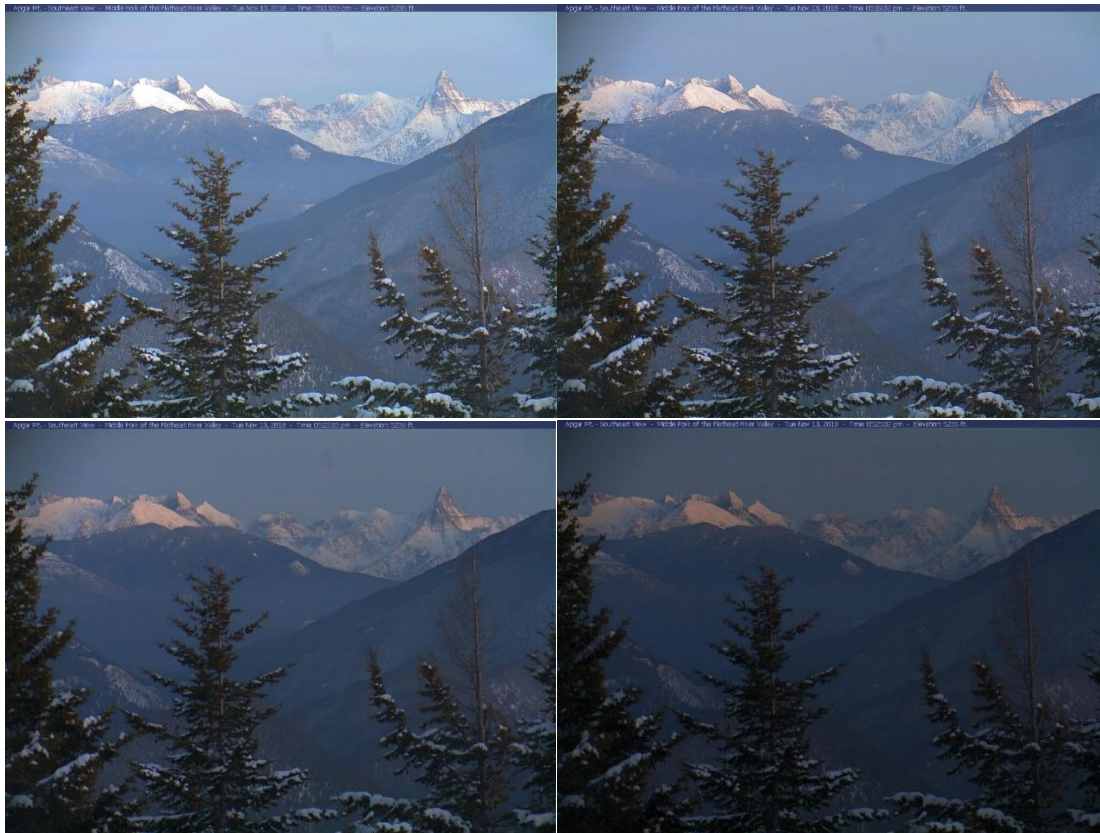


Keeping the Crown of the Continent Connected

An Interagency US2 Connectivity Workshop Report



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Introduction

At over 2.5 million acres, Glacier National Park and the Bob Marshall Wilderness complex form one of the largest protected areas in the continental United States. Straddling the Continental Divide, these two areas form a vital linkage between vast areas of public land to the south towards Yellowstone, and contiguous protected areas north of the US-Canada border. However, US Highway 2 (US2) and the Burlington Northern-Santa Fe (BNSF) railroad separate Glacier National Park to the north from the Bob Marshall Wilderness complex to the south. While this narrow ribbon of development passes through primarily public land, it is bordered in some areas by narrow strips of private land. Many of these private parcels are developed as ranches, campgrounds, or seasonal and permanent home sites and businesses.

Currently, two of the defining characteristics of this portion of the US2 corridor are relatively low highway traffic volume, but relatively high railroad traffic volume. The highway had a 2017 annual average daily traffic volume (AADT) of 1859 vehicles, far less than other interstate highways around the region which often have AADTs well over 10,000. Conversely, the BNSF railroad line currently carries about 33 trains per day, making it one of the busier railroad lines in the northwestern US.

While wildlife movement patterns across this corridor have not been well studied, the existing data suggests that wildlife can still make frequent and successful crossings at current railroad and highway traffic levels. However, as the region's human population grows, we expect that connectivity to diminish. Over the past decade (2000-2017), based on census data, Flathead County has grown by 10% and Glacier County has grown by 1.5%. A study on loss of open space found that Flathead County alone accounts for 15% of the new homes built in Montana since 2000 (<https://headwaterseconomics.org/economic-development/local-studies/montana-home-construction/>). Outdoor recreation and tourism have also been breaking participation records (source: GPI record passengers <https://flatheadbeacon.com/2018/01/24/glacier-park-international-airport-sees-record-passengers-2017/>, GNP record visitation <https://www.usnews.com/news/best-states/montana/articles/2018-01-15/glacier-national-park-breaks-visitation-record-in-2017>). This growth has been accompanied by a ~50% increase in highway traffic volume in the corridor over the past decade (Waller and Miller 2015). This increased traffic is decreasing the time available for wildlife to cross the highway and appears to be increasing the frequency of wildlife killed by vehicles (Fig. 1 and 2).

In addition, the Middle Fork of the Flathead River is a favored river for recreation, and this also appears to be growing. In the summer of 2017, researchers recorded 136 boats per day in July and 93 boats per day in August. Although the river does not extend along the entire highway, it extends along 31 miles of the highway corridor.

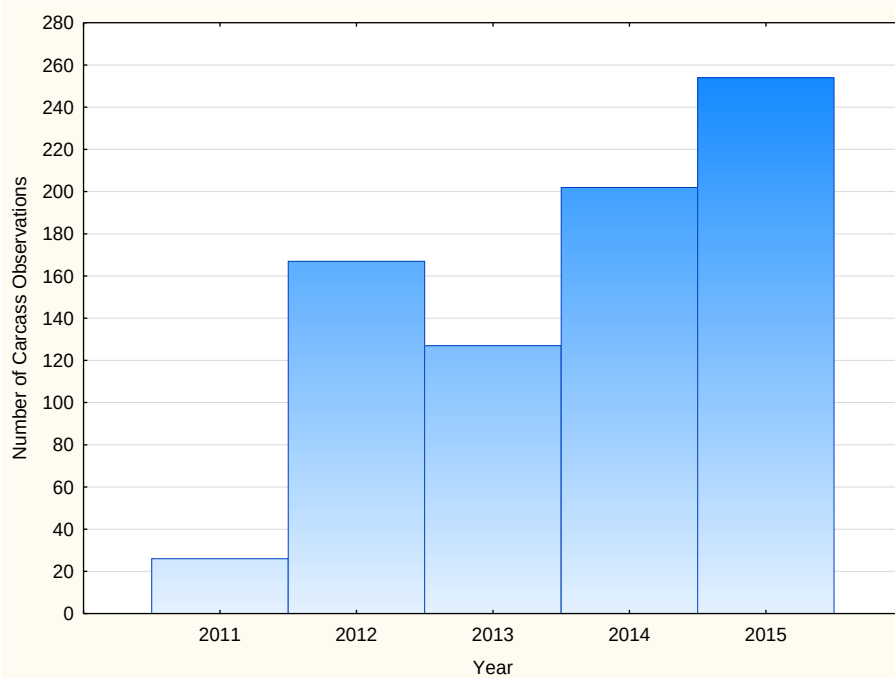


Figure 1. Annual Montana Department of Transportation carcass observations on US Highway 2 between mileposts 80 and 197.

