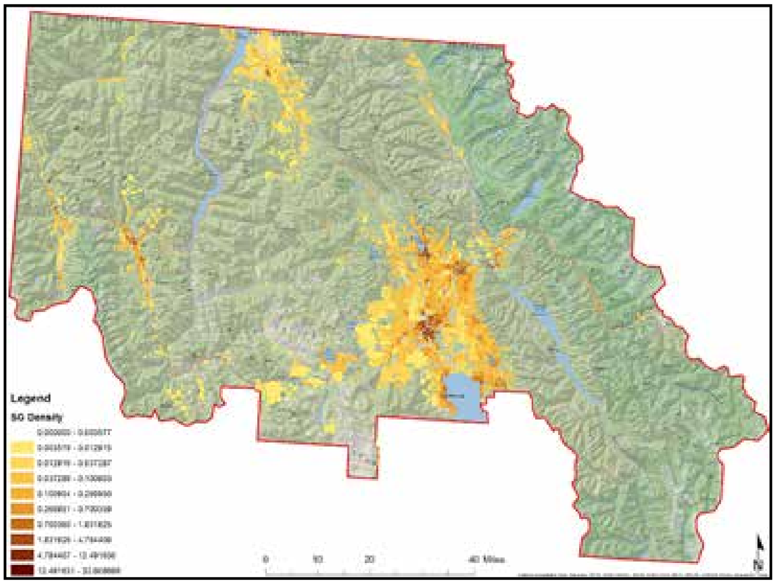


Figure 13: *Smart growth* density projection for 2030.

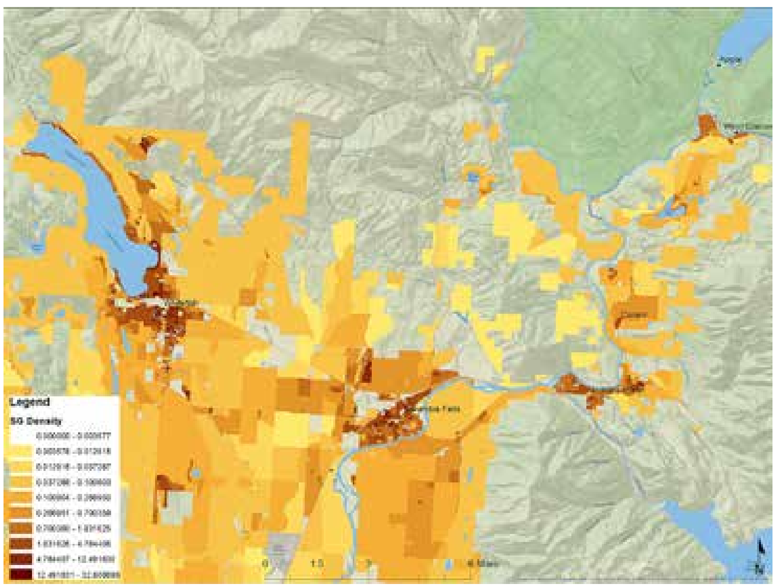


Figure 14: Detail of *smart growth* density projection for 2030.

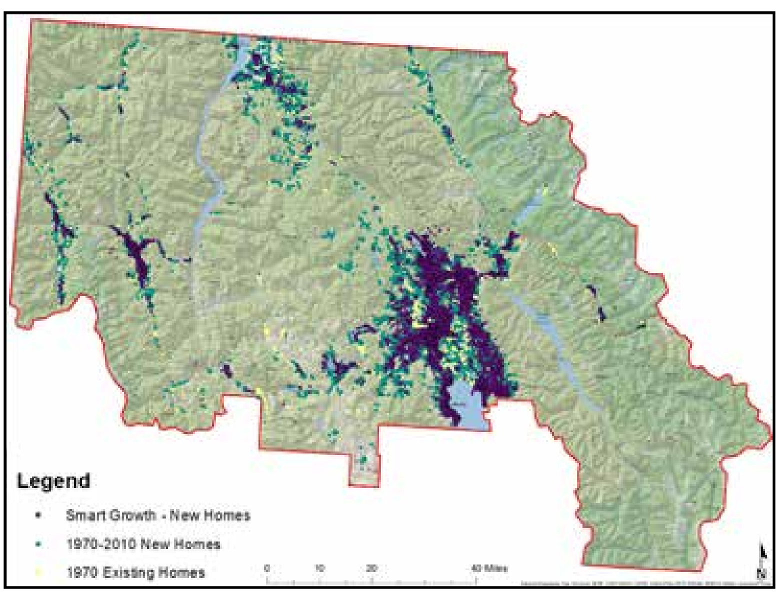


Figure 15: *Smart growth* projection for 2030 - new homes displayed as points.

The *smart growth* projections allocated all new residences into grid cells with existing development, resulting in almost no conversion of large agricultural or undeveloped tracts into new residences.

Therefore, we chose to use the *business as usual* scenario to avoid confusion between scenarios and to focus on mitigation opportunities, rather than land use planning.

The *smart growth* projections allocated all new residences into grid cells with existing development, resulting in almost no conversion of large agricultural or undeveloped tracts into new residences. Rather than adding a new ring of exurban development around the study area's population centers, the *smart growth* projection concentrated new development into the urban areas, such as Whitefish, Kalispell, Columbia Falls, and Libby. Smaller urbanized areas, such as Eureka, Troy, and Hungry Horse also saw growth consolidated in their urban cores, rather than into the surrounding land.

LIMITATIONS: All projections are inherently limited. The purpose of this growth projection is limited strictly to informing regional traffic estimates conducted at the census-block level. It is not appropriate for applications requiring higher spatial resolution.

This model also operates on the assumption that densities will increase proportionally across the entire study area. For example, a grid cell with a density of one home per acre in 2010 will advance at the same rate near Libby as a grid cell of the same 2010 density near Kalispell. At a small scale this type of density-dependent growth may not be readily apparent; however, at the regional scale examined in this project, it is an accurate description of historic growth patterns (Woods & Poole Economics 2013).

4.4. Implications

The construction of more homes means more traffic. Where those homes are spatially located on the landscape determines where the major traffic impacts will occur. Dispersed patterns of development are often accompanied by numerous social, environmental, and economic costs, including increased vehicle miles traveled. Generally, a compact pattern of development results in fewer vehicle miles traveled and concentrates the daily impacts of development into a few urban areas. These results could, in theory, have fewer impacts on wildlife. However, the difference between the two scenarios was often not significant enough to push traffic levels into impactful categories (see next chapter for thresholds), particularly on highway segments outside of urban areas that are most likely to impact wildlife connectivity. Therefore, we chose to use the *business as usual* scenario to avoid confusion between scenarios and to focus on mitigation opportunities, rather than land use planning.

5. TRAFFIC DEMAND FORECASTING MODEL

5.1. Introduction

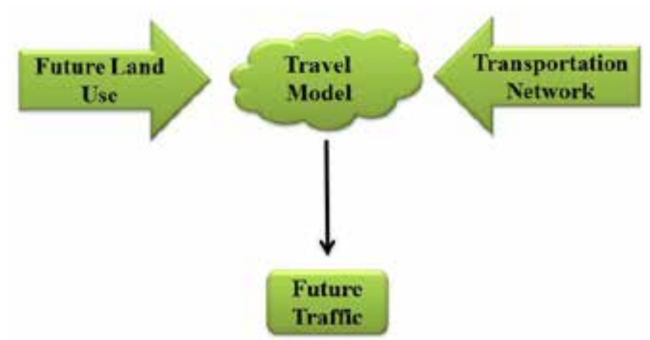
Travel demand forecasting models (TDFM) are used to estimate the magnitude of future traffic on roads in a given study area. These are typically completed for an urban area as part of the transportation planning process. The current U.S. transportation act that guides federal spending for transportation is titled the Moving Ahead for Progress in the 21st Century Act (MAP-21). It mandates that any metropolitan planning organization have a long-range transportation plan that includes a TDFM with a 20-year forecast.

In a very basic sense a TDFM uses land use data on where people live, work, and access services to predict how they will travel. The model is built for today and calibrated using current traffic counts; then it is applied using future land use scenarios and possibly future improvements to the transportation network (Figure 16: Travel demand forecasting model process).

There are numerous formulations of travel demand models currently in use. The most common basic model, particularly for rural areas, is known as the four-step process or the rapid assessment method (NCHRP 2102). While other models use one of the numerous activity-based model structures, the four-step process does not require extensive local activity survey data and is thus more easily implemented. The four steps are trip generation, trip distribution, mode choice, and traffic assignment, which are described in detail below.

Predicting how a population will travel 20 years into the future is slightly speculative and model results should be taken with an understanding of this inherently hypothetical level of precision. They are intended for planning purposes to identify comparative changes in traffic volume (e.g., an order of magnitude increase). Further, the purpose of the model for this project is to predict traffic on rural roads, not necessarily in urban core areas. The approach used for this study attempted to minimize the level of effort, while maintaining the desired accuracy for rural roads. Thus, subtle congestion effects and specific routes within urban core areas were not as critical to the results of the model for this project.

BUILD MODEL



APPLY MODEL

Figure 16: Travel demand forecasting model process.

This chapter provides a summary of model methodology, including some adjustments made for this project. The results are then provided and implications of traffic discussed.

5.2. Methods for Building Model

Although specifics for implementing the model for this study area are provided below, refer to McNally (2000) for a more detailed background of the four-step process.

5.2.1. Basic approach

CREATING THE NETWORK The transportation network for this model is a spatially precise, digital representation of actual roads. This basic network was provided by the Montana Department of Transportation (MDT) and is the same network their planning department uses to develop TDFM for major cities in Montana. As shown in Figure 17, the road network contains county roads, private roads, and forest service roads. This network is used in the TDFM to calculate travel times and can be adjusted based on congestion using the traffic flow results of the model. The two-county study area is shown in Figure 17, but note that the network used included counties to the south as they contain potential alternate routes. This network contains approximately 14,000 miles of roadways.

Census-block centroids are used to join the land use data to the transportation network. A centroid is placed within each census block (there are 13,666 census blocks in the study area), and the households and employment values are attributed to these centroid points. The centroids are connected to the nearest road with a centroid connector that acts as a driveway for developments to access the transportation system.

Step 1 **TRIP GENERATION**: Once the map is created, trip ends are generated at homes and job centers. Three trip types are considered for this model. Work trips (often referred to as home-based work) have one end at the home and the other at a job. Regular non-work trips (often referred to as home-based other) have one end at the home and the other at some attraction or service (for this model we used retail locations identified from employment data). There are also trips that do not start or end at home (often referred to as non-home based trips) which have a

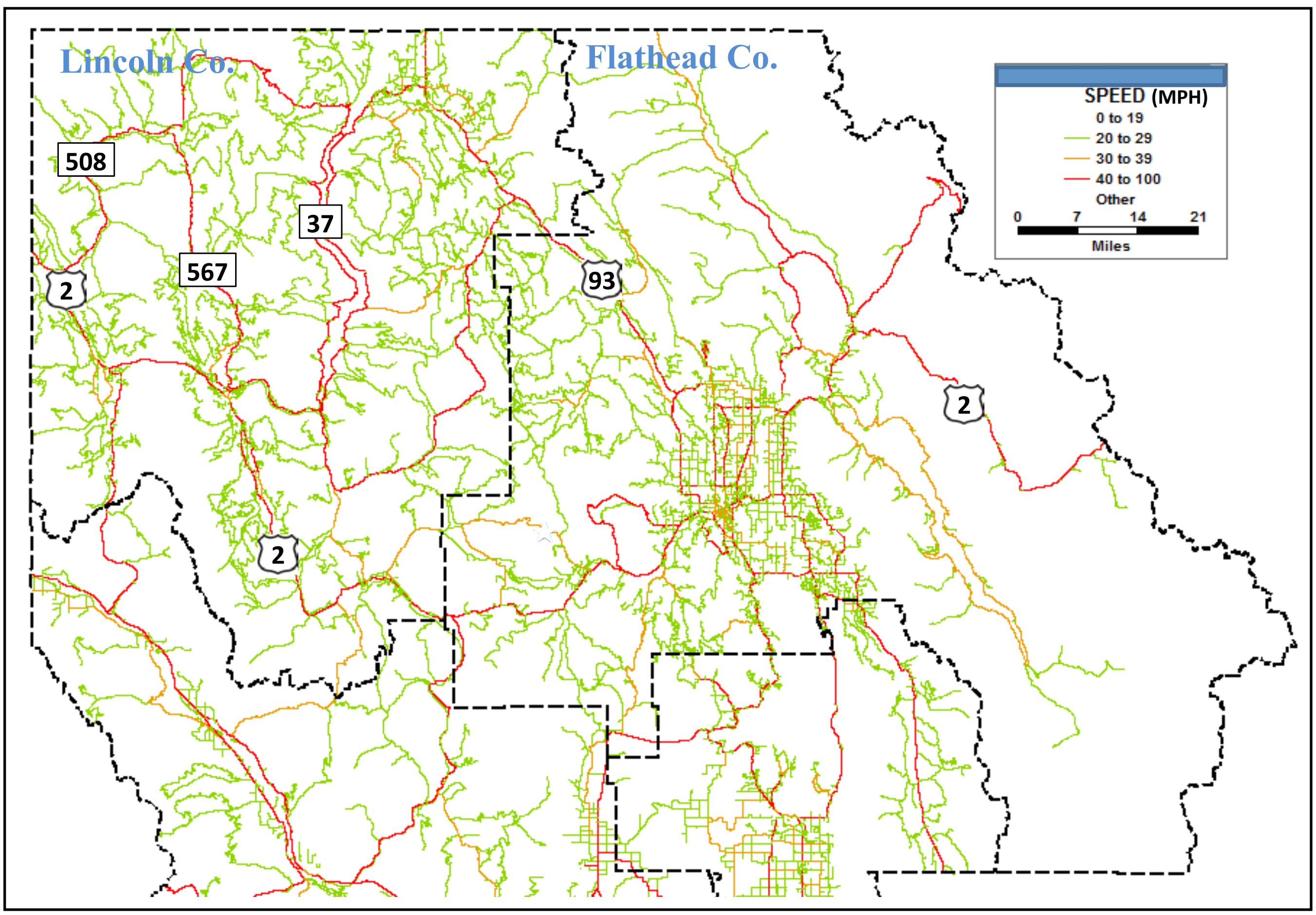


Figure 17: Basic transportation network in Flathead and Lincoln counties.

variety of attractors (e.g., between jobs and retail locations). A non-home based trip may have an end at a home, but it is not the home of the person making the trip.

Trip generation rates are based on several sources and calibrated for a previous local model in Montana (refer to Berger 2012 for more detail how these factors were developed). The trip generation rates below represent the number of trip ends. For example, on average, a household makes 2.3 work trips per day:

- Number of home side work trips = 2.3 x households
- Number of work side work trips = 1.7 x total jobs
- Number of home side home-based other trips = 8.6 x households
- Number of non-home side home-based other trips = 10 x retail jobs + 0.5 x non-retail jobs + 1 x households
- Number of non-home based trips (both sides) = 2.8 x households + 2 x retail jobs + 2.5 x non-retail jobs

For each of the trip types, the non-home trip ends are adjusted so the total is equal to the home side trip ends (known as trip generation balancing).

The trip ends above account for the traffic within the study area. There are trips that start and end outside of the study area. These are accounted for by external stations. Every major highway that crosses the study area boundary has an external station added to it. The trip ends are calculated based on traffic counts. Although the highways internal to the study area have seen growth in traffic volume over time, the ones that cross the boundary are relatively stable. Traffic for the past 10 years for the external stations was evaluated (Figure 18). Average Annual Daily Traffic (AADT) for some external stations had an apparent drop in 2010; however, upon more detailed investigation, this drop was determined to be artificial and actually due to MDT's changing the highway segment endpoint locations in 2010 for some of these roads. Although the last three years are excluded from the figure for clarity, they show either an artificial drop due to the change in AADT calculation, or they maintain the trend shown in the figure. Typically some traffic growth factor is calculated and applied, but as shown in the figure, the growth is fairly small. Further, other than on the roads around Flathead Lake, the traffic exiting and entering the study area is fairly low. External stations trip ends were calculated in the typical way and no growth factor was used for the future projection.

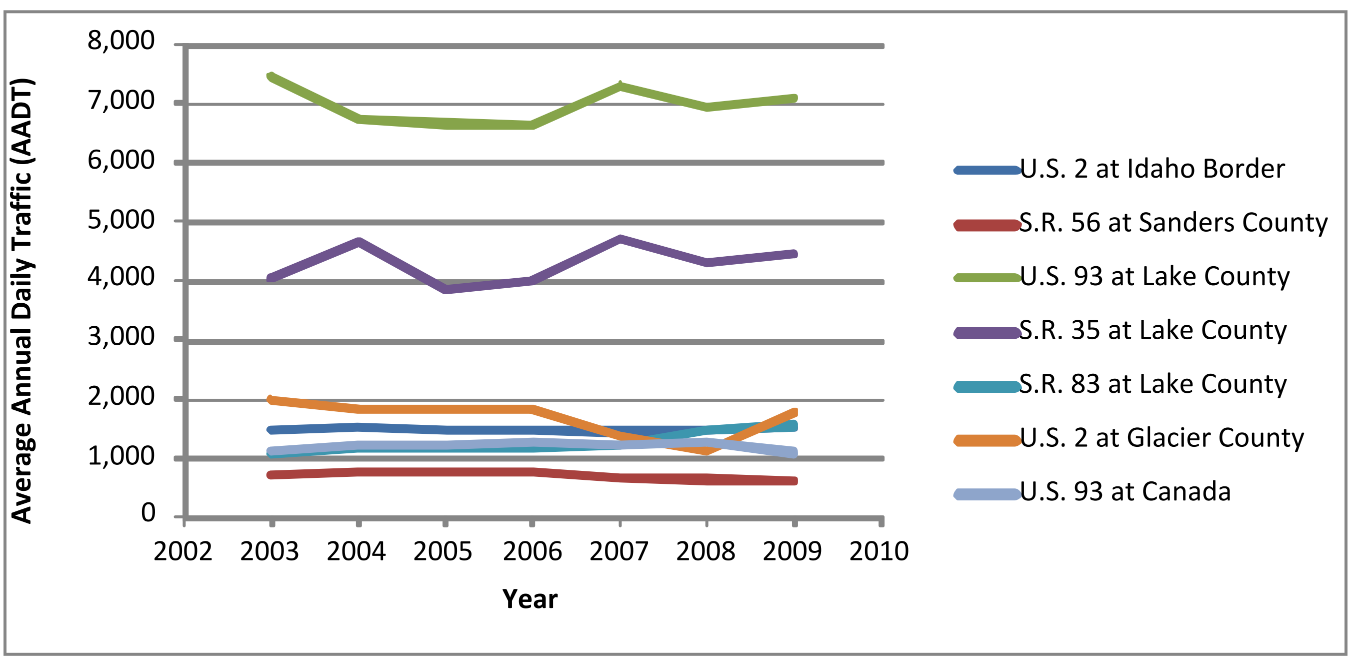


Figure 18: Traffic growth for highways entering study area (external stations).

STEP 2 TRIP DISTRIBUTION: The trip ends created in the trip generation step are matched. For example each work trip at a household side is matched to a work trip end at the employment side. This is accomplished with a model known as the doubly constrained gravity model (McNally 2000). This model matches the trip ends in such a way as to maximize the entropy (or randomness), while fitting the travel times to a probability distribution of typical travel times, typically referred to as friction factors. Figure 19 displays the travel time distributions used in this study.

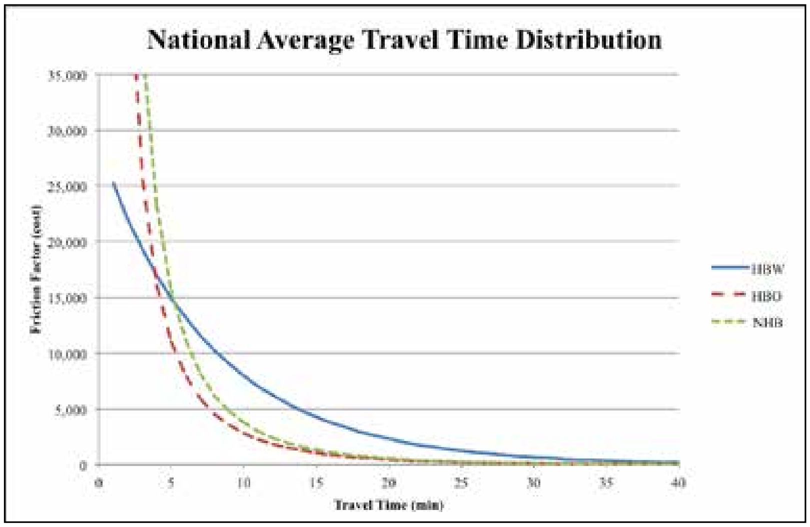


Figure 19: Typical travel time distributions (Data Source NCHRP 1998). A different distribution was used for each trip type: home-based work trips (HBW), home-based other trips (HBO), and non-home based trips (NHB).

The travel time between each census block pair is determined using the shortest travel path between the two blocks on the transportation network. Intra-zonal travel times are set at infinity, thus forcing trips to go to at least the neighboring census block.

STEP 3 MODE CHOICE: The mode choice assigns people trips to primary modes such as single person auto, carpool, transit, bike, etc. The most basic method, which was used for this study, is to use standard occupancy rates. This is essentially a ratio of the number of people trips per auto trip since auto trips are the real concern. Rates used were:

- 1.4 people per vehicle for home-based work
- 1.9 people per vehicle for home-based other
- 1.6 people per vehicle for non-home based (Vander Way 2012)

Typically, the time of day is handled in this step as well, based on the trip type and typical time-of-day distributions (e.g., most work trips leave home between 7:00 and 8:00 a.m.). In order to reduce the modeling burden, travel was aggregated for the whole day instead of a separate model for each hour. This limits the ability of the model to adjust for congestion in route choice, but because congestion delays on rural highways are likely not significant enough to cause travelers to go hundreds of miles out of their way to take an alternate route, this approach is acceptable for this study area.

STEP 4 ROUTE CHOICE: The last step provides a matrix of where every auto trip starts and ends, assigning each trip to the transportation network. This is typically done using the Franke-Wolf Algorithm (also known as user equilibrium; refer to McNally 2000), which suggests that travelers will generally choose the shortest route. Because congestion effects were ignored, the resulting assignment was essentially an all-or-nothing assignment.

Calibration/Validation: For calibration, the AADT estimates published by MDT were used. Figure 20 identifies the roads used for model calibration. As discussed previously, the urban area around Whitefish and Kalispell was not included in the model calibration. Again, the purpose of this model is not intended to determine which roads in an urban area will be over-capacity in the future, but to determine the future traffic flow for areas outside of urban areas.

Two primary modeling adjustments were used to calibrate the model to existing traffic: an adjustment factor to all trip ends and an adjustment to the travel time. After the basic calibration, model validation showed three major errors. Traffic around Glacier National Park was

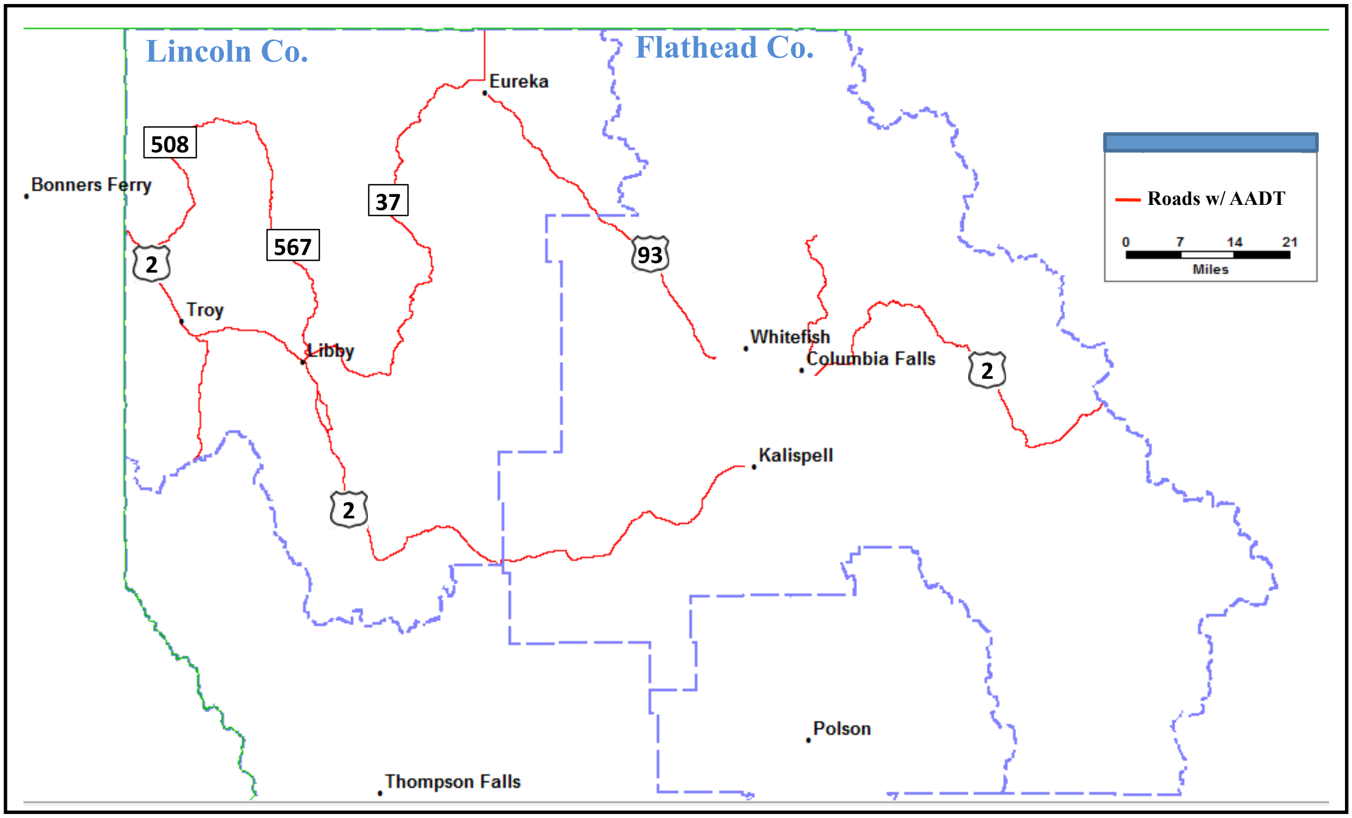


Figure 20: Roads with available traffic flows used for calibration.

estimated by the model to be too low. Because of the job imbalance between the counties, the model is forced to link too many Lincoln County residents with jobs in Flathead County. Traffic around the Libby area did not match measured counts. These issues are addressed below.

