US-191/MT-64
WILDLIFE & TRANSPORTATION ASSESSMENT

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Figure 1 Elk on roadway in path of oncoming car. Photo by Holly Pippel.

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Disclaimer

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A reasonable effort has been undertaken to make this document compliant with Section 508 of the Rehabilitation Act. If you would like assistance, please contact: info@largelandscapes.org.

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List of Abbreviations

AADT	Average Annual Daily Traffic
Assessment	US-191/MT-64 Wildlife & Transportation Assessment
BIL	Bipartisan Infrastructure Law
CGNF	Custer Gallatin National Forest
FHWA	Federal Highway Administration
FWP	Montana Fish, Wildlife & Parks
GPS	Global Positioning System
GYE	Greater Yellowstone Ecosystem
IGBST	Interagency Grizzly Bear Study Team
IIJA	Infrastructure Investment and Jobs Act
km	Kilometer
mi	Mile
MT-64	Montana State Highway 64 (Lone Mountain Trail)
MDT	Montana Department of Transportation
MHP	Montana Highway Patrol
MSU-WTI	Montana State University-Western Transportation Institute
MWTP	Montana Wildlife and Transportation Partnership
MWA	Moving Window Average
NCDE	Northern Continental Divide Ecosystem
NDVI	Normalized Difference Vegetation Index
RM	Road Mile Post
ROaDS	Roadkill Observation and Data System Tool
SNOTEL	Snow Telemetry Network
TAC	Technical Advisory Committee
NPS	National Park Service
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WTI	Montana State University-Western Transportation Institute
WVC	Wildlife-Vehicle Collision
US-191	U.S. Highway 191

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Report Summary

The US Highway 191 (US-191)/Montana Highway 64 (MT-64) Wildlife & Transportation Assessment (the "Assessment") improves understanding of the issues affecting driver safety, wildlife mortality, and wildlife movement along the major routes that connect Yellowstone National Park, the Custer Gallatin National Forest, and other public lands to the growing population centers of Bozeman, Big Sky, and nearby communities in Southwest Montana. By engaging personnel from multiple federal, state, and local agencies along with key stakeholders to examine problems and possibilities through the lens of spatial ecology, the US-191/MT-64 Wildlife & Transportation Assessment brings new insight into the impact of two major roads that unite local communities yet divide the landscape and natural habitats.

The information included in this report should inform and support area communities and agency decision-makers to select and pursue wildlife accommodation options. With the passage of the Infrastructure Investment and Jobs Act of 2021, significant funds for wildlife accommodation measures are available nationwide on a competitive basis. The US-191/MT-64 Wildlife & Transportation Assessment better equips part of Southwest Montana's gateway to Yellowstone National Park to take advantage of new funding opportunities.

Methodology

As detailed in Chapter 2, the Assessment compiles, overlays, and evaluates wildlife-vehicle collision and wildlife carcass data, wildlife movement and habitat data, and live wildlife observations from aerial surveys. It also incorporates wildlife sightings and roadkill information gathered via citizen science. The Assessment further draws upon local and expert knowledge gathered through in-person outreach and an interactive map. Road areas identified through an in-depth spatial data analysis were evaluated in a field review conducted by an interdisciplinary Technical Advisory Committee of county, state, and federal planners, along with biologists, engineers, transportation experts, and the Research Team from the Center for Large Landscape Conservation (CLLC) and Montana State University's Western Transportation Institute (WTI).

Spatial Analysis

The results of the spatial analysis, developed from 26 data sets, are shown in a series of maps in Chapter 3. These maps illustrate key characteristics of the US-191 and MT-64 road corridors along each 0.1-mile segment within the study area. The characteristics illustrated are Wildlife-Vehicle Collision Risk, Wildlife Road Crossings, Wildlife Observations Near Roads (intensity of wildlife use of roadside environments), and Regional Conservation Value (see Figures 9-13). The latter of these is based on models of habitat connectivity/suitability to ensure that species from bighorn sheep to wolverine to sage grouse, which are either not prominent or not accounted for in other data sets, are included. The data sets that make up the key characteristics are shown in Table 2.

In order to identify an initial set of road areas for field evaluation, a Composite Index was developed from a weighted combination of the key characteristics (see Section 3.5). The Composite Index value of each 0.1-mile road segment is shown on the map in Figure 15. Additional details of initial road area selection—including a smoothing process used to find not only important 0.1-mile segments but also broader areas with consistently elevated values—are described in Section 3.6. The results are seven Priority Road Areas shown on the map in Figure 17.

The CLLC-WTI research team also identified three more road areas to include in the field review based on the spatial analysis. Two of these areas were included due to their high rates of wildlife-vehicle collisions and concerns for human safety, and one due to its high connectivity value in an area where development pressure is increasing. While the work to determine these initial areas is robust, Section 2.5 of the report describes data gaps, limitations, and general assumptions that require further research to better assess their impact.

Evaluation of Priority Road Areas and Recommendations

Descriptions of eleven Priority Sites that are located in areas important areas for wildlife movement and/or pose elevated risks to human and wildlife safety, as well as recommendations for sites reviewed in the field, are described in Chapter 6. During the field review, the CLLC-WTI research team and Technical Advisory Committee evaluated and ranked sites via a consensus process using a site evaluation matrix that includes the results of the data analysis along with other factors to address wildlife-vehicle collision risk, conservation value, mitigation options, barrier effect of the road corridor, vulnerability to future change, and land security (see Chapter 5). The data analysis and field review process led to the definition of nine priority sites. Following the spatial analysis and field review, two more priority sites were identified by the CLLC-WTI research team upon the availability of additional data and greater insight into potential opportunities for wildlife accommodations. These sites are supported by recent and historical data. The recommendations also highlight that mitigation along other areas of the study roads may also be warranted and should be considered based on the documentation and analysis of the report, especially when highway projects are planned.

Culvert Assessment

In addition to consideration of terrestrial species, Chapter 9 provides information on an evaluation of the impacts of US-191 and MT-64 on aquatic species and aquatic connectivity. The information summarizes the potential “barrier effect” of culverts passing under US-191 and MT-64 based on an assessment of factors in the field. Fifty-three culverts were coded based on whether substrate is present and continuous throughout the structure, outlet drop, culvert slope, and presence/absence of internal baffling structures designed for fish passage. The details of each criterion are in Table 39. Of the total structures, 30 ranked as green, which implies conditions are adequate for upstream passage of fish. Six of the culverts ranked as gray, meaning conditions may or may not be adequate for upstream passage of fish. Lastly, 17 culverts ranked as red, indicating conditions may not be adequate for fish passage, and further evaluation should be considered. It is important to note that there are some instances where fish passage is not desirable, such as where there is a need to protect native fish populations from non-native or invasive species. Local biologists should always be consulted prior to initiating any project to remove a potential barrier.

Recommendations and Cost-benefit Analysis

The recommendations in Chapter 6 describe appropriate locations for prospective wildlife accommodation measures such as culverts, bridges, underpasses and overpasses, and/or animal detection systems—each in combination with fencing—and take into account both terrestrial and/or aquatic wildlife passage. Many sites include major drainages from surrounding public lands that intersect with US-191 or MT-64 and feature existing infrastructure that has the potential to facilitate animal movements, such as a bridge spanning a riparian corridor. During the field evaluation, the CLLC-WTI research team and Technical Advisory Committee considered means to incorporate existing infrastructure, new structures, and additional alternatives to reduce collisions with wildlife (e.g., variable message signs for areas that have spatially discreet or seasonal conflicts and traffic calming measures to effectively reduce the design speed of the highway). Chapter 4 describes types of wildlife accommodation measures and their effectiveness (see Table 11). A range of accommodation strategies have a role to play in helping to reduce collisions and maintain wildlife movement in the study area.

In the case of terrestrial species, despite crossing structures with fencing requiring high initial investment, research shows they are cost-effective over the course of their lifetime (generally 75 years or more) due to greater efficacy in reducing wildlife-vehicle collisions and lower maintenance costs than other options

(Brennan, Chow, and Lamb 2022; Huijser et al. 2009). Further, given that bridges and culverts that are upscaled and designed to allow for wildlife passage are usually better able to accommodate stream and floodplain function due to larger size and capacity, they may also make infrastructure more resilient to “extreme” weather events like flooding.

Chapter 11 addresses the cost-benefit of a suite of wildlife accommodation measures. Based on available carcass data, three locations meet the threshold for structural wildlife accommodation measures; however, the chapter also details the well-documented under-reporting of carcass data and the possibility of a correction factor to allow for a more accurate cost-benefit examination of potential measures in the study area.

The Montana Department of Transportation has already identified several bridges in need of replacement in the study area. Applying the findings of this Assessment to bridges or other priority locations when replacement is scheduled offers a best-case scenario for cost-effective implementation.

Funding

Chapter 8 overviews federal funding sources that could be used to advance the wildlife accommodation measures discussed in this Assessment, along with innovative state and local funding mechanisms. The vast majority of Montana’s roads and bridges are funded through federal dollars, and the Montana Department of Transportation receives no funding from the state’s general revenue fund (Montana Department of Transportation 2022). One of the criteria against which the Federal Highway Administration may evaluate project proposals under various programs of the Infrastructure Investment and Jobs Act is the extent to which a proposed project leverages other funding sources, including from public-private partnerships. Strong partnerships include diverse stakeholders—such as wildlife and transportation agencies, counties, academic researchers, non-governmental organizations, and local landowners and business owners—working together to advance the common cause of making roads safer for drivers and wildlife.

Spatio-temporal Hotspot Analysis

Chapter 10 of this report is a spatiotemporal hotspot analysis that uses US-191 as a case study that considers how wildlife-vehicle collision hotspots may shift based on varying timescales in order to test the validity of using various lengths of data sets (3, 5, and 10 years) to identify locations for prospective wildlife mitigation measures. The results of the analysis are not intended as guidance in the same manner as in other sections of this Assessment. Rather, they provide additional information intended to further substantiate best practices for the preparation of wildlife and transportation assessments.

Next Steps

The options for prospective wildlife accommodation measures along key road segments described in this report are intended as a guide to inform decision-making processes rather than serve as a prescription for specific actions. Implementation of any prospective measure depends upon multiple factors such as public support, design, and engineering feasibility, potential agreements with land management agencies and/or private landowners, as well as funding availability.

Wildlife accommodations are carried out as part of planning under Montana’s Five-year Statewide Transportation Improvement Plan and a new program of the Montana Wildlife and Transportation

Partnership[1] (described in Section 8.4.1). Montana Department of Transportation is the key agency partner responsible for actions to change or improve US-191 and MT-64.

The CLLC-WTI Research Team suggests that making US-191 and MT-64 safer for travelers and wildlife is a multi-year, multi-site, multi-stakeholder proposition that will take collective action to bring about. The Assessment provides a foundation to allow for discussion about how to reach these goals based on robust understanding.

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[1] The Montana Wildlife and Transportation Partnership consists of representatives of Montana Department of Transportation, Montana Fish, Wildlife and Parks, and Montanans for Safe Wildlife Passage. https://www.mdt.mt.gov/pubinvolve/mwt/

1. Introduction

Figure 2 Archway about a mile north of Spanish Creek (circa 1927-30) and the same location along US-191 in 2016. Credits: Historic photo-National Park Service; Recent photo-Duncan Patten

The goal of the US Highway 191 (US-191)/Montana Highway 64 (MT-64) Wildlife & Transportation Assessment (Assessment) is to improve understanding of the issues affecting driver safety, wildlife mortality, and wildlife movement along the major routes that connect Yellowstone National Park, the Custer Gallatin National Forest, and other public lands to the growing population centers of Bozeman, Big Sky, and nearby communities in Southwest Montana. A joint project of the Center for Large Landscape Conservation (CLLC) and Montana State University's Western Transportation Institute (WTI), this Assessment provides robust information on opportunities to improve highway safety and ecological connectivity[2] for terrestrial and aquatic species.

Prepared using a landscape approach, the Assessment brings together disciplines and data from ecology to engineering, as well as local knowledge, to devise integrated solutions that convey benefits to human safety, ecological connectivity, and infrastructure resilience.

The options for prospective wildlife accommodation measures along key road segments described in this report are intended as a guide to inform decision-making processes rather than serve as a prescription for specific actions. Implementation of any prospective measure depends upon multiple factors, such as public support, design and engineering feasibility, and potential agreements with land management agencies and/or private landowners, along with funding availability. Wildlife accommodations are carried out as part of planning under Montana’s Five-year Statewide Transportation Improvement Plan (Montana Department of Transportation 2022) and a new program of the Montana Wildlife and Transportation Partnership[3] (described in Section 8.4.1).

Montana Department of Transportation is the key agency partner in charge of US-191 and MT-64. The CLLC-WTI Research Team (see report authors) suggests that making US-191 and MT-64 safer for travelers and wildlife is a multi-year, multi-site, multi-stakeholder proposition that will take collective action to bring about.

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[2] Ecological Connectivity is defined as *the unimpeded movement of species and the flow of natural processes that sustain life on Earth*. Wildlife need to be able to move to find food, water, and mates and carry out daily and seasonal life needs.

[3] The Montana Wildlife and Transportation Partnership consists of representatives of Montana Department of Transportation, Montana Fish, Wildlife and Parks, and Montanans for Safe Wildlife Passage. https://www.mdt.mt.gov/pubinvolve/mwt/

1.1. Project Overview

The US-191/MT-64 Wildlife & Transportation Assessment combines local and expert knowledge, public data, citizen science, and engineering expertise to identify feasible sites for a range of potential wildlife accommodation options to improve the safety of travelers and wildlife. By engaging personnel from multiple federal, state, and local agencies along with key stakeholders to examine problems and possibilities through the lens of spatial ecology, the US-191/MT-64 Wildlife & Transportation Assessment brings new insight into the impact of two major roads that unite local communities yet divide the landscape and natural habitats.

The Assessment is intended to:

a) Lay the groundwork for the implementation of best management practices to conserve wildlife, reduce the barrier effect[4] of highways, and improve driver safety in the face of unprecedented regional traffic growth.
b) Provide residents and officials of communities along US-191 and MT-64 with essential tools to guide decision-making.
c) Enable public agencies to prioritize win-win designs in future road redevelopment projects.
d) Identify key road segments that might benefit from wildlife accommodation measures.

The information in this report should inform and support area communities and agency decision-makers to select and pursue wildlife accommodation options. With the passage of the Infrastructure Investment and Jobs Act of 2021, significant funds for wildlife accommodation measures are available nationwide on a competitive basis. The information in this Assessment better equips part of Southwest Montana's gateway to Yellowstone National Park to take advantage of new funding opportunities.

As described in detail in the Methodology (see Chapter 2), the Assessment compiles, overlays, and evaluates information from multiple public agencies: wildlife-vehicle collision and wildlife carcass data, wildlife movement and habitat data, and live wildlife observations from aerial surveys. It also incorporates information on roadkill and wildlife sightings collected by citizen scientists using the ROaDS (Roadkill Observation and Data System) Tool, a smartphone application that allows the collection of spatially precise information. The Assessment further draws upon local and expert knowledge gathered through in-person outreach and an interactive map. The priority road segments identified through spatial data analysis were evaluated in a field review conducted by an interdisciplinary Technical Advisory Committee of county, state, and federal planners, biologists, engineers, transportation experts, and the joint CLLC-WTI Research Team.

In addition to consideration of terrestrial species, the Assessment includes a chapter on the evaluation of the impacts of US-191 and MT-64 on aquatic species and aquatic connectivity (see Chapter 9). This chapter summarizes the potential "barrier effect"[5] of all culverts passing under US-191 and MT-64 based on a field survey carried out in the fall of 2021.

The Assessment identifies appropriate locations for prospective wildlife accommodation measures such as culverts, bridges, underpasses and overpasses, and/or animal detection systems—each in combination with fencing—and takes into account both terrestrial and/or aquatic wildlife passage. In the case of terrestrial

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[4] The barrier effect of a highway may be due to road width, associated habitat change, or traffic volume, among other factors. While high speed roads with large traffic volumes may be the most disruptive to animal movements and population interchange, secondary highways and unpaved roads can also impede animal movements (Clevenger and Huijser 2011).

[5] Culverts beneath roads can impede aquatic organism passage. The impediments they may pose are described in Chapter 9.

species, while crossing structures with fencing require high initial investment, research shows they are cost-effective over the course of their lifetime (generally 75 years or more) due to greater efficacy in reducing wildlife-vehicle collisions and lower maintenance costs than other options, like animal detection systems (Brennan, Chow, and Lamb 2022; Huijser et al. 2009). Further, given that bridges and culverts that are upscaled and designed to allow for wildlife passage are usually better able to accommodate stream and floodplain function due to larger size and capacity, they may also make infrastructure more resilient to "extreme" weather events like flooding. These types of events are occurring with increased frequency and severity (Hoeppe 2016). MDT has already identified several bridges in need of replacement in the study area. Applying the findings of this Assessment to bridges or other priority locations when replacement is scheduled offers a best-case scenario for cost-effective implementation. As described in the recommendations (see Chapter 6), a range of accommodation strategies have a role to play in helping to reduce collisions and maintain wildlife movement in the study area. Further, Chapter 4 provides an overview of the effectiveness of various wildlife accommodation measures.

Figure 3 Roadway into West Yellowstone (circa 1910-1914) and US-191 (2016) in the same location (Road Mile Post 6). Credits: Historic photo-Yellowstone Heritage Center; Recent photo-Duncan Patten

1.2. Wildlife-Vehicle Interactions and Ecological Connectivity

Beyond severing intact landscapes and serving as one of the greatest threats to habitat connectivity, increasing traffic volumes through areas of regular wildlife movement poses a growing safety risk to motorists and wildlife alike. In the U.S., 200 people, 1-2 million large animals, and countless smaller animals die every year in vehicle crashes with wildlife—which also lead to 26,000 human injuries—at an annual cost of more than $8 billion (Conover et al. 1995; Huijser et al. 2009). In addition to these impacts, roads can act as barriers to wildlife movement, reducing the ability of wildlife to find adequate food, water, or mates or to complete their seasonal migrations. For example, one grizzly bear attempted to cross I-90 in Montana near Drummond 46 times—over 29 days in Fall 2020 and 25 days in Spring 2021—before finally succeeding (Pashby 2022). Another study estimated that US Highway 2 near Glacier National Park is a barrier to grizzly bears when traffic exceeds 100 vehicles per hour (Waller and Miller 2015).

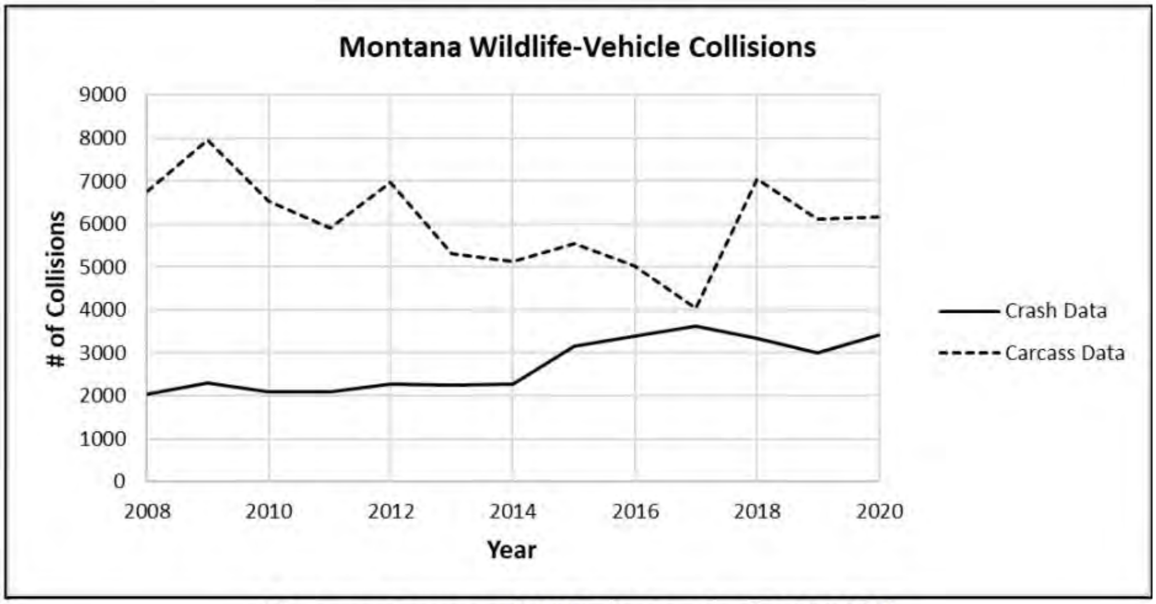
In this Assessment, we analyzed data sources that relate both to direct human and wildlife safety (crashes and carcass records) and ecological connectivity (wildlife movement, wildlife observation, and habitat suitability) to identify priority locations for potential wildlife accommodation measures.

Figure 4 Aftermath of a wildlife-vehicle collision on US-191 just outside the mouth of the Gallatin Canyon. Credit: Holly Pippel

1.3. Earlier Research and Regional Priorities

A 2020 MDT Corridor Study of US-191 (Four Corners to Beaver Creek) found 24% of all crashes in the study area are due to collisions with wildlife. Across Montana, 10% of all crashes reported to law enforcement involve wildlife (Mat Bell, MSU-WTI, pers. comm; see Figure 5), while nationally, animal-caused vehicle crashes comprise less than 5% of total crashes (National Center for Statistics and Analysis 2022). State Farm Insurance consistently rates Montana as second in the nation for risk of collision with wildlife based on claims reported (State Farm 2023). Crashes involving wildlife increased by over 50% between 2008 and 2020, according to an analysis of Montana Department of Transportation data, and over 90% of these crashes were with whitetail and mule deer (Mat Bell, MSU-WTI, pers. comm; see Figure 5). The US-191 Corridor Study states: “MDT will consider the potential for targeted wildlife study and standalone wildlife accommodation projects within the corridor based on [Montana Wildlife and Transportation Partnership] efforts or through partnerships with other interested stakeholders resulting in the identification of data collection gaps, research needs, and funding opportunities.” This Wildlife & Transportation Assessment helps to fulfill the need for additional research to determine potential wildlife accommodation measures (Montana Department of Transportation 2020).

In addition to the existing MDT Corridor Study, the US-191/MT-64 Wildlife & Transportation Assessment aligns with a statewide "areas of greatest need" assessment (see MWTP Planning Tool) developed by the Montana Wildlife and Transportation Partnership and with the Gallatin County Growth Policy, which calls for identification of suitable wildlife crossing areas. It also helps to realize the goals outlined in *Our Big Sky: Community Strategy and Vision*, devised as a strategic plan for the Big Sky community.



Montana: Percent of WVCs by Species (2008-2020)

White-tailed Deer	Mule Deer	Elk	Pronghorn	Moose	Grizzly Bear	Wolf	Other
67.78	26.46	2.80	1.24	0.42	0.03	0.02	1.24

Figure 5 Reported Crashes and Carcasses Collected in Montana, 2008-2020, and Average Percent of Wildlife-Vehicle Collisions by Species. Compiled by Matthew Bell, MSU-WTI.

The Assessment follows upon earlier studies, including a review of high-risk zones for collisions between vehicles and large ungulates during Montana's fall migration season (Creech, McClure, and Callahan 2016) and a preliminary assessment of wildlife and transportation issues in the Greater Yellowstone Ecosystem (Hardy, Willer, and Williamson 2008). Both efforts describe portions of the present study area as high priority. The former found a 10-mile segment of US-191 south of Four Corners to have the second highest mean frequency of recorded ungulate carcasses (whitetail deer, mule deer, elk, pronghorn, moose, and/or bighorn sheep) per mile in Montana each fall, from 2010-2015. The latter found four areas of US-191 between Bozeman and West Yellowstone with relatively high numbers of recorded wildlife-vehicle collisions based on crash and carcass data from 1998-2002. It also describes a portion of the study area as part of the Gallatin River *megasite*, which it identifies as 4th priority in Greater Yellowstone in part due to US-191 bisecting the extensive elk migration corridor that links Yellowstone National Park to the Madison Range. One further study is a 2012 assessment of bison-vehicle collisions along 10 miles of US-191 from West Yellowstone to the border of Yellowstone National Park. Based on data collected from 1999-2009, this study and its findings are described in relation to more recent information in Section 6.10 (Dupree and Dimambro 2012).

1.4. Study Area Overview

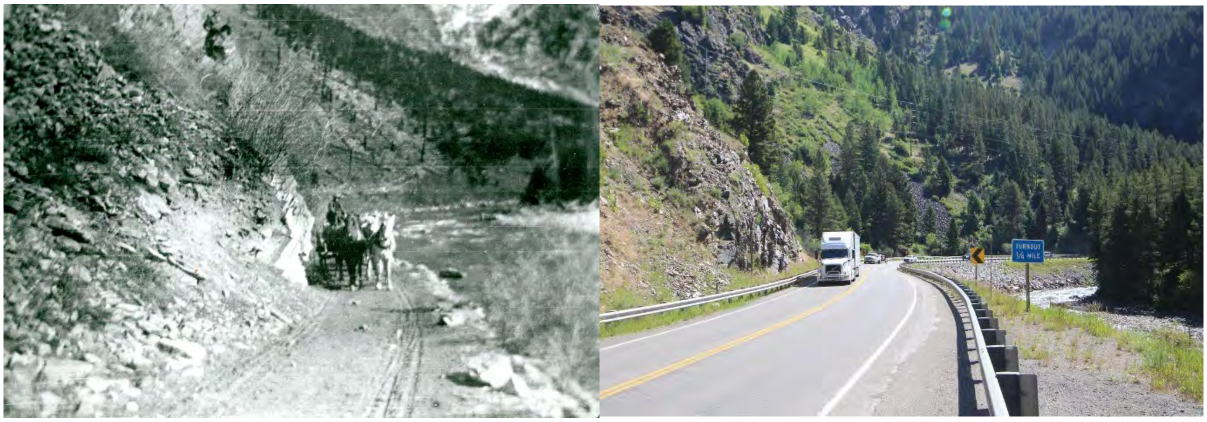


Figure 6 The Gallatin Way to Yellowstone (Road Mile Post 61.1) around 1900 and the same stretch of US-191 through Gallatin Canyon in 2016. Credits: Historic photo-Gallatin History Museum; Recent photo-Duncan Patten

1.4.1. Road Use and Area Visitation

US Highway 191 (US-191) facilitates vehicle travel from Grand Teton National Park to Yellowstone National Park and through the expansive national forest lands that join them to the expanding population centers of Big Sky and Bozeman, Montana. Visitation to Yellowstone National Park increased by 20% from 2014-2017, and over 1 million trips on US-191 occur each year to enter Yellowstone (National Park Service 2022). West Yellowstone, Montana, is the busiest of Yellowstone's gateways, hosting over 4 million visitors per year (National Park Service 2022). As traffic increases along this route, the movement of bighorn sheep, bison, elk, moose, mule, and whitetail deer herds, as well as black and grizzly bears, is progressively threatened.

The study area (see Figure 7), which extends 82 miles along US-191 from Four Corners to West Yellowstone and includes the 10-mile extent of MT-64, is busy due to additional attributes associated with the region's growth: 2,500 construction and service workers commute daily along the highway from Bozeman and nearby communities to Big Sky as part of the area's ongoing development boom (Future West 2019). Big Sky Ski Resort has grown to over 500,000 skier visits per year (Max 2017). The area is part of the fastest-growing region in the United States. Gallatin County's population increased by nearly a third from 2010-2020, with Bozeman ranking among the fastest-growing areas in the nation each year since 2018. Maintaining the connectivity of critical wildlife routes outside of Yellowstone National Park along US-191 and those that cross the sole public access to Big Sky, named Lone Mountain Trail (MT-64), requires intentional action (Dietrich 2022; Policom 2023; US Census Bureau 2023).

1.4.2. Study Area Context

High traffic volumes along US-191 in its current form are a relatively recent phenomenon. In *The Gallatin Way to Yellowstone*, Bozeman author Duncan Patten describes trailing 120 horses 35 miles along US-191 from Spanish Creek at the mouth of the Gallatin Canyon to Elkhorn Ranch near Sage Creek during several springs in the 1950s without encountering issues with traffic. The book also documents changes in the highway from its initial construction in 1911 to the first paving in the 1930s to redesign with alterations to the Gallatin River and reconstruction into a modern highway in the 1950s and 1960s.

In Southwest Montana, three valleys—the Madison, Gallatin, and Paradise—are crossed by highways that lead through the surrounding landscape to Yellowstone's North and West entrances. In this region, a mix of public and private land serves as the "Gateway to Yellowstone," where busier roads and growing subdivisions have the potential to fragment the Greater Yellowstone Ecosystem[6] that is home to the largest concentration of wildlife species in the lower 48 states (National Park Service 2023). In the study area, US-191 leads from Yellowstone National Park through the Gallatin National Forest, which is also crossed by MT-64. At lower elevations along the US-191 road corridor, privately held ranch land provides habitat, including critical winter range for wildlife, along with livestock.

The *Environmental Scan* developed for the MDT Corridor Study of US-191 describes the study area as follows:

> Vegetation below the tree line consists of coniferous forests, grasslands, shrublands, and willow and aspen groves in the riparian areas. The coniferous forest community is dominated by conifers such as lodgepole pine and Douglas fir but also contains Engelmann spruce and subalpine fir. Big sagebrush dominates the grassland shrubland community, with other co-dominant shrubs including silver sagebrush, antelope bitterbrush, three-tip sagebrush, Idaho fescue, spike fescue, and poverty oatgrass. The riparian community is dominated by black cottonwood, aspen, snowberry, Wood's rose, white spirea, red-osier dogwood, pacific willow, sandbar willow, reed canarygrass, and smooth scouring rush. Areas of cultivated cropland and developed lands are also present in the study area, primarily from Four Corners to the mouth of Gallatin Canyon (Montana Department of Transportation 2020).

Most of the land adjacent to the road corridor in the study area is managed by the U.S. Forest Service, with numerous recreational accesses within the Custer Gallatin National Forest, including the Lee Metcalf Wilderness Area and indirect access to the Beaverhead-Deerlodge National Forest. The state-owned Gallatin Wildlife Management Area encompasses 8,611 acres along the eastern side of US-191, just south of MT-64. Just over 20 miles of the study area pass through Yellowstone National Park. US-191 serves the communities of Four Corners, Gallatin Gateway, and Big Sky and the town of West Yellowstone, with developed areas experiencing unprecedented growth in recent years.

As described in the MDT *Environmental Scan* (2020), much of the area along US-191 provides significant wildlife habitat:

> The Gallatin River riparian corridor provides important wildlife habitat in areas that have been less impacted by adjacent development. Common wildlife includes those found in the adjacent shrub/woodlands and grasslands and species frequenting riparian areas like bats, martens, weasels, and raccoons. The riparian zone provides habitat for ducks, geese, herons, eagles, and other raptors, as well as migratory songbird species found in the adjacent non-riparian areas. Common riparian species include painted turtles, northern leopard frogs, and western toads. In addition, the Gallatin Canyon provides forested and riverine habitat for a variety of Montana wildlife species, including large ungulates, carnivores, small mammals, raptors, amphibians, reptiles, and aquatic species.
>
> The Gallatin Range provides suitable habitat for elk, moose, mountain goats, and bighorn sheep because of its relatively large size, its relatively diverse and high-quality vegetative communities, and elevational relief, its geographic location and connectivity to other habitats, and its relatively low level of human development. In addition to providing habitat for resident wildlife, the Gallatin

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[6] The National Park Service describes the Greater Yellowstone Ecosystem in the following link: https://www.nps.gov/yell/learn/nature/greater-yellowstone-ecosystem.htm

Range plays a role in maintaining habitat connectivity for wide-ranging wildlife species such as wolverine, lynx, grizzly bear, mountain lion, and wolf. The Gallatin Range represents the northern reaches of core wildlife habitat within the Greater Yellowstone Ecosystem, and the northern end of the range forms a possible linkage to a wildlife corridor that may connect the Greater Yellowstone Ecosystem to the Northern Continental Divide Ecosystem (Gehman 2010). Grizzly bears currently occupy the entire Gallatin and Madison Ranges, which are the boundaries of the Gallatin Canyon.

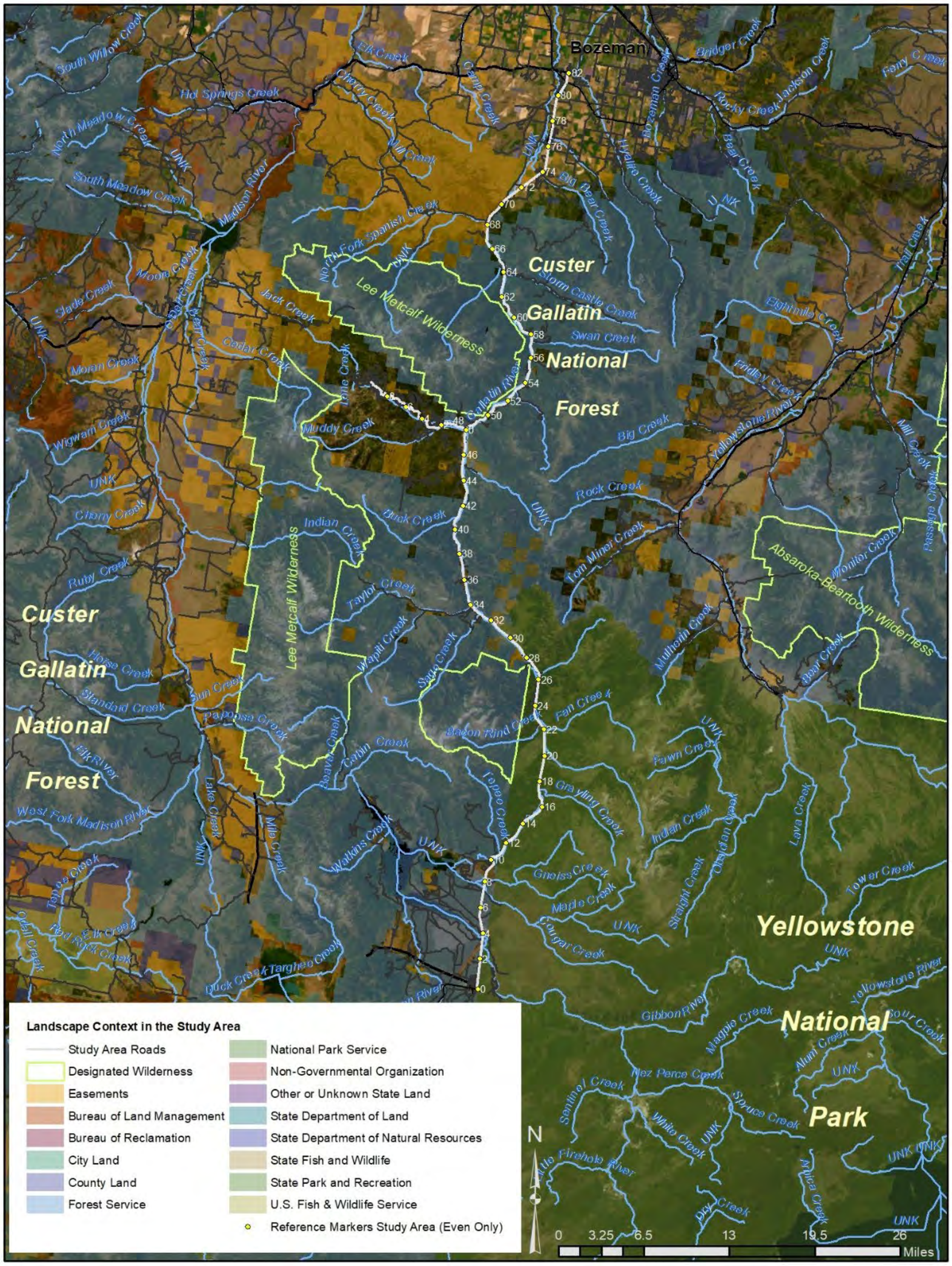

Figure 7 Study Area Overview Map

2. Methodology

2.1. Study area

The study focused on two roads within the Greater Yellowstone Ecosystem, US Highway 191 (US-191) and Montana Highway 64 (MT-64, also known as Lone Mountain Trail), for which adequate data were available for identifying priority sites and potential wildlife accommodations to reduce wildlife-vehicle collisions and maintain or improve habitat connectivity. The study area includes 82 miles of US-191, from road milepost (RM) 0 through RM 81, and 10.1 miles of MT-64, from RM 0 through RM 9.

In order to engage with communities along US-191 and MT-64, project members reached out to businesses, homeowner associations, community groups, and nonprofit partners to invite staff, residents, and commuters to use the Roadkill Observation and Data System (ROaDS) Tool to record wildlife sightings and gain local insight through an interactive map. Users logged more than 2,225 sightings of live and road-killed animals and provided 100 additional comments. Further, project members have spoken at public gatherings, engaged with local Chambers of Commerce, spent time at community events, and provided information to local organizations to help raise awareness of the Assessment and invite participation.

2.2. Data sources

The CLLC-WTI Research Team acquired a diversity of data sets to inform the analyses, which can be classified into five categories: (1) law enforcement records of wildlife-vehicle collisions (WVCs); (2) records of wildlife carcasses observed along roads; (3) observations of live wildlife on or near roads; (4) observations of wildlife crossing roads; and (5) other ecological data such as wildlife telemetry locations, habitat models, and connectivity models. Available data emphasize large mammals, which tend to be species of management or conservation concern (e.g., grizzly bears) or greater human safety risks associated with collisions (e.g., elk, moose, deer). Data sources vary with respect to temporal extent, spatial extent, locational accuracy, and number of observations. Brief descriptions of the data sets in each category follow, with the characteristics of each data set summarized in Table 1.

Wildlife-Vehicle Collision Data: We obtained Montana Highway Patrol (MHP) records for wildlife-vehicle collisions (WVCs) occurring during 2012-2020 via a data request submitted to the Montana Department of Transportation (MDT). These records included the date, time, and location of all WVCs to which MHP responded.

Carcass data: We obtained data on animal carcasses observed along study area roads from four sources: (1) MDT maintenance personnel records from 2012-2020; (2) National Park Service (NPS) records of wildlife carcasses along study area roads from 1989-2021[7]; (3) Interagency Grizzly Bear Study Team (IGBST) records of grizzly carcasses along study area roads from 1977-2021; and (4) records of wildlife carcasses recorded by citizen scientists using the Roadkill Observation and Data System (ROaDS) smartphone application from March 6, 2021 through March 8, 2022. We reviewed these data for possible duplication of records by date and distance and removed any we suspected, as described in Table 1 below.

Wildlife Observation data: We obtained records of observations of live animals on or near roads from four sources: (1) Montana Fish, Wildlife and Parks (FWP) flight monitoring data from 2002-2022; (2) FWP Madison Elk Herd telemetry data[*] from 2006-2020; (3) FWP Gallatin Elk Herd telemetry data[*] from 2002-

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[7] Note that NPS records were not used in spatial analyses but were used to supplement data in priority sites identified, when available, and in developing recommendations.

[*] Elk collar data do not cover the entire study area, including the area north of RM 51, where high rates of collisions with elk exist. For more information on elk collar data limitations, please see Section 2.4.

2005; and (4) observations of live wildlife recorded by citizen scientists using the ROaDS smartphone application during 2021-2022.

Wildlife Movement data: We received data on wildlife movement from three sources: (1) Interagency Grizzly Bear Study Team (IGBST) road crossing locations of 34 GPS-collared grizzly bears and crossing frequency records during 2000-2020; (2) observations of wildlife crossings of study area roads recorded by citizen scientists using the ROaDS smartphone application during 2021-2022; and (3) Montana Fish, Wildlife and Parks (FWP) elk telemetry data[*] for the Madison (2006-2020) and Gallatin (2002-2005) elk herds. As noted in the prior paragraph, elk telemetry data were used to infer locations of road crossings, as detailed below in Section 2.3.1.

Habitat Suitability & Connectivity Models: We obtained habitat suitability and connectivity data for multiple species, including habitat specialists and species that do not disperse to new areas readily, to capture the habitat and movement needs of a diversity of wildlife. The models, which are described below and in Table 1, are derived from several sources:

We used geospatial data from *A Wildlife Conservation Assessment of the Madison Valley, Montana* (Brock et al. 2006) on potential habitat suitability for several focal species, including wolverine, bighorn sheep, elk, and boreal toad. These data incorporate relevant human influences and predict the distribution of habitat quality. Potential winter, nesting, and brood habitat for sage grouse and potential habitat for grizzly bears are also included.

We used geospatial data from *Northern Rockies Black Bear Connectivity* (Cushman, Lewis, and Landguth 2013) generated by applying cumulative factorial least-cost path modeling coupled with resistant kernel analysis to predict a movement corridor network associated with locations of actual bear highway crossings.

We used geospatial data from Peck et al. (2017) on potential grizzly bear road crossings, which include raster values converted to point features 300 m apart at intersections with major transportation corridors for grizzly bear movement between the Greater Yellowstone Ecosystem and the Northern Continental Divide Ecosystem based on Randomized Shortest Path analysis.

We used geospatial data from Brock (unpublished) on range-wide habitat suitability for bison in winter and summer based on Shamon et al. (2022).

We used geospatial data from Krosby et al. (2018) on riparian climate corridors to determine where roads intersect with riparian zones that are likely to facilitate climate-induced species range shifts. This data set includes a resiliency index for each riparian zone based on its ability to facilitate range shifts and serve as a climate micro-refugium (estimated based on the temperature gradient along its length and degree of canopy cover, solar insolation, and human modification).

We used geospatial data from Dickson et al. (2016) on ecological connectivity to determine where roads intersect with major dispersal corridors. This data set is the product of a Circuitscape analysis of species-neutral connectivity among large, protected areas within the western U.S. and contains a connectivity value for each landscape pixel reflecting its estimated contribution to west-wide connectivity. Movement is assumed to be more difficult through areas with more rugged topography and a higher degree of human modification.

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[*] Elk collar data do not cover the entire study area, including the area north of RM 51, where high rates of collisions with elk exist. For more information on elk collar data limitations, please see Section 2.4.

Table 1 Description of Data Sets Used in Analyses

Dataset	Description	Sampling Period	Spatial Extent	Sample Size[1]	Precision[2]
Wildlife Crash (MDT)	Coordinates, date, time	2012-2020	US-191 and MT-64	328	Good
Wildlife Carcass (MDT)	Coordinates of wildlife carcasses, date, species, sex	2012-2020	US-191 and MT-64	1,077 Removed 2 grizzly bear records included in IGBST data	Good
Grizzly Bear Roadkill (IGBST)	Coordinates, ID, age class, sex, date, location details of loss	1977-2021	US-191	12	Good
ROaDS Tool: Wildlife Carcass	Records of wildlife carcasses submitted by local residents using the ROaDS smartphone application	3/2021-3/2022	US-191 and MT-64	62 minus 7 that were off study routes = 55 minus 1 duplicate dated 12/2/21 = 54	Good
US-191 Flight Monitoring Data (FWP)	Coordinates, date, and species from aerial monitoring flights	2002-2022	US-191	3041	Good
ROaDS Tool: Wildlife Alive on Road	Records of live wildlife on or near roads submitted by local residents using the ROaDS smartphone application	3/2021-3/2022	US-191 and MT-64	122	Good
Gallatin Elk Herd Telemetry Data (FWP)	Coordinates, Animal ID, Device ID, date, time	2002-2005	Within 5 miles of US-191	33,772	Good
Madison Elk Herd Telemetry Data (FWP)	Coordinates, Animal ID, Device ID, date, time	2006-2020	Within 5 miles of US-191	102,152	Good
Grizzly Bear Crossings Telemetry Data (IGBST)	Animal ID, age, sex, cohort	2000-2020	US-191 and MT-64	34 individuals 236 events	Good
Elk Crossings (FWP)	Generated from Madison Valley and Gallatin Herd data (approach described in Section 2.3.1); coordinates, Animal ID, Device ID, date, time	Gallatin Herd 2002-2005; Madison Valley Herd 2006-2020	Within 5 miles of US-191	37 individuals 2,189 events	Good
ROaDS Tool: Wildlife Crossings	Records of wildlife crossings submitted by local residents using the ROaDS smartphone tool	3/2021-3/2022	US-191 and MT-64	62	Good
Potential Grizzly Bear Passage Along Major Road Corridors	Point features 300 m apart identifying indices of potential passages at intersections with major	2018	GYE to NCDE	339 on US-191	Moderate[3]

Dataset	Description	Sampling Period	Spatial Extent	Sample Size[1]	Precision[2]
in Northwest Montana	transportation corridors for grizzly bear movement between GYE and NCDE based on Randomized Shortest Path (Peck et al. 2016).				
Grizzly Bear Habitat Suitability (Craighead et al. 2006)	Functional habitat of a minimum quality, size, and distance from major core areas	N/A	Study Area	N/A	Moderate[3]
Northern Rockies Black Bear Connectivity (Cushman et al. 2013)	Cumulative factorial least cost path modeling coupled with resistant kernel analysis to predict movement corridor network; associated with locations of actual bear highway crossings.	2013	Montana, Idaho	N/A	Moderate[3]
Wolverine Habitat Effectiveness (Brock et al. 2006)	Potential habitat mapped using logistic regression from wolverine telemetry and GPS locations	N/A	Study Area	N/A	Moderate[3]
Bison Summer Habitat Suitability Index (Shamon et al. 2022)	Preferred summer habitat types and estimates of plant biomass needed to support bison populations; restricted to slopes below 35 percent; further constrained to remove roads and cropland.	N/A	Range-wide	N/A	Moderate[3]
Bison Winter Habitat Suitability Index (Brock unpublished)	Potential year-round (a.k.a. winter range) for bison in the mountainous West; generally a subset of summer habitat where snow depth remains low through the winter, allowing for year-round use.	N/A	Rocky Mountains	N/A	Moderate[3]
Bighorn Sheep Potential Habitat Effectiveness (Brock et al. 2006)	Preferred habitat types within a certain distance of escape terrain, adjusted to eliminate areas impacted by domestic sheep grazing allotments and road salting	N/A	Study Area	N/A	Moderate[3]
Elk Habitat Effectiveness (Brock et al. 2006)	Range of habitats with emphasis on winter range, riparian areas, mountains, and valleys	N/A	Study Area	N/A	Moderate[3]

Dataset	Description	Sampling Period	Spatial Extent	Sample Size[1]	Precision[2]
Boreal Toad Habitat Effectiveness (Brock et al. 2006)	Modeled habitat components (i.e., wetlands, landcover, edge, and soils) within 300 m of lakes, ponds, and springs and adjusted to address threats (dewatering, fish stocking, floodplain loss, pollution, roads)	N/A	Study Area	N/A	Moderate[3]
Sage Grouse Potential Nesting Habitat (Brock et al. 2006)	Modeled stands of sagebrush with 15-31% cover using 30 m GAP Land Cover and late May NDVI	N/A	Study Area	N/A	Moderate[3]
Sage Grouse Potential Brood Habitat (Brock et al. 2006)	Fall greenness calculated from Landsat imagery, masked to include only areas within potential brood habitat landcover classes (e.g., sagebrush, shrub/steppe, grassland)	N/A	Study Area	N/A	Moderate[3]
Sage Grouse Winter Habitat Suitability (Brock et al. 2006)	Preferred habitat types refined with slope, aspect, and NDVI calculated from spring Landsat Thematic Mapper imagery to detect areas where sagebrush protrudes above snow cover	N/A	Study Area	N/A	Moderate[3]
Ecological Connectivity (Dickson et. al. 2016)	Estimated value for facilitating ecological flows (e.g., wildlife movement) between protected areas in the Western U.S.	NA	Study Area	NA	Moderate[3]
Riparian Climate Corridors (Krosby et al. 2018)	Estimated value of riparian corridors for facilitating climate-induced species range shifts	NA	Study Area	NA	Moderate[3]

[1] Sample size is the total number of observations (e.g., carcasses, crashes, or live animal sightings) along study roads.

[2] A rough, categorical estimate of locational error associated with the data set. Good: location recorded at the time of observation with GPS coordinates. Moderate: location recorded at time of observation with road reference marker to the nearest mile or detailed location description based on local landmarks. Poor: location estimated based on memory of past events.

[3] Data set consists of connectivity model output rather than locations of specific events, assigned to the moderate precision category based on the spatial resolution of the model.

2.3. Initial Screening of Road Segments

To identify an initial set of road segments for potential wildlife accommodation measures, we categorized the data sets described in Section 2.2 and Table 1 into four Prioritization Characteristics, each of which represents a specific mitigation rationale: 1) wildlife-vehicle collision risk, 2) live wildlife observations along roads, 3) evidence of wildlife crossing roads, and 4) modeled wildlife habitat suitability or connectivity value. Each Prioritization Characteristic is informed by a distinct subset of the 26 available data sets, which were weighted according to the sample size, spatial precision, duration, and diversity or conservation importance of wildlife species represented (see Table 2), and then applied to each road segment. Finally, based on a weighted average of the four Prioritization Characteristics (see Table 3), we calculated a Composite Importance Index for each road segment.

To identify potential locations for wildlife crossing improvements, we used 0.10-mile road segments as our unit of analysis. We determined these segments as follows: (1) we used the Montana Department of Transportation (MDT) reference markers point shapefile to divide polyline shapefiles for US-191 and MT-64 into 1-mile segments between mile markers using the Split Line at Point tool in ArcGIS. [N.B. The starting mile MDT reference marker was included in each segment]; (2) each 1-mile segment was then divided into 0.10-mile segments using the Split Command and given a unique ID using the MDT reference marker as a prefix (e.g., RM 81.0 through RM 81.9). Overall, the study area includes 921 0.10-mile segments.