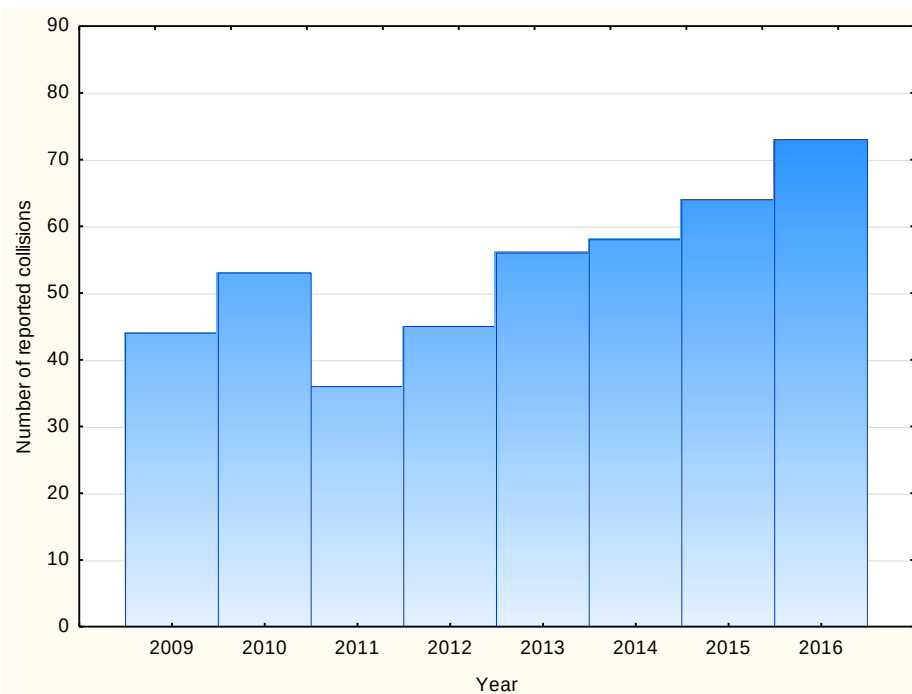


Figure 2. Annual wildlife collisions recorded by Montana Highway Patrol on US Highway 2 between milepost 80 and 197.

One species of interest along the US2 corridor is the grizzly bear. Two studies illustrate our current knowledge of bear connectivity along this stretch of highway. Waller and Servheen (2005) found that grizzly bears collared on the eastern end of this study area were crossing the road, but were doing so

mostly at night when traffic volume was low. Kendall et al. (2009) found signals of some genetic differences between bears north and south of the highway on the western end of the Northern Continental Divide Ecosystem. These genetic differences did not exist on the eastern end of the highway corridor, which is consistent with the results of Waller and Servheen (2005), i.e. that at that time bears could still cross the highway in that area. These studies are based on bear data from 2004 and earlier however, and we do not know whether connectivity across the US2 corridor has increased or declined since then.

These trends have led experts in both the Crown Manager's Partnership and the Great Northern Landscape Conservation Cooperative, as well as Cushman et al. (2009) to identify this corridor as a priority area for wildlife connectivity planning (Ament and Creech 2016).

Over the last year, an interagency group of local researchers and managers met in two workshops to evaluate existing research and data sources, identify knowledge gaps, and establish a research framework to increase understanding of wildlife use of the US2 corridor. The long-term goal is to identify explicit management options for preserving short-term trans-highway movements, seasonal migrations, and dispersal movements of animals, plants, and ecological processes. This report builds on previous efforts to understand and plan for terrestrial wildlife connectivity across this inter-jurisdictional corridor by beginning a multi-agency conversation for collaborative research and management.

The high levels of participation in this process illustrate the agreement among agencies that addressing connectivity across this highway is a high priority. Participating agencies included Glacier National Park, the U.S. Forest Service, Montana Fish Wildlife and Parks, the Blackfeet Nation, the Confederated Salish and Kootenai Tribe, the U.S. Geological Survey, the University of Montana, the Montana Department of Transportation (MDOT), and BNSF Railroad. Participants agreed on the importance of establishing a process to facilitate communication, identify desired research, and develop support for ensuring connectivity for future generations. There was also strong support for building on existing data, recognizing that previous planning efforts had limitations, including limited local fine-scale data, prioritization processes that were not fully collaborative, and a lack of information on many species. In addition, participants developed a preliminary list of potential funding sources, important to furthering any research or management process.

Prior Research and Prioritization

The last 15 years have seen a surge across the world in research on the impacts of highways and habitat fragmentation on wildlife (e.g. Trombulak and Frissell 2000, Spellerberg 2002, Forman 2003, Bissonnette & Adair 2008, Dodd et al. 2007, Roeber et al. 2010, Northrup et al. 2012, Proctor et al. 2012, Rytwinski and Fahrig 2012) and management options for mitigating those impacts (e.g., Clevenger and Waltho 2005, Gagnon et al. 2011, Iglesias et al. 2012, van der Ree et al. 2015a, Huijser et al. 2016, Simpson et al. 2016, Dilkina et al. 2017). Research consistently shows that engineered wildlife crossings are used by animals (review in van der Ree et al. 2007, e.g., Murphy-Mariscal 2015), although it can take time for animals to learn to use them; the landscape context, size and openness of the structure, and other design features influence the degree to which they enable animal movement (Clevenger & Waltho 2005, Purdum 2013, Huijser et al. 2016). In addition, cost benefit analyses of crossing structures have illustrated that installation of wildlife crossings at high vehicle collision locations is economically justified even when benefits to the animal populations themselves are not quantified (Attah 2012).

Because this research is quite extensive, several overall reviews exist, and new journal articles typically summarize previous research (e.g., van der Ree et al. 2015b, Huijser et al. 2016), this report focuses on local information.

Prior research fits into 3 categories: 1) local species-specific data sets, 2) highway specific data sets, and 3) earlier reports prioritizing locations for highway wildlife crossings.

Local species-specific data sets

Only a few species have been intensively studied at local scales within the US2 corridor, namely grizzly bears (Waller and Servheen 2005, Kendall et al. 2009), black bears (Stetz et al. 2014), and bighorn sheep (Tosa et al. In Review, Flesch et al. In prep). There have also been studies focusing on a highway underpass constructed for mountain goats in Glacier National Park, using primarily observations of goats crossing the highway along a small section and evaluating the impacts of visitors on mountain goat highway crossing behavior (Singer 1978, Pedevilanno & Wright 1987). Some of the existing data sources were not analyzed with a focus on connectivity across US2, but could inform connectivity planning (namely grizzly and black bear genetic data included in Kendall et al. 2009, Stetz et al. 2014 and bighorn sheep data Tosa et al. In Review, Graves personal communication). Currently no fine-scale data exist on nearly any other terrestrial species in this highway corridor, including commonly studied species such as elk, mule and whitetail deer, mountain lions, or wolves, but also more rare species of concern such as mountain goats, moose, wolverine, lynx, and fisher. Similarly, no local data or analyses exist on the current state of demographic or genetic connectivity for small mammals, birds, or other carnivores.

This interagency group agrees that aquatic species, plants, and ecological processes are also important to consider, but this set of workshops did not review that literature given the expertise of participants and the funding available for this initial review.

Highway-specific data sets

Participants identified several data sets relevant for connectivity planning in the US2 corridor. A couple of previous efforts involving many of these same agencies were conducted under the auspices of the Great Northern Environmental Stewardship Area (GNESA). This organization was formed as a non-profit to promote environmental action in the corridor (overview of activities in Waller 2017). The GNESA organization funded a project in 2007 to acquire and document local knowledge concerning the distribution and crossing behaviors of wildlife in the corridor. Datasets developed through that work used a variety of approaches including interviews with people that lived and worked in the corridor and GIS mapping of wildlife concentration areas. GNESA also provided funding for development of a map of wildlife trails within the highway corridor between West Glacier and East Glacier, with portions completed as a Master's project (Roesch 2010) and the remainder as a report (Holdhusen 2016). Maps of animal trails between Highway 206 and West Glacier do not exist, but that region is rapidly developing and this information would be useful in planning efforts.