5.2.2. Special generator and seasonal variation

Seasonal variation is a common issue in rural areas where tourist traffic can create large variation in traffic flows during certain times of the year. Seasonal variation is almost a given on any road within the study area. Figure 21 shows a site in the study area that might be more typical of rural highways where the peak months of July and August are 17 percent higher than the annual average.

On the same highway a little further east, the seasonal variation is more extreme (Figure 22). This portion of U.S. 2 between Columbia Falls and West Glacier is the primary access to Glacier National Park. Here, the peak summer months have nearly twice (89 percent higher) the traffic of the

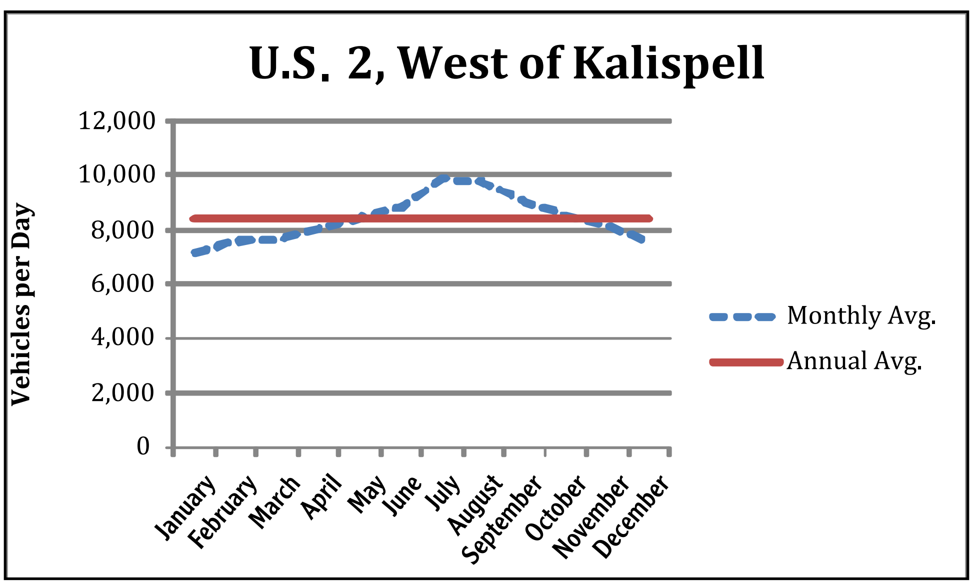


Figure 21: Typical seasonal variation in traffic volume in the study area (Data Source MDT 2013).

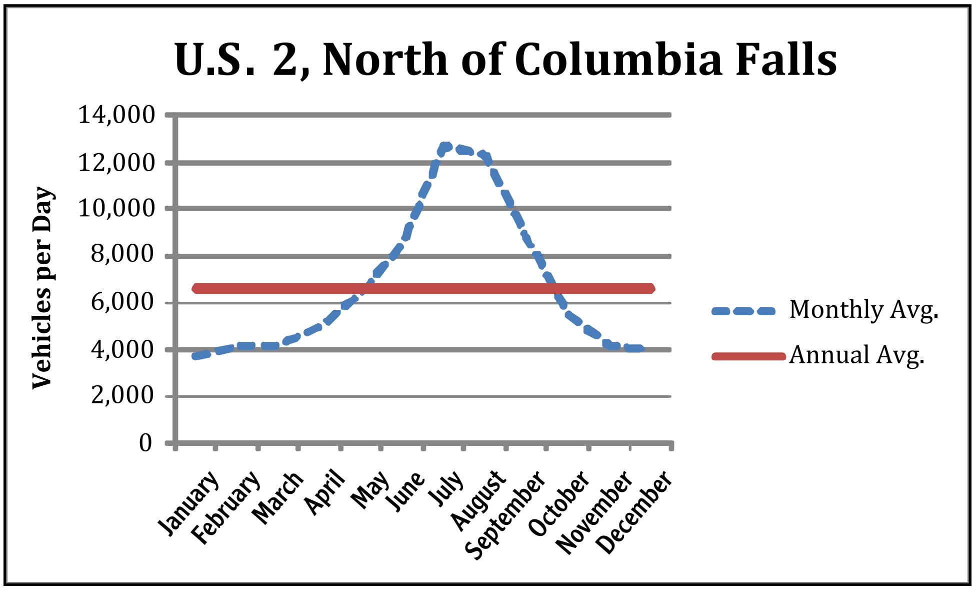


Figure 22: Seasonal variation in traffic volume near Glacier National Park (Data Source: Montana Department of Transportation 2013).

Road may have this variation as well, but to a lesser extent due to gravel road with occasional washboard surface. In addition to this seasonality variation, a second problem exists in the model. The initial run of the model resulted in very low traffic estimates on U.S. 2 when compared to actual measured counts. Remember that the model is based on residents and employment. The number of residents and employees (both retail and total) in and around Glacier National Park is small, yet the park generates a large number of trips each year (Figure 23).

Locations that generate much more traffic than the land use data would suggest are known as "special generators." Glacier National Park was treated as a special generator, using the typical implementation used in urban areas for locations such as sports arenas, airports, or universities. The growth factor for this traffic is applied independently of the land use projections. Based on the data shown in Figure 23, an annual

annual average. This increase in summer traffic is particularly problematic, since grizzlies are also more active during these months.

Traffic counts collected by John Waller in the summer of 2013 indicate that this seasonal variation continues east of West Glacier (Waller 2014). Waller's traffic counts were from June to October. Comparing July (peak month) to October (assumed to be near annual average), Figure 23 shows a 131 percent variation. Waller's count 44 miles east of this count (about 20 miles east of West Glacier) shows a 109 percent increase, and his count 18 miles further east (past the county line, just outside of the study area) shows an increase of 141 percent. Note that even though these counts show a drop in average vehicles per day with increasing distance from Columbia Falls, the seasonality remains.

U.S. 2 from Columbia Falls to Glacier Park is the only road known to have this heavy seasonal variation in the study area. The North Fork

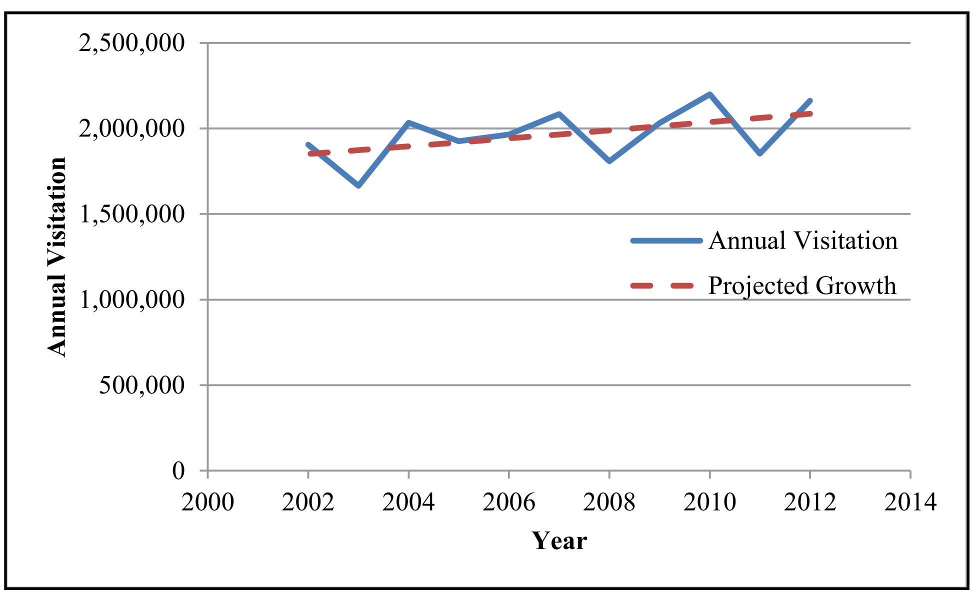


Figure 23: Annual visitation to Glacier National Park.

compounding growth rate of 1.2 percent was found by conducting a regression analysis. Note that the visitation numbers are expressed in people per year. The growth rate in visitation is assumed to be similar to the growth rate in vehicle traffic. This results in a 27 percent increase for the 20-year forecast.

The seasonality issue and special generator were dealt with together. After the model was calibrated for current year using all other roads in the study area, the gap between the seasonal peak traffic to Glacier National Park and the model result was calculated. This difference is due to park visitation and was added to the future projections with the 27 percent growth factor.

5.2.3. Modification for larger rural area

As Figure 24 shows, there is an imbalance in the housing and employment across the study area. For example, Lincoln County has 16 percent of the housing, but only 13 percent of the employment. Because the trip distribution is calibrated across the entire study area, 3/16ths of the work trips originating in Lincoln County must travel to work in Flathead County. This imbalance is even worse when considering trips to access services. Some residents of Lincoln County likely work in Flathead County, and certainly residents in Lincoln County will access services in Flathead County. Still, this imbalance is such that if the study area is modeled as a whole, the trip distribution cannot be calibrated to bring the average trip length in line with the measured values. This issue exists in typical TDFM models for urban areas where the jobs are concentrated in the urban core, and residents in the suburbs. The problem is that the size of the study area for this research project is too big to use the typical trip distribution adjustment.

We sought to adjust the above imbalances based

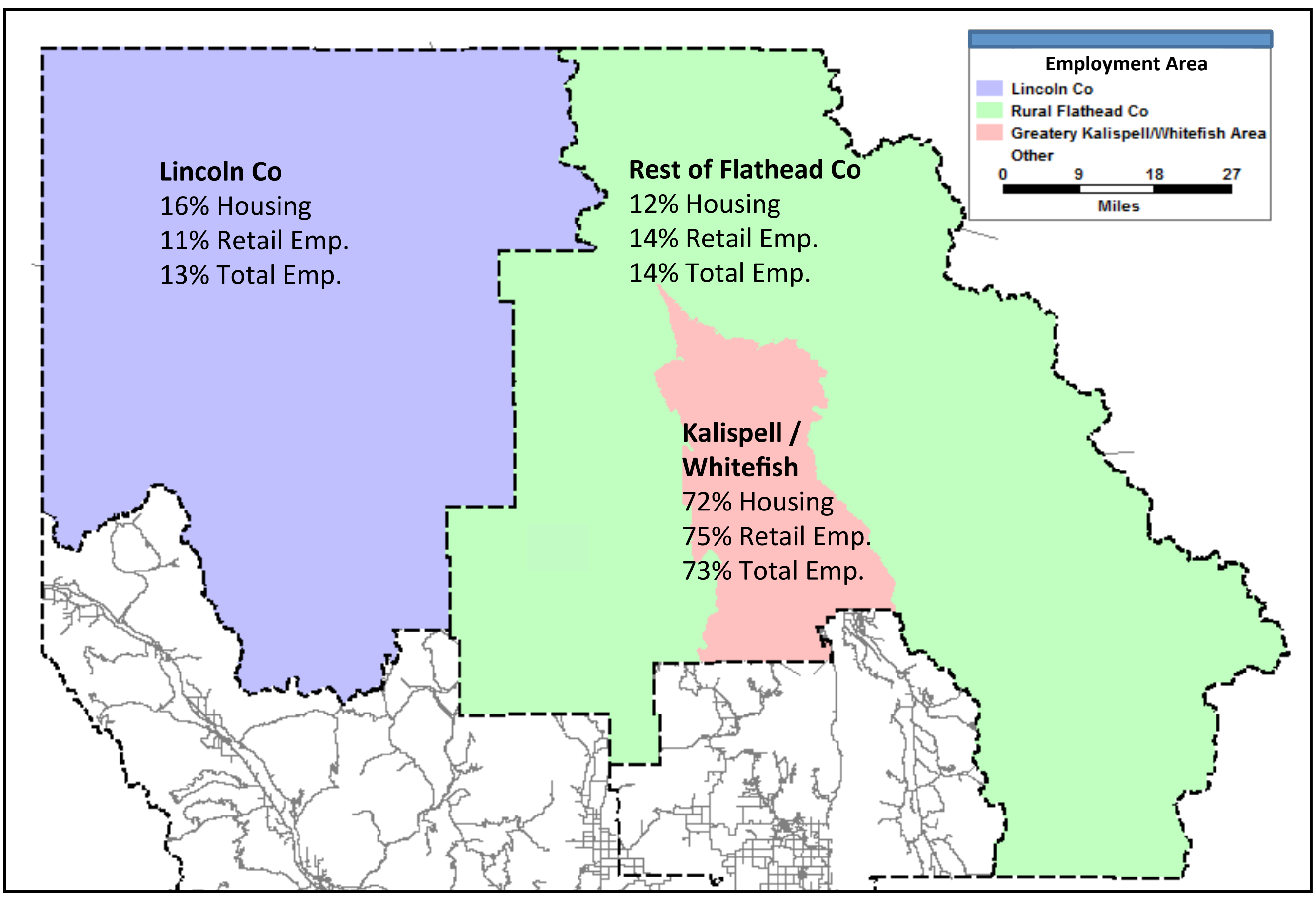


Figure 24: Housing/job imbalance in the study area.

on available data. Table 2 shows employment data from the 2010 U.S. Census. This employment rate was used to create an adjustment factor for the trips generated at the household based on the ratio of the employment rate for the sub-area compared to the employment rate for the entire study area.

Table 2: Employment data for Lincoln and Flathead counties from the 2010 U.S. Census.

COUNTY	% EMPLOYED	ADJUSTMENT TO HOUSING TRIPS
Lincoln Co	46%	0.817
Rural Flathead Co	53%	0.933
Urban Flathead Co	60%	1.057
Total	57%	

5.2.4. Adjusting traffic estimations for Libby, MT area

After these adjustments were made, the model was validated by comparing modelled current traffic with actual measured current traffic (Figure 25). With the exception of a group of segments in the Libby area, where the model underestimated the actual traffic, the model results were good. These errors were ignored for the same reason the Kalispell/Whitefish area was excluded from the calibration: because the model was calibrated for rural highway traffic. There may be many more frequent shorter trips made in urban areas that will increase the actual traffic that is not captured by this model.

5.3. Application of Model to Forecast Year

The calibrated model was applied using the future year land use forecasts (Chapter 4). The adjustment for external stations and the special generator (Glacier Park) were applied as previously discussed. The results of the model application are shown in Figure 26.

The thickest lines in Figure 26, representing roads over 10,000 vehicles per day, will become near

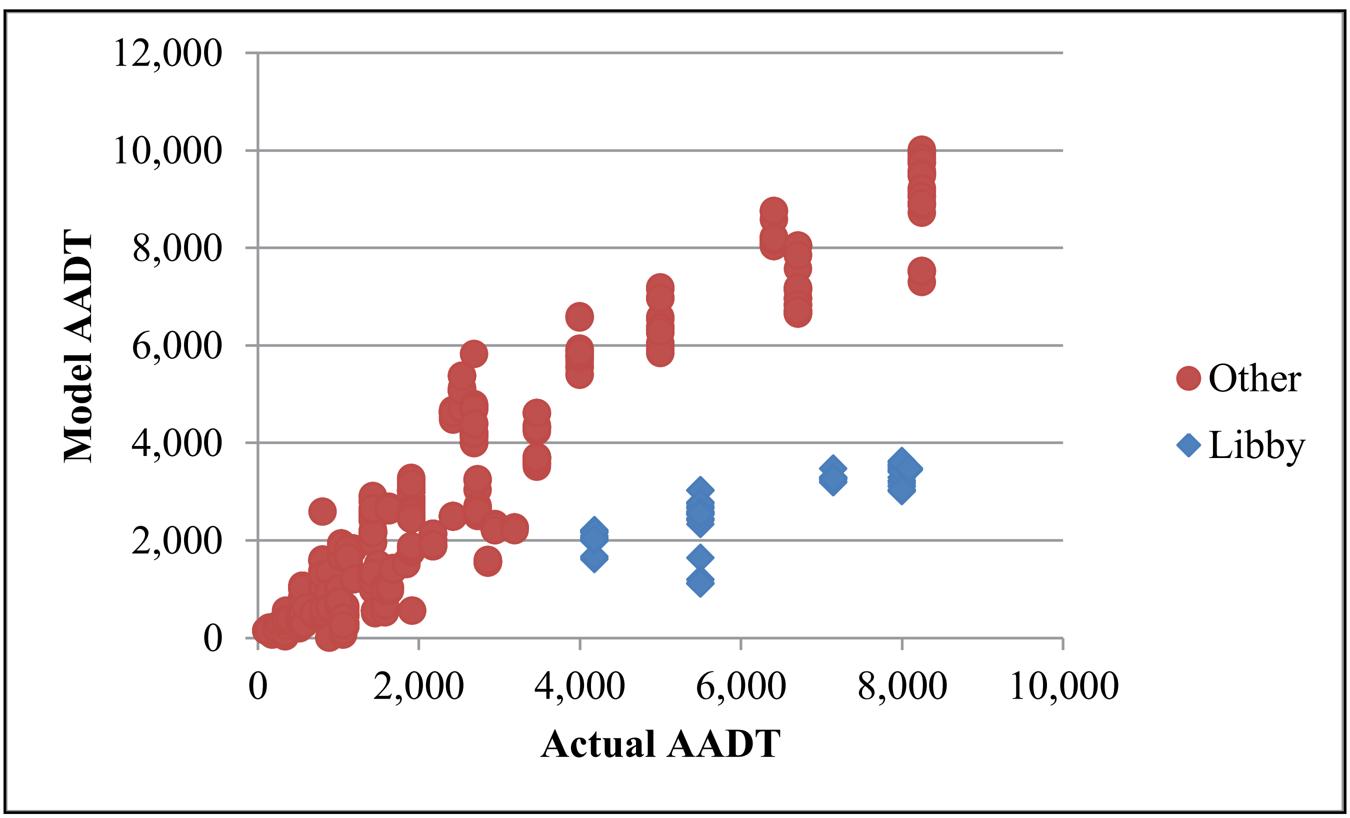


Figure 25: A comparison of current modeled traffic with actual traffic in the study area validated the model.

total barriers to wildlife, as discussed below. These roads are contained within the Whitefish/ Columbia Falls/Kalispell area. The medium lines are in the 3,000 to 10,000 vehicles-per-day range and will likely act as a substantial partial barrier to wildlife. The thin lines are roads with a lower predicted barrier impact, with 200 to 3,000 vehicles per day. Roads below 200 vehicles per day are not shown.

The traffic for the *smart growth* land use scenario did reduce overall vehicle miles travelled by 3.4 percent. It also concentrated traffic into the cities more than the *business as usual* scenario. However, for the rural highways, it did not drastically change the predicted traffic. Comparing Figure 26 with the *smart growth* results in Figure 27, it is interesting to note that some sections of S.R. 567 fall below the 200 vehicles per day threshold in the *smart growth* scenario and the point at which U.S. 2 west of Kalispell meets the 3,000 to 10,000 vehicle threshold shifts a few miles closer to Kalispell.

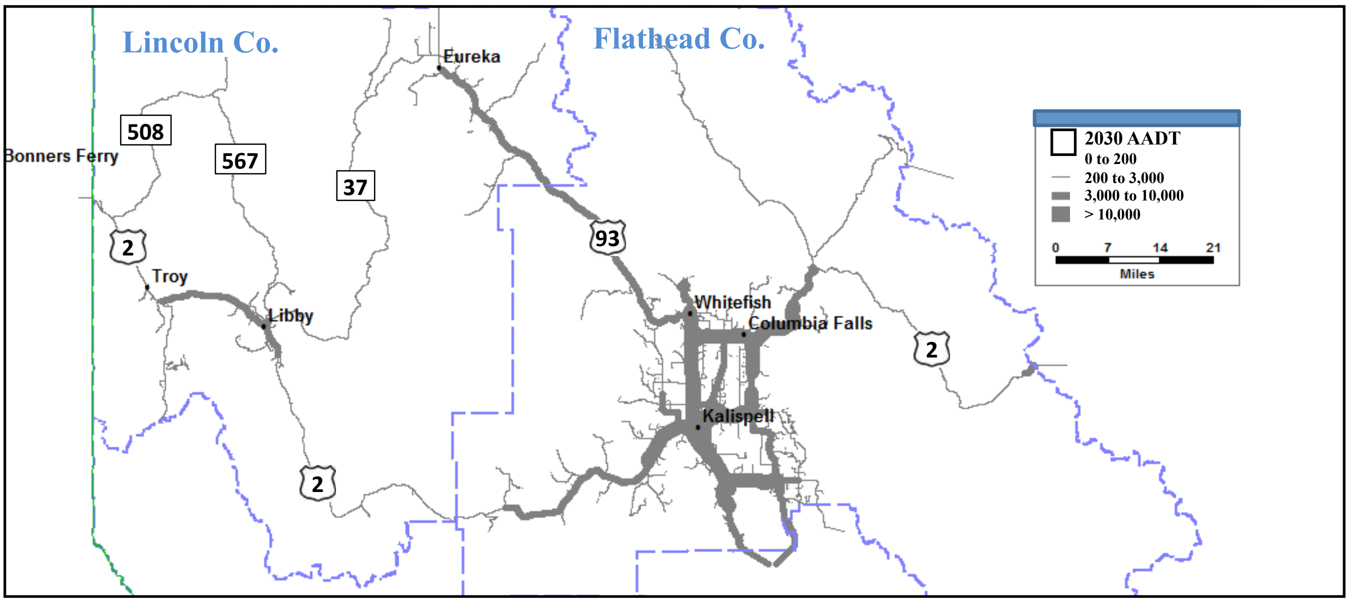


Figure 26: 2030 traffic forecast for major roads in study area.

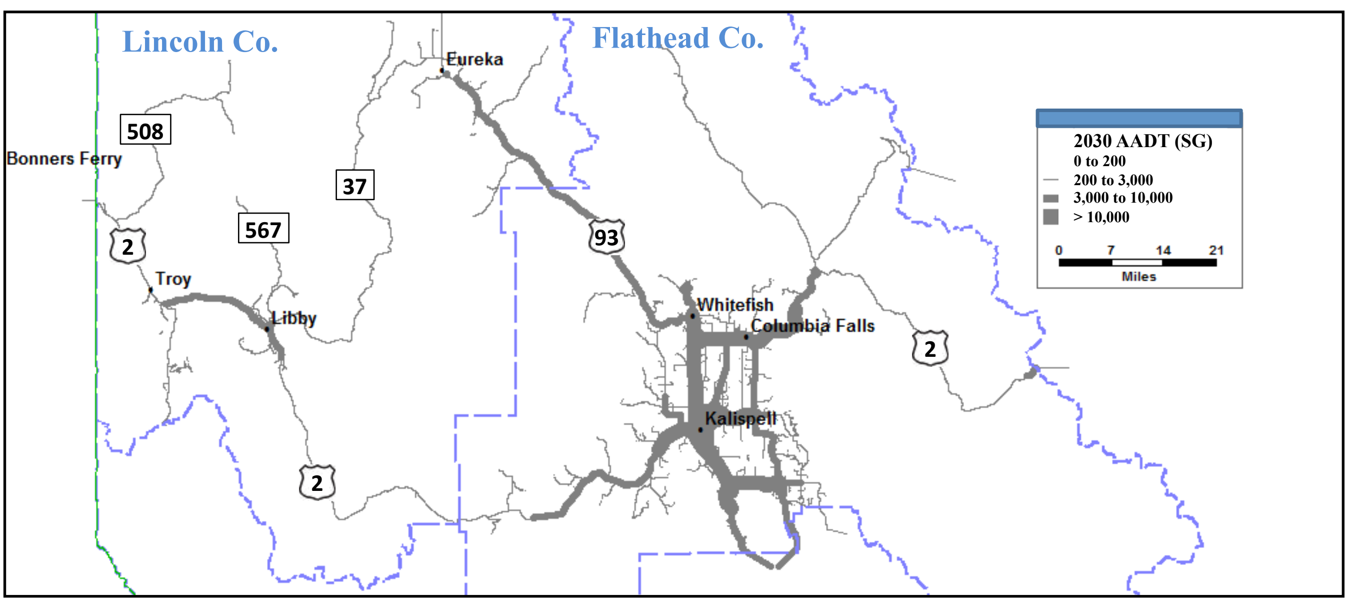


Figure 27: 2030 traffic forecast for *smart growth* land use scenario in study area.

5.4. Implications

Traffic is one lens through which to look at wildlife movement but should not be considered alone. Looking only at traffic forecasts in order to prioritize mitigation, for example, could lead one to focus all mitigation efforts in the most urban areas around Kalispell. This would be a poor use of resources because, as one might predict and as the next chapter shows, the Kalispell area is not a priority for habitat connectivity. Instead, resources should be concentrated at locations identified as priority linkage areas today, as well as in locations where traffic is expected to grow to (or already is at) the point that it will act as a barrier.