Table 2 Within-Category Weights for Each Prioritization Characteristic

Dataset	Within-category weight	Weight justifications
Wildlife-Vehicle Collision Risk Prioritization Characteristic		
Wildlife Crash (MDT)	0.4	Large, precise dataset
Wildlife Carcass (MDT)	0.4	Large, precise dataset
Grizzly Bear Roadkill (IGBST)	0.1	Very small number of observations, but high conservation importance
ROaDS Tool: Wildlife Carcass	0.1	Small number of observations and short study duration; probably poorer spatial precision than other WVC datasets
Wildlife Observation Near Roads Prioritization Characteristic		
Flight Monitoring Data: US-191 (FWP)	0.3	Large, long-duration, multi-species dataset
ROaDS Tool: Wildlife Alive on Road	0.1	Small number of observations and short study duration; likely poorer spatial precision than other WVC datasets
Gallatin Elk Herd (FWP)	0.3	Large, precise, single-species dataset, only partial spatial coverage
Madison Elk Herd (FWP)	0.3	Large, precise, single-species dataset, only partial spatial coverage
Wildlife Road Crossings Prioritization Characteristic		
Grizzly Bear Crossings (IGBST)	0.45	Moderate number of observations and high conservation importance
Elk Crossings (FWP)	0.45	Large number of observations but lower conservation importance, only partial spatial coverage
ROaDS Tool: Wildlife Crossings	0.1	Small number of observations and likely poorer spatial precision than other movement datasets

Habitat Suitability/Connectivity Prioritization Characteristic		
Potential grizzly bear passage along major road corridors in northwest Montana (Peck et al. 2016)	0.05	Each of the data sets in this category were weighted equally. For species with more than one model, weights were divided equally among the multiple models (e.g., each of the 2 grizzly bear models weighted at 0.05).
Grizzly Bear Habitat Suitability (Craighead et al. 2006)	0.05	
Northern Rockies Black Bear Connectivity (Cushman et al. 2013)	0.1	
Wolverine Habitat Effectiveness (Brock et al. 2006)	0.1	
Bison Summer Habitat Suitability Index (Shamon et al. 2022)	0.05	
Bison Winter Habitat Suitability Index (Brock unpublished)	0.05	
Bighorn Sheep Potential Habitat Effectiveness (Brock et al. 2006)	0.1	
Elk Habitat Effectiveness (Brock et al. 2006)	0.1	
Sage Grouse Potential Nesting Habitat (Brock et al. 2006)	0.033	
Sage Grouse Potential Brood Habitat (Brock et al. 2006)	0.033	
Sage Grouse Winter Habitat Suitability (Brock et al. 2006)	0.034	
Boreal Toad Habitat Effectiveness (Brock et al. 2006)	0.1	
Ecological Connectivity (Dickson et al. 2016)	0.1	
Riparian Climate Corridors (Krosby et al. 2018)	0.1	

Table 3 Weights for Composite Importance Index

Prioritization Characteristic	Weight
Wildlife-Vehicle Collision Risk	0.30
Wildlife Observations Near Roads	0.10
Wildlife Road Crossings	0.30
Habitat Suitability/Connectivity	0.30

2.3.1. Indices of Road Segment Importance for each Prioritization Characteristic

Establishing a segment-level importance index for each Prioritization Characteristic required combining results across data sets. First, we developed segment-level indices for each data set within each characteristic. Indices for the WVC Risk, Wildlife Observation, and Wildlife Road Crossing Prioritization Characteristics are based on counts of events (e.g., crashes, carcasses, pathways intersecting the road) or numbers of individuals (e.g., live animals) within each 0.10-mile road segment. We generated indices for the Habitat Suitability/Connectivity Prioritization Characteristic by extracting the maximum value (e.g., highest suitability, maximum connectivity value) of the pixels intersecting each road segment. The Index values generated for each data set were rescaled to range from 0 to 1 to allow for comparison. We used a weighted averaging approach for the contributing data sets to each Prioritization Characteristic to derive segment-level importance indices.

We also generated general summary statistics for each data set and Prioritization Characteristic.

Wildlife-Vehicle Collision Risk Prioritization Characteristic: We calculated the number of recorded collisions with wildlife and the number of carcasses within each 0.10-mile road segment, as described in Table 1, as an index of WVC risk using 4 data sets:

- Wildlife Crash (MDT)
- Wildlife Carcass (MDT)
- Grizzly Bear Roadkill (IGBST)
- ROaDS Tool: Wildlife Carcass

We calculated the rate of collisions or carcasses (x per 0.10-mile) for each segment in each data set. We then normalized the native values from each data set (i.e., rescaled from 0 to 1). Using the within-category weights in Table 2, we developed a Wildlife-Vehicle Collision Importance Index calculated from the weighted mean of the normalized values across the data sets.

Wildlife Observation Near Roads Prioritization Characteristic: We calculated the number of recorded wildlife observations within 500 meters of each 0.10-mile road segment as an index of animal use intensity using 4 data sets:

- Flight Monitoring Data US-191 Clip (FWP)
- ROaDS Tool: Wildlife Alive on Road
- Gallatin Elk Herd (FWP)*
- Madison Elk Herd (FWP)*

We calculated the number of recorded wildlife observations within 500 m of the road for each segment within each data set. We then normalized the native values from each data set (i.e., rescaled from 0 to 1). Using the within-category weights in Table 2, we developed a Wildlife Observation Importance Index calculated from the weighted mean of the normalized values across the data sets.

Wildlife Road Crossings Prioritization Characteristic: We calculated the number of grizzly bear or elk paths intersecting each 0.10-mile road segment (i.e., number of inferred road crossings by bears or elk) or live observations of road crossings from the ROaDS Tool as an index of safe wildlife passage for each of the 3 data sets:

- Grizzly Bear Crossings (IGBST)
- Elk Crossings (FWP) *
- Roads Tool: Wildlife Crossings

Using the elk telemetry data, we converted locations into movement paths by assuming straight-line travel between consecutive telemetry fixes, limiting our analysis to fixes separated by less than 8 hours to minimize potential deviation from assumed straight-line paths. We then determined where inferred movement paths intersected the road network (i.e., approximate locations of elk crossings).

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* Elk collar data do not cover the entire study area, including the area north of RM 51, where high rates of collisions with elk exist. For more information on elk collar data limitations, please see Section 2.4.

For each data set, we calculated the number of paths intersecting the road or recorded the number of wildlife crossings for each segment. The native values from each data set were then normalized (i.e., rescaled from 0 to 1). Using the within-category weights in Table 2, we developed a Wildlife Movement Importance Index calculated from the weighted mean of the normalized values across the data sets.

Habitat Suitability/Connectivity Prioritization Characteristic: We generated indices for the Habitat Suitability/Connectivity prioritization characteristic by extracting the maximum value (e.g., highest suitability, maximum connectivity value) of the pixels overlapping each road segment in each data set:

- Potential grizzly bear passage: We calculated the maximum index value of potential passage rates for grizzly bears overlapping each road segment (Peck et al. 2017) as an index of importance for facilitating regional connectivity for grizzly bears.
- Grizzly bear habitat (Craighead 2006): We calculated the maximum suitability value of the pixels overlapping each road segment as an index of importance for grizzly bear habitat.
- Northern Rockies black bear connectivity (Cushman, Lewis, and Landguth 2013): We calculated the maximum connectivity value of the pixels overlapping each road segment from Cushman, Lewis, and Landguth (2013) as an index of importance for black bear connectivity.
- Bison summer and winter habitat suitability (2 data sets): We calculated the maximum habitat suitability value of the pixels overlapping each road segment as an index of importance for bison winter and summer habitat from Brock (unpublished) and Shamon et al. (2022), respectively
- Wolverine habitat effectiveness: We calculated the maximum value from Brock et al. (2006) of the pixels overlapping each road segment as an index of importance for Wolverine habitat.
- Bighorn sheep habitat effectiveness: We calculated the maximum value from Brock et al. (2006) of the pixels overlapping each road segment as an index of importance for bighorn sheep habitat.
- Elk habitat effectiveness: We calculated the maximum value from Brock et al. (2006) of the pixels overlapping each road segment as an index of importance for elk habitat.
- Sage grouse winter, nesting, and brood habitat (3 data sets): We calculated the maximum value from Brock et al. (2006) of the pixels overlapping each road segment as an index of importance for sage grouse winter, nesting, and brood habitat.
- Boreal toad habitat effectiveness: We calculated the maximum value from Brock et al. (2006) of the pixels overlapping each road segment as an index of importance for boreal toad habitat.
- Riparian climate corridors: We calculated the maximum resiliency index value from Krosby et al. (2018) of any riparian zones intersecting each road segment as an index of potential importance for climate change adaptation.
- Ecological connectivity: We calculated the maximum connectivity value from Dickson et al. (2016) of the landscape pixels overlapping each road segment as an index of importance for multi-species connectivity.

We then normalized the values from each data set (i.e., rescaled from 0 to 1). Using the within-category weights in Table 2, we developed a Habitat Suitability/Connectivity Importance Index calculated from the weighted mean of the normalized values across the data sets.

2.3.2. Composite Indices of Road Segment Importance

We weighted each Prioritization Characteristic, as shown in Table 3, to develop a Composite Importance Index for each road segment:

(WVC Importance Index x 30%) + (Wildlife Observation Importance Index x 10%) + (Wildlife Movement Importance Index x 30%) + (Suitability/Connectivity Importance Index x 30%) = Composite Importance Index. Following this calculation, the resulting values were rescaled from 0 to 1.

To identify priority sites for field evaluation, we spatially smoothed the results of the Composite Importance Index using a Moving Window Average (MWA) to identify road areas with consistently elevated values for the prioritization characteristics. We calculated an MWA for each 0.10-mile road segment by taking the average of the Composite Importance Index values for each road segment with the values for the five segments to either side of each segment (i.e., each MWA value applied to a road section of 1.1 miles). We then selected the Top 10% of MWA values for each highway as areas for field evaluation.

The approaches described above tend to identify road segments with high index values across multiple characteristics and may overlook road segments that are extremely important for a single characteristic, such as wildlife-vehicle collision risk (that have lower composite index values). In order to include WVC outlier segments with high risk, we added 2 areas along US-191 to the priority sites identified by the MWA for field evaluation (see Section 3.6 for further discussion).

2.4. Data Gaps, Limitations, and General Assumptions

The analysis within this Assessment is based on available data. Not all data sets are comprehensive; some are collected opportunistically (including both MDT and ROaDS Tool carcass data), and the data sets are skewed towards large mammals and charismatic species such as elk and grizzly bears. Further, some basic assumptions have been made throughout the document as information is still being learned about the ways in which wildlife interact with roads and transportation. Some data gaps, limitations, and general assumptions of this report that require further research to better assess their impact are described below:

Underreporting: The primary carcass data available for this study are: MDT maintenance personnel removal of wildlife carcasses along roadsides and citizen science-collected data. These data sets are opportunistically—rather than systematically—collected and are likely to represent only a fraction of the animals hit and killed along roads. These data sets are also skewed towards large animals that can be easily seen when driving along a highway (> 90% of all MDT carcass data are deer). In addition to not accounting for smaller wildlife, these data are likely an undercount of large species such as deer and elk, given that many animals hit do not die on a road surface or immediately next to a road. Studies that document the underreporting of WVCs have found up to 8.5 times more animals are hit on roads than reported (Donaldson 2017). In Montana, while crashes reported to law enforcement have nearly doubled over the last 10 years, the number of wildlife carcasses removed from roads has declined (Figure 5). This is more likely due to changes in search and reporting procedures than fewer wildlife-vehicle collisions on Montana's roads. This factor is important to consider in reading Chapter 11 on cost-benefit analysis for constructing wildlife accommodation measures, as cost-benefit thresholds are based on carcass data.

Gaps in Existing Wildlife Movement Data: Individual, GPS-collared wildlife provides the primary wildlife movement data available for the study. These data were only available for two species: elk from the Gallatin and Madison herds and grizzly bears. The elk collar data are not necessarily representative of all elk herds or their movement in the study area. Further, the data do not cover the entire study area, including the area north of RM 51, where high rates of collisions with elk are documented. This is a limiting factor in the Wildlife Crossing Road Importance Index as the two sets of collar data are primary contributors. During the site visits, local wildlife biologists scored each priority site based on conservation value, including the importance for wildlife movement to offset this limitation. Collar data for an expanded group of species and additional elk herds, such as those in the Gallatin Gateway area, could help to better inform potential locations for wildlife accommodations.

Traffic Volumes: Studies of the impact of traffic volumes on wildlife crossing behavior and WVC risk are limited in number. For moose, Seiler (2003) found a non-linear relationship between traffic volumes and a) WVCs and b) the barrier effect of a highway. The highest rates of WVCs were at moderate traffic volumes (2,500-10,000 vehicles per day; Figure 8), with the road posing nearly a complete barrier for safe wildlife crossings at traffic volumes between 10,000 and 15,000 vehicles per day. A recent study in

Wyoming (Riginos 2022) found traffic volumes above 15,000 AADT pose a complete barrier to wildlife movement.

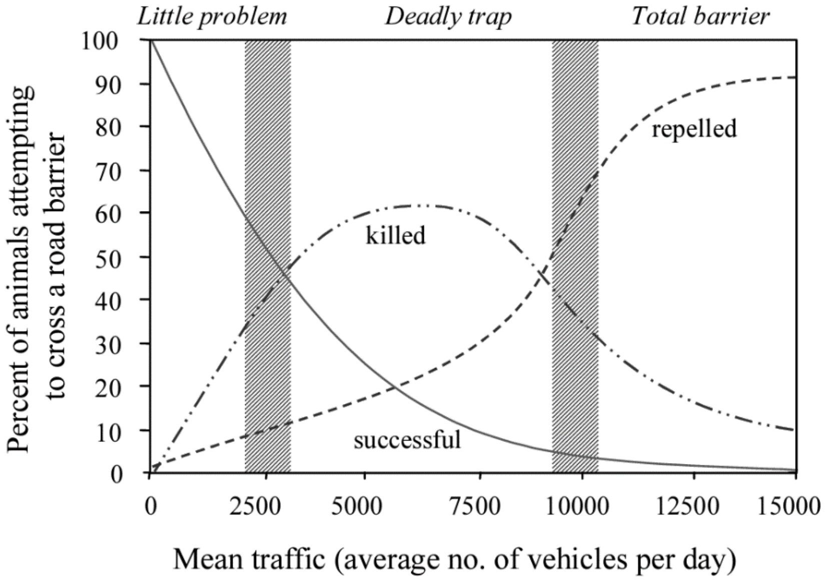


Figure 8 The Relationship between Average Daily Traffic, WVCs, and the Barrier Effect of a Road (from Seiler 2003).

Some species-specific studies have described hourly traffic thresholds. A study in northwest Montana found traffic volumes of over 100 vehicles per hour to be a substantial barrier to grizzly bear movement (Waller and Servheen 2005; Waller and Miller 2015). For mule deer, a study in western Wyoming found traffic volume over 120 vehicles per hour to be a substantial barrier, with interactions between deer and vehicles often unsafe or not allowing passage when less than 60 seconds between vehicles exist (Riginos et al. 2018). These finer-scale studies help to show the degree to which a road poses a barrier. For the Assessment, the available traffic volume data are Annual Average Daily Traffic (AADT), which is an average across the full year that does not account for temporal (day/night) or seasonal (winter/summer) variations. Each of the US-191 and MT-64 road corridors is highly influenced by temporal and seasonal variations. AADT is not adequate to determine when wildlife movements are likely to be impeded by traffic volume. Additional research is necessary to determine whether portions of US-191 and MT-64 have become a significant barrier to wildlife movement and when they are likely to become one.

3. Results

3.1. Wildlife Road Crossings Importance Index

In the Wildlife Road Crossings Prioritization Characteristic, 48% (439/921) of segments have recorded safe passages, with the top 10% of these segments having index values of 0.463 or greater (Figure 9). The total number of wildlife detected crossing roads is 2,484, with a maximum of 39 crossings in any one 0.10-mile segment (mean = 2.70, SD = 4.85). All data for the top 10 segments identified in the Wildlife Road Crossing Importance Index are shown in Table 4.

Table 4 Wildlife Road Crossing Importance Index: Top Ten 0.10-mile Segments

Road Segment ID	Elk Crsgs	Griz Crsgs	ROaDS Crsgs	Elk Crsgs Normalized	Griz Crsgs Normalized	ROaDS Crsgs Normalized	Add Weighted N = (ElkCrsN*0.45) + (GrizCrsN*0.45) + (ROaDCrsN*0.1)	Wildlife Crossings Imp Index
RM7.7	2	5	0	0.051	1.000	0.000	0.473	1.000
RM3.1	0	5	0	0.000	1.000	0.000	0.450	0.951
RM46.4	39	0	0	1.000	0.000	0.000	0.450	0.951
RM46.3	37	0	0	0.949	0.000	0.000	0.427	0.902
RM46.0	35	0	0	0.897	0.000	0.000	0.404	0.854
RM46.5	33	0	0	0.846	0.000	0.000	0.381	0.805
RM11.1	1	4	0	0.026	0.800	0.000	0.372	0.785
RM1.4	0	4	0	0.000	0.800	0.000	0.360	0.761
RM7.9	0	4	0	0.000	0.800	0.000	0.360	0.761
RM45.9	29	0	0	0.744	0.000	0.000	0.335	0.707

There are 2,189 crossing events from 37 individual collared elk in the Gallatin and Madison herds. These collar data have the largest sample size of all data used in this analysis. Thus, it is not surprising that elk make up the great majority (88%: 2,189/2,484) of crossings, with a maximum of 39 elk crossings in any one segment (RM 46.4) and a mean of 2.38 (SD = 4.70). Elk crossings occur in 353 of the 921 0.10-mile segments. Roughly 20% (70/353) of these segments have ≥ 10 elk crossings and 10 have > 20 elk crossings, all of which are in RM 45 and 46. About 55% (195/353) of segments have ≤ 5 elk crossings. Of the 37 collared elk that cross the study roads, seven individuals make > 145 crossings and 3 individuals cross the highway more than 200 times, with elk #22164 making the greatest number of crossings at 248 events. Nineteen individuals cross between 10 and 88 times, and 11 individuals make <10 crossings.

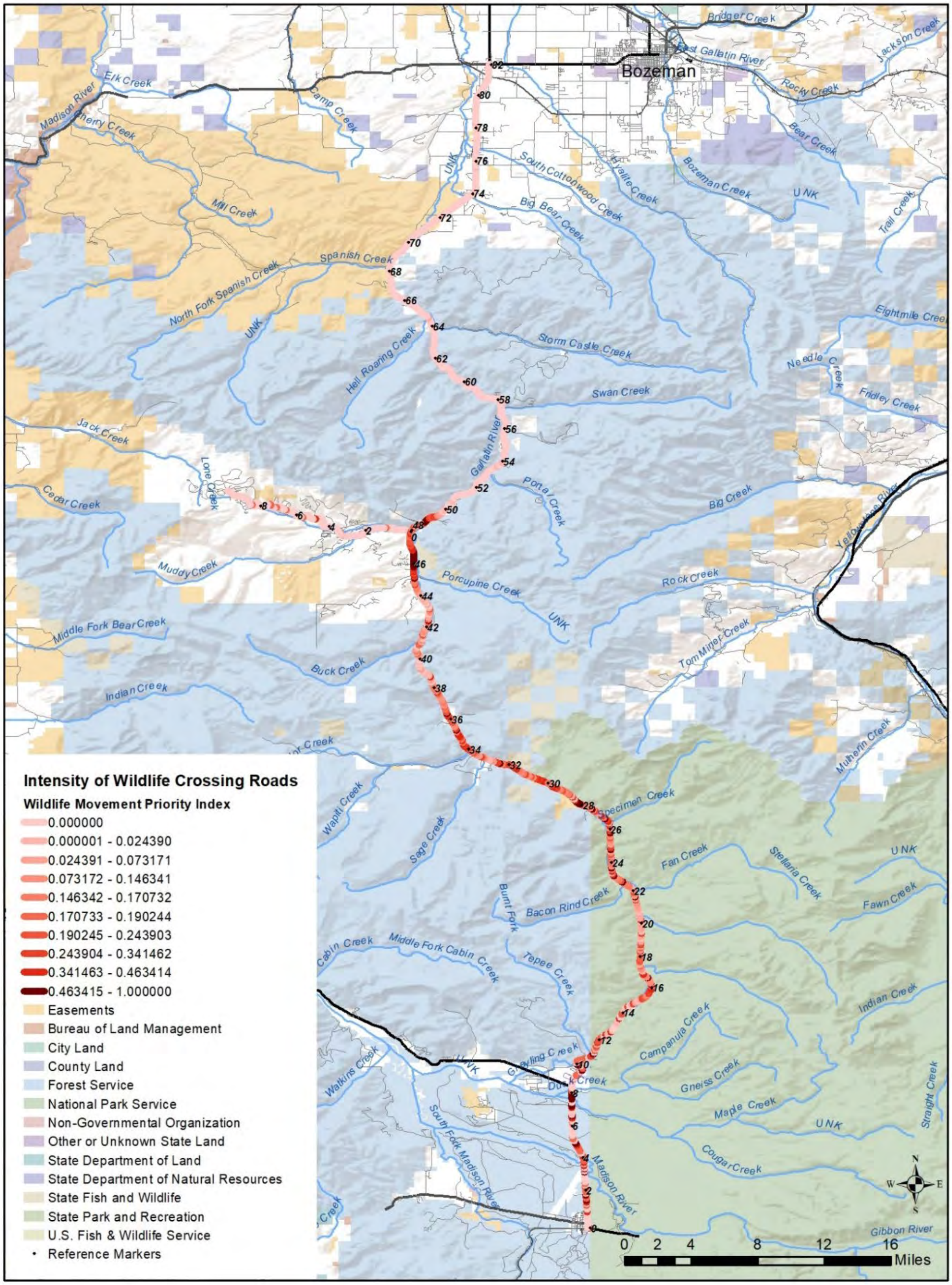


Figure 9 Intensity of Wildlife Crossing Roads in the Study Area

There are 236 crossing events by 34 individual collared grizzly bears between 2000-2020. Grizzly bears make up 9.5% (236/2484) of total crossings, with a maximum of 5 grizzly bear crossings (mean = 0.26, SD = 0.66) in 2 segments (i.e., RM 3.1 and RM 7.7). Grizzly bear crossings occur in 17% (159/921) of the 0.10-mile segments, with one-time crossing events in 68% (108/159) of segments. Five individual bears that make >10 crossings contribute roughly 55% (129/236) of crossing events, with GB0653 having the most crossings at 60 events, before eventually being struck and killed by a vehicle near RM 23 (Figure 10).

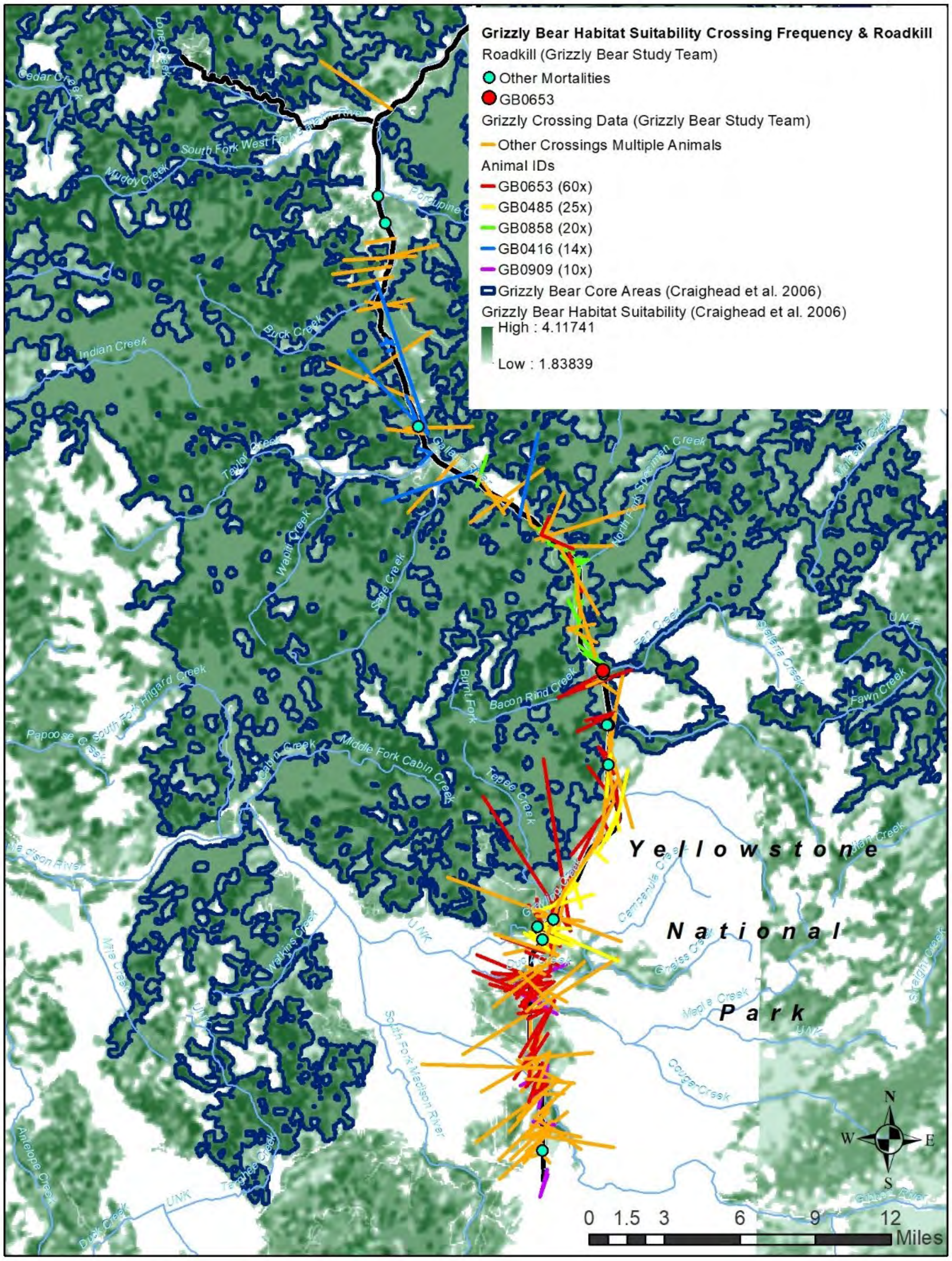


Figure 10 Grizzly Bear Habitat Suitability, Crossing Frequency and Roadkill

There are 59 crossing events by various species (e.g., bison, elk, white-tailed deer, mule deer) recorded in the ROaDS Tool by citizen scientists in the analysis. ROaDS Tool crossings make up 2.4% of total crossings (59/2,484) and are documented in 14 of the 0.10-mile segments, ranging from 1 to 30 crossings per event. About 51% (30/59) of the recorded crossings are a herd of 30 bison crossing in segment RM 3.7.

3.2. Wildlife Observation Importance Index

In the Wildlife Observations Near Roads Prioritization Characteristic, 54% (498/921) of segments have various species of wildlife recorded within 500 m of US-191 or MT-64 in the study area, with the top 10% of these segments having importance index values of 0.364 or greater (Figure 11). The total number of wildlife observed is 10,727 with a maximum of 285 observations in any one 0.10-mile segment (mean = 11.65, SD = 24.79). All data for the top 10 segments identified in the Wildlife Observation Importance Index are shown in Table 5.

Table 5 Wildlife Observation Importance Index: Top Ten 0.10-mile segments

Road ID	**ROaDS # Obs**	**Madison Elk #Obs**	**Gallatin Elk #Obs**	**Flight Clip #Obs**	**Total #Obs**	**ROaDS # Obs Normal-ized**	**Madison Elk # Obs Normal-ized**	**Gallatin Elk # Obs Normal-ized**	**Flight Clip # Obs Normal-ized**	**(RDSN*0.10) + (MADN*0.30) + (GALN*0.30) + (FLTN*0.30) = Observations**	**Wildlife Obs Imp Index**
RM46.7	0	0	28	206	234	0.000	0.000	0.609	0.805	0.424	1.000
RM24.8	0	83	4	1	88	0.000	1.000	0.0870	0.004	0.327	0.772
RM72.7	29	0	0	256	285	0.180	0.000	0.000	1.000	0.318	0.750
RM46.5	0	0	38	56	94	0.000	0.000	0.826	0.219	0.313	0.739
RM26.3	0	74	5	1	80	0.000	0.892	0.109	0.004	0.301	0.710
RM46.2	0	0	46	1	47	0.000	0.000	1.000	0.004	0.301	0.710
RM24.6	42	74	0	1	117	0.261	0.892	0.000	0.004	0.295	0.695
RM46.1	0	0	33	62	95	0.000	0.000	0.717	0.242	0.288	0.679
RM46.4	0	0	29	69	98	0.000	0.000	0.630	0.270	0.270	0.637
RM29.9	0	58	9	0	67	0.000	0.699	0.196	0.000	0.268	0.633

Wildlife observations from roughly 20 years of flight monitoring data make up 35% (3,761/10,727) of the total wildlife observations within 500 m of the study roads, ranging from 0 to 256 observations per event (mean = 4.08, SD = 18.23). These observations are documented in 24% (217/921) of the 0.10-mile segments. Of the 217 events, 3 road segments have over 200 individuals observed in discrete events (RM 72.6, RM 72.7, and RM 46.7) and 7 road segments have over 100 individuals observed in each event. The primary species encountered within 500 m of the study area roads, from the greatest to least number of occurrences, include elk, bighorn sheep, moose, bison, black bear, mule deer, white-tailed deer, and wolf.

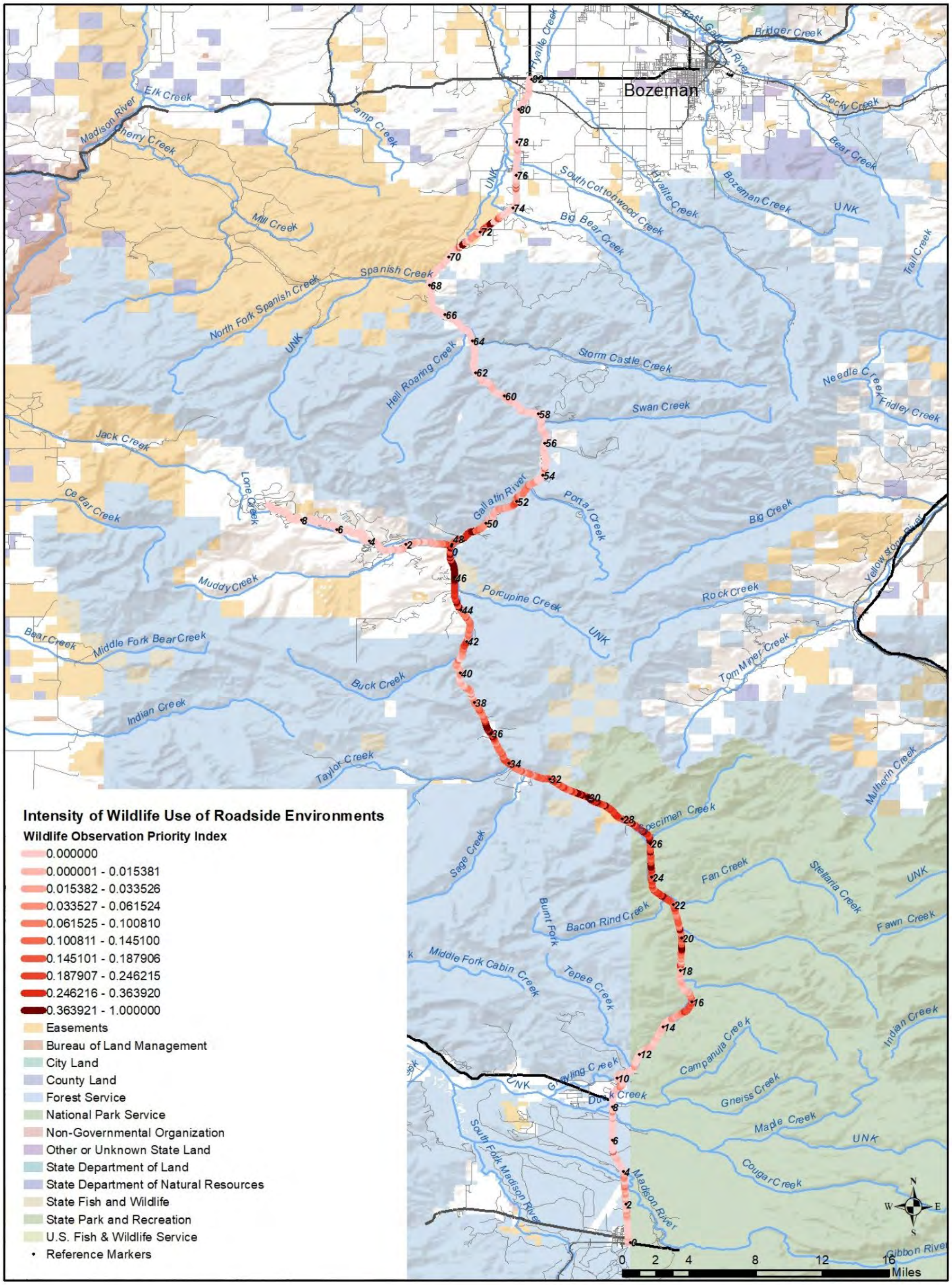


Figure 11 Intensity of Wildlife Use of Roadside Environments in the Study Area

Data on collared individuals in the Madison Elk Herd make up roughly 31% (3,304/10,727) of the total wildlife observations within 500 m of study area roads, with a maximum of 83 individual elk observed in any segment (RM 24.8) and a mean of 3.59 (SD = 9.64). Elk observations from the Madison herd occur in 256 of the 921 0.10-mile segments and all but 6 of these events occur between RM 20.1 and RM 36.7. Roughly 3.9% (10/256) of these segments have ≥ 50 elk observed in any one event and 57 of these segments have > 20 elk observed.

Data on collared individuals in the Gallatin Elk Herd make up about 22% (2,333/10,727) of the total wildlife observations within 500 m of the study area roads, with a maximum of 46 individual elk observed in any one segment (RM 46.2) and a mean of 2.53 (SD = 5.20). Elk observations from the Gallatin herd occur in 38% (353/921) of the 0.10-mile segments. Twenty of the segments have ≥ 20 individuals observed and all but 2 of these segments are between RM 44.9 and RM 49.3.

There are 1,329 wildlife observations of various species (e.g., bighorn sheep, elk, bison, white-tailed deer, mule deer) recorded by citizen scientists in the ROaDS Tool included in the analysis. ROaDS Tool data make up 12.3% of total observations (1,329/10,727) and are documented in 73 of the 0.10-mile segments, ranging from 0 to 161 observations per event (mean = 1.44, SD = 10.64). There are 8 segments with ≥ 50 individuals recorded and all of these observations are between RM 71.8 and RM 75.4.

3.3. Wildlife-Vehicle Collision Risk Importance Index

In the Wildlife-Vehicle Collision Risk Prioritization Characteristic, 56% (512/921) of segments have at least one WVC (i.e., crash or carcass), with the top 10% of these segments having importance indices of 0.411 or greater (Figure 12). The total number of WVCs (i.e., crash and carcass) across the 10 years analyzed is 1,852 with a maximum of 25 WVCs in any one 0.10-mile segment (mean = 2.01, SD = 3.62). Road Mile segment 79.8 has the highest total count of WVCs. All data for the top 10 segments identified in the Wildlife Vehicle Collision Importance Index are included in Table 6.

In the MDT carcass data, 44% (408/921) of the segments have at least one carcass. The total number of carcasses across the 10 years analyzed is 1,347 with a maximum of 22 carcasses in any one 0.10-mile segment (mean = 1.46, SD = 3.0). Road Mile segment 77.6 has the highest total count of carcasses. The top 10 segments with carcasses are all between RM 73.0 and RM 79.8.

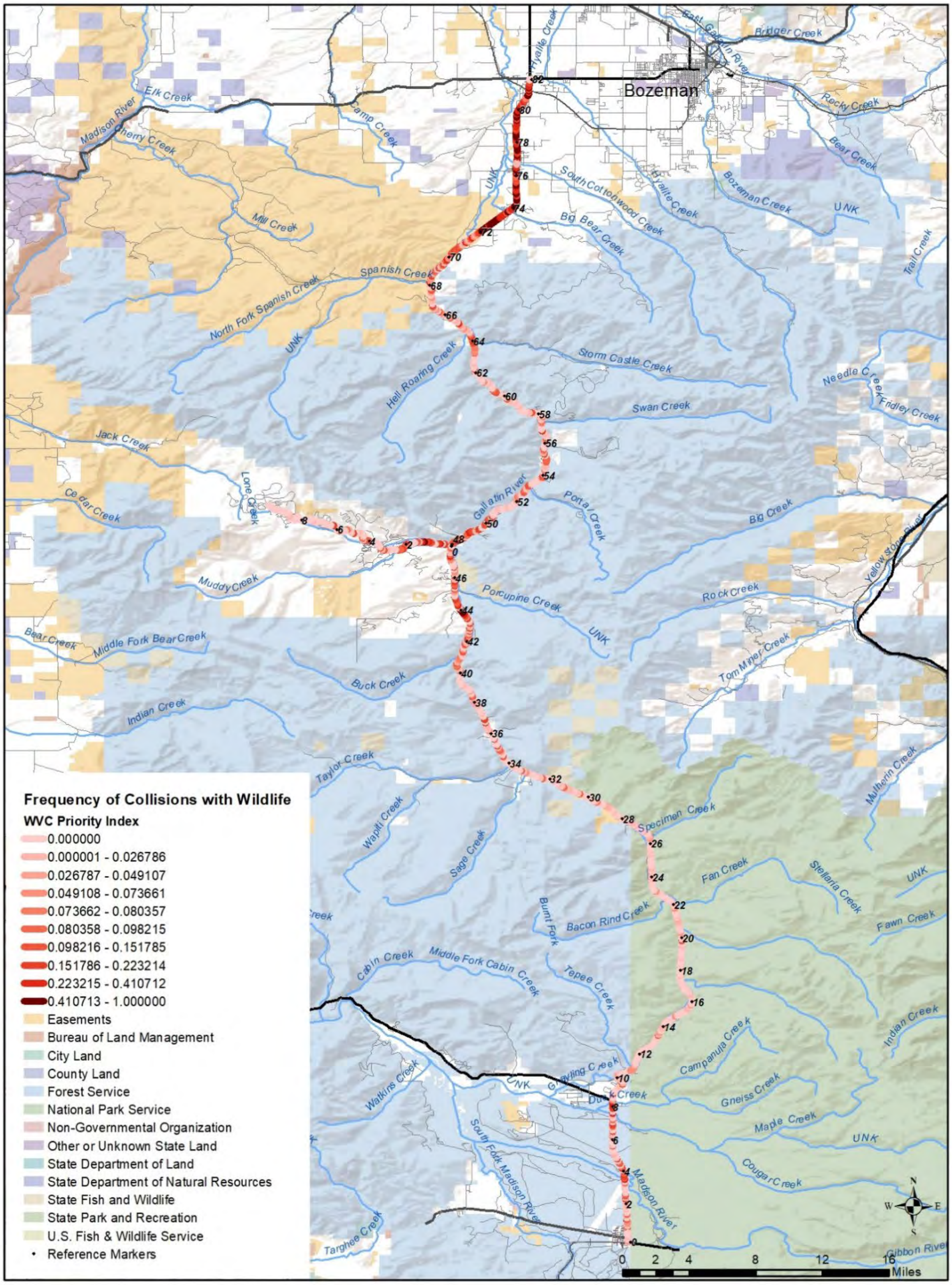


Figure 12 Frequency of Collisions with Wildlife in the Study Area based on Crash and Carcass Data

Table 6 Wildlife Vehicle Collision Risk Importance Index: Top Ten 0.10-mile Segments

Road ID	# CARCASS	# CRASH	# GRIZ KILL	#ROaDS KILL	Total WVC	# Carcass Normal-ized	# Crash Normal-ized	# Griz Kill Normal-ized	# ROaDS KILL Normal-ized	(CARC*0.40) + (CRASH*0.40) + (GRIZ*0.10) + (RDS*0.10) = WVC	WVC Imp Index
RM79.0	19	5	0	0	24	0.864	0.833	0.000	0.000	0.679	1.000
RM74.3	17	5	0	0	22	0.773	0.833	0.000	0.000	0.642	0.946
RM79.5	11	6	0	1	18	0.500	1.000	0.000	0.333	0.633	0.933
RM79.8	20	2	0	3	25	0.909	0.333	0.000	1.000	0.597	0.879
RM77.5	13	5	0	0	18	0.591	0.833	0.000	0.000	0.570	0.839
RM72.9	12	5	0	0	17	0.545	0.833	0.000	0.000	0.552	0.813
RM72.7	5	6	0	1	12	0.227	1.000	0.000	0.333	0.524	0.772
RM77.6	22	1	0	1	24	1.000	0.167	0.000	0.333	0.500	0.737
RM79.6	7	4	0	3	14	0.318	0.667	0.000	1.000	0.494	0.728
RM75.0	8	5	0	0	13	0.364	0.833	0.000	0.000	0.479	0.705

In the MDT crash data, 29% (267/921) of the segments have at least one crash. The total number of crashes across the 10 years analyzed is 439 with a maximum of 6 crashes in any one 0.10-mile segment (mean = 0.48, SD = 0.93). Road Mile segments 48.4, 72.7, and 79.5 have the highest number of crashes. Roughly 60% (160/267) of the segments have just one crash, while 14% have 3 or more crashes. The great majority of crashes are on US-91 north of its intersection with MT-64, with quite a few crashes also within about the first mile MT-64.

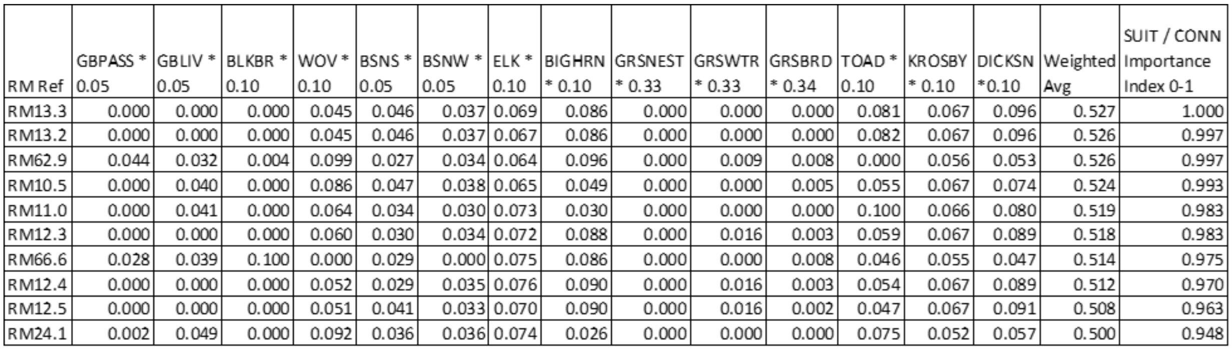
The Interagency Grizzly Bear Study Team (IGBST) has recorded a dozen grizzly bears killed on US-191 over roughly a 40-year period. All recorded roadkills occur in 11 0.10-mile segments, with 2 grizzly bears as the maximum killed in any one segment (at RM 19.8). While none of the 11 segments are in top 10 of the WVC Importance Index shown in Table 6, four segments with grizzly bear kills (i.e., RM 9.5, RM 10.2, RM 10.9 and RM 35.2) occur within the Teepee Creek and Taylor Fork Priority Sites that are described in Chapter 6.

The carcass data collected by citizen scientists using the ROaDS Tool over a one-year period include a total of 54 events, with a maximum of 3 individual carcasses recorded in any one event (mean = 0.06, SD = 0.28). These data are recorded on 46 0.10-mile segments, with 76% of the events recorded north of RM 50.0 on US-191. Only one event is recorded on MT-64 at RM 0.3.

3.4. Habitat Suitability/Connectivity (Regional Conservation Value) Importance Index

Figure 13 shows regional conservation value of all segments in the study area as described by Habitat Suitability/Connectivity Importance Index, with the top 10% having index values of 0.804 or greater. Table 7 highlights the top ten 0.10-mile segments with the highest values of this index, the majority of which are along the southern extent of US-191 in the study area within Yellowstone National Park, with the highest value at RM 13.3. This is due to the expanse of relatively intact habitat within the park compared to the matrix of public and private land under development pressure further north. The average value of this index across all 921 0.10-mile segments is 0.53 (SD = 0.21) with a minimum value of <0.001 in the northernmost part of the study area.

Table 7 Habitat Suitability/Connectivity (Regional Conservation Value) Importance Index: Top Ten 0.10-mile Segments



RM Ref	GBPASS * 0.05	GBLIV * 0.05	BLKBR * 0.10	WOV * 0.10	BSNS * 0.05	BSNW * 0.05	ELK * 0.10	BIGHRN * 0.10	GRSNEST * 0.33	GRSWTR * 0.33	GRSBRD * 0.34	TOAD * 0.10	KROSBY * 0.10	DICKSN *0.10	Weighted Avg	SUIT / CONN Importance Index 0-1
RM13.3	0.000	0.000	0.000	0.045	0.046	0.037	0.069	0.086	0.000	0.000	0.000	0.081	0.067	0.096	0.527	1.000
RM13.2	0.000	0.000	0.000	0.045	0.046	0.037	0.067	0.086	0.000	0.000	0.000	0.082	0.067	0.096	0.526	0.997
RM62.9	0.044	0.032	0.004	0.099	0.027	0.034	0.064	0.096	0.000	0.009	0.008	0.000	0.056	0.053	0.526	0.997
RM10.5	0.000	0.040	0.000	0.086	0.047	0.038	0.065	0.049	0.000	0.000	0.005	0.055	0.067	0.074	0.524	0.993
RM11.0	0.000	0.041	0.000	0.064	0.034	0.030	0.073	0.030	0.000	0.000	0.000	0.100	0.066	0.080	0.519	0.983
RM12.3	0.000	0.000	0.000	0.060	0.030	0.034	0.072	0.088	0.000	0.016	0.003	0.059	0.067	0.089	0.518	0.983
RM66.6	0.028	0.039	0.100	0.000	0.029	0.000	0.075	0.086	0.000	0.000	0.008	0.046	0.055	0.047	0.514	0.975
RM12.4	0.000	0.000	0.000	0.052	0.029	0.035	0.076	0.090	0.000	0.016	0.003	0.054	0.067	0.089	0.512	0.970
RM12.5	0.000	0.000	0.000	0.051	0.041	0.033	0.070	0.090	0.000	0.016	0.002	0.047	0.067	0.091	0.508	0.963
RM24.1	0.002	0.049	0.000	0.092	0.036	0.036	0.074	0.026	0.000	0.000	0.000	0.075	0.052	0.057	0.500	0.948

The Habitat Suitability/Connectivity Importance Index is derived from 14 different data sets (Table 1), most of which are species-specific. Table 8 provides summary statistics for the normalized values of each of the habitat suitability/connectivity model inputs. We highlight the results of two of the model inputs that are species-neutral here (see Figure 14). The information from Dickson et al. (2016), which is based on current ecological flows of connectivity among large, protected areas in the western U.S., shows the majority of the study area is relatively permeable south of RM 72.0. The most highly permeable area is between Bacon Rind and Teepee creeks, where 60 segments have connectivity values above 0.80. The average connectivity value along the study area roads is 0.46 (SD = 0.19). The top 10% of the riparian climate corridors delineated in Krosby et al. (2018) that intersect with study area highways are south of RM 18.0 and include Grayling, Teepee, Duck, and Cougar Creeks. However, the highest rank is RM 64.3, where Hell Roaring Creek flows into the Gallatin River, and RM 53.1-2, where Portal Creek flows into the Gallatin River, also scores in the top 10%.