The MDOT records the location and species of road-killed animals and the Montana Highway Patrol records collisions where a police report was made. Both of these data sources vary in consistency and location accuracy through time depending on the personnel involved in reporting and agency priorities. Nonetheless, they offer some information on locations where wildlife deaths occur along the highway.

Structural data that exist include a map of culverts and bridges created by MDOT and a similar map of railroad structures created by BNSF, although the railroad data were not made available for this assessment due to security concerns.

Other existing datasets that are useful for corridor planning include land ownership, presence of conservation easements, land cover type, avalanche paths and sheds, hydrology, digital elevation models, and corresponding derived topographic elements. These maps illustrate the context of the highway and railroad in terms of other potential barriers to wildlife movement.

Earlier prioritizations

There have been several assessments of potential regions or localities for wildlife crossing structures. They provide an excellent starting point for consideration of potential projects and highlight many of the threats to connectivity in the region. However, the approaches of those assessments were not comprehensive, involved interviewing a relatively small number of experts, and have not evaluated whether the activities identified in those assessments would be sufficient to achieve the wildlife connectivity objectives of this interagency group.

Roesch (2010) identified areas near milepost (MP) 173, MP 181 to 184, and MP 189 to 193. Roesch (2010) found that the 1-km segment with the most wildlife trails was between MP 181-182, that the 3-km segments with the most trails were at MP 181-182.9 and MP 182.9-184.7, and that the 5-km segment with the most trails was at MP 181-184 (Table 1). Overall, the 8-km stretch from MP 179-184 contained ~41% of the surveyed trails between West Glacier and MP 184. The entirety of this stretch was a no-passing zone and had a speed limit of 55mph as it is within Glacier National Park boundaries.

Table 1. List of bridges and tunnels along US-2 and the number of trails and GNESA wildlife crossing locations within 1 km. From Roesch (2010).

Structure	MP	Trails	GNESA
RR Tunnel 2	153.0	2	2
RR Tunnel 3	156.1	3	2
Bridge over Deerlick Creek	159.2	2	0
Bridge over RR 1	162.4	0	0
Bridge over RR 2	165.5	2	1
RR Tunnel 1	168.6	8	1
Middle Fork Flathead Bridge at Essex	171.7	4	0
Goat Underpass	174.8	8	2
Bridge over Snowslide Gulch	178.0	7	1
RR Bridge over Hwy	181.1	6	0
Bridge over Bear Creek	184.2	1	1
Bridge over Devil Creek	187.3	4	1
Bridge over Bear Creek 2	190.4	1	1

He also found more trails in areas without guardrails, at the end of a guardrails, and found no trails in the four-lane stretch of highway that coincided with the residential community of Pinnacle, MT. He found more wildlife trails in areas with lower distance to cover and riparian areas. He deployed remote cameras and identified primarily deer and elk in the photos, but also obtained photos of moose, black bear, coyote,

hare, wolf, and cougar. Numbers of wildlife photos peaked at crepuscular times, and were higher in the middle of the night than the middle of the day, concurrent with the lowest traffic volumes. Holdhusen (2016) continued with the same study design as Roesch (2010), from the end of the Roesch study area (MP 193) to East Glacier (MP 209) and identified 2 regions, MP 197-197.2 and 199.8-200 with many wildlife trails that could be important crossing areas.

Ament et al. (2014) contains a good overview of the changes in exurban growth, traffic demand, and connectivity values in Lincoln and Flathead counties. The report focuses on habitat connectivity for lynx, wolverine, black bear, and particularly grizzly bears. It summarizes models of connectivity that in some cases are based on animal location data from elsewhere (black bears-Cushman et al. 2009, grizzly bears-Proctor et al. 2015, lynx- Squires et al. 2013, wolverines- Schwartz et al. 2009) and two coarse-filter approaches (forest generalist species- MFWP 2011, forest biome- WGA 2013) that partially overlap the US2 study area. It also prioritizes 3 lengths of highway in this study area as potential highway mitigation sites, namely east of Essex between mileposts 181 and 184; east of Essex between mileposts 189 and 190; and the South Fork of the Flathead intersection with US2 near Hungry Horse. The last location is currently under reconstruction.

Weaver (2014) created circuit theory based (McRae et al. 2008; Dickson et al. 2018) models for grizzly bears, wolverines, and mountain goats in the US2 corridor between East and West Glacier. Based on model outputs, he selected the length of highway between Pinnacle (MP 175) and Skyland (MP 194) as a priority area to maintain connectivity for these species and others.

Servheen et al. (2003) analyzed the extent of fracture in linkage areas between grizzly bear recovery areas, but also included fractures within the US2 corridor between East and West Glacier. Areas without development were identified as putative linkage zones.

One important component is consideration of the appropriate scale for research and management. While it is useful to begin with an understanding of general regions that need to be connected, at some point, fine-scale data is needed to refine and focus mitigation efforts.

Assessments of existing datasets conducted for this report

In the first workshop meeting, participants identified some simple assessments to help inform the state of our datasets and knowledge. We gathered and then evaluated basic relationships between existing mapped datasets and looked closely at the context of the locations identified as priorities in earlier work to assess whether those were reasonable mitigation locations.

Patterns along the highway

From west to east, the corridor is a moderately developed area on the west, to a section of largely protected and forested lands with a moderately large fast moving river between West Glacier and the entry of the Middle Fork, to a complex set of smaller streams and riparian vegetation on the east. We summarized the local highway datasets described above by mile to visualize outstanding patterns. The highest number of carcasses by far occurs on the west end of the study area (MP 140; Figure 3). There are a few regions where carcasses occur in closer proximity to streams (Figure 4). The maps also highlight a few areas where wildlife trails are in close proximity to areas with carcasses (Figure 5). Some overlap exists for carcass and collision sites (Figure 6). Visualization of the distance between wildlife trails and streams not including the Flathead River, suggests that many of the wildlife trails, particularly on the eastern half of the corridor are very near streams (Figure 7). Wildlife trails occur on a mix of private ownership, public ownership, and conservation easement lands (Figure 8).