The impact of traffic on wildlife connectivity probably follows a gradient as shown in Figure 28. However, several factors make it difficult to determine the specific thresholds at which traffic becomes a barrier to wildlife. Species vary in their sensitivity to traffic levels, and in their responses to it. Sensitive species may adapt to traffic and cross the roadway at night when traffic levels are lower. This may reduce the risk of collision—or make it worse because of reduced visibility at night. Also, daily traffic flow estimates are very coarse and overlook variability throughout the day. In an extreme case, if all of the traffic for a day occurs only during one hour, with no traffic the rest of the day, the barrier could be very small. These complications notwithstanding, the remainder of this chapter attempts to summarize information on how daily traffic relates to increased mortality risk to wildlife, particularly grizzly bears.

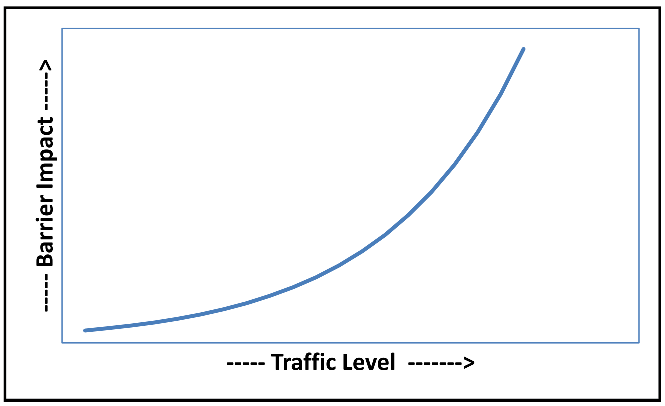


Figure 28: Possible relationship between traffic level and impact on wildlife movement.

Traffic creates a barrier in at least two ways. First, when traffic increases on a roadway, the road will often be upgraded, which entails creating a larger pavement and roadside footprint that is unnatural habitat for wildlife. Second, the traffic itself becomes a barrier.

Table 3 shows traffic levels at which highway upgrades may be required. These numbers are very general, and actual upgrades depend on a number of factors (e.g., grades, directional traffic distribution, etc.). But with some basic assumptions, the traffic flow ranges in Table 3 can be identified. More detail on how these numbers were determined is provided in Appendix B. Note, there are two major thresholds, one at around 400 AADT when significant roadside shoulders and clear zones are added, and another around 3,000 AADT when additional lanes are added.

Despite numerous studies investigating traffic impacts on wildlife movement, no clear thresholds have resulted. Chruszcz et al. (2003) compared grizzly bear movements around and across several highways. The Trans-Canada

Table 3: Traffic thresholds that may instigate road upgrades.

Average annual daily traffic (AADT)	Lane number and width	Shoulder type	Clear zone distance from paved surface
0 – 400	Two 9 ft.	-	-
400 – 2,000	Two 11 ft.	5 ft. paved/unpaved	10 to 30 ft.
2,000 – 3,000	Two 12 ft.	8 ft. paved	30 to 40 ft.
3,000 – Undetermined[a]	Three 12 ft.	8 ft. paved	30 to 40 ft.
3,000 – 18,000	Four 12 ft.	10 ft. paved	30 to 40 ft.
18,000 – 27,000	Six 12 ft.	10 ft. paved	30 to 40 ft.

[a] The exact threshold is less than the 18,000 determined for upper limit of four lane highway, but how much less requires analysis beyond the scope of this report.

Highway (TCH) had a summer average daily traffic (ADT) as high as 21,500 vehicles per day. For comparison, portions of Highways 93 and 40 in the project area have 2,000 to 3,000 vehicles per day, respectively. (Note these are highways in Alberta and not the same as Highway 93 in the study area in northwest Montana.) Chruszcz et al. used radio collar data and analyzed location data with distance to the roads and actual crossing events. Bears were less likely to be close to the TCH than a random distribution, but the other highways did not seem to change the bears' choice of habitat use. However, the authors note that the more productive habitat in the valley bottoms, near the roadways, may lead bears to be more likely to use habitat closer to roads. Further, the bears present near Highways 93 and 40 were likely habituated bears, and bears new to the area may avoid these roads. With regard to crossings, grizzly bears rarely crossed the TCH, and then only to access higher quality habitat. The lower-traffic highways 93 and 40 are more permeable than the TCH, but even with its high traffic flows, the TCH is not a total barrier to bears. The authors noted that mortality is still an issue on Highways 93 and 40.

Kendall et al. (2009) found a clear genetic difference across a segment of Highway 2 that is within this study area. Looking at Highway 2 between Kalispell and Browning, the western portion creates a clear genetic barrier, whereas the eastern portion does not. Recent traffic for these segments as measured by MDT is 1,180 – 2,540 AADT for the western portion (traffic decreases as the distance from Kalispell increases) and 1,180 – 1,070 for the eastern segment. It should be noted that these are AADT and that in the summer months daily traffic is double these values.

Waller and Servheen (2005) looked at GPS and radio collar data for 25 grizzly bears in a similar segment of U.S. 2 with about 2,000 vehicles per day. This study was interesting in that they measured the hourly traffic volume. Bears were much more likely to cross the road at night when traffic flows were lower (around 30 vehicles per hour). The authors' model, relating bears' crossing frequency to hourly traffic flow, had a very good fit with a negative exponential function, indicating very low probability of crossing once traffic reached 100 vehicles per hour. Based on this and the raw data, they identified 100 vehicles per hour as the threshold at which highways become a significant barrier to grizzly bear movement. The study also showed that bears were less likely to be present in habitat closer to the road; this effect seemed to taper off around 500 meters from the road. Although this study showed reduced presence near the road, and a clear avoidance of crossing the road during daytime traffic levels above 100 vehicles per hour, the GPS collar data showed that bears are still crossing this highway.

Traffic is one lens through which to look at wildlife movement but should not be considered alone.

Northrup et al. (2012) studied radio-collared grizzly bears in southwestern Alberta and reported that bears did not avoid areas near roads with less than 20 vehicles per day (VPD), avoided roads in the 20-100 VPD category, and strongly avoided roads when traffic reached 100 VPD or more. The study suggests that even 20 VPD could have a barrier effect.

Roever et al. (2010) studied grizzly bears with GPS radio collars in the foothills of Alberta. Modeling a step-selection function, they found grizzly bears had similar movement patterns across both high and low traffic roads. The barrier effect break point between high and low traffic was around 850 VPD (Roever, C., personal communication, March 2013).

Aside from grizzly bears, other species have been studied in relation to traffic levels. Sawyer & Rudd (2005) suggest that for pronghorn, (*Antilocarpa americana*), traffic over 2,000 AADT becomes high enough to warrant mitigation. Clevenger & Huijser (2011) suggest that 2,000-3,000 AADT may be a general threshold at which to consider mitigating highway impacts to large wildlife. They state, however, that this is not a clear threshold and that the level of impact depends on a number of local factors. Dodd et al. (2011) found that a roadway with 10,000 AADT had nearly a complete barrier effect on pronghorn.

Summarizing the literature discussed in this section, roads appear to affect grizzly behavior even at very low traffic volumes (20 VPD), although some studies show little impact of roads even up to several hundred VPD. Even modest traffic (2,000-3,000 VPD) becomes a barrier during the peak traffic times of the day. High traffic roadways (over 10,000 AADT) significantly restrict grizzly bear movements. However, from a more general habitat connectivity perspective, individual grizzly bears can move across highways with high traffic. Based on these studies and the traffic thresholds associated with road upgrades, the following general thresholds for road impacts on grizzlies and other carnivores were estimated:

- <200 AADT — Minimal Concern
- 200 – 3,000 AADT — Some Concern
- 3,000 – 10,000 AADT — Heavy Concern
- >10,000 AADT — Highest Concern

These thresholds should only be used as a general guide and may be context and species dependent. The projected traffic at sites identified in the next chapter were used during the site visits and considered during the review of potential mitigation measures.

Development in the study area, surrounded by carnivore habitat. Photo: Sonoran Institute, Aerial support provided by LightHawk

6. SYNTHESIS OF WILDLIFE CONNECTIVITY VALUES

6.1. Introduction

This section seeks to synthesize available data pertaining to habitat connectivity values for grizzly bears and other wide-ranging carnivores that are expected to be impacted by future highway infrastructure and traffic in northwest Montana. Vulnerability of a species can be defined by two components: sensitivity and exposure. Data and models that capture the connectivity value of a given location for movement of wildlife provide an index of the sensitivity of wildlife movement to impacts of road infrastructure and vehicle traffic. On the other hand, traffic model projections presented in Chapter 5 provide an estimate of how future growth may increase wildlife exposure to road impacts. Assessing vulnerability based on these two factors allows identification of sites at which wildlife are most likely to be a primary concern for future highway planning and construction in Lincoln and Flathead counties.

6.2. Data Sources

First, available data sources in the study area with relevance to connectivity for grizzlies and other wide-ranging carnivores were identified (Table 4). Raw radio- or GPS-collar data that identified grizzly bear movement paths or map outputs from data-driven models of grizzly bear connectivity were considered ideal. However, much of the movement data that has been collected is considered proprietary due to the pending publication of a connectivity model based on this data; a data sharing agreement could not be secured. Instead, published map images of these data were utilized, along with corridor models developed for species with similar habitat requirements and non-species-specific corridor models derived from indices of landscape quality. These models are expected to be representative of grizzly habitat needs.

6.2.1. Grizzly bear movement data and linkage zones

Kasworm et al. (2012) provide a comprehensive research and monitoring report for the U.S. Fish and Wildlife Service (USFWS) Cabinet-Yaak Grizzly Bear Recovery Area, which includes map images of radio- and GPS-collar data locations of grizzlies in the Northern Rockies region from 1983 to 2011, some of which indicate possible road crossing locations within the study area. While precise crossing locations cannot be identified from these data, it is possible in many cases to infer approximate locations of likely crossing sites and identify broad areas in which many likely bear crossings occur. These locations have potentially high connectivity and importance for grizzly movement.

In a webinar given for the Great Northern Landscape Conservation Cooperative (GNLCC), Proctor & Servheen (2012) provided a map image of modeled grizzly bear linkage zones (Proctor et al. in review). They used circuit theory models developed from relocation and genetic data to

Table 4: Summary characteristics of connectivity data sources used to derive wildlife connectivity values.

FOCAL SPECIES/ LANDSCAPE	REFERENCE	DATA/MODEL TYPE	MAP DATA/ IMAGE	GEOGRAPHIC EXTENT
Grizzly bear	Kasworm et al. 2012	GPS collar relocations	Image	Northern Rockies
Grizzly bear	Proctor & Servheen 2012	Circuit theory model	Image	Northern Rockies
Black bear	Cushman et al. 2008	Least-cost distance model	Image	U.S. Northern Rockies
Wolverine	Schwartz et al. 2009	Least-cost distance model	Image	U.S. Northern Rockies
Lynx	Squires et al. 2013	Least-cost distance model	Image	Crown of the Continent
Forest generalist species	MT FWP 2011	Least-cost distance model	Data	Montana
Forest biome	WGA 2013	Multiscale least-cost-path flowline centrality model	Data	Western U.S.

predict key highway crossing zones for grizzly bears across a large portion of the study area. We consider this the most reliable indication of crucial linkage zones for grizzly bears available at this time for the study area.

6.2.2. Connectivity models for other wide-ranging carnivores

Several researchers have produced species-specific models of connectivity for forest carnivores in the study area. These models use genetic and/or telemetry data to quantify resistance to movement associated with landscape characteristics, then identify areas offering the least resistance to movement. These species, such as black bear, wolverine, and lynx, are expected to have similar habitat requirements for movement as those of grizzlies. We therefore expect that these models can serve as valuable proxies for identifying key areas in which to prioritize road mitigation for grizzly movement.

Cushman et al. (2009) modeled regional conservation corridors for the American black bear. Using a genetically based landscape resistance model and least-cost-path analysis, they predicted optimal movement corridors for black bears as well as barriers to population connectivity between Yellowstone National Park and the Canadian border. The authors used causal modeling to assign resistance values to landscape features that were most consistent with observed spatial genetic structure, concluding that forested, mid-elevation habitats offer low resistance to movement, while roads present high resistance to movement.

Schwartz et al. (2009) identified wolverine dispersal corridors in the U.S. Northern Rockies based on persistence of spring snow cover. They tested whether a dispersal model in which wolverines prefer to disperse through areas characterized by persistent spring snow cover produced least-cost paths that correlated with genetic distance among individuals, and found that successful dispersal paths are indeed likely to be associated with snow cover, even after accounting for distance effects. While this model is driven by snow, wolverines are expected to share many of the same habitat requirements as grizzlies, such as forest cover and low levels of human development, including roads (Inman et al. 2013). Although in some cases wolverines have been observed to readily cross roads (Moriarty et al. 2009, Inman et al. 2009), many studies document avoidance of roads, reluctance to cross approached roads, and possible road mortality (US DOI 2013).

Squires et al. (2013) used telemetry data to model suitable lynx habitat in the U.S. Northern Rockies, then applied least-cost-path modeling to predict key dispersal corridors. They found that lynx selected mid-elevation habitat with high canopy cover, high vegetation greenness, and low surface roughness (i.e., mild terrain), and that connectivity with Canadian populations is expected to be maintained by only a handful of putative dispersal paths. These paths are likely to be of crucial importance for connectivity between U.S. grizzlies and stable Canadian populations as well.

6.2.3. Landscape integrity-based connectivity models

Two connectivity models designed to predict key corridors between large intact blocks of natural habitat were available for the study area. These models are not species-specific; instead, they serve as a coarse-filter approach to identifying areas expected to support movement of forest generalists. Both models are intended to provide a first-pass, “20,000- foot” view of areas expected to be important for connectivity and, taken alone, should not form the basis for fine-scale, site-level management decisions. Instead, these models can help to guide selection of general areas within which to assess additional finer-scale data.

While both models were designed with the same concept in mind, they employ different methodology, encompass different geographic extents, and are presented in different forms. Therefore, while similarities exist, predictions of key corridors from each model will often disagree, particularly at finer scales. We suggest that both models offer a potentially valuable perspective on priorities for connectivity, and that both should be considered alongside the species-specific data sources above.

The Montana Department of Fish, Wildlife & Parks (MFWP) produced the Crucial Areas

Planning System (CAPS) as part of the Western Governors' Association Wildlife Corridors and Crucial Habitat Initiative, which includes guild-level analysis of wildlife connectivity (MFWP 2011). Habitat connectivity for forest generalists was assessed using least-cost-corridor methods to model corridors between pairs of large landscape blocks, or primary habitat patches. Pairwise cost-distance surfaces were compiled to produce a final continuous connectivity surface in which cost-distance values were scaled to percentiles. This model provides continuous relative connectivity values across the entire road network of the study area; for the purposes of this study, values within the 97th percentile are considered to be primary corridors.

Two connectivity models designed to predict key corridors between large intact blocks of natural habitat serve as a coarse filter approach to identifying areas expected to support movement of forest generalists.

The Western Governors' Association has produced a West-wide Crucial Habitat Assessment Tool (CHAT) as part of its Wildlife Corridors and Crucial Habitat Initiative (WGA 2013). The CHAT is a cooperative effort of 16 Western states to provide the public and practitioners working in a variety of industries with a high-level overview of "crucial habitat" across the West. As part of the WGA's CHAT effort, connectivity among large intact blocks of habitat was modeled throughout the West. These models identify centrality flow lines, or corridor routes predicted to be crucial for maintaining broad-scale connectivity of several major biomes, including forested systems, at multiple spatial scales. This approach is based on concepts of hydrologic flow; movements of individual animals originating from points throughout the landscape can be conceptualized as raindrops falling across a landscape and accumulating along ravines and valleys to form streams and then rivers. These flow lines represent major corridors expected to offer the lowest resistance to movement. Flow lines are represented as discrete lines rather than forming a continuous connectivity surface. In this study, they pinpoint sites at which connectivity across the road network of northwest Montana is most crucial and most likely to be supported (within a recommended buffer of one mile addressing uncertainty and variability).

6.3. Methods

PROCESS DATA LAYERS: Where actual map data layers could not be obtained (e.g., grizzly relocations and some published connectivity model outputs), map images were geo-referenced in ArcMap 10.1 (ESRI) based on visible linear and point features, and then highway crossing locations were hand-digitized. Grizzly crossing locations were inferred from relocation data by identifying pairs of points falling closest to either side of a road and connecting them with a straight line segment. Confidence in these inferred crossing sites was quantified as the inverse of the distance between relocations: because bears do not necessarily move in a straight line and their probability of deviating from a straight line increases with time between relocations, confidence in the precision of inferred crossing locations was assumed to decrease as distance between relocations increases. Sites at which modeled corridors intersected roads were digitized as polygons and assigned ranked quality values corresponding to the color scheme presented in each map image. Note that identification of modeled corridor crossing sites from geo-referenced map images was dependent upon symbolization used in these images (line widths and color schemes). Corridor width and relative quality value should therefore be interpreted with some caution; these caveats are discussed further below.

ASSIGN CONNECTIVITY VALUES: All connectivity values derived from data sources not directly pertaining to grizzly bears were combined into a single multi-species connectivity index. Because the range of values provided by each model differed, each was rescaled to fall between 0 and 1. These values were extracted to sample points placed every 0.5 miles throughout the MDT on-system road network, then added together to produce an index of each half-mile segment's multispecies connectivity value. Connectivity values from grizzly data and models were then overlaid on this index independently. This allowed identification of sites with high overall connectivity value based on both consideration of sites with potential connectivity value unique to grizzlies, and assessment of the multi-species connectivity value for which grizzlies could serve as an umbrella species.

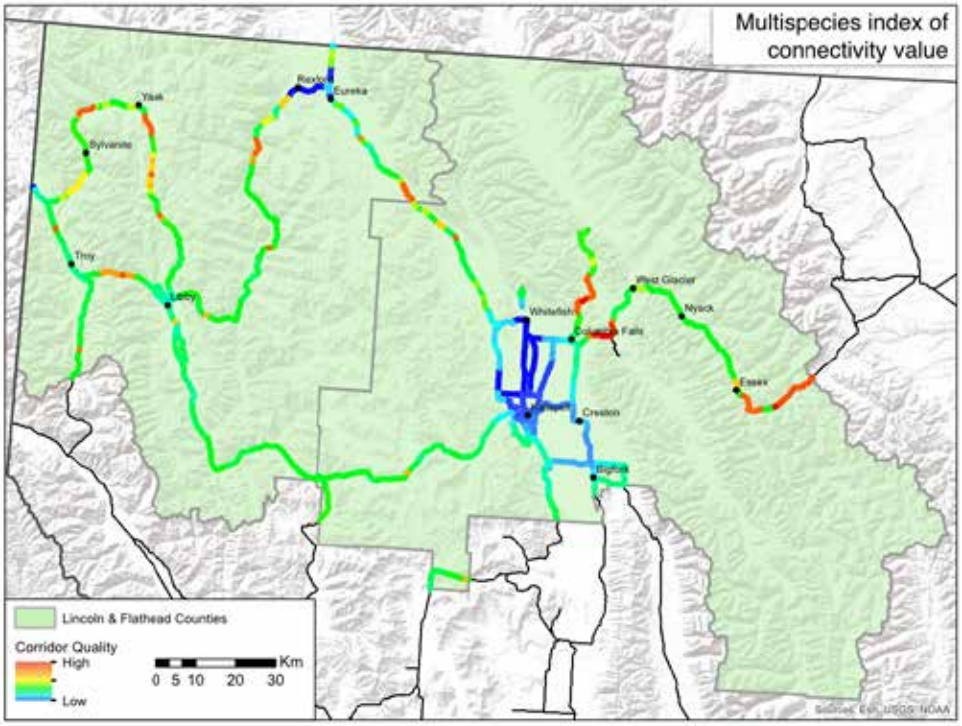


Figure 29: Multispecies connectivity value index based on corridor models for black bear, wolverine, lynx, and forest generalists.

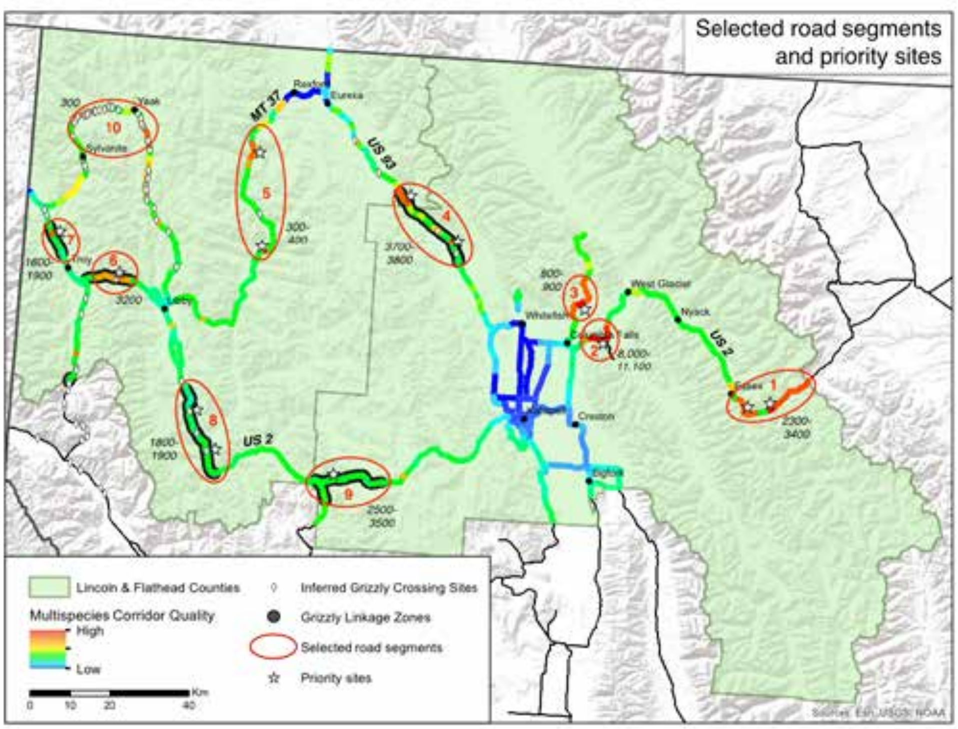


Figure 30: Selected road segments and priority sites. Road segments numbered in red correspond to segment numbers in Table 5. Black number ranges indicate projected traffic volume (AADT).

SELECT PRIORITY SITES: High-value road segments were identified as those containing multispecies connectivity index values greater than 1.5 and/or those identified as grizzly bear linkage zones. Projected traffic volume was overlaid on these segments, and those currently exposed to low traffic volumes that are expected to continue to experience low traffic flows in the future were excluded from further consideration for mitigation emphasis. Within the remaining high-value road segments, we then selected site-level priorities (one- to three-mile stretches) to serve as the most feasible and relevant targets for site visits (Chapter 7). Segments were narrowed to priority sites based on site-scale peaks in connectivity values when possible, or by factoring in topography, vegetation cover, and patterns of human settlement when necessary.

6.4. Results

DATA SOURCES IDENTIFIED: Two sources of grizzly bear connectivity data, three connectivity models for other wide-ranging carnivores with similar habitat needs, and two landscape integrity-based connectivity models with relevance to grizzly habitat needs were identified in the study area (Table 4). Map data layers were available for both landscape integrity-based connectivity models, while all other data sources were available in image form only and were thus geo-referenced and digitized as described above.

CONNECTIVITY VALUES ASSIGNED: Connectivity values indicated by each data source not specific to grizzly bears were standardized and combined to produce the connectivity value index shown

Table 5: Attributes of priority wildlife mitigation sites based on connectivity value and projected traffic volume.

SEGMENT	SEGMENT DESCRIPTION	ROUTE	SITE	MILE MARKER	CONNECTIVITY VALUES	PROJECTED TRAFFIC VOLUME
1	East of Essex	U.S. 2	1a	181-184	black bear & forest generalist corridors, wildlife trails[a]	2,400
			1b	189-190	wolverine & forest generalist corridors, forest centrality, wildlife trails	2,400
2	East of Columbia Falls	U.S. 2	2a	141-143	black bear & lynx corridors	8,900
3	North of Columbia Falls	Rt 486	3a	7-9	black bear, lynx, & forest generalist corridors	800
4	Between Whitefish & Eureka	U.S. 93	4a	148	grizzly linkage zone, forest centrality	3,800
			4b	157-160	grizzly linkage zone, black bear & forest generalist corridors	3,700
5	South of Rexford	MT 37	5a	47-50	black bear & forest generalist corridors	300
			5b	28-29	forest centrality, forest generalist corridor	400
6	Between Libby & Troy	U.S. 2	6a	23-24	grizzly linkage zone, wolverine & forest generalist corridors, forest centrality	3,200
7	Northwest of Troy	U.S. 2	7a	8-9	grizzly linkage zone, forest centrality	1,600
8	South of Libby	U.S. 2	8a	49-50	grizzly linkage zone, approx. grizzly crossing	1,800
			8b	56-57	grizzly linkage zone, forest generalist corridor	1,900
9	Between Libby & Kalispell	U.S. 2	9a	81-84	grizzly linkage zone, forest generalist corridor	2,500

[a] Roesch 2006

in Figure 30. Inferred grizzly crossing sites and grizzly linkage zones were then overlaid on this index (Figure 30). As indicated in the figure, note that the grizzly linkage zone analysis (Proctor & Servheen 2012; Proctor et al. in review) did not cover the entire study area. We therefore relied solely on the multispecies connectivity index outside the coverage zone of this analysis.

PRIORITY SITES SELECTED: Ten high-value road segments were initially identified based on their value for wildlife connectivity (Figure 30). These included (1) Highway 2 east of Essex, (2) Highway 2 east of Columbia Falls, (3) Route 486 north of Columbia Falls, (4) Highway 93 between Whitefish and Eureka, (5) Route 37 south of Rexford, (6) Highway 2 between Libby and Troy, (7) Highway 2 northwest of Troy, (8) Highway 2 south of Libby, (9) Highway 2 between Libby and Kalispell, and (10) Route 508 through Sylvanite and Yaak.

