Cost-benefit analyses for mitigation measures aimed at reducing large wild mammal-vehicle collisions and providing safe crossing opportunities for large wild mammals in Gallatin County, Montana, USA

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Prepared by:

Marcel P. Huijser, PhD
Senior research ecologist

&

Matthew A. Bell, MSc
Research Engineer

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Huijser, M.P. https://orcid.org/0000-0002-4355-4631 Bell, M.A. https://orcid.org/0000-0002-1482-9747	

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16. Abstract

This report summarizes cost-benefit analyses for mitigation measures aimed at reducing large wild mammal-vehicle collisions and providing safe crossing opportunities for large wild mammals in Gallatin County, Montana. Based on the analyses of wild mammal-vehicle crashes and large wild mammal carcass removal data, it is evident that there are many highway sections in Gallatin County where the economic benefits of mitigation measures exceed the costs. While differences exist between the results based on crash or carcass data, the economic thresholds for fences in combination with wildlife crossing structures were met or exceeded for several sections of I-90 and US Hwy 191. Based on the crash data, the section of US Hwy 191 where mitigation measures would be most economically advantageous is between Four Corners to the mouth of Gallatin Canyon. Based on the carcass data, the sections of US Hwy 191 where mitigation measures would be most economically advantageous are between Four Corners to the mouth of Gallatin Canyon, just north and south of Big Sky, and between the junction with US Hwy 287 and West Yellowstone. Other road sections that met or exceeded the thresholds include US Hwy 287 just west of the junction with US Hwy 191, US Hwy 20 west of West Yellowstone, MT Hwy 84 just east of the Madison River, and several other short road sections in the north of Gallatin County. The number of reported crashes and carcasses must be considered minimum estimates; the true number of large wild mammals killed by vehicles is likely substantially higher, suggesting that the economic benefits of mitigation measures are even greater than the results of the cost-benefit analyses suggest. Finally, the parameters included in the cost benefit model are not complete, and the values are subject to change. However, more complete models and updated values have historically been showing increased rather than decreased economic arguments for implementing mitigation measures.

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- Montana Fish, Wildlife & Parks (Justin Gude).

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1 Introduction

1.1 Background

This report summarizes cost-benefit analyses for mitigation measures aimed at reducing large wild mammal-vehicle collisions and providing safe crossing opportunities for large wild mammals in Gallatin County, Montana. The input data come from a related but separate project and associated report (Huijser & Bell, 2024).

1.2 Goals and objectives

The goal of this project is to enhance road safety for humans in Gallatin County, Montana, by reducing collisions with large wild mammals, while also ensuring safe crossing opportunities for wildlife.

The primary objective of this project is to conduct cost-benefit analyses for mitigation measures aimed at reducing large wild mammal-vehicle collisions and providing safe crossing opportunities for large wild mammals in Gallatin County, Montana.

A previous effort and associated report (Huijser & Bell, 2024) identified and prioritized the road sections in Gallatin County that have a relatively high concentration of collisions involving large wild mammals. These road sections may then later be evaluated for potential future mitigation measures aimed at:

- Reducing collisions with large wild mammals.
- Providing safe passage across roads for large wild mammals as well as other wildlife species in the area, including small mammals, reptiles, and amphibians. In wetlands and at stream or river crossings, safe crossing opportunities may also relate to aquatic species, including fish species.

2 Methods

2.1 Collision data sources and data selection

The input data for the cost-benefit analyses were conducted separately for crash data and carcass removal data and came from Huijser & Bell (2024). In summary, the collision data relates to:

- Wild mammal-vehicle crash data obtained through the Montana Department of Transportation (MDT) and large wild mammal carcass removal data. The carcass removal data are a combination of carcass removal data obtained through MDT and grizzly bear road mortality data obtained through the Interagency Grizzly Bear Study Team at the U.S. Geological Survey (USGS).
- Data Period: Data from all three sources covered the period from 1 January 2008 through 31 December 2022, totaling 15 full calendar years.
- Roads included: All MDT on-system roads in Gallatin County, such as Interstates, US Highways, and numbered MT Highways, including MT 64 (Figure 1; Figure 2). Other roads were not included.
- Species: Only records that relate to wild animal species were included. Records involving domesticated animal species were removed.
- Species size: For the MDT carcass database, only records that related to species larger than coyotes were included.
- Maximum distance from road: Collision records within 25 meters (m) of on-system roads were included, while those beyond 25 m were excluded from the analysis. In cases where locations could be projected onto more than one road, we verified the projections and removed duplicates.
- Carcass data: Carcass removal data, collected by MDT road maintenance personnel, were combined with grizzly bear road mortality data compiled by researchers from USGS into one carcass removal database.