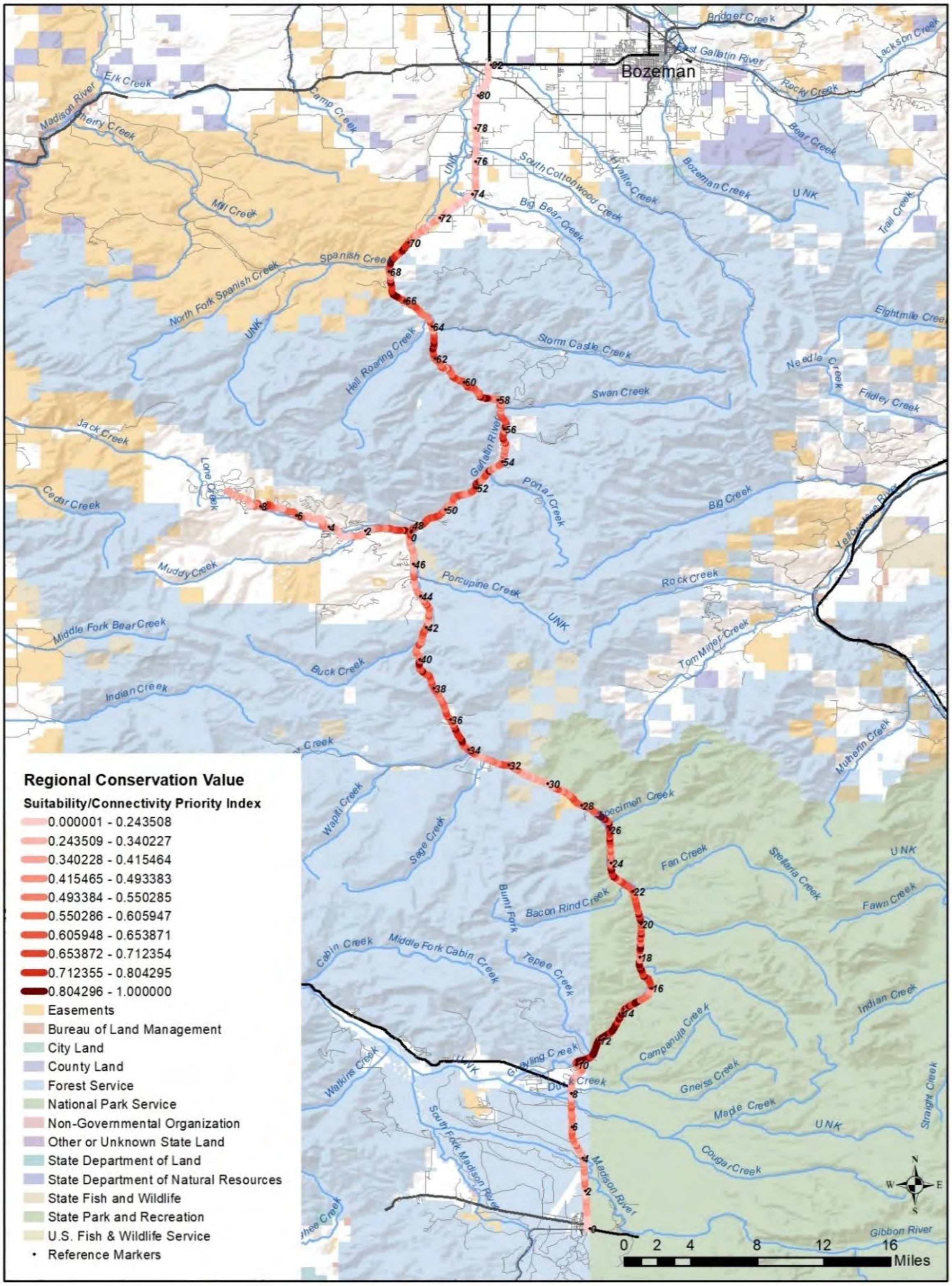


Figure 13 Regional Conservation Value

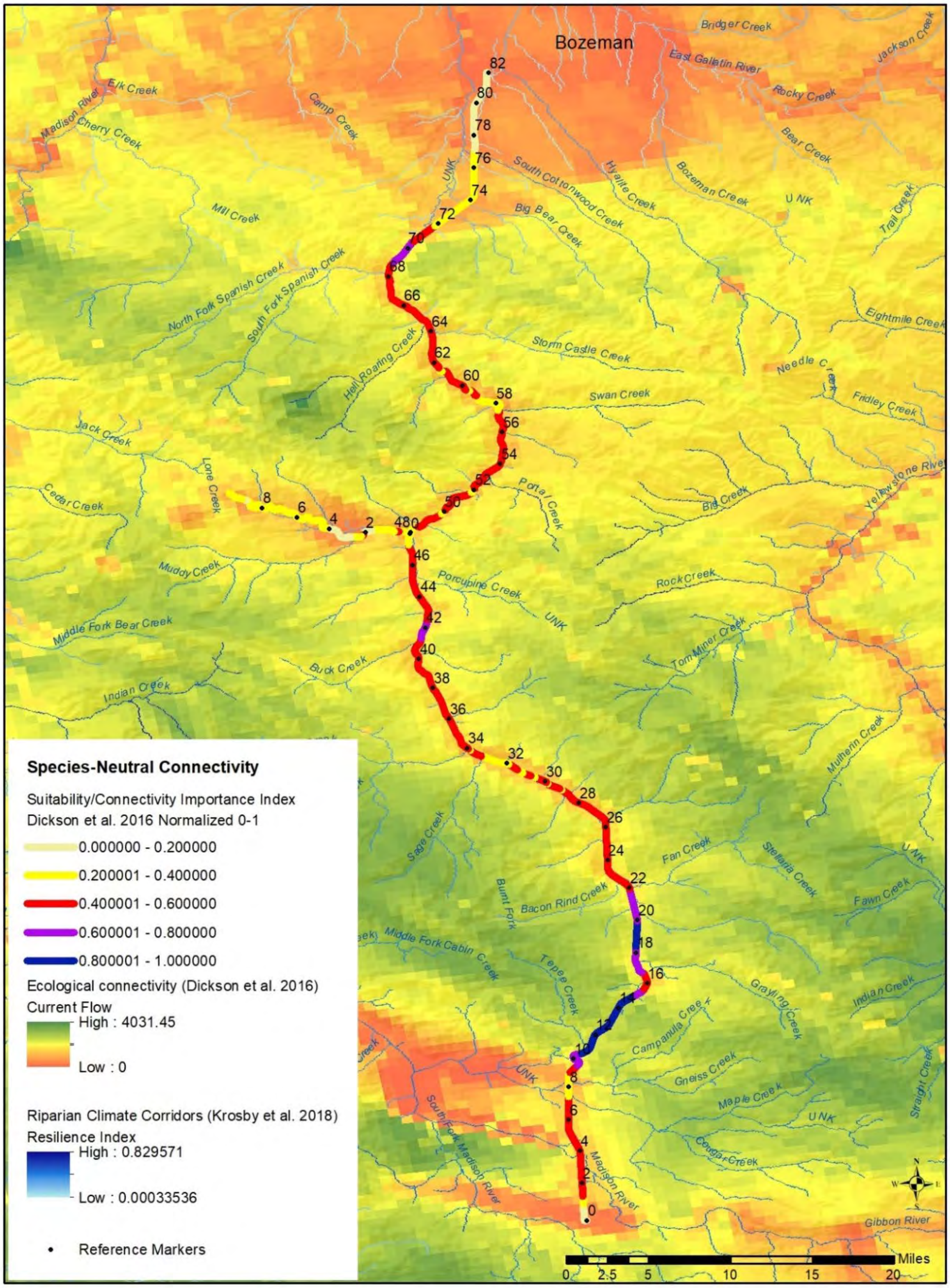


Figure 14 Species-neutral Connectivity Showing General Permeability of the Landscape to Ecological Flows and Riparian Corridors Important for Climate Resilience

Table 8 Summary Statistics on Normalized Values for Habitat Suitability/Connectivity (Regional Conservation Value) Model Inputs

Data Input	Min	Max	Mean	SD	No. of Segments with Values	Highest Value Segment or Range of Segments
Ecological Connectivity	0	1	0.465	0.189	921	RM 13.4-14.0 (US-191)
Riparian Climate Corridors	0.059	1	0.551	0.118	340	RM 64.3 (US-191)
Boreal Toad Habitat Effectiveness	0.003	1	0.382	0.225	354	RM 11.0 (US-191)
Sage Grouse Potential Brood Habitat	0.018	1	0.435	0.210	435	RM 8.6 (US-191)
Sage Grouse Winter Habitat Suitability	0.287	1	0.615	0.123	144	RM 8.5 (US-191)
Sage Grouse Potential Nesting Habitat	0.066	1	0.292	0.227	122	(highest) RM 8.6 (US-191); top 20 values between RM 4.1-8.9 (US-191)
Bighorn Sheep Habitat Effectiveness	0.128	1	0.574	0.274	422	RM 63.0-63.9 (US-191)
Elk Habitat Effectiveness	0.124	1	0.671	0.145	921	RM 4.3 (MT-64)
Bison Winter Habitat Suitability	0.437	1	0.740	0.115	553	RM 81.8-81.9 (US-191)
Bison Summer Habitat Suitability	0.233	1	0.711	0.175	624	RM 1.0-7.1 (US-191)
Wolverine Habitat Effectiveness	0.001	1	0.490	0.3052	424	RM 39.4 (US-191)
Northern Rockies Black Bear Connectivity	0.005	1	0.046	0.117	463	RM 66.5-67.0 (US-191)
Grizzly Bear Habitat Suitability	0.555	1	0.751	0.106	581	(highest) RM 43.7 (US-191); 154 segments > 0.8, most of which are south of RM 44 on US-191; and between RM 4.5-8.5 on MT-64
Potential Grizzly Bear Passage	0.036	1	0.301	0.258	345	RM 63.6 (US-191)

3.5. Priority Composite Index

Figure 15 provides an overview of how each of the 921 0.10-mile road segments evaluated ranks in the Priority Composite Index, highlighting the top 10% of each highway separately. The top 10% of the 820 segments analyzed on US-191 have index values between 0.689 and 1, while the top 10% of the 101 segments evaluated on MT-64 have index values between 0.456 and 0.632. Tables 9 and 10 provide detailed rankings of the top 10% of the 0.10-mile road segments along US-191 and MT-64 with the highest Priority Composite Index values. The top 10% of 0.10-mile segments overall are along US-191 with the highest value at RM 11.1. The average Priority Composite Index value of all 921 0.10-mile segments is 0.45 (SD = 0.17).

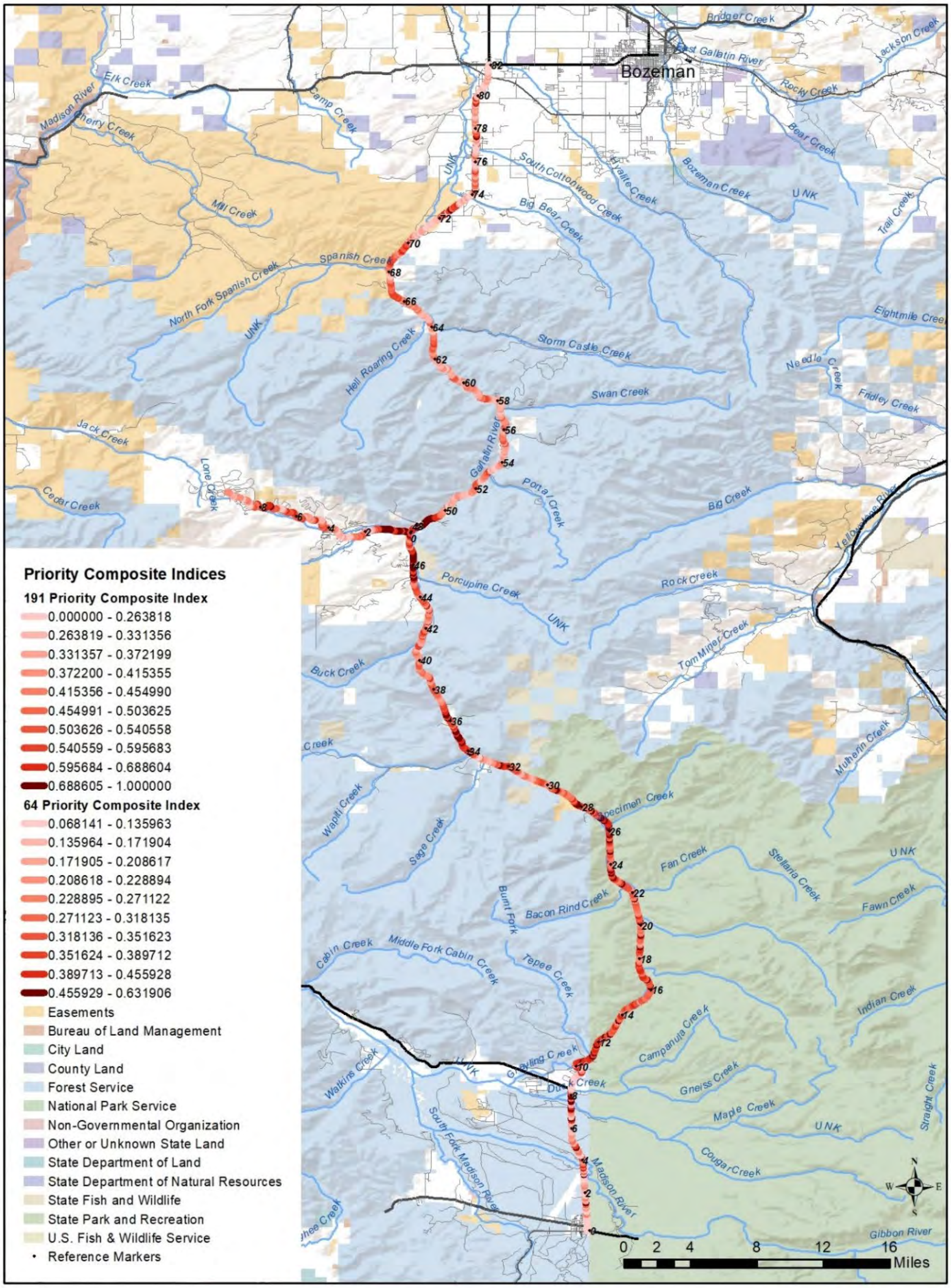


Figure 15 Priority Composite Indices for US-191 and MT-64

Table 9 Top 10% 0.10-mile Road Segments on US-191 for the Priority Composite Index

US-191 Road Mile Reference	**Wildlife Movement Importance Index (WMII)**	**Wildlife Observation Importance Index (WOII)**	**Suitability / Connectivity Importance Index (SCII)**	**WVC Importance Index (WVCII)**	**WMII * 0.30**	**WOII * 0.10**	**SCII * 0.30**	**WVCII * 0.30**	***(WMII*0.30) + (WOII*0.10) + (SCII*0.30) + (WVCII*0.30) = Composite Index***	**Priority Composite Index Normal-ized**
RM11.1	0.785	0.000	0.808	0.054	0.236	0.000	0.242	0.016	0.494	1.000
RM23.7	0.576	0.193	0.919	0.000	0.173	0.019	0.276	0.000	0.468	0.945
RM23.2	0.668	0.191	0.810	0.000	0.200	0.019	0.243	0.000	0.463	0.935
RM46.4	0.951	0.637	0.309	0.054	0.285	0.064	0.093	0.016	0.458	0.925
RM46.0	0.854	0.431	0.272	0.223	0.256	0.043	0.082	0.067	0.448	0.904
RM24.8	0.644	0.772	0.579	0.000	0.193	0.077	0.174	0.000	0.444	0.896
RM26.3	0.337	0.710	0.847	0.054	0.101	0.071	0.254	0.016	0.442	0.892
RM7.6	0.595	0.000	0.470	0.393	0.179	0.000	0.141	0.118	0.437	0.882
RM26.7	0.502	0.312	0.848	0.000	0.151	0.031	0.254	0.000	0.436	0.880
RM46.3	0.902	0.426	0.351	0.054	0.271	0.043	0.105	0.016	0.435	0.877
RM19.4	0.337	0.562	0.925	0.000	0.101	0.056	0.277	0.000	0.435	0.876
RM36.4	0.551	0.433	0.717	0.027	0.165	0.043	0.215	0.008	0.432	0.870
RM46.5	0.805	0.739	0.350	0.000	0.241	0.074	0.105	0.000	0.421	0.847
RM48.8	0.507	0.313	0.782	0.000	0.152	0.031	0.235	0.000	0.418	0.842
RM21.6	0.693	0.123	0.659	0.000	0.208	0.012	0.198	0.000	0.418	0.841
RM3.1	0.951	0.119	0.389	0.000	0.285	0.012	0.117	0.000	0.414	0.834
RM48.9	0.463	0.319	0.710	0.098	0.139	0.032	0.213	0.029	0.413	0.832
RM22.4	0.483	0.530	0.714	0.000	0.145	0.053	0.214	0.000	0.412	0.830
RM46.1	0.561	0.679	0.354	0.223	0.168	0.068	0.106	0.067	0.409	0.824
RM34.9	0.434	0.132	0.779	0.098	0.130	0.013	0.234	0.029	0.406	0.818
RM7.7	1.000	0.090	0.321	0.000	0.300	0.009	0.096	0.000	0.405	0.816
RM12.4	0.380	0.000	0.970	0.000	0.114	0.000	0.291	0.000	0.405	0.816
RM10.0	0.380	0.000	0.779	0.179	0.114	0.000	0.234	0.054	0.401	0.808
RM34.6	0.390	0.138	0.899	0.000	0.117	0.014	0.270	0.000	0.400	0.806
RM49.1	0.293	0.337	0.607	0.321	0.088	0.034	0.182	0.096	0.400	0.805
RM28.2	0.644	0.200	0.591	0.027	0.193	0.020	0.177	0.008	0.398	0.801
RM35.0	0.244	0.116	0.887	0.152	0.073	0.012	0.266	0.046	0.396	0.797
RM25.8	0.502	0.102	0.783	0.000	0.151	0.010	0.235	0.000	0.396	0.796

US-191 Road Mile Reference	**Wildlife Movement Importance Index (WMII)**	**Wildlife Observation Importance Index (WOII)**	**Suitability / Connectivity Importance Index (SCII)**	**WVC Importance Index (WVCII)**	**WMII * 0.30**	**WOII * 0.10**	**SCII * 0.30**	**WVCII * 0.30**	***(WMII*0.30) + (WOII*0.10) + (SCII*0.30) + (WVCII*0.30) = Composite Index***	**Priority Composite Index Normal-ized**
RM47.8	0.366	0.374	0.729	0.098	0.110	0.037	0.219	0.029	0.395	0.795
RM45.8	0.585	0.369	0.313	0.295	0.176	0.037	0.094	0.088	0.395	0.794
RM48.4	0.073	0.157	0.521	0.670	0.022	0.016	0.156	0.201	0.395	0.794
RM27.5	0.551	0.364	0.610	0.027	0.165	0.036	0.183	0.008	0.393	0.790
RM49.0	0.220	0.563	0.620	0.277	0.066	0.056	0.186	0.083	0.391	0.786
RM28.3	0.551	0.351	0.632	0.000	0.165	0.035	0.190	0.000	0.390	0.784
RM35.3	0.478	0.127	0.769	0.000	0.143	0.013	0.231	0.000	0.387	0.778
RM13.6	0.405	0.015	0.824	0.054	0.121	0.002	0.247	0.016	0.386	0.776
RM48.7	0.230	0.431	0.803	0.107	0.069	0.043	0.241	0.032	0.385	0.774
RM36.2	0.366	0.510	0.690	0.054	0.110	0.051	0.207	0.016	0.384	0.771
RM7.2	0.571	0.000	0.607	0.098	0.171	0.000	0.182	0.029	0.383	0.769
RM20.2	0.405	0.119	0.825	0.000	0.121	0.012	0.247	0.000	0.381	0.765
RM46.7	0.561	1.000	0.375	0.000	0.168	0.100	0.113	0.000	0.381	0.765
RM31.4	0.580	0.138	0.640	0.000	0.174	0.014	0.192	0.000	0.380	0.763
RM16.2	0.454	0.171	0.753	0.000	0.136	0.017	0.226	0.000	0.379	0.761
RM26.9	0.312	0.328	0.841	0.000	0.094	0.033	0.252	0.000	0.379	0.761
RM16.6	0.478	0.015	0.774	0.000	0.143	0.002	0.232	0.000	0.377	0.757
RM49.2	0.244	0.396	0.684	0.196	0.073	0.040	0.205	0.059	0.377	0.757
RM45.3	0.415	0.309	0.583	0.152	0.124	0.031	0.175	0.046	0.376	0.754
RM26.2	0.454	0.452	0.647	0.000	0.136	0.045	0.194	0.000	0.375	0.754
RM1.4	0.761	0.051	0.375	0.098	0.228	0.005	0.112	0.029	0.375	0.754
RM35.1	0.434	0.079	0.762	0.027	0.130	0.008	0.229	0.008	0.375	0.753
RM23.5	0.361	0.314	0.781	0.000	0.108	0.031	0.234	0.000	0.374	0.751
RM72.7	0.000	0.750	0.225	0.772	0.000	0.075	0.067	0.232	0.374	0.751
RM42.0	0.361	0.135	0.786	0.054	0.108	0.013	0.236	0.016	0.374	0.750
RM74.3	0.000	0.009	0.295	0.946	0.000	0.001	0.088	0.284	0.373	0.749
RM24.1	0.215	0.241	0.948	0.000	0.064	0.024	0.284	0.000	0.373	0.748
RM45.9	0.707	0.574	0.316	0.027	0.212	0.057	0.095	0.008	0.373	0.748
RM7.9	0.761	0.000	0.247	0.223	0.228	0.000	0.074	0.067	0.369	0.741

US-191 Road Mile Reference	**Wildlife Movement Importance Index (WMII)**	**Wildlife Observation Importance Index (WOII)**	**Suitability / Connectivity Importance Index (SCII)**	**WVC Importance Index (WVCII)**	**WMII * 0.30**	**WOII * 0.10**	**SCII * 0.30**	**WVCII * 0.30**	***(WMII*0.30) + (WOII*0.10) + (SCII*0.30) + (WVCII*0.30) = Composite Index***	**Priority Composite Index Normal-ized**
RM45.5	0.390	0.334	0.545	0.179	0.117	0.033	0.164	0.054	0.368	0.737
RM49.3	0.341	0.387	0.618	0.125	0.102	0.039	0.186	0.038	0.364	0.730
RM46.6	0.683	0.390	0.298	0.098	0.205	0.039	0.089	0.029	0.363	0.728
RM11.8	0.312	0.000	0.892	0.000	0.094	0.000	0.268	0.000	0.361	0.725
RM46.9	0.366	0.348	0.495	0.223	0.110	0.035	0.148	0.067	0.360	0.722
RM4.8	0.380	0.008	0.616	0.196	0.114	0.001	0.185	0.059	0.359	0.719
RM7.0	0.380	0.000	0.562	0.250	0.114	0.000	0.169	0.075	0.358	0.717
RM45.2	0.341	0.261	0.708	0.054	0.102	0.026	0.212	0.016	0.357	0.715
RM10.5	0.190	0.000	0.993	0.000	0.057	0.000	0.298	0.000	0.355	0.711
RM48.6	0.293	0.335	0.627	0.152	0.088	0.033	0.188	0.046	0.355	0.711
RM34.0	0.532	0.158	0.594	0.000	0.160	0.016	0.178	0.000	0.354	0.708
RM11.0	0.190	0.000	0.983	0.000	0.057	0.000	0.295	0.000	0.352	0.705
RM35.4	0.288	0.024	0.876	0.000	0.086	0.002	0.263	0.000	0.352	0.704
RM6.6	0.571	0.000	0.599	0.000	0.171	0.000	0.180	0.000	0.351	0.703
RM12.7	0.405	0.015	0.758	0.000	0.121	0.002	0.227	0.000	0.350	0.702
RM33.9	0.337	0.224	0.755	0.000	0.101	0.022	0.227	0.000	0.350	0.701
RM48.5	0.268	0.169	0.684	0.152	0.080	0.017	0.205	0.046	0.348	0.697
RM25.5	0.195	0.400	0.831	0.000	0.059	0.040	0.249	0.000	0.348	0.696
RM79.0	0.000	0.000	0.158	1.000	0.000	0.000	0.047	0.300	0.347	0.695
RM17.7	0.246	0.084	0.880	0.000	0.074	0.008	0.264	0.000	0.346	0.693
RM28.0	0.385	0.171	0.658	0.054	0.116	0.017	0.197	0.016	0.346	0.693
RM11.3	0.215	0.033	0.901	0.027	0.064	0.003	0.270	0.008	0.346	0.693
RM29.5	0.268	0.372	0.681	0.076	0.080	0.037	0.204	0.023	0.345	0.690
RM77.5	0.000	0.022	0.301	0.839	0.000	0.002	0.090	0.252	0.344	0.689
RM36.5	0.244	0.606	0.674	0.027	0.073	0.061	0.202	0.008	0.344	0.689

Table 10 Top 10% 0.10-mile Road Segments on MT-64 for the Priority Composite Index

MT-64 Road Mile Reference	Wildlife Movement Importance Index (WMII)	Wildlife Observation Importance Index (WOII)	Suitability / Connectivity Importance Index (SCII)	WVC Importance Index (WVCII)	WMII * 0.30	WOII * 0.10	SCII * 0.30	WVCII * 0.30	(WMII*0.30) + (WOII*0.10) + (SCII*0.30) + (WVCII*0.30) = Composite Index	Priority Composite Index Normalized
RM0.5	0.000	0.075	0.781	0.250	0.000	0.007	0.234	0.075	0.317	0.632
RM0.3	0.000	0.151	0.809	0.196	0.000	0.015	0.243	0.059	0.317	0.632
RM0.6	0.000	0.041	0.785	0.196	0.000	0.004	0.236	0.059	0.299	0.594
RM1.0	0.000	0.011	0.673	0.250	0.000	0.001	0.202	0.075	0.278	0.551
RM0.2	0.000	0.217	0.759	0.027	0.000	0.022	0.228	0.008	0.257	0.509
RM1.2	0.000	0.000	0.437	0.420	0.000	0.000	0.131	0.126	0.257	0.508
RM1.1	0.190	0.018	0.441	0.196	0.057	0.002	0.132	0.059	0.250	0.494
RM1.3	0.000	0.000	0.506	0.321	0.000	0.000	0.152	0.096	0.248	0.490
RM7.4	0.190	0.000	0.625	0.000	0.057	0.000	0.187	0.000	0.244	0.482
RM0.9	0.000	0.030	0.649	0.125	0.000	0.003	0.195	0.038	0.235	0.463

3.6. Identifying Areas for Field Evaluation

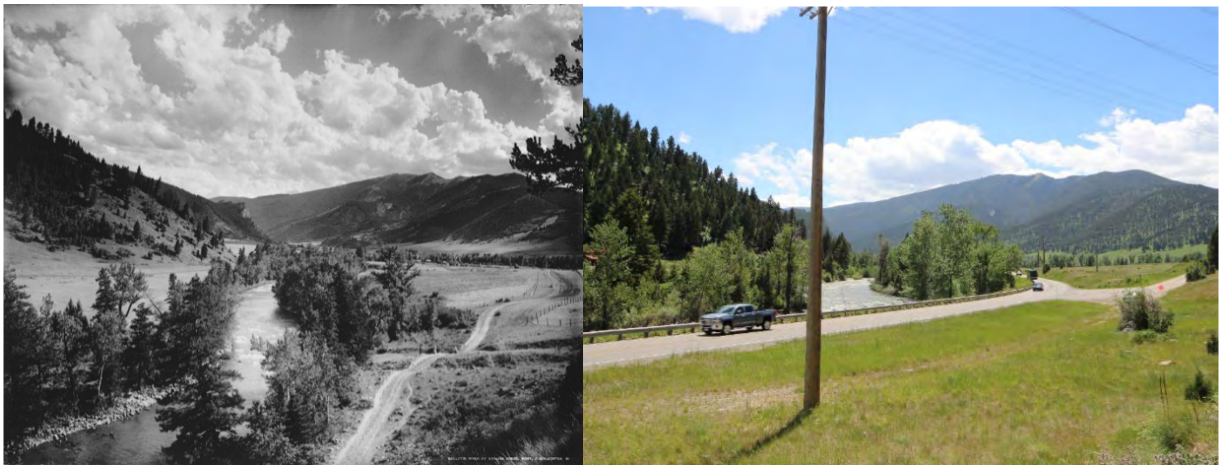


Figure 16 A view of early road configuration within the Gallatin Gateway to Spanish Creek Priority Site looking south to Gallatin Canyon at the beginning of the 1900s, and in 2016. Credits: Historic photo-Museum of the Rockies; Recent photo- Duncan Patten.

We used a MWA to smooth the results of the Priority Composite Index described in the previous section to identify areas of highway with consistently elevated values for field evaluation. The general rationale for using a MWA approach is three-fold: (1) averaging helps to lessen the effects of any spatial error in the recording of specific locations (e.g., WVCs); (2) the 0.1-mile segments used as units of analysis are small and the counts for wildlife crossings, crash, carcass, or observations for any single segment are more likely to be influenced by statistical sampling noise than are the counts for a group of consecutive segments; and (3) from a mitigation perspective, it can be useful to identify longer stretches with elevated values (e.g., high WVCs) than to identify short individual segments with the highest WVCs (e.g., when considering mitigation measures designed to reduce WVCs at more than a point location, such as fencing).

The top 10% of all 921 0.1-mile segments identified by the MWA on US-191 and MT-64 are clustered in seven locations: six on US-191 and one on MT-64 (Figure 17). The top 10% MWA of the 820 segments analyzed on US-191 have index values between 0.624 and 0.797, while the top 10% MWA of the 121 segments evaluated on MT-64 have index values between 0.406 and 0.500. These seven locations are:

US-191

- Teepee Creek from RM 10.4 to RM 11.6
- Bacon Rind Creek from RM 23.2 to RM 24.0
- Specimen Creek from RM 25.8 to RM 27.1
- Taylor Fork from RM 34.2 to RM 35.5 + RM 36.4
- Porcupine Creek from RM 45.4 to RM 47.0
- North of Big Sky from RM 48.1 to RM 49.4

MT-64

- West Fork Gallatin on MT-64 from RM 0.2 to RM 1.2

Roughly half of the top 10% segments with the highest Priority Composite Index values (see Tables 9 and 10) are included in the locations identified by the MWA for field evaluation. While many of the highest individual 0.10-mile segments are omitted, a number of these segments show localized spikes not surrounded by other high-value segments.

Along with the seven locations identified via the MWA, we identified three additional areas for field evaluation. We included two areas on the northern end of the study area with the highest WVC risk to capture the important human safety concerns in those locations (Four Corners to Gallatin Gateway and Gallatin Gateway to Spanish Creek), as well as one area on MT-64 based on habitat suitability/connectivity. These three locations are:

US-191

- Gallatin Gateway to Spanish Creek along US-191 from RM 68.1 to RM 73.7
- Four Corners to Gallatin Gateway along US-191 from RM 74.1 to RM 81.3

MT-64

- Upper Big Sky Connectivity Area on MT-64 from RM 7.3 to RM 8.2

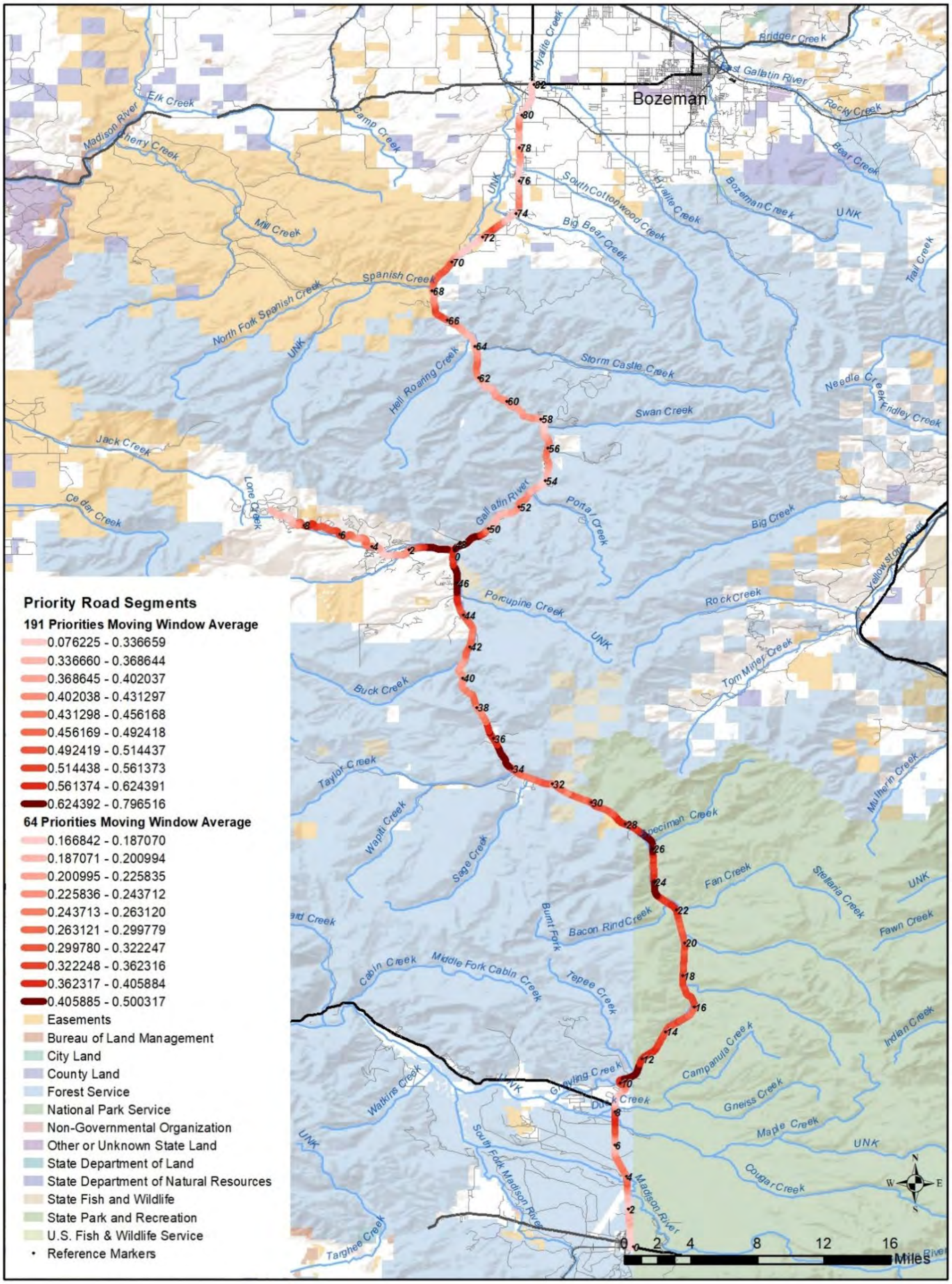


Figure 17 Priority Road Areas for Field Evaluations

During field visits, the CLLC-WTI research team and Technical Advisory Committee (TAC) expanded 3 of these locations to include additional segments among the top 10% of Priority Composite Index values. The Teepee Creek site was expanded southward to incorporate RM 9.5 to RM 10.3. The Bacon Rind and Specimen Creek sites were combined and expanded to incorporate RM 24.1 to RM 25.7. Following the field visits, the Porcupine Creek site was extended south to RM 43 based on additional conversations with area biologists from MDT and FWP (Deb Wambach, Butte District Biologist, MDT; Julie Cunningham, Bozeman Area Biologist, FWP, pers. comms.). Detailed maps and descriptions of each of the expanded sites are in Chapter 6.

4. Wildlife Accommodation Measures

A wildlife overpass was first installed in France in the 1950s, with Utah installing the first similar structure in the U.S. in 1975 on I-15 near Beaver, followed by additional construction of dedicated crossings for wildlife in New Jersey and other states. Today, many states have installed wildlife crossing structures, with the majority allowing animals to cross beneath the road surface via specially designed culverts, underpasses, and bridges rather than more visible wildlife overpasses. Dozens of wildlife crossing structures have been installed along US-93 in western Montana, including an overpass. While structures usually serve multiple species, they must be located and designed with appropriate characteristics to serve target species and based on data about crossing locations.

The wildlife accommodation measures considered in this report fall into two overarching categories: a) measures aimed at influencing driver behavior and b) measures to make roads more permeable to wildlife. A discussion of both categories follows. While some measures to influence driver behavior may reduce the risk of wildlife-vehicle collisions, with varying degrees of success, this category of measures generally fails to address the barrier effect of roads on wildlife movement, a key concern of this study. The latter category, in which wildlife is separated from traffic by fencing and crossing structures designed to enable safe wildlife passage, achieves the dual objectives of reducing wildlife-vehicle collisions and maintaining habitat connectivity.

A 2021 Pooled Fund Study supported by the Departments of Transportation of nine states in cooperation with the Federal Highway Administration reviewed the literature on known accommodation measures for both large and small (coyote or smaller) animals to determine effectiveness. The information below and summarized in Table 11 is derived from this review by Huijser et al. (2021).

Table 11 Effectiveness of Mitigation Measures

Mitigation Measure	Effectiveness in Reducing Collisions with Large Mammals	Effectiveness in Reducing the Barrier Effect of Roads and Traffic
Measures aimed at influencing driver behavior		
Seasonal wildlife warning signs	9-50%	None
Animal detection systems	33-97%	None
Seasonal road closure	100% during closure	Reduces barrier effect of traffic, not the road, during closure
Increase visibility for the driver	57-68%	None, may increase barrier effect for some species
Reduced speed with traffic calming measures	Unknown-59%	Unknown
Measures to separate wildlife from the road and traffic		
Barriers: fences, boulders, walls	80-100%	None, increases barrier effect
Underpasses and overpasses without fencing	Varies greatly based on structural design and location	Reduces barrier effect
Underpasses and overpasses with fencing	80-100%	Reduces barrier effect

(Adapted from Huijser et al. 2021)

4.1. Measures to Influence Driver Behavior

4.1.1. Permanent or Temporary Warning Signs

While commonly implemented, permanent warning signs have been found to reduce collisions with wildlife only for a short period of time after their installation. They are generally considered to be ineffective, in spite of the fact that they may increase driver awareness or cause temporary speed reduction (Pojar et al. 1975; Coulson 1982; Al-Ghamdi 2004; Sullivan et al. 2004; Meyer 2006; Bullock, Malan, and Pretorius 2011). Researchers believe they may help increase awareness of collision danger, yet may also falsely suggest that signs alone are an effective tool.

In contrast, while studies are limited, temporary warning signs may reduce collisions. Effectiveness, however, varies substantially (9–50%) (Sullivan et al. 2004; Colorado Department of Transportation 2014). It appears that seasonal or other types of enhanced warning signs increase in effectiveness when used in increasingly precise locations during specific periods of high risk. However, as enhanced wildlife warning signs are often applied over long road sections, and not limited to periods of high risk, their effectiveness may be limited in practice (Huijser et al. 2015).

4.1.2. Animal Detection Systems

Like temporary warning signs, animal detection systems can reduce wildlife-vehicle collisions with large mammals. Collisions may be reduced by as much as 33-97% when sensors are able to reliably detect the target species (Mosler-Berger and Romer 2003; Dai, Young, and Vander Giessen 2009; Gagnon et al. 2010; Strein 2010; Minnesota Department of Transportation 2011; Sharafsaleh et al. 2012; Huijser, Gunson, and Abrams 2006). It is important to note that animal detection systems may be most appropriate on low-volume roads (such as less than 5,000 vehicles per day) to limit the likelihood of rear-end collisions when vehicles brake suddenly. Further, vehicle speed may have to be reduced substantially (for example, to 35-40 miles per hour) to reduce the likelihood of a collision (Huijser et al. 2015). Animal detection systems are still considered experimental, especially as a stand-alone measure on open roads over longer distances; technology, management, and maintenance issues hamper their effectiveness. Animal detection systems that have had the highest efficacy are those that have been used in combination with other measures and which have a very discreet detection zone, such as at the end of wildlife exclusion fencing or at an animal “crosswalk” or gap in fencing (Gagnon et al. 2010).

4.1.3. Reduced Speed Limit

Speed management is often suggested as a strategy to reduce wildlife-vehicle collisions. However, unless the design speed of the road is also reduced, posting a lower speed limit may lead to more dangerous driving conditions due to a mix of slower and faster drivers who continue to follow a road’s ‘design speed’ rather than the speed limit. This phenomenon, called “speed dispersion” (a mix of fast- and slow-moving vehicles), is known to increase crashes (Elvik 2014; Huang et al. 2013). Regardless of the speed limit, most drivers operate their vehicles at a rate that is near to or higher than a road’s design speed (Fitzpatrick 2003; Ouyang, Jiang, and Jadaan 2016; Donnell, Kersavage, and Tierney 2018).

Further, even with substantial enforcement, lowered speed limits do not change driver behavior sufficiently to reduce collisions with wildlife. For example, despite a 43% increase in citations issued over two years following the reduction of nighttime speed limits (to 55 miles/hr) in marked wildlife crossing zones in Colorado, collisions with wildlife increased in nearly half of the areas studied (Colorado Department of Transportation 2014). Drivers continued to exceed the posted limit by 11 miles/hr (Colorado Department of Transportation 2014). Similarly, in a Wyoming study in which nighttime speed limits were lowered by 15 miles/hour during times of the year with the greatest mule deer collision risk, drivers reduced their speed by only 3-5 miles/hr (Riginos et al. 2019).

Finally, because most collisions occur at dawn and dusk, highway speeds would need to be considerably slower than is common for drivers whose headlights have median reach to avoid a collision with a large mammal. An operating speed of only 40 miles/hr is still insufficient to allow one-half of drivers to stop a vehicle in time to avoid a collision (Huijser, Fairbank, and Abra 2017). To allow nearly all drivers to stop in time, the nighttime operating speed of a road needs to be as low as 25-30 miles/hr, far lower than the design speed of most roads (Huijser, Fairbank, and Abra 2017; Huijser et al. 2015).

4.1.4. Highway Lighting

Highway lighting may reduce wildlife-vehicle collisions by 57-68% (McDonald 1991; Riley and Marcoux 2006; Wanvik 2009). It is unclear, however, if collision reductions along lighted highways are because of increased visibility of the animals to drivers or because animals avoid lighted highways.

It is likely that highway lighting contributes to the barrier effect of roads for some species. While a reasonable tool to consider in high-risk areas to reduce wildlife-vehicle collisions, highway lighting is less appropriate where habitat connectivity is an objective. Lights can be expected to increase the barrier effect of roads for species that are light-avoidant, such as nocturnal species. At the same time, other species may be attracted to lights and experience a higher risk of road mortality. Since highway lighting can affect animal physiology and behavior, and even predation rates, its use may require additional measures to reduce effects on wildlife (Blackwell, DeVault, and Seamans 2015). Limiting highway lighting to periods when vehicles approach can reduce the negative impacts of lighting on wildlife, such as restricting lighted areas to those that increase drivers' sight distance on the road and roadside.

4.2. Measures to Separate Wildlife from Traffic

4.2.1. Wildlife Crossing Structures

The main objective of wildlife crossing structures is to connect wildlife populations or entire ecosystems and allow ecosystem processes to continue over or under a road. These structures allow for safe daily, seasonal, or dispersal movements between areas on either side of a highway (Dodd et al. 2007; Gagnon et al. 2010; Huijser et al. 2015; Huijser, Fairbank, et al. 2016). Wildlife use of crossing structures increases when the structures are connected to fencing (see Wildlife Fencing, below), which also serves to reduce wildlife-vehicle collisions.

4.2.2. Wildlife Underpasses

Wildlife underpasses are designed to allow wildlife to cross safely under the road. When designed for large mammals, they can also successfully allow passage of smaller species. Designing an underpass and its approaches with appropriate vegetative cover encourages use by target species and also makes smaller species feel more secure in its use. Underpasses can also be adapted to support use by amphibian and semi-aquatic species and to accommodate water flow.

Often, existing bridges or culverts that span water bodies can be re-designed to be longer and/or wider to make space for riparian habitat alongside a river or stream beneath a bridge or within a culvert, allowing for use by more species. As these structures are often located in riparian areas that are attractive to terrestrial wildlife, appropriately designed culverts and bridges can support the movement of both aquatic and terrestrial species.

Numerous types of underpass structures exist, including open-span bridges, concrete bottomless arches, corrugated steel arches, and box culverts. Because these structures are "bottomless," each allows for the natural substrate of the area to be used within the crossing structure. Dimensions vary greatly, depending on the target species, local terrain, and other parameters.

4.2.3. Wildlife Overpasses

Due to their size and visibility to drivers and the public, wildlife overpasses may be the most commonly known type of wildlife accommodation measure and are typically designed to allow movement by a suite of large animals. By including specific design elements, however, they can also attract small- and medium-sized mammals, as well as amphibians, reptiles, semi-aquatic species, ground-dwelling birds, and butterflies. Some species, such as elk, moose, pronghorn, and grizzly bears, have demonstrated a preference for overpasses in certain locales. Family groups of species like grizzly bears prefer larger open structures like overpasses but may also use large-span bridges as a wildlife underpass (Clevenger and Barrueto 2014; Ford, Barrueto, and Clevenger 2017; Sawyer, Rodgers, and Hart 2016).

4.2.4. Wildlife Fencing (in combination with Wildlife Crossing Structures)

On average, an 87 percent reduction in wildlife-vehicle collisions can be expected from fencing when combined with wildlife crossing structures (Huijser 2008). Because fencing itself creates a barrier, it is not a solution to wildlife connectivity but rather is intended to guide animals to crossing structures.

Wildlife fencing is commonly constructed at a height of 8 ft (2.4 m). Wildlife fencing is typically placed at the edge of a department of transportation's right-of-way, or at least outside of the clear zone of the highway, so it does not interfere with operations such as snow plowing.

Effective fencing may be continuous between safe passage opportunities (Clevenger and Barrueto 2014) or partial (i.e., disjunct fenced segments of highway with numerous fence ends) (Gagnon et al. 2010; Huijser et al. 2016; Huijser, Camel-Means, et al. 2016). Fencing should include escape ramps or "jump-outs," which allow wildlife trapped on the highway side of a fence to jump to safety outside the fenced section. The height of a jump-out should be 4-6 ft (1.2-1.8 m) above the outside surface to deter wildlife from jumping up and entering a roadway. Fencing may also need to include climbing or digging barriers to be effective for species adept at climbing or digging. Fencing usually needs to extend 1.5 miles on either side of a crossing structure or adjacent to a series of crossing structures to be most effective. Fence-end treatments may be necessary where fencing terminates in an area with wildlife movement potential. Fence-end treatments can include cattle guards, electrified mats, boulder fields, or natural landscape features, such as a cliff or other feature that acts as a barrier. Animal detection systems can also be used at fence ends to warn drivers when an animal is approaching or crossing the road.

5. Field Evaluation and Ranking of Priority Sites

Representatives of the Center for Large Landscape Conservation (CLLC) and Western Transportation Institute (WTI) research team and an interdisciplinary Technical Advisory Committee (TAC) of biologists, transportation ecologists, engineers, and land-use planners visited each of the 10 highway sites identified through spatial analysis on October 12-13, 2022, in order to evaluate their potential for wildlife accommodations. The following individuals participated in the field evaluation:

CLLC-WTI Research Team Representatives

- Rob Ament - Western Transportation Institute, MSU
- Marcel Huijser - Western Transportation Institute, MSU
- Damon Fick - Western Transportation Institute, MSU
- Matthew Bell - Western Transportation Institute, MSU
- Elizabeth Fairbank - Center for Large Landscape Conservation
- Abigail Breuer - Center for Large Landscape Conservation
- Braden Hance - Center for Large Landscape Conservation

Technical Advisory Committee

- Deb Wambach - Montana Department of Transportation
- Dave Gates - Montana Department of Transportation
- Mike McGrath - U.S. Fish and Wildlife Service
- Jeff Patten - Federal Highway Administration
- Randy Scarlett - U.S. Forest Service
- Kyle Meakins - National Park Service
- Doug Madsen - National Park Service
- Sean O’Callaghan - Gallatin County
- Frank Van Manen - Interagency Grizzly Bear Study Team

The research team and TAC evaluated and ranked each site using a Field Evaluation Matrix (see Section 5.1) to assess WVC risk, conservation value, mitigation options, barrier effect of the road corridor, vulnerability to future change, and land security. Many sites include major drainages from surrounding public lands that intersect with US-191 or MT-64 and feature existing infrastructure that has the potential to facilitate animal movements, such as a bridge spanning a riparian corridor. The research team and TAC evaluated existing infrastructure for its (1) current ability to function as a wildlife crossing, (2) potential for retrofitting to provide safe crossing opportunity, and (3) potential for replacement to provide safe crossing opportunity where retrofitting is not possible. The construction of purpose-built structures for wildlife crossing in areas of high-quality habitat is important for wildlife movement, as is the feasibility or advisability of adding wildlife exclusion fencing to new or existing structures. Wildlife crossing structures combined with fencing are the most effective way to reduce collisions with wildlife while maintaining habitat connectivity (Huijser et al. 2021). The research team and TAC also considered other alternatives to reduce collisions with wildlife that can be effective (see Table 11), including: animal detection systems that warn drivers when wildlife is on the road, variable message signs for areas that have spatially discreet or seasonal conflicts, and traffic calming measures to effectively reduce the design speed of the highway.

The Field Evaluation Matrix used to rank each site provides a score from 1 (low priority) to 5 (high priority) for each of 9 criteria:

1. **Wildlife-vehicle collision risk:** Frequency of collisions with wildlife.
2. **Wildlife crossing roads:** Intensity of wildlife crossing roads.

3. **Live wildlife near roads:** Intensity of wildlife use of roadside environments.
4. **Regional conservation value:** Contribution to regional conservation (if mitigated) by serving as a movement corridor or high-quality wildlife habitat at the regional scale.
5. **Land security:** Presence/absence of “secured” land (e.g., state or federal land or private holdings with voluntary conservation easements) on both sides of the road to allow for effective crossing structures.
6. **Local conservation value:** Contribution to regional conservation (if mitigated) by serving as a movement corridor or high-quality wildlife habitat at the local scale.
7. **Mitigation options:** Type and engineering feasibility of mitigation measures that could be implemented.
8. **Barrier effect:** Degree of negative impact on wildlife movement potential due to high traffic volume, non-wildlife-friendly fencing, or other adjacent linear features.
9. **Vulnerability:** Potential for future increase in WVC risk or negative impact on wildlife due to increased speed limit, traffic volume, road width, or number of lanes

Criteria 1-5 were scored based on the spatial data analysis, with the research team representatives and TAC confirming or adjusting the scores by consensus based on local conditions during field evaluation. Criteria 6-9 were scored by consensus in the field. At the conclusion of the site visits, each site received an overall score (from 1 to 5) by averaging the scores of each of the 9 criteria.