Of these segments, segment (10), Route 508, was excluded from further analysis as a potential mitigation emphasis site due to low current and projected traffic volumes, despite evidence of frequent grizzly crossings. This choice was supported by cross reference with MDT carcass data for this road segment, which indicates that very few wildlife and no grizzly or other carnivore carcasses were collected on this road segment in the 10 years (2003-2012) for which data were available.

Within the remaining nine segments, a total of 13 priority sites were selected based on site-level connectivity values, topography (e.g., major drainages), and/or human settlement patterns. All sites had value for connectivity indicated by two or more data sources (Table 5) except in segments (8) and (9), which were retained for consideration because they were indicated as important grizzly linkage zones (Proctor & Servheen 2012; Proctor et al. in review).

Finally, localized datasets pertaining to road segments within the study area were consulted to determine whether revision or adjustment of our priority site selection may be warranted. Great Northern Environmental Stewardship Area (NPS 2007) data on wildlife trails across a portion of Highway 2 (mile markers 139-215) and the adjacent BNSF Railway suggested that trails occurred throughout this stretch of roadway and did not necessarily align with our priority sites. However, metadata for this dataset indicated that trail locations were identified based on interviews with road and rail maintenance crews rather than telemetry data. We therefore did not have high confidence in these trail locations and did not adjust our priority site designations based on this information. Roesch (2006), in contrast, collected field data on wildlife trail use across Highway 2 (mile markers 153-193), and these data strongly supported our selection of priority sites 1a (mile markers 181-184) and 1b (mile markers189-190) (Figure 31).

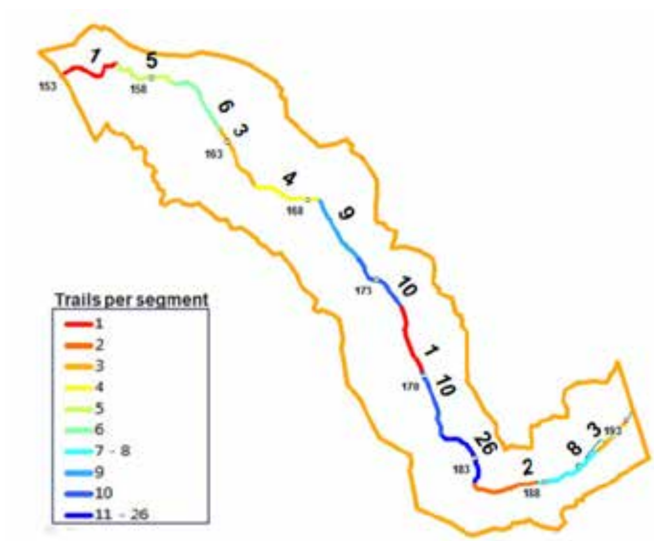


Figure 31: Density of wildlife trails observed by Roesch (2006) crossing U.S. 2 between mile markers 153 and 193.

6.5. Implications

We found frequent overlap in the locations of corridors indicated by alternative models. This is to be expected as all models were driven by similar factors and similar species' needs (e.g., large swaths of forested habitat, minimal human development, and mild terrain). In particular, in the portion of our study area in which grizzly linkage zones were modeled, linkage zones frequently encompassed sites identified by other models as offering high potential connectivity. This suggests that grizzly corridors may serve as good umbrellas for the movements of other species as has often been suggested, and that non-species-specific models are in fact frequently capturing the needs of multiple species. While the models also disagreed on some locations, this outcome is also to be expected given the different methodology, species targets, data, assumptions, and scales or scopes addressed by each. Ultimately, the ensemble of available models appears to have provided a reasonable set of priority sites for connectivity in northwest Montana.

This suggests that grizzly corridors may serve as good umbrellas for the movements of other species as has often been suggested, and that non-species-specific models are in fact frequently capturing the needs of multiple species.

It is important to note that none of the data sources utilized in this study, except grizzly crossings inferred from radio- and GPS-collar movement data, suggests that functional connectivity actually exists at priority sites. All connectivity models will produce a predicted best path or set of paths across a solid potential barrier like a road, but it is in no way guaranteed that this best path actually enables an animal to cross that barrier. Determination of the extent to which the road serves as a barrier requires assessment of conditions and study of animal movements on the ground at a given priority site.

We culled sites identified as having high connectivity value but little risk from current or future traffic from our set of priorities; despite high sensitivity to traffic impacts, these sites have low exposure and thus relatively low vulnerability at this time. These sites should be monitored to prevent future impacts, and any future highway construction in these areas that may increase traffic volumes or other impacts on the ability of animals to move across these highways should be considered carefully in light of the connectivity they currently support.

Wolf using a highway underpass. Photo: WTI-Parks Canada

7. FIELD EVALUATION OF HIGHWAY MITIGATION SITES

7.1. Introduction

After the modeling of housing and job growth (Chapter 4) was used to project traffic demand (Chapter 5), and the transportation results were then evaluated in conjunction with a synthesis of the wildlife connectivity models (Chapter 6), priorities for wildlife mitigation for the highways of Lincoln and Flathead counties were established (Chapter 6). This resulted in the selection of 13 highway segments within the project area that had the highest potential to adversely impact grizzly bear connectivity as well as other native wildlife movement due to housing and commercial development and its resulting increase in traffic (Figure 30).

Since most of the study was based on models, it was important to visit each of these 13 mitigation sites to evaluate their relative importance for wildlife mitigation purposes. Invited local wildlife experts joined the research team on visits to the selected locations to gauge whether these sites were consistent with the local wildlife biologists' understanding of priority mitigation sites for the wildlife species that were used in the models (i.e., grizzly bear, wolverine, and lynx). The field review also was conducted to appraise each mitigation site (MS) for other values, such as the constructability of wildlife mitigation measures and land security (from future development) on either side of the highway.

The research team conducted a webinar with the local experts on 24 March 2014 to explain the scientific methods for selecting the MS. This was the first peer review of the modeling methods and their results before entering the field. Participating were wildlife biologists and transportation experts from northwest Montana. The research team was able to respond to the experts' comments to improve the analyses and then adjust the models based on expert comment before finalizing the mitigation sites for the field review. The webinar also explained the values matrix (Table 6) that would be used during the field review to develop prioritization values for the MS.

A field review of the 13 MS was conducted on 9-10 April 2014. On April 9, the team visited the following MS: 1a, 1b, 2, 3, 8a, 8b, and 9 (Table 7 and Figure 30). Wildlife biologists who joined the April 9 field review included:

Scott Jackson
National Carnivore Program Leader, USDA Forest Service

Reed Kuennen
Wildlife Biologist, Flathead National Forest

John Waller
Supervisory Wildlife Biologist, Glacier National Park

Table 6: Values matrix to identify priority wildlife mitigation sites in the study area.

Mitigation Site Number	Description	Mile Markers	Road	County	Wildlife Model Support[1]	Connectivity Value	Non Modeled Species Conservation Value	Highway-Wildlife Mitigation Feasability	Adjacent Land Ownership[2]	Land Security Value	Average Annual Daily Traffic (AADT)	Projected Traffic Volume Increase	Traffic Volume (vehicles/day)	Traffic Threat	Total Priority Value

On April 10, the team visited the follow MS: 4a, 4b, 5a, 5b, 6, and 7 (Table 7 and Figure 30). The local wildlife biologists who assisted the research team in evaluating these sites were:

Wayne Kasworm

Wildlife Biologist, U.S. Fish and Wildlife Service

Tim Thier

Wildlife Biologist, MT Department of Fish, Wildlife & Parks

Jeremy Anderson

Wildlife Biologist, Kootenai National Forest

7.2. Ranking Process and Categorical Values

The 13 mitigation sites emerged from the modeling effort as the most important wildlife connectivity locations being adversely impacted by predicted growth and traffic demand in the two-county study area. These MS were located on U.S. and state highways where predicted traffic volumes would potentially impact wildlife connectivity. County and municipal roads did not emerge from the modeling as being as problematic for wildlife connectivity, either because they were within urban areas and therefore the index of sensitivity of wildlife was low (Chapter 6), or because the exposure due to traffic flow levels was low (Chapter 5) when compared to the major highways and roads.

A field evaluation ranking system was developed to help transportation, wildlife, county, federal land management, and other interested planners and project leaders better understand the relative values for prioritizing mitigation of wildlife for the 13 different sites. The values used for setting priorities were relative to one another across the study area, not just for the particular highway segment where the MS is located.

Some of the columns in the values matrix (Table 6) were completed before the field review: MS Number, Description, Mile Markers, Highway, County, Wildlife Model Support, Adjacent Land Ownership, AADT, Projected Traffic Volume Increase and Traffic Volume. These columns of information were used to guide the team of experts as they visited each MS.

Values for each of the following five categories were assigned during the field evaluation for each MS: Connectivity Value, Non-modeled Species Conservation Value, Highway-Wildlife Mitigation Value, Land Security Value, and Traffic Threat Value (Table 6). Each category value for each MS was assigned by the field evaluation team based on a mixture of spatial model results (see Chapters 4 and 5), existing wildlife and landscape connectivity model results (Chapter 6), other studies of roads and wildlife in the project area, and important local knowledge of the area by working wildlife biologists. Lastly, the research team, joined by local wildlife experts, visited each site to "ground truth" the model results and to pinpoint the best mitigation location(s) within the one- to three-mile-long mitigation sites.

All five categories were evaluated on a relative numerical scale from very low value (1) to very high value (5). The five categories were developed to capture values important for setting MS priorities for mitigation and are defined further below.

THE CONNECTIVITY VALUE captures the importance of maintaining connectivity for the movement of grizzly bears and other forest carnivores based on existing models as well as GPS collar data information from the U.S. Fish and Wildlife Service (Kasworm et al. 2012). Given that total grizzly bear crossings of highways are much less numerous than native ungulate crossing, frequent grizzly crossing locations are much more difficult to ascertain. Therefore, models built largely on genetic data were used in addition to the

The 13 mitigation sites emerged from the modeling effort as the most important wildlife connectivity locations being adversely impacted by predicted growth and traffic demand in the two-county study area.

limited information available from telemetry of grizzly movements. We did not rely on wildlife-vehicle collisions from Montana Highway Patrol and carcass removal data from MDT maintenance crews, since these statistics are almost wholly comprised of ungulate mortality, with little information available on carnivore road mortality locations, particularly for grizzly bears. Thus, MS were selected for their conservation value for grizzly bears and ancillary values for other species' movement, but not as a result of concerns for motorist safety due to high levels of wildlife-vehicle collisions. The connectivity value is therefore primarily a conservation value, rather than a value prioritizing motorist safety.

The values used for setting priorities were relative to one another across the study area, not just for the particular highway segment where the MS is located.

The boundary of the Proctor et al. (in review) and other grizzly bear linkage zone studies did not cover the two counties completely. Thus, other studies on carnivores and landscape integrity were used to help identify important wildlife crossing sites of highways. Those studies which identified the MS were listed in the Wildlife Model Support category in the values matrix prior to the field evaluation. Each of these models is explained in Chapter 5. Success for some of the rarer species may be measured by safe passage at highway crossings at very low crossing rates, since effective population levels are so low. For example, it has been estimated that effective population size for wolverine in the Northern Rocky Mountain states is 35 individuals (Schwartz, et al. 2009), indicating that maintaining low highway mortality rates is important for maintaining viable populations of this low-density carnivore.

THE NON-MODELED SPECIES CONSERVATION VALUE sought to capture the crossing needs of species that did not have models or published literature in the study area. This category's value was derived primarily based on the local knowledge of the federal and state wildlife biologists who visited the MS with the research team. They are involved on an ongoing basis with elk, deer, moose, bighorn sheep, mountain goats, meso-carnivores (i.e., bobcats, fisher) and other species that occupy habitats adjacent to the MS and have known locations for frequent highway crossings or highway mortality within or adjacent to the MS.

THE HIGHWAY-WILDLIFE MITIGATION VALUE was based on opportunities presented at the MS by its geographical setting and features (i.e., stream crossing, terrain, slope stability); the difficulty or ease for the placement and design of infrastructure (i.e., underpass, overpass); the age, condition and appropriate size of existing infrastructure (i.e., culverts, bridges); and other physical, biological and social (i.e., recreational trails) features. The value for each MS represents the relative ease or difficulty presented to the field review participants during its field visit on 9-10 April 2014. Geotechnical information and other engineering studies were not available during the development of this category's values in the field.

LAND SECURITY VALUE was the category that evaluated the condition of the lands directly adjacent to the MS. Investing in highway infrastructure that provides safe passage for wildlife is often an expensive undertaking that could cost a million dollars or more. Therefore, assuring that the lands that provide access and egress to crossing infrastructure will not be developed for commercial, residential, or industrial purposes is an important consideration for setting mitigation priorities. Such development on lands adjacent to the MS could impede or create a barrier to wildlife movement and access to the crossing structures, and therefore reduce the effectiveness of the mitigation measures. Land security values were developed using Geographical Information System (GIS) information and via the local site visits, since it could often change over the course of the one- to three-mile highway segment. Values for land security were then developed based on land ownership, existing conservation easement information, and land development attributes on both sides of the highway at each MS. The highest value (5) was very secure and the lowest value (1) had development on lands on both sides of the highway at the MS location:

- **5** Public lands (federal, state) or private lands with a conservation easement on both sides of MS
- **4** Public lands or conservation easement on one side of MS, open space on the other (with unsecured easements)
- **3** Open space lands on both sides, but unsecured conservation easements for these private lands
- **2** Housing development or industrial/commercial site on one side, open space on other side (with unsecured easements)
- **1** Housing development or industrial/commercial sites on both sides of highway at MS

Most of the values were derived using GIS, but were reviewed and revised if needed, once a MS was located along each highway segment identified during the field review. This helped to assure that ownership of the land on both sides of the potential mitigation site was properly identified.

TRAFFIC THREAT VALUE was derived based on the travel demand model (Chapter 4), which predicted the increase in the average annual daily traffic (AADT) 20 years in the future at each of the MS highway segments. These values were included in the value matrix for the field review. Note that the AADT estimates as of the field review have since been revised based on feedback from local experts. Two of the major adjustments were inclusion of Plum Creek land in the land use modeling, and seasonality produced by high tourist use during the summer months at Glacier National Park. Although the AADT values brought to the field review did not include the seasonal variation, this limitation was identified and ranking values adjusted accordingly.

7.3. Results

It was recognized that the 13 mitigation sites were not all-encompassing for every wildlife connectivity concern in the study area. Still, feedback during the field evaluation confirmed that the highway segments and specific mitigation sites within those segments that were identified by this study generally aligned with recognized priority locations for maintaining habitat connectivity across highways.

The MS with the highest overall priority value (23) was east of Essex, MT, on Highway 2 (MS 1a, Table 7). This part of the highway lies between Glacier National Park to the north and the Great Bear Wilderness Area of the Flathead National Forest to the south (Figure 30). There were four other MS that had total value scores of 22: the MS on the North Fork Road or Route 486 (MS 3), the two MS between Whitefish and Eureka on Highway 93 (MS 4a and 4b), and the MS at mile markers 23-24 on Highway 2 between Libby and Troy (MS 6) (Table 7 and Figure 30). The two lowest sites of total mitigation priority values were for the MS on Highway 2 east of Essex between mile markers 189-190 (MS 1b) that had private land and development on both sides of the highway so its land security value was low. The second lowest MS was the site along Lake Koocanusa on Route 37 between mile markers 28 and 29 (MS 5b) that had low traffic threat and low connectivity values, most likely as a result of the highway's adjacency to the lake and due to the importance of connectivity along the entire highway (Table 7 and Figure 30).

Most of the values were derived using GIS, but were reviewed and revised if needed, once a MS was located along each highway segment identified during the field review.

Table 7: Prioritization values for the 13 mitigation sites selected in the study area.

Mitigation Site Number	Description	Mile Markers	Road	County	Connectivity Model Support[a]	Connectivity Value	Non-Modeled Species Conservation Value	Highway-Wildlife Mitigation Feasibility	Adjacent Land Ownership[b]	Land Security Value	Average Annual Daily Traffic (AADT)	Projected Traffic Volume Increase	Traffic Volume (vehicles/ day)	Traffic Threat Value	Total Priority Value
1a	East of Essex	181-184	Hwy 2	Flathead	BB; field survey	5	4	5	GNP/FNRR	5	1500	1-1.4X	200-3000	4	23
1b	East of Essex	189-190	Hwy 2	Flathead	HC; W	4	4	4	GNP/FNF	2.5	1500	1-1.4X	200-3000	4	18.5
2	East of Columbia Falls	141-143	Hwy 2	Flathead	BB; L; topo	4	5	4	FNF/FNRR/ PVT	3	9-10 k	1-1.4X	>10000	5	21
3	North of Columbia Falls	7-9	Rte 486	Flathead	BB; L; topo	5	5	4	FNF/PVT	5	100-800	>1.8	200-3000	3	22
4a	Whitefish-Eureka	148	Hwy 93	Flathead	GLZ; HC	4	4	4	SSF	5	3900-4400	1.4-1.8X	3000-10000	5	22
4b	Whitefish-Eureka	157-160	Hwy 93	Lincoln	GLZ; BB	4	4	4	SSF/KNF	5	3900-4400	1.4-1.8X	3000-10000	5	22
5a	South of Rexford	47-50	Rte 37	Lincoln	BB	3	4	5	KNF/LK	5	300-500	1-1.4X	200-3000	3	20
5b	South of Rexford	28-29	Rte 37	Lincoln	HC; W	3	4	4	KNF/LK	5	300-500	1.4-1.8X	200-3000	3	19
6	Libby-Troy	23-24	Hwy 2	Lincoln	GLZ; MC; W	5	5	3	KNF/KFWMA	5	3400	1-1.4X	3000-10000	4	22
7	NW of Troy	8-9	Hwy 2	Lincoln	GLZ; HC	5	5	3.5	KNF/LK	5	800-1900	1-1.4X	200-3000	3	21.5
8a	South of Libby	49-50	Hwy 2	Lincoln	GLZ; Approx Griz; W	5	4	3	FNF/PVT/ MDT	2	2400	1.4-1.8X	200-3000	3	17
8b	South of Libby	56-57	Hwy 2	Lincoln	GLZ; topo	4	4	5	PC/PVT	3	2400	1.4-1.8X	200-3000	5	21
9	Libby-Kalispell	81-84	Hwy 2	Flathead	GLZ; topo	4	4	5	PC/PVT	3	2900-4100	1.4-1.8X	200-3000	5	21

a Grizzly Linkage Zone (GLZ); Black Bear (BB); Wolverine (W); Lynx (L); High Centrality/Moderate Centrality (HC/MC), Master's Thesis (MT), Topography (T), Approx. Griz is from GPS collar data and is not precise where animals crossed road

b Flathead NF (FNF); Kootenai NF (KNF) Plum Creek (PC), Glacier NP (GNP); Stillwater State Forest (SSF); Private (PVT) Flathead National Recreational River (FNRR); Lake Koocanusa (LK); Kootenai Falls Wildlife Management Area (KFWMA)

8. MITIGATION SITES

8.1. Introduction

Thirteen mitigation sites (MS) were selected in the study area, each presenting a unique challenge and opportunity for wildlife mitigation. This section briefly describes each of the MS based on both model information (Chapter 6 and Figure 30) and the field review (Chapter 7). The research team and the local wildlife biologists sought to identify the best location within the one- to three-mile highway segments that identified each MS. We used milepost markers along the highway to describe sites and locales. For some MS, it was difficult to find an exact location, given extenuating circumstances such as land ownership or lack of terrain complexity.

Given the expected growth in communities and traffic in the two-county study area, and the potential expansion of transportation infrastructure, there are opportunities both in the short term and long term to address the impacts of this growth on wildlife movement and habitat connectivity. Short-term mitigation is often less effective, but is inexpensive and can be deployed as soon as funding is available. We describe potential options for these types of mitigation. Long-term mitigation refers to more permanent and expensive infrastructure, such as wildlife overpasses and underpasses, that may be best implemented during a highway reconstruction project. These types of highway structures are normally designed and built with a life expectancy of 50-75 years. (See Appendix A for descriptions of various wildlife mitigation measures recommended in this section.)

While this report seeks to identify opportunities for implementing long-term wildlife mitigation structures as part of larger highway reconstruction projects, there is no mandate to do so. Indeed, wildlife crossing structures are being constructed now in the western U.S. without related highway construction/reconstruction projects. For example, the Wyoming Department of Transportation recently built a stand-alone wildlife mitigation infrastructure project, constructing two overpasses and six underpasses with fencing that linked the eight crossing structures together near Pinedale, WY, on U.S. 191 in 2012. Therefore, wildlife overpasses and underpasses could be constructed in the two-county project area at the point when traffic volumes, wildlife-vehicle collision rates, and/or wildlife conservation values are not being met by the current highway configuration. If adequate funding can be obtained, many of the MS sections of the highways in the two-county study area of Montana may be similarly attractive for structural mitigation projects absent highway reconstruction.

8.2. Existing Structures

Wildlife may be able to safely cross highways in the identified MS using existing below-grade passage structures (i.e., culverts, creek bridge structures). Little is known regarding current wildlife use of the existing structures within the MS and the structures' potential for passing wildlife safely under the highway. Some existing bridges have been identified as perfectly suited for long-term mitigation in some of the MS, but may require slope stabilization, wing fencing, vegetation, or other minor modifications. However, the field review did not do a survey of all existing below-grade passage structures. All existing structures in the highway segments should be identified and monitored to determine their current use by different wildlife species. This data will not only determine current functionality of existing structures, but may also inform different species' requirements and structure design types. Conducting snow tracking and setting up camera traps on either end of these structures would be a very efficient way to better understand the existing permeability of the MS and thus future needs.

8.3. Priority Mitigation Sites

MITIGATION SITE 1a

East of Essex on Highway 2, mileposts 181-184, Flathead County

Figure 32: Gulley on Highway 2 within Mitigation Site 1a that could be targeted for an underpass structure.

OVERVIEW

This MS is on an east-west transportation corridor (Highway 2 and the parallel BNSF Railway) that separates the large wild areas of Glacier National Park to the north and the Bob Marshall Wilderness Complex to the south. It was selected as a result of its importance for connectivity from the black bear corridor model (Cushman et al. 2009), MFWP's forest generalist corridor model, and wildlife trails identified by a master's professional paper (Roesch 2006). Its overall prioritization value was the highest in the study area (23). A recent grizzly bear study (Proctor et al., in review) did not cover this eastern portion of the study area to identify the importance of this MS to the threatened species. A study of Highway 2 crossings by 25 radio- and GPS-tracked grizzly bears and the parallel railroad indicates bears are more likely to cross Highway 2 when traffic levels during the night are very low (Waller and Servheen 2005). The authors hypothesize that traffic levels greater than 100 vehicles/hour may become a barrier to grizzly movement. Projections for this MS are for traffic to exceed this level in the future during daytime, necessitating wildlife mitigation measures not only at this MS but at other locations along Highway 2 from Essex, MT, to East Glacier, MT, and its junction with MT Highway 49.

Immediately to the west of the MS, in the Nyack area, is a large ranch with many open meadows among the forested areas, ideal for use by elk, deer, and other grazers. There is no conservation easement on the property. Local wildlife biologists related that there are documented lynx and wolverine highway crossings within the MS even though neither regional model of these species highlighted this as an important connectivity area. Two underpasses exist in the MS due to terrain conditions, and these may already act as a wildlife mitigation measure for mountain goats, Oreamnus americanus. Near mile marker 182 is the "goat-lick" underpass that allows the mountain goats to safely access a natural salt lick. Near milepost 183.8 is a gulley with a culvert currently plugged from an avalanche chute. Just past mile marker 184 is a railroad bridge over the highway. Grizzly bears have been hit by trains while trying to cross the railway bridge over Highway 2 or via a nearby railroad trestle over the Middle Fork Flathead River. A positive feature of this MS is that there is no parallel railroad close to the highway in this area. Although the railroad crosses over Highway 2 just past the east end of this MS, it moves away from the highway and lies on the other side of the Middle Fork Flathead River.

BEST MITIGATION LOCATION

The best location identified for wildlife mitigation in the three-mile-long MS was at mile marker 185, near the confluence of Bear Creek and the Middle Fork Flathead River, a natural topographic movement area for wildlife. This area has a gulley (Figure 32) that is also an avalanche chute passing under the highway, and has an existing small culvert that only passes flowing water and is not large enough for middle- and large-sized wildlife.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:

This location toward the east side of MS 1a, where Highway 2 passes over an avalanche gulley, could easily have an open-arched bridge or large wildlife-friendly culvert installed to promote wildlife movement. If such a structure is constructed, approximately 500 meters of fencing to guide wildlife to the crossing should be built on both sides of the structure and on both sides of the highway.

SHORT-TERM:
U.S. Highway 2 is rich in wildlife and has many at-grade crossings by moose, deer, elk, bears, and other wildlife to the east, to the west, and within this MS. Therefore, a "watch out for wildlife" driver awareness program with periodic wildlife signage from Lake Five to Skyland Creek would be helpful. The effectiveness of driver awareness in reducing crashes with wildlife is poorly understood, but given that this is a major transportation route for tourists as well as for commercial traffic to facilities such as the Bakken oil fields, many drivers are not local and may not know the dangers of collisions with wildlife in this stretch of U.S. Highway 2. A variable message sign would best be used during the busy summer months when Glacier National Park receives most of its visitation. The messages could display either the number of animals by species killed on the highway or the number of safe crossings, if they are tabulated in the area. These signs should run primarily during dusk, dawn, and nighttime hours, when the likelihood of grizzly bear crossing attempts and increasing traffic overlap.