Note that in this report, the term “collisions” relates to both crashes and carcasses.

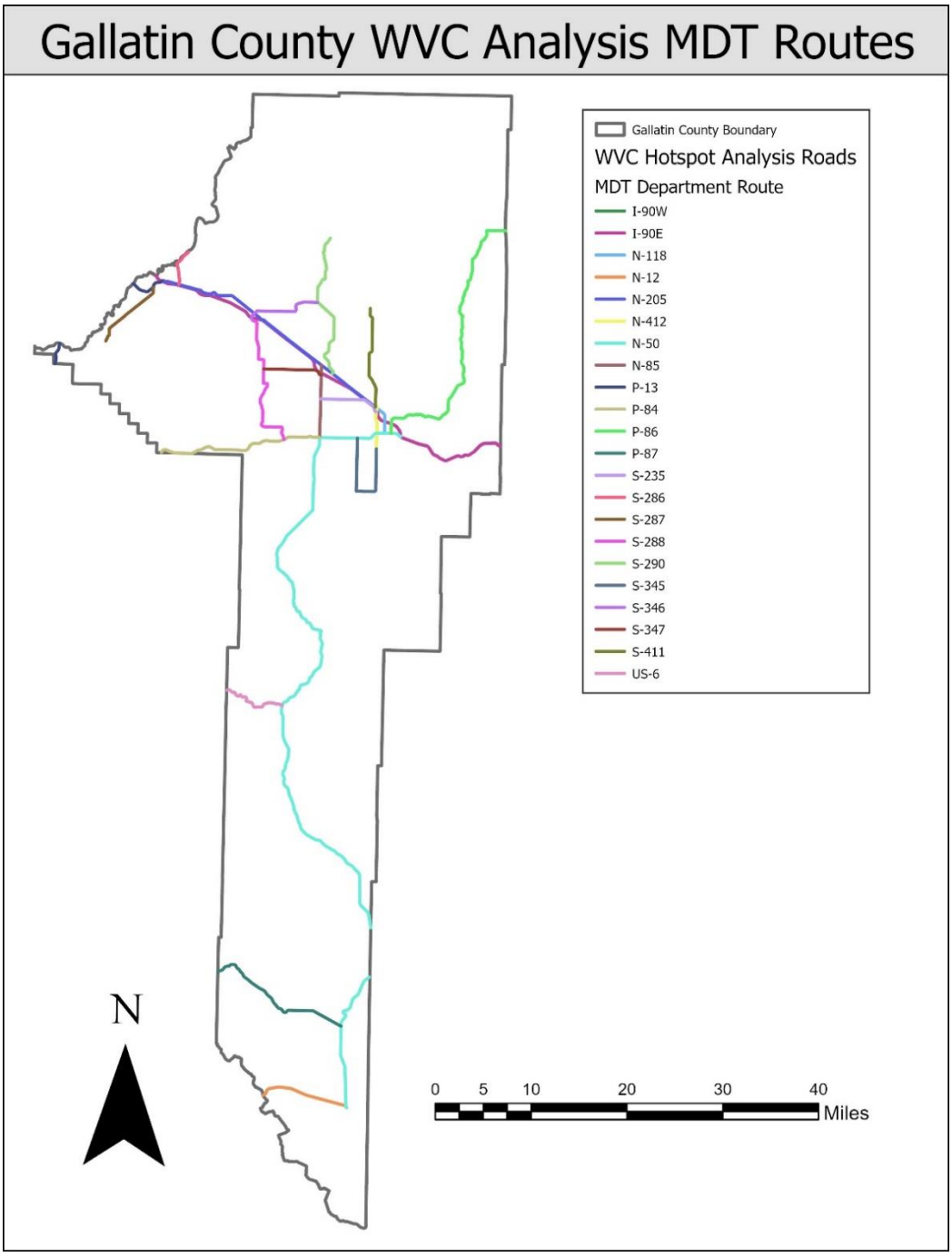

Figure 1: The selected roads in Gallatin County.