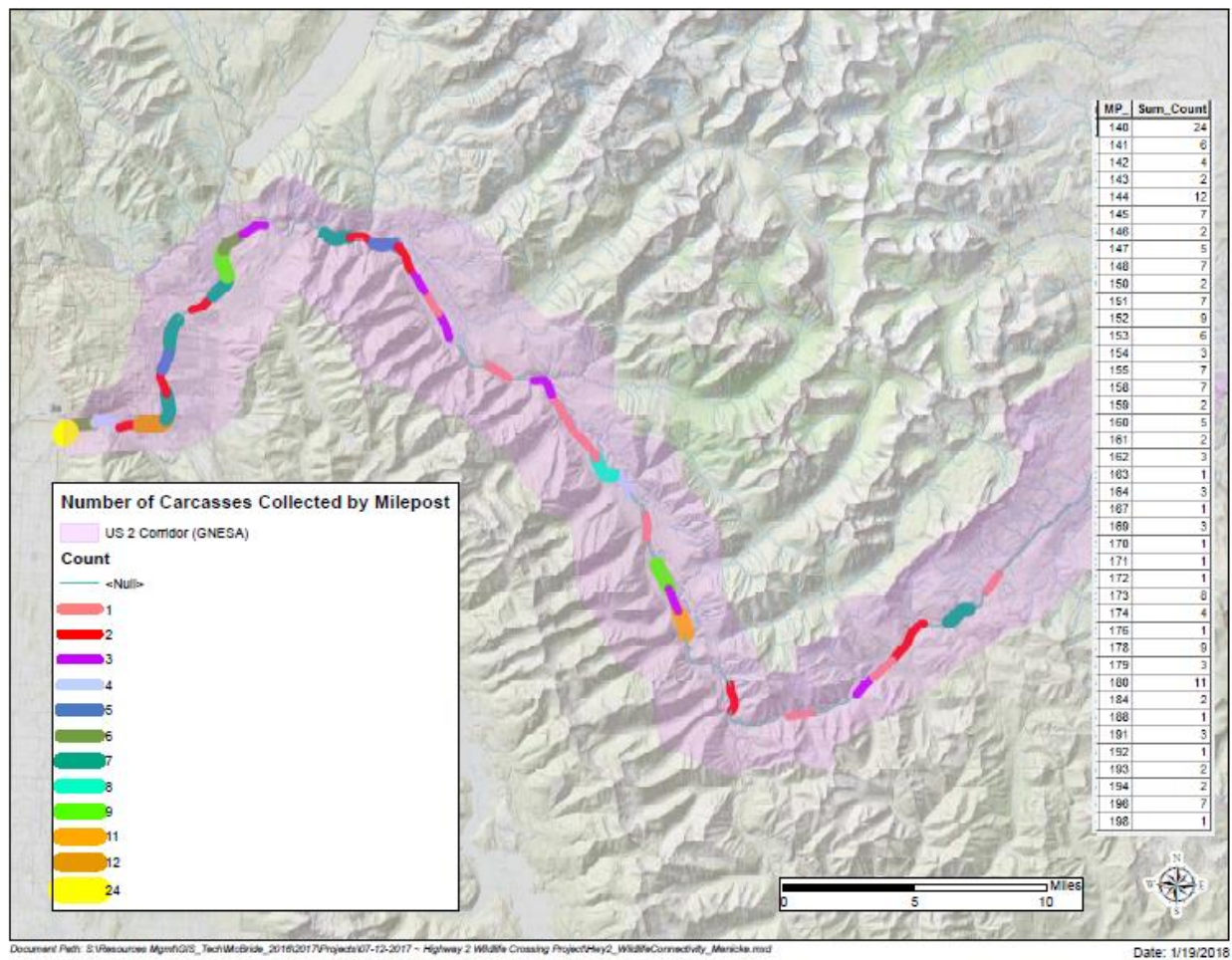


Figure 3. Carcasses collected by MDOT along US2 in Flathead County in density per mile.

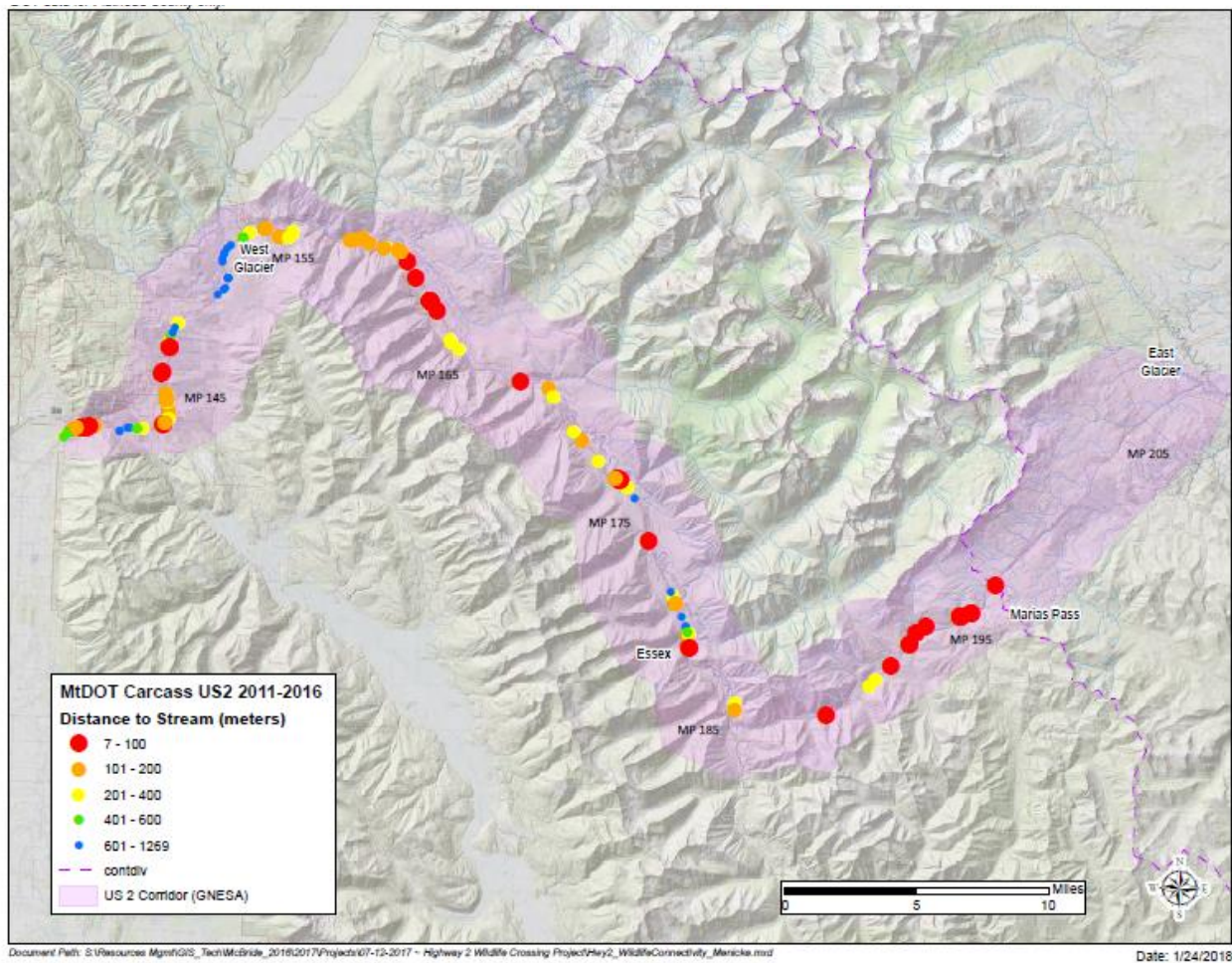


Figure 4. Carcasses collected by MDTOT along US2 in Flathead County by distance to nearest stream.