The goat lick underpass could have wing fencing to guide other wildlife species to this crossing structure. The feasibility of widening the railway overpass and adding a barrier between the tracks and edge of the overpass for the safe passage of grizzly bears and other wildlife on the railroad bridge could be investigated.

MITIGATION SITE 1b

East of Essex on Highway 2, mileposts 189-190, Flathead County

OVERVIEW

This MS was selected as a result of its high centrality rating in the Western Governors' Association's regional wildlife connectivity model, as well as in Montana Department of Fish, Wildlife & Parks' (MFWP's) forest generalist connectivity model. It also is important for wolverine connectivity in that species' model (Schwartz et al. 2009). Overall, the total priority value was the second lowest of the 13 MS (18.5), as a result of land ownership within the MS. Because the Zips cabin area is ripe for private lands development, ownership is in flux, and both sides of the highway are projected to have decreases in habitat quality and quantity.

BEST MITIGATION LOCATION

The field review of the MS revealed seemingly intractable issues concerning private lands adjacent to the Highway 2, such as their development and related high levels of human activities that would make the area a poor place to invest in wildlife mitigation of the highway. As a result, the research team, in concert with the invited local wildlife biologists, suggests that mitigation would best be deployed near mile marker 192-194, where lands on both sides of Highway 2 are either Flathead National Forest and/or Glacier National Park lands, and are therefore secure. This alternative area has known summer ungulate use and movement. The Autumn Creek drainage is a topographical feature syphoning animals through the area and across the highway.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
The highway travels through relatively flat terrain in this MS, so overpasses would be the most likely candidates for structural mitigation.

SHORT-TERM:
Installation of an at-grade animal detection system (ADS) should be investigated. A driver warning system with fencing and a crosswalk could be installed where there are public lands on both sides of MS 1b. Thus, one ADS with one-half mile of wing fencing on both sides of the crosswalk and both sides of the highway would mitigate a mile section of highway.

The Autumn Creek drainage is a topographical feature syphoning animals through the area and across the highway.

MITIGATION SITE 2

East of Columbia Falls on Highway 2, mileposts 141-143, Flathead County

Figure 33: Potential crossing mitigation location on Highway 2 in Mitigation Site 2, at the South Fork of the Flathead River Bridge.

Figure 34: A view looking south along the gravel road that provides river access for recreationists in Mitigation Site 2 and passes under Highway 2 on the east side of the South Fork of the Flathead River Bridge.

OVERVIEW

Local wildlife biologists feel the area of Highway 2 between Columbia Heights and West Glacier is most vulnerable to human development in the upcoming decades. This area was important to connectivity based on the black bear and lynx models (Cushman et al. 2009; Squires et al. 2013). It is essential for ungulate use, as it is winter range for these species. As a significant connector between the South, North and Middle Fork drainages of the Flathead River, it is topographically important as well. Human recreational use and development are high on both sides of the highway. However, the Flathead National Forest also has lands on both sides of the highway in some areas of the MS.

BEST MITIGATION LOCATION

The best opportunity for mitigation in this MS is in the area from the Badrock River access site to just east of the bridge across the South Fork of the Flathead River (Figure 33). There is currently a 4.5-mile-long project, the Columbia Heights-Hungry Horse Highway 2 expansion from Columbia Heights to Hungry Horse, which will expand Highway 2 from a two-lane to a four- and five-lane highway. It is not know at this time if the bridge location will remain at its current location or be moved approximately 100 yards downriver. Regardless of the final decision on the bridge's location, mitigation, particularly on the west side of the bridge, would be ideal since wildlife movement is frequent along the river's riparian areas.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
Any new bridge construction, relocated or not, should allow for wildlife movement on both sides of the Flathead River. Essentially this would be an expanded bridge design that incorporates both sides of the river's riparian areas under the bridge to allow for terrestrial wildlife movement.

SHORT-TERM:
Given the reconstruction project slated for Highway 2 and the Flathead River Bridge, no short-term mitigation is recommended for MS 2.

Local wildlife biologists feel the area of Highway 2 between Columbia Heights and West Glacier is most vulnerable to human development in the upcoming decades.

MITIGATION SITE 3
North of Columbia Falls on Route 486, mileposts 7-9, Flathead County

Figure 35: Typical road profile within Mitigation Site 3 near milepost 9 on Route 486 (North Fork Road), Flathead County.

OVERVIEW

This MS is in a rich wildlife area and was identified for connectivity by the black bear and lynx models (Cushman et al. 2009; Squires et al. 2013), as well as MFWP's forest generalist model. It has relatively low traffic volumes during the winter and higher levels in the summer, when tourism and summer home use are at their peaks.

BEST MITIGATION LOCATION

The roadside along MS 3 is relatively homogeneous, and there are no topographic features (i.e., creeks, drainages, cliffs, steep slopes) that make the construction of wildlife crossing structures easier. There are some private homes and properties along this stretch of Route 486, although there are many areas where the Flathead National Forest has land on both sides of the road. No particular location within the MS is better than any other. However, selection of a site should be sure to address land security, so that public lands are on both sides of the highway.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
Due to the homogeneity of the MS and the lack of topographical features, no wildlife crossing structures are recommended for this site. Instead, the recommendation is a mitigation measure that could be deployed at-grade, when summer traffic exceeds high levels. A permanent animal detection – driver warning system using a solar array for power would be the best option.

SHORT-TERM:
Variable message signs could be deployed within MS 3 during the summer months when traffic is especially heavy. This would only be necessary when long periods of high traffic are recorded in the next 5-10 years. Messages could be powered by a solar array if power lines are not available in the right-of-way of this section of Route 486.

MITIGATION SITE 4a
Between Whitefish and Eureka, on Highway 93, near milepost 148, Flathead County

Figure 36: Highway 93 near milepost 148 at the Lincoln-Flathead county line lies within Mitigation Site 4a of this study.

Figure 37: A wildlife-transportation study (unpublished mapping information provided by Montana Department of Fish, Wildlife & Parks) that highlighted important wildlife crossings (numbers 5 and 6 in the image), aligns with the selection of Mitigation Site 4a of this project.

OVERVIEW

This MS was identified as an important connector across U.S. 93 by the grizzly bear linkage zone study (Proctor et al. in review) and is identified as the Salish Demographic Connectivity Area in the draft Grizzly Bear Conservation Strategy (USFWS 2013). It also rated high as an important corridor in the Western Governors' Association's (WGA's) centrality model. It had the second highest total priority value (22) of all the MS in the study area (there were four sites tied at 22). Although there are many private properties along Highway 93, there are some areas within MS 4a that have Flathead or Kootenai National Forest lands or Stillwater State Forest lands on both sides of Highway 93. Land directly adjacent to the highway is protected in some areas; however, a very large tract of land owned by Plum Creek Timber Company could be slated for sale and developed for homes further east of this site and continuing southward in the future, if PCTC actions in other areas are any indication.

BEST MITIGATION LOCATION

In conjunction with information from the local wildlife biologist during the field review, the research team selected the best site to be near Dog Lake at milepost 148.2. This is near the Lincoln-Flathead county line (Figure 36). Forest Service or Montana Department of Natural Resource and Conservation (DNRC) lands are on both sides of the highway in this locale. Since DNRC lands are managed to produce revenue for the trust beneficiaries while also considering environmental factors and protecting the future income-generating capacity of the land, mitigation efforts will have to take into consideration future plans for DNRC forests adjacent to mitigation efforts along the highway.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
Given the high projected traffic volumes on Highway 93 in this MS—up to 4,000 vehicles per day—a structural overpass is recommended. This would include fencing to guide animals to the structure and could be tied in to the sharp upslope on the east side of the highway. Wildlife often follows ridges, so the crossing could be directed along the low ridge paralleling the highway on the east side of the MS. Additional considerations for preserving private lands from development surrounding Highway 93 may eventually secure future crossing areas and protect wildlife habitat.

SHORT-TERM:
U.S. Highway 93 for many miles to the south and north of this MS is rich in wildlife and has many at-grade crossings by moose, deer, bears, etc. Therefore, a "watch out for wildlife" driver awareness program with wildlife signage for the Whitefish-Eureka segment of this highway would be helpful. Since many drivers are not local on this popular route to Canada, they may not know the dangers of collisions with wildlife in the area.

MITIGATION SITE 4b

Between Whitefish and Eureka, on Highway 93, mileposts 157-160, Lincoln County

Figure 38: Highway 93 south of Dickey Lake in Mitigation Site 4b.

Figure 39: A wildlife-transportation study (unpublished mapping data provided by Montana Department of Fish, Wildlife & Parks) that highlighted important wildlife crossings (numbers 10-12 in the image), aligns with this project's selection of Mitigation Site 4b.

OVERVIEW

MS 4b had the second highest total priority value (22) in the study area. It is heavily forested on both sides of the highway, with public forest lands (state and federal) interspersed with private forest lands and homes. It had high connectivity value based on the grizzly linkage zone study (Proctor et al. in review), the black bear study (Cushman et al. 2009), and MFWP's forest generalist model. Traffic is high relative to the study area and is projected to increase even further. There is a spur railroad to the west of the highway, but it receives little traffic. The small enclave of Stryker is within the MS, and a bridge over the Stillwater River between mileposts 158 and 159 would allow for a retrofitted underpass. However, there are too many homes and private properties adjacent to the bridge to justify such an investment.

BEST MITIGATION LOCATION

The best mitigation location was identified south of Dickey Lake (Figure 38) at milepost 160.5, which is just within the Kootenai National Forest, so lands are secure on both sides of the highway. Just south of this site the highway passes through Montana's Stillwater State Forest. The terrain is relatively flat and heavily forested on both sides of the highway.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
Due to the flat terrain, a wildlife overpass offers the best option. Another option would be to raise the road bed where the current sides of the road slope away and create an underpass. Either an overpass or underpass would benefit from wing fencing directing wildlife to the structure.

SHORT-TERM:
A driver awareness and education project for this highway segment may benefit wildlife and drivers, alike (see short-term discussion for MS 4a).

MS 4b had the second highest total priority value (22) in the study area.

MITIGATION SITE 5a

South of Rexford on Route 37, mileposts 47-50, Lincoln County

Figure 40: Viewing the west side of Sutton Creek Bridge on Route 37 in Mitigation Site 5a.

Figure 41: Viewing the east side of Sutton Creek Bridge within Mitigation Site 5a on Route 37.

OVERVIEW

Route 37 connects Libby and Eureka, MT, and follows the Kootenai River and the shore of Lake Koocanusa after the Libby Dam. MS 5a is located where Route 37 follows the shore of Lake Koocanusa and, along with MS 5b, has the lowest traffic volume of any of the sites in the study area. The lands on both sides of the highway are managed by the Kootenai National Forest. The MS was identified as important for connectivity based on the black bear model (Cushman et al. 2009) and MFWP's forest generalist model. There also is a small herd of native bighorn sheep, *Ovis canadensis*, that uses the area and crosses the highway. Known as the Ural Tweed herd, it is one of only two such herds in northwest Montana (for more information on their conservation see: http://fwp.mt.gov/fishAndWildlife/management/bighorn/plan.html#plan). Most of the MS has steep terrain with regular cut slopes with forested terrain to the east of the highway. However a major drainage cuts through to the lake.

BEST MITIGATION LOCATION

The best location for mitigation is where Sutton Creek creates a deep incision in the landscape. Route 37 has a considerable bridge over Sutton Creek that spans the length of the incised drainage (Figure 40). Wildlife following the drainage either upstream into the mountains or downstream to the lake has adequate terrain to pass safely under the highway.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
Adding new crossing structures to this MS is not recommended. The Sutton Creek Bridge provides an existing underpass for wildlife, and simply attaching wing fencing to guide wildlife to the existing bridge could provide long-term mitigation. Adding gabion or other type of retaining wall to prevent further erosion of the traversable slope and attaching some relatively short wing fencing to the bridge abutments to guide animals could improve this underpass. Since traffic is projected to be relatively low on this roadway, it will likely remain only a minor barrier to movement.

SHORT-TERM:
Due to the low traffic volumes on this highway, simple wildlife signage at key locations could alert drivers to problem areas.

MITIGATION SITE 5b

South of Rexford on Route 37, mile makers 28–29, Lincoln County

Figure 42: Typical road segment of Route 37 in Mitigation Site 5b.

Figure 43: View of available terrestrial habitat under the 5 Mile Creek Bridge of Route 37 within Mitigation Site 5b.

OVERVIEW

Similar to MS 5a, this MS is also along the shores of Lake Koocanusa. It is recognized as having a high value for connectivity by the WGA's centrality model and MFWP's forest generalist model. It also was identified as a corridor by the wolverine model (Schwartz et al. 2009). Traffic volumes are projected to remain relatively low over the next two decades. Most of the terrain for MS 5b is a homogenous forest with only slight undulations (Figure 41). However, there is a key topographical feature, at approximately milepost

29.5, where the Five Mile Creek drainage crosses Route 37.

BEST MITIGATION LOCATION

There is a significant break in an otherwise relatively homogenous terrain at Five Mile Creek. Since wildlife often follows riparian areas along a drainage, this is an excellent site for mitigating Route 37.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
There currently exists a significant bridge that spans the entire Five Mile Creek drainage (Figure 43). Under the bridge, there is sufficient terrain on both sides of the creek to serve as an underpass for animals of all sizes. Portions of the slope under the bridge are flat and create easy routes for wildlife movement. If more linear mitigation is needed for this MS in the future, wing fencing up to a half mile in either direction of the bridge could keep wildlife off of the highway and direct them to the bridge underpass.

SHORT-TERM:
Due to the low traffic volumes on this highway, wildlife signage at key locations could alert drivers to problem areas, although this is not very effective for protection of rarer species that only sporadically cross the highway.

▶ MITIGATION SITE 6

Between Libby and Troy on Highway 2, mileposts 23-24, Lincoln County

Figure 44: Highway 2 along the Kootenai River to the north (left in the picture) and steep slopes to the south (right in the picture) within Mitigation Site 6 west of Libby, MT.

OVERVIEW

Mitigation Site 6 had the second highest total priority value (22) in the study area. In this MS, Highway 2 parallels a railroad and the Kootenai River. Connectivity across Highway 2 in this area was identified as important by the grizzly bear linkage zone model (Proctor et al. in review). The Cabinet-Yaak population of grizzly bears is estimated to consist of 45-49 individuals. MS 6 also was identified by the wolverine model and MFWP's forest generalist model for its corridor potential, in addition to receiving a moderate score from the Western Governors' Association's centrality model. Lastly, it is an area identified as important for connectivity in the Kootenai National Forest's revised Land and Resource Management Plan (Forest Plan). MS 6 is close to the Kootenai River. Milepost 25.4 is a known bighorn sheep crossing site. In addition, the Coeur d'Alene salamander, *Plethodon idahoensis*, is known to exist in this area and is a species of conservation concern. The state of Montana's Kootenai-Falls Wildlife Management Area and Kootenai National Forest lands are along the highway in this MS.

BEST MITIGATION LOCATION

Building any wildlife crossing structure in this area would be difficult due to the tight terrain created by the Kootenai River and the railroad on the north side of Highway 2 and steep slopes to the south. The best location for wildlife mitigation is where the Williams Creek drainage intersects the highway and the creek flows under the highway.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
The Williams Creek drainage is the only area of varied terrain where a crossing structure—preferably a new bridge, or an extension or lengthening of the current structure—could be designed to allow both the creek and wildlife to pass under the highway and fit within the topographic constraints. The structure should also have fences to guide animals to the underpass along this busy highway segment.

SHORT-TERM:
The MS is in a highway corridor where recreational use is very high in the summer, the

same time when bears are also active. Kootenai Falls viewing, boating access, fishing, and many other activities in the MS and adjacent areas could justify traffic calming for a reasonable length of Highway 2 surrounding MS 6 (i.e., lowering speed limits to 45 mph, adding new wildlife warning signs, alerting drivers to upcoming recreational use). In combination, these mitigation measures would benefit both human and wildlife safety.

MITIGATION SITE 7

Northwest of Troy on Highway 2, mileposts 8-9, Lincoln County

Figure 45: Typical heavily forested roadsides along Highway 2 northwest of Troy, MT, within Mitigation Site 7.

OVERVIEW

The importance for connectivity across Highway 2 in this MS is based on the grizzly bear zone model, as well as on a high ranking from the Western Governors' Association's centrality model. Less than a mile west of the MS are 80 acres of private land owned by a grizzly bear conservation group, Vital Ground, which has an easement on the property. A private timber company also has secured conservation easements on its lands in the area. The Kootenai National Forest is a major landowner along this section of Highway 2. Just to the west of MS 7, at milepost 6.3, the Yaak River crosses under Highway 2.

BEST MITIGATION LOCATION

MS 7 is densely forested and has flat terrain along the highway. Therefore, there is no particular location that is ideal for wildlife mitigation. It simply needs to be located where public lands or conservation easements are on both sides of the highway to assure the long-term protection from development of the adjacent lands.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
As is the case with other flat and forested MSs in the project area, an overpass is the preferred wildlife structure for such terrain. It should also include wing fencing to direct animals to its location.

SHORT-TERM:
If wildlife-vehicle collisions are determined to be a problem in this MS, and AADT exceeds 3,000, then a variable message sign should be deployed. Messages should describe the number of animals and the species killed along this section of Highway 2.

MITIGATION SITE 8a

South of Libby on Highway 2, mileposts 49-50, Lincoln County

Figure 46: Mix of private and public lands along Highway 2 within Mitigation Site 8a in Lincoln County, MT.

OVERVIEW

MS 8a is an important area for connectivity based on the grizzly bear linkage model. This site has also had telemetry data from grizzly bear collars (Kasworm et al. 2012) from which crossings of Highway 2 in this area were inferred. The wolverine model (Schwartz et al. 2009) shows this as an important corridor for that species. There are also significant wetlands in the area that are habitat for a multitude of species.

On public lands to the west of the MS, there is the possibility of a mine expansion that would greatly increase traffic volumes in the future. Since mine development is not imminent, however, it was not included in the traffic volume model. Much of the

MS has private lands along the highway, making land security for a wildlife crossing structure poor.

MS 8a currently has narrow shoulders, is located along a small creek, and has various ranches along the highway and dotted throughout the adjacent landscape (Figure 46). It was obvious from the field review that this highway segment is actively being reconstructed. MDT is moving a creek from its current location, and the highway is being realigned and reconstructed within the MS.

BEST MITIGATION LOCATION

It was difficult to establish land ownership in the field, so identifying an exact mitigation location was problematic. Since the highway reconstruction is not complete, it would be ideal to re-visit the site for a post-construction mitigation recommendation in 2015 to determine the best location.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
Wildlife mitigation should be considered after the Highway 2 reconstruction project is completed in this MS. A wildlife crossing should be located where Kootenai National Forest lands are located on both sides of the highway. Due to steep slopes on the west side of the highway (Figure 46), an overpass may be the best option for this section of highway. If a crossing structure is deemed too difficult to deploy due to slope instability or other geologic considerations not available for this study, the next option would be to deploy an animal detection—driver warning system when AADT exceeds 3,000.

SHORT-TERM:
MS 8a is currently being reconstructed by MDT. Since post-construction mitigation would be an ideal time to implement wildlife mitigation, there would be no need for short-term measures.

MS 8a is an important area for connectivity based on the grizzly bear linkage model.

MITIGATION SITE 8b

South of Libby on Highway 2, mileposts 56-57, Lincoln County

Figure 47: Typical road segment within Mitigation Site 8b on Highway 2 south of Libby, MT.

OVERVIEW

MS 8b is located on a long, straight highway section passing through primarily forested lands, some regenerating from previous clear cuts. It is near the Fisher River which parallels the highway at this location. Ownership of the forest on both sides of MS 8b is a mixture of private forest lands and the Kootenai National Forest. This site was identified as important for connectivity based on the grizzly bear model (Proctor et al. manuscript in preparation), MFWP's forest generalist model, and due to the topography of the Fisher River drainage nearby that is followed by wildlife.

BEST MITIGATION LOCATION

Given the long, straight, flat nature of this MS, there are no obvious topographic features, such as a stream, to locate a mitigation structure. Therefore, the most important factor for location is to assure roadside security, by selecting a location with public lands on both sides of the highway within the MS.

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
A wildlife overpass on a highway section where the Kootenai NF owns land on both sides of the highway would be the best long-term solution to mitigate MS 8b.

SHORT-TERM:
Variable message signs are an option as AADTs

continue to increase from present levels. This section may also require traffic calming, since this straight section of highway allows motorists to travel at high speeds. It may be necessary to set night time maximum speeds at 45 miles per hour, so that drivers have more time to react to wildlife on the highway, particularly around dusk and dawn. If AADT exceeds 3,000, it may be necessary to implement an animal detection – driver warning system.

MITIGATION SITE 9

Between Libby and Kalispell on Highway 2, mileposts 81–84, Flathead County

Figure 48: The best location for retrofitting a fill slope in a natural drainage with a wildlife underpass (i.e., large culvert, arched bridge) within Mitigation Site 9 on Highway 2.

OVERVIEW

MS 9 is located along a three-mile section of Highway 2 east of its junction with Route 556 in the Chain of Lakes area. Most of the MS is forested on both sides of the highway, and it has few drainages passing under the road bed. On the east side of MS 9, around mile marker 84, there is steep, rugged terrain on the south side of Highway 2 making it difficult for wildlife mitigation. It was identified as a wildlife crossing area by the grizzly linkage zone study (Proctor et al. in review) and MFWP's forest generalist model. Traffic is projected to be relatively high (2,500 – 3,500 AADT) on this highway segment in the next 20 years.

BEST MITIGATION LOCATION

The best location is directly west of the junction of Highway 2 and Route 556 (Figure 48). At this locale, Highway 2 was constructed with a large amount of fill to keep the roadbed at a consistently sloped grade. Wildlife naturally flows down the unnamed drainage at this site (to the left of the guard rail in Figure 48).

WILDLIFE MITIGATION OPTIONS

LONG-TERM:
An underpass on Highway 2 employing an arched span or large culvert would be very easy to deploy at this location. Wing fencing to guide animals to the structure would be difficult, since Route 556 is immediately west and a MDT structure and yard lie to the east. Below the crossing area is a private meadow that appears attractive to ungulates. Deer tracks observed on both sides of guard rail indicate wildlife use and crossings in this area.

SHORT-TERM:
A relatively simple short-term mitigation measure could be traffic calming or variable message signs deployed when traffic is especially heavy. Since the MS is at the junction of two highways, a speed zone of 40-45 miles per hour could be established one-half mile in either direction of the junction on Highway 2 and Route 556, possibly with rumble strips since the highway is designed for higher speeds and drivers may not adhere to the slower posted speeds.

An underpass on Highway 2 employing an arched span or large culvert would be very easy to deploy at this location.

9. COOPERATIVE PLANNING OPPORTUNITIES

9.1. Planning Opportunities

The results of this study address wildlife habitat connectivity and where habitat linkages are most likely to be threatened by increased future traffic. The roads in this study are largely under the jurisdiction of the Montana Department of Transportation, although adjacent lands have an array of ownership. To that end, future highway improvements will need to include cooperation from adjacent land managers—some of whom, like the U.S. Department of Agriculture, U.S. Forest Service (USFS), the Montana Department of Natural Resources, the U.S. National Park Service, or the Montana Department of Fish, Wildlife & Parks (MFWP), have an interest in protecting wildlife and their movement. There are several agencies and entities that could use the results of this study to inform their planning efforts. Additionally, this report could be used in the development of future federal or state Environmental Impact Statements (EIS) or influence actions under the National Environmental Policy Act (NEPA) and the state equivalent MEPA.

9.1.1. Cooperative planning opportunities-local governments

Local governments in Flathead and Lincoln counties are projected to experience population growth in the next decades. Where this population growth is located on the landscape can have far-reaching consequences both for the community and for the area's wildlife. Some growth patterns may have more impacts on wildlife and may produce higher incidences of wildlife-vehicle conflicts than others. This report could help inform future growth policy updates and subsequent code amendments so that habitat connectivity and the safety of both wildlife and humans can be considered during those updates.

A growth policy, known as a "comprehensive plan" in other states, is the long-term vision that an individual community develops to describe how that community would like to grow. Both Flathead and Lincoln counties have adopted growth policies. Flathead County: http://flathead.mt.gov/planning_zoning/growth_resolution2015a.php, Lincoln County: http://www.lincolncountymt.us/planning/2009-LINCOLNCOUNTYGROWTHPOLICY.pdf

It is important to note that a growth policy is not a regulatory document but rather a guide for local elected officials to use when they face decisions about the physical development of their community. Per state statute, growth policies must meet certain minimum requirements for content, which include elements that can directly address wildlife connectivity issues such as:

- a community's goals and objectives as they relate to wildlife and wildlife habitat;
- maps and narrative describing the community's natural resources, including wildlife and wildlife habitat;
- projected trends, including those for population growth and traffic projections;
- a narrative describing the policies and regulations that could be used to achieve the goals and objectives; and
- a narrative of how a governing body will evaluate and make decisions regarding proposed subdivisions with respect to the review criteria established in the Montana Subdivision and Platting Act (these criteria include, among other things, the natural environment; wildlife and wildlife habitat; and public health and safety, all of which are at the heart of this report).

Again, it is important to note that a growth policy in and of itself is not a regulatory document, and the guidance found in it can only be implemented through the use of tools such as subdivision and zoning regulations.

SUBDIVISION REGULATIONS

Mandatory under statute for all local governments in Montana, including both Flathead and Lincoln counties, subdivision regulations direct the process of dividing land into lots and providing public infrastructure and facilities to those lots. As the primary mechanism for Montana's local governments to review and approve new developments, these regulations also represent local governments' key tool for preventing or minimizing adverse impacts on public health and safety, the natural environment, and wildlife.