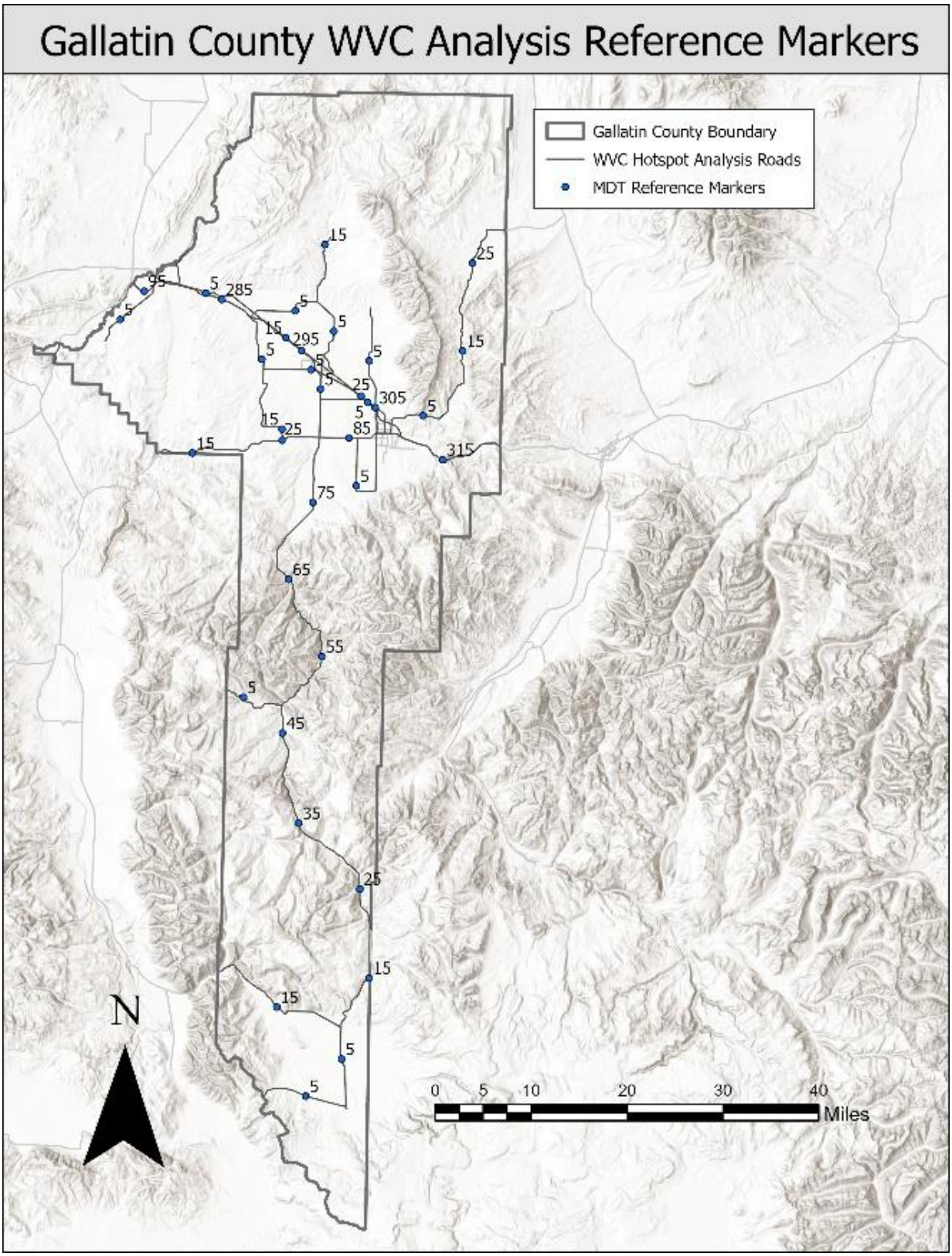

Figure 2: The mile reference posts along the selected roads in Gallatin County.