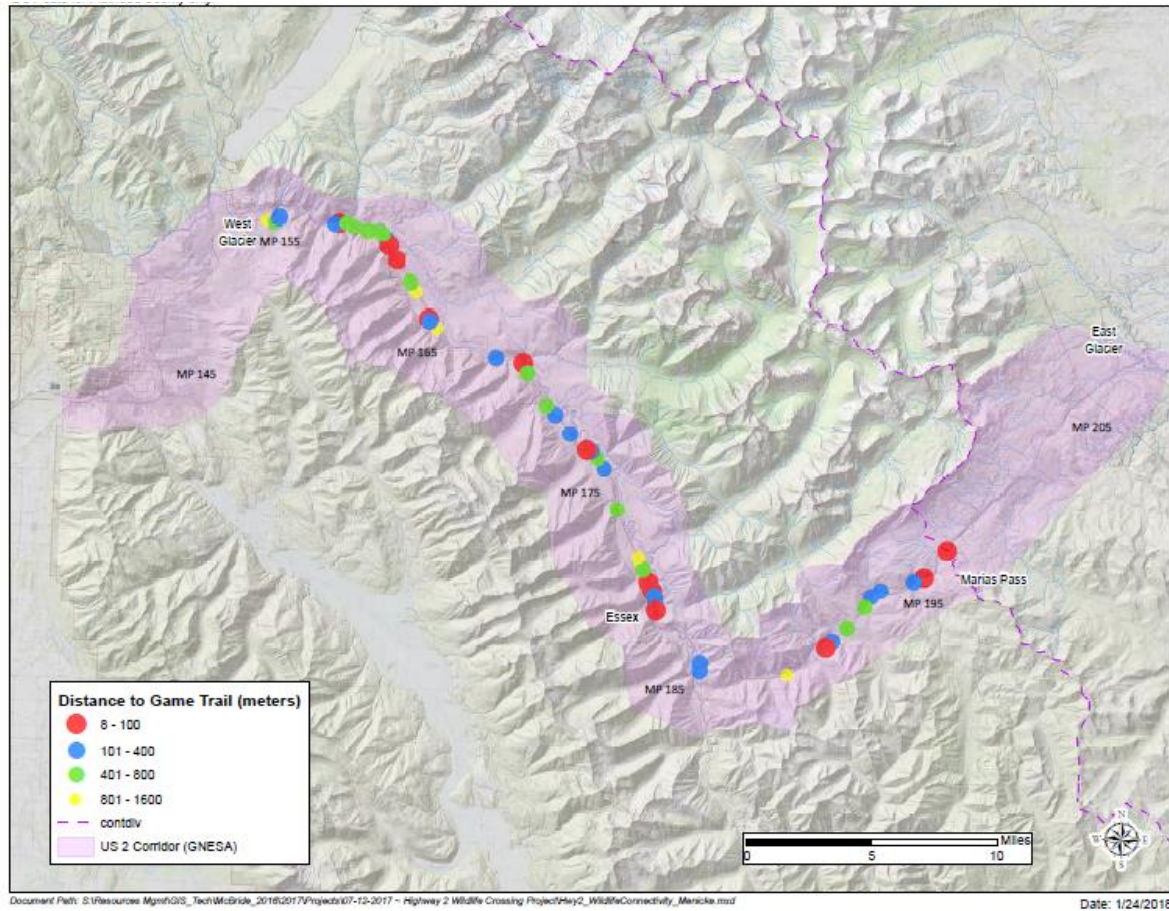


Figure 5. Carcasses collected by MDOT along US2 in Flathead County by distance to nearest wildlife trail.

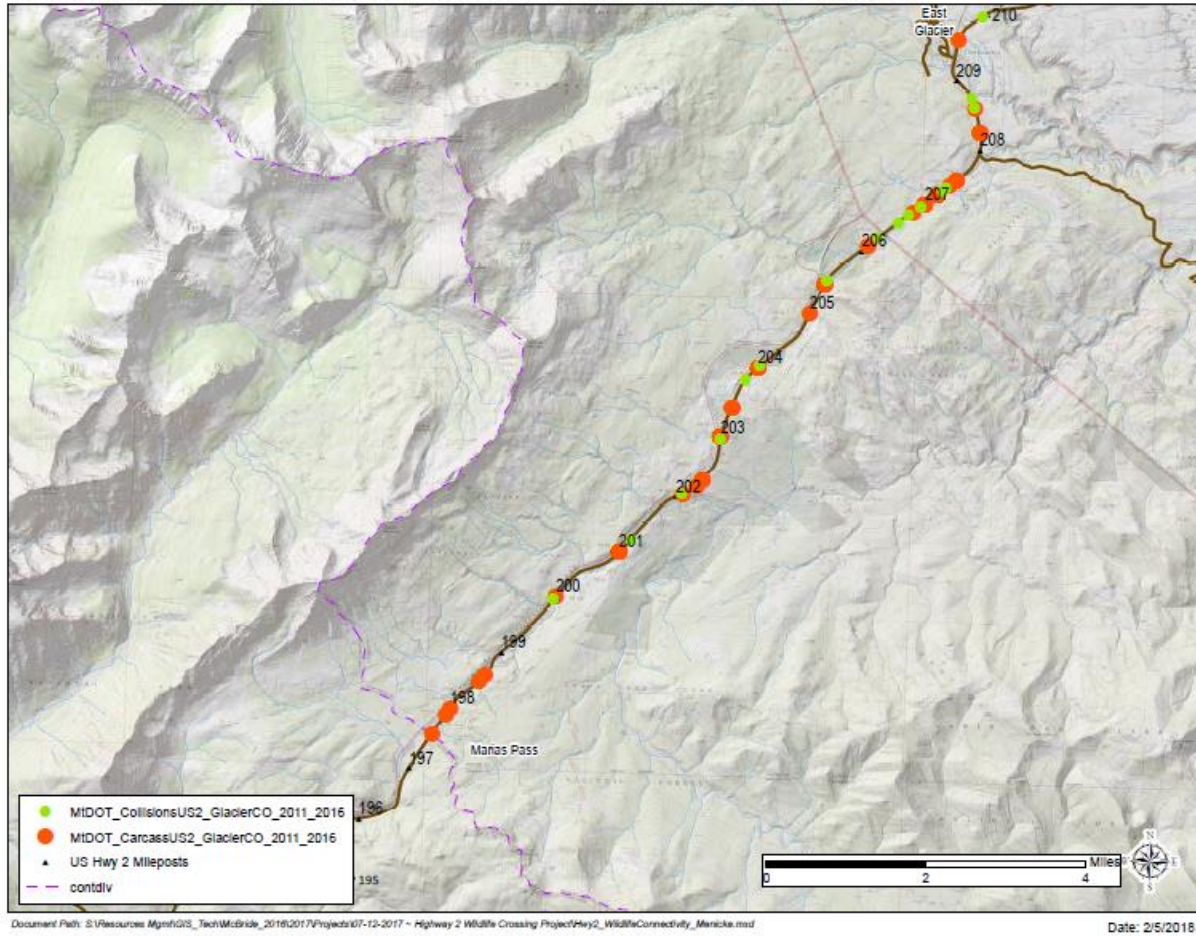


Figure 6. Carcasses and collision sites recorded by MDOT along US2 in Glacier County.