It is important to note that subdivision regulations are not designed to nor can they control changes in land use; they can only address issues such as subdivision design and adequate facilities and services. Mitigation for the impacts of new subdivisions on wildlife can run the gamut, from such things as imposing requirements for building setbacks from riparian areas to constructing wildlife-friendly fencing within a subdivision. In the case of protecting wildlife habitat connectivity, subdivision regulations could include a provision to require a traffic study if a development might cause traffic levels to impact wildlife. Such a study would either show no impact, or recommend ways to mitigate an impact.

ZONING REGULATIONS

Flathead County has a limited amount of zoning, primarily associated with the areas near or adjacent to the cities of Columbia Falls, Kalispell, and Whitefish. Lincoln County does not have any zoning regulations at this time. When, or if, zoning regulations are adopted in the study area, this report could inform decisions about identifying appropriate areas for intense or low-impact development standards.

9.1.2. Cooperative planning opportunities - state agencies

MONTANA DEPARTMENT OF FISH, WILDLIFE & PARKS

Despite having the legal authority to enact subdivision regulations, local governments through the years have struggled to find effective and legally defensible steps to mitigate the impacts of new subdivisions upon wildlife. To assist them, the Montana Department of Fish, Wildlife & Parks initiated a process several years ago to develop a recommended set of defensible standards that local governments could voluntarily adopt into their subdivision regulations to use when reviewing subdivisions located within wildlife habitat. Released in April of 2012, *Fish and Wildlife Recommendations for Subdivision Development in Montana* was the culmination of years of work by MFWP staff and many others to develop a set of draft standards that, in the words of the introduction to the document, would:

> generate an open discussion on the implementation of consistent fish and wildlife conservation recommendations for subdivision development in Montana. The recommendations are designed to help guide fish and wildlife professionals, and to help inform municipal and county leaders and land developers.

These recommendations provide very comprehensive guidance to communities wishing to better mitigate the impacts of residential development upon wildlife and their habitat (MFWP 2012).

Additionally, Montana Fish, Wildlife & Parks has adopted a *Grizzly Bear Management Plan for Western Montana*, which includes road density recommendations and supports collaboration with other agencies, including MDT. The plan states that,

> FWP will work with the Montana Department of Transportation and the Western Federal Lands Highway Division to address wildlife crossing needs on their projects. A Memorandum of Understanding (MOU) or other agreement may be developed to provide guidelines to enhance the ability of bears and other wildlife to cross roads and reduce habitat fragmentation (MFWP 2006).

This report may be able to inform a collaborative discussion to help reduce habitat fragmentation during future planning processes.

DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION (DNRC)

The Montana DNRC controls a large swath of state trust land along Highway 93 between Whitefish and Eureka known as the Stillwater Management Zone (SMZ). The SMZ is part of the Montana DNRC Forested State Trust Lands *Habitat Conservation Plan* (HCP), adopted in 2011. This plan limits the density of new roads and intends to maintain habitat connectivity for wildlife species including grizzly bears and lynx.

Knowing that conserving habitat connectivity within the SMZ is a goal of the DNRC, this report could serve as a resource to help implement that goal.

MONTANA DEPARTMENT OF TRANSPORTATION (MDT)

The Statewide Transportation Improvement Program (STIP) publication is required by the federal government to identify funding obligations for MDT over a three-year period for improvements to Montana's transportation system, particularly its highways. Although the projects and dates in the STIP are MDT objectives, the execution of this program is contingent on a number of factors, including federal and state funding availability, right-of-way acquisition, utility relocations, environmental review, surveying, and design.

TransPlan21, a state-wide transportation plan, identifies wildlife-vehicle collisions as a threat to human and wildlife safety. Action A.8. in the plan states, "Continue to monitor and evaluate animal and vehicle crash mitigation research methods and projects in Montana" (MDT 2007). Wildlife collisions are just one threat to traveler safety, and MDT must consider a suite of other considerations. By distilling information on habitat connectivity in the area and helping prioritize mitigation opportunities, this report can provide a reference for MDT officials to use when proposing future improvements to highways in the study area.

Where wildlife issues are a priority for projects identified in the STIP, MDT could use the analysis provided by this report to take the necessary steps to ensure wildlife issues are considered early in the transportation planning process. Successfully mitigating impacts early on will make northwestern Montana's highways safer for the motoring public as well as for wildlife.

9.1.3. Cooperative planning opportunities – federal land management agencies

UNITED STATES FOREST SERVICE

Each National Forest must produce a forest-specific Land Resource and Management Plan (LRMP), "which, under the newly issued Forest Planning regulations, must incorporate the needs for ecological connectivity into its future management actions." The 2012 National Forest Management Act (NFMA) planning rule (36 Code of Federal Regulations [CFR] Part 219) governing the Flathead National Forest revision enables proactive planning and the chance to manage and evaluate the effectiveness of connectivity as a landscape-scale conservation strategy. Using the best available scientific information will provide the opportunity to project into the future and make the best planning decisions. The planning process and subsequent implementation allows managers to maintain habitat connectivity through a proactive process and effectively prepare for future conditions whether they are within Forest Service boundaries or border non-National Forest property. Maintaining these habitat connections improves landscape integrity and sustains wildlife populations.

The Kootenai National Forest recently revised its forest plan (LRMP) and the Flathead National Forest is in the process of revising its LRMP. The recently revised Kootenai National Forest Plan generally provides that, "During the construction or reconstruction of highways that cross national forest lands, or high use forest roads, wildlife crossing features should be included in the design where necessary to contribute to connectivity of wildlife populations" (USFS 2013). Additionally, it states, "In wildlife linkage areas identified through interagency coordination, federal ownership should be maintained" (USFS 2013). This evaluation would assist the Kootenai and Flathead National Forests with implementation of standards in the *Northern Rockies Lynx Management Directive* (USFS 2007), including Standard LINKS1 ("When highway or forest highway construction or reconstruction is proposed in linkage areas, identify potential highway crossings") and Standard ALLS1 ("New or expanded permanent development and vegetation management projects must maintain habitat connectivity in an LAU [Land Area Unit] and/or linkage area").

The information from this report can help inform the future revisions and implementation of National Forest plans in these areas so they incorporate methods to maintain habitat connectivity across National Forest lands and between National Forest lands and adjacent habitats. Thus, mitigating highways for connectivity is well within the interests of KNF and FNF. Incorporating information from this study that projects impacts of traffic over the next 20 years into the LRMP can help inform future management actions for the identified highway segments and their adjacent lands.

NATIONAL PARK SERVICE

Glacier National Park is within the study area and is inherently part of the intact habitat that this report seeks to keep connected to other large swaths of high-quality habitats. Recognizing that the importance of the habitats protected within their system does not end at the its borders, the National Park Service's planning documents include a discussion of the importance of keeping Park Service habitat connected to other habitats. Glacier National Park's *General Management Plan* (GMP) considers the connectivity of habitat across boundaries and roads. It promotes cooperation with other agencies and recognizes the Park's importance in the general recovery of grizzlies in northwest Montana. Increasing traffic on roads surrounding Glacier National Park could potentially isolate populations of wildlife inside, and outside, of the park. This report offers opportunities to corroborate the GMP and gives specific ideas for how to maintain connected habitat in particular locations on Highway 2 and on the outside North Fork Road.

9.1.4. Other entities

Other non-public entities concerned about wildlife habitat connectivity and road safety may also find this report useful as a resource. Land trusts such as Vital Ground, the Flathead Land Trust, the Montana Nature Conservancy, and the Montana Land Reliance work in the study area and promote habitat conservation and connectivity, mostly through the purchase of conservation easements (MFWP 2006).

The Great Northern Environmental Stewardship Area (GNESA) is a cooperative organization encompassing public and private entities working on habitat conservation in the Middle Fork of the Flathead drainage. This area includes critical wildlife habitat. GNESA has already provided data useful in making habitat management decisions in the area and continues to support collaborative efforts and open dialogue that leads to positive wildlife outcomes (MFWP 2006). We hope this group will consider the information from this report to guide future activities.

The Plum Creek Timber Company (PCTC 1997) has implemented voluntary grizzly habitat guidelines in its *Grizzly Bear Management Best Management Practices*. While these practices are primarily designated in site-specific areas, Plum Creek and The Nature Conservancy are also part of the *Swan Valley Grizzly Bear Conservation Agreement* (1997) which also includes the Montana DNRC, the Flathead National Forest, and conservation easements on private lands in the Swan Valley. This agreement manages conservation on an ecosystem scale and includes maintaining habitat linkages zones (PCTC 1997). The transfer of PCTC lands to some of these other landowners through the Legacy Lands project also provides an opportunity to maintain or enhance connectivity in the future.

9.2. Partnerships Needed for Future Wildlife Mitigation Projects

Obtaining funding for wildlife mitigation for highways via traditional transportation programs will be increasingly challenging given the shrinking budgets of state and federal transportation agencies. There have been no solutions to reinvigorate the declining Highway Trust Fund, the primary source of funding for roads. Since state departments of transportation budgets are largely dependent on federal funding, the future appears bleak. The Congressional Budget Office (CBO 2013) predicted that the Highway Trust Fund will have insufficient funds to meet all of its obligations by federal Fiscal Year 2015. Thus, future wildlife mitigation may require a broadening of interests and funding sources to supplement traditional transportation resources.

The focus of this project was to identify mitigation opportunities at locales that will help maintain highway permeability for rarer species, particularly carnivores. Such mitigation directed for these species, if designed properly, will also benefit many other species. Because the intent of the report was to identify mitigation opportunities focused on wildlife conservation rather than on reducing WVCs for motorist safety, obtaining transportation funding may be even more challenging. Therefore, it may be that a greater variety of funding sources will need to be identified to help implement wildlife crossings, fencing, and other related mitigation measures in the future, particularly when these measures are focused on rarer species, conservation, and connectivity.

Highway projects that include wildlife mitigation or stand-alone wildlife mitigation projects in the two-county project area may require MDT to develop partnerships that can help diversify access to funding and grants. That way, wildlife mitigation projects would not only rely on a mix of the traditional transportation programs, but could also add funding from non-transportation agencies and other interested non-transportation partners. The fact that the benefits from the mitigation infrastructure reach well beyond the realm of the transportation sector by providing wildlife conservation, including the protection of threatened and/or endangered species, improved habitat, and landscape permeability creates an opportunity to develop new partnerships that can access resources of non-transportation agencies. These partners could include wildlife agencies, land management agencies, the Environmental Protection Agency, BNSF Railway, counties, non-governmental organizations, conservation groups, philanthropic foundations, corporations, non-motorized recreationists (for multi-functional crossings), and/or a variety of private landowners. This mix of federal, state, local, and private organizations working together would help maximize the sources of funding that could be utilized to implement the wildlife mitigation options detailed in this report.

One such exemplary project has already been completed on Montana Highway 206, in the Flathead Valley outside of the project area. When MDT was developing its slope-flattening project on Highway 206, local ranch owners were interested in creating a wildlife crossing and fencing that would also benefit their livestock. As a result, a 2.7 meter (9 feet) high by 4 meter (13 feet) wide underpass and wing fencing were added to the original project's design. On the lands adjacent to the crossing site, ranchers Jay and Sandy Whitney put a conservation easement on 80 acres to assure no future development adjacent to the crossing. A wide mix of public and private contributors provided the $165,000 needed to fund the wildlife mitigation project, including: the Whitneys, Flathead County Commissioners, American Wildlands, Yellowstone to Yukon Conservation Initiative, Wildlife Land Trust, Northern Rockies Conservation Cooperative, Friends of the Wild Swan, Swan View Coalition, Montana Backcountry Hunters and Anglers, 16 individuals and ranches, the Montana Department of Fish, Wildlife & Parks, and a Community Transportation Enhancement Program grant.

Such a broad convergence of interests and joint fundraising demonstrates what may be possible for future wildlife mitigation in the project area.

Lynx on a highway overpass. Photo: HighwayWilding.org

10. REFERENCES

Alexander, S., N. Waters and P. Paquet. 2005. Traffic volume and highway permeability for a mammalian community in the Canadian Rocky Mountains. The Canadian Geographer/Le Géographe Canadien, 49(4): 321-331.

Andelt, W. and P. Gipson. 1979. Home range, activity, and daily movements of coyotes. Journal of Wildlife Management, 43 (4): 944-951.

Anderson, D., J. Forester, M. Turner, J. Frair, E. Merril, D. Fortin, J. Mao and M. Boyce. 2005. Factors influencing female home range sizes in elk (Cervus elaphus) in North American landscapes. Landscape Ecology, 20: 257–271.

Andrews, A. 1990. Fragmentation of habitat by roads and utility corridors: A review. Australian Journal of Zoology, 26:130-141.

Apps, C.D. 2000. Space-use, diet, demographics, and topographic associations of lynx in the southern Canadian Rocky Mountains: a study. pp 351-371. In: Ruggiero, L., Aubry, K., Buskirk, S., Koehler, G., Krebs, C., McKelvey, K. and J. Squires. Ecology and conservation of lynx in the United States. General Technical Report RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Baker, R. 1978. Evolutionary ecology of animal migration. Holmes and Meier Publishers, New York, NY. 1012 pp.

Banci, V. and A. Harestad. 1990. Home range and habitat use of wolverines (Gulo gulo) in Yukon, Canada. Holarctic Ecology, 13 (3): 195-200.

Barrueto, M., A. Ford, and A. Clevenger. 2014. Anthropogenic effects on activity patterns of wildlife at crossing structures. Ecosphere, 5(3): art27.

Bennett, A. 1991. Roads, roadsides and wildlife conservation: A review. In: Saunders, D.A. and R.J. Hobbs, editors. Nature Conservation 2: The Role of Corridors. Chipping Norton, Australia: Surrey Beatty. p. 99-117.

Berger, A. 2012. A Travel demand model for rural areas. Master's Thesis, Montana State University, Civil Engineering Department, Bozeman, MT.

Berger, J. 2007. Fear, human shields and the redistribution of prey and predators in protected areas. Biology Letters, 3(6): 620-623.

Berger, J. 2004. The last mile: How to sustain long-distance migration in mammals. Conservation Biology, 18 (2): 320-331.

Bissonette, J. and M. Hammer. 2000. Effectiveness of earthen ramps in reducing big game highway mortality in Utah: Final Report. Utah Cooperative Fish and Wildlife Research Unit Report Series, 2000 (1): 1-29.

Brand, C., L. Keith and C. Fischer. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. Journal of Wildlife Management, 40 (3): 416-428.

CBO (Congressional Budget Office). 2013. Statement for the record, status of the highway trust fund. Sarah Puro, Analyst for surface transportation programs, for the Committee on the Budget, U.S. House of Representatives, April 24, 2013. 6 pp.

Chomitz, K., and D. Gray. 1996. Roads, land use, and deforestation: a spatial model applied to Belize. The World Bank Economic Review, 10: 487-512.

Chruszcz, B., A. Clevenger, K. Gunson and M. Gibeau. 2003. Relationships among grizzly bears, highways, and habitat in the Banff-Bow Valley, Alberta, Canada. Canadian Journal of Zoology, 81: 1378-1391.

Clevenger, A. and N. Waltho. 2000. Factors influencing the effectiveness of wildlife underpasses in Banff National Park, Alberta, Canada. Conservation Biology, 14(1): 47-56.

Clevenger, A., B. Chruszcz and K. Gunson. 2001. Highway mitigation fencing reduces wildlife–vehicle collisions. Wildlife Society Bulletin, 29: 646–653.

Clevenger, A., R. Long and R. Ament. 2008. I-90 Snoqualmie Pass East wildlife monitoring plan. Prepared for the Washington Department of Transportation, Yakima, Washington. 47 pp.

Clevenger, A., A. Ford and M. Sawaya. 2009. Banff wildlife crossings project: Integrating science and education in restoring population connectivity across transportation corridors. Final report to Parks Canada Agency, Radium Hot Springs, British Columbia, Canada.

Clevenger, T. and M. Huijser. 2011. Handbook for design and evaluation of wildlife crossing structures in North America. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.cflhd.gov/programs/techDevelopment/wildlife/documents/01_Wildlife_Crossing_Structures_Handbook.pdf .

Costello, C., S. Creel, S. Kalinowski, N. Vu and H. Quigley. 2008. Sex-biased natal dispersal and inbreeding avoidance in American black bears as revealed by spatial genetic analyses. Molecular Ecology, 17(21): 4713-4723.

Cushman, S., K. McKelvey and M. Schwartz. 2009. Use of empirically derived source□destination models to map regional conservation corridors. Conservation Biology, 23(2): 368-376.

Dalerum, F., S. Boutin and J. Dunford. 2007. Wildfire effects on home range size and fidelity of boreal caribou in Alberta, Canada. Canadian Journal of Zoology, 85(1):26-32.

Demarchi, R., C. Hartwig and D. Demarchi. 2000. Status of the Rocky Mountain bighorn sheep in British Columbia. Wildlife Society Bulletin, B-99: 56 pp.

Dingle, D. 1996. Migration: the biology of life on the move. Oxford University Press, New York, N.Y.

Dodd, N, J. Gagnon, S. Sprague, S. Boe and R. Schweinsburg. 2011. Assessment of pronghorn movements and strategies to promote highway permeability. U.S. Highway 89. Report No. FHWA-AZ-10-619. Arizona Game and Fish Department. Research Branch, Phoenix, Arizona, USA. http://www.azdot.gov/TPD/ATRC/publications/project_reports/PDF/AZ619.pdf .

Donaldson, B. and N. Lafon. 2008. Testing an integrated PDA-GPS system to collect standardized animal carcass removal data. FHWA/VTRC 08-CR10. Virginia Transportation Research Council, Charlottesville, Virginia, USA.

ElectroBraid. 2008a. Available from the internet: http://www.electrobraid.com/wildlife/highway_fence.html.

ElectroBraid. 2008b. Available from the internet: http://www.electrobraid.com/wildlife/reports/Wasilla_ElectroMAT.pdf.

Epps, C., P. Palsbøll, J. Weyhausen, G. Roderick, R. Ramey and D. McCullough. 2005. Highways block gene flow and cause a rapid decline in genetic diversity of desert bighorn sheep. Ecology Letters, 8: 1029-1038.

Fahrig, L., J. Pedlar, S. Pope, P. Taylor and J. Wegner. 1995. Effect of road traffic on amphibian density. Biological Conservation, 74: 177-182.

Feldhamer, G., J. Gates, D. Harman, A. Loranger and K. Dixon. 1986. Effects of interstate highway fencing on white-tailed deer (*Odocoileus virginianus*) activity. Journal of Wildlife Management, 50 (3): 497-503.

Ford, A. and A. Clevenger. 2010. Validity of the prey-trap hypothesis for carnivore-ungulate interactions at wildlife-crossing structures. Conservation Biology, 24(6): 1679–1685.

Forman, R. 2000. Estimate of the area affected ecologically by the road system in the United States. Conservation Biology, 14: 31-35.

Forman, R. and L. Alexander. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics, 29: 207-31.

Frey, S. and M. Conover. 2006. Habitat use by meso-predators in a corridor environment. Journal of Wildlife Management, 70(4): 1111–1118.

Gavin, S. and P. Komers. 2006. Do pronghorn (Antilocapra americana) perceive roads as a predation risk? Canadian Journal of Zoology, 84: 1775-1780.

Gerlach, G. and K. Musolf. 2000. Fragmentation of landscape as a cause for genetic subdivision in bank voles. Conservation Biology, 14: 1066-1074.

Gese, E., O. Rongstad and W. Mytton. 1988. Home range and habitat use of coyotes in southeastern Colorado. Journal of Wildlife Management, 52 (4): 640-646.

Gibbs, J. and D. Steen. 2005. Trends in sex ratios of turtles in the United States: Implications of road mortality. Conservation Biology, 19: 552–556.

Gibbs, J. and G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology, 16:1647-1652.

Gibeau, M., S. Herrero, B. McLellan and J. Woods. 2001. Managing for grizzly bear security areas in Banff National Park and the Central Canadian Rocky Mountains. Ursus, 12: 121-129.

Gilbert-Norton, L., R. Wilson, J. Stevens and K. Beard. 2010. A meta-analytic review of corridor effectiveness. Conservation Biology, 24(3): 660–668.

Gordon, K. and S. Anderson. 2004. Mule deer use of underpasses in Western and Southeastern Wyoming. In: Proceedings of the 2003 International Conference on Ecology and Transportation, Eds. Irwin C, Garrett P, McDermott KP. Center for Transportation and the Environment, North Carolina State University, Raleigh, NC: pp. 309-318.

Grilo, C., J. Bissonette and M. Santos-Reis. 2008. Response of carnivores to existing highway culverts and underpasses: implications for road planning and mitigation. Biodiversity and Conservation, 17(7): 1685-1699.

Gunther, K., M. Haroldson, K. Frey, S. Cain, J. Copeland and C. Schwartz. 2004. Grizzly bear-human conflicts in the Greater Yellowstone ecosystem, 1992-2000. Ursus, 15(1): 10-22.

Haas, C. and G. Turschak. 2002. Responses of large and medium bodied mammals to recreation activities: the Colima Road underpass. Final report. U.S. Geological Survey, Western Ecological Research Center. Corona, CA, USA.

Hedlund, J., P. Curtis, G. Curtis and A. Williams. 2004. Methods to reduce traffic crashes involving deer: what works and what does not. Traffic Injury Prevention, 5: 122–131.

Heller, N. and E. Zavelata. 2009. Biodiversity management in the face of climate change: a review of 22 years of recommendations. Biological Conservation, 142(2009): 14-32.

Huijser, M. 2000. Life on the edge. Hedgehog traffic victims and mitigation strategies in an anthropogenic landscape. PhD thesis, Wageningen University, Wageningen. Available from the internet: http://edepot.wur.nl/121248.

Huijser, M., P. McGowen, W. Camel, A. Hardy, P. Wright, A. Clevenger, L. Salsman and T. Wilson. 2006. Animal vehicle crash mitigation using advanced technology. Phase I: review, design and implementation. SPR 3(076). FHWA-OR-TPF-07-01, Western Transportation Institute – Montana State University, Bozeman, Montana, USA.

Huijser, M., J. Fuller, M. Wagner, A. Hardy and A. Clevenger. 2007. Animal–vehicle collision data collection. A synthesis of highway practice. NCHRP Synthesis 370. Project 20-05/Topic 37-12. Transportation Research Board of the National Academies, Washington, D.C., USA.

Huijser, M., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A. Clevenger, D. Smith and R. Ament. 2008a. Wildlife-vehicle collision reduction study. Report to Congress. U.S. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available from the internet: http://www.tfhrc.gov/safety/pubs/08034/index.htm.

Huijser, M., K. Paul, L. Oechsli, R. Ament, A. Clevenger and A. Ford. 2008b. Wildlife-vehicle collision and crossing mitigation plan for Hwy 93S in Kootenay and Banff National Park and the roads in and around Radium Hot Springs. Report 4W1929 B, Western Transportation Institute – Montana State University, Bozeman, Montana, USA. Available from the internet: http://www.wti.montana.edu/RoadEcology/Projects.aspx?completed=1.

Huijser, M., P. McGowen, A. Clevenger and R. Ament. 2008c. Best Practices Manual, Wildlife-vehicle Collision Reduction Study, Report to U.S. Congress. Federal Highway Administration, McLean, VA, USA. Available from the internet: http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm.

Huijser, M., J. Duffield, A. Clevenger, R. Ament and P. McGowen. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. Ecology and Society, 14(2): 15. Available from the internet: http://www.ecologyandsociety.org/viewissue.php?sf=41.

Huijser, M., T. Allen, J. Purdum and W. Camel. 2011. Wildlife crossing monitoring and research on the Flathead Indian Reservation between Evaro and Polson, Montana. Annual Report 2011. Western Transportation Institute, College of Engineering, Montana State University, Bozeman, MT, USA. Available from the internet: http://www.mdt.mt.gov/other/research/external/docs/research_proj/wildlife_crossing/phaseii/annual_2011.pdf.

Inman, R., M. Packila, K. Inman, B. Aber, R. Spence and D. McCauley. 2009. Greater Yellowstone Wolverine Program: Progress Report December 2009. Wolverine Program Field Office, Wildlife Conservation Society. Ennis, Montana. 23 pp.

Inman, R., M. Packila, K. Inman, A. Mccue, G. White, J. Persson, B. Aber, M. Orme, K. Alt, S. Cain, J. Fredrick, B. Oakleaf and S. Sartorius. 2012. Spatial ecology of wolverines at the southern periphery of distribution. The Journal of Wildlife Management, 76(4): 778-792.

Inman, R., B. Brock, K. Inman, S. Sartorius, B. Aber, B. Giddings, S. Cain, M. Orme, J. Fredrick, B. Oakleaf, K. Alt, E. Odell and G. Chapron. 2013. Developing priorities for metapopulation conservation at the landscape scale: Wolverines in the Western United States. Biological Conservation, 166: 276-286.

Jones, D. and J. Theberge. 1982. Summer home range and habitat utilization of the red fox Vulpes vulpes in a tundra habitat northwest British Columbia, Canada. Canadian Journal of Zoology, 60 (5): 807-812.

Kasworm, W., H. Carriles, T. Radandt, J. Teisberg, M. Proctor and C. Servheen. 2012. Cabinet-Yaak grizzly bear recovery area 2011 research and monitoring progress report. United States Fish & Wildlife Service. Missoula, Montana. 90 pp.

Kendall, K., J. Stetz, J. Boulanger, A. Macleod, D. Paetkau and G. White. 2009. Demography and genetic structure of a recovering grizzly bear population. Journal of Wildlife Management, 73(1).

Knapp, K., X. Yi, T. Oakasa, W. Thimm, E. Hudson and C. Rathmann. 2004. Deer–vehicle crash countermeasure toolbox: a decision and choice resource. Final report. Report Number DVCIC – 02. Midwest Regional University Transportation Center, Deer–Vehicle Crash Information Clearinghouse, University of Wisconsin-Madison, Madison, Wisconsin, USA.