Criteria 1-4 were assigned a value of 1 (low priority) to 5 (high priority) based on mean percentiles calculated from the road segments within each priority site. These percentile categories are shown in Table 12.

Table 12 Categories Used to Score Criteria 1-4 based on the Spatial Data Analysis.

Score	Percentile Categories	Description
5	95-100%	The 5% of road segments with the highest index values
4	75-94.9%	The next 20% of road segments with the highest index values
3	50-74.9%	The next 25% of road segments with the highest index values
2	25-49.9%	The next 25% of road segments with the highest index values
1	<24.9%	The 25% of road segments with the lowest index values

Using the following rubric, Criteria 5 on land security was also scored prior to field evaluation, with the Research team and TAC adjusting the score if conditions encountered during the field visits substantiated doing so:

1. Housing or industrial/commercial development on both sides of site (or adjacent/nearby)
2. Housing or industrial/commercial development on one side of the site, privately owned open space on the other side (no conservation easement).
3. Privately owned open space lands on both sides (no conservation easement).
4. Public lands (federal, state, or tribal) or private land with a voluntary conservation easement on one side of the site, open space on the other side (no conservation easement)
5. Public lands (federal, state, or tribal) or private lands with conservation easements on both sides

The research team and TAC assigned Criteria 6-9 a value from 1 (low priority) to 5 (high priority) during field visits based on collective, expert understanding through a consensus process. Scores for all criteria (Criteria 1-9) evaluated are shown in Table 13 below.

Table 13 Summary of Scores and Ranking of each Priority Site following Field Evaluation.

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Site Rank
Four Corners to Gallatin Gateway	4	1	1	1	1	3	2	5	4	2.40	6
Gallatin Gateway to Spanish Creek	3	1	1	2	4	5	4	4	4	3.11	1
N. of Big Sky Entrance	1	2	2	3	3	3	4	4	3	2.78	2
Porcupine Creek	1	3	2	2	2	2	4	4	5	2.78	2
Taylor Fork	1	2	1	4	3	3	2	3	3	2.44	5
Specimen Creek to Bacon Rind Creek	1	2	2	4	5	5	2	1	2	2.67	3
Teepee Creek	1	1	1	4	5	4	3	1	2	2.44	5
West Fork Gallatin	1	1	1	3	4	3	4	3	3	2.56	4
Upper Big Sky	1	1	1	3	2	4	1	1	3	1.89	7

Note: Two sites tied at each of Rank 2 and Rank 5

5.1. Field Evaluation Matrix Form

Highway 191: Field Evaluation Matrix

Site ID:

AADT:

Site Description: ______________________________

____

____

- **Overall Composite Score:** Max________, Min________, Avg________.
- **Individual Evaluation Criteria Scores:**
  - **WVC risk:** Max________, Min________, Avg________.
  - **Wildlife crossing road:** Max________, Min________, Avg________.
  - **Live wildlife near road:** Max________, Min________, Avg________.

Scenario	**Description**	**Score**	**Evaluation method**
WVC risk	Frequency of collisions with wildlife		Data analysis
Wildlife Crossing Road	Intensity of wildlife crossing the road		Data analysis
Live wildlife near roads	Intensity of wildlife use of roadside environments		Data analysis
Regional conservation value	Contribution to regional conservation (if mitigated) by serving as a movement corridor or high-quality wildlife habitat at the regional scale		Data analysis
Land security	Presence/absence of "secured" land (e.g., state, federal, private conservation easement) on both sides of road to allow for effective crossing structures		Data Analysis/Field
Local conservation value	Contribution to regional conservation (if mitigated) by serving as a movement corridor or high-quality wildlife habitat at the local scale		Field
Wildlife accommodation options	Type and engineering feasibility of wildlife accommodations that could be implemented		Field
Barrier effect	Degree of negative impact on wildlife movement potential due to high traffic volume, non-wildlife-friendly fencing, adjacent linear features, etc.		Field
Vulnerability	Potential for future increase in WVC risk or negative impact to wildlife due to increased speed limit, traffic volume, road width, number of lanes, or other development pressure		Field
Overall Average Score	Take the average from all scenarios		Field

Regional conservation value: Max________, Min________, Avg________.

6. Priority Sites and Recommendations

6.1. Teepee Creek

- **TEEPEE CREEK:** US Highway 191 (US-191), RM 9.5-11.6

AADT: 2,509

Priority Rank: 5 (tied with Taylor Fork Site)

Table 14 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Teepee Creek Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	1.0	0.545	0.661
WVC Risk	0.074	0.0	0.016
Wildlife Crossing Road	0.785	0.0	0.205
Live Wildlife Near Road	0.043	0.0	0.006
Regional Conservation Value	0.993	0.731	0.886

Table 15 Teepee Creek Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
Teepee Creek	1	1	1	4	5	4	3	1	2	2.44	5

The Teepee Creek Priority Site is surrounded by public lands, including Yellowstone National Park (YNP) and Custer Gallatin National Forest (CGNF). The site includes a mix of forest and wetlands and provides important habitat for a variety of species, including elk, moose, and grizzly bears. Upon visiting the site, the research team and TAC extended it south to include the Grayling Creek drainage as well as Fir Ridge, which are important for wildlife movement between YNP and CGNF. A highway bridge runs over the Grayling Creek drainage, along with a snowmobile bridge that runs parallel just west of the road. The highway bridge provides some opportunity for terrestrial wildlife passage, especially during periods of low flow. To allow for terrestrial wildlife passage most of the year, the highway bridge should be expanded to include the stream banks on either side and sufficient vertical clearance for large mammals (>15 ft or 4.6 m) (Clevenger and Huijser 2011). This expansion could occur at the end of its service life when replacement is scheduled or earlier. The snowmobile bridge would need to be expanded at the same time, especially if located within the fenced road corridor.

The existing double-pipe culvert at Teepee Creek is perched (Figure 18) above the surrounding landscape and is not passable by most wildlife. Teepee Creek is surrounded by wetlands and non-wetland riparian habitat in this area (RM 11-11.1) and has some of the highest values of the composite and habitat connectivity/suitability indices for elk, grizzly bears, bighorn sheep, wolverine, and boreal toad, and wildlife movement for elk and grizzly bears (Table 16). Three grizzly bear mortalities have been documented within this site, in addition to moose, elk, and deer mortalities, and many smaller species, including coyotes, foxes, pine martens, beaver, and porcupines. Few of the wildlife mortalities recorded by the National Park Service have been reported as vehicle crashes. Especially in the case of larger-bodied species, this may indicate that the mortalities were caused by large vehicles like semi-trucks, which are less likely to sustain damage or report accidents with wildlife (Huijser and Begley 2019; Abra et al., 2019).

While reported WVC numbers are not high in this location compared to some others, as traffic volumes increase, WVCs may increase. Present traffic volume is relatively low, at just over 2,500 AADT, such that wildlife can cross the highway safely during some parts of the day or year by taking advantage of times when traffic volume is lesser (Riginos 2022; Riginos et al. 2018). However, as traffic volume continues to increase due to YNP visitation, local population growth, and recreation on public lands, this is an important area to implement measures to mitigate WVCs and to maintain habitat connectivity for multiple species between YNP and CGNF.

Near the Teepee Creek culvert, the area has the highest composite score (1.0) of any of the 0.10-mile segments across all priority sites (see Figure 17). Ultimately, the culvert at Teepee Creek should be replaced with a structure that has sufficient vertical clearance to provide suitable safe crossing opportunities for elk, moose, and grizzly bears; this would require >15 ft (4.6 m) vertical clearance above stream banks (Clevenger and Huijser 2011). An optimized structure design would span all, or the majority of, the wetlands and riparian habitat surrounding Teepee Creek. Nonetheless, a structure of this type is unlikely to accommodate movements by grizzly bear family groups (i.e., sows with cubs), which strongly prefer overpasses or large-span bridges (Ford, Barrueto, and Clevenger 2017). If a goal is to reduce WVCs in the area while maximizing crossing structure use, wildlife-exclusionary fencing should be used and extended north and south of the structure. Such fencing may be tied into the Grayling Creek bridge (Dodd et al. 2007; Gagnon et al. 2010).

Key Next Steps:

- Grayling Creek Bridge should be expanded to include dry terrestrial passage opportunities beneath it along both sides of the creek year-round when the bridge reaches the end of its service life or earlier. The adjacent snowmobile bridge should be expanded similarly.
- The double-pipe culverts at Teepee Creek should be replaced with a structure large enough for use by elk, moose, and grizzly bears and should span the majority of the wetland and riparian area.
- Once these structures have been upgraded to meet the needs of the target species, they could be connected by fencing that may extend as far south as Fir Ridge in order to reduce WVCs while providing connectivity.

Figure 18 Double Culverts Facilitating Water Flow from Teepee Creek

Table 16 Index Values of all 0.10-mile Segments within the Teepee Creek Priority Site

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
9.5	0.571	0.024	0.448	0.100	0.676	0.413
9.6	0.214	0	0.526	0.026	0.453	0.423
9.7	0.190	0	0.517	0	0.414	0.450
9.8	0	0	0.439	0	0.248	0.485
9.9	0.570	0.002	0.518	0.026	0.670	0.518
10	0.380	0	0.778	0.178	0.807	0.565
10.1	0	0	0.688	0	0.403	0.561
10.2	0.190	0	0.655	0.073	0.547	0.577
10.3	0.190	0.005	0.833	0.026	0.629	0.589
10.4	0.190	0	0.901	0	0.654	0.625
10.5	0.190	0	0.993	0	0.711	0.628
10.6	0.190	0	0.882	0	0.642	0.646
10.7	0.214	0	0.828	0	0.624	0.662
10.8	0	0.005	0.923	0	0.550	0.676
10.9	0.263	0	0.730	0.073	0.639	0.668
11	0.190	0	0.983	0	0.705	0.663
11.1	0.785	0	0.807	0.053	1	0.661
11.2	0	0.043	0.916	0.053	0.587	0.651
11.3	0.214	0.033	0.900	0.026	0.692	0.660
11.4	0.024	0	0.891	0	0.544	0.665
11.5	0.190	0	0.820	0	0.603	0.657
11.6	0.214	0	0.932	0	0.688	0.641

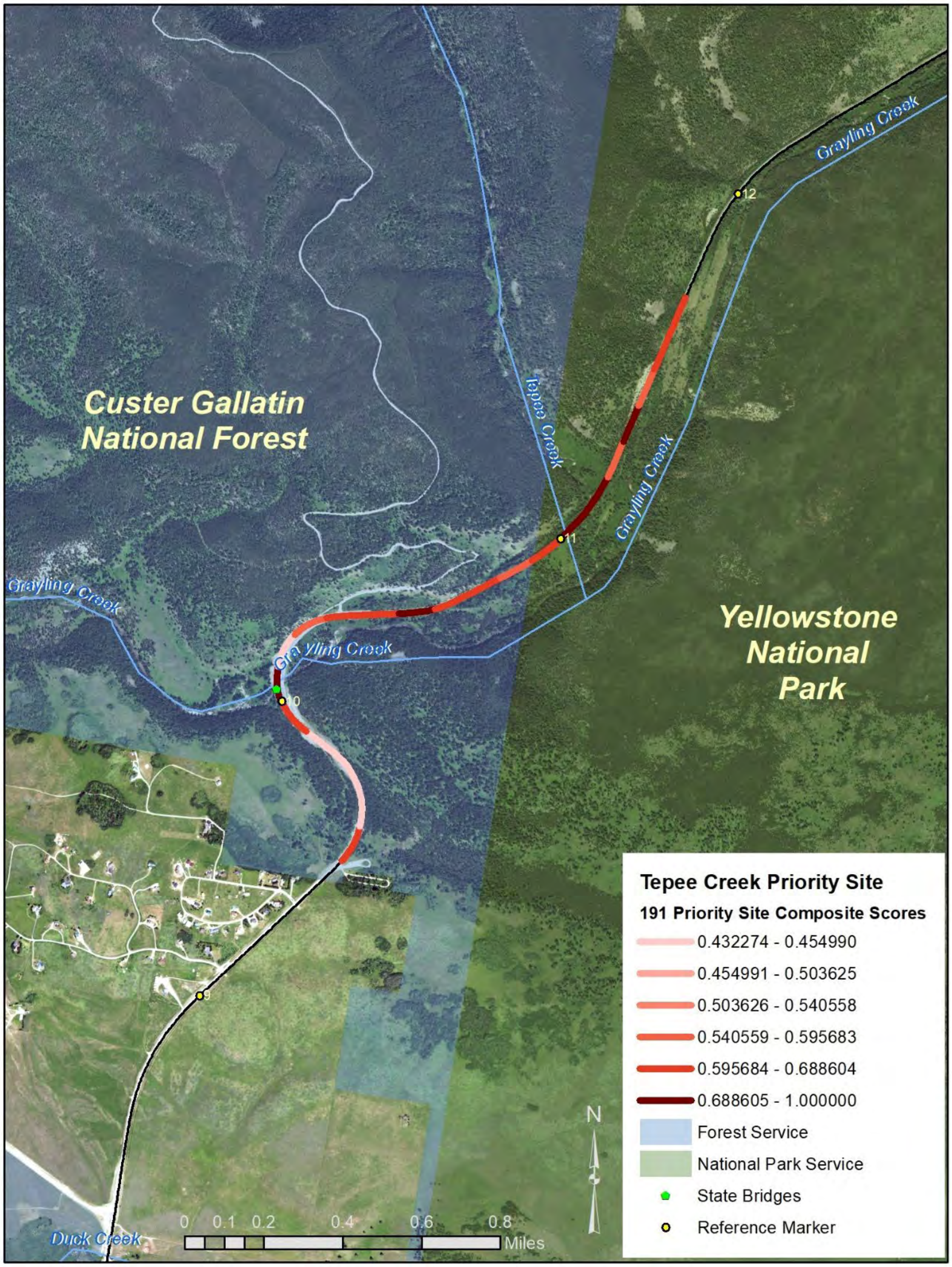


Figure 19 Teepee Creek Priority Site Map

6.2. Specimen Creek to Bacon Rind Creek

- SPECIMEN CREEK TO BACON RIND CREEK: US Highway 191 (US-191), RM 23.2-27.1

AADT: 2509

Priority Rank: 3

Table 17 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Specimen Creek to Bacon Rind Creek Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.945	0.38	0.630
WVC Risk	0.054	0	0.010
Wildlife Crossing Road	0.668	0.024	0.240
Live Wildlife Near Road	0.772	0.009	0.261
Regional Conservation Value	0.948	0.473	0.714

Table 18 Specimen Creek to Bacon Rind Creek Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
Specimen Creek-Bacon Rind Creek	1	2	2	4	5	5	2	1	2	2.67	3

The Specimen Creek to Bacon Rind Creek Priority Site was initially identified as two shorter stretches of highway that fell into the top 10% MWA overall. During site visits, the research team and TAC decided to combine them into a single site due to their proximity and the fact that they follow continuous riparian meadows along the Gallatin River and US-191 highway corridor. This site occurs within the boundary of Yellowstone National Park (YNP), and the public lands on either side of the highway connect YNP to the Custer Gallatin National Forest (CGNF) and Lee Metcalf Wilderness Area. It is characterized by open riparian meadows along the roadside and river corridor, which provide forage and water for wildlife; lower elevation areas are surrounded by forested slopes. This area is very important from both a regional and local conservation perspective, with frequent crossings by elk and grizzly bears documented by GPS. In recent years, numerous elk have been hit in this section of highway, along with moose, bighorn sheep, deer, black bears, wolves, coyotes, foxes, pine martens, and beavers. Grizzly bear road mortalities have also been documented approximately one mile to the south. Almost none of these mortalities were reported as crashes. Especially in the case of larger-bodied species, this may indicate that the mortalities were caused by large vehicles like semi-trucks, which are less likely to sustain damage or report collisions with wildlife (Huijser and Begley 2019; Abra et al. 2019).

While reported WVC numbers are not high in this location compared to some others, as traffic volumes increase, WVCs may increase. Present traffic volume is relatively low, at just over 2,500 AADT, such that wildlife can cross the highway safely during some parts of the day or year by taking advantage of times when traffic volume is lesser (Riginos 2022; Riginos et al. 2018). However, as traffic volume increases due to YNP visitation, local population growth, and recreation on public lands, this is an important area for measures to mitigate WVCs in order to maintain habitat connectivity between YNP and CGNF for multiple species.

There are two bridges within this priority site: one over the Gallatin River (between RM 23 and 24) and one over Specimen Creek (between RM 26 and 27). These bridges have low vertical clearance and are not suitable for species like elk, moose, or grizzly bears. Both bridges also have little streambank (horizontal) clearance, with abutments and riprap making passage by ungulates difficult, especially during higher flows (see Figure 20). These bridges should be replaced by larger structures with higher vertical clearance (>15 ft or 4.6 m above stream banks) and span the full width of the stream banks along Specimen Creek and the Gallatin River to allow for safe passage (Clevenger and Huijser 2011). Replacement could happen at the end of their service life. However, with an increase in traffic volume or WVCs, the bridges may need to be replaced to accommodate wildlife movement before that time.

Because this priority site is within YNP, concerns exist over the aesthetics of fencing. While appropriately sized crossing structures without fencing may be used opportunistically by wildlife, without fencing, structures will not prevent animals from crossing the road at-grade. If WVCs continue to increase, it would likely be necessary to add fencing in addition to improved bridges to achieve the dual goals of maintaining connectivity and reducing WVCs. Fencing becomes a more urgent consideration in areas where threatened or endangered species, such as grizzly bears, are killed by vehicles. Fencing might also become more urgent if WVCs involving large ungulates (e.g., moose, bison, elk) become more frequent, increasing property damage, risk of human injury or fatality, and wildlife mortality. If fencing remains undesirable due to aesthetic reasons, alternative options that may aid in reducing WVCs are: a) changing the management of the road and b) installing an animal detection system.

Despite passing through Yellowstone National Park, US-191 in this area is managed as a through-road. Alternately, US-191 could be managed as a “park road” in this section and either not permit through traffic or be managed in a hybrid fashion in which through traffic is allowed during the day but not at night (especially for semi-trucks) when collisions are most likely to occur (i.e., a partial night-time closure). Another potential measure to reduce WVCs might be the installation of an animal detection system to warn drivers of animals’ presence. However, this alternative does not reduce the potential barrier effect of the highway (Huijser et al. 2015).

There are four smaller culverts within this priority site (see Chapter 9: Wetland #1, Wetland #2, Terminal Monument Creek, Wickup Creek), and one larger culvert south of the priority site at Bacon Rind Creek. If highway projects are proposed, these structures should be evaluated for potential use by aquatic, semi-aquatic and terrestrial species. At least two of the structures are small pipe culverts built into deep fill. These structures could be upsized to better accommodate aquatic organism passage and to provide safe crossing opportunities for small terrestrial wildlife. The culvert at Bacon Rind Creek is much larger and could be upsized to accommodate small- to medium-sized terrestrial or semi-aquatic wildlife, with dry crossing opportunities provided along the stream bank.

Key Next Steps:

- Continue to evaluate traffic volume, wildlife movement, and WVCs.
- Replace existing bridges over the Gallatin River and Specimen Creek with structures that fully span the stream banks, allow for dry terrestrial passage year-round, and have sufficient vertical clearance (a minimum of 15 ft or 4.6 m) for use by species such as elk, moose, and grizzly bears.
- If a highway improvement or stand-alone wildlife accommodation project is proposed in the area, evaluate the five existing culverts to determine the feasibility of upsizing them to allow for suitable safe passage by both aquatic and small- to medium-sized terrestrial species. See Chapter 9 for more information on these culverts and aquatic organism passage at this site.
- Once the bridges and culverts have been replaced with structures suitable for the full range of target species, these structures could be tied together with fencing to further reduce WVCs and to guide wildlife to the structures. Alternatively, an animal-detection system could be implemented.

- Another potential measure to reduce WVCs could be a change in the designation and management of the highway in this section through Yellowstone National Park.

Figure 20 Bridge over the Gallatin River (between RM 23-24)

Table 19 Index Values of all 0.10-mile Segments within the Specimen Creek to Bacon Rind Creek Priority Site

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM23.2	0.668	0.191	0.810	0.000	0.935	0.640
RM23.3	0.361	0.079	0.722	0.000	0.665	0.648
RM23.4	0.073	0.159	0.778	0.000	0.538	0.654
RM23.5	0.361	0.314	0.781	0.000	0.751	0.663
RM23.6	0.146	0.130	0.902	0.000	0.654	0.679
RM23.7	0.576	0.193	0.919	0.000	0.945	0.680
RM23.8	0.122	0.317	0.758	0.000	0.589	0.654
RM23.9	0.171	0.152	0.487	0.027	0.432	0.631
RM24.0	0.361	0.009	0.654	0.027	0.625	0.625
RM24.1	0.215	0.241	0.948	0.000	0.748	0.606
RM24.2	0.146	0.173	0.737	0.054	0.594	0.594
RM24.3	0.263	0.232	0.718	0.027	0.651	0.589
RM24.4	0.073	0.264	0.540	0.000	0.411	0.583
RM24.5	0.215	0.225	0.484	0.027	0.473	0.578
RM24.6	0.171	0.695	0.490	0.027	0.547	0.562
RM24.7	0.073	0.496	0.634	0.000	0.518	0.533
RM24.8	0.644	0.772	0.579	0.000	0.896	0.531
RM24.9	0.337	0.194	0.473	0.000	0.519	0.527
RM25.0	0.098	0.165	0.498	0.000	0.380	0.553
RM25.1	0.073	0.123	0.642	0.000	0.445	0.552

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM25.2	0.049	0.153	0.639	0.000	0.435	0.550
RM25.3	0.098	0.197	0.796	0.000	0.572	0.575
RM25.4	0.146	0.147	0.787	0.027	0.603	0.556
RM25.5	0.195	0.400	0.831	0.000	0.696	0.554
RM25.6	0.098	0.231	0.586	0.027	0.465	0.569
RM25.7	0.171	0.159	0.656	0.000	0.522	0.597
RM25.8	0.502	0.102	0.783	0.000	0.796	0.639
RM25.9	0.293	0.179	0.791	0.000	0.687	0.642
RM26.0	0.024	0.329	0.644	0.054	0.493	0.648
RM26.1	0.122	0.145	0.747	0.000	0.546	0.643
RM26.2	0.454	0.452	0.647	0.000	0.754	0.681
RM26.3	0.337	0.710	0.847	0.054	0.892	0.694
RM26.4	0.024	0.252	0.892	0.027	0.614	0.691
RM26.5	0.454	0.170	0.576	0.027	0.668	0.683
RM26.6	0.312	0.261	0.664	0.000	0.637	0.691
RM26.7	0.502	0.312	0.848	0.000	0.880	0.685
RM26.8	0.171	0.423	0.780	0.027	0.671	0.672
RM26.9	0.312	0.328	0.841	0.000	0.761	0.629
RM27.0	0.146	0.145	0.809	0.000	0.600	0.645
RM27.1	0.073	0.201	0.830	0.000	0.579	0.624

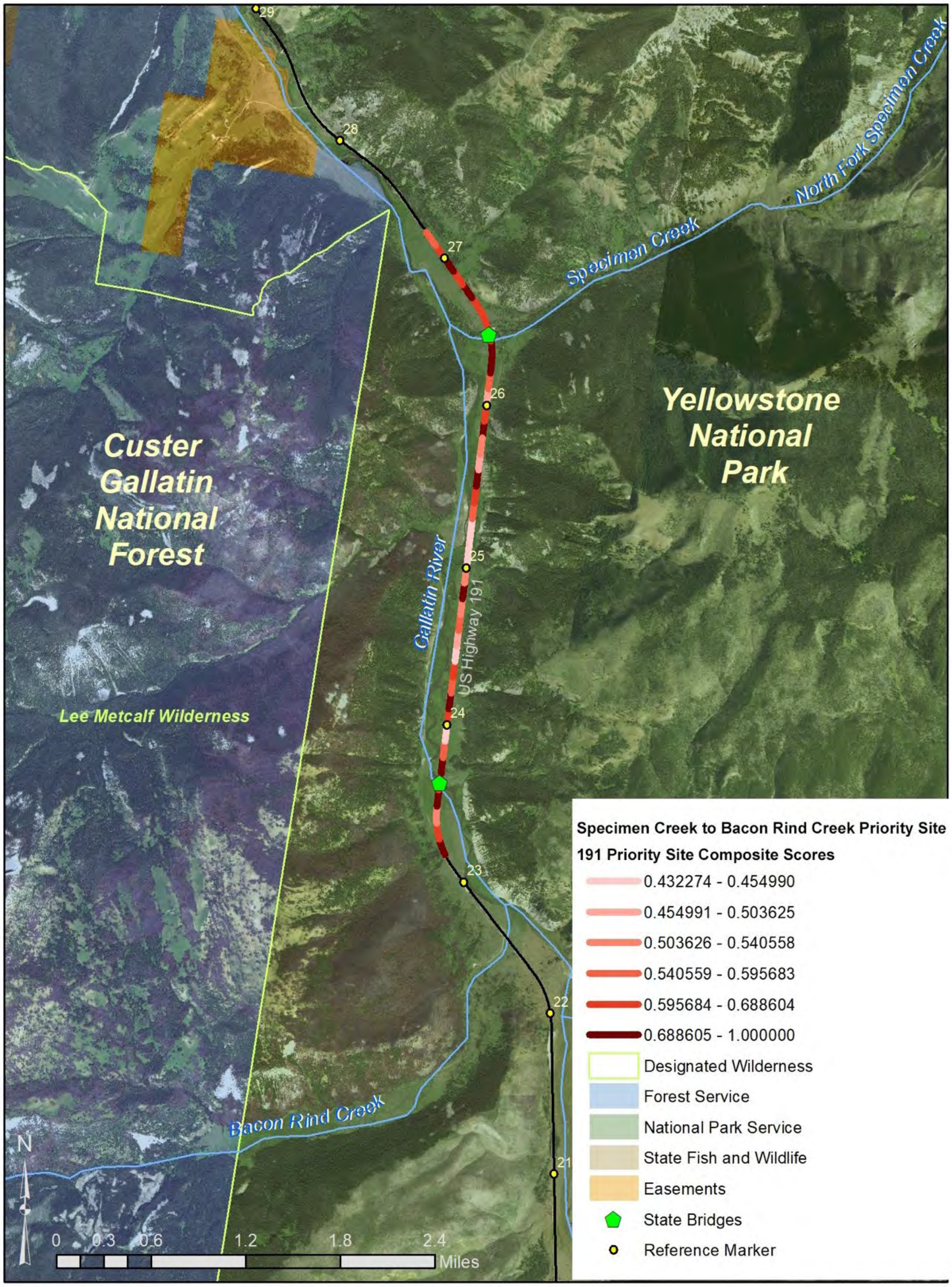


Figure 21 Specimen Creek to Bacon Rind Creek Priority Site Map

6.3. Taylor Fork

- **TAYLOR FORK:** US Highway 191 (US-191), RM 34.2-36.4

AADT: 2,239

Priority Rank: 5 (tied with Teepee Creek Site)

Table 20 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Taylor Fork Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.87	0.518	0.694
WVC Risk	0.152	0	0.040
Wildlife Crossing Road	0.551	0.098	0.311
Live Wildlife Near Road	0.433	0.024	0.147
Regional Conservation Value	0.899	0.567	0.755

Table 21 Taylor Fork Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
Porcupine Creek	1	3	2	2	2	2	4	4	5	2.78	2

The Taylor Fork drainage is an important wildlife movement corridor between the Madison and Gallatin Mountain Ranges and Valleys. The Taylor Fork Priority Site is primarily surrounded by the Custer Gallatin National Forest (CGNF) on both sides of the highway with a private land inholding between RM 35-36. This site was identified due to its high regional conservation value and high composite scores. Elk crossings were documented in each of the 0.10-mile segments and grizzly bear crossings documented in 5 out of 15 0.10-mile segments. The site also has high habitat connectivity/suitability values for grizzly bears, elk, bighorn sheep, and wolverines. One grizzly bear mortality has been documented, along with moose, elk, deer, and pine marten mortalities. Only about one in three of these wildlife mortalities were reported as crashes. Especially in the case of larger-bodied species, this may indicate that the mortalities were caused by large vehicles like semi-trucks, which are less likely to sustain damage or report collisions with wildlife (Huijser and Begley 2019; Abra et al. 2019)

While reported WVC numbers are not high in this location compared to some others, as traffic volume increases, WVCs may increase. Present traffic volume is relatively low, at just over 2,200 AADT, such that wildlife can cross the highway safely during some parts of the day or year by taking advantage of times when traffic volume is lesser (Riginos 2022; Riginos et al. 2018). However, as traffic volume continues to increase due to YNP visitation, local population growth, and recreation on public lands, this is an important area to implement measures to mitigate WVCs and to maintain habitat connectivity between YNP and CGNF for multiple species.

A bridge exists just south of the priority area (RM 33.9) over Taylor Fork. It has low vertical clearance as well as riprap extending nearly to the water's edge, which makes it unsuitable for use by large ungulates (Figure 22). Although the existing structure is beyond the priority area based on the top 10% MWA scores, it should be replaced to provide safe wildlife passage. The bridge would need to be expanded in length and height to span the stream banks and to provide greater clearance in order to accommodate wildlife movement. This could occur at the end of its service life or earlier. Once it has been made suitable for passage by large mammals [i.e., minimum 15 ft (4.6 m) vertical clearance and natural stream banks free of riprap, allowing for dry, unobstructed passage (Clevenger and Huijser 2011)] the bridge should be combined with fencing to reduce WVCs and to guide animals to safe crossing. A small pipe culvert just south of RM 36 (Chapter 9: Flints Creek, 320 Ranch) should be evaluated for upsizing to accommodate aquatic and potential small mammal passage. See Chapter 9 for more information on this culvert and aquatic organism passage at this site.

Key Next Steps:

- Replace the Taylor Fork bridge with a larger structure to provide a safe crossing opportunity for target species such as elk, moose, and grizzly bears, as well as a variety of smaller species. This structure should be wide enough to fully span the stream banks and provide year-round dry passage, with >15 ft (4.6 m) of vertical clearance above the stream banks and terrestrial walkways.
- If a highway improvement project is planned in the area, the culvert immediately south of RM 36 should be evaluated and potentially upsized to better accommodate movement across the highway by aquatic, semi-aquatic, and small terrestrial species.

Figure 22 Bridge over Taylor Fork (RM 33.9)

Table 22 Index Values of all 0.10-mile segments within the Taylor Fork Priority Site

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM34.2	0.366	0.173	0.596	0.000	0.609	0.635
RM34.3	0.293	0.224	0.567	0.000	0.556	0.643
RM34.4	0.439	0.233	0.602	0.000	0.671	0.667
RM34.5	0.122	0.092	0.751	0.125	0.615	0.676
RM34.6	0.390	0.138	0.899	0.000	0.806	0.680

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM34.7	0.171	0.158	0.853	0.000	0.645	0.686
RM34.8	0.195	0.085	0.763	0.049	0.619	0.702
RM34.9	0.434	0.132	0.779	0.098	0.818	0.715
RM35.0	0.244	0.116	0.886	0.152	0.797	0.701
RM35.1	0.434	0.079	0.762	0.027	0.753	0.700
RM35.2	0.171	0.116	0.766	0.127	0.661	0.662
RM35.3	0.478	0.127	0.769	0.000	0.778	0.654
RM35.4	0.288	0.024	0.876	0.000	0.704	0.647
RM35.5	0.098	0.087	0.746	0.000	0.518	0.625
RM36.4	0.551	0.433	0.717	0.027	0.870	0.626

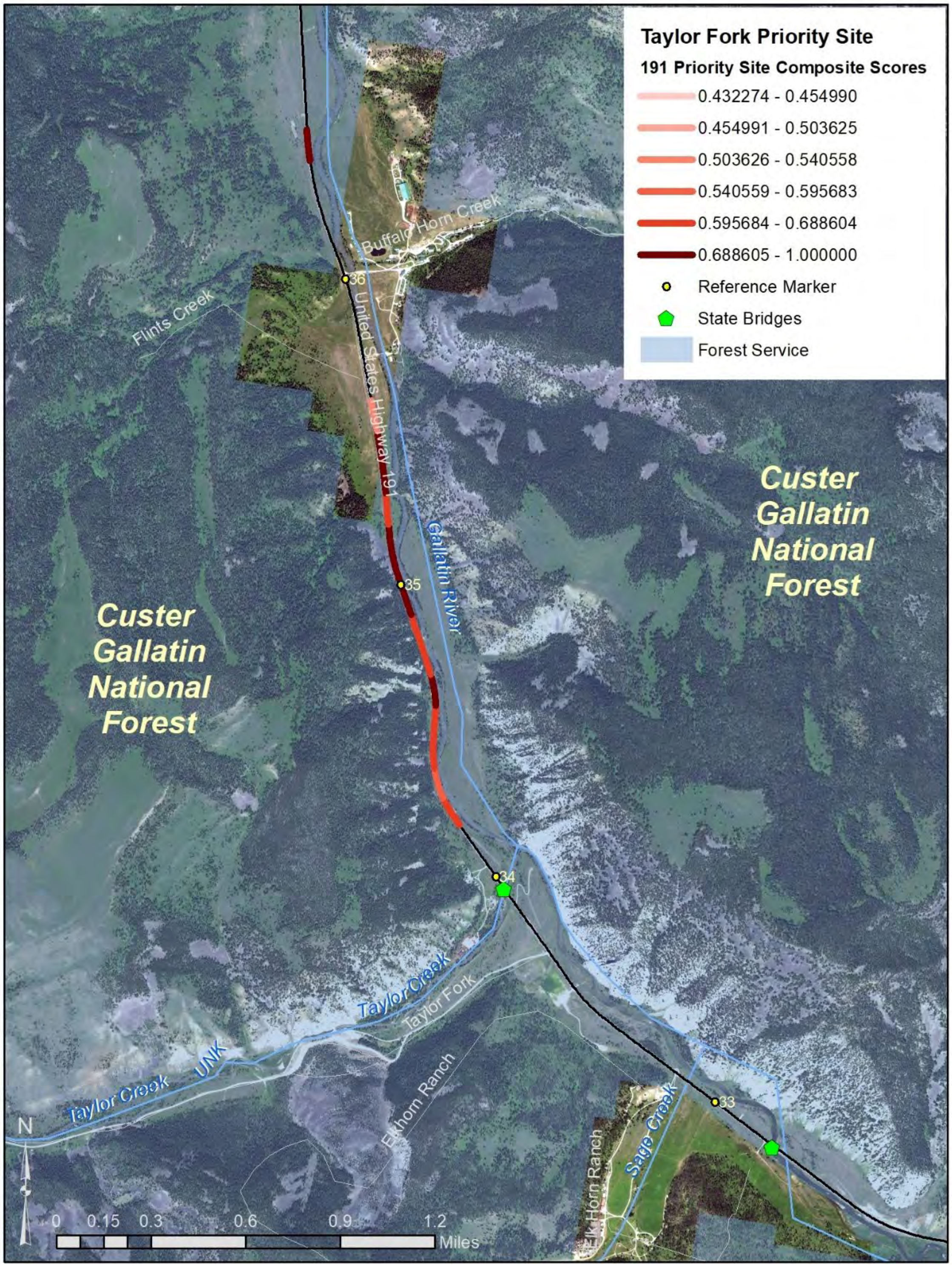


Figure 23 Taylor Fork Priority Site Map

6.4 Porcupine Creek

- **PORCUPINE CREEK:** US Highway 191 (US-191), RM 43.0-47.0

AADT: 7,348

Priority Rank: 2 (tied with N. of Big Sky Entrance Site)

Table 23 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Porcupine Creek Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.925	0.546	0.740
WVC Risk	0.295	0	0.100
Wildlife Crossing Road	0.951	0.195	0.556
Live Wildlife Near Road	1.0	0.193	0.491
Regional Conservation Value	0.638	0.272	0.392

Table 24 Porcupine Creek Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
Porcupine Creek	1	3	2	2	2	2	4	4	5	2.78	2

The Porcupine Creek Priority Site is located just over one mile south from the intersection of US-191 and MT-64 (Lone Mountain Trail). This site borders the Gallatin Wildlife Management Area and Custer Gallatin National Forest (CGNF) on the east side of the highway and has high concentrations of elk and other wildlife moving through the area. The research team extended the priority site south to RM 43 following the site visits, due to the existence of WVCs and documented wildlife movement in the extended area and absence of feasible options for safe crossing structures within the initial site location. Local biologists emphasize the significance of the large, migratory elk herd that moves from Yellowstone National Park and CGNF west into the Madison Valley (Deb Wambach, Butte District Biologist, MDT; Julie Cunningham, Bozeman Area Biologist, FWP, pers. comms.).

The east side of the highway is primarily public land covered by riparian meadows along the Gallatin River that lead to forested slopes in the Gallatin Mountains. This area provides important winter habitat for elk. Private land holdings exist along the west side of the highway, with dense development from RM 45-47, and primarily larger parcels south of RM 45.

Porcupine Creek and Beaver Creek, which border the site on the west and east, respectively, serve as movement corridors for wildlife traveling between the Gallatin and Madison Ranges. The site scores very high for wildlife crossing the road (especially elk, from GPS collar data), regional conservation value, and composite importance. This site has relatively high rates of WVCs with elk and deer compared to other areas along US-191 and is tied for the second-highest priority ranking within the study area. Two grizzly bear mortalities have been documented within 1.5 miles south of the priority site. While the 0.10-mile segments with the highest scores (RM 45.5-47) might have been an ideal location to construct an overpass and develop fencing to allow wildlife to maintain habitat connectivity, existing levels of development increases the potential human-wildlife conflict, especially in areas west of the highway.

By extending the priority area south to RM 43, a wildlife overpass (preferred by elk, moose, and grizzly bears) could be built away from the densest levels of development and connected by fencing to guide animals to an overpass. The fence end locations would need to be strategically located and include end treatments such as an animal detection system to warn drivers of animals trying to cross. In addition to structural improvements such as an overpass and fencing with fence end treatments, additional measures should be considered in the northern portion of the priority site to reduce WVCs.

During the site visit, the research team and TAC observed an injured and dying elk that had been hit by a vehicle near RM 45. To reduce WVCs with elk and other species from RM 45-47, mitigation measures that reflect the increasingly suburban nature of this zone are appropriate. Adding traffic-calming measures within the roadway to slow vehicle speeds and night-time lighting to make wildlife on the road more visible to drivers are options, even though the latter may increase the barrier effect of the road for some species. Potential physical changes to slow traffic include rumble strips, new pavement marking strategies, and roundabouts and other intersection improvements that also improve safety for vehicles entering and exiting the roadway. Roundabouts could feature elk or bighorn sheep sculptures to serve the dual purpose of slowing traffic and announcing the gateway to Big Sky. Similar measures have been developed in Radium Hotsprings, British Columbia. Physical changes, in addition to roadway lighting, may help to reduce WVCs, but would not provide habitat connectivity (Huijser et al. 2021). It is important to note that solely lowering the posted speed limit is generally not effective in changing driver behavior (Riginos 2022) and can lead to more frequent and severe crashes by introducing a phenomenon known as “speed dispersion” in which some drivers observe the posted limit while others drive the design speed of the road (Elvik 2014).

Also at this site, a culvert at Beaver Creek (just north of RM 45) should be evaluated to provide safe crossing opportunity for small to medium-sized aquatic, semi-aquatic, and terrestrial wildlife. See Chapter 9 for more information on this culvert and aquatic organism passage at this site.

Key Next Steps:

- Determine the potential to achieve land security through voluntary conservation easements on the west side of the road (RM 43-45). If land security is possible, then determine the engineering and design feasibility of an overpass and fencing, along with animal detection systems at fence ends.
- Examine designs and feasibility for traffic-calming measures to reduce vehicle speed significantly, improve intersection safety, and increase the visibility of wildlife on and near roads from RM 45-47.
- Evaluate and potentially upsize the Beaver Creek culvert to accommodate passage by aquatic, semi-aquatic, and terrestrial wildlife. See Chapter 9 for more information on this culvert and aquatic organism passage at this site.

Figure 24 View north toward the Porcupine Creek Priority Site, just south of Big Sky in 1922 (left) and 2016 (right). Credit: Historic photo-Gamel Family; Recent photo-Duncan Patten.

Table 25 Index Values of all 0.10-mile Segments within the Porcupine Creek Priority Site

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM43.0	0.0244	0.042	0.492	0.134	0.388	0.421
RM43.1	0.2146	0.135	0.548	0.125	0.555	0.438
RM43.2	0.0244	0.107	0.614	0.000	0.394	0.453
RM43.3	0.0000	0.068	0.537	0.000	0.323	0.458
RM43.4	0.0488	0.052	0.752	0.223	0.623	0.462
RM43.5	0.0000	0.201	0.526	0.054	0.377	0.480
RM43.6	0.0244	0.039	0.652	0.107	0.471	0.481
RM43.7	0.0244	0.089	0.540	0.348	0.561	0.465
RM43.8	0.0488	0.098	0.356	0.422	0.510	0.477
RM43.9	0.0244	0.073	0.374	0.429	0.505	0.494
RM44.0	0.0000	0.070	0.512	0.429	0.575	0.484
RM44.1	0.0244	0.032	0.548	0.098	0.399	0.500
RM44.2	0.0732	0.377	0.452	0.000	0.380	0.504
RM44.3	0.0488	0.123	0.515	0.277	0.524	0.494
RM44.4	0.1463	0.189	0.423	0.223	0.507	0.482
RM44.5	0.1707	0.464	0.448	0.098	0.517	0.495
RM44.6	0.1463	0.333	0.519	0.152	0.553	0.502
RM44.7	0.2683	0.252	0.320	0.196	0.515	0.531
RM44.8	0.1707	0.175	0.335	0.196	0.448	0.565
RM44.9	0.1707	0.308	0.374	0.000	0.377	0.568
RM45.0	0.1951	0.231	0.458	0.350	0.648	0.589
RM45.1	0.5366	0.218	0.456	0.027	0.654	0.592
RM45.2	0.3415	0.261	0.708	0.054	0.715	0.593
RM45.3	0.4146	0.309	0.583	0.152	0.754	0.618

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM45.4	0.2439	0.318	0.589	0.000	0.559	0.646
RM45.5	0.3902	0.334	0.545	0.179	0.737	0.693
RM45.6	0.3415	0.354	0.361	0.098	0.546	0.700
RM45.7	0.4390	0.307	0.308	0.103	0.567	0.716
RM45.8	0.5854	0.369	0.313	0.295	0.794	0.708
RM45.9	0.7073	0.574	0.316	0.027	0.748	0.719
RM46.0	0.8537	0.431	0.272	0.223	0.904	0.752
RM46.1	0.5610	0.679	0.354	0.223	0.824	0.779
RM46.2	0.4634	0.710	0.351	0.000	0.629	0.797
RM46.3	0.9024	0.426	0.351	0.054	0.877	0.781
RM46.4	0.9512	0.637	0.309	0.054	0.925	0.769
RM46.5	0.8049	0.739	0.350	0.000	0.847	0.720
RM46.6	0.6829	0.390	0.298	0.098	0.728	0.707
RM46.7	0.5610	1.000	0.375	0.000	0.765	0.693
RM46.8	0.4146	0.545	0.452	0.000	0.627	0.685
RM46.9	0.3659	0.348	0.495	0.223	0.722	0.762
RM47.0	0.1951	0.193	0.638	0.134	0.617	0.642
RM45.4	0.244	0.318	0.589	0.000	0.559	0.646
RM45.5	0.390	0.334	0.545	0.179	0.737	0.693
RM45.6	0.341	0.354	0.361	0.098	0.546	0.700
RM45.7	0.439	0.307	0.308	0.103	0.567	0.716
RM45.8	0.585	0.369	0.313	0.295	0.794	0.708
RM45.9	0.707	0.574	0.316	0.027	0.748	0.719
RM46.0	0.854	0.431	0.272	0.223	0.904	0.752
RM46.9	0.366	0.348	0.495	0.223	0.722	0.762
RM46.1	0.561	0.679	0.354	0.223	0.824	0.779
RM46.2	0.463	0.710	0.351	0.000	0.629	0.797
RM46.3	0.902	0.426	0.351	0.054	0.877	0.781
RM46.4	0.951	0.637	0.309	0.054	0.925	0.769
RM46.5	0.805	0.739	0.350	0.000	0.847	0.720
RM46.6	0.683	0.390	0.298	0.098	0.728	0.707
RM46.7	0.561	1.000	0.375	0.000	0.765	0.693
RM46.8	0.415	0.545	0.452	0.000	0.627	0.685
RM47.0	0.195	0.193	0.638	0.134	0.617	0.642

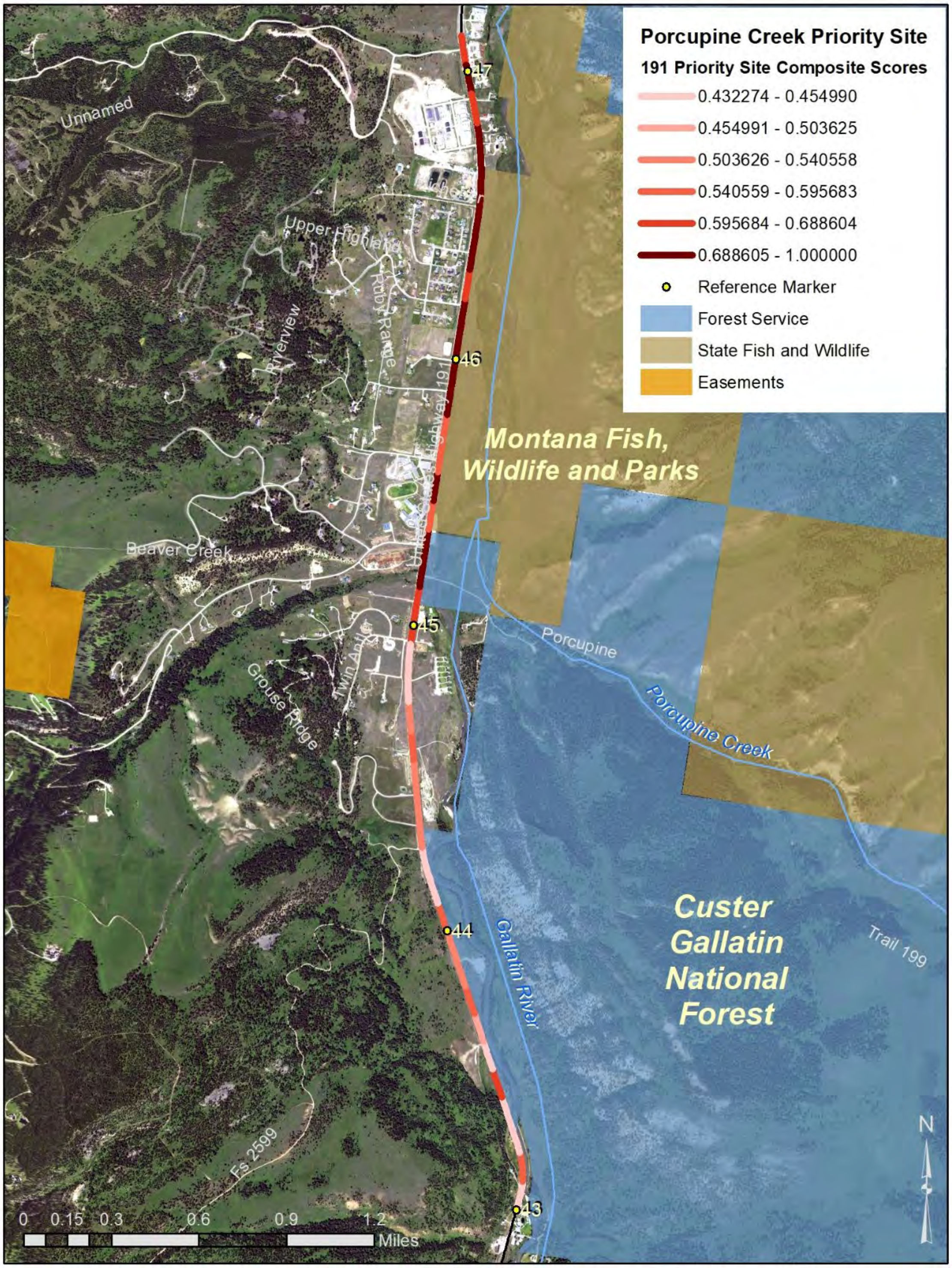


Figure 25 Porcupine Creek Priority Site Map

6.4. North of Big Sky Entrance

- **NORTH OF BIG SKY ENTRANCE:** US Highway 191 (US-191), RM 48.1-49.4

AADT: 8,421

Priority Rank: 2 (tied with Porcupine Creek Site)

Table 26 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the North of Big Sky Entrance Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.842	0.593	0.7319
WVC Risk	0.67	0	0.186
Wildlife Crossing Road	0.507	0.073	0.263
Live Wildlife Near Road	0.563	0.088	0.2796
Regional Conservation Value	0.803	0.521	0.6736

Table 27 North of Big Sky Entrance Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
N. of Big Sky Entrance	1	2	2	3	3	3	4	4	3	2.78	2

The North of Big Sky Entrance Priority Site was selected due to WVC risk as well as importance for wildlife movement and regional conservation value. Elk, deer, and bighorn sheep have been hit in this location. Elk frequently cross the highway along each of the 0.10-mile segments within the site, and bighorn sheep are often observed using the road to access water as well as to lick salt residue on the highway. With traffic volume nearing 8,500 AADT and rising, this area is high-risk for wildlife-vehicle conflict both in terms of WVCs and barrier effect to wildlife movement.