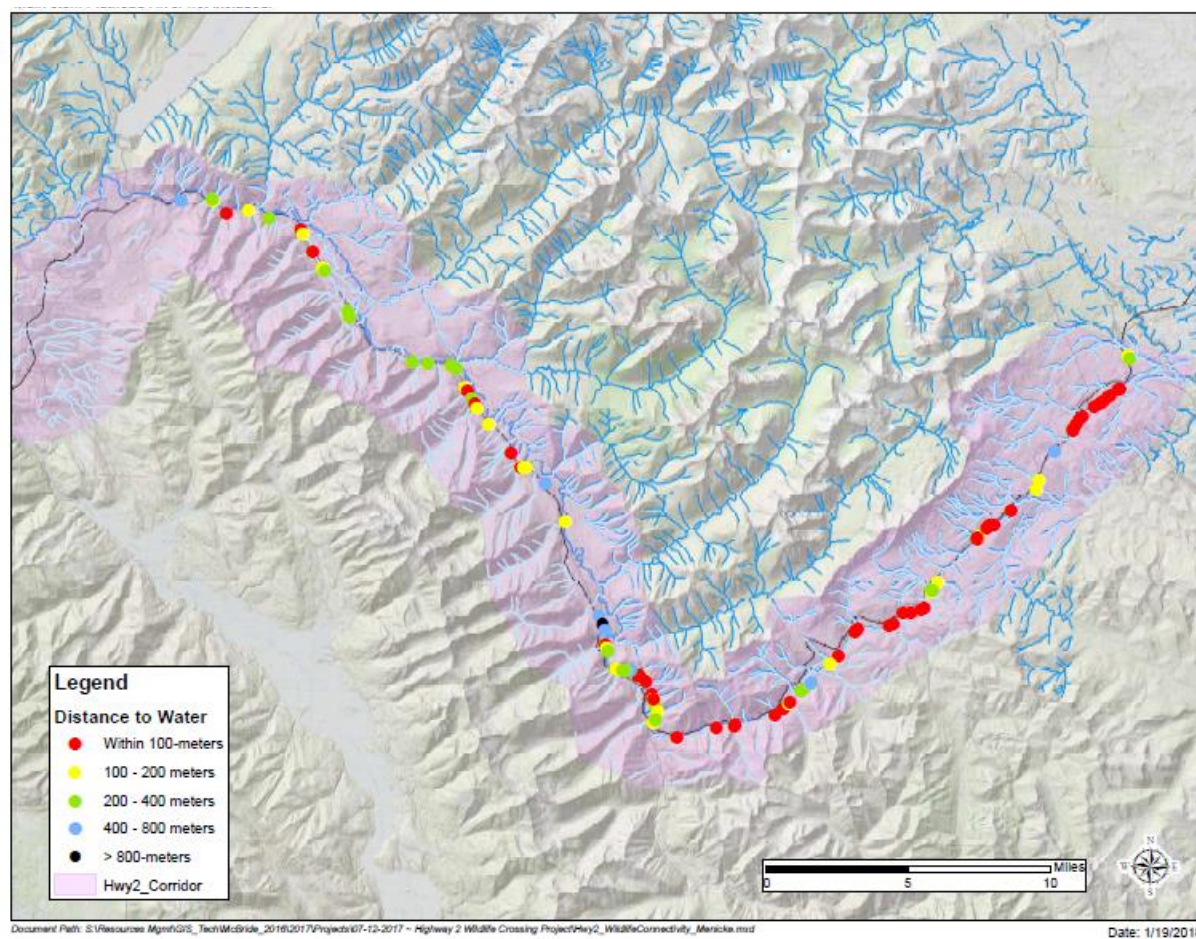


Figure 7. Wildlife trails by proximity to water along US2 between West Glacier and East Glacier, Montana, (not including the main stem Flathead River).

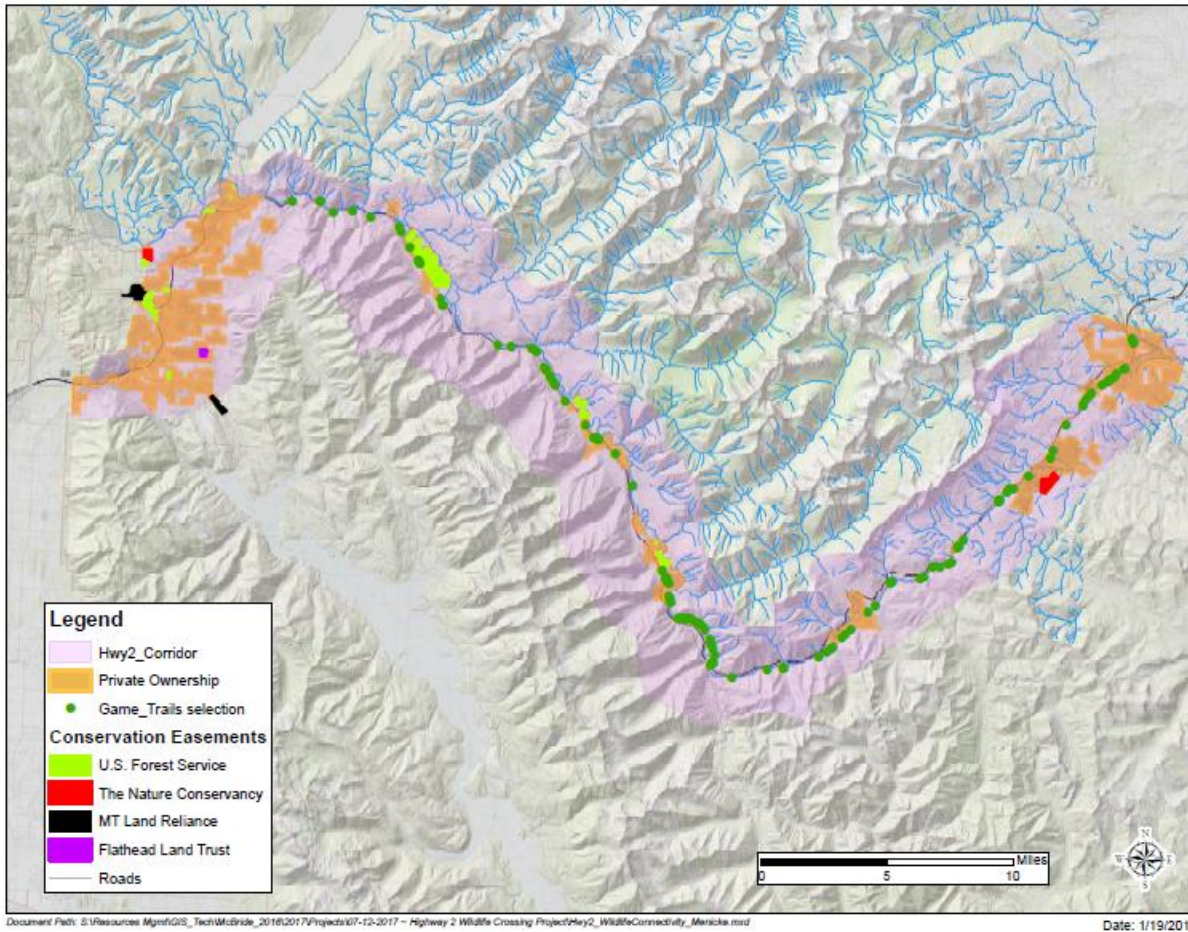


Figure 8. Wildlife trails by land ownership along US2 between West Glacier and East Glacier, Montana.

Basic summaries

As an additional initial assessment, we evaluated correlations among highway variables we expected could be related to each other. We calculated the correlations based on the summaries of the variables by mile (e.g., the correlation of minimum elevation per mile with the number of wildlife trails per mile). At this scale and with this rather limited approach, we found only moderate levels ($r < 0.47$) of correlation among elevation, average slope, the number of wildlife trails, the number of collisions between November and April, the number of collisions between May and October, the number of carcasses between November and April, and the number of carcasses per mile between May and October (Table 2). This suggests that relationships among these variables are either not causal (i.e., average slope is not related to wildlife trails or the number of summer collisions), or alternatively that relationships are more complex than this simple approach identified. It is likely that there are more complex relationships given the landscape variation along the length of the highway corridor.

Table 2. Correlations of variables along the highway (based on characterization at 1 mile intervals)

	Elev_FtMin	Elev_FtMax	Average Slope	Wildlife Trails	Collisions Nov-April	Collisions May-Oct	Carcasses Nov-April
Elev_FtMin							
Elev_FtMax	0.99						
Average Slope	-0.18	-0.13					
Wildlife Trails	0.31	0.30	0.04				
Collisions Nov-April	-0.24	-0.24	0.13	-0.17			
Collisions May-Oct	-0.26	-0.27	-0.15	-0.25	0.29		
Carcasses Nov-April	-0.28	-0.28	0.12	-0.23	0.35	0.35	
Carcass May-Oct	-0.03	-0.03	0.04	-0.07	0.09	0.41	0.47

We assessed relationships between counts of wildlife trails per mile and multiple variables that we hypothesized could be related to the distribution of wildlife trails including water (streams, rivers), bridges, culverts, and cover. As noted earlier, the wildlife trail map extends only between West Glacier and East Glacier, so this analysis applies only to that area. The strongest pattern was between wildlife trails and culverts. The majority of wildlife trails were very near culverts, half of them within 120 m of a culvert (Figure 9). The culvert placement should reflect not only larger streams, but also micro-topography where drainage occurs. As animals may also move along micro-topography, this might reflect a straightforward and inexpensive approach to considering placement for wildlife crossings. Although patterns in wildlife trail distance to cover were not obvious, this might reflect the methods used to quantify distance to cover more than a lack of pattern. We recorded distance to cover based on aerial imagery. However, in many cases it appeared that there was imperfect alignment between wildlife trail locations and the imagery. Furthermore, micro-topography can also shield animals from view. Thus, to better understand the placement of wildlife trails, measurements with a rangefinder at the wildlife trail locations would be needed.