Knowles, P. 1985. Home range size and habitat selection of bobcats (*Lynx rufus*) in north-central Montana. Canadian Field-Naturalist, 99 (1): 6-12.

Krebs, J., E. Lofroth and I. Parfitt. 2007. Multiscale habitat use by wolverines in British Columbia, Canada. Journal of Wildlife Management, 71(7): 2180–2192.

Kruidering, A., G. Veenbaas, R. Kleijberg, G. Koot, Y. Rosloot and E. Van Jaarsveld. 2005. *Leidraad faunavoorzieningen bij wegen*. Rijkswaterstaat, Dienst Weg-en Waterbouwkunde, Delft, The Netherlands.

Latham, A. 2009. Wolf ecology and caribou-primary prey-wolf spatial relationships in low productivity peatland complexes in northeastern Alberta. PhD Thesis. University of Alberta, Edmonton, Alberta, Canada.

Laundré, J. and B. Keller. 1984. Home range size of coyotes: A critical review. Journal of Wildlife Management, 48 (1): 127-139.

Leach, R. and W. Edge. 1994. Summer home range and habitat selection by white-tailed deer in the Swan Valley, Montana. Northwest Science, 68 (1): 31-36.

Lindstedt, S., B. Miller and S. Buskirk. 1986. Home range, time, and body size in mammals. Ecology, 67 (2): 413-418.

Little, S., R. Harcourt and A. Clevenger. 2002. Do wildlife passages act as prey-traps? Biological Conservation, 107(2): 135-145.

Litvaitis, J., J. Sherburne and J. Bissonette. 1986. Bobcat habitat use and home range size in relation to prey density. Journal of Wildlife Management, 50 (1): 110-117.

Lovallo, M. and E. Anderson. 1996. Bobcat movements and home ranges relative to roads in Wisconsin. Wildlife Society Bulletin, 24: 71-76.

Ludwig, J. and T. Bremicker. 1983. Evaluation of 2.4 m fences and one-way gates for reducing deer vehicle collisions in Minnesota. Transportation Research Record, 913: 19-22.

Lyon, L. 1983. Road density models describing habitat effectiveness for elk. Journal of Forestry, 81: 592-95.

Lyons, R. 2005. Conservation priorities for maintaining large mammal migrations in the Greater Yellowstone. Master's Thesis, Nicholas School of the Environment and Earth Sciences, Duke University, Durham, NC. 38 p.

Mace, R., J. Waller, T. Manley, L. Lyon and H. Zuuring. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains Montana. Journal of Applied Ecology, 1395-1404.

Mackie, R., D. Pac, K. Hamlin and G. Dusek. 1998. Ecology and management of mule deer and white-tailed deer in Montana. Montana Fish, Wildlife and Parks, Wildlife Division, Helena, Montana, USA.

Mawdsley, J., R. O'Malley and D. Ojima. 2009. A review of climate-change adaptation strategies for wildlife management and biodiversity conservation. Conservation Biology, 23 (5): 1080–1089.

McCoy, K. 2005. Effects of transportation and development on black bear movement, mortality, and use of the Highway 93 corridor in northwest Montana. MSc. Thesis, University of Montana, Missoula, MT.

McNally, M. 2000. The Four Step Model. Center for Activity Systems Analysis, Institute of Transportation Studies, UC Irvine. UCI-ITS-AS-WP-00-5.

McRae, B., B. Dickson, T. Keitt and V. Shah. 2008. Using circuit theory to model connectivity in ecology, evolution and conservation. Ecology, 89: 2712-2714.

Mercer, G., J. Whittington, G. Skinner and D. Mucha. 2004. South Jasper woodland caribou research and monitoring program. 2002/03 Progress Report. Jasper National Park, Parks Canada.

DNRC (Montana Department of Natural Resources and Conservation). 2011. Record of Decision, Forested State Trust Lands Habitat Conservation Plan and Environmental Impact Statement. December 19, 2011.

MDT (Montana Department of Transportation). 2013. Montana's Automatic Traffic Records for 2012. March 27, 2013.

MDT (Montana Department of Transportation). 2007. TranPlan21, Traveler Safety, Policy Paper. Amended 2007. Available from the internet: http://www.mdt.mt.gov/publications/docs/brochures/tranplan21/travelersaf.pdf.

MFWP (Montana Fish Wildlife and Parks). 2006. Grizzly bear management plan for western Montana, final programmatic Environmental Impact Statement 2006 – 20016. December, 2006. Available from the internet: http://fwp.mt.gov/fishAndWildlife/management/grizzlyBear/managementPlan.html.

MFWP (Montana Fish, Wildlife, and Parks). 2011. Montana connectivity project: A statewide analysis. Final Report. Helena, Montana. 294 pp.

MFWP (Montana Fish, Wildlife, and Parks). 2012. Fish and wildlife recommendations for subdivision development in Montana: A working document. Montana Fish, Wildlife & Parks, Helena, Montana.174 pp. Available from the internet: http://fwp.mt.gov/fishAndWildlife/livingWithWildlife/buildingWithWildlife/subdivisionRecommendations/documents.html.

Moriarty, K., W. Zielinski, A. Gonzales, T. Dawson, K. Boatner, C. Wilson, F. Schlexer, K. Pilgrim, J. Copeland and M. Schwartz. 2009. Wolverine confirmation in California after nearly a century: native or long-distance immigrant? Northwest Science, 83 (2): 154-162.

Muhly, T., C. Semeniuk, A. Massolo, L. Hickman and M. Musiani. 2011. Human activity helps prey win the predator-prey space race. PLoS, 6(3): e17050. doi:10.1371/journal.pone.0017050

Mumme, R., S. Schoech, G. Woolfenden and J. Fitzpatrick. 2000. Life and death in the fast lane: demographic consequences of road mortality in the Florida scrub-jay. Conservation Biology, 14: 501-12.

Mundinger, J.1981. White-tailed deer reproductive biology in the Swan Valley, Montana. Journal of Wildlife Management, 45 (1): 132-139.

Mysterud, A., F. Pérez-Barbería and I. Gordon. 2001. The effect of season, sex and feeding style on home range area versus body mass scaling in temperate ruminants. Oecologia, 127: 30-39.

NCHRP (National Cooperative Highway Research Program). 1998. Travel estimation techniques for urban planning. NCHRP Report 365, National Academy Press, Washington, DC.

NCHRP (National Cooperative Highway Research Program). 2012. Travel demand forecasting: Parameters and techniques. NCHRP Report 716, National Academy Press, Washington, DC.

NFMA (National Forest Management Act Of 1976) of October 22, 1976. (P.O. 94-588, 90 Stat. 2949, as amended; 16U.S.C.).

NPS (National Park Service). 2007. Wildlife crossings along US Highway 2 and the BNSF Railroad within the GNESA corridor, Montana. Great Northern Environmental Stewardship Area vector digital data. Glacier National Park. West Glacier, Montana.

Northrup, J., J. Pitt, T. Muhly, G. Stenhouse, M. Musiani and M. Boyce. 2012. Vehicle traffic shapes grizzly bear behavior on a multiple-use landscape. Journal of Applied Ecology, 49: p1159-1167. 2012

Noss, R., H. Quigley, M. Hornocker, T. Merrill and P. Paquet. 1996. Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology, 10: 949-963.

PCTC (Plum Creek Timber Company, Montana DNRC, Flathead National Forest, U.S. Fish and Wildlife Service). 1997. Amended and Restated Conservation Agreement. June 6, 1997. Available from the internet: https://dnrc.mt.gov/Forestry/Assistance/Stewardship/Documents/SwanAgmt97.pdf.

Poole, K. 1997. Dispersal patterns of lynx in the Northwest Territories. The Journal of Wildlife Management, 497-505.

Proctor, M., B. McLellan, C. Strobeck and R. Barclay. 2004. Gender-specific dispersal distances of grizzly bears estimated by genetic analysis. Canadian Journal of Zoology, 82(7): 1108-1118.

Proctor, M. and C. Servheen. 2012. De-fragmenting the West: providing adaptive options for grizzly bears to respond to climate change. Great Northern Landscape Conservation Cooperative webinar. Mar 14, 2012. Available from the internet: http://greatnorthernlcc.org/event/226.

Reed, D., T. Pojar and T. Woodard. 1974. Use of 1 way gates by mule deer. Journal of Wildlife Management, 38 (1): 9-15.

Reeve, A. and S. Anderson. 1993. Ineffectiveness of Swareflex reflectors at reducing deer–vehicle collisions. Wildlife Society Bulletin, 21: 127–132.

Riley, S. and A. Marcoux. 2006. Deer–vehicle collisions: an understanding of accident characteristics and drivers' attitudes, awareness and involvement. Research report RC-1475. Department of Fisheries and Wildlife, Michigan State University, East Lansing, Michigan, USA.

Roesch, M. 2006. Identifying wildlife crossing zones for the prioritization of highway mitigation measures along U.S. Highway 2: West Glacier, MT to Milepost 193. Professional paper. The University of Montana. Missoula, Montana. 53 pp.

Roever, C., M. Boyce and G. Stenhouse. 2010. Grizzly Bear Movements Relative to Roads: Application of Step Selection Functions. Journal of Ecography, 33: 1113-1122.

Ross, P. and M. Jalkotzy. 1992. Characteristics of a hunted population of cougars in southwestern Alberta. Journal of Wildlife Management 56 (3): 417-426.

Rowland, M., M. Wisdom, B. Johnson and J. Kie. 2000. Elk distribution and modeling in relation to roads. Journal of Wildlife Management, 64: 672-684.

Sawaya, M., A. Clevenger and S. Kalinowski. 2013. Demographic connectivity for ursid populations at wildlife crossing structures in Banff National Park. Conservation Biology, 27(4): 721-730.

Sawaya, M., S. Kalinowski and A. Clevenger. 2014. Genetic connectivity for two bear species at wildlife crossing structures in Banff National Park. Proceedings of the Royal Society B: Biological Sciences, 281(1780): 20131705.

Sawyer, H. and B. Rudd. 2005. Pronghorn roadway crossings: A review of available information and potential options. Western EcoSystems Technology, Inc., Cheyenne, Wyoming, USA. Available on the internet: http://www.west-inc.com/reports/pronghorn_report_final.pdf .

Schwartz, M., J. Copeland, N. Anderson, J. Squires, R. Inman, K. McKelvey, K. Pilgrim, L. Waits and S. Cushman. 2009. Wolverine gene flow across a narrow climatic niche. Ecology, 90(11): 3222-3232.

Servheen, C. 1983. Grizzly bear food habits, movements, and habitat selection in the Mission Mountains, Montana. Journal of Wildlife Management, 47 (4): 1026-1035.

Sielecki, L. 2004. WARS 1983–2002—Wildlife accident reporting and mitigation in British Columbia: Special annual report. Ministry of Transportation, Engineering Branch. Environmental Management Section. Victoria, British Columbia, Canada.

Singer, F. and J. Doherty. 1985. Movements and habitat use in an unhunted population of mountain goats Oreamnos americanus. Canadian Field Naturalist, 99 (2): 205-217.

Spreadbury, B., K. Musil, J. Musil, C. Kaisner and J. Kovak. 1996. Cougar population characteristics in southeastern British Columbia. Journal of Wildlife Management, 60 (4): 962-969.

Squires, J. and T. Laurion. 2000. Lynx home range and movements in Montana and Wyoming: preliminary results. In: Ruggiero et al., eds. Ecology and conservation of lynx in the United States. pp 337-349. In: Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, G.M. Koehler, C.J. Krebs, K.S. McKelvey & J.R. Squires. Ecology and conservation of lynx in the United States. General Technical Report RMRS-GTR-30WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Squires, J., N. DeCesare, L. Olson, J. Kolbe, M. Hebblewhite and S. Parks. 2013. Combining resource selection and movement behavior to predict corridors for Canada lynx at their southern range periphery. Biological Conservation, 157: 187-195.

Sweanor, L., K. Logan and M. Hornocker. 2000: Cougar dispersal patterns, metapopulation dynamics, and conservation. Conservation Biology, 14: 798-808.

Tardif, L-P & Associates Inc. 2003. Collisions involving motor vehicles and large animals in Canada. Final report. L-P Tardif and Associates Inc., Nepean, Ontario, Canada.

Taylor, P., L. Fahrig, K. Henein and G. Merriam. 1993. Connectivity is a vital element of landscape structure. Oikos, 571-573.

Ujvári, M., H. Baagøe and A. Madsen. 1998. Effectiveness of wildlife warning reflectors in reducing deer–vehicle collisions: a behavioural study. Journal of Wildlife Management, 62: 1094–1099.

US DOI (United States Department of Interior). 2013. Endangered and threatened wildlife and plants: Threatened status for the distinct population segment of the North American wolverine occurring in the contiguous United States. 78 Federal Register 23 (February 4, 2013). Pp 7864-7890.

USFWS (United States Fish and Wildlife Service). 2013. NCDE Grizzly bear conservation strategy – draft. U.S. Fish and Wildlife Service, April 2013. Available on the internet: http://www.fws.gov/mountain-prairie/species/mammals/grizzly/NCDE_Draft_CS_Apr2013_Final_Version_corrected_headers.pdf.

USFS (United States Forest Service). 2013. Kootenai National Forest Land Management Plan (KNF LMP). 2013 Revision.

USFS (United States Forest Service). 2007. Northern Rockies Lynx Management Direction Record of Decision. March 2007. Available on the internet: http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5277399.pdf .

van der Grift. E.A., J. Dirksen, F. Ottburg and R. Pouwels. 2010. Recreatief medegebruik van ecoducten; effecten op het functioneren als faunapassage. Alterra-rapport 2097. Alterra Wageningen UR, Wageningen, The Netherlands.

Vander Way, A. (2012) Typical occupancy rates used by Montana Department of Transportation [personal communication].

Van Dyke, F., W. Klein and S. Stewart. 1998. Long-term range fidelity in Rocky Mountain elk. Journal of Wildlife Management, 62 (3): 1020-1035.

Vokurka, C. and R. Young. 2008. Relating vehicle-wildlife crashes to road reconstruction. TRB 2008 Annual Meeting CD-ROM, Transportation Research Board, 86th Annual Meeting, January 13-17, 2008, Washington, DC, USA.

Waller, J. 2014. Raw data provided by personal communication.

Waller, J and C. Servheen. 2005. Effects of transportation infrastructure on grizzly bears in northwestern Montana. Journal of Wildlife Management, 69: 985-1000.

Wayne, R., N. Lehman, M. Allard and R. Honeycutt. 1992. Mitochondrial DNA variability of the gray wolf: Genetic consequences of population decline and habitat fragmentation. Conservation Biology, 6: 559-569.

Weir, R. and F. Corbould. 2010. Factors affecting landscape occupancy by fishers in north-central British Columbia. Journal of Wildlife Management, 74(3): 405-410.

WGA (Western Governors' Association) Wildlife Council. 2013. Crucial habitat assessment tool. Available on the internet: http://www.westgovchat.org .

WGA (Western Governors' Association). 2008. Wildlife corridors initiative: June 2008 report. Western Governors' Association. Denver, CO. Available on the internet: http://www.westgov.org/wildlife .

Whitman, J., W. Ballard and C. Gardner. 1986. Home range and habitat use by wolverines in southcentral Alaska. Journal of Wildlife Management, 50 (3): 460-463.

Woods & Poole Economics, Inc. 2013. Regional projections and database. Washington, D.C.

Yost, A. and R. Wright. 2001. Moose, caribou, and grizzly bear distribution in relation to road traffic in Denali National Park, Alaska. Arctic, 54: 41-48.

Young, B. and R. Ruff. 1982. Population dynamics and movements of black bears in east central Alberta. Journal of Wildlife Management, 46 (4): 845-860.

11. APPENDIX A: WILDLIFE MITIGATION MEASURES

This appendix provides detailed information on measures to mitigate the impact of highways on wildlife connectivity.

11.1. Background

Road ecologists and transportation engineers at the Western Transportation Institute – Montana State University (WTI) have produced several key national reports, two highway-specific studies and a peer-reviewed journal article that, wholly, or in part, evaluate, discuss and/or review the wildlife mitigation measures recommended in this report. The three national studies evaluated over 30 wildlife mitigation measures that have been employed across the U.S. and internationally, and included reviews of studies that evaluated their effectiveness. WTI researchers involved in this study were also coauthors of five of the six documents below:

- **National Guidelines and Manuals**
    - A handbook for the design and evaluation of wildlife crossing structures (Clevenger and Huijser 2011)
    - A report to the U.S. Congress on the causes and solutions to wildlife-vehicle collisions (Huijser et al. 2008a)
    - The best practices manual for reducing wildlife-vehicle collisions (Huijser et al. 2008b)
- **Journal Article (Ecology and Society)**
    - Cost-benefits analyses of wildlife mitigation measures (Huijser et al. 2009)
- **Highway Studies**
    - A wildlife mitigation analysis of three Jackson Hole, WY, highways (Huijser et al. 2011)
    - A connectivity and wildlife mitigation study of Highway 3 in British Columbia and Alberta (Clevenger et al. 2011)

Appendix A only briefly summarizes each mitigation measure option suggested for deployment in this study. The authors of this report recommend reviewing the six aforementioned reports for more details regarding wildlife mitigation measures for highways, since they provide extensive and comprehensive information. The citations in the reference section for the six studies include links via the Internet to the reports.

For mitigating wildlife-vehicle collisions, there are three basic strategies: change driver behavior (i.e., speed limits, rumble strips, signs), change wildlife behavior (i.e., treat roadside vegetation, create loud noises, install light reflectors), or separate wildlife from motorists (i.e., fences, overpasses, underpasses). Not all measures under each of these strategies are highly effective, nor are they equally beneficial in mitigating habitat fragmentation. The mitigations most applicable to habitat fragmentation are summarized in below.

11.2. Introduction

The research team for this report considers separating wildlife from motorists via wildlife fencing, in combination with wildlife underpasses and overpasses, to be the best long-term mitigation option to promote connectivity and reduce mortality on the highways in the study area. Evaluations for this mitigation approach continue to demonstrate very high levels of effectiveness in promoting connectivity and decreasing mortality. Animal detection systems are a lower-cost alternative and have been proven to decrease mortality in several preliminary studies, although not as effectively as fencing. It should be noted that animal detection systems are still considered experimental and the various vendors of such electronic systems are continually modifying and improving their performance.

11.2.1. WILDLIFE FENCING

On average, an 87 percent reduction in wildlife-vehicle collisions can be expected from fencing when combined with overpasses or underpasses (Huijser et al. 2008a). Because fencing itself creates a barrier, it is not a solution to wildlife connectivity, but rather is intended to guide animals to crossing structures or crosswalks (gaps in fence that allow animals to cross at grade).

Most fencing is constructed at 2.4 meters (m) or approximately 8 feet high. Wire mesh fence with an opening size of 10.2 centimeters (cm) (or 4 inches [in]) deters most medium- to large-sized animals from passing through the fence. It is worth noting that one species of interest in the study area, lynx, has been known to pass through such a tight mesh fence; a female lynx with her kitten have been photographed doing so in Banff National Park. Wildlife fencing is typically placed at the edge of the right-of-way, or at least outside the clear zone of the highway so it does not interfere with operations, such as snow plowing.

Figure A1: A 10.2 cm (4 inch) square mesh, metal woven fence that is 2.4m high (~8 feet) with buried apron along the Trans-Canada Highway in Banff National Park (Phase 3-A) (© Tony Clevenger).

Fencing should include jump outs or escape ramps. Jump outs or escape ramps allow wildlife trapped on the highway side of a fence to jump to safety outside the fenced section. The jump out opening is high enough above the surface outside the fence to deter most wildlife from jumping inside the fencing (Figure A2). It is recommended that these be constructed near each side of any structure (i.e., overpasses, underpasses) where fencing is deployed. The height of the jump out should be approximately 1.2-1.8 meters (4-6 feet) above the outside surface so that wildlife are deterred from jumping up and entering the roadway.

Figure A2: This jump out or wildlife escape ramp was constructed on U.S. Highway 93 in western Montana as an opening created in the highway fencing to allow wildlife caught on the highway side of the fence to jump out to safety (© Rob Ament/WTI).

11.2.2. WILDLIFE OVERPASSES

Wildlife overpasses are perhaps the most iconic of all the wildlife mitigation measures due to their size and visibility to motorists and the public (Figure A3). They are designed to allow movement of large animals, but by including additional design elements they can also pass small- and medium-sized mammals, as well as amphibians, reptiles, semi-arboreal and/or semi-aquatic species. Since they are often the most expensive of the wildlife mitigation measures, wildlife overpasses cost, along with their fencing, between $1 million -$9 million each, depending on their length, width, and landscape setting. For large mammals in the two-county project area, particularly grizzly bears, it is recommended that the width of the structures be at least 50 meters (164 feet) wide and preferably 60 meters (197 feet) wide. They are most often vegetated structures, matching their surrounding habitats, and thus must be designed to carry a sufficient amount of soil for water retention and plant nutrition.

Figure A3: Wildlife overpass on U.S. Highway 93 on the Flathead Reservation in western Montana (© Rob Ament/WTI).

11.2.3. WILDLIFE UNDERPASSES

The wildlife underpass is designed specifically for wildlife use and often focused on passing large wildlife safely under the road (Figure A4). When designed for large mammals, it also can successfully allow movement through of small- and medium-sized mammals. Designing the structure and its approaches with vegetative cover or placing brush or root wads in the underpass can help many small mammals feel secure in its use. Underpass structures can be readily adapted for amphibians, semi-aquatic, and semi-arboreal species as well. There are many types of underpass structures, including concrete open-span bridges, concrete bottomless arches, corrugated steel arches, and box culverts. All of these allow for the natural substrate to be continued from outside to within the crossing structure. Dimensions can be equally diverse depending on the species that the design seeks to allow for safe passage.

Some underpasses are designed not solely for wildlife but for multiple-use with vehicles, pedestrians, or bicycles. It is recommended to keep human noise and activity as separate as possible from the more natural portion of the crossing allocated and designed for animal use. Barriers can be erected within the underpass to buffer noise, light, and motion caused by humans from the wildlife side of the crossing structure.

Lastly, underpasses often can accommodate water flow, such as rivers or streams, with wildlife movement. Often bridges or culverts that are required to span the water bodies can be designed even wider/longer to accommodate terrestrial habitat. Since they are generally located in riparian habitats and wildlife frequently move in association with riparian habitats, these types of underpasses support the movement of both aquatic and terrestrial species.

Figure A4: Grizzly bear using wildlife underpass culvert under Trans-Canada Highway in Banff National Park (© www.highwaywilding.org).

11.2.4. WILDLIFE CROSSWALKS

A less desirable solution to building underpasses and overpasses is to create what is often referred to as wildlife crosswalks: gaps in fencing (approximately 30 m wide), coupled with an animal detection system to warn drivers during crossing events. When wildlife crosswalks are positioned at grade and focus wildlife crossings to a short segment of roadway, drivers can be appropriately warned and slow or even stop to allow animals to cross. These areas should have a combination of vehicle speed reduction, warning signs, and public education (these elements are discussed in items 5-8 below as either stand-alone measures or used in combination with crosswalk gaps in a fence).

Along State Road 260 near Payson, AZ, a wildlife crosswalk was created with a gap in an electric fence. In advance of this gap are nonstandard warning signs (Figure A7), variable message signs (Figure A8), and an animal detection system. Collisions with elk were reduced in the area by 97 percent (Gagnon et al., 2010).

11.2.5. VEHICLE SPEED REDUCTION

Traffic calming via maximum speed limit reductions has had mixed results in protecting wildlife (and motorists) from collisions. If drivers do adhere to the slower speed, it gives them more time to react to wildlife that are on, or entering, the road surface. Thus, slower speeds equate to longer braking distances for drivers to avoid collisions with wildlife. Since drivers adhere more to the design speed of a highway rather than the posted speed limit, the lowering of maximum speeds is only recommended in tandem with increased enforcement (note that posting speeds well below the design speed without enforcement on two-lane rural highways is known to lead to an increase in fatal head-on collisions). Therefore, decisions to lower speed limits must be a consensual priority for both transportation and law enforcement agencies.

Figure A5: Bumper sticker increasing awareness of Grand Teton National Park's reduced nighttime maximum speed on U.S. Highway 89/191 within the park to protect wildlife. An ongoing study is collecting data to determine its effectiveness (© Rob Ament/WTI).

A recent two-year study in Colorado on a state-wide program using warning signs in combination with reduced posted speed limits that were enforced in wildlife crossing zones has had little effect in increasing safety for wildlife or motorists. Early results from the project indicate that the measure reduced wildlife-vehicle collisions by 9 percent (CDOT 2012) in the mitigated areas across the state. This reduction is well below many other mitigation measures that reduce WVCs by 50 percent or more. The authors of the report stated there was no information on whether drivers slowed down, and, due to a lack of pre-construction data, no strong case can be made that the reduction in collisions was a result of the lower posted speed limits.

The priority highway segments identified in this study are mostly on primary state highways that functionally are intended to have the highest mobility (i.e., moving traffic quickly and efficiently between cities). Thus, it is unlikely that reducing vehicle speeds at all times for the entire length of the roadway is feasible. A speed reduction should be focused and implemented for only:

- short segments, possibly with traffic calming such as transverse rumble strips;
- certain seasons, such as summer months when grizzly bears are more active; and/or
- specific times of day, such as nighttime hours, when wildlife are more likely to move across the roadway.

It is possible that lower vehicle speeds will allow animals to better judge gaps in traffic and be more likely to attempt a crossing. However, aside from reducing wildlife mortality, there is no scientific evidence that reducing vehicle speed increases wildlife connectivity.