Just north of the site, a bridge over the Gallatin River exists that is not suitable for use by most ungulates due to low vertical clearance and riprap that extends to the water's edge, disrupting terrestrial passage. This bridge should be upsized to accommodate safe passage for ungulates and other wildlife. As an interim measure, fill could be added on top of the riprap along the north side of the bridge to create a pathway for terrestrial species. A purpose-built overpass structure in combination with fencing is recommended to accommodate safe passage across the highway for elk, which move between steep slopes on the west side down to the Gallatin River and riparian meadows (See conceptual rendering in Section 7.3). A wildlife overpass could also accommodate bighorn sheep with appropriate management. According to local biologists, bighorn sheep reside primarily in steep habitat west of the road (Julie Cunningham, Bozeman Area Biologist, FWP; Randy Scarlett, Wildlife Biologist, USFS, pers. comms.). During the site visits, the research team and TAC identified an area with heavy wildlife use where a steep slope west of the highway leads to a riparian meadow on the east, providing an ideal location to construct an overpass for wildlife (just north of Dudley Creek/RM 49). An overpass is a preferred structure for elk and bighorn sheep, as well as grizzly bears, which also use the area. The structure should include fencing to keep wildlife off the road and to guide them towards safe crossing. Fencing could connect to the bridge to the north, especially following its reconstruction to accommodate large wildlife such as elk [i.e. minimum 15 ft (4.6 m) vertical clearance and natural stream banks free of riprap, allowing for dry, unobstructed passage (Clevenger and

Huijser 2011)]. This location is largely surrounded by the Custer Gallatin National Forest and leads to the Lee Metcalf Wilderness Area northeast of the highway; however, several private parcels are located immediately adjacent to the highway and one or more of the parcels would have to hold a voluntary conservation easement for the development of a purpose-built structure at this site. A parcel along the east side already holds a voluntary conservation easement. Determining where the exclusionary fencing might tie into on the landscape toward the south for effectiveness is also a challenge of the location, given the nearby intersection of US-191 and MT-64 (Lone Mountain Trail), along with access roads and driveways.

Key Next Steps:

- Determine the potential to achieve land security through voluntary conservation easements on the west side of the road. If land security is possible, then consider the engineering and design feasibility of an overpass near RM 49 and fencing.
- Evaluate retrofitting opportunities to render the bridge over the Gallatin River (between RM 49-50) passable by wildlife species. Following shorter-term retrofitting and longer-term replacement to accommodate safe passage, consider the addition of fencing, especially if connection to an overpass is possible.

Table 28 Index Values of all 0.10-mile Segments within the North of Big Sky Entrance Priority Site

US-191 Road Mile Reference	Wildlife Movement Importance Index	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
RM48.1	0.146	0.088	0.665	0.152	0.593	0.641
RM48.2	0.195	0.119	0.676	0.107	0.608	0.675
RM48.3	0.122	0.160	0.743	0.223	0.685	0.696
RM48.4	0.073	0.157	0.521	0.670	0.794	0.700
RM48.5	0.268	0.169	0.684	0.152	0.697	0.722
RM48.6	0.293	0.335	0.627	0.152	0.711	0.739
RM48.7	0.230	0.431	0.803	0.107	0.774	0.754
RM48.8	0.507	0.313	0.782	0.000	0.842	0.765
RM48.9	0.463	0.319	0.710	0.098	0.832	0.760
RM49.0	0.220	0.563	0.620	0.277	0.786	0.746
RM49.1	0.293	0.337	0.607	0.321	0.805	0.736
RM49.2	0.244	0.396	0.684	0.196	0.757	0.710
RM49.3	0.341	0.387	0.618	0.125	0.730	0.678
RM49.4	0.293	0.141	0.690	0.027	0.632	0.639

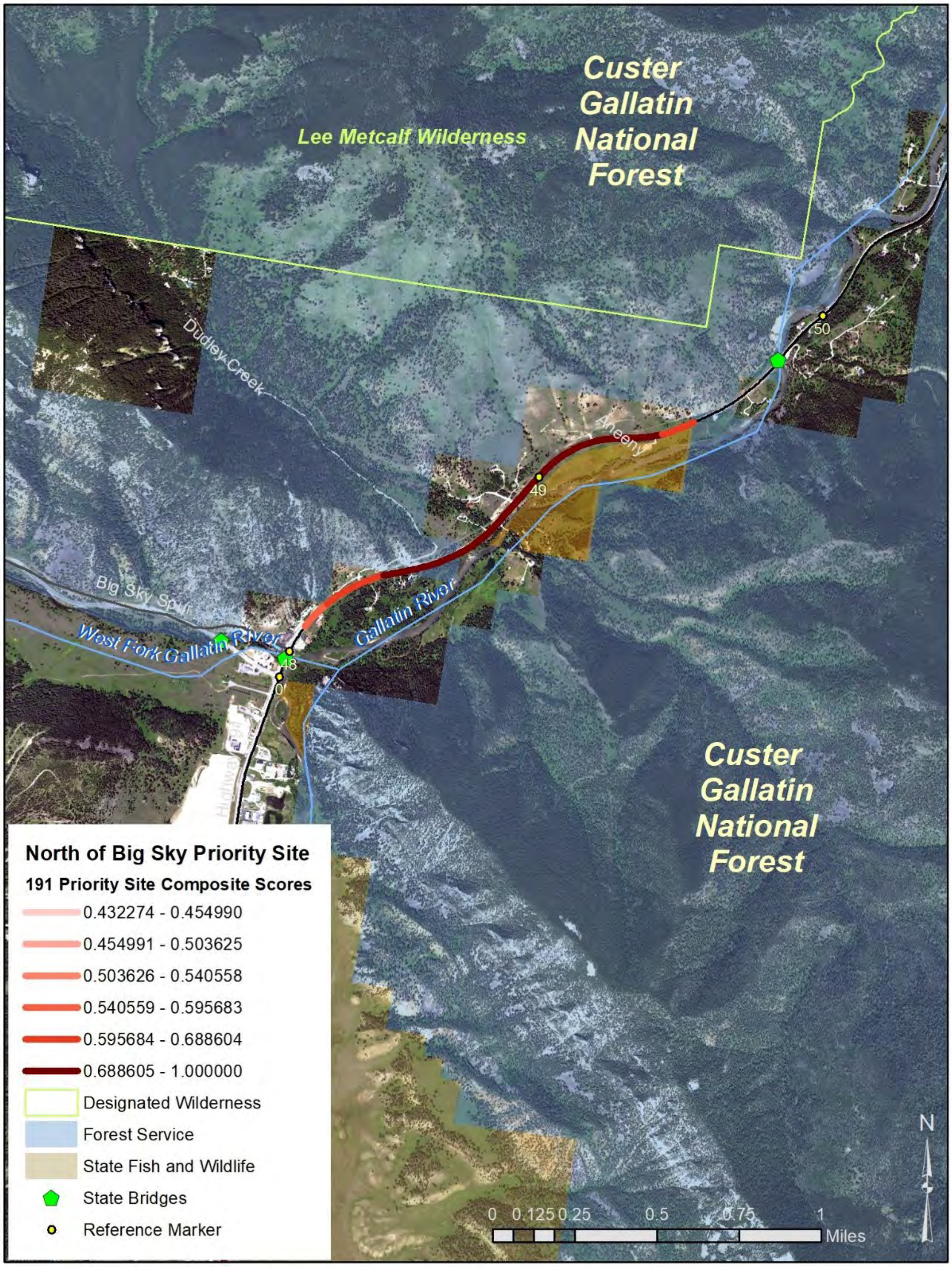


Figure 26 North of Big Sky Priority Site Map

6.5. Gallatin Gateway to Spanish Creek

- **GALLATIN GATEWAY TO SPANISH CREEK:** US Highway 191 (US-191), RM 68.1-73.7

AADT: 10,047

Priority Rank: 1 - Highest Priority

Table 29 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Gallatin Gateway to Spanish Creek Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.541	0.256	0.414
WVC Risk	0.812	0	0.231
Wildlife Crossing Road*	0	0	0
Live Wildlife Near Road	0.750	0	0.058
Regional Conservation Value	0.896	0.148	0.463

*See Section 2.4 on data gaps and limitations

Table 30 Gallatin Gateway to Spanish Creek Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
Gallatin Gateway to Spanish Creek	3	1	1	2	4	5	4	4	4	3.11	1

The Gallatin Gateway to Spanish Creek Priority Site ranked as the Assessment’s highest priority primarily due to WVC risk as well as due to high regional and local conservation value in localized areas, especially from Big Bear Creek to the south. This area is one of the longest priority sites, covering over five miles, and has a variety of land-use and habitat types. The northern end is characterized by open grasslands, while south of RM 70, the highway begins to enter Gallatin Canyon. The area north of RM 70.5 is significantly fragmented and includes both residential and agricultural uses, especially east of the highway. Many smaller roads along with access areas and driveways complicate the potential for use of wildlife-exclusionary fencing. The Custer Gallatin National Forest is set back from the highway east of the site. To the west, a single property under a voluntary conservation easement borders the highway.

Because of land ownership patterns, there is potential to build an overpass with fencing to reduce WVCs and to connect the remaining grassland ecosystem between Gallatin Gateway and the Gallatin River bridge (RM 71-73), providing safe passage for elk and other species. The connection to the grassland ecosystem has been lost further north due to development. Given the current rate of subdivision and development, the opportunity to conserve habitat connectivity at the site may be lost without near-term action to conserve land. An overpass would be the most effective measure to reduce WVCs and to accommodate safe passage for elk; it is also the primary option available given that the roadbed is largely at-grade with the surrounding landscape. To do so would require ensuring land security long-term through voluntary measures east of the highway.

Two bridges are within this site: one across the Gallatin River (RM 70.5, Figure 27) and another at the southern extent of the site across Spanish Creek (Figure 28). Neither of these structures are suitable for wildlife use due to the lack of passable stream banks along both sides. The Spanish Creek bridge also has low vertical clearance. The Gallatin River bridge should be retrofitted in the near-term to provide a terrestrial pathway along the north side by adding fill to allow ungulates and other species to pass (See conceptual rendering in Section 7.1). To do so may require securing a voluntary conservation easement on a property that lies east of the river and highway. When replaced, this bridge should be increased to provide natural streambanks beneath it along both sides of the river to accommodate terrestrial wildlife movement. In addition to facilitating safe passage, an expanded bridge would increase infrastructure resilience to extreme weather events and lateral stream channel migration.

Figure 27 Gallatin River Bridge (RM 70.5)

On the southern end of the site, replacement of the bridge across Spanish Creek (Figure 28) is included in the MDT 2022-2026 Statewide Transportation Improvement Program. When this structure is replaced, it should be expanded to allow for greater vertical clearance beneath the bridge (>15 ft or 4.6 m from stream banks) and to provide natural passable stream banks for terrestrial wildlife movement under the bridge through the riparian area (Clevenger and Huijser 2011). In addition to facilitating safe passage, an expanded bridge would increase infrastructure resilience to extreme weather events and lateral stream channel migration. The area around Spanish Creek is an important area for local and regional conservation that serves as a movement corridor for wildlife. This area also has a localized spike in WVCs. When the bridge is expanded, wildlife-exclusionary fencing should be added along the highway both to the north and to the south in order to keep wildlife off the highway and guide them toward the underpass. Other areas south of Spanish Creek have the potential for purpose-built crossings for elk and grizzly bears as part of a larger project combining overpasses, underpasses, and exclusionary fencing for comprehensive mitigation of this stretch of highway.

Key Next Steps:

- Determine the potential to achieve land security through voluntary conservation easements from RM 70.5-73. If land security is possible, then engineering and design feasibility for an overpass and fencing in this area should also be pursued.
- Continue to deploy variable message signs seasonally in the area of high WVCs from RM 70-73 to warn drivers of elk and other wildlife on the road.
- Determine if land conservation is necessary to retrofit the bridge over the Gallatin River at RM 70.5. Based on feasibility, retrofit the structure to allow for wildlife to pass underneath by reconfiguring the riprap and providing a pathway for wildlife. Upon replacement, use a larger structure that allows for wildlife to pass along natural dry streambanks of both sides of the river.

- Upon replacement (currently in the planning phase), expand the Spanish Creek bridge at RM 68.1 to allow passage along natural stream banks for terrestrial wildlife along both sides and vertical clearance of >15 ft (4.6 m) from the stream banks for species like elk, moose, and grizzly bears. Consider opportunities for additional wildlife crossings further to the south and connect safe crossing locations with fencing.

Figure 28 Spanish Creek Bridge (RM 68.1)

Table 31 Index Values of all 0.10-mile Segments within the Gallatin Gateway to Spanish Creek Priority Site

US-191 Road Mile Reference	Wildlife Movement Importance Index *	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
68.1	0	0	0.631816	0.026786	0.384627	0.417188
68.2	0	0	0.536896	0.276786	0.481187	0.430612
68.3	0	0	0.695195	0.053571	0.440765	0.451993
68.4	0	0	0.710097	0.053571	0.450044	0.475578
68.5	0	0	0.874782	0.026786	0.535909	0.487866
68.6	0	0	0.882024	0.223214	0.662721	0.495209
68.7	0	0	0.859868	0.080358	0.559976	0.498273

US-191 Road Mile Reference	Wildlife Movement Importance Index *	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
68.8	0	0.001465	0.896951	0.026786	0.550014	0.486031
68.9	0	0	0.76874	0.098215	0.514355	0.492418
69	0	0	0.647574	0.075893	0.425014	0.506814
69.1	0	0	0.751853	0	0.442689	0.503197
69.2	0	0	0.560951	0.151785	0.418333	0.488862
69.3	0	0	0.597409	0	0.346526	0.498014
69.4	0	0	0.763372	0.098215	0.511014	0.494244
69.5	0	0.008291	0.836662	0.178571	0.608401	0.4974
69.6	0	0	0.810894	0.026786	0.496128	0.492264
69.7	0	0	0.726984	0.125	0.505034	0.496598
69.8	0	0	0.771544	0.330357	0.660643	0.489033
69.9	0	0	0.804065	0.053571	0.508552	0.501921
70	0	0	0.601271	0.321429	0.549065	0.489273
70.1	0	0	0.605947	0.026786	0.36852	0.45492
70.2	0	0	0.64985	0.178571	0.490363	0.440397
70.3	0	0	0.480874	0.098215	0.335117	0.417249
70.4	0	0	0.601893	0.223214	0.488299	0.390681
70.5	0	0	0.48635	0.151785	0.371884	0.36643
70.6	0	0.00293	0.28511	0.125	0.230513	0.348113
70.7	0	0.157534	0.350024	0.178571	0.336375	0.336577
70.8	0	0	0.344826	0.098215	0.250408	0.311813
70.9	0	0.54446	0.424255	0.026786	0.368393	0.295239
71	0	0	0.277426	0.151785	0.241797	0.275629
71.1	0	0.030762	0.267412	0.321429	0.347574	0.263464
71.2	0	0.037588	0.362829	0.053571	0.241623	0.264772
71.3	0	0	0.364132	0.026786	0.217956	0.262537
71.4	0	0.030762	0.177823	0.098215	0.15281	0.265249
71.5	0	0.035929	0.189894	0.276786	0.272585	0.256519

US-191 Road Mile Reference	Wildlife Movement Importance Index *	Wildlife Observation Importance Index	Suitability / Connectivity Importance Index	WVC Risk Importance Index	Composite Importance Index	Moving Window Average
71.6	0	0.021973	0.362324	0.053571	0.238068	0.277964
71.7	0	0.036621	0.395205	0.026786	0.244902	0.285405
71.8	0	0.073243	0.436855	0.080358	0.311793	0.32074
71.9	0	0.014649	0.262847	0.223214	0.280235	0.358229
72	0	0	0.201522	0.276786	0.272367	0.371918
72.1	0	0	0.343788	0.464286	0.477694	0.396472
72.2	0	0.146485	0.172794	0.508928	0.429424	0.443101
72.3	0	0.235841	0.331697	0.642859	0.630302	0.465904
72.4	0	0.219727	0.444272	0.535714	0.630339	0.489622
72.5	0	0.124512	0.258954	0.22768	0.303393	0.5117
72.6	0	0.574862	0.167242	0.553573	0.542675	0.541669
72.7	0	0.750002	0.22468	0.772323	0.750991	0.53182
72.8	0	0	0.22096	0.616072	0.495726	0.514368
72.9	0	0	0.148154	0.812501	0.572697	0.48334
73	0	0.004395	0.227724	0.651786	0.523087	0.456238
73.1	0	0.228923	0.266276	0.665179	0.602029	0.449093
73.2	0	0.046875	0.265771	0.352679	0.369356	0.433039
73.3	0	0.030762	0.179833	0.232144	0.237451	0.375323
73.4	0	0	0.183585	0.321429	0.288996	0.347676
73.5	0	0	0.217281	0.357143	0.332213	0.330764
73.6	0	0	0.29478	0.107143	0.224807	0.316673
73.7	0	0	0.195762	0.433036	0.366071	0.302376

*See section 2.4 on data gaps and limitations

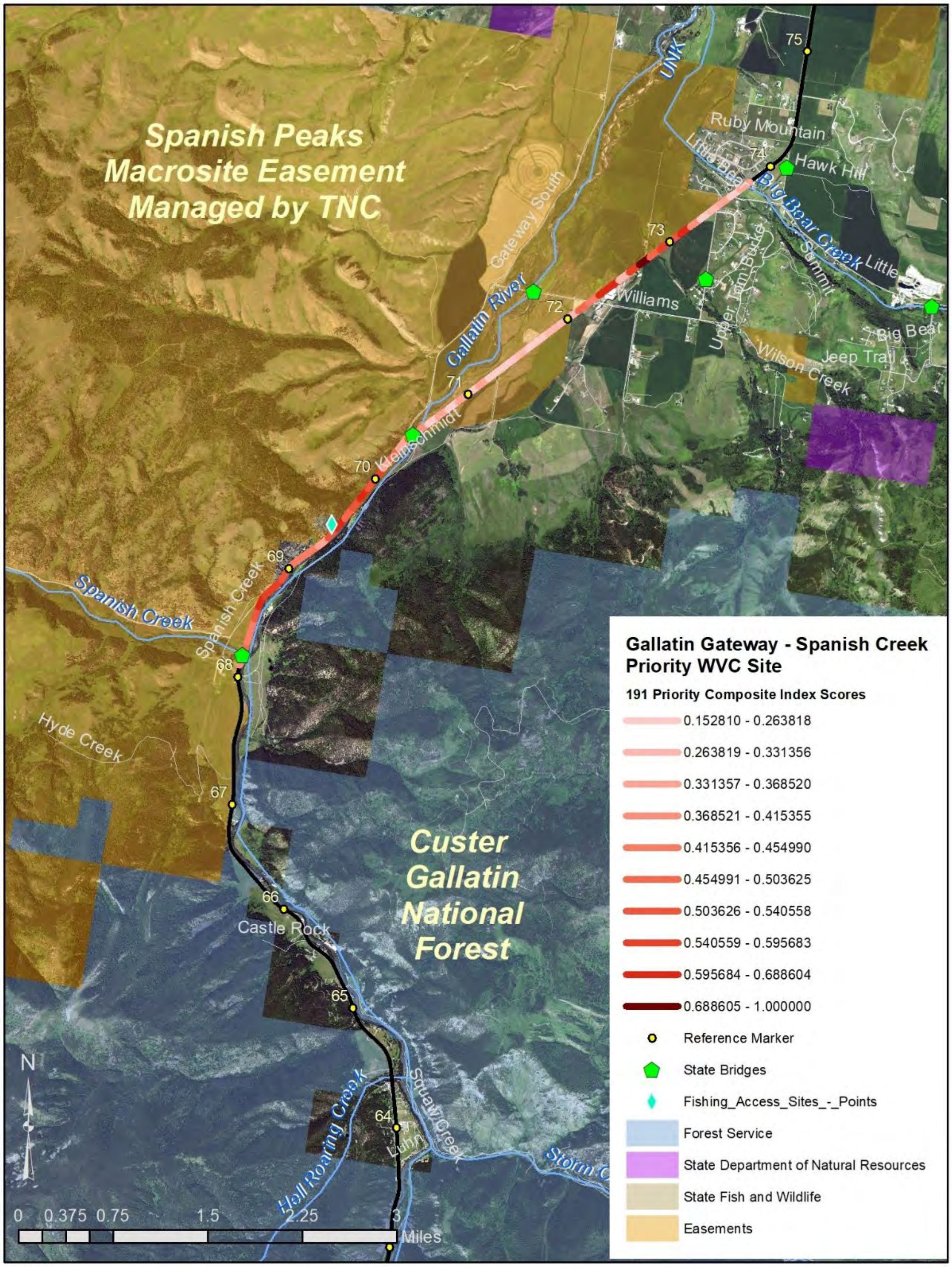


Figure 29 Gallatin Gateway to Spanish Creek Priority Site Map

6.6. Four Corners to Gallatin Gateway

- **FOUR CORNERS TO GALLATIN GATEWAY:** US Highway 191 (US-191), RM 74.1-81-3

AADT: 14,607

Priority Rank: 6

Table 32 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Four Corners to Gallatin Gateway Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.455	0.220	0.360
WVC Risk	1.0	0.080	0.403
Wildlife Crossing Road*	0.140	0	0
Live Wildlife Near Road	0.183	0	0.005
Regional Conservation Value	0.403	0.090	0.220

*See section 2.4 on data gaps and limitations

Table 33 Four Corners to Gallatin Gateway Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Priority Rank
Four Corners to Gallatin Gateway	4	1	1	1	1	3	2	5	4	2.40	6

Located between Four Corners and Gallatin Gateway, this priority site was selected due to the number of WVCs over the last 10 years. The area is heavily developed, with new construction ongoing. It has the highest traffic volume of any location within the study area and traffic volume has also increased rapidly (>38%, MDT 2020). Studies from Wyoming have found that a road becomes an absolute barrier for wildlife movement at traffic volumes above 15,000 AADT; most animals will stop trying to cross, and the few which try have a high likelihood of being struck by a vehicle (Riginos 2022). This site is likely to approach this threshold in the near future, resulting in severed connectivity and decreased frequency of wildlife attempting to cross the highway.

Due to intensive development and the presence of many secondary roads, access roads, and driveways, few mitigation measures can be implemented. Neither highly nor even moderately effective options (i.e., wildlife crossings with fencing, fencing, animal detection systems) are feasible due to high traffic volumes and the number of access points along the highway. Seasonal signage, novel signage, alternative modes of transportation (e.g., shared transit options), and intelligent transportation system (ITS) features could help to incrementally reduce collisions but are unlikely to result in major reductions in WVCs. Lack of spatial planning for conservation has severely limited the available mitigation options. A medium box culvert at South Cottonwood Creek just south of RM 77 could provide safe passage opportunity for small- to medium-sized terrestrial wildlife species when water levels are low.

Key Next Steps:

- Consider the use and potential for seasonal and/or novel signage, alternative modes of transportation (shared transit options and intelligent transportation system features), with the understanding that none of these are likely to result in major reductions in WVCs.
- Evaluate the culvert at South Cottonwood Creek for use by small and medium terrestrial wildlife species. Consider the potential for the addition of a dry shelf for use by small to medium terrestrial species during higher flows.

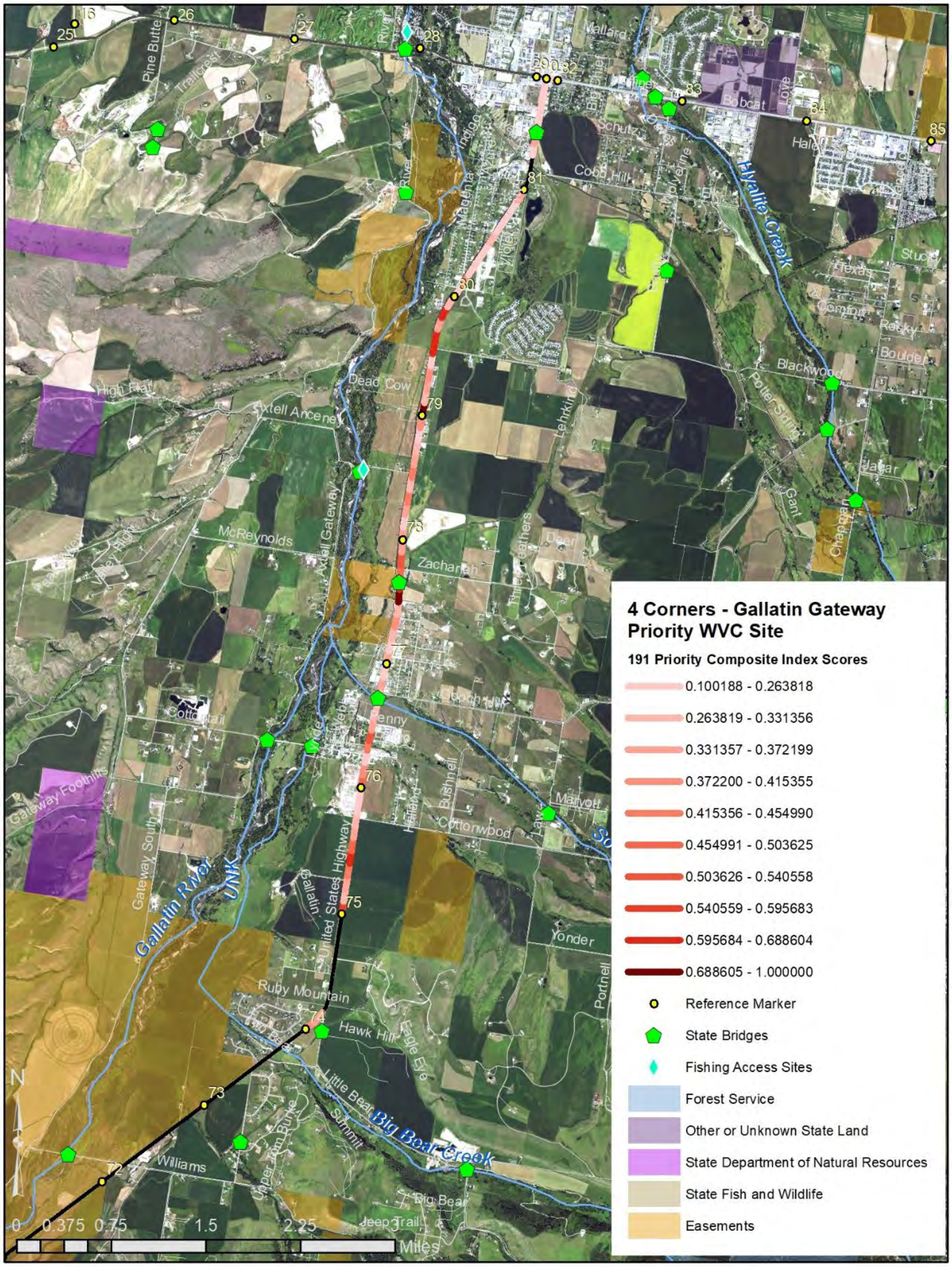


Figure 30 Four Corners to Gallatin Gateway Priority Site Map

6.7. West Fork Gallatin

➢ **WEST FORK GALLATIN:** MT-64 (Lone Mountain Trail), RM 0.2-1.2

AADT: 10,513

Priority Rank: 4

Table 34 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the West Fork Gallatin Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.632	0.354	0.500
WVC Risk	0.420	0	0.150
Wildlife Crossing Road	0.19	0	0.017
Live Wildlife Near Road	0.217	0	0.056
Regional Conservation Value	0.809	0.437	0.657

Table 35 West Fork Gallatin Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Site Rank
West Fork Gallatin	1	1	1	3	4	3	4	3	3	2.56	4

The West Fork Gallatin Priority Site is located on MT-64 (Lone Mountain Trail) just west of the intersection with US-191. This area has relatively high traffic volumes (>10,000 AADT) and provides the sole access to the rapidly growing community of Big Sky. Residents and commuters report frequent sightings of bighorn sheep and elk. Bighorn sheep are primarily on steep slopes of the Custer Gallatin National Forest located on the north side of the road, while elk are often grazing in the meadows on mostly private land on the south side. Although bighorn sheep regularly approach the road to lick salt, the area is not considered critical for connectivity for either bighorn sheep or elk (Randy Scarlett, Wildlife Biologist, USFS, pers comm). The site has two existing structures: a small bridge at RM 0.2 (Figure 31) and a culvert at RM 1.1. While the east side of the underpass below the existing bridge is likely passable by bighorn sheep, black bears, mountain lions and small- to medium-bodied mammals such as coyotes, bobcats, lynx and wolverines, it is not passable by elk on the west side (Figure 31). Similarly, the culvert at RM 1.1 is potentially passable by small- and medium-sized species but not by large mammals.

The research team and TAC believe the area could be treated with wildlife-exclusionary fencing between the two existing structures to keep wildlife, especially bighorn sheep, off of MT-64, while the smaller structures could still provide connectivity for other species. The fencing could extend beyond the priority site to the west and connect on the north side to fencing associated with the proposed overpass in the North of Big Sky Priority Site along the Custer Gallatin National Forest boundary. Fence-end treatments would need to be incorporated to keep bighorn sheep from accessing the road to lick salt. Traffic calming features such as transverse rumble strips or intersection control improvements could be used to slow vehicles where they are most likely to encounter bighorn sheep, along with an animal-detection system to alert drivers when wildlife is on the road. In addition, we recommend replacement of the culvert at RM 1.1 at the end of its service life with a larger structure that accommodates natural substrate or by a small span bridge to allow for movement by a broader suite of wildlife species including deer and black bears.

Key Next Steps:

- Evaluate the feasibility of a combination of fencing, traffic calming measures, and animal detection systems to reduce WVCs.
- When the culvert at RM 1.1 needs to be replaced, consider expansion to a larger structure or span bridge that could be used by species such as deer and black bears.

Figure 31 Bridge over the West Fork of the Gallatin River along MT-64 (Lone Mountain Trail) RM 0.2

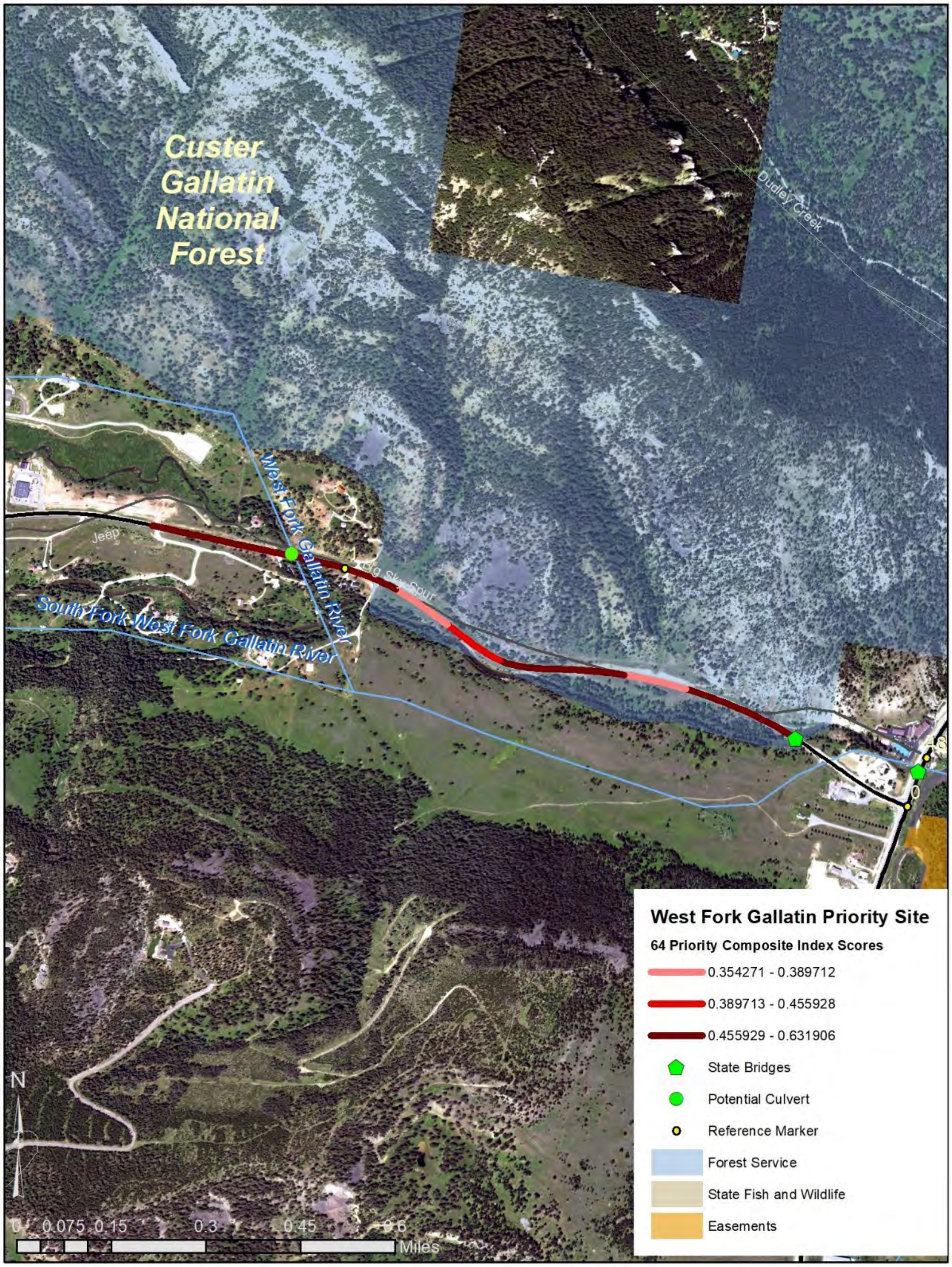


Figure 32 West Fork Gallatin Priority Site Map

6.8. Upper Big Sky Connectivity Area

- **UPPER BIG SKY CONNECTIVITY AREA:** MT-64 (Lone Mountain Trail), RM 7.3-8.2

AADT: 2,891

Priority Rank: 7

Table 36 Maximum, Minimum, and Average Index Values for each Prioritization Characteristic and Composite Index of all 0.10-mile Road Segments within the Upper Big Sky Connectivity Area Priority Site

Prioritization Characteristic	Maximum Index Value	Minimum Index Value	Average Index Value
Composite (overall)	0.482	0.307	0.397
WVC Risk	0.027	0	0.005
Wildlife Crossing Road	0.190	0	0.038
Live Wildlife Near Road	0	0	0
Regional Conservation Value	0.758	0.533	0.636

Table 37 Upper Big Sky Connectivity Area Field Evaluation Scores and Priority Ranking

Priority Site	WVC Risk	Wildlife Crossing Road	Live Wildlife Near Road	Regional Conservation Value	Land Security	Local Conservation Value	Wildlife Accommodation Options	Barrier Effect	Vulnerability	Overall Average Score	Site Rank
Upper Big Sky	1	1	1	3	2	4	1	1	3	1.89	7

The Upper Big Sky Connectivity Area Priority Site was selected due to its habitat value for higher elevation species including wolverines. This area sits high on steep slopes with low traffic and lower speed limits compared to other sites in the study area. Due to the currently low barrier effect of the road and low WVC rates, along with limited wildlife accommodation options due to topography and steep roadway grades, this area does not require immediate attention. Rather, as development and traffic volumes increase, it should be monitored for opportunities to help maintain regional connectivity and offset potential increases in WVCs.

Key Next Steps:

- None at this time. Continue to monitor and evaluate based on development and traffic pressures.

6.9. Considerations for Additional Priority Sites

In addition to the areas ranking in the highest 10% of the MWA identified in the Assessment and described in detail in Sections 6.1-6.9, other areas highlighted by the study remain important to consider in light of WVCs and the opportunity to maintain or improve habitat connectivity. Additional road segments and areas should be considered on a case-by-case basis, especially when planned highway projects align with nearby areas of wildlife-vehicle conflict. For example, areas adjacent to Yellowstone National Park regularly experience WVCs. When bridges in these areas are scheduled for replacement, standard practice should include development of structures with span lengths and clear heights suitable for safe passage by all species known to use an area, especially those for which wildlife-vehicle conflict is documented (Figure 33).

The information in Figure 33 also provides insight into localized considerations for bison. All recently recorded bison-vehicle collisions on US-191 have occurred south of RM 20. Within Yellowstone National Park, 15 bison carcasses were recorded by the National Park Service in the 1990s, along with single carcasses in both 2001 and 2004 (from a data set covering 1989-2021). The majority of these carcasses were recorded between RM 13-14, with a few in the vicinity of RM 20. From 2011-2020, the Montana Department of Transportation collected data on 29 bison carcasses south of RM 9.3. This total rose steeply in late 2022 due to the collision of a herd of 13 bison with a semi-truck near RM 4, increasing the total of recently recorded bison killed along this stretch of US-191 to 42.

Based on these data, the vast majority [74% (42/57)] of bison-vehicle collisions on US-191 beyond Yellowstone National Park in Montana have occurred south of RM 10. Including the data from the December 2022 incident, 22 bison crashes and carcasses have been recorded between RM 3-4 (Madison River), with 6 recorded between RM 7-9 (Cougar Creek and Duck Creek). This finding is consistent with a 2012 Western Transportation Institute assessment of bison-vehicle collisions based on data collected from 1999-2009, which identified two priority mitigation sites at these locations. The 2012 assessment states: “The road segment between 2.5 to 4.5 at the Madison River mitigation site includes 2 miles (3.22 km) of very high BVC rates, representing only 20% of the total highway segment under study and 51% of the total BVCs (Dupree and Dimambro 2012).” The area near Cougar Creek also has very high composite scores in the present analysis, with five of the ten 0.1-mile segments scoring in the top 10% of the composite index values. Thus, the Cougar/Duck Creek and Madison River sites should be considered as potential additional priority sites.

Mitigation options are complicated due to bison life-history characteristics, limited existing safe-crossing opportunities, and the need to provide connectivity for other wildlife species. Moose is the only other carcass data recorded in these two stretches. Crossing structures or other wildlife accommodation measures located at or near the Madison River bridge and Duck Creek bridge would require at least one mile of fencing, north and south along US-191, on both sides of the highway, to keep bison and other wildlife off of the road and direct them to crossings. Careful consideration should be given to where the fencing starts and ends, and fence end treatments will likely be necessary to discourage animals from entering the fenced road corridor. Other measures, such as animal detection systems, may be suitable as well.

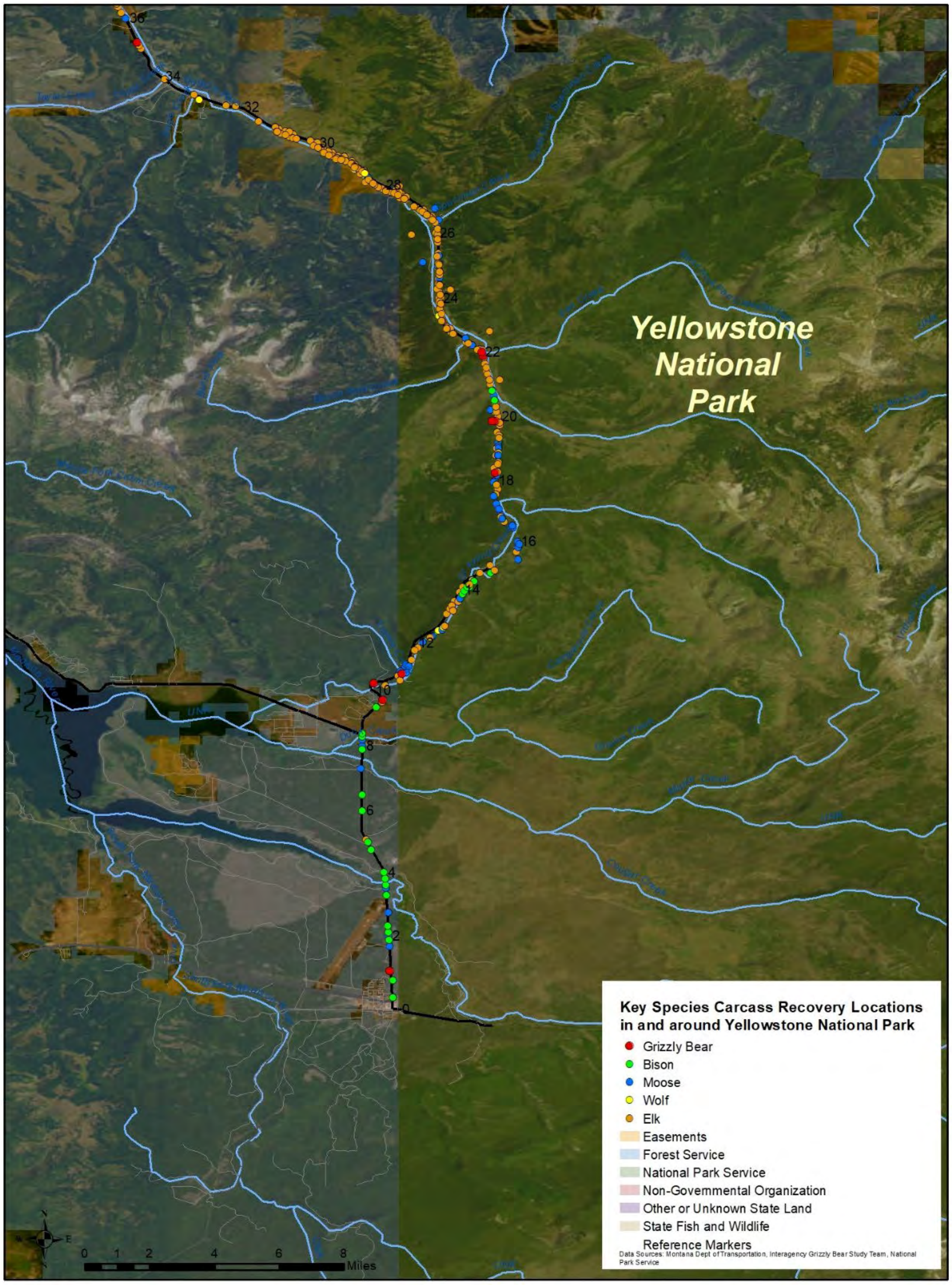


Figure 33 Map of Carcass Data along US-191 in Areas within and adjacent to Yellowstone National Park

6.10. Discussion

US-191 and MT-64 bisect important wildlife habitat and movement corridors between Yellowstone National Park, the Custer Gallatin National Forest, and the Gallatin and Madison Ranges and their surrounding valleys. Rapidly expanding development, visitation, recreation, and traffic volumes are increasing the risk of human-wildlife conflict both in terms of WVCs and habitat connectivity for wildlife. In some areas, lack of spatial planning for conservation has limited effective wildlife accommodation measures. Long-term land conservation, such as through voluntary conservation easements, is critical to siting and implementing measures to reduce WVCs and to maintain or improve habitat connectivity for wildlife in priority sites from Porcupine Creek north to Four Corners.

Traffic volume is a major factor influencing WVC risk and the barrier effect of a highway to wildlife movement. Traffic on US-191 from Porcupine Creek north to Four Corners already represents a significant impediment to wildlife (Riginos et al. 2018; Waller and Miller 2015). South of Porcupine Creek, traffic volumes are lower but may still be a partial barrier to wildlife movement depending on time of year or time of day. For this Assessment, the research team had access to Average Annual Daily Traffic (AADT) as a metric of traffic volume. However, this annual average is not representative of traffic patterns, especially in areas with large fluctuations in seasonal use (see Section 2.4). Conducting additional traffic studies to determine locations where seasonal traffic volumes present a substantial barrier to wildlife movement would provide more information about the potential effect of accommodation measures.

The US-191/MT-64 Wildlife and Transportation Assessment identifies and prioritizes highway locations with the highest rank based on a combination of human safety and biological conservation factors. Mitigation along other areas of the study roads may be warranted and should also be considered based upon the documentation and analysis in this report, especially when highway projects are planned.

This report includes recommendations for mitigation measures along priority road locations. The recommendations are based on the dual objectives of reducing collisions with larger-bodied wild mammals and providing safe crossing opportunities for wildlife given parameters such as local traffic volume and topography. However, the recommended measures should not be considered actions that must happen specifically as described. Rather, the human safety, biological conservation, and economic information summarized should be used to understand why certain highway sections are important to mitigate for wildlife, target species by location, and type of measures that may be effective. The exact location, type, and dimensions of any prospective measure depends upon public support, design and engineering feasibility, potential agreements with land management agencies and/or private landowners, and funding availability.

7. Renderings of Potential Wildlife Accommodation Options

7.1. Retrofit of an Existing Structure

In some locations in the study area, it may be possible to retrofit existing bridges to improve terrestrial habitat connectivity as a relatively low-cost improvement. The image below illustrates a conceptual bridge retrofit based upon an existing bridge over the Gallatin River (Figure 34; RM 70.5) within the Gallatin Gateway to Spanish Creek Priority Site. Currently, the area adjacent to the bridge abutments is covered in riprap and steeply angled, such that deer, elk, and moose are limited in their ability to move along the riparian corridor beneath the highway.

By incorporating an elevated, gravel path into the area below the bridge, a retrofit would provide a secure option for terrestrial species to cross beneath the bridge year-round. The example protects the existing bridge abutment with a concrete retaining wall in order to enable development of the built-up, gravel path. Preferably, the path would have a minimum vertical clearance of 15 ft (4.6 m) to accommodate elk and moose, in addition to smaller-bodied species. The path also needs to be as wide as possible to provide a clear crossing area (Clevenger and Huijser 2011). In the example, a sloped rock embankment wall extends from the path to the riverbank (which is covered in snow in the image) to reduce erosion during high-water events.

Figure 34 (Top image) Existing Gallatin Gateway Bridge; (bottom image) Conceptual Bridge Retrofit (for illustrative purposes only).

Note: Rendering is an artist interpretation to help visualize possible solutions to accommodate wildlife. Renderings are not drawn to scale, nor do they incorporate FHWA or MDT bridge specifications or other required elements.

7.2. Replacing and Upsizing an Existing Structure

Replacement of existing bridges prior to or at the end of their service life with structures that can accommodate terrestrial wildlife passage offers another option to improve connectivity significantly. In this example, the existing bridge over Spanish Creek (Figure 35) is replaced with a upscaled version to accommodate terrestrial species, including moose and elk. The current bridge has low vertical clearance and sits just a few feet above the stream banks. It also barely spans the stream channel, such that no suitable dry passage exists for large wildlife to travel along the riparian corridor beneath the highway. The greater span length and height of an upscaled bridge provides dry footing and sufficient clearance to allow terrestrial wildlife to move freely beneath the bridge year-round, including during high water. At least 15 ft (3.7 m) of vertical clearance is preferable to accommodate elk and moose (Clevenger and Huijser 2011).

Figure 35 (Top image) Existing Spanish Creek Bridge; (bottom image) Conceptual Bridge Replacement (for illustrative purposes only)

Note: Rendering is an artist interpretation to help visualize possible solutions to accommodate wildlife. Renderings are not drawn to scale, nor do they incorporate FHWA or MDT bridge specifications or other required elements.

7.3. New Wildlife Overpass

A purpose-built structure such as a wildlife overpass, in conjunction with fencing, is a highly effective option to maintain wildlife movement while reducing wildlife-vehicle collisions. This example depicts a conceptual wildlife overpass (Figure 36) in the North of Big Sky Entrance Priority Site, one of three locations where a wildlife overpass is among the recommendations of this report. In order to accommodate elk as a target species, an overpass would need a minimum width of 164 ft (50 m) and provide a clear line of sight across the entire structure. At this and other sites, an overpass would need to be combined with 8 ft (2.43 m) high wildlife exclusionary fencing along the highway in both directions to guide wildlife onto the structure in order to reduce WVCs (Huijser, Fairbank, et al. 2016).

This example depicts an arched structure with a minimum vertical clearance of 16.5 ft (5.03 m) over a 32 ft (9.75 m) roadway. Greater vertical clearance may be necessary in areas with high volumes of truck traffic. For this reason, the CLLC-WTI research team recommends increasing the minimum clearance by 1-2 ft (0.3-0.61 m) to 17.5-18.5 ft (5.3-5.6 m) decrease the risk of a truck strike.