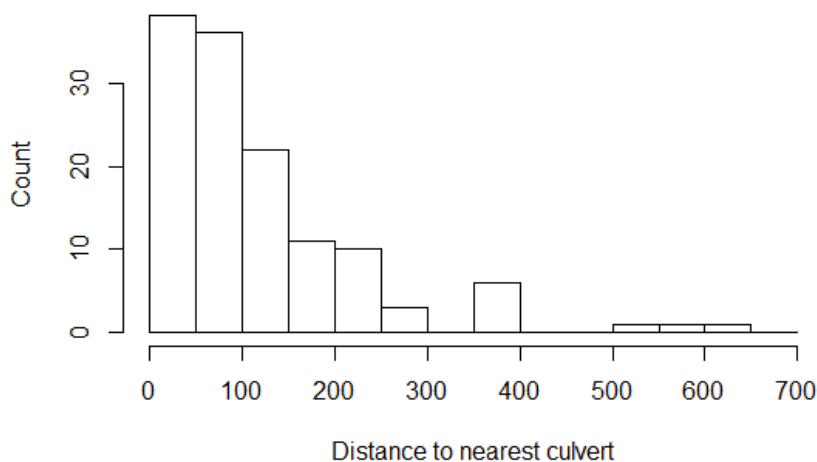


Figure 9. Wildlife trails by distance to nearest culvert.

Review of previously identified mitigation locations

Altogether, 6 general areas have been identified as potential highway mitigation sites in previous reports: 1) the South Fork of the Flathead intersection with US2 near Hungry Horse, MP 142 (Ament et al. 2014), 2) near MP 173 (Roesch 2010), 3) east of Essex, MP 181 to 184 (Roesch 2010; Ament et al. 2014), 4) MP 189 to 193 (Roesch 2010; Ament et al. 2014), 5) MP 197-197.2 (Holdhusen 2016), and 6) MP 199.8-200 (Holdhusen 2016). The first location is currently under reconstruction and we will not consider it further here. Weaver (2014) identified a broad stretch of the highway between Pinnacle (MP 175) and Skyland (MP 194) as a priority area to maintain connectivity for grizzly bears, wolverines, and mountain goats. As this area encompasses several of the finer scale locations identified by others we focus here on those locations.

MP 173

Roesch (2010) identified this area with a railroad tunnel that had several wildlife trails directly above the tunnel, a large culvert running underneath the highway at Tunnel Creek, and a railroad bridge crossing Tunnel Creek as well. He suggested enlargement of this tunnel might promote movement even further.

In evaluating the 2009 and 2013 NAIP imagery for this site, little obvious change in land cover or development has occurred. Public land is present on both sides of the US2 corridor here. Thus, this location seems to have value for further consideration. Also, a few additional collisions have occurred in this area since Roesch's figure below, suggesting that mitigation may result in safety improvements.

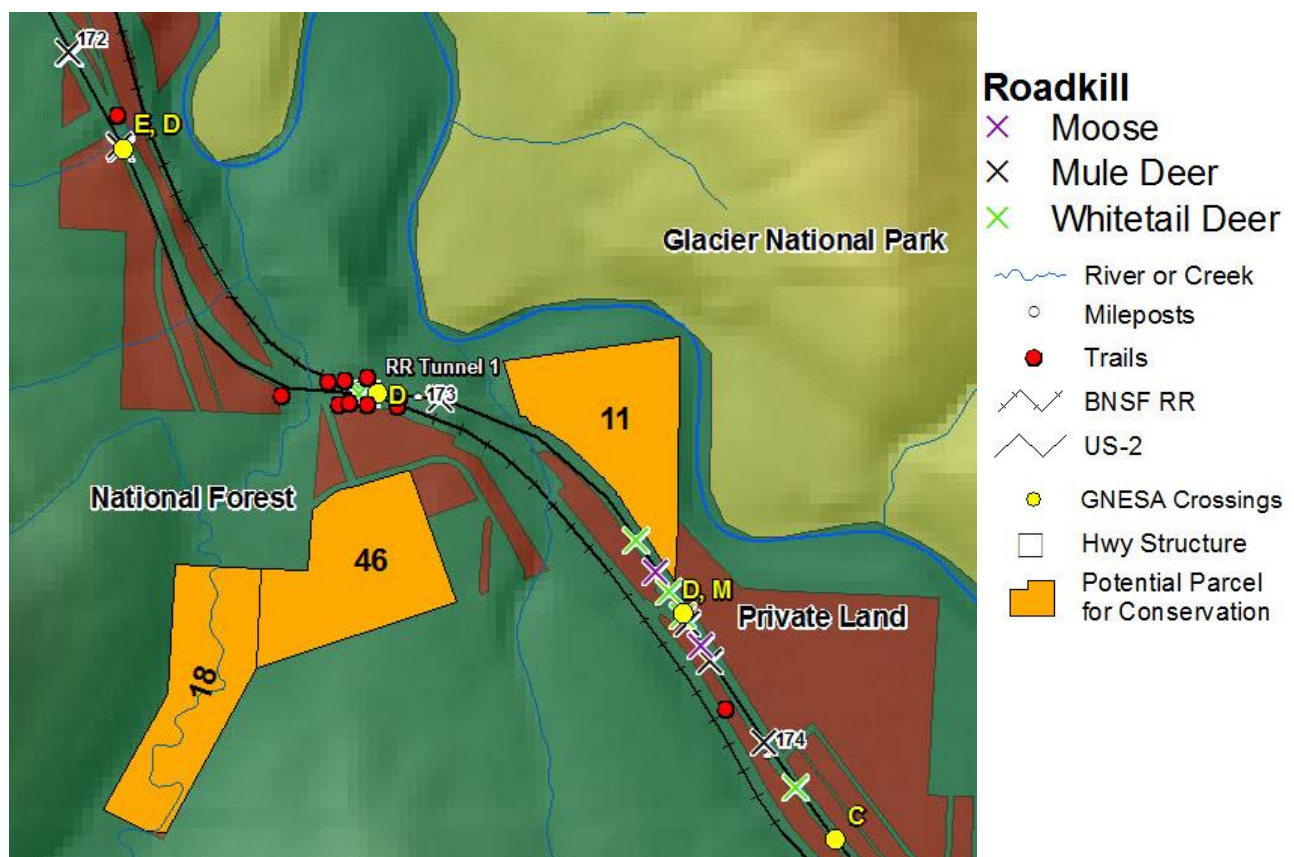


Figure 10. Figure 9 from Roesch (2010) illustrating relevant data from MP173. Crossings identified in the first GNESA effort to include observations are identified as C=Cougar, E=elk, M=Moose, and D= deer.



Figure 11. Site photo from Roesch (2010)