11.2.6. ANIMAL DETECTION SYSTEMS

Animal detection systems (ADS) use sensors to detect large animals that approach the road. Once a large animal is detected, warning signals are activated to inform the drivers that a large animal may be on or near the road at that time (Figure A6). There are two categories of ADS: area-cover and break-the-beam systems. Area-cover systems detect large animals within a certain range of a sensor. These systems send a signal over an area and measure its reflection. The primary active area coverage system uses microwave radar. Break-the-beam sensors detect large animals when the animal's body blocks or reduces a beam of infrared, laser, or microwave radio signals sent by a transmitter to a receiver. Beams are usually directed parallel to the road in the clear zone (Figure A6).

Figure A6: This "break-the-beam" animal detection system (above) and its warning sign (below) is no longer in operation along U.S. 191 in Wyoming (© Rob Ament/WTI).

ADS are ideal for allowing animals to cross the road at-grade without requiring infrastructural changes to the highway. These systems could be installed at gaps in the fence, similar to the crosswalk mitigation, or continuously without fencing, and can be erected and removed relatively easily if circumstances change. Estimated costs of ADS systems are $40,000 to $96,000 per kilometer ($65,000 to $154,000 per mile) excluding installation costs (unpublished data, Marcel Huijser, Western Transportation Institute – Montana State University). They are not as expensive as structures (overpasses and underpasses) initially, but require constant maintenance and upkeep and last only a decade or so. So while initial investments may be low, over the long term ADS can be as expensive as infrastructural mitigation. Another limiting factor of ADS is that they only detect large mammals. If conservation of mid-sized and smaller wildlife needs to be addressed, then this may not be the ideal measure. One study found an 82 percent reduction in WVCs (Huijser et al. 2008a), however, it should be noted ADS are still considered an experimental mitigation measure and there are many different systems to choose from, including many that have not been thoroughly tested for effectiveness.

11.2.7. WARNING SIGNS AND VARIABLE MESSAGE SIGNS

Figure A7: Typical roadside warning sign made nonstandard with the use of flags (© Rob Ament/WTI).

Wildlife warning signs (Figures A7) along highways are perhaps the most commonly applied wildlife mitigation measure to promote safe passage of wildlife across the road. Intended to alert drivers to the potential presence of wildlife on or near the road, these signs seek to make drivers more alert, to reduce their speed, or both. If successful the signs help avoid crashes with animals or reduce the severity of the crashes. Driver awareness and response may be influenced by the type of warning sign. It appears that larger, non-standard signs (e.g., ones with flags attached to warning signs or those with flashing lights) are more effective than standard signs. Their impact on habitat connectivity is unknown.

The typical static warning signs have been shown to be ineffective. If used, signing should be only placed seasonally and/or have more visibility than typical signs. Messages displayed on variable message signs (Figure A8) are designed to attract the attention of the driver and invoke a response to a greater extent than standard wildlife warning signs. Wildlife advisory messages posted on portable variable message signs, such as the one in Figure A8, have been found to reduce vehicle speeds. Variable message signs appear to have potential to reduce wildlife–vehicle collisions, but additional studies are needed to better evaluate their effectiveness.

Figure A8: A variable message sign, describing the number and location of a large focal species—moose, *Alces alces*—killed on the road on WY Highway 390 (© Rob Ament/WTI).

11.2.8. PUBLIC AWARENESS AND EDUCATION

Most wildlife-related driver education programs seek to reduce WVCs and increase motorist safety, and are less concerned with providing connectivity for animals across the road. They pursue these goals by increasing motorists' awareness of the impacts, causes, and high-risk locations of wildlife on or near the road. There is little or no evidence that education programs actually achieve these goals. Nonetheless, an education program can help build public support for the implementation of long-term wildlife mitigation measures that are more effective in reducing habitat fragmentation and the negative impacts of the project area's roads on wildlife connectivity.

Another avenue to increase public engagement in protecting wildlife along roads is via citizen science programs that involve local community members in helping collect information on the wildlife observed, both dead and alive, along roads. Often coined "road watch," this type of citizen science program is being conducted in many states across the U.S. as well as in Canadian provinces. One such program in the Crown of the Continent ecosystem is "Road Watch in the Pass" that collects wildlife observations on Highway 3 in Alberta, Canada (online at: http://www.rockies.ca/roadwatch/about.php). Citizens' wildlife observations on or along Highway 3 are compiled and shared with the public as well as given to the provincial transportation agency. It was found that volunteer citizen information was reliable and robust in comparison to the data collected by researchers (Paul et al. 2014).

Photo: CSKT, MDT, & WTI-MSU

12. APPENDIX B: TRAFFIC THRESHOLDS FOR HIGHWAY UPGRADES

This appendix provides supporting evidence for thresholds signifying when future traffic might become a significant barrier to wildlife. The question answered here is: at what traffic level will a highway be upgraded such that the pavement and roadside width result in a wider footprint of degraded habitat? Such highway improvements may include wider lanes, wider shoulders, additional lanes, and a widened roadside clear zone. The clear zone is the area next to the road that is free of fixed objects or steep slopes to enable an errant vehicle to come to a stop without a major impact or rollover. One other improvement is an increase in the "design speed" which limits the curvature of the roadway and can result (at least in mountainous areas) in more/ steeper cut and fill slopes.

There are numerous factors in addition to traffic levels that result in upgraded roads. Highways have different functional categories due largely to the size of the populated cities they connect. Some of these categories have specified width requirements regardless of traffic flows (e.g., interstates require two lanes in each direction even if very low traffic). Also, funding availability statewide and that which is earmarked for a specific functional class of highway may be limited, resulting in delaying upgrades even when the traffic levels may warrant it.

Still there are guidelines in the literature and levels that can be calculated through capacity analysis that can provide some estimates of when a highway is likely to be upgraded.

12.1. AASHTO "Green Book"

The Policy on Geometric Design of Highways and Streets published by the American Association of State Highway and Transportation Officials (AASHTO 2011) provides national geometric design guidance for different functional classifications of roads. Because we are primarily concerned with areas outside of cities, urban road guidelines were ignored. The remaining design requirements are intended to do two things: maximize mobility (move many vehicles quickly-essentially average travel speed) and access (number of driveways and intersections to enter neighboring lands).

Different functional classes identified in this manual include the following:

- Principal arterial roads (inter-state travel and connecting major cities bigger than 25,000-50,000) which can be further divided into:
  - Interstates
  - Non-interstate freeways (these don't really exist in rural areas)
  - Other principal arterials
- Minor arterial roads (inter-county travel, connect or at least come near, any developed areas)
- Rural collectors (intra-county travel, connect county seats and larger towns to arterials) which can be divided into:
  - Major
  - Minor
- Rural local roads (connect land uses to collectors)

Increasing traffic may result in a highway being re-designated into another functional class which increases the design guidelines. Within a given functional class, increasing traffic will increase the desired minimum guidelines. Below (Table B1) are some values pertinent for this study, which are from the AASHTO "Green Book." Note that since terrain has an impact on classification, higher classifications are further divided (e.g., level, rolling, or mountainous).

Generally 400 ADT is a threshold where the entire footprint goes from 18 feet (two 9 foot lanes, no shoulder, no clear zone) to 34 feet or greater (two 10-12 foot lanes, two 5 foot shoulders, two 7-10 foot clear zones which include shoulders). Exceeding the higher traffic and/or speed thresholds results in adding a few feet to the width of a road component (lane or shoulder).

Table B1: Traffic thresholds for recommended increase in design minimums (Summarized from AASHTO 2011)

Functional Class and Terrain	Minimum Design Speed for Average Daily Traffic (ADT) Volumes	Lane Width	Median	Shoulder [a]	Clear Zone (including shoulder)
Local-Level	< 250 ADT 30mph 250-400ADT 40mph >400 ADT 50mph	9' 9' 11 - 12'	0	400-1500 ADT 5'	
Local-Rolling	<50ADT 20mph 50-400ADT 30mph >400ADT 40mph	9' 9' 10 - 12'	0	400-1500 ADT 5'	
Local-Mountainous	<400 ADT 20mph 400-600ADT 30mph >600 ADT 30mph	9' 9' 10 - 12'	0	400-600 ADT 2' >600 ADT 5'	
Local-All	Varies	Also varies with design speed <400ADT 9-11' 400-1500ADT 10-11' 1500-2000ADT 10-12' >2000 ADT 11-12'	0	(typ. unpaved) <400ADT 2' 400-1500 ADT [b] 1500-2000 ADT 6' >2000 ADT 8'	<400 ADT 0' [c] >400 ADT 7-10'
Collector-Level	<400ADT 40mph 400-2000ADT 50mph >2000ADT 60mph	10' 11' 12'	0		
Collector-Rolling	<400ADT 30mph 400-2000ADT 40mph >2000ADT 50mph	10' 11' 12'	0		
Collector-Mountainous	<400ADT 20mph 400-2000ADT 30mph >2000ADT 40mph	10' 10-11' 12'	0		
Collector-All	Varies	Also varies with design speed <400 ADT 10-11' 400-1500 ADT 10-11' 1500-2000 ADT 11-12' >2000 ADT 12'	0	(could be paved) <400ADT 2' 400-1500 ADT 5' 1500-2000 ADT 6' >2000 ADT 8'	7-10' for lower speeds
Arterials-All (except freeway)	40-75 mph	Also varies with design speed <400ADT 11-12' 400-1500ADT 11-12' 1500-2000ADT 11-12' >2000 ADT 12'	0 unless multi-lane	Should all be paved (min. 2' paved) <400ADT 4' 400-1500ADT 6' 1500-2000ADT 6' >2000 ADT 8'	
Multilane arterials-All (except freeways)	40-75 mph	12' 11' possible on reconstruction	4' strongly rec.	Should be paved 8'	
Freeway	50-60 mph mountainous 70 mph otherwise	12'	10-30' w/ barrier 50'	Paved <250 veh/hr 10' >250 veh/hr 12'	

a if barrier (i.e., guardrail) is used typical minimum of 4' shoulder

b shoulder width in this range of AADT varies for mountainous local roads

c this is from AASHTO 2001 low-volume roads and encourages clear zone use if inexpensive or high crash history

12.2. AASHTO Roadside Design Guide 2006

More detail on clear zone width is provided by the AASHTO Roadside Design Guide (AASHTO 2006).

A clear zone is defined as a flat, recoverable slope free of any fixed object. With the addition of an adequate clear zone, the majority of run-off-the-road, single-vehicle accidents are essentially eliminated because the vehicle does not flip, or hit a fixed object, but rather comes to a safe stop with minor or no damage to the vehicle.

The width of the clear zone is measured from the edge of the travelled lane (i.e., includes the shoulder) and is determined by the design speed of the road, the traffic level, and the slope of the embankments on either side of the road (sideslopes). The grade and direction of the sideslopes require different widths. In general, steeper sideslopes require wider clear zones. However, backslopes (sideslopes that have a positive grade as one moves away from the roadway) and can be steeper and require less distance than typical. The values in Table B2 are worst case, the steepest recoverable foreslope (25 percent).

Table B2: Clear Zone Requirements (feet) for Different Traffic Flows

	DESIGN SPEED (MPH)				
AADT	<=40	45-50	55	60	65-70
<750	10	14	18	24	26
750-1500	14	20	24	32	36
1500-6000	16	26	30	40	42
>6000	18	28	32	44	46

Note. Requirements are more a function of the design speed, but increase steadily as traffic flows increase.

12.3. FHWA Highway Functional Classification Concepts, Criteria, and Procedures

FHWA (2013) does provide AADT cutoffs for rural highway functional classes. If traffic on a highway increases beyond these thresholds, the state would consider changing the functional class, and thus the minimum design standards summarized above. These thresholds for rural highways are:

- Interstate 12,000 – 34,000
- Other freeways/expressways 4,000 – 18,500
- Other principal arterial 2,000 – 8,500
- Minor arterial 1,500 – 6,000
- Major collector 300 – 2,600
- Minor collector 150 – 1,110
- Local 15 – 400

12.4. Capacity Analysis

The biggest footprint increase results from the need for more than two lanes. The number of lanes is not necessarily consistent within a functional category, but based on capacity analysis. Freeways require at least two lanes in each direction; all others require only one lane in each direction. Minor arterials, collectors, and local streets rarely have enough traffic to warrant a second lane, but they may need occasional passing lanes. This section includes a capacity analysis to generalize when a traffic level creates a situation where additional lanes are required to keep the highway from exceeding traffic capacity.

The highway capacity manual (TRB 2010) provides analysis methods to determine the level of congestion and/or delay. For each facility type, threshold values are used to determine a letter grade (A-F) for the facility, known as level of service (LOS). Montana sets a target LOS B for interstates and C for all other roadways (MDT 2009, 2010, 2012).

For the analysis summarized in this section, the primary concern is at what traffic level a highway will require additional lanes to maintain the target level of service. There are many other factors besides number of lanes and traffic that go into the capacity analysis. Some factors are:

- Percent trucks
- Grades
- Percent of no-passing zones and directional traffic split
- Lane width
- Shoulder width/clear zone
- Proportion of unfamiliar drivers

- Number of interchanges/intersections
- Design speed of the facility
- Median type

For the above values, the analysis assumed either some average value, or if there is significant impact, several values were analyzed. Trucks and steep grades can combine to seriously impact congestion, particularly on two-lane roads (one in each direction). Considering that much of the area of concern in this study is in the valley bottoms on relatively level terrain, this may not be an issue. For level roads, nothing in the above list impacts LOS more than peak hour traffic flow and number of lanes. Three facility types will be considered: freeways, multi-lane highways (two or more in each direction), and two-lane highways.

12.4.1. Freeways (interstate highways)

The freeway analysis was completed assuming 12 foot lane widths, a paved shoulder 6 feet or more in width, 2 feet of median clearance (to Jersey barrier), no trucks, more than 3 miles between interchanges, and level terrain. These are generally ideal conditions.

The resulting flow rate for LOS B is 1,330 vehicles per hour per lane. Thus, 2,660 vehicles per hour in the peak direction would warrant a third lane in that direction. Assuming 15 percent of AADT occurs during the design hour, a peak hour factor of 0.85, and a 65/35 directional split, this would result in an AADT of 23,190.

If unfamiliar drivers are present, this can reduce the traffic flow rate at the LOS B. We will assume the less-than-ideal case of unfamiliar drivers (fp=0.90). This results in 20,870 AADT.

The presence of large trucks and grades can also have a negative impact on flows. If 10 percent of the vehicles are trucks, the 20,870 number is adjusted down to:

- 19,880 for level terrain,
- 18,150 for rolling terrain, and
- 15,460 for mountainous terrain.

The threshold for adding a fourth lane is essentially 1.5 of the numbers above.

12.4.2. Multi-lane highways

A multi-lane highway is a non-interstate functional class that has at least two lanes in each direction. The analysis of multi-lane highways shows when a multi-lane highway will go from four lanes (two in each direction) two six lanes. Note that thresholds for a two-lane highway needing upgrades to four lanes are discussed in the next section.

This analysis assumes 12 foot lane widths, 8 foot paved right shoulders, 2 foot median clearance (to Jersey barrier), few intersections, a divided highway (i.e., it has a median), and level terrain. These are generally ideal conditions.

The resulting flow rate for LOS C and a design speed of 60 mph is 1,550 vehicles per hour per lane. Thus 3,100 vehicles per hour in the peak direction would warrant a third lane in that direction. Assuming 15 percent of AADT occurs during the design hour, a peak hour factor of 0.85, and a 65/35 directional split, this would result in an AADT of 27,030.

With the unfamiliar driver and 10 percent trucks assumption, the threshold becomes:

- 23,160 for level terrain,
- 21,150 for rolling terrain, and
- 18,020 for mountainous terrain.

The reason these values are higher than for freeways is because of the less strict congestions threshold (LOS C vs. LOS B). If a fourth lane in each direction were needed, the facility would typically be upgraded to a freeway. If it was not upgraded to a freeway the threshold would also be 1.5 of the above numbers. The design speed could vary for multi-lane highways. Assuming level terrain and above assumptions, the thresholds would be:

- 23,160 for 60 mph,
- 21,370 for 55 mph,
- 19,430 for 50 mph, and
- 17,620 for 45 mph.

12.4.3. Two-lane highways

The point at which a two-lane highway requires upgrading has much lower per-lane thresholds than above. This is due to vehicles not being able to get around slower moving traffic without attempting a passing maneuver. Well before traffic breaks down to stop-and-go conditions, a safety issue emerges when vehicles are trapped behind a slow moving truck and start to make unsafe passing maneuvers.

If a two-lane highway fails capacity, it may not necessarily be upgraded to a multi-lane highway. Instead, intermittent passing lanes may be used, making it essentially a three-lane highway.

The capacity analysis was completed assuming a base free-flow speed (similar to speed limit) of 70 mph, 12 foot lanes, 10 foot shoulders, no median, rolling terrain, a 50/50 directional split for traffic, few intersections and driveways, and 50 percent of the highway has no passing zones.

The resulting flow rate for LOS C is 400 vehicles per hour (both lanes). Assuming 15 percent of AADT occurs during the design hour, and a peak hour factor of 0.85, this would result in an AADT of 3,630. With a more uneven directional split (e.g., 80/20) this would be reduced to 3,400 AADT. With very few passing zones this would result in 2,700 AADT.

12.5. Summary

Traffic thresholds that result in upgrading highways depend on a number of factors. For example, an interstate that has a large footprint could have very low traffic for some segments. On the other extreme, a two-lane highway could carry much higher traffic if the unsafe passing maneuvers were ignored. There are some major break points that are seen in this jumble of information. When thinking about lane, shoulder, and roadside width minimums, there is a jump at 400 AADT and another less severe increase at 2,000 AADT. The biggest increase in highway footprint is probably due to adding lanes. Two-lane highways may need upgrades to at least intermittent passing zones at around 3,000 AADT. This upgrade at 3,000 AADT could be to a multi-lane highway. Looking at multi-lane highways and interstates, they might be upgraded from four lanes to six lanes at around 18,000 AADT.

Development in the study area, surrounded by carnivore habitat. Photo: Sonoran Institute, Aerial support provided by LightHawk

13. APPENDIX C: REFERENCES FOR APPENDICES A AND B

AASHTO (American Association of State Highway and Transportation Officials). 2011. A Policy on Geometric Design of Highways and Streets 2011. AASHTO, Washington, DC.

AASHTO (American Association of State Highway and Transportation Officials). 2006. Roadside Design Guide. 3rd ed. AASHTO, Washington, DC.

CDOT (Colorado Department of Transportation). 2012. Colorado Department of Transportation's wildlife crossing zones report to the House and Senate committees on transportation. Denver, Colorado, USA.

Clevenger, T. and M.P. Huijser. 2011. Handbook for Design and Evaluation of Wildlife Crossing Structures in North America. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available on the internet: http://www.westerntransportationinstitute.org/documents/reports/425259_Final_Report.pdf.

Clevenger, A., C. Apps, T. Lee, M. Quinn, D. Paton, D. Poulton, and R. Ament. 2010. Highway 3: Transportation mitigation for wildlife and connectivity in the Crown of the Continent Ecosystem. Miistakis Institute, University of Calgary, Calgary, Alberta, Canada. Available on the internet: http://y2y.net/files/highway-3-report.

FHWA (Federal Highway Administration). 2013. Highway Functional Classification Concepts, Criteria and Procedures [web document]. Available on the internet: http://www.fhwa.dot.gov/planning/processes/statewide/related/highway_functional_classifications/index.cfm.

Gagnon, J., N. Dodd, S. Sprague, K. Ogren and E. Schweinsburg. 2010. AZ SR 260 Preacher Canyon Wildlife Fence and Crosswalk Enhancement Project Evaluation. Final Report for Project JPA 04-088. Arizona Department of Transportation, Phoenix, AZ.

Huijser, M.P., R.J. Ament and J.S. Begley. 2011. Highway mitigation opportunities for wildlife in Jackson Hole, Wyoming. A report prepared for the Jackson Hole Conservation Alliance, Jackson, WY. 119 pp. Available on the internet: http://www.jhalliance.org/Library/Reports/WTIwildlifecrossingstudy.12-14-11.pdf.

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament and P.T. McGowen. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. Ecology and Society 14(2): 15. Available on the internet: http://www.ecologyandsociety.org/viewissue.php?sf=41.

Huijser, M.P., P. McGowen, J. Fuller, A. Hardy, A. Kociolek, A.P. Clevenger, D. Smith & R. Ament. 2008a. Wildlife-vehicle collision reduction study. Report to Congress. U.S. Department of Transportation, Federal Highway Administration, Washington D.C., USA. Available on the internet: http://www.tfhrc.gov/safety/pubs/08034/index.htm

Huijser, M.P., P. McGowen, A. P. Clevenger, and R. Ament. 2008b. Best Practices Manual, Wildlife-vehicle Collision Reduction Study, Report to U.S. Congress. Federal Highway Administration, McLean, VA, USA. Available on the internet: http://www.fhwa.dot.gov/environment/hconnect/wvc/index.htm.

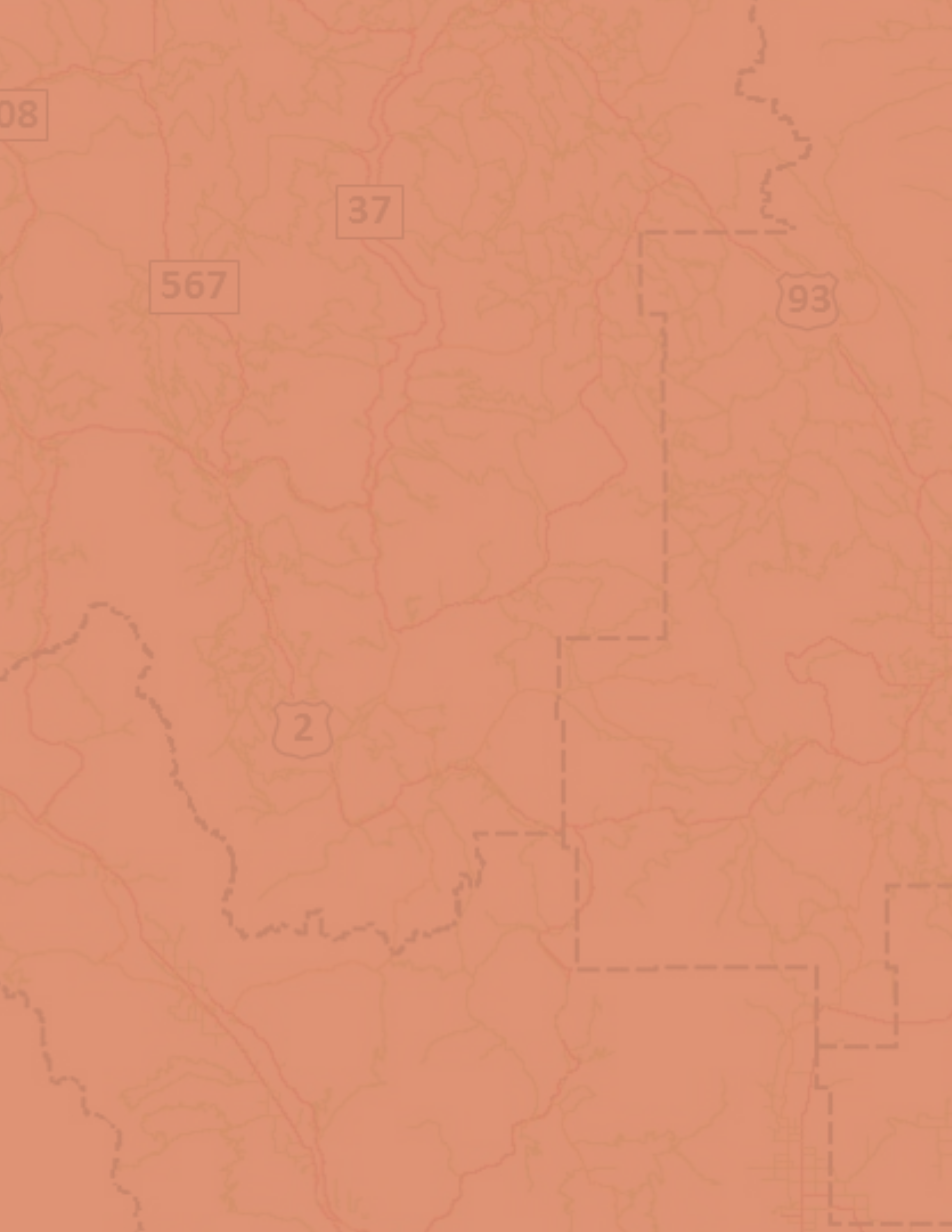
MDT (Montana Department of transportation). 2009. State Traffic Engineering Manual. MDT, Helena, MT. Available on the internet: http://www.mdt.mt.gov/publications/manuals.shtml.

MDT (Montana Department of Transportation). 2010. A Guide to Functional Classification, Highway Systems and Other Route Designations in Montana. MDT, Helena, MT. Available on the internet: http://www.mdt.mt.gov/publications/docs/manuals/route_designations.pdf

MDT (Montana Department of Transportation). 2012. MDT Performance Programming Process 2012 Update. MDT, Helena, MT.

Paul, K., M.S. Quinn, M.P. Huijser, J. Graham and L. Broberg. 2014. An evaluation of citizen science data collection for recording wildlife observations along a highway. Journal of Environmental Management, 139: (2014): 180-187.

TRB (Transportation Research Board). 2010. Highway Capacity Manual, 2010. TRB, Washington, DC.



08
37
567
93
2

HIGHWAY MITIGATION FOR WILDLIFE IN NORTHWEST MONTANA

Estimating The Impacts Of Exurban Growth And Traffic Demand On Grizzly Bears And Other Key Wildlife Species

SONORAN INSTITUTE
Shaping The Future of the West

THE CENTER FOR LARGE LANDSCAPE CONSERVATION

MONTANA STATE UNIVERSITY
Western Transportation Institute