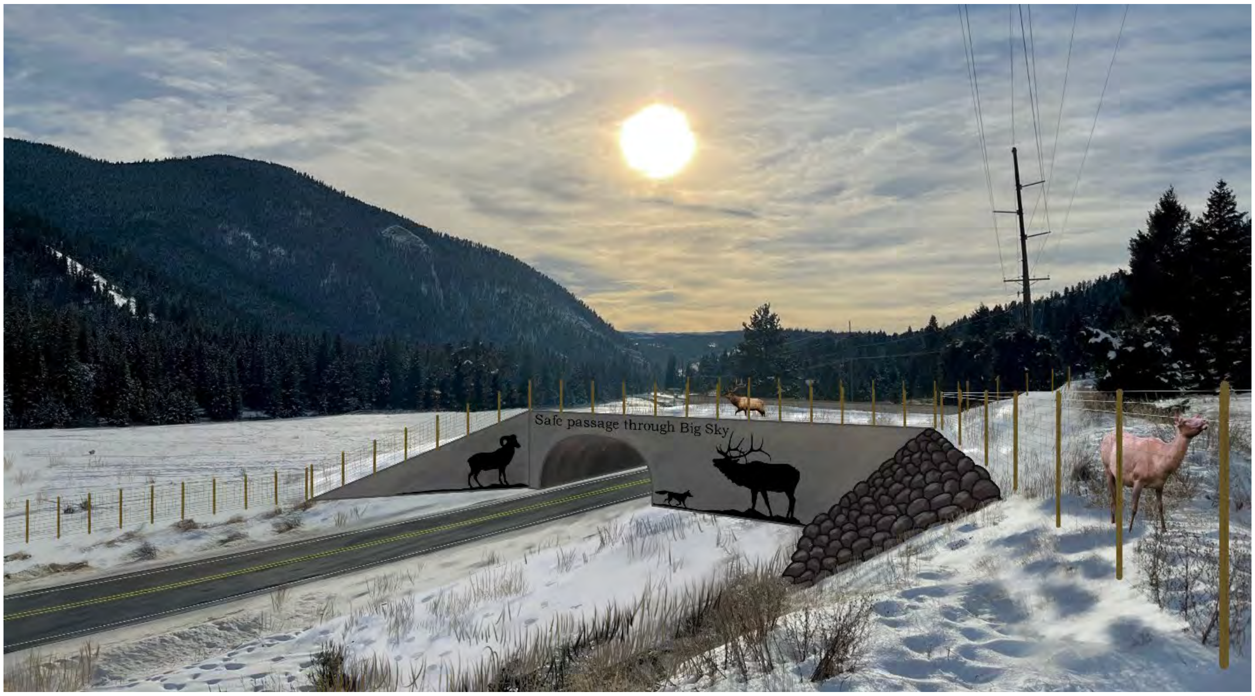


Figure 36 (Top image) US-191 north of Big Sky; (bottom image) Conceptual Wildlife Overpass (for illustrative purposes only)

8. Potential Funding Sources

8.1. Introduction

According to Montana Department of Transportation (MDT) surveys, safety concerns and "wildlife crossings and barriers" are both in the top three or four priorities that stakeholders and the public would like to see the agency address in order to improve our state's transportation system. However, the number one obstacle to advancing more wildlife crossing projects in the U.S. is a lack of available funding, according to a recent survey of state Department of Transportation staff across the country (Cramer 2022). Fortunately, growing support for wildlife crossings nationwide, across all levels of government, has established unprecedented new public funding opportunities for this work. Additionally, there is increasing interest from the philanthropic community in investing in projects that reduce wildlife-vehicle collisions while improving habitat connectivity. These wildlife accommodations can be "stand-alone" projects or incorporated into a variety of transportation improvement projects, including new construction and reconstruction; resurfacing; restoration, rehabilitation, or replacement; "spot improvements" and safety projects; and preservation of roads and bridges. To learn more, see the definition of "construction" under 23 USC § 101(a)(4) and the improvement types listed on pages 8-9 of Montana's 2022-2026 Statewide Transportation Improvement Program.

This chapter begins with an overview of existing federal funding sources that could be used to advance the wildlife accommodation measures discussed in this Assessment. The majority of public funding available comes from these federal sources, given that 88.5% of Montana's roads and bridges are funded through federal dollars, and the Montana Department of Transportation receives no funding from the state's general revenue fund (Montana Department of Transportation 2022). The majority of non-federal matching funds come from Montana's fuel tax and gross vehicle weight fees (Montana Department of Transportation 2022).

After reviewing federal funding sources, this chapter offers examples from across the country of innovative state and local funding mechanisms, as well as public-private partnerships. These examples could serve as models for establishing additional funding sources to implement the recommendations of the Assessment. Many wildlife accommodation projects throughout the U.S. are funded through a diverse array of funding sources, including local, state, and federal funding, as well as private contributions from individuals, foundations, and corporations. Leveraging all existing, eligible funding sources—in addition to establishing new funding streams and attracting private investments—is paramount for garnering sufficient funds to complete successful wildlife accommodation projects. A diversified portfolio approach is important for advancing both dedicated wildlife accommodations and wildlife accommodation measures as components of larger transportation projects.

8.2. Federal Infrastructure Funding Sources

In 2021, the federal government enacted the Infrastructure Investment and Jobs Act ("IIJA," Public Law 117-58), which established the first-ever *dedicated* federal funding for wildlife crossings. In addition to this dedicated funding, projects to reduce wildlife-vehicle collisions and/or improve habitat connectivity are eligible for funding from at least fourteen other federal infrastructure programs. While there are billions of dollars available under the latter programs, they do not have funding set aside specifically for wildlife crossings. However, examples of wildlife crossing projects that have received federal funding under these broader transportation programs are provided in this section. Thus, wildlife components of larger capital improvement projects can receive funding from a variety of sources.

The funding amounts listed in the descriptions below are for fiscal years 2022-2026. Eligible entities for each of these programs are listed in Table 38. Additional information and resources on the programs described below can be found on the Center for Large Landscape Conservation’s Wildlife and the Bipartisan Infrastructure Law webpage, Animal Road Crossings Solutions’ webpage, the Federal Highway Administration’s Bipartisan Infrastructure Law webpage, and the US Department of Transportation’s notice of funding opportunities webpage. For further information about wildlife crossing projects that have taken advantage of federal transportation dollars, including many of those described in this chapter, visit the Wonderful World of Wildlife Crossings Story Map.

Table 38 Eligible recipients for transportation funding programs under the Infrastructure Investment and Jobs Act of 2021

Program	State	Metro/Regional	Local	Tribal	Federal
Bridge Formula Program	x				
Bridge Investment Program	x	x	x	x	x
Federal Lands Access Program	x		x	x	x
Federal Lands Transportation Program	x				x
Forest Service Legacy Road and Trail Remediation Program					x
Highway Safety Improvement Program	x				
National Infrastructure Project Assistance (Mega) Program	x	x	x	x	
Local and Regional Project Assistance Grants (RAISE)	x	x	x	x	x
National Culvert Removal, Replacement, and Restoration Program	x		x	x	
Nationally Significant Federal Lands and Tribal Projects	x		x	x	x
Nationally Significant Freight and Highway Projects (INFRA)	x	x	x	x	x
PROTECT (competitive)	x	x	x	x	x
PROTECT (formula)	x				
Rural Surface Transportation Grant	x	x	x	x	
Surface Transportation Block Grant	x				
Wildlife Crossings Pilot Program	x	x	x	x	x

Categories of eligible entities listed in the header include state departments of transportation (“State”), metropolitan planning organizations or regional transportation authorities (“Metro/Regional”), local transportation authorities (“Local”), tribal departments of transportation (“Tribal”), and federal natural resource management agencies (“Federal”). Programs are listed in alphabetical order.

Montana's funding flow for federal-aid funding, MDT’s non-federal matching funds, state-funded programs, and other federal allocations and transfers is illustrated in Figure 37.

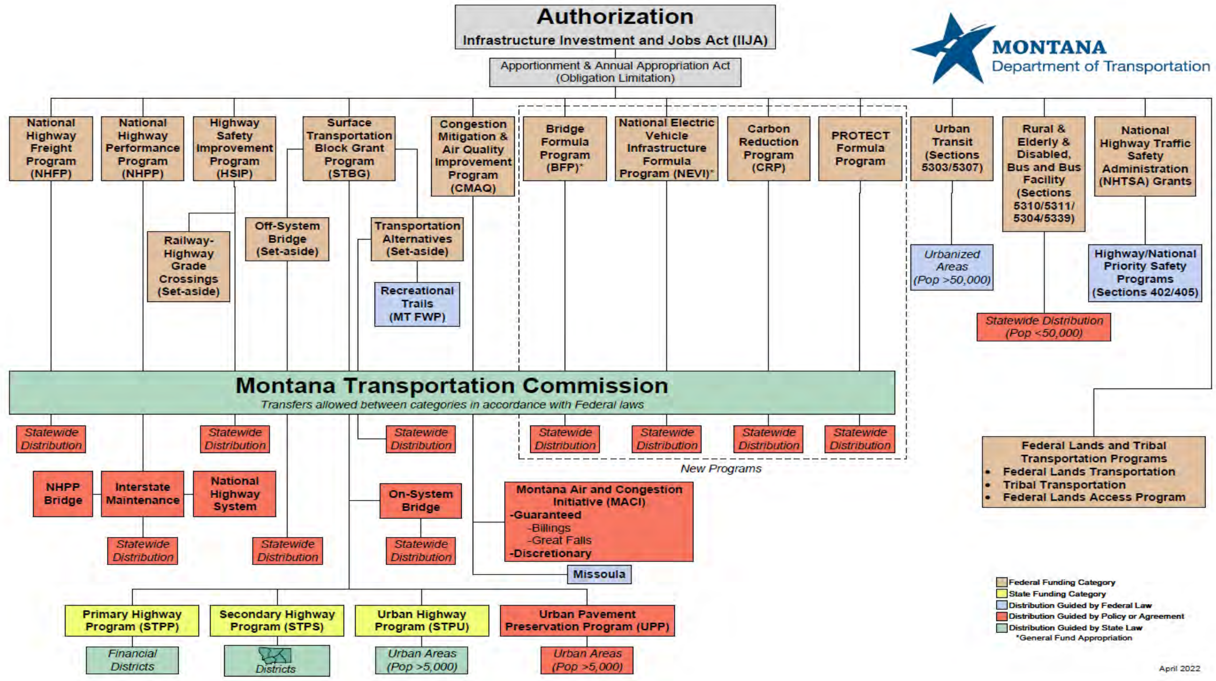


Figure 37 Funding Flow for Federal Reauthorization Funds (Montana Department of Transportation, 2022-2026 Statewide Transportation Improvement Program)

8.2.1. Discretionary Grant Programs

The following Infrastructure Investment and Jobs Act (IIJA) programs provide discretionary grants distributed through competitive application processes at the national level.

8.2.2. Wildlife Crossings Pilot Program

This new $350-million pilot grant program establishes dedicated funding for projects to reduce wildlife-vehicle collisions and improve habitat connectivity (23 USC § 17). Proposals for funding under this program will also be evaluated based on the extent by which the project leverages non-federal funding, supports local economies and tourism, integrates innovative technology and design techniques, provides educational and outreach opportunities, and evaluates the efficacy of the project. Eligible entities include state departments of transportation, Tribes, federal land management agencies, metropolitan planning organizations, local governments, regional transportation authorities, and special districts. Eligible partners include foundations, non-governmental organizations, universities, and other government agencies. Additionally, 60% of funds will go to projects in rural areas (Federal Highway Administration 2022).

8.2.2.1. Rural Surface Transportation Grant Program

This new $2-billion program is for highway, bridge, or tunnel projects to improve and expand the surface transportation infrastructure in rural areas (those with a population of fewer than 200,000 residents) to increase connectivity, improve safety, enhance reliability, generate regional economic growth, and improve quality of life (23 USC § 173). Wildlife infrastructure projects, including tunnels and detection systems, are eligible for funding. Projects must have completed preliminary engineering studies and begin construction within 18 months. The federal cost share is generally 80%, and other sources of federal assistance can be used for match (US Department of Transportation 2023).

8.2.2.2. Promoting Resilient Operations for Transformative, Efficient, and Cost-saving Transportation (PROTECT)

This new program includes $7.3 billion in formula allocation funding and $1.4 billion in discretionary grant funding for states and communities to make transportation resilience improvements to mitigate the risk of recurring damage from extreme weather events, flooding, or other natural disasters (23 USC § 176). Eligible projects include natural infrastructure and "protective features" that increase the size or number of drainage structures, replace culverts with bridges, lengthen or raise bridges, or upsize culverts for climate resilience and ecosystem benefits (Federal Highway Administration 2022). The federal cost share for projects under this program in Montana is 86.58% (Montana Department of Transportation 2022).

8.2.2.3. Bridge Investment Program

This new $12.5-billion program is for projects to replace, rehabilitate, preserve, or protect one or more bridges on the National Bridge Inventory; replace or rehabilitate culverts for purposes of improving flood control; and to improve habitat connectivity for aquatic species (23 USC § 124). The program includes $100 million in grants for planning, feasibility analysis, and revenue forecasting. This set-aside is for measures to improve bridge and culvert condition, safety, efficiency, and reliability and to replace, rehabilitate, preserve, or protect one or more bridges on the National Bridge Inventory. More specifically, projects that replace or rehabilitate culverts to improve flood control and habitat connectivity for aquatic species are eligible for funding. The federal cost share is 50% for large bridge projects, 80% for other bridge projects, and up to 90% for "off-system" bridges.

Example: In 2022, Flathead County (Montana) secured $240,000 in Bridge Investment Program funding for bridge improvements, including wildlife connectivity improvements (*Federal Highway Administration 2022*).

8.2.2.4. National Culvert Removal, Replacement and Restoration Program

This new $1-billion program is for states, local governments, and Tribes to facilitate fish passage by removing, replacing, or repairing culverts or weirs (23 USC § 6703). The federal cost share is up to 80% (Federal Highway Administration 2023).

8.2.2.5. Local and Regional Project Assistance Grants: Rebuilding American Infrastructure Sustainably and Equitably (RAISE)

This $7.5-billion program is for road, rail, transit, and other surface transportation of local and/or regional significance (49 USC § 6702). Selection criteria include safety, sustainability, equity, economic competitiveness, mobility, and community connectivity. Eligible projects include those that replace or rehabilitate a culvert or prevent stormwater runoff for the purpose of improving habitat for aquatic species. The maximum award is $25 million per project. The federal cost share is generally 80% but could be higher for projects located in rural, disadvantaged, or impoverished areas (U.S. Department of Transportation 2022).

Example: In 2019, the Wyoming Department of Transportation received $14.5 million under a previous iteration of this program (Better Utilizing Investments to Leverage Development, or "BUILD") to construct wildlife crossings (including underpasses, fencing, and jump-outs) along U.S. Route 189 (*Wyoming Department of Transportation 2019*).

8.2.2.6. Nationally Significant Multimodal Freight and Highway Projects Program (INFRA)

This $8-billion program is for multimodal freight and highway projects of national or regional significance that improve the safety, efficiency, and reliability of the movement of freight and people (23 USC § 117). Projects that increase safety on freight corridors where wildlife frequently cross the road are now eligible for funding. At least 30% of funding for small projects ($5 million minimum) goes towards rural areas, and 25% of funding for large projects ($25 million) goes towards rural areas. Large projects must have completed preliminary engineering studies, begin construction within 18 months, demonstrate a need for federal funding, and demonstrate available non-federal funding. The federal cost share is generally 60% but could be up to 80% for small projects (U.S. Department of Transportation 2022).

Example: In 2022, the Colorado Department of Transportation (CDOT) received a $100-million INFRA grant for highway improvements on Interstate 70 (*U.S. Department of Transportation 2022*). The project includes the construction of a wildlife underpass and directional fencing, "the first major wildlife crossing to be constructed along the I-70 Mountain Corridor, and it will allow wildlife to safely cross underneath the interstate at a location which has historically been a hotspot for wildlife related crashes," according to CDOT (*Colorado Department of Transportation 2022*)

8.2.2.7. Nationally Significant Federal Lands and Tribal Projects

This $275-million program is for the construction, reconstruction, and rehabilitation of nationally significant federal lands and tribal transportation projects (23 USC § § 203). Federal entities and state, county, or local governments may apply if sponsored by an eligible federal land management agency or Tribe. Eligible projects include measures to mitigate wildlife-vehicle collisions and mitigate damage to habitat connectivity and aquatic organism passage, including constructing, maintaining, replacing, or removing culverts and bridges. The federal cost share is up to 90% for projects on non-tribal transportation facilities (Federal Highway Administration 2022).

8.2.2.8. National Infrastructure Project Assistance ("Mega")

This new $5-billion program is for large and complex transportation projects (including highway, bridge, freight, railway, and certain public transportation projects) with national or regional economic, mobility, or safety benefits. Half of the funds are allocated to projects greater than $500 million, and the other 50% are allocated to projects between $100-500 million. The federal cost share is 60%, but total federal assistance for a project receiving a grant under this program could be up to 80% (U.S. Department of Transportation 2023).

Example: In 2023, the North Carolina Department of Transportation was awarded $110M to replace the Alligator River Bridge on U.S. Highway 64. The project includes wildlife crossing structures and directional fencing to improve habitat connectivity between the north and south areas of the roadway and reduce wildlife-vehicle collisions (*U.S. Department of Transportation 2022*).

8.2.3. Formula Funding Programs

The following IIJA programs distribute funding directly to states via formula allocations or formula grants.

8.2.3.1. Bridge Formula Program

This new $27.5-billion program is for states to complete bridge replacement, rehabilitation, preservation, protection, or construction projects on public roads (23 USC § 124). Funds can be used to plan, design, engineer, or construct bridges, to replace and rehabilitate bridges, and to improve bridges in poor condition. Given that "improvements that reduce the number of wildlife-vehicle collisions, such as wildlife crossing structures" are included in the definition of "construction" under IIJA (23 USC § 101(a)(4)(H)), wildlife crossings are presumably an eligible component of construction projects funded under this program (Federal Highway Administration 2022). The federal cost share for projects under this program in Montana is 86.58% (Montana Department of Transportation, 2022-2026 Statewide Transportation Improvement Program).

8.2.3.2. Surface Transportation Block Grant Program

This $72-billion program is for state and local government projects on federal-aid highways and bridges on any public road, as well as transit capital projects (23 USC § 133). It includes the design, construction, monitoring, and maintenance of wildlife crossing structures or other measures designed to reduce wildlife-vehicle collisions. The $7.2 billion for the Transportation Alternatives (TA) set-aside has funding available for local transportation projects, including environmental mitigation activities, such as reducing wildlife mortality caused by roads or improving terrestrial or aquatic connectivity. Local governments and other eligible entities (such as metropolitan planning organizations and non-profits) can apply for this funding through a competitive grant process developed by the state (Federal Highway Administration 2022). The federal cost share in Montana for projects under this program is 86.58% (Montana Department of Transportation, 2022-2026 Statewide Transportation Improvement Program).

Example: In 2010, a public-private partnership secured a Transportation Alternatives grant that—when matched with a State Wildlife Grant and from the U.S. Fish and Wildlife Service and private dollars—funded the construction of underpasses and fencing to provide safe passage for amphibians during their seasonal migration across the Monkton-Vergennes Road in Vermont.

8.2.3.3. Highway Safety Improvement Program

This $15.6-billion program provides states with funding to save lives and prevent serious injuries on public roads in accordance with their highway safety plans (23 USC § 148). Projects that improve safety by reducing wildlife-vehicle collisions are eligible. The federal cost share is 90% (Federal Highway Administration 2022).

Example: In 2015, the Colorado Department of Transportation used Highway Safety Improvement Program dollars to construct a series of wildlife underpasses along State Highway 160 (Colorado Department of Transportation 2015).

8.2.3.4. Federal Lands Transportation Program

This $2.2-billion program is for projects that improve multimodal transportation on roads, bridges, trails, transit systems, and other transportation facilities (23 USC § 204). It includes $130 million in direct federal spending for the U.S. Forest Service, $180 million for the U.S. Fish & Wildlife Service, $1.7 billion for the National Park Service, and $154 million in competitive grant funding for other federal land management agencies. IIJA doubles the previous cap of $10 million to a current cap of $20 million per year for funds under this program that can be used for projects that reduce wildlife mortality due to roads while maintaining habitat connectivity (Federal Highway Administration 2022).

Example: In recent years, the Texas Department of Transportation, in coordination with the US. Fish & Wildlife Service constructed a series of wildlife underpasses, primarily for ocelots, around the Laguna Atascosa National Wildlife Refuge using Federal Lands Transportation Program funds *(Federal Highway Administration 2023*).

8.2.3.5. Federal Lands Access Program

This $1.5-billion program is for improving multimodal transportation on roads, bridges, trails, transit systems, and other transportation facilities that access the federal estate on infrastructure owned or maintained by states and local governments (23 USC § 204). It places an emphasis on high-use federal recreation sites and federal economic generators. It includes environmental mitigation during planning, engineering, and construction phases on or adjacent to federal lands to reduce wildlife mortality due to roads and maintain habitat connectivity (Federal Highway Administration 2023).

Example: In 2017, the Idaho Department of Transportation received $2.8 million in Federal Lands Access Program funds to build a wildlife overpass on State Highway 21, with $220,000 in matching funds from a public-private partnership including Idaho Department of Fish and Game, the U.S. Forest Service, Army Corps of Engineers, the Western Federal Lands Highway Division, non-governmental organizations, and local cities and counties (*Idaho Department of Transportation*).

8.3. Federal Conservation Funding Sources

8.3.1. Collaborative-based, Aquatic-focused, Landscape-scale Restoration Program

IIJA established this new $80-million competitive funding program for projects to restore water quality or fish passage on federal and non-federal lands (23 USC § 204). Priority is given to a proposal resulting in the most miles of streams being restored for the lowest amount of federal funding. Projects should contain proposed non-federal funding and request no more than $5 million (U.S. Forest Service 2023).

8.3.2. Forest Service Legacy Road and Trail Remediation Program

IIJA provided $250 million for direct federal spending on capital improvement and maintenance under this existing program (established under 16 USC 532). Eligible projects include decommissioning and repairing roads and trails to mitigate detrimental impacts on sensitive ecosystems and watersheds. Additionally, funding can be used to replace or install bridges and culverts (or low-water trail crossings), address public safety of roads and trails, restore unneeded roads and trails to a more natural state, address storm-damaged areas, and remove or replace pipes and other structures that impede aquatic habitat connectivity (U.S. Forest Service 2023).

8.3.3. America the Beautiful Challenge

The America the Beautiful Challenge combines funding from federal agencies and the private sector for a total of $1 billion over the next five years to support the implementation of large-scale ecosystem conservation and restoration across public and private lands. It provides funding for projects to address five objectives, one of which is “connecting and reconnecting wildlife corridors, large landscapes, watersheds, and seascapes” (National Fish and Wildlife Foundation 2022). The first funding cycle was completed in November 2022 and awarded $91 million. The 2023 Request for Proposals was issued and closed on April 20, 2023. Implementation grants are $1 million to $5 million in size over four years (with landscape-scale restoration projects potentially eligible to receive more), and planning grants are $200,000 to $2 million in size over two or three years. State government agencies, U.S. territories, Indian Tribes, non-profit 501(c) organizations, local governments, municipal governments, and educational institutions are eligible to apply for the grants.

8.3.4. Proposed Recovering America's Wildlife Act

Recovering America's Wildlife Act is a proposed bipartisan, popular piece of federal legislation (S. 1149) that would provide significant financial and technical assistance to states and Tribes to recover listed species, including implementation of State Wildlife Action Plans. This funding could be used to conserve or restore wildlife and plant species of greatest conservation need, support state wildlife conservation strategies, or enable wildlife conservation education and recreation. Montana's State Wildlife Action Plan identifies habitat fragmentation as a specific threat to the state's wildlife and habitat and further identifies highways as a major source of fragmentation (Montana Fish, Wildlife & Parks, 2015).

8.3.5. U.S. Fish & Wildlife Service Funding for Imperiled Species

Wildlife accommodation projects that conserve species that are listed as threatened or endangered under the Endangered Species Act and/or conserve the habitat of those species could potentially receive funding from existing U.S. Fish and Wildlife Service (USFWS) grant programs such as the Cooperative Endangered Species Conservation Fund and the Partners for Fish and Wildlife Program. Additional USFWS financial assistance opportunities can be found here.

8.3.6. Western Big Game Seasonal Habitat and Migration Corridors Fund

The National Fish and Wildlife Foundation administers the Western Big Game Seasonal Habitat and Migration Corridors Fund, which provides grants for projects to conserve the winter range and migration routes of pronghorn, elk, and mule deer in 11 western states, including Montana (National Fish and Wildlife Foundation 2022(a)). The fund has around $3 million available annually, awards approximately six to ten grants per cycle, and requires a 1:1 non-federal match of in-kind or cash contributions. One of the four strategies of the program is to work **"**cooperatively with tribal nations, private landowners and *state highway departments to improve fencing*, including modifying, removing, installing if serving to direct big game movement out of harm's way, or seasonally adapting fencing if proven to impede movement of big game through priority migration corridors" (emphasis added, National Fish and Wildlife Foundation 2022(b)). The program has funded a number of projects to reduce wildlife-vehicle collisions and improve habitat connectivity across highways. For instance, in 2022, the program funded the following initiatives:

- A project in Montana to "address habitat connectivity on the Blackfeet Nation through removal and upgrade of fences, [and] reduction of animal-vehicle collisions along key sections of highway."
- A project in Idaho to "improve big game passage success rates across US-95 ... and reduce wildlife-vehicle collisions by repairing and extending 2.8 miles of wildlife funnel fencing along wildlife crossing infrastructure."
- A project in Oregon to install 10 miles of fencing that will "direct mule deer and elk to a newly constructed wildlife underpass along U.S. Highway 97," thereby reducing wildlife-vehicle collisions and reconnecting 75 miles of a wildlife migration corridor.

8.4. Innovative State Funding Mechanisms

8.4.1. Montana Wildlife and Transportation Partnership Project Program

In 2018, the Montana Department of Transportation (MDT), Montana Fish, Wildlife, & Parks, and Montanans for Safe Wildlife Passage formed the Montana Wildlife and Transportation Partnership (MWTP) to address wildlife-vehicle conflicts. In 2023, MWTP launched a new planning tool and program to identify areas of greatest need of wildlife accommodations on highways throughout the state and strategically pursue effective solutions. This includes a new MWTP Project Program to solicit, evaluate, and advance public-private partnership proposals for transportation projects specifically aimed at addressing wildlife-vehicle conflicts and improving habitat connectivity. Under this program, MDT funding may be available for feasibility studies of selected projects. However, applicants should identify additional sources of funding to design and build the proposed project if it is determined feasible by the preliminary analyses (Montana Department of Transportation, 2023).

8.4.2. Other State Funding Models

Additionally, other states are establishing innovative funding mechanisms for wildlife crossing projects rather than drawing resources from existing state transportation budgets. The following examples could serve as potential models for a new, state-level funding mechanism for wildlife crossings:

- In 2005, the Wyoming Legislature created the Wyoming Wildlife & Natural Resource Trust to fund habitat and natural resource conservation across the state. Eligible projects include those that mitigate adverse consequences to wildlife habitat or mitigate wildlife conflicts, including wildlife crossings (Wyoming Wildlife & Natural Resource Trust 2023). The fund allows individuals and organizations to donate to these projects.
- Both Wyoming and Oregon have created specialty wildlife conservation license plates. Money from the sale of these license plates and the renewal fees go towards established state funds that support habitat connectivity and wildlife crossing projects (Wyoming Game & Fish Department 2023, Oregon Wildlife Foundation 2022).
- Wildlife connectivity legislation enacted in California in 2021 sets up a compensatory mitigation credit scheme that allows the California Department of Fish and Wildlife to grant the California Department of Transportation credits for wildlife crossings that can be used for future transportation projects requiring environmental mitigation (California Legislative Information 2021).

8.5. Innovative Local Funding Mechanisms

One tool that local governments have employed to fund wildlife crossing projects is the establishment of special purpose taxes. For instance, in 2019, Teton County (Wyoming) passed a $10-million Special Purpose Exercise Tax to support the construction of priority wildlife crossing structures identified in the county-wide Wildlife Crossing Master Plan (Jackson Hole Conservation Alliance 2020). Similarly, Pima County, Arizona, dedicated $45 million of its local sales tax revenues to conserve and restore “critical wildlife linkages” through measures such as building wildlife crossings, including underpasses on State Route 86 (Regional Transportation Authority, Pima County 2022).

8.6. Public-Private Partnerships

Fully covering all the costs associated with designing, building, monitoring, and maintaining wildlife crossing infrastructure is more feasible when partnerships are able to secure private contributions to match public funding available for a project. Indeed, one of the criteria against which the Federal Highway Administration will evaluate proposals under the Wildlife Crossings Pilot Program is the extent to which the proposed project leverages other funding sources, including from public-private partnerships (as stated explicitly in the statute, 23 USC § 171(e)(2)(A)). Identifying or establishing a non-profit organization that can receive tax-deductible donations for the project is an important consideration. Private contributions often come from individuals, charitable foundations, or corporations. Additionally, land trusts across the country are contributing to wildlife crossing projects by ensuring land on both sides of the road remains protected as viable habitat for the species attempting to cross (Center for Large Landscape Conservation 2022).

Below are some examples of public-private partnerships that have funded wildlife crossing projects:

- The Western Big Game Seasonal Habitat and Migration Corridors Fund is a public-private partnership between the National Fish and Wildlife Foundation, the Department of the Interior, the Department of Agriculture, Bezos Earth Fund, and several corporations: Burlington North Santa Fe Railway, ConocoPhillips, Altria Group, and Microsoft. The program has awarded $11.7 million across 52 projects, leveraging $57.5 million in matching contributions (National Fish and Wildlife Foundation 2022(c)).
- A large portion of the Liberty Canyon wildlife crossing on US Highway 101 in California has been funded through private contributions. The project has received donations from thousands of private, philanthropic, and corporate institutions globally, including $26 million from the Annenberg Foundation and Wallis Annenberg, who is now the namesake of the overpass (Annenberg Foundation 2022).
- The Land Trust of Santa Cruz County protected three properties on both sides of Highway 17, collected data, raised funds, and is partnering with the California Department of Transportation, Santa Cruz County Regional Transportation Commission, and others to construct a wildlife underpass (Land Trust of Santa Cruz County 2022).
- In 2017, the Adirondack Chapter of The Nature Conservancy (TNC), Adirondack Land Trust, and the New York State Department of Transportation partnered to install the state's first "critter shelf" inside a large culvert to help wildlife safely cross underneath the road (Civil & Structural Engineer Media 2017). The culvert is located between private lands protected by conservation easements, and TNC monitored the culvert with wildlife cameras (The Nature Conservancy 2019).
- The WYldlife Fund, a partner foundation of the Wyoming Game and Fish Department, has prioritized funding wildlife crossing projects, such as building 15 miles of exclusionary fencing to direct wildlife to underpasses on Interstate 25 (WYldlife Fund 2022).

In Montana, public-private partnerships have long been a critical source of support for conserving the state's natural heritage. For instance, Montana's Outdoor Legacy Foundation (MOLF) is the primary non-profit partner of Montana Fish, Wildlife, and Parks, and the two entities have partnered on funding proposals to reconnect habitats and facilitate wildlife movement. MOLF leverages private funding for conservation (including "wildlife/wildlands management and care") and manages the Montana Fish and Wildlife Conservation Trust (Montana Outdoor Legacy Foundation 2023). Thus, Montana has an existing entity that could potentially play a similar role to the WYldlife Fund and the Oregon Wildlife Foundation in funneling private funding toward wildlife accommodation projects to leverage public dollars.

8.7. Conclusion

In summary, there are various public and private transportation and conservation funding sources currently available to support the implementation of the recommendations of the Assessment. In addition, a number of state and local funding programs could be established to provide financial support. Ultimately, cultivating public-private partnerships will be important for securing robust and reliable funding streams for all the phases and elements of successful wildlife crossing projects. The strongest project partnerships include diverse stakeholders—such as wildlife and transportation agencies, academic researchers, non-governmental organizations, and local landowners and business owners—working together to advance the common cause of making roads safer for drivers and wildlife.

9. Aquatic Organism Passage Assessment

9.1. Introduction

Fish and other aquatic species move throughout their range from streams and rivers to connected tributaries, lakes, and wetlands. If improperly designed, maintained, or constructed, road crossings can impede or prevent the upstream movement of aquatic species such as fish. In some cases, establishing or maintaining a structure as a barrier may be desired to protect a native species from introgressive hybridization or competition with non-native species.

The Gallatin River on the northern end of the study area and the streams and rivers near Hebgen Lake at its southern extent support world-class fisheries and native fish, including Westslope cutthroat trout (*Oncorhynchus clarkii lewisi*). Other fish species along the corridor in the Gallatin River include brook trout (*Salvelinus fontinalis*), brown trout (*Salmo trutta*), longnose dace (*Rhinichthys cataractae*), mottled sculpin (*Cottus Bairdii*), mountain whitefish (*Prosopium williamsoni*), rainbow trout (*O. mykiss*), white sucker (*Catostomus commersonii*), and Yellowstone cutthroat trout (*O. clarkii bouvieri*) (MDT, 2020). Tributaries have similar species assemblages; however, in many cases, only a few species may be present. Westslope cutthroat trout are a species of concern in Montana and are often considered the target species for habitat restoration or connectivity efforts. Arctic grayling (*Thymallus arcticus*), native to the upper Missouri River, were present in portions of the study area but are now absent.

Aquatic connectivity refers to the movement of all aquatic organisms and ecological flows and processes. Ecological flows include the movement of water, nutrients, woody debris, sediment, and other materials. The degree to which existing US-191 infrastructure prevents, limits, or provides aquatic passage for native fish species is the focus of this chapter.

This information in this chapter is based upon an initial field evaluation of road-stream crossings along US-191 and MT-64 in the study area carried out over the course of September-December 2021. The information is intended to provide a baseline and initial ranking of crossings in terms of aquatic organism passage, with preliminary recommendations from which more detailed studies could be initiated or mitigation measures, such as new crossing designs, could be implemented when sections of this highway are under reconstruction.

9.1.1. Objectives

The objectives of this aquatic organism assessment are:

- Collect baseline data of existing road-stream crossings along the corridor,
- Perform an initial assessment of culverts along the highway corridor to identify the level of connectivity through each structure, and
- Identify culverts that may be limiting the unimpeded movement of fish species and opportunities to improve connectivity.

9.1.2. Literature Review

9.1.2.1. Fish Passage and Approaches to Assess Culvert Barriers

Culverts are a common and often cost-effective means of providing transportation intersections with naturally occurring streams or rivers but have been identified as potential barriers to fish mobility. Bridges, as compared to culverts, are typically used to cross larger waterways and generally do not impede fish movements. Fish passage presents a complex challenge to engineers, hydrologists, and biologists due in part to the dynamic nature of streams and rivers, both physically and biologically. The interactions between the physical and biological elements further complicate the problem. There are many physical factors that determine whether a fish can or cannot pass through a culvert; insufficient water depth, large outlet drop height, and excessive water velocity comprise the most common physical factors limiting passage (Baker and Votapka 1990; Burford et al. 2009; Votapka 1991; Fitch 1995). Biological factors such as a fish's swimming ability, motivation, and behavior play an equally important role in passage.

Although no comprehensive inventory of the number of culverts on fish-bearing streams in North America is available, there are an estimated 5+ million stream-road crossings in the United States. Examples of the number of culvert barriers from various parts of North America highlight the problem that improperly designed, constructed, or maintained culverts can pose to fish movement. Sixty-one percent of culvert crossings in the Notikewin watershed and 74% of culvert crossings in the Swan River watershed, both in Alberta, likely impede fish movement (Tchir, Hvenegaard, and Scrimgeour 2004). In Whatcom County, Washington, researchers assessed the passage status of culvert crossings on 1,673 crossings; they believe 837 (50%) are barriers to fish passage (Whatcom County Public Works 2006). An analysis of fish passage across road-stream crossings identified 2,900 culverts on 50,000 miles of forest roads in Montana, northern Idaho, and western North and South Dakota. The analysis showed that about 80% of the culverts are barriers to Westslope or Yellowstone cutthroat trout at some life stage. Of the total surveyed, 576 (about 20%) were classified as total barriers that completely isolate upstream fish populations (USDA National Technology Development Program 2008). An evaluation of four bridges and 47 culverts along a 210-km segment of the Trans Labrador Highway in Canada identified that 53% of the culverts posed fish passage problems due to poor design or construction (Gibson, Haedrich, and Wernerheim 2005). In Alberta's Kakwa River watershed, 57% of culvert crossings are perched, thus blocking fish access to an estimated 98 km of upstream habitats (Johns and Ernst 2007).

There are many different methods to analyze the barrier status of culverts, each with distinct advantages and disadvantages. For this discussion, these methods are split into direct and indirect assessments. Direct assessments measure the amount of movement by fish in the field with an experiment such as a mark-recapture study (Cahoon et al. 2005; Belford and Gould 1989; Warren Jr and Pardew 1998). Another method that can directly measure passage and also allows for the ability to analyze fish movement through a range of flow conditions is the use of PIT (passive integrated transponder) tags and antennae placed at the upstream and downstream ends of a culvert (Cahoon et al. 2005). These approaches can provide detailed information concerning both the passage status of a culvert and the hydraulic environment within and adjacent to the culvert that allows or prevents passage; however, they can be labor-intensive and are only practical for assessing a smaller number of culverts.

Indirect methods generally approximate fish movement potential by comparing the culvert's physical conditions to those the fish are known to be able to overcome. FishXing is a software program that combines culvert characteristics (slope, length, roughness, etc.) and stream hydrology to model the hydraulic conditions in and near the culvert (Six Rivers National Forest 2012). These hydraulic conditions are then compared to the swimming ability of the fish species of interest to determine a passage status. Although this method of analysis may be useful for assessing a large number of culverts with a relatively small amount of field data collection, caution must be used when interpreting the results, as research shows that this method can provide a conservative (i.e. more barriers to movement are predicted when compared to direct assessment results) estimate of the barrier status of culverts (Cahoon et al. 2005; Karle 2005). HEC 26, developed by the Federal Highway Administration, also provides guidance on passage assessment, inventory, and design of culverts for fish and aquatic organism passage (Kilgore, Bergendahl, and Hotchkiss 2010).

A common indirect approach—the one used in this study—to provide an initial assessment of how well a culvert allows, limits, or impedes upstream passage is to evaluate the culvert slope, outlet drop, and level of continuous substrate in the bottom. As the culvert slope increases, the upstream passage becomes more challenging for fish because water velocity increases with increasing culvert slope. Outlet drop is the difference in vertical elevation between the water surface in the culvert outlet (downstream end) and the water surface in the pool downstream. Some fish species do not jump, and in all cases, fish of a given size and species can only jump a certain height. Thus, outlet drops may present a barrier to upstream movement. Continuous substrate in a culvert usually means the culvert was designed in this manner, often following a stream-simulation approach where the conditions within the culvert are constructed to match the conditions of the natural channel. The assumption is that if a culvert “mimics” the natural channel, passage through it should be no more or less challenging than along the stream itself. Finally, a culvert may impede passage by having a somewhat steep slope combined with an outlet drop. This condition can be viewed as a combination barrier where slope or outlet drop alone may not create issues; yet, the combined effect of slope with outlet drop makes for a challenging passage.

Species abundance, size structure, and genetic differentiation can also be used as an indirect approach to evaluate fish passage. Typically, such studies compare the results of fish samples taken from locations upstream and downstream of a culvert. For example, population surveys performed upstream and downstream of a perched culvert indicated that cutthroat trout density was 64% lower upstream than downstream, and size structure was skewed to a higher proportion of large fish downstream of the culvert, suggesting the culvert was functioning at least as a partial barrier to upstream movement (US Fish and Wildlife Service 2002). This upstream and downstream approach can provide valuable information about how culverts affect the abundance, size structure, and distribution of fish populations; however, results from these types of studies may be inconclusive regarding the barrier status of a culvert. There may not be significant differences between upstream and downstream samples, even when a culvert is a barrier. Inconclusive results may indicate either recent genetic isolation or that a culvert allows partial movement of a species of interest (Knaepkens et al. 2004).

9.1.2.1. Other Impacts of Roads on Aquatic Habitat

Although the focus of this assessment is on aquatic connectivity, a brief discussion of other impacts of roads on aquatic habitats is warranted. Roads and crossing structures can alter flow regimes, surface and groundwater hydrology, local geomorphology, and nutrient cycling (McKay et al. 2013). Some impacts may include the channelization of streams to accommodate road infrastructure, changes to flood dynamics, and changes to groundwater-surface water interactions. Roads can penetrate soil horizons that are conduits for water flows from groundwater to surface water and disrupt pathways. Groundwater temperatures do not fluctuate as much as surface water temperatures and typically maintain more constant temperatures throughout the year; therefore, they can help regulate stream temperatures, an especially important process during summer low flow periods (Edwards 1998; Giller 1998). For example, bull trout seek habitat with groundwater upwelling or downwelling for spawning sites (Baxter and Hauer 2000).

Debris and sediment movement across landscapes can be altered by roads (Jones et al. 2000). Road-stream crossings can increase the accumulation of fine sediment downstream of crossings with potential impacts to salmonids, such as brook trout (Lachance et al. 2008). However, if proper best management practices (BMPs) are used at crossings, sediment load can be minimized (Morris et al. 2016; USDA National Technology Development Program 2008)

9.2. Methods

Study methods involved gathering basic physical data at road-stream crossings. The baseline data was then used to assess passage at each crossing (an indirect assessment method described in greater detail in the Literature Review, section 9.1.2, above) and identify opportunities for improving connectivity.

9.2.1. Data Collection

Crossing locations were initially identified using the national hydrography dataset (NHD) to identify intersections between US-191, MT-64 and streams. A few additional crossings were identified in the course of assessing other structures in the field.

Baseline field data was collected over several months during Fall 2021 at each crossing location. Monthly average stream flows for September, October, November, and December of 2021, as measured at Gallatin Gateway (USGS Gage No. 06043500) compared to the 20-year average for those same months, indicated 2021 had lower average flows than the past 20 years. For comparison, 2021 average flow for September was 368 cubic feet per second (cfs) compared to the 20-year average of 442 cfs. For October, the 2021 average was 393 cfs compared to the 20-year average of 424 cfs. For November, the 2021 average was 350 cfs compared to the 20-year average of 364 cfs. For December, the 2021 average was 280 cfs compared to the 20-year average of 295 cfs. Section 9.5 exhibits the sample data sheet used for data collection activities. The physical data collected includes:

- Shape of culvert,
- Culvert dimensions, including length, width (span), and height,
- Culvert material,
- Culvert length and slope,
- Presence of internal structures such as baffles,
- Amount of substrate (if any) within the culvert barrel, and
- Outlet drop height (perch).

In addition, field personnel made observations of any structural defects, such as exposed rebar or separated culvert sections, to aid in operation and maintenance (O&M). Field personnel also collected photographs of each road-stream crossing for potential future use.

9.2.2. Initial Passage Assessment

We used an indirect assessment approach to provide an initial assessment of passage at all road-stream crossings utilizing culverts. This approach assumes all bridge structures provide unimpeded fish passage; therefore, it was not applied to bridge structures. The approach is a blend of approaches used in the Northern Region of the USDA Forest Service for juvenile Yellowstone or Westslope cutthroat trout (USDA National Technology Development Program 2008), the Alaska Region of the USDA Forest Service, Region 10 for juvenile coho salmon, and California's Assessment Screen for juvenile salmonids (Taylor and Love 2002).

The primary criteria include whether the substrate is present and continuous throughout the structure, outlet drop, culvert slope, and presence/absence of internal baffling structures designed for fish passage. Table 39 provides the details for each criterion and describes outcomes as one of three possibilities:

- Green: indicates conditions through the structure are assumed adequate for passage of fish.
- Gray: indicates conditions may or may not be adequate for unimpeded passage of fish.
- Red: indicates conditions may not be adequate for unimpeded passage of fish.

Table 39 Aquatic Passage Assessment: The table summarizes the criteria, thresholds, and passage assessment outcome.

Criteria	Assessment	Passage Assessment Outcome
Continuous Substrate Throughout Structure or No Outlet Drop Combined with Slope < 1.0%	Conditions assumed adequate for passage of fish	Green
Outlet Drop > 0.34 ft or Slope > 0.01 ft/ft (1.0%)	Conditions may or may not be adequate for unimpeded passage of fish	Gray
Outlet Drop > 0.34 ft and Slope > 0.01 ft/ft (1.0%) and No Internal Structures	Conditions may not be adequate for unimpeded passage of fish	Red
Slope > 0.03 ft/ft (3%) or Outlet Drop > 2.0 ft and No Internal Structures	Conditions may not be adequate for unimpeded passage of fish	Red

9.3. Results

9.3.1. Physical Data

A total of 41 road-stream crossings with culverts were surveyed. Nine sites included multiple structures, resulting in a total of 53 different culverts surveyed. Sixteen structures had either continuous substrate throughout them or a natural channel bottom. Internal baffles were not observed in any structure. Table 40 summarizes the key physical characteristics of each culvert. Road-stream crossings with multiple structures (such as Big Bear Creek 2.0 A and B) are identified by the number of structures on site.

Table 40 Aquatic Passage Assessment: Summary of Key Physical Characteristics at Each Crossing

Crossing Name	Number of Structures at this Site	Shape of Structure	Slope (%)	Width (ft)	Height (ft)	Structure Material	Outlet Drop (ft)	Latitude	Longitude
South Cottonwood Creek	1	Box	0.14%	18.75	10.00	Concrete	0.00	-111.196	45.597
Big Bear Creek 1.0	1	Pipe_Arch,Open Bottom_Arch	2.19%	12.83	6.33	Annular_CMP	0.00	-111.204	45.556
Big Bear Creek 2.0 b	1 of 2	Pipe_Arch	1.08%	7.17	3.17	Concrete	0.00	-111.205	45.555
Big Bear Creek 2.0 a	2 of 2	Pipe_Arch	1.11%	7.33	4.17	Concrete	0.00	-111.205	45.555
Wilson Creek b	1 of 2	Pipe_Arch	0.85%	5.96	2.54	Concrete	0.00	-111.216	45.547
Wilson Creek a	2 of 2	Pipe_Arch	0.39%	4.92	2.58	Concrete	0.00	-111.216	45.547
Logger Creek	1	Box	2.84%	4.00	4.17	Concrete	2.50	-111.244	45.455
Hellroaring Creek	1	Circular	2.76%	11.50	13.40	Annular_CMP	1.00	-111.237	45.449

Crossing Name	Number of Structures at this Site	Shape of Structure	Slope (%)	Width (ft)	Height (ft)	Structure Material	Outlet Drop (ft)	Latitude	Longitude
Pioneer Lakes	1	Circular	6.58%	1.50	1.50	Annular_CMP	0.00	-111.199	45.390
Greek Creek	1	Pipe_Arch	7.57%	4.92	3.00	Concrete	0.00	-111.177	45.380
Moose Creek	1	Box	5.98%	8.00	6.00	Concrete	0.00	-111.172	45.352
Tamphery Creek	1	Circular	4.22%	3.00	3.00	Annular_CMP	0.00	-111.175	45.324
Portal Creek	1	Box	3.88%	18.00	8.17	Concrete	0.00	-111.186	45.317
Goose Creek	1	Circular	2.87%	3.00	3.00	Annular_CMP	0.00	-111.199	45.301
Beehive Basin Creek Upstream	1 of 2	Circular	5.62%	3.88	3.88	Annular_CMP	0.50	-111.387	45.290
Beehive Basin Creek 2	2 of 2	Circular	6.40%	6.17	6.17	Annular_CMP	0.00	-111.387	45.290
Dudley Creek	1	Box	8.91%	13.08	4.00	Concrete	0.00	-111.242	45.272
West Fork Gallatin River	1	Pipe_Arch	2.93%	15.50	10.50	Annular_CMP	0.00	-111.274	45.268
North Fork Gallatin River	1	Open_Bottom_Arch	2.71%	20.00	12.16	Annular_CMP	0.00	-111.321	45.268
Beaver Creek	1	Pipe_Arch	3.82%	11.25	7.42	Annular_CMP	0.00	-111.251	45.226
Corral Creek	1	Circular	0.67%	3.00	3.00	Annular_CMP	0.00	-111.238	45.194
Creek Across from Rainbow Ranch	1	Circular	1.22%	2.00	2.00	Annular_CMP	0.00	-111.238	45.193
Buck Creek b	1 of 2	Pipe_Arch	2.65%	8.42	6.17	Annular_CMP	0.67	-111.245	45.168
Buck Creek a	2 of 2	Pipe_Arch	0.76%	8.42	6.17	Annular_CMP	0.00	-111.245	45.168
Cinnamon Creek	1	Circular	2.85%	3.00	3.00	Annular_CMP	0.00	-111.225	45.113
Flints Creek (320 Ranch)	1	Circular	2.67%	2.58	2.58	Annular_CMP	0.00	-111.218	45.100
Sage Creek	1	Pipe_Arch	1.02%	13.00	7.25	Annular_CMP	0.00	-111.188	45.067
Snowflake Springs/Teepee Creek	1	Circular	2.65%	4.00	4.00	Annular_CMP	0.00	-111.168	45.062
Dailey Creek	1	Circular	1.40%	8.00	5.33	Annular_CMP	0.00	-111.140	45.048
Black Butte Creek	1	Circular	4.79%	4.00	4.00	Annular_CMP	0.00	-111.114	45.034
Wickup Creek	1	Circular	-3.78%	2.00	2.00	Annular_CMP	0.00	-111.091	45.020

Crossing Name	**Number of Structures at this Site**	**Shape of Structure**	**Slope (%)**	**Width (ft)**	**Height (ft)**	**Structure Material**	**Outlet Drop (ft)**	**Latitude**	**Longitude**
Terminal Monument Creek	1	Circular	0.44%	4.00	7.75	Annular_CMP	0.00	-111.079	44.986
Wetland #1	1	Circular	0.15%	2.67	1.83	Annular_CMP	0.00	-111.079	44.981
Wetland #2	1	Circular	1.26%	3.00	2.75	Annular_CMP	0.00	-111.079	44.978
Bacon Rind Creek	1	Circular	0.67%	11.60	12.16	Annular_CMP	0.00	-111.067	44.958
Tributary 1 of Grayling Creek	1	Circular	1.11%	6.92	7.00	Annular_CMP	0.50	-111.054	44.894
Tributary 2 to Grayling Creek	1	Circular	5.79%	2.00	2.00	Annular_CMP	1.00	-111.054	44.887
Grayling Creek 1c	1 of 3	Pipe_Arch	-0.13%	10.00	7.00	Annular_CMP	0.00	-111.022	44.882
Grayling Creek 1b	2 of 3	Pipe_Arch	-0.06%	10.00	7.00	Annular_CMP	0.00	-111.045	44.872
Grayling Creek 1a	3 of 3	Pipe_Arch	0.24%	7.00	10.00	Annular_CMP	0.00	-111.045	44.872
Tributary 3 to Grayling Creek	1	Circular	0.24%	3.00	1.00	Annular_CMP	0.00	-111.047	44.862
Grayling Creek 2b	1 of 3	Pipe_Arch	0.66%	10.00	7.00	Annular_CMP	0.17	-111.054	44.857
Grayling Creek 2c	2 of 3	Pipe_Arch	0.37%	10.00	7.00	Annular_CMP	0.33	-111.054	44.857
Grayling Creek 2a	3 of 3	Pipe_Arch	0.72%	10.00	7.00	Annular_CMP	0.08	-111.054	44.857
Grayling Creek 3b	1 of 3	Pipe_Arch	0.95%	10.00	7.00	Annular_CMP	0.00	-111.058	44.855
Grayling Creek 3a	2 of 3	Pipe_Arch	0.29%	10.00	7.00	Annular_CMP	0.00	-111.058	44.855
Grayling Creek 3c	3 of 3	Pipe_Arch	0.31%	10.00	7.00	Annular_CMP	0.00	-111.058	44.855
Grayling Creek 4a	1 of 3	Pipe_Arch	0.67%	10.00	6.75	Annular_CMP	0.00	-111.063	44.853
Grayling Creek 4b	2 of 3	Pipe_Arch	1.25%	10.00	6.75	Annular_CMP	0.67	-111.063	44.853
Grayling Creek 4c	3 of 3	Pipe_Arch	0.85%	10.00	6.75	Annular_CMP	0.00	-111.062	44.853
Teepee Creek a	1 of 2	Pipe_Arch	1.77%	11.75	7.71	Annular_CMP	1.17	-111.095	44.810

Crossing Name	Number of Structures at this Site	Shape of Structure	Slope (%)	Width (ft)	Height (ft)	Structure Material	Outlet Drop (ft)	Latitude	Longitude
Teepee Creek b	2 of 2	Pipe_Arch	1.53%	11.42	7.75	Annular_CMP	0.67	-111.095	44.810
Duck Creek	1	Pipe_Arch	1.47%	15.25	9.13	Annular_CMP	0.00	-111.113	44.780

Table Note: “Annular CMP” refers to a corrugated metal pipe (CMP) with annular (circular) corrugations.