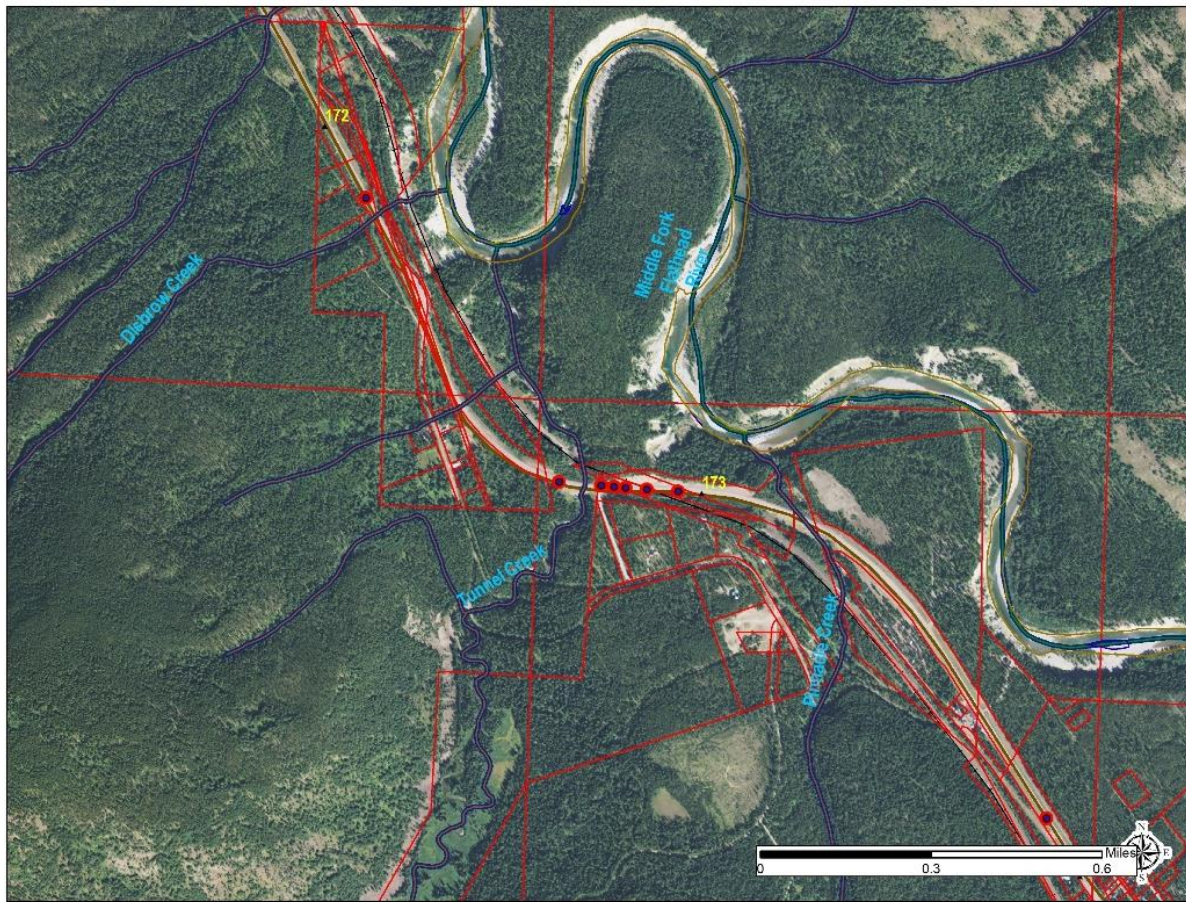


Figure 12. NAIP 2013 imagery with the Montana Cadastral property ownership outlines (red), wildlife trails (red with dark dots), US2 (brown) and streams (blue).

MP 181 - MP 184

Roesch (2010) initially identified this potential crossing zone due to a large density of wildlife trails at multiple scales of his assessment. There is also a relatively large distance between the railroad and US2 here. The only railroad bridge over the Middle Fork of the Flathead is near MP 184. Also in this stretch are the mountain goat underpass, a highway bridge over Snowslide Gulch, and a highway bridge over the Middle Fork of the Flathead.

This area has Glacier National Park on one side and Flathead National Forest on the other. Avalanches are common on the east side of this stretch of the corridor, so it is possible that maintenance would be reduced if culverts were enlarged where possible. Relatively few collisions have been recorded in this area. Thus, this stretch seems to have value for more local consideration.



Figure 13. Figure 8 from Roesch (2010) illustrating relevant data from MP181-184. Crossings identified in the first GNESA effort to include observations are identified as E=elk, G=Goats, and MD=mule deer.

MP 189-193

This area was identified by both Roesch (2010) and Ament et al. (2014). There is public land on both sides of the corridor. Houses were added to the subdivision near Giefer Creek between 2009 and 2013, and there are a few new collision records in this stretch since Roesch (2010). When this area is given fine-scale evaluation, potential unintended consequences of funneling animals into this subdivision should be considered.

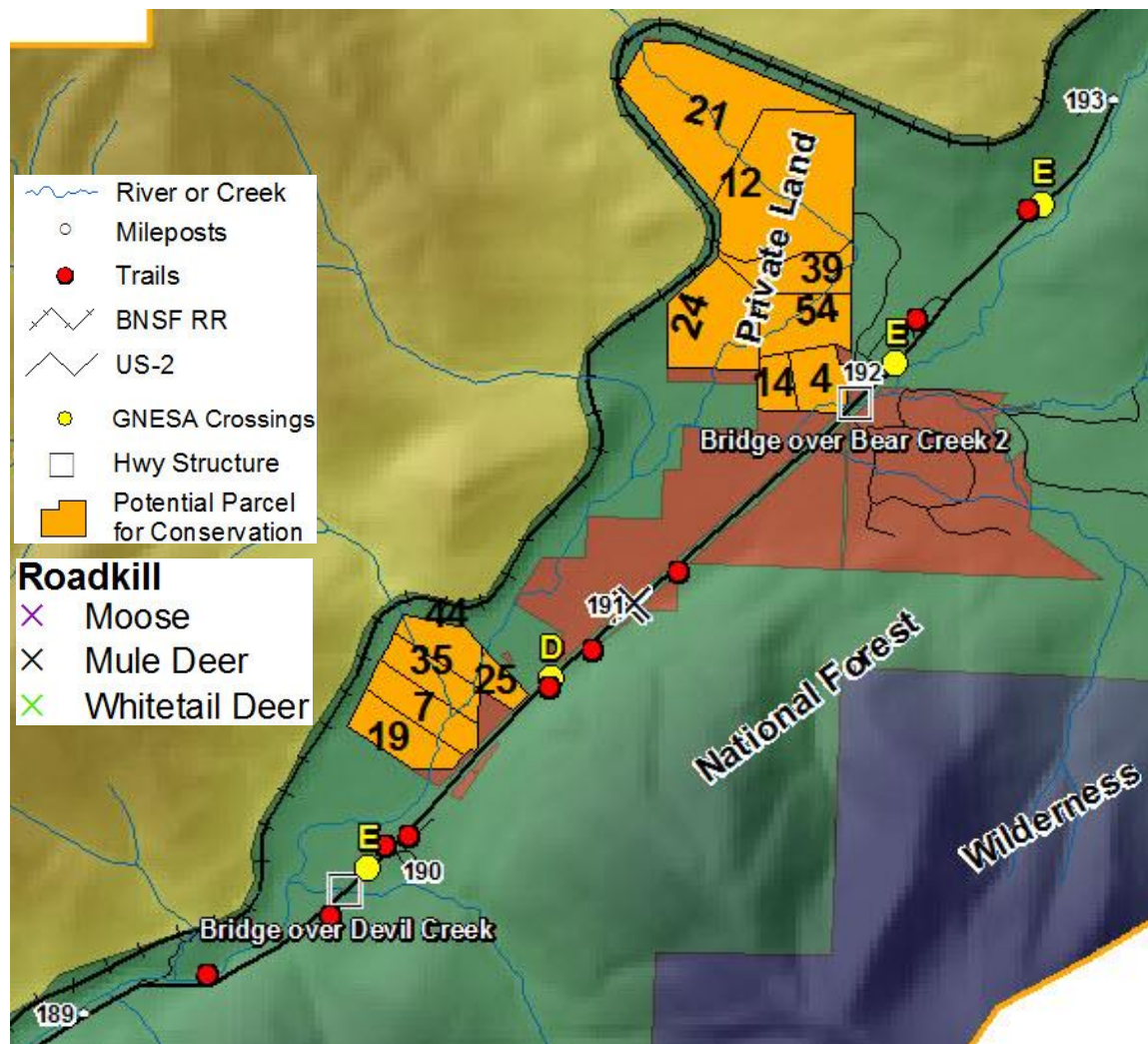


Figure 14. Figure 11 from Roesch (2010) illustrating relevant data from MP189-193. Crossings identified in the first GNESA effort to include observations are identified as E=elk, and D= deer.