2.2 Species categories

We based the cost-benefit analysis for crash and carcass removal data on Huijser et al. (2009, 2022). The costs associated with large wild mammal-vehicle collisions included the following types of parameters: vehicle repair costs, costs associated with human injuries and human fatalities, and passive use values. Passive use values, also known as 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 & Neher 2019).

While there are differences in costs associated with different large wild animal species, the crash data did not include species names. Therefore, for the purpose of the cost-benefit analysis, all wild mammal-vehicle crashes were assumed to be "deer," which resulted in relatively conservative cost estimates associated with the crashes. In contrast, the carcass removal data did include species names. However, since we did not have cost estimates for every large wild mammal species, the carcass removal data were grouped into different species categories based on similarity in body size and body weight (Table 1).

Table 1: The species categories and costs of a collision used for the cost-benefit analysis and the species as noted in the carcass removal data.

Species categories for the purpose of the cost-benefit analysis	**Species as noted in the carcass removal data**	**Costs (in 2020 US$) (Huijser et al., 2022a)**
"Deer"	White-tailed deer, mule deer, unknown deer species, pronghorn, bighorn sheep, mountain goat, black bear, mountain lion	$19,089
"Elk"	Elk	$73,196
"Moose"	Moose, bison	$110,397
"Grizzly bear"	Grizzly bear	$4,249,784
"Wolf"	Wolf	$54,356

2.3 Cost estimates for collisions for every tenth of a mile

We summed the number of crashes or carcasses per species category for each tenth of a mile segment for all 15 years. To recognize the spatial imprecision in the data (see Huijser & Bell, 2014), we summed the values from the five preceding 0.1-mile segments, the 0.1 mile segment concerned, and the five following 0.1 mile segments (eleven 0.1 mile segments in total) and calculated the number of crashes or carcasses per mile (divide by 1.1) per year (divide by 15) for each 0.1 mile segment. We based the calculations on fewer 0.1-mile segments for 0.1-mile segments that were within 0.5 mile from the start or end of a numbered road. We ignored transitions to different numbered roads, including junctions.

The number of crashes or carcasses per species category for each tenth of a mile segment was then multiplied with the cost estimates for the species category concerned (see Table 1). Finally, for the carcass removal data, the costs for all species categories were summed for each tenth of a mile. The costs associated with large wild mammal crashes and carcasses were then compared to the thresholds, or "break-even values" for two different combinations of mitigation measures (

Table 2). If the costs associated with large wild mammal-vehicle collisions on a road section are higher than the costs associated with implementing the mitigation measures (the thresholds), it is economically advantageous to implement the mitigation measures on that road section, at least based on the parameters and values included in the cost-benefit model. If the costs associated with large wild mammal-vehicle collisions on a road section are lower than the costs associated with implementing the mitigation measures (the thresholds), it is not economically advantageous to implement the mitigation measures on that road section, at least not based on the parameters and values included in the cost-benefit model. We only included two different combinations of mitigation measures, and both include wildlife fences in combination with wildlife crossing structures. We restricted the mitigation measures to those that included both fences and wildlife crossing structures because:

- Fences are the most effective and robust measure to reduce wildlife-vehicle collisions (almost always 80-100% reduction) (Huijser et al., 2016, 2021).
- Fences alone would result in an absolute or near absolute barrier for the target species which is not ethical (Moore et al., 2021).
- Wildlife crossing structures provide safe crossing opportunities for wildlife and can increase permeability compared to an unmitigated road with a smaller footprint, allow for seasonal migration of large ungulates to continue, and can help improve population viability for select species (review in Huijser et al., 2021).

No other mitigation measures, other than fences in combination with wildlife crossing structures, can both substantially reduce wildlife-vehicle collisions and maintain or improve connectivity for wildlife (Huijser et al., 2021). The thresholds associated with two different combinations of mitigation measures are listed in Table 2. There are many considerations for these cost estimates including a projected 25-year lifespan for fences, and a 75-year lifespan for crossing structures (see Huijser et al., 2009, 2022). The thresholds for the two different combinations of mitigation measures are based on the average costs per road length unit (both in kilometers and miles). However, the spatial scale of the mitigation measures affects their effectiveness:

- Mitigated road sections that are at least 3 miles long almost always reduce collisions with large wild mammals within the mitigated road section by 80-100% (Huijser et al., 2016). Shorter mitigated road sections are on average less effective (about 50%) and highly variable in their effectiveness depending on local circumstances (Huijser et al., 2016).
- For mitigated road sections to be effective on a larger spatial scale, we must avoid moving the collisions to adjacent road sections (Huijser & Begley, 2022). In this context, the mitigation measures may need to be implemented at road sections that are even longer than 3 miles in length. For example, it is considered good practice for the mitigation measures to cover the entire suitable habitat for the species, including an adjacent buffer zone based on the size of the home range of the target species (Huijser et al., 2022b). In practice this means that the length of the mitigated road sections should probably be many miles, potentially dozens of miles.

Table 2: The thresholds associated with two different combinations of mitigation measures (see Huijser et al. (2022) for details).

Combination of mitigation measures	**Threshold in US$/km/yr (in 2020 US$ based on 3% discount rate)**	**Threshold in US$/mi/yr (in 2020 US$ based on 3% discount rate)**
Fence (apron), large mammal underpass once every 2 km (width 7.0-8.5 m, height 3.7-5.6 m), and 7 jump-outs per km road length	$25,388	$40,858
Fence with apron, large mammal underpasses once every 2 km (width 7.0-8.5 m, height 3.7-5.6 m), large mammal overpasses once every 24 km (50-60 m wide, replaces an underpass once every 24 km), and 7 jump-outs per km road length.	$32,030	$51,547

3 Results

3.1 Wild mammal-vehicle crash data

Based on wild mammal-vehicle crashes, the economic thresholds for two different combinations of mitigation measures were especially met or exceeded for several sections of I-90 and US Hwy 191 (Figure 3). The section of US Hwy 191 where mitigation measures would be most advantageous based on economics are between Four Corners to the mouth of Gallatin Canyon (Figure 3).