Four different culvert types were identified: (1) pipe arch, (2) circular, (3) box, and (4) open bottom arch. Figure 38 includes a pie chart summarizing the number of structures by culvert type. The dominant culvert types were pipe arch at 25 and circular at 21, respectively. Pipe slopes ranged from adverse (negative) slopes up to approximately 0.1 ft/ft (or 10%). Figure 39 highlights the number of culverts in each slope range and the cumulative frequency distribution. The majority of culverts (n=29) had slopes ranging between 0.0 and 0.02 ft/ft (or 2%). Twelve of 53 structures had outlet drops ranging from 0.08 ft to a maximum of 2.5 ft. Figure 40 presents the number of culverts in each outlet drop range and the cumulative frequency distribution.

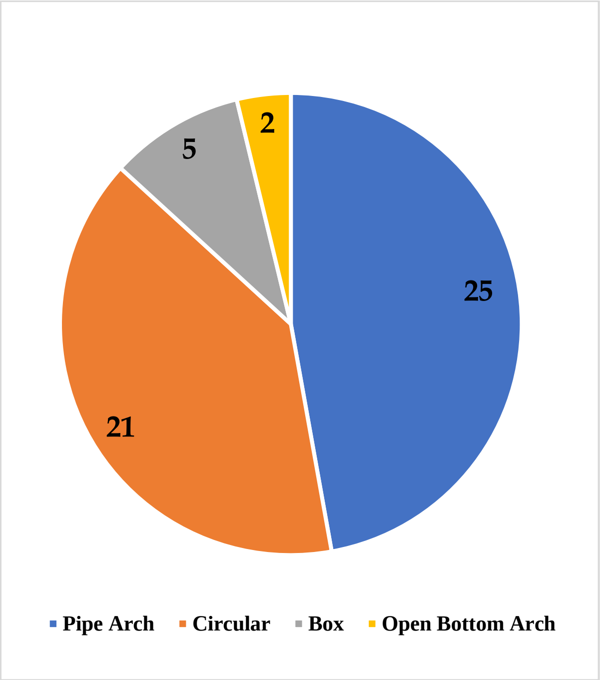


Figure 38 Aquatic Passage Assessment: Pie Chart Showing the Number of Culverts by Type

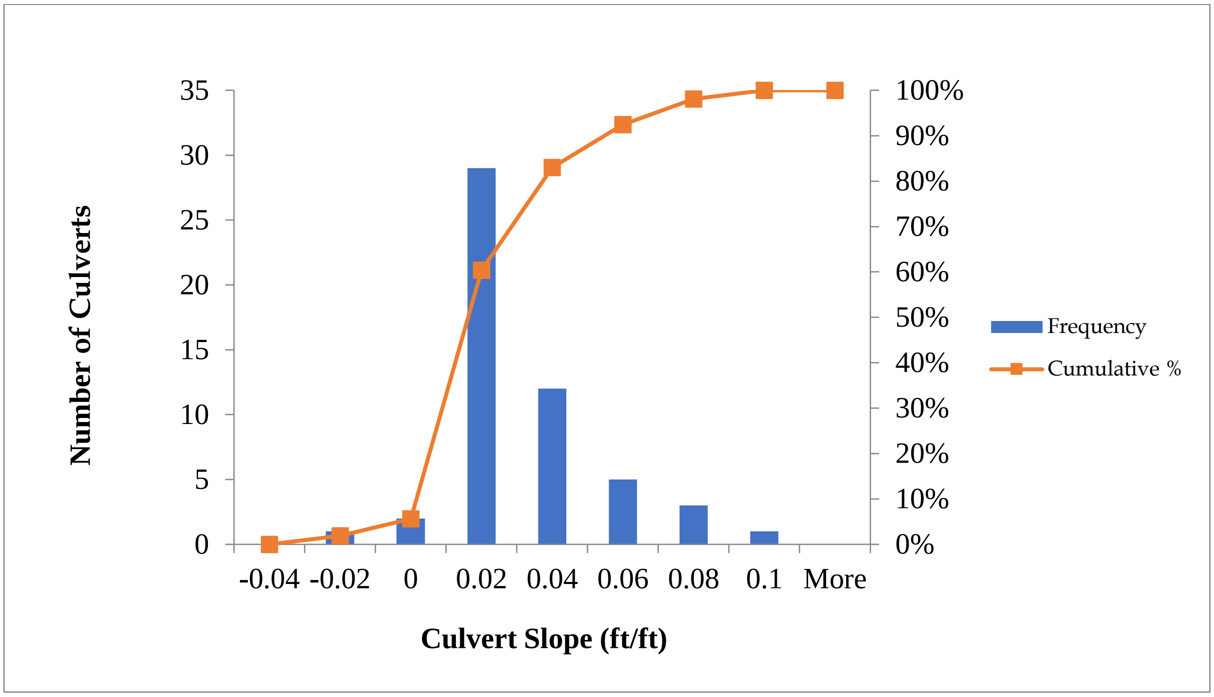


Figure 39 Aquatic Passage Assessment: Cumulative Frequency and Histogram of Culvert Slope

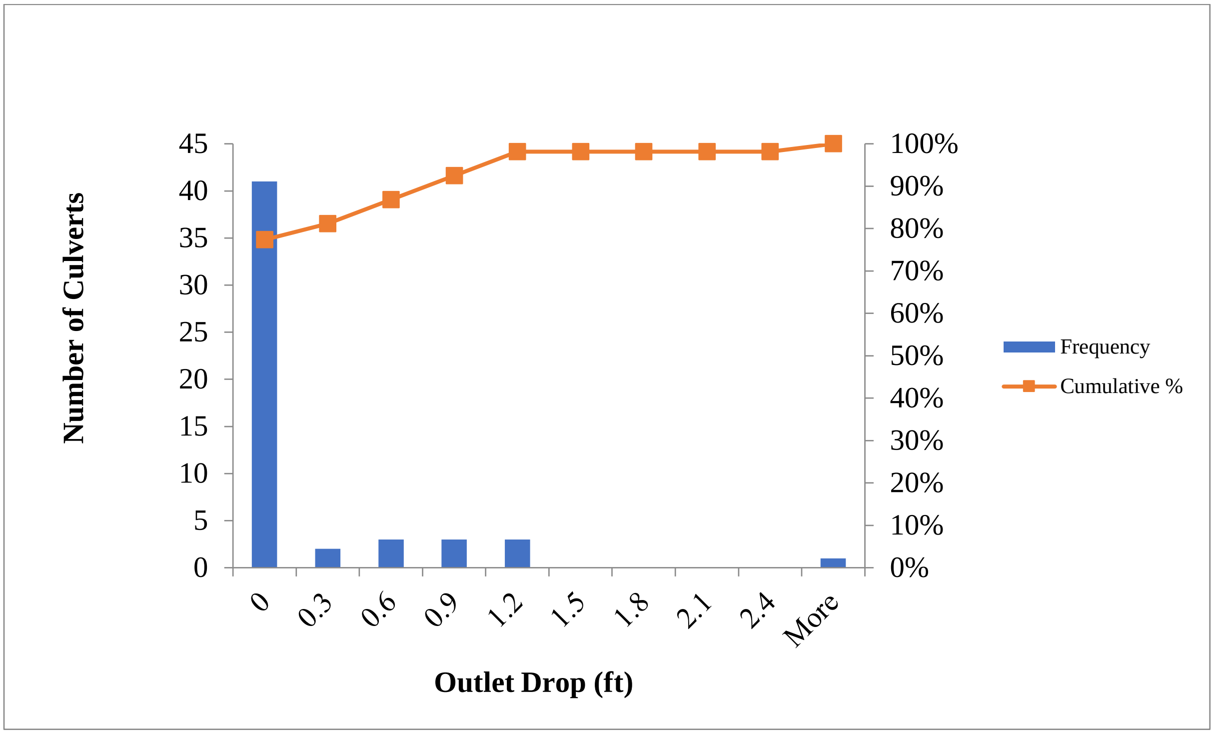


Figure 40 Aquatic Passage Assessment: Cumulative Frequency and Histogram of Outlet Drop

There were 13 bridges within the study area. Bridges were not assessed for fish passage as they are assumed to provide unimpeded passage to resident fish at all flows.

9.3.2. Initial Passage Assessment

Table 41 provides a summary of the initial passage assessment of road-stream crossings along the study corridor and Figure 41 provides a map of the crossing locations and their passage assessment. In addition, bridges are also identified in addition to the culverts.

Of the total structures, thirty ranked as green, which implies conditions are adequate for the upstream passage of fish. Many of the green structures had substrate throughout, a natural channel bottom, or gentle slopes of less than 1.0%. Six of the culverts ranked as gray, meaning conditions may or may not be adequate for upstream passage of fish. A gray ranking does not necessarily mean the culvert is creating passage issues but should be viewed as a structure that may necessitate further evaluation. Lastly, 17 culverts ranked as red, indicating conditions may not be adequate for fish passage, and further evaluation should be considered. The numbers in the "ID for Map" column of the table correspond to the numbers on Figure 41.

Table 41 Aquatic Passage Assessment: Summary of Initial Passage Assessment at Each Crossing

Crossing Name	**ID for Map**	**Slope (S)**	**Outlet Drop (O)**	**Continuous Substrate (Sub.) in Structure?** **Yes (Y) or No (N)**	**Passage Assessment Rank: Green, Gray, or Red** **Reason: Slope (S), Outlet Drop (O), or Substrate (Sub.)**
		%	ft		
South Cottonwood Creek	1	0.14%	0.00	Y	🟩
Big Bear Creek 1.0	2	2.19%	0.00	Y	🟩
Big Bear Creek 2.0 b	3	1.08%	0.00	Y	🟩
Big Bear Creek 2.0 a	4	1.11%	0.00	Y	🟩
Wilson Creek b	5	0.85%	0.00	Y	🟩
Wilson Creek a	6	0.39%	0.00	Y	🟩
Logger Creek	7	2.84%	2.50	N	🟥 S, O
Hellroaring Creek	8	2.76%	1.00	N	🟥 S, O
Pioneer Lakes	9	6.58%	0.00	N	🟥 S
Greek Creek	10	7.57%	0.00	N	🟥 S
Moose Creek	11	5.98%	0.00	N	🟥 S
Tamphery Creek	12	4.22%	0.00	N	🟥 S

Crossing Name	ID for Map	Slope (S)	Outlet Drop (O)	Continuous Substrate (Sub.) in Structure? Yes (Y) or No (N)	Passage Assessment Rank: Green, Gray, or Red Reason: Slope (S), Outlet Drop (O), or Substrate (Sub.)
Portal Creek	13	3.88%	0.00	Y	🟩
Goose Creek	14	2.87%	0.00	Y	🟩
Beehive Basin Creek Upstream	15	5.62%	0.50	N	🟥 S, O
Beehive Basin Creek 2	16	6.40%	0.00	N	🟥 S
Dudley Creek	17	8.91%	0.00	N	🟥 S
West Fork Gallatin River	18	2.93%	0.00	N	▨ S
North Fork Gallatin River	19	2.71%	0.00	Y	🟩
Beaver Creek	20	3.82%	0.00	N	🟥 S
Corral Creek	21	0.67%	0.00	Y	🟩
Creek Across from Rainbow Ranch	22	1.22%	0.00	N	▨ S
Buck Creek b	23	2.65%	0.67	N	🟥 S, O
Buck Creek a	24	0.76%	0.00	N	🟩
Cinnamon Creek	25	2.85%	0.00	N	▨ S
Flints Creek (320 Ranch)	26	2.67%	0.00	N	▨ S
Sage Creek	27	1.02%	0.00	Y	🟩
Snowflake Springs/Teepee Creek	28	2.65%	0.00	N	▨ S
Dailey Creek	29	1.40%	0.00	Y	🟩
Black Butte Creek	30	4.79%	0.00	N	🟥 S
Wickup Creek	31	-3.78%	0.00	N	🟩
Terminal Monument Creek	32	0.44%	0.00	N	🟩

Crossing Name	ID for Map	Slope (S)	Outlet Drop (O)	Continuous Substrate (Sub.) in Structure? Yes (Y) or No (N)	Passage Assessment Rank: Green, Gray, or Red Reason: Slope (S), Outlet Drop (O), or Substrate (Sub.)
Wetland #1	33	0.15%	0.00	Y	🟩
Wetland #2	34	1.26%	0.00	Y	🟩
Bacon Rind Creek	35	0.67%	0.00	Y	🟩
Tributary 1 of Grayling Creek	36	1.11%	0.50	N	🟥 S, O
Tributary 2 to Grayling Creek	37	5.79%	1.00	N	🟥 S, O
Grayling Creek 1c	38	-0.13%	0.00	N	🟩
Grayling Creek 1b	39	-0.06%	0.00	N	🟩
Grayling Creek 1a	40	0.24%	0.00	N	🟩
Tributary 3 to Grayling Creek	41	0.24%	0.00	Y	🟩
Grayling Creek 2b	42	0.66%	0.17	N	🟩
Grayling Creek 2c	43	0.37%	0.33	N	🟩
Grayling Creek 2a	44	0.72%	0.08	N	🟩
Grayling Creek 3b	45	0.95%	0.00	N	🟩
Grayling Creek 3a	46	0.29%	0.00	N	🟩
Grayling Creek 3c	47	0.31%	0.00	N	🟩
Grayling Creek 4a	48	0.67%	0.00	N	🟩
Grayling Creek 4b	49	1.25%	0.67	N	🟥 S, O
Grayling Creek 4c	50	0.85%	0.00	N	🟩
Teepee Creek a	51	1.77%	1.17	N	🟥 S, O
Teepee Creek b	52	1.53%	0.67	N	🟥 S, O
Duck Creek	53	1.47%	0.00	N	▨ S

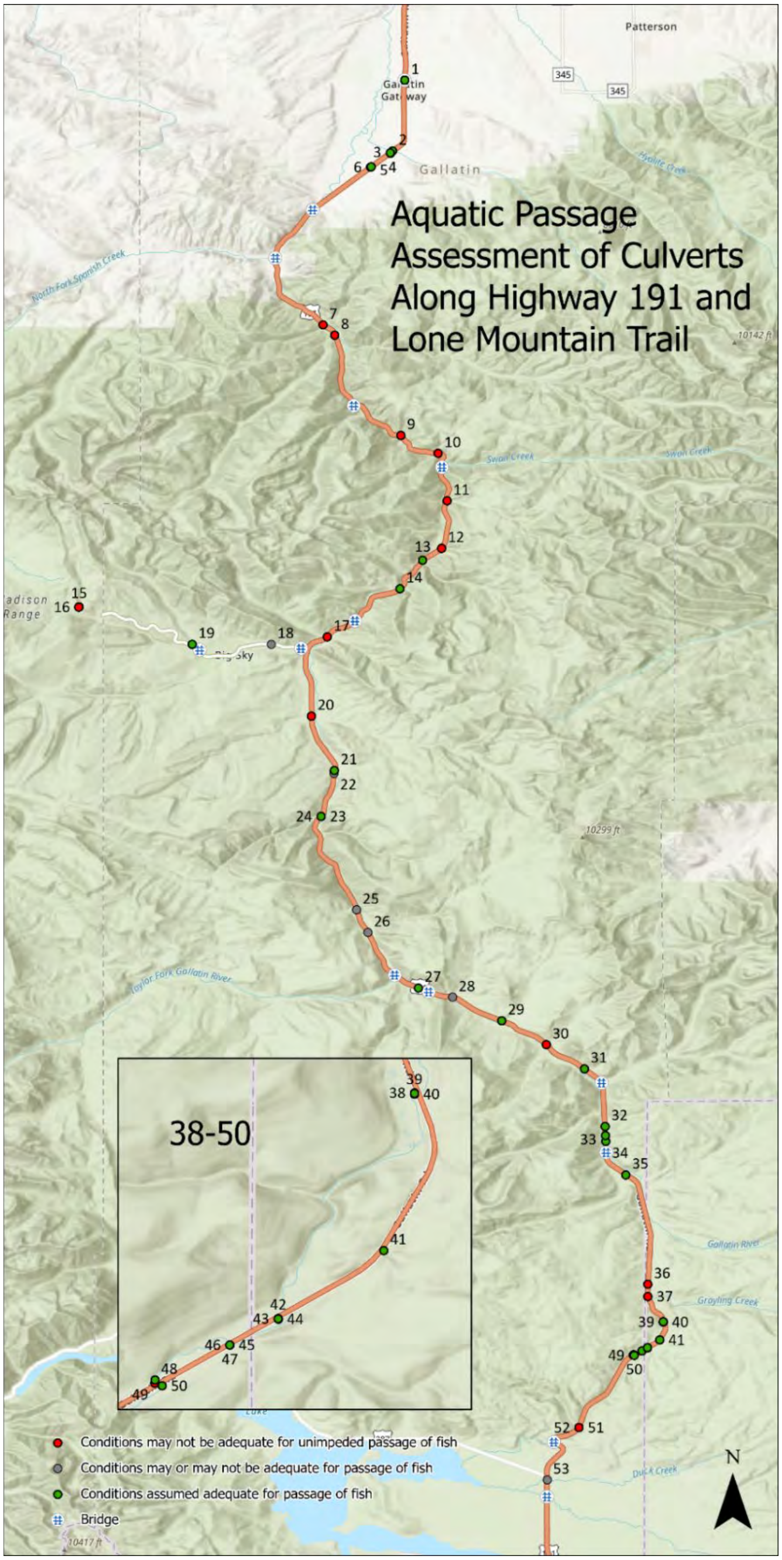


Figure 41 Aquatic Passage Assessment of Culverts Along US-191 and MT-64

Figure 42 shows three photos that are representative of the three possible passage rankings: “green,” “gray,” and “red”:

- The left photo shows a “green” culvert, which indicates conditions are adequate for fish passage. This is because the continuous substrate throughout the structure mimics natural channel conditions. The substrate provides a range of different water depths and velocities, in addition to interstitial areas, for both large and small fish to move upstream through the structure as well as to rest or hide within it.
- The middle photo shows a “gray” culvert, which indicates conditions may or may not provide adequate passage of fish. Potential passage issues are due to the culvert restricting channel flow (i.e., the culvert width is less than the stream channel width; this is often referred to as a “constriction ratio”), and there is an outlet drop.
- The right photo shows a “red” culvert, which indicates conditions may not be adequate for unimpeded passage. The culvert creates shallow water depths and high velocity because it is set at a steep slope and may be undersized.

Figure 42 Aquatic Passage Assessment: Images of a “Green” Crossing (left), a “Gray” Crossing (middle), and a “Red” Crossing (right)

9.4. Recommendations

These recommendations describe general mitigation strategies for improving aquatic connectivity and include information on the benefits of larger structures for resiliency to climate change. They also summarize possible next steps to implement in order to improve aquatic connectivity along US-191.

9.4.1. Mitigation for Aquatic Connectivity

From the standpoint of aquatic species, the goal of a new crossing should be to ensure passable conditions are maintained throughout the engineering life of a crossing. This goal implies that “best” approaches are crossings that prevent passage problems—such as outlet drops or elevated velocities—from developing once a crossing is in operation. In some cases, passage problems are created when crossings restrict or impede natural channel function or stream continuity, which then degrades the stream channel bed near them. Or in other cases, crossings that are undersized or set on a shallower slope than the natural stream slope may promote the aggradation of sediment and/or woody debris and create a damming effect on the upstream end of the crossing. This situation may not only reduce passage but can also create conditions that result in a structure failing.

There are a range of options available for the design and construction of road-stream crossings specifically for aquatic organism passage and many good design manuals such as the FHWA document: *HEC 26 - Culvert Design for Aquatic Organism Passage*, the USDA manual *Stream Simulations: An Ecological Approach to Providing Passage for Aquatic Organisms at Road-Stream Crossings*, and state guidance like the Washington Department of Fish and Wildlife design manual: *Water Crossing Design Guidelines (2013)*. When possible, using bridges that are wide enough to allow for full floodplain function through them allows for the natural function of the stream or river and riparian area. Figure 43 is an illustration, taken from Huijser et al. 2018, of a bridge spanning a high-gradient mountain stream similar to those in the Gallatin River corridor (Huijser et al. 2018). These types of structures can also provide connectivity for both terrestrial and aquatic species. However, bridges are typically a more expensive option for road-stream crossings, which in some cases makes them infeasible.

Figure 43 Aquatic Passage Assessment: illustration of a bridge spanning a mountain stream

Other types of smaller crossing structures that fully span a stream or river and its banks provide the next-best solution to ensure long-term passage of fish and aquatic species and are typically less expensive than bridges (USDA National Technology Development Program 2008). The stream-simulation approach relies upon the following basic principle:

> "…designing crossing structures (usually culverts) that create a structure that is as similar as possible to the natural channel. When channel dimensions, slope, and stream bed structure are similar between the crossing and the natural channel, water velocities and depths will also be similar. Thus, the simulated channel should present no more of an obstacle to aquatic animals than the natural channel (USDA National Technology Development Program 2008).
>
> Stream-simulation culverts can be designed and constructed using a variety of different culvert types and shapes, including round, bottomless arches, box, and squash (or elliptical) shapes, amongst others (USDA National Technology Development Program 2008; Barnard et al. 2015). In addition, these designs can utilize single channel and additional structures to convey higher flows that activate side-channels or floodplain areas."

Recent studies investigated the effects of "stream simulation" on aquatic species movement, habitat, and channel form. In Alaska, crossings on a salmon stream in Anchorage were replaced with new crossings designed to mimic natural channel conditions. The study used a pre-post monitoring scheme to evaluate the response of salmon in the system to the new crossings. Monitoring showed a 300% increase in coho salmon escapement from pre-restoration to post-restoration conditions, i.e., from 481 adults in 2008 to approximately 1,500 adults on average, 2009-2013 (Myers and Nieraeth 2016). A study in Washington State evaluated 50 culverts designed following stream-simulation approaches by comparing channel bed and hydraulic conditions between culvert (treatment) reach and reference reaches. Sediment size and gradation, the velocity at the 2-year recurrence interval (RI) flow, and flow widths (i.e., the width of water at the surface) during the 2-year RI flow were similar in both the culvert and reference reaches. The culvert reaches, however, were not as likely to maintain channel complexity due to the difficulty of accommodating natural channel-forming features (such as woody debris or vegetative processes) within them. The stream-simulation culverts did not deteriorate from large flood events observed during the study, implying that such an approach maintains flood resiliency (Barnard et al. 2015).

9.4.2. Other Benefits to Large Structures (Resilience to Climate Change)

Designing larger spans to better accommodate stream and floodplain function, along with fish and wildlife passage, makes a crossing more resilient to future large flood events. One of the most promising mitigation techniques for aquatic species under changing climates is to increase habitat connectivity (Lawler et al. 2009). Climate forecasts for the Greater Yellowstone Region indicate a shift towards higher temperatures, which could result in more precipitation as rain instead of snow and changes to the amount and timing of spring runoff (National Park Service 2022). Based on the last 50 years of recorded climate data in Yellowstone National Park, there are 80 more days with above-freezing temperatures at the northeast entrance and approximately 30 fewer days per year with snow on the ground than in the 1960s.

Road crossing design requires the estimation of a flood flow to determine the size of crossing structures and road surface elevations, amongst other road features. In the United States, the design flood flow for many smaller county roads is the 50-year recurrence interval (RI) flood; for interstates and larger state highways, the design flood flow is often the 100-year flood flow. This value is typically determined based on empirical data from the past climate record using either records of gaged data or regional regression equations. With changing climates affecting future flood size and frequency, some countries have already begun to change their design flood RI, or their road design practices, based upon how the future climate may look versus relying upon past climate records. For example, the Norwegian Public Roads Administration is requiring design elevation for road surfaces based on a 200-year RI.

Recent historic flooding in Yellowstone National Park and surrounding areas highlights the need to build new highway infrastructure that will be resilient to large flow events. Figure 44 shows the hydrograph for the Gardner River (USGS gage #06191000) near Gardiner, Montana, and the Yellowstone River at Corwin Springs (USGS gage #06191500) downstream of Gardiner. The 2022 flood event was caused by a combination of excessive rainfall on top of a wet snowpack. Natural Resources Conservation Service SNOTEL sites in the area recorded up to 8.7 inches of combined rainfall and snow water equivalent (SWE) leading up to this flood. From June 10-13, 2022, the Fisher Creek gage station in the North Beartooth Wilderness recorded 5.1 inches of rain and 3.6 inches of SWE melt. Katherine Chase, a hydrologist with the United States Geological Survey, stated in *The Livingston Enterprise (Jun 18, 2022)* that the flood peak in the Yellowstone River near Livingston, about 50 miles downstream of Gardiner, was a 1 in 500-year event or larger. A 1 in 500-year event has a 0.2% chance of occurring every year.

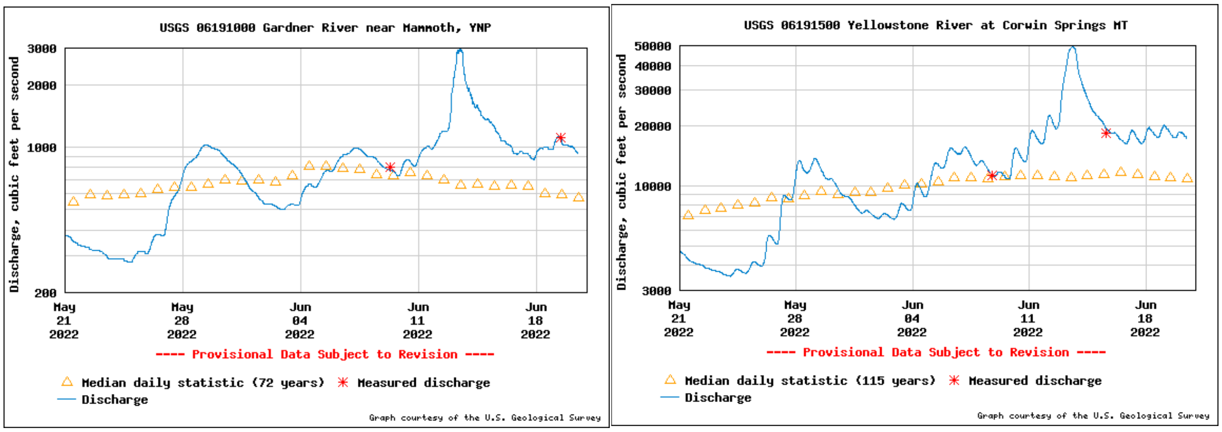


Figure 44 Aquatic Passage Assessment: Hydrographs for the Gardner River and Yellowstone River at Corwin Springs showing the June 13/June 14, 2022, historic flood event

9.4.3. Possible Next Steps

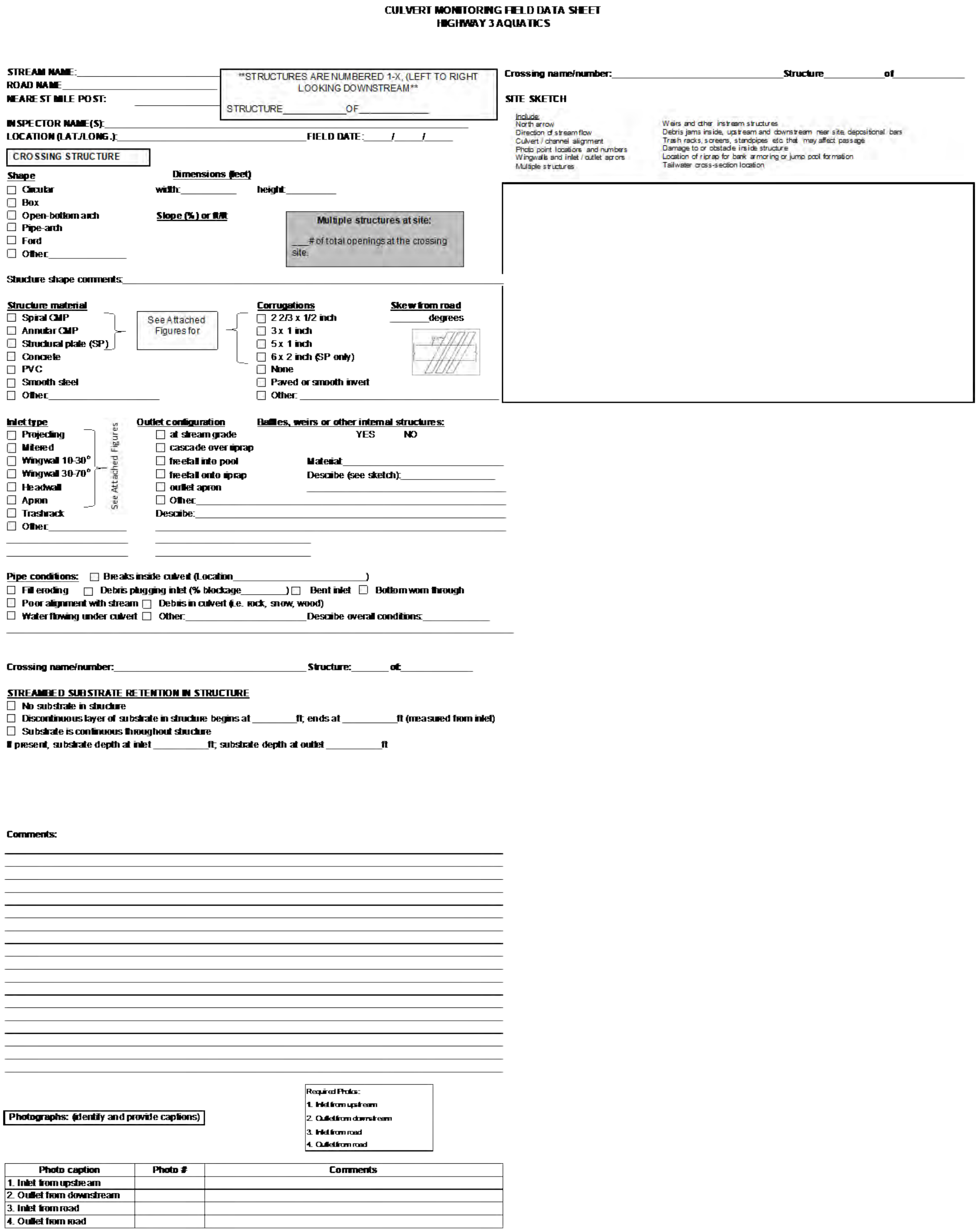
Possible next steps are described below.

- Confirm the presence of fish species in crossings assessed as gray or red prior to initiating mitigation. Stream habitat upstream of each crossing should be evaluated to determine if natural barriers exist. Natural barriers close to a culvert may make re-construction of a crossing a poor investment should habitat be limited regardless of the degree of passage through the crossing.
- Carry out additional evaluation at sites identified as red or gray to better understand the degree to which passage may be limited. In some cases, the culverts may already provide sufficient passage without significant impact on fish species. One option for red and grey sites would be to perform a more detailed hydraulic analysis as a relatively easy and cost-effective way to gauge what flows and how often a structure might be limiting upstream passage.
- Design new structures following the approaches identified in section 9.4.1 as possible when sections of US-191 or MT-64 are upgraded.

- Evaluate aquatic passage for species other than fish. This study focused on fish passage; other aquatic species and semi-aquatic species would also benefit from improved connectivity along US-191 and MT-64.
- Consult with Montana Fish, Wildlife and Parks, the US Forest Service (USFS), and the National Park Service to identify opportunities to protect native species. In some cases, such as streams with pure cutthroat populations in upper reaches or headwaters, it may be desirable to leave a barrier culvert in place or to design the new crossing as a complete barrier to protect native species. For example, Figure 45, below, shows a culvert designed as an intentional barrier to protect Westslope cutthroat trout on a USFS road over Leverich Creek, south of Bozeman.

Figure 45 Aquatic Passage Assessment: The picture shows a culvert designed as a fish barrier

9.5. Sample Culvert Data Collection Sheet



CULVERT MONITORING FIELD DATA SHEET
HIGHWAY 3 AQUATICS

STREAM NAME:______________________
ROAD NAME______________________
NEAREST MILE POST: ______________

STRUCTURES ARE NUMBERED 1-X, (LEFT TO RIGHT LOOKING DOWNSTREAM)
STRUCTURE__________OF__________

INSPECTOR NAME(S):______________________________
LOCATION (LAT./LONG.):______________________ **FIELD DATE:**_____/_____/_____

Crossing name/number:______________________ **Structure**__________ **of**__________

SITE SKETCH

Include:
North arrow
Direction of stream flow
Culvert / channel alignment
Photo point locations and numbers
Wingwalls and inlet / outlet aprons
Multiple structures
Weirs and other instream structures
Debris jams inside, upstream and downstream near site, depositional bars
Trash racks, screens, standpipes etc that may affect passage
Damage to or obstacle inside structure
Location of riprap for bank armoring or jump pool formation
Tailwater cross-section location

CROSSING STRUCTURE

Shape
☐ Circular
☐ Box
☐ Open-bottom arch
☐ Pipe-arch
☐ Ford
☐ Other_______________

Dimensions (feet)
width:__________ height:__________

Slope (%) or ft/ft

Multiple structures at site:
___# of total openings at the crossing site.

Structure shape comments:______________________________

Structure material
☐ Spiral CMP
☐ Annular CMP
☐ Structural plate (SP)
☐ Concrete
☐ PVC
☐ Smooth steel
☐ Other_______________

See Attached Figures for

Corrugations
☐ 2 2/3 x 1/2 inch
☐ 3 x 1 inch
☐ 5 x 1 inch
☐ 6 x 2 inch (SP only)
☐ None
☐ Paved or smooth invert
☐ Other: _______________

Skew from road
_______degrees

Inlet type
☐ Projecting
☐ Mitered
☐ Wingwall 10-30°
☐ Wingwall 30-70°
☐ Headwall
☐ Apron
☐ Trashrack
☐ Other_______________

See Attached Figures

Outlet configuration
☐ at stream grade
☐ cascade over riprap
☐ freefall into pool
☐ freefall onto riprap
☐ outlet apron
☐ Other:_______________
Describe:_______________

Baffles, weirs or other internal structures:
YES NO
Material:_______________
Describe (see sketch):_______________

Pipe conditions: ☐ Breaks inside culvert (Location_______________)
☐ Fill eroding ☐ Debris plugging inlet (% blockage_______) ☐ Bent inlet ☐ Bottom worn through
☐ Poor alignment with stream ☐ Debris in culvert (i.e. rock, snow, wood)
☐ Water flowing under culvert ☐ Other:_______________ Describe overall conditions:__________

Crossing name/number:______________________ **Structure:**_______ **of:**__________

STREAMBED SUBSTRATE RETENTION IN STRUCTURE
☐ No substrate in structure
☐ Discontinuous layer of substrate in structure begins at _______ft; ends at _______ft (measured from inlet)
☐ Substrate is continuous throughout structure
If present, substrate depth at inlet _______ft; substrate depth at outlet _______ft

Comments:

Photographs: (identify and provide captions)

Required Photos:
1. Inlet from upstream
2. Outlet from downstream
3. Inlet from road
4. Outlet from road

Photo caption	Photo #	Comments
1. Inlet from upstream		
2. Outlet from downstream		
3. Inlet from road		
4. Outlet from road		

10. Spatio-temporal Hotspot Analysis

10.1. Background

The following theoretical analysis based on crash and carcass data is included in this report to test the validity of using various lengths of data sets (3, 5, and 10 years) to identify locations for prospective wildlife mitigation measures. It uses US-191 as a case study. The results are not intended as guidance in the same manner as in other sections of this Assessment. Rather, this analysis provides additional information to further substantiate best practices for preparing wildlife and transportation assessments as part of an ongoing research program of MSU-Western Transportation Institute (WTI) and the Small Urban and Rural Transportation Center on Mobility (SURTCOM). This analysis adds to the body of road ecology knowledge drawn upon to prepare the US-191/MT-64 Wildlife & Transportation Assessment and provides additional insight into best practices in the field.

Many transportation agencies use wildlife-vehicle collision (WVC) crash and carcass data for planning and project development under the Federal Highway Administration's (FHWA's) Highway Safety Improvement Program as well as other federal and state highway programs. Working with WVC data can be challenging because it is often not systematically collected and has been susceptible to under-reporting (Bíl et al. 2019; Donaldson 2017). The difference between the number of reported crash and carcass locations for the same section of road demonstrates the variability between these two types of WVC data and highlights the importance of robust mechanisms to predict high-risk locations (Creech, McClure, and Callahan 2016; Wang et al. 2010). The two types of WVC data also produce data sets with different strengths. Carcass data can be better for identifying animal characteristics (e.g., species, sex, age), while crashes reported by law enforcement can capture collision scenarios more accurately (e.g., weather, time, day, and driver characteristics). The spatial accuracy of WVC locations also varies greatly depending on the methods used by the individuals collecting and reporting data and the resources they have available (Creech et al. 2019).

There are different WVC analysis methods that researchers generally agree upon, and many continue to develop innovative methods to increase the accuracy of models (Creech et al. 2019). Something that does not appear to be agreed upon is the amount of data required to get accurate results (Hou, Huo, and Leng 2020; Santos et al. 2017). WVC data sets are highly variable in both the amount and the types of information collected. Some published results are based on analyses that use as little as three years of data (Favilli et al. 2018), while others take advantage of more than 20 years of data (L. McDonald, Messmer, and Guttery 2019). Most studies, regardless of the cumulative years of data used, identify patterns and landscape characteristics associated with road segments with high rates of WVCs. Such locations are often referred to as "hot spots." Most models evaluate WVCs and their associated variables over the longest time frame that data has been consistently collected. Rarely do models evaluate subsets of data for shorter time frames to determine a data set's variability over time or to identify changes in the locations of hot spots over time. Thus, variations in hot spot locations over time and environmental factors that are temporal are often masked in the longer-term data sets.

This analysis aims to explore WVC data sets to determine if WVC hotspots are highly variable or temporally invariant for the same road segments based on the number of years of crash and carcass data incorporated into analyses. This question has important consequences for transportation agency investment in mitigation measures, such as the siting of wildlife overpasses and underpasses with life expectancies of 50 to 100 years. If hotspot locations migrate over time, and the magnitude of the change in distance of a hotspot location exceeds the spatial extent of crossing structures and associated wildlife fencing, the long-term effectiveness of mitigation measures could potentially be greatly diminished. Ultimately, mitigation efforts are based on the number of years of WVC data used and when an analysis is conducted. Results may vary if an agency uses five years of data in 2012 compared to the same number of years of data in

2017. Hotspot locations may change between the time of an initial analysis and when the installation of mitigation elements may be completed. This analysis evaluates and compares multiple scenarios using different types (e.g., crash and carcass) and amounts (e.g., number of years) of data analyzed over time.

10.2. Case Study Framework

Identifying the amount and type of WVC data required to conduct a hotspot analysis is a complex problem. Numerous approaches exist to compare the different amounts of data used in a specific analysis and resulting hotspots. For this reason, we developed a case study to examine results based on actual mitigation practices, using US-191 as an example. The intent of this case study is to decipher the degree to which initial mitigation efforts capture WVC hotspots compared to a future period when new crash and carcass data are available.

Three "year-groups" (i.e., 3, 5, and 10 years) of data were compared during the period from 2008 to 2020. Initial analyses were conducted to identify significant WVC hotspot locations along US-191 for each 3-, 5-, and 10-year group. The initial hotspot analysis for the 3-year group is based on the years 2008-2010, the initial 5-year analysis is based on the years 2008-2012, and the initial 10-year analysis is based on the years 2008-2017. We assumed the top ten hotspot locations identified in the initial analyses would be mitigated to reduce WVCs. To simplify, we focused on fencing practices as a mitigation measure and assumed 1.86 mi (3 km) of fencing would be installed in each direction in addition to the 0.62 mi (1 km) road segment with the identified hotspot (Huijser et al. 2015). Therefore, if a hotspot in a future analysis was identified within 1.86 mi (3 km) of an initial hotspot, it was assumed to be captured by the initial mitigation effort. A threshold of 80% similarity was used to assess whether the year-group comparisons were similar or different. A hotspot analysis was conducted in each following year to see how hotspots move based upon when an analysis was conducted. The average of each year group of data analyzed was used to determine how well subsequent years compared with the initial year examined.

10.3. Methods

We obtained 13 years (2008-2020) of WVC data crash and carcass data along US-191 from Four Corners to West Yellowstone. Crash data was obtained from the Montana Highway Patrol (MHP) and included all records involving collisions with animals resulting in a human injury or fatality or where property damage exceeds $1,000 (Montana Uniform Accident Reporting Act, Section 61-7-109). Only reported crashes where a collision with an animal was identified as the first harmful event were included in the data analyzed. Crash data are less spatially biased than carcass data because MHP responds to a collision regardless of location, which is recorded with GPS accuracy. Carcass data were obtained from the Montana Department of Transportation (MDT) and include all carcass locations picked up by MDT maintenance staff, US Forest Service (USFS), Montana Fish, Wildlife and Parks (FWP), or other local agencies, and are recorded to the nearest tenth-mile. All state roads are not surveyed equally, with bias to roads that are monitored more frequently. US-191 may show some bias in some locations due to the multiple agencies that collect carcasses and some areas not conducive to locating carcasses (e.g., thick vegetation, steep embankments, seasonal weather, etc.). This fact may cause issues in comparing analyses statewide and even along US-191, even though carcass data is abundant. Such inconsistencies within data sets should be considered when interpreting the results of any WVC analysis. For both crash and carcass data sets, all domestic (e.g., livestock, horses, dogs, sheep, etc.) and small animals (e.g., coyote, bobcat, badger, beaver, etc.) were removed so that data sets analyzed only include larger-bodied wildlife.

To understand the amount of WVC data required to capture the hotspots along a road, we adapted a nonparametric Monte Carlo approach to compare two point-location data sets to see how they proportionately differ from each other (Andresen 2009; Creech et al. 2019). This is a practical approach to compare two data sets where there are large differences between the groups. Following Creech et al. (2019), we: (1) assigned a year group as the reference data and calculated the proportion of WVCs observed in each 0.62 mi (1 km) road segment along the US-191 study area; (2) randomly selected 85% of test data for 1,000 simulations; (3) calculated the percentage of WVCs within each km road segment for each of the random samples; (4) calculated a 95% confidence interval for each of the km road segments from the test data; (5) identified if the reference data set proportions were within a 95% confidence interval for each road segment created from the test data. All statistical analyses were performed using R version 4.2.1.

To identify and compare WVC hotspots along US-191, we used a KDE+ clustering method (Bíl, Andrášik, and Janoška, 2013). This clustering analysis is commonly used in transportation hotspot identification analyses (Bíl et al. 2019; Favilli et al. 2018; Andrášik and Bíl 2015). The KDE+ is based on the Kernel Density Estimate (KDE), which estimates the expected density of the input data. It uses Monte Carlo simulations to identify only statistically significant clusters and ranks them based on cluster strength (Bíl, Andrášik, and Janoška 2013). This hotspot identification method is applicable to this analysis because the cluster strength is based on the total number of collisions (i.e., crash or carcass) that happen along a road segment and can identify locations along the roadway with the highest probability of collisions regardless of the number of collisions along a roadway. The results from the hotspot analysis were overlaid upon 0.62 mi (1 km) road segments to compare differences along US-191.

The same US-191 study area analyzed throughout this report was divided into 132 segments, with the first segment located in West Yellowstone and the 132nd segment ending at Four Corners. The KDE+ analyses were performed using the KDE+ toolbox version 3.3 for ArcGIS Desktop version 10.8 using a bandwidth of 150 with 800 Monte Carlo simulations per analysis.

10.4. Results

The two WVC data sets were subset to include only records within 328 ft (100 m) of US-191 from West Yellowstone in the south to Four Corners in the north. Crash data contained 451 collision locations, while the carcass data had 1,685 locations (Figure 46). It is a common trend across the entire state of Montana to have more carcass data than crash data along a road segment. There is a decreasing trend in the number of carcasses along US-191 over the 13-year period examined, while the opposite, a slight upward trend, exists for the crash data. Both data sets show a large decrease in the number of collisions in 2020, which is likely influenced by the COVID-19 pandemic shutdown and lower traffic volume numbers.

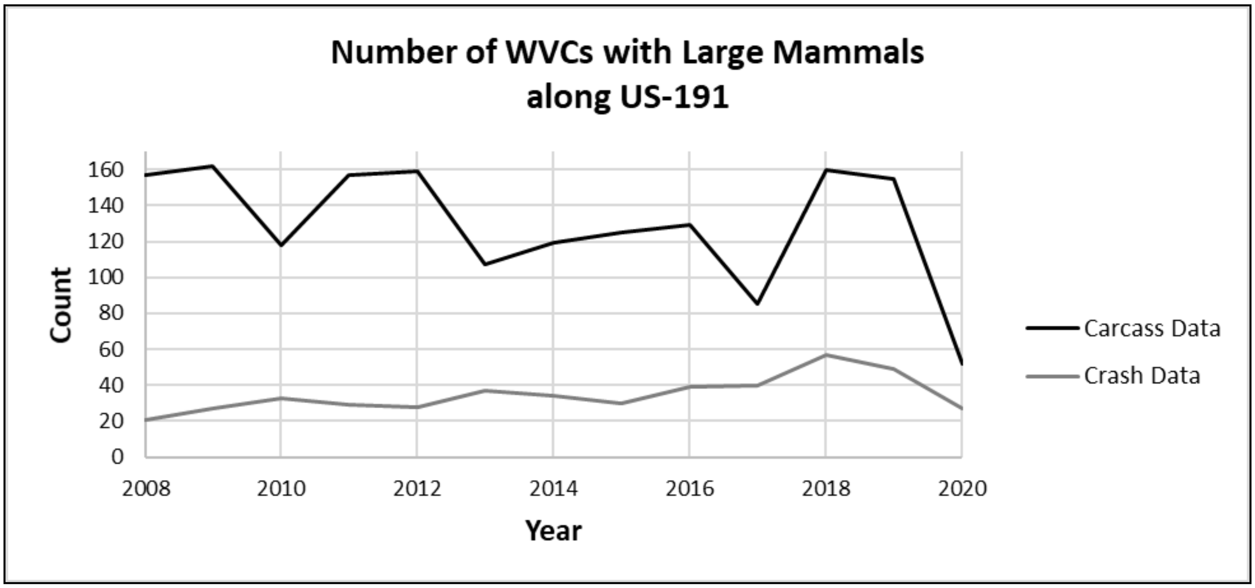


Figure 46 Distribution of WVC data with Large Mammals within the US-191 Study Area

10.4.1. Crash Data Analysis

The proportion of crash locations shows that using fewer years of data in the analysis leads to less similar results than using 10 years of data (Figure 47). Based on the Monte Carlo simulations, using 7 to 9 years of data shows over 80% similarity in the proportion of crashes for the 0.62 mi (1 km) road segments along US-191 when looking at the averages of the four analyses. This comparison shows that, on average, using one year of data is approximately 52% proportionately similar to using 10 years of data.