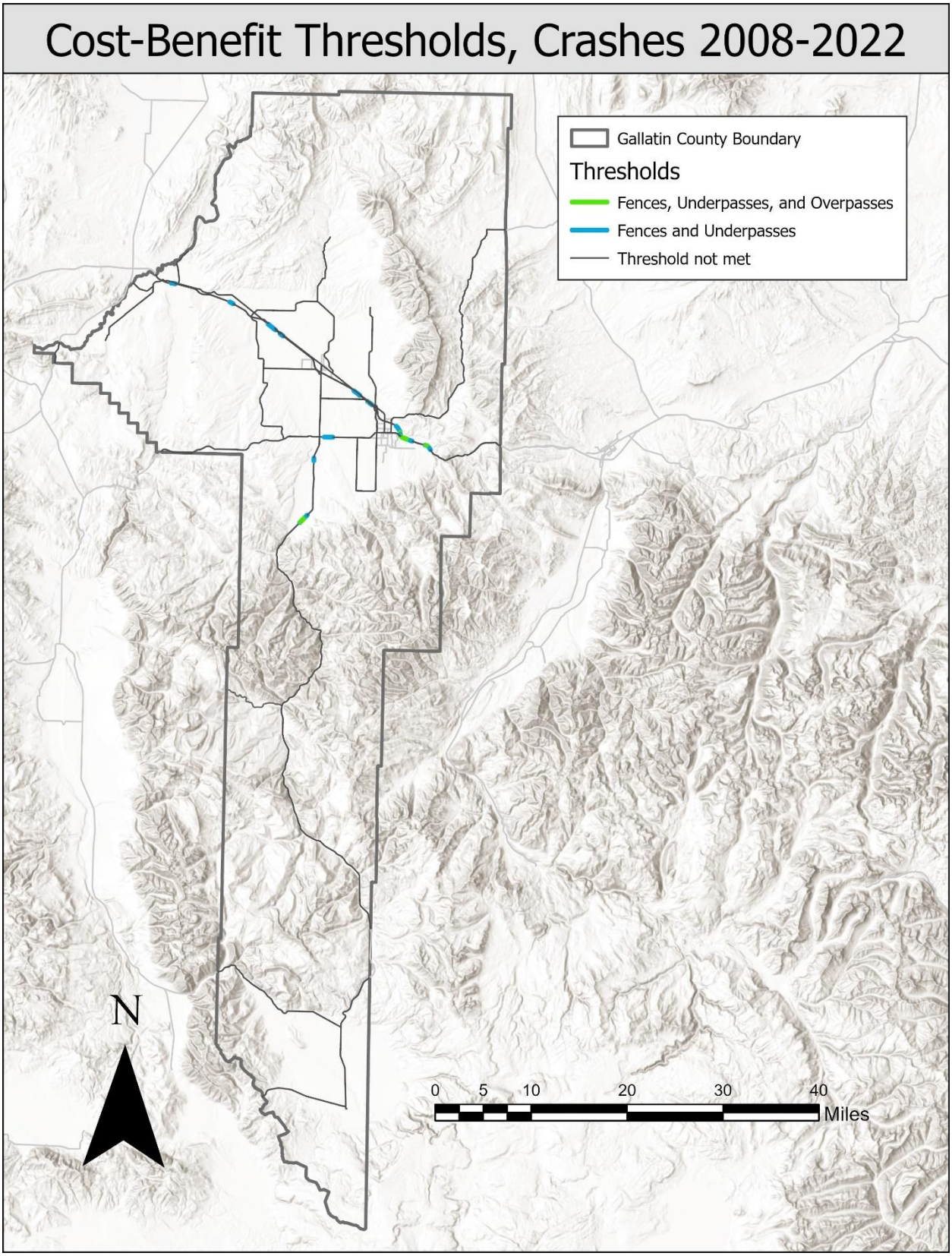

Figure 3: The road sections where the economic thresholds were met for the two different combinations of mitigation measures based on wild mammal-vehicle crash data in Gallatin County.

3.2 Large wild mammal carcass removal data

Based on large wild mammal carcass removal data, the economic thresholds for two different combinations of mitigation measures were especially met or exceeded for several sections of I-90 and US Hwy 191 (Figure 4). The sections of US Hwy 191 where mitigation measures would be most advantageous based on economics are between Four Corners to the mouth of Gallatin Canyon, just north and south of Big Sky, and between the junction with US Hwy 287 and West Yellowstone (Figure 4). Other road sections that met or exceeded include US Hwy 287 just west of the junction with US Hwy 191, US Hwy 20 west of West Yellowstone, MT Hwy 84 just east of the Madison River, and several other short road sections in the north of Gallatin County (Figure 4).