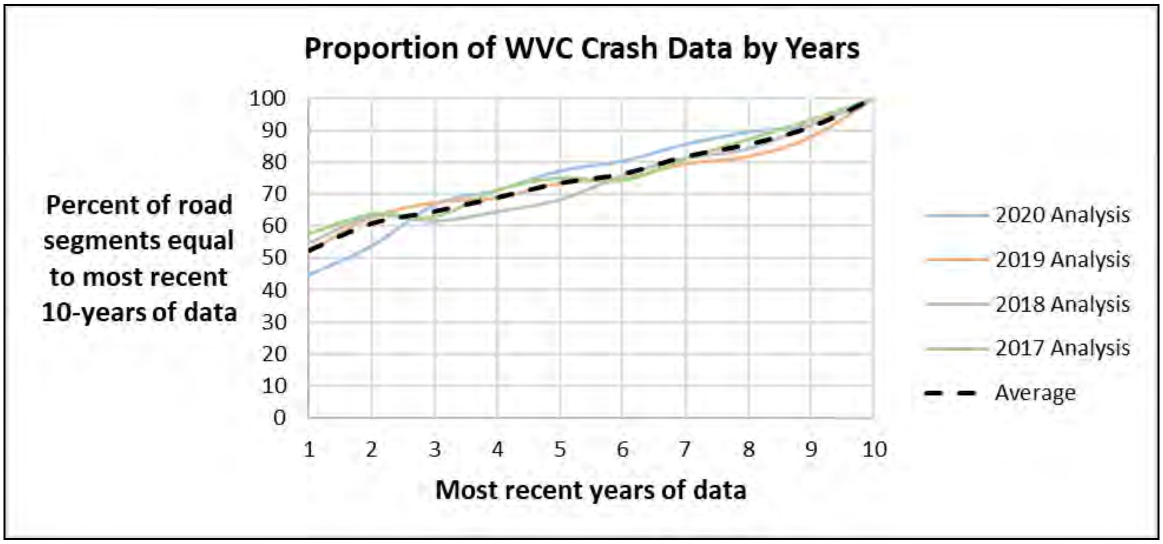


Figure 47 Proportion of WVC Data per kilometer of road segments equal to using 13 years of Crash Data

10.4.1.1. 10-year Crash Data Analysis

A total of 32 significant hotspots were identified in the initial 10-year crash data analysis. The top 10 hotspots identified result in a total of 46 km of fencing with five distinct mitigated areas: 1-5 km, 66-72 km, 76-83 km, 91-97 km, and 114-132 km. A comparison of each of the four time periods analyzed (2008-2017, 2009-2018, 2010-2019, and 2011-2020 data years) and the initial mitigation is shown in Figure 48.

In three analyses (2009-2018, 2010-2019, and 2011-2020 data years) following the initial analysis (2008-2017 data years), the top 10 hotspots identified were located within the initial mitigation efforts 83.3% of the time (Table 42). The hotspots that were not captured by the mitigation efforts were 1.24-5.6 mi (2-9 km) away from the fence ends established under the initial analysis.

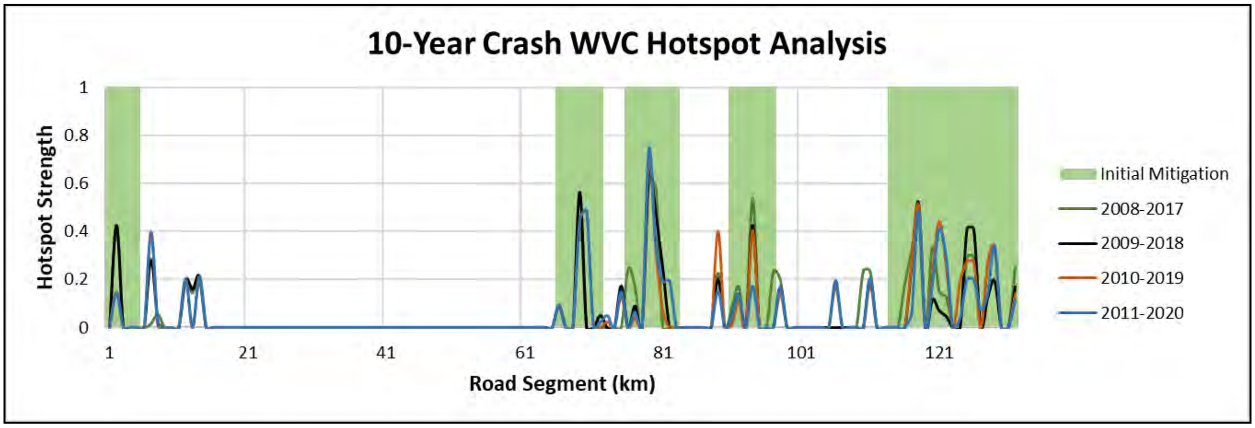


Figure 48 Comparison of WVC Hotspots per kilometer of road segments using 10 years of Crash Data

Table 42 Comparison of the top 10 identified WVC hotspots using 10 years of crash data

Hotspot Rank	Top 10 Road Segment Hotspots (km)			
	2008-2017	2009-2018	2010-2019	2011-2020
1	79	79	79	79
2	80	69	118	118
3	94	118	70	70
4	118	80	69	69
5	69	94	121	121
6	2	2	94	7
7	120	125	89	80
8	129	126	7	129
9	117	7	129	122
10	125	117	80	14
% Covered by Initial Mitigation		90	80	80

10.4.1.2. 5-year Crash Data Analysis

A total of 20 significant hotspots were identified in the initial 5-year crash data analysis. The top 10 hotspots result in a total of 29.2 mi (47 km) of fencing used in four distinct mitigated areas: segments 4-16, 66-82, 114-123, and 125-132. A comparison of each of the nine 5-year periods analyzed with the initial mitigation is shown in Figure 49.

In the eight analyses following the initial period (2008-2012 data years), the top 10 hotspots identified were located within the initial mitigation efforts 71.3% of the time (Table 43). The hotspots not captured were 1.86-9.32 mi (3-15 km) away from the fence ends established under the initial analysis.

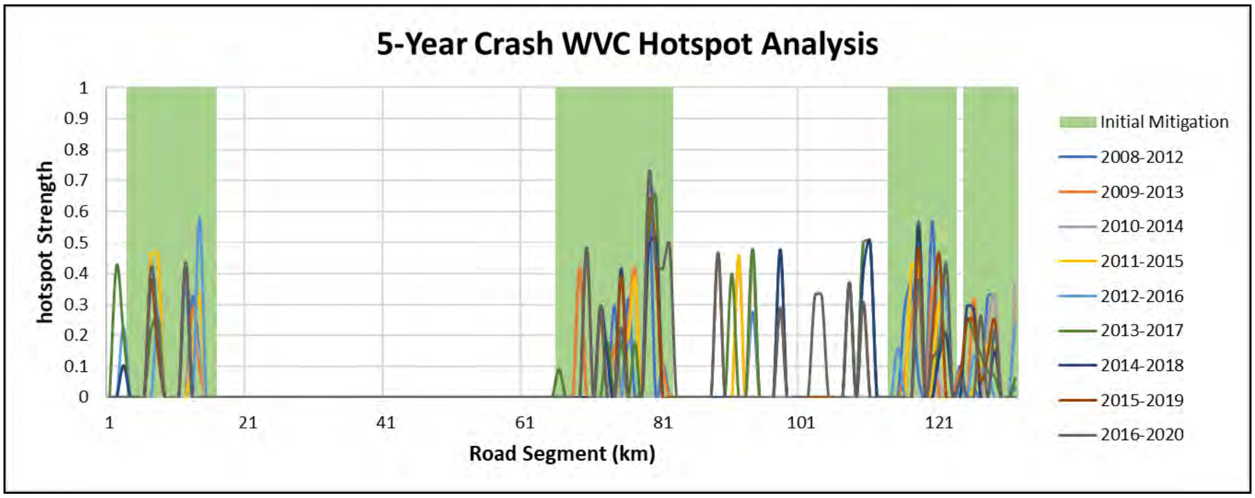


Figure 49 Comparison of WVC Hotspots per kilometer of road segments using 5 years of Crash Data

Table 43 Comparison of the Top 10 Identified WVC Hotspots using 5 Years of Crash Data

Hotspot	Top 10 Road Segment Hotspots (km)								
Rank	2008-2012	2009-2013	2010-2014	2011-2015	2012-2016	2013-2017	2014-2018	2015-2019	2016-2020
1	79	79	80	80	79	80	118	79	79
2	120	80	79	79	80	118	80	70	82
3	7	7	7	110	14	79	111	118	70
4	8	8	8	111	118	110	79	89	89
5	69	94	92	94	110	111	98	121	80
6	117	69	94	7	111	94	12	80	12
7	13	77	117	8	94	98	75	12	122
8	128	120	118	92	121	12	110	75	7
9	129	118	77	117	12	2	7	108	81
10	76	129	132	118	122	91	108	7	118
% Covered by Initial Mitigation		90	80	60	70	40	60	80	90

10.4.1.3. 3-year Crash Data Analysis

A total of nine significant hotspots were identified in the initial 3-year crash data analysis. These hotspots result in a total of 16.78 mi (27 km) of fencing with two distinct mitigated areas: segments 91-97, and 113-132. A comparison of each of eleven 3-year analyses with the initial mitigation is shown in Figure 50.

In the 10 analyses conducted following the initial period (2008-2010 data years), the top 10 hotspots identified were located within the mitigation efforts 40% of the time (Table 44). The hotspots that were not captured in the mitigation efforts were 1.24-54.06 mi (2-87 km) away from the fence ends established under the initial analysis (2008-2010 data years). Only the second analysis (2009-2011 data years) following the initial mitigation hotspot analysis captured greater than 50% of the top 10 hotspots previously identified.

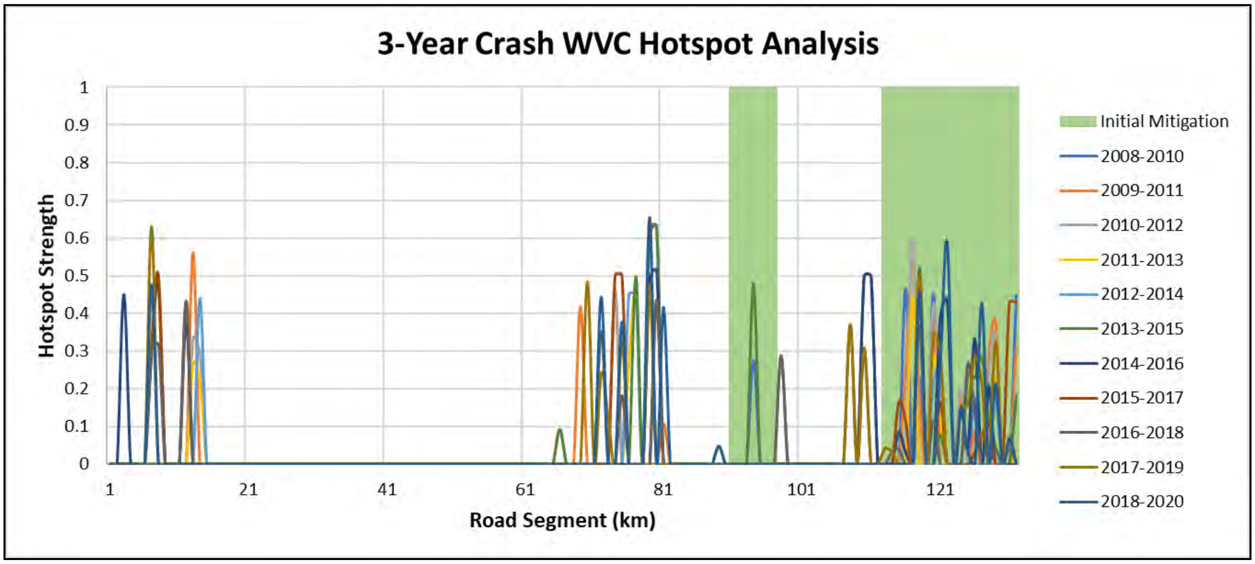


Figure 50 Comparison of WVC Hotspots per kilometer of road segments using 3 years of Crash Data.

Table 44 Comparison of the Top 10 Identified WVC Hotspots using 3 years of Crash Data

Hotspot	Top 10 Road Segment Hotspots (km)										
Rank	2008-2010	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020
1	116	13	117	79	80	80	80	74	80	7	79
2	120	117	79	7	79	79	110	75	12	118	122
3	132	74	7	8	76	118	111	8	108	70	7
4	94	69	8	77	77	110	79	118	118	79	118
5	118	129	74	117	14	111	8	80	72	108	72
6	128	120	120	120	118	77	118	12	8	120	127
7	129	132	129	13	121	94	3	132	110	129	81
8	126	128	13	76	120	127	122	131	7	75	75
9	124	116	14	129	132	125	121	7	98	110	121
10	-	124	128	14	66	126	12	98	125	121	129
% Covered by Initial Mitigation		70	40	30	40	50	30	30	20	40	50

10.4.2. Carcass Data Analysis

Similar to the crash data, the proportion of carcass locations shows that using fewer years of data in the analysis leads to less similar results than using 10 years of data (Figure 51). Based on the Monte Carlo simulations, using 8 to 9 years of data shows over 80% similarity in the proportion of crashes for the 0.62 mi (1 km) road segments along US-191 when looking at the averages of the four analyses. This comparison shows that, on average, using a single year of data is approximately 32% proportionately similar to using 10 years of data.

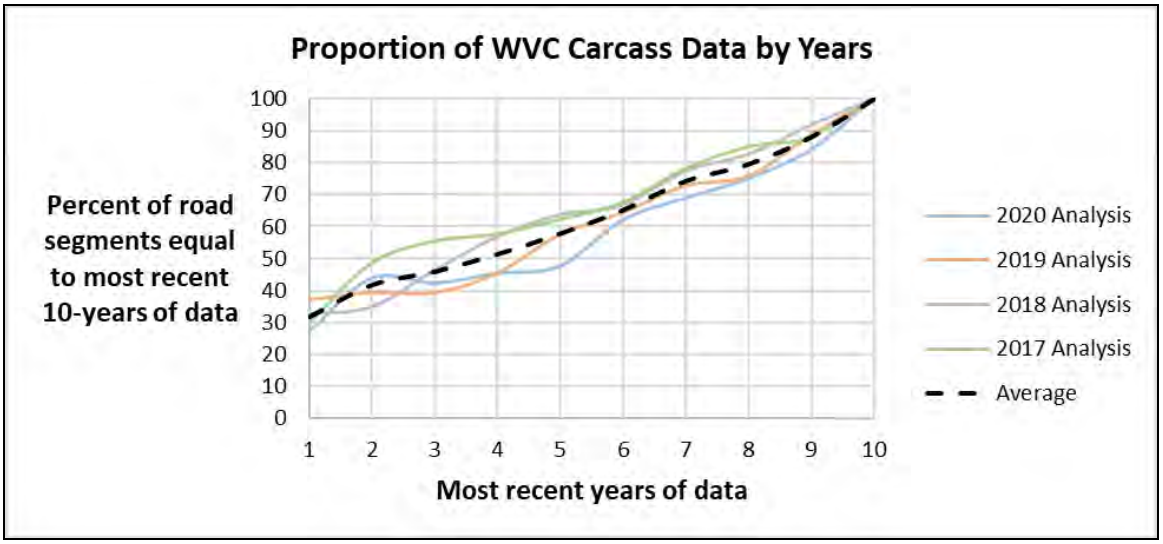


Figure 51 Proportion of WVC Data per kilometer of road segments equal to using 13 years of Carcass Data

10.4.2.1. 10-year Carcass Data Analysis

A total of 52 significant hotspots were identified in the initial 10-year carcass data analysis. The top 10 hotspots result in a total of 28.58 mi (46 km) of fencing with five distinct mitigated areas: segments 1-4, 6-22, 65-73, 101-107, and 115-123. A comparison of the four analysis periods with the initial mitigation areas is shown in Figure 52.

In the three analyses conducted following the initial analysis period (2008-2017 data years), the top 10 hotspots identified were located within the mitigation efforts 96.7% of the time (Table 45). The one hotspot not captured in mitigation efforts was 4.97 mi (8 km) away from the fence ends established under the initial analysis.

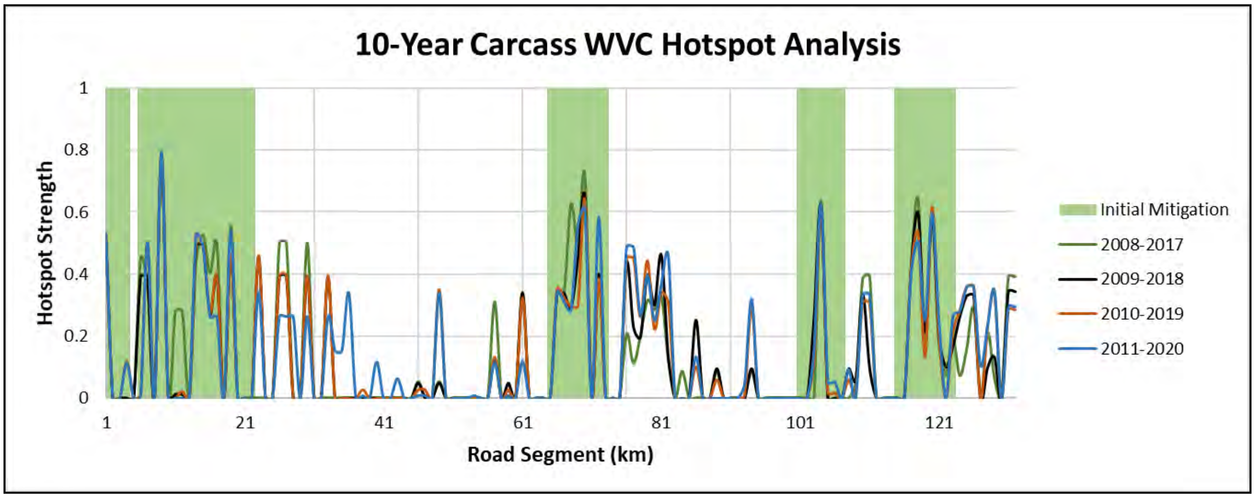


Figure 52 Comparison of WVC Hotspots per kilometer of road segments using 10 years of Carcass Data

Table 45 Comparison of the Top 10 Identified WVC Hotspots using 10 years of Carcass Data

Hotspot Rank	Top 10 Road Segment Hotspots (km)			
	2008-2017	2009-2018	2010-2019	2011-2020
1	9	9	9	9
2	70	70	70	104
3	118	104	120	70
4	104	118	104	120
5	68	120	118	72
6	120	1	1	69
7	19	14	7	19
8	1	15	14	1
9	15	81	15	14
10	17	19	19	118
% Covered by Initial Mitigation		90	100	100

10.4.2.2. 5-year Carcass Data Analysis

A total of 43 significant hotspots were identified in the initial 5-year carcass data analysis. The top 10 hotspots result in a total of 32.93 mi (53 km) of fencing with seven distinct mitigated areas: segments 3-9, 11-18, 23-29, 58-64, 66-73, 101-107, and 115-123. A comparison of the nine analysis periods and initial mitigation areas is shown in Figure 53.

In the eight analyses conducted following the initial analysis period (2008-2012 data years), the top 10 hotspots identified were within the mitigation efforts 76.3% of the time (Table 46). The hotspots that were not captured in the mitigation efforts were 0.62-2.49 mi (1-4 km) away from the fence ends established under the initial analysis.

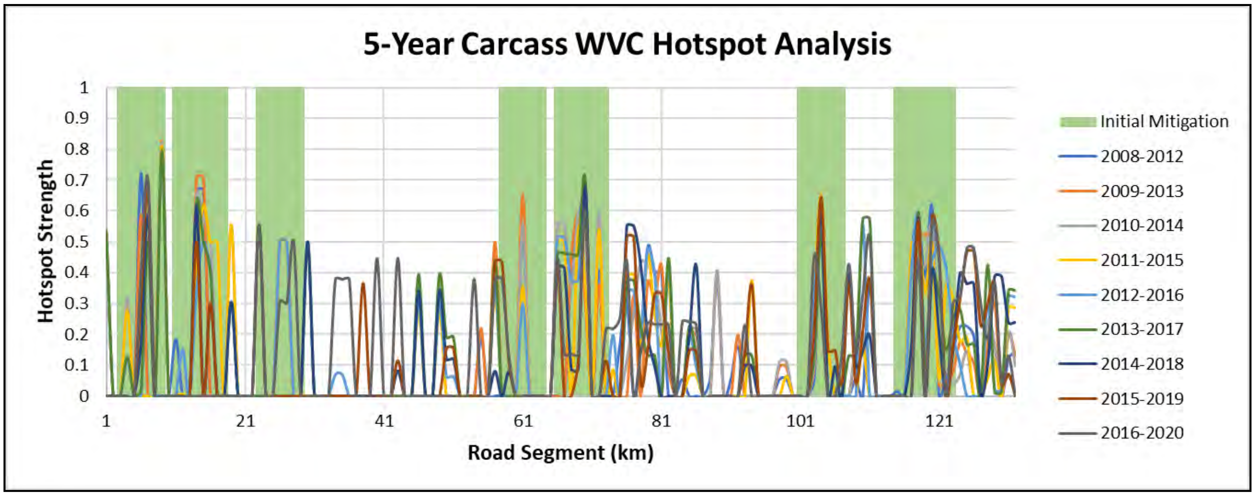


Figure 53 Comparison of WVC Hotspots per kilometer of Road Segments using 5 years of Carcass Data

Table 46 Comparison of the Top 10 Identified WVC Hotspots using 5 years of Carcass Data

Hotspot Rank	Top 10 Road Segment Hotspots (km)								
	2008-2012	2009-2013	2010-2014	2011-2015	2012-2016	2013-2017	2014-2018	2015-2019	2016-2020
1	6	9	9	9	9	9	70	7	7
2	14	14	14	104	70	70	14	104	70
3	15	15	72	15	118	14	104	70	120
4	70	61	69	19	110	118	7	120	23
5	120	69	15	72	1	111	118	118	111
6	104	6	104	69	66	110	23	23	28
7	69	104	70	1	67	1	77	77	125
8	118	120	61	118	104	104	76	76	126
9	61	1	66	16	7	7	30	14	103
10	26	118	67	17	15	15	78	125	43
% Covered by Initial Mitigation		90	100	80	80	70	60	70	60

10.4.2.3. 3-year Carcass Data Analysis

A total of 33 significant hotspots were identified in the initial 3-year carcass data analysis. The top 10 hotspots lead to a total of 29.2 mi (47 km) of fencing with four distinct mitigated areas: segments 3-18, 66-73, 75-81, and 108-123. A comparison of the 11 analyses with the initial mitigation areas is shown in Figure 54.

In the 10 analyses conducted following the initial analysis period (2008-2012 data years), the top 10 hotspots identified were located within the mitigation efforts 61% of the time (Table 47). The hotspots that were not captured in the mitigation efforts were 1.24-14.29 mi (2-23 km) away from the fence ends established under the initial analysis.

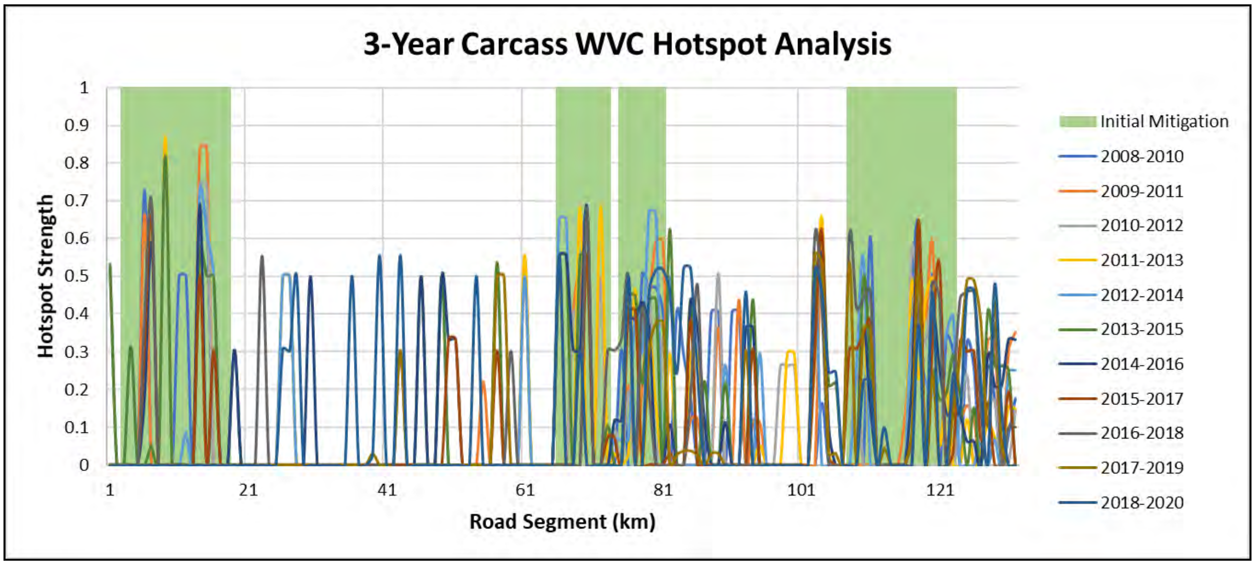


Figure 54 Comparison of WVC Hotspots per kilometer of Road Segments using 3 years of Carcass Data

Table 47 Comparison of the top 10 identified WVC hotspots using 3 years of carcass data

Hotspot Rank	Top 10 Road Segment Hotspots (km)										
	2008-2010	2009-2011	2010-2012	2011-2013	2012-2014	2013-2015	2014-2016	2015-2017	2016-2018	2017-2019	2018-2020
1	6	14	14	9	9	9	14	7	7	103	43
2	14	15	15	72	14	82	70	118	70	66	66
3	15	6	117	69	79	104	118	104	108	108	40
4	70	80	61	104	80	118	7	70	103	104	85
5	118	81	104	61	66	14	104	121	23	118	84
6	111	104	89	14	67	70	66	14	76	57	103
7	78	120	26	1	15	66	67	77	120	58	80
8	120	118	27	57	70	67	46	76	86	76	81
9	69	61	79	26	69	69	49	111	111	125	28
10	11	69	72	27	110	57	30	85	126	126	36
% Covered by Initial Mitigation		80	50	40	100	70	60	80	60	40	30

10.4.3. Results Summary

Table 48 summarizes the results of all the hotspot analyses conducted using the two data types (i.e., crash and carcass), including the mitigation fence length (km), the number of mitigated highway sections, and the degree to which hotspots covered by the initial mitigation efforts were captured in subsequent data years analyzed (Table 48).

Table 48 Summary of Results from the KDE+ Hotspot Analyses

Data Type	Number of Data Years	Number of Significant Hotspots	Mitigation Fence Length (km)	Number of Mitigated Sections	Hotspots within Initial Mitigation (%)	Distance to Hotspots Outside of Mitigation (km)
Crash	10	32	46	5	83.3	2-9
Crash	5	20	47	4	71.3	3-15
Crash	3	9	27	2	40	2-87
Carcass	10	52	46	5	96.7	8
Carcass	5	43	53	7	76.3	1-4
Carcass	3	33	47	4	61	2-23

10.5. Discussion

This case study was designed to investigate the variation in WVC hotspots by conducting sequential analyses each year and comparing them to an initial analysis used to identify where a road should be mitigated for WVCs to increase human safety. The hotspot locations are based on the type of data (i.e., crash vs. carcass), the number of years of data used, and the year in which an analysis is conducted. There may be large fluctuations in the number of collisions along a road segment each year identified by either data type (Figure 47). For each of the analyses using crash and carcass data sets, this case study suggests that using more data is supported by the proportions of WVCs along road segments (Figures 48 and 52). It shows that using data from shorter time periods (i.e., 3- and 5-year intervals) leads to results that are less similar to long-term trends found over 10-year intervals. This means there is higher variability in hotspot locations identified in analyses conducted using fewer years of data. More years of data capture hotspots that are persistent over a longer time period and de-emphasize locations where hotspots may only appear for a short timeframe.

The 10-year crash data analysis captures similar hotspots regardless of the year in which an analysis is conducted. There are higher densities of hotspots in similar locations year after year, and “new” top 10 hotspots not captured under initial mitigation efforts are only short distances away from initial fence ends. The 10-year carcass data analysis is even more successful at capturing subsequent top 10 hotspots in initial mitigation efforts. The carcass data sets also capture weaker hotspots that are more variable from one year to the next. There are many more carcass observations than there are crash data locations; crash data focus on WVCs that involve reports of property damage or injuries to vehicle passengers. Both data sets capture over 80% of the top 10 hotspot locations in subsequent year analyses and are within the priority areas identified for US-191 via the more in-depth analysis carried out in the US-191 and MT-64 Wildlife & Transportation Assessment.

The 5-year crash data analysis also identifies the top 10 hotspots in its initial year but only captures 71.3% of the top 10 hotspots in subsequent years. This is beneath the 80% similarity target set as a target in the case study. Hotspots not captured under initial mitigation measures were 1.24-9.32 mi (2-15 km) away from fence ends and, even if 3.1 mi (5 km) mitigation extensions were used (rather than the minimum 1.86 mi (3 km) used in this case study), would still not capture all hotspots. However, longer mitigation sections would surpass the 80% similarity threshold. The initial 5-year carcass data analysis is similar to the crash data but captures only 76.3% of subsequent hotspots. Using longer mitigation sections would also lead the 5-year carcass analysis to meet the 80% threshold. However, so doing would still not capture 100% of subsequent year hotspots identified in the 5-year analyses.

The 3-year analysis suggests how much variation exists in the movement of hotspots from year to year and shows how a single year of data can change the distribution of hotspots dramatically. In the initial 3-year crash data analysis (2008-2010 data years), hotspots are clustered at the northern end of US-191 (between segments 94-132). In the following four analysis years that use crash data from 2009-2014, some top 10 hotspots are clustered at the southern end (at segments 7-8 and 13-14). The southern hotspots disappear in the fifth analysis (2013-2015 data years) but reappear in each additional subsequent year analysis. The carcass data follows a similar pattern but captures hotspots more successfully. The initial 3-year carcass data analysis captures the southern hotspots along US-191 (at segments 6, 11, 14, and 15). The following eight analyses using carcass data between 2009 and 2018 also capture hotspots in the general area of the southern section of the road. However, these are not captured in the final two analyses conducted in 2019 and 2020. This highlights how a large number of collisions recorded in a single year can change hotspots identified using a 3-year time frame. Areas with high collision rates within a single year have less impact when data sets include longer time frames (i.e., 5-10 years of data).

10.6. Conclusions

This analysis shows that the top 10 hotspots along a section of the road vary over time based on the number of years of data and the type of data used in the analysis. Crash and carcass data both capture the strongest hotspot locations when using 10 years of data; however, because the amount of carcass data is three times greater than the amount of crash data, crash data does not capture weaker and more variable hotspots located outside of the top 10 hotspot locations. Using carcass data captures the top 10 hotspots and also identifies weaker hotspots that are more variable from year to year.

The quantity of data used in an analysis should reflect desired outcomes. If a goal is the construction of WVC mitigation infrastructure to increase human safety long-term, then 10 years of crash or carcass data should be analyzed. If identification of changes in hotspot locations due to changes in the landscape, traffic conditions, land use, or other factors is a goal, then smaller, 3-year data sets are appropriate.

None of the mitigation efforts identified in the initial analyses captured 100% of the top 10 hotspots identified in subsequent year timeframes. The best results came from using 10 years of carcass data. The lowest percentage of hotspots captured under initial mitigation efforts occurred using 3-year crash data sets. Due to high fluctuations in collisions along a road segment from year to year, use of 3-year data sets to identify mitigation areas for improving human safety does not capture hotspots that are prevalent over a longer time period. Five-year data sets are acceptable and the use of multiple 5-year analyses over a longer timeframe ensures that the hotspot locations are captured. Extending the length of fencing in areas identified using 5-year data sets increases the similarity to mitigation efforts identified with 10-year data sets but requires more fencing to be installed and maintained, increasing overall project cost.

Based on the 80% similarity target of this case study, using ten years of carcass data in the analysis does the best job of capturing the variation of future hotspots through initial mitigation efforts. Using ten years of WVC data to identify locations where mitigation efforts should be implemented to increase driver safety smooths out the random noise of the weaker temporal hotspots and shows stronger, more robust hotspot locations over the long term.

11. Cost Benefit Analysis

11.1. Introduction

This chapter provides a cost-benefit analysis based on public agency data on wildlife carcasses collected over a ten-year period from 2011-2020. However, the available data are likely to represent only a fraction of the actual number of animals killed by vehicles on US-191 and MT-64 over this time period. In general, the underreporting of wildlife crash and carcass data remains a major obstacle in accurately accounting for the number of crashes with wildlife and the impact of wildlife-vehicle collisions on wildlife mortality. Underreporting is also a complicating factor in the preparation of cost-benefit analyses. Snow et al. (2015) summarize the reasons for underreporting identified by academic literature. These include: duration of intervals between carcass collection activities; injured animals moving away from roads following collisions; carcasses scavenged, dragged off the road, decomposed, or removed for salvage; carcasses out of sight (hidden in vegetation, etc.) and not detected, or not a species of concern to departments of transportation. The present analysis shows areas where the benefits of implementing measures to reduce wildlife-vehicle collisions exceed the costs of their construction based on the available data. However, more accurate data may increase the number of locations where the cost-benefit threshold is met. Additional information, such as a correction factor for underreporting described in Section 11.4, below, could help to highlight additional sites.

11.2. Methods

Highway Sections

US-191: mile marker 0.0 (West Yellowstone) - 81.9 (Four Corners)

MT-64: mile marker 0.0 (Junction with US-191) – 10.0 (up the mountain)

11.2.1. Period

1 Jan 2011-31 Dec 2020 (10 years).

11.2.2. Carcass Removal Data

Carcass removal database (Montana Department of Transportation), supplemented by grizzly bear road mortalities (Interagency Grizzly Bear Study Team).

Table 49 Species, Number of Carcasses Recorded, and Percentage of Each Species of the Total Number of Recorded Carcasses

Species	Number	%
White-tailed deer	895	67.70
Mule deer	181	13.69
Elk	161	12.18
Moose	29	2.19
Bison	29	2.19
Bighorn sheep	17	1.29
Grizzly bear	5	0.38

Species	Number	%
Black bear	4	0.30
Gray wolf	1	0.08
Total	**1322**	**100.00**

11.2.3. Costs of Wildlife-Vehicle Collisions

The costs of collisions with wildlife used in this analysis are based on those described in Huijser et al. (2022) and shown in Table 50. These costs include direct costs associated with vehicle repair, human injuries, and human fatalities, as well as passive use values. Passive use or non-use values are the values individual people place on the existence of a given animal species or population, as well as the bequest value of knowing that future generations will also benefit from preserving the species (Duffield and Neher 2019).

Table 50 Total Costs Associated with Wildlife-Vehicle Collisions (in 2020 US$)

	Costs per collision				
Cost category	**Deer**	**Elk**	**Moose**	**Gray wolf**	**Grizzly bear**
Direct costs					
Vehicle repair	$4,418	$7,666	$9,435	$4,418	$4,418
Human injuries	$6,116	$14,579	$26,811	$6,116	$6,116
Human fatalities	$3,480	$23,200	$46,400	$3,480	$3,480
Subtotal	$14,014	$45,445	$82,646	$14,014	$14,014
Passive use value	$5,075	$27,751	$27,751	$40,342	$4,235,770
Total	$19,089	$73,196	$110,397	$54,356	$4,249,784

In order to carry out cost-benefit analyses of potential wildlife accommodation measures along US-191 and MT-64 within the study area, the carcasses recorded by the Montana Department of Transportation and Interagency Grizzly Bear Study Team (see Table 49), were categorized based on their size and weight to match species for which economic data are available. The species for which economic data are available are shown in Table 50. In order to take advantage of this information, some species were recategorized; for example, bighorn sheep were categorized as deer, as shown in Table 51. As a result, the potential passive use values for several species, including bison, bighorn sheep, and black bears, are likely severely underestimated.

Table 51 Species Reported in Carcass Data as Categorized for Cost-benefit Analyses

Species Reported in Carcass Data	"Species" categorized in Cost-benefit Analyses
White-tailed deer	Deer
Mule deer	Deer

Species Reported in Carcass Data	"Species" categorized in Cost-benefit Analyses
Elk	Elk
Moose	Moose
Bison	Moose
Bighorn sheep	Deer
Grizzly bear	Grizzly bear
Black bear	Deer
Gray wolf	Gray wolf

11.2.4. Costs of Mitigation Measures

The cost of a large mammal fence (with buried apron), an underpass once every 2 km, and jump-outs is \$25,388 per km per year (\$40,858 per mile per year) at a discount rate of 3% (Huijser et al. 2022). The total cost of including an additional wildlife overpass once every 24 km instead of an underpass is \$32,030 per km per year (\$51,547 per mile per year) (Huijser et al. 2022).

11.3. Results

11.3.1. Cost-Benefit of Wildlife-Vehicle Collisions along US-191 and MT-64

The number of wildlife-vehicle collisions along US-191 and MT-64 per species was calculated for each 0.1-mile road segment. However, the number was averaged over a 1.1-mile road segment (including five 0.1-mile segments just before and five 0.1-mile segments just after each 0.1-mile segment as a moving window). Since the carcass data related to a 10-year period, the number of carcasses per species was then divided by 10 to obtain the number of roadkilled animals per mile per year for each tenth of a mile road segment. The number of roadkilled animals per species was then multiplied by the average costs for a collision with that species (see Table 50). Finally, the costs for the different species were summed into the total costs per mile per year for each 0.1-mile road segment.

In Figure 55, which shows US-191 in the study area, the costs of wildlife-vehicle collisions based on carcass counts are represented by the jagged line (in 2020 US\$). The two horizontal lines are the thresholds for two different types and combinations of mitigation measures at which benefits exceed cost over a 75-year period with a discount rate of 3%.

In Figure 56, which shows MT-64 in the study area, the costs of wildlife-vehicle collisions based on carcass counts are represented by the jagged line (in 2020 US\$). The two horizontal lines are the thresholds for two different types and combinations of mitigation measures at which benefits exceed cost over a 75-year period with a discount rate of 3%.

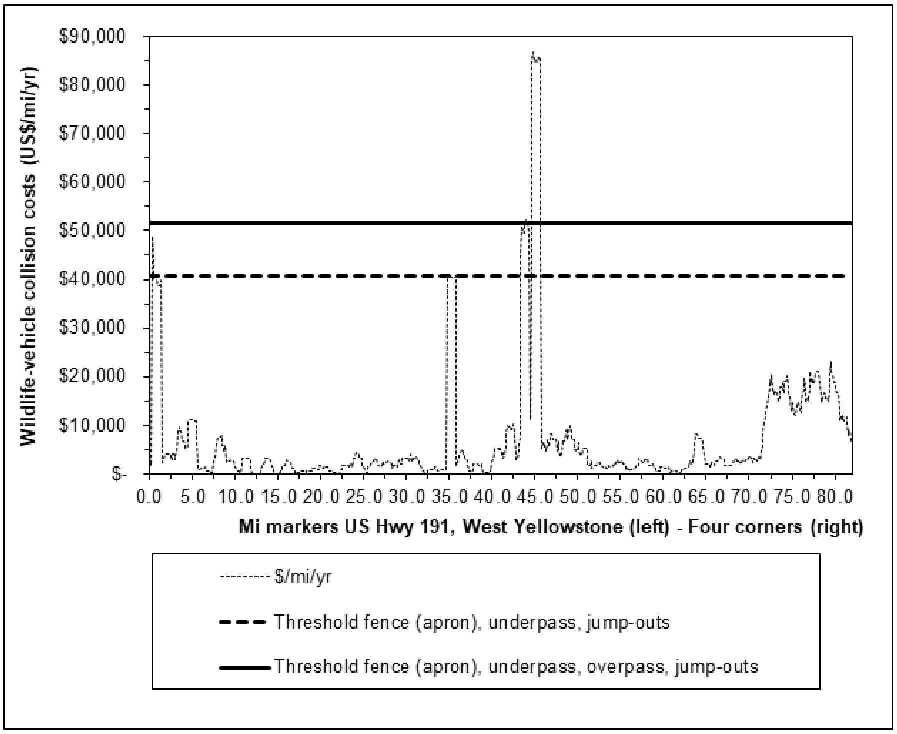


Figure 55 US-191 from West Yellowstone (left side of graph) to Four Corners (right side of graph).

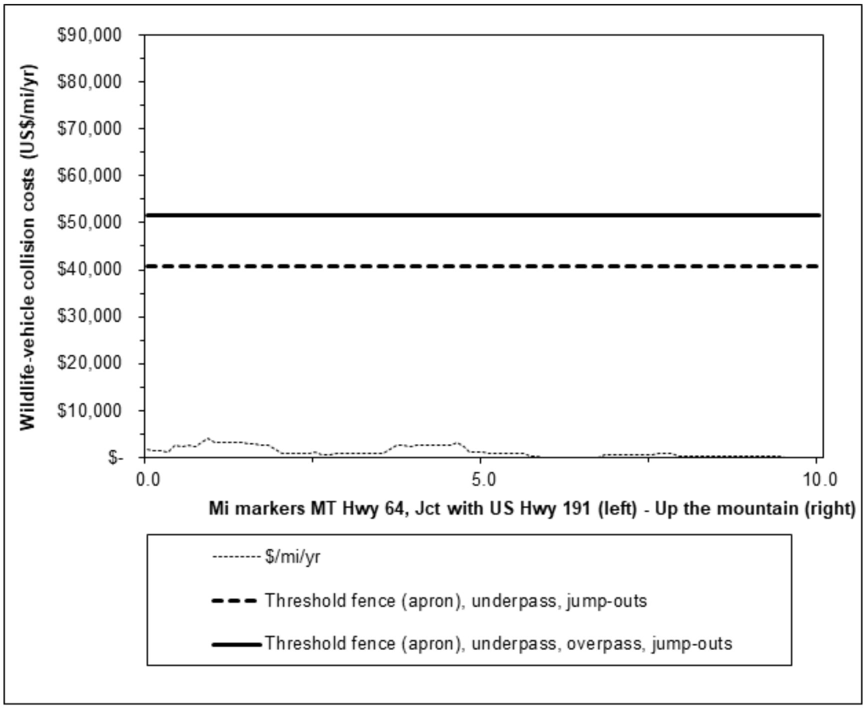


Figure 56 MT-64 from the junction with US-191 (left side of graph) to the end of the road up the mountain (right side of graph).

11.4. Discussion

In the study area, the costs associated with wildlife-vehicle collisions spike where grizzly bear road mortalities occur. However, the total number of carcasses of all species is low compared to the quantity that would meet or exceed the thresholds for the different types and combinations of mitigation measures in most locations. However, it is important to remember that reported carcass removal data are likely to be an undercount, such that the total number of animals that have been hit may be significantly higher (see Section 2.4 for more information on underreporting of carcass data).

It is important to note that just one or a few more grizzly bears hit along a road section would substantially affect results. Moreover, while passive use values for wildlife were integrated into the analyses, the model does not necessarily capture the full economic value of wildlife and maintaining viable populations.

Nevertheless, three areas along US-191 meet or exceed the threshold. Two of these areas are located within priority areas identified in this report: the Porcupine and the Taylor Fork Priority Sites. The Porcupine site, for which an overpass is recommended, exceeds the economic threshold for implementing this type of structure. The Taylor Fork site exceeds the threshold for the construction of underpasses and fencing. Because grizzly bears are among the target species in these locations, special consideration should be given to structures that accommodate their movements. Grizzly bear family groups require open structures such as overpasses and large-span bridges (Ford et al. 2017). The third area is located at RM 0.8, adjacent to West Yellowstone, and was identified primarily due to a recorded grizzly bear mortality. As stated earlier in Section 6.10, mitigation along other areas of the study roads may be warranted. It should also be considered based on the documentation and analysis in this report, especially when highway projects are planned.

To prepare a more thorough cost-benefit metric, the CLLC-WTI research team could take a “correction factor” based on a study of how available carcass data may relate to the actual number of wildlife struck and killed by vehicles (Lee et al. 2021). This type of study is now underway in Montana, and it may be appropriate to use the correction factors determined once available, especially given the difficulty of data collection along some sections of US-191 and MT-64 (where there are few opportunities to pull over safely). Once appropriate correction factors have been determined, this chapter's cost-benefit analyses may be updated to provide greater insight into the potential economic benefits of implementing measures to reduce wildlife-vehicle collisions.

12. Conclusion

The information included in this report should inform and support area communities and agency decision-makers to select and pursue wildlife accommodation options. With the passage of the Infrastructure Investment and Jobs Act of 2021, significant funds for wildlife accommodation measures are available nationwide on a competitive basis. The US-191/MT-64 Wildlife & Transportation Assessment better equips part of Southwest Montana's gateway to Yellowstone National Park to take advantage of new funding opportunities.

The Assessment compiled, overlaid, and evaluated wildlife-vehicle collision and wildlife carcass data, wildlife movement and habitat data, and live wildlife observations from aerial surveys. It also incorporated wildlife sightings and roadkill information gathered via citizen science. The Assessment further drew upon local and expert knowledge gathered through in-person outreach and an interactive map. Road areas identified through an in-depth spatial data analysis were evaluated in a field review conducted by an interdisciplinary Technical Advisory Committee of county, state, and federal planners, along with biologists, engineers, transportation experts, and the Research Team from the Center for Large Landscape Conservation (CLLC) and Montana State University's Western Transportation Institute (WTI).

The report describes eleven Priority Sites located in important areas for wildlife movement and/or that pose elevated risks to human and wildlife safety and provides recommendations for potential wildlife accommodation measures. Mitigation along other areas of the study roads may also be warranted based on the documentation and analysis in this report, especially when highway projects are planned.

In addition to the terrestrial Priority Sites, the report summarizes the potential "barrier effect" of culverts passing under US-191 and MT-64 based on an assessment of factors in the field, finding that over 40% of existing culverts may not allow for the unimpeded passage of fish. While retaining a barrier to passage may be desirable in some cases to protect the integrity of native species, further evaluation is suggested to assess the status of these culverts more fully.

The report's recommendations describe appropriate locations for prospective wildlife accommodation measures such as culverts, bridges, underpasses and overpasses, and/or animal detection systems—each in combination with fencing—that consider terrestrial and/or aquatic wildlife passage. Many sites include major drainages from surrounding public lands that intersect with US-191 or MT-64 and feature existing infrastructure that has the potential to facilitate animal movements, such as a bridge spanning a riparian corridor. During the field evaluation, the CLLC-WTI research team and Technical Advisory Committee considered means to incorporate existing infrastructure, new structures, and additional alternatives to reduce collisions with wildlife (e.g., variable message signs for areas that have spatially discreet or seasonal conflicts and traffic calming measures to effectively reduce the design speed of the highway). A range of accommodation strategies have a role to play in helping to reduce collisions and maintain wildlife movement in the study area.

In the case of terrestrial species, despite crossing structures with fencing requiring high initial investment, research shows they are cost-effective over the course of their lifetime (generally 75 years or more) due to greater efficacy in reducing wildlife-vehicle collisions and lower maintenance costs than other options (Brennan, Chow, and Lamb 2022; Huijser et al. 2009). Further, given that bridges and culverts that are upscaled and designed to allow for wildlife passage are usually better able to accommodate stream and floodplain function due to larger size and capacity, they may also make infrastructure more resilient to "extreme" weather events like flooding. The Montana Department of Transportation has already identified several bridges needing replacement in the study area. Applying the findings of this Assessment to bridges or other priority locations when replacement is scheduled offers a best-case scenario for cost-effective implementation.

The analysis within this report is based on available data. Not all data sets are comprehensive; some are collected opportunistically (including both Montana Department of Transportation and citizen science carcass data), and the data sets are skewed towards large mammals and charismatic species such as elk and grizzly bears. Some data gaps and limitations that could be aided by further research are mentioned in the discussion of Priority Sites.

The options for prospective wildlife accommodation measures along key road segments described in this report are intended as a guide to inform decision-making processes rather than serve as a prescription for specific actions. Implementation of any prospective measure depends on factors such as public support, design, engineering feasibility, potential agreements with land management agencies and/or private landowners, and funding availability.

The CLLC-WTI Research Team suggests that making US-191 and MT-64 safer for travelers and wildlife is a multi-year, multi-site, multi-stakeholder proposition that will take collective action to bring about. The Assessment provides a foundation to allow for discussion about how to reach these goals based on robust understanding.

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