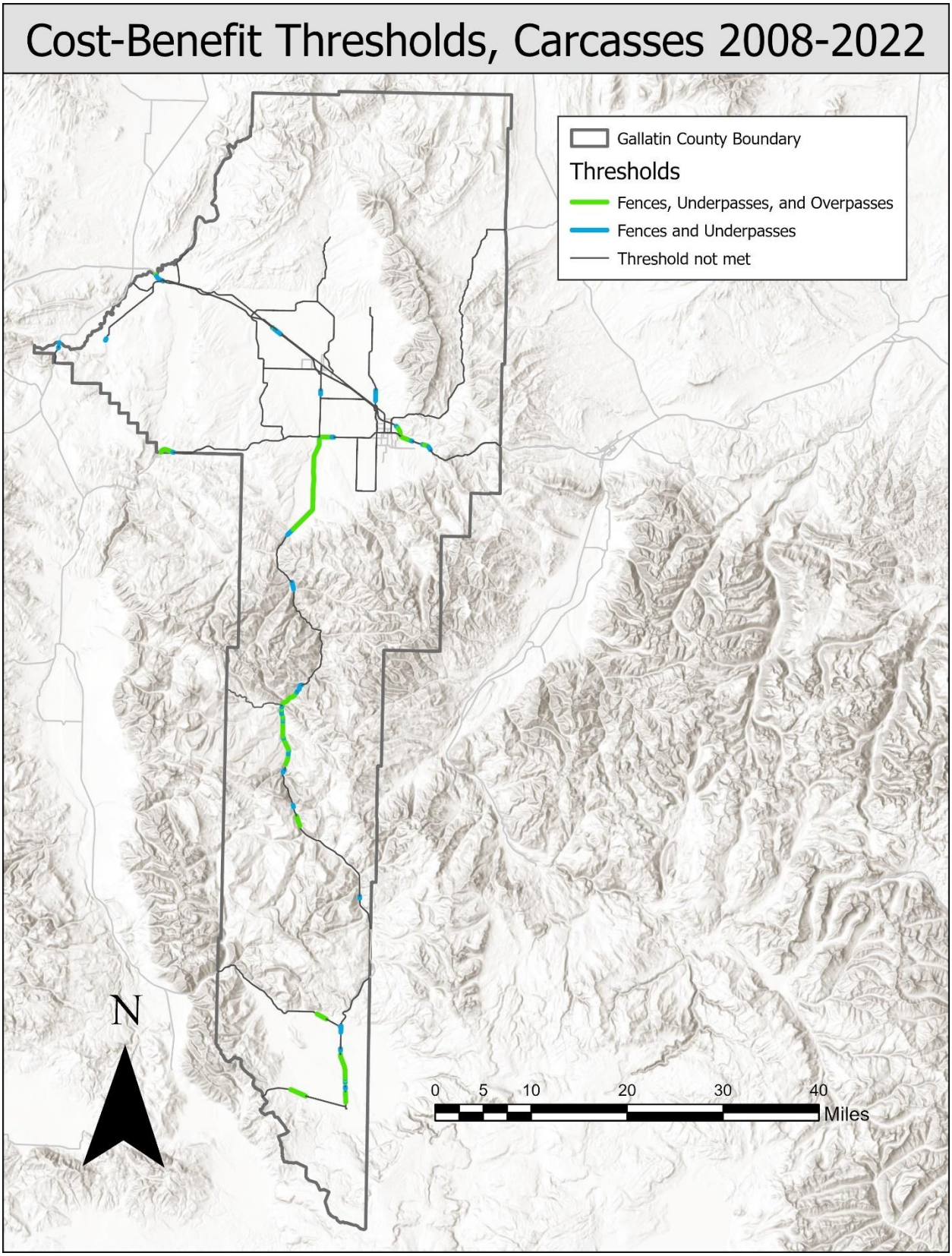

Figure 4: The road sections where the economic thresholds were met for the two different combinations of mitigation measures based on large wild mammal carcass removal data in Gallatin County.

4 Discussion

While the costs associated with wild mammal-vehicle collisions are based on both human safety and biological conservation parameters, these cost estimates are not necessarily complete, and they are also subject to changes (Huijser et al., 2009; 2022). The same is true for the costs for the individual mitigation measures (e.g., price of fuel, concrete, and steel). However, more complete models and updated values have historically been showing increased rather than decreased economic arguments for implementing mitigation measures (Huijser et al., 2022). Regardless, it is evident that there are many highway sections in Gallatin County where the economic benefits of mitigation measures exceed the costs.

Furthermore, the number of wild mammal crashes, and the number of large wild animal carcasses must be regarded as a minimum estimate; the true number of large wild mammals that are hit is likely substantially higher. For example, weekly carcass counts of deer and elk by a researcher were about eight times higher than the number of deer and elk recorded by MDT maintenance personnel along a highway in a neighboring county (Fairbank et al. 2024). In addition, compared to wild mammal-vehicle crashes, the carcass removal records collected by MDT maintenance personnel have been declining between 2008-2022. This suggests an increasing underestimation of the number of large wild animals that are killed by vehicles (Huijser & Bell, 2024). Underestimation of the number of large wild animals that are hit by vehicles means that the economic benefits of mitigation measures are even greater than the results of the cost-benefit analyses suggest. This also means that it is likely that more road sections, or longer road sections, would meet or exceed the thresholds of the mitigation measures.

Note that the thresholds only related to mitigation measures that included wildlife crossing structures. The costs associated with fences only – without wildlife crossing structures – are substantially lower and the thresholds for fences only would be reached along much greater road lengths. However, “fences only” would result in a near absolute barrier of the transportation corridor for the target species (i.e., no connectivity), which is considered unethical (Moore et al., 2021). But long road sections with fences (at least 3 miles, potentially even dozens of miles in the context of the large-scale suitable habitat for large wild mammals in many areas in Gallatin County) in association with wildlife crossing structures are required to be at least 80% effective in reducing collisions inside the fenced road sections (Huijser et al., 2016). Furthermore, long road sections of wildlife fences also reduce the likelihood of simply moving the collision problem up or down the road beyond the mitigated road sections (Huijser & Begley, 2022).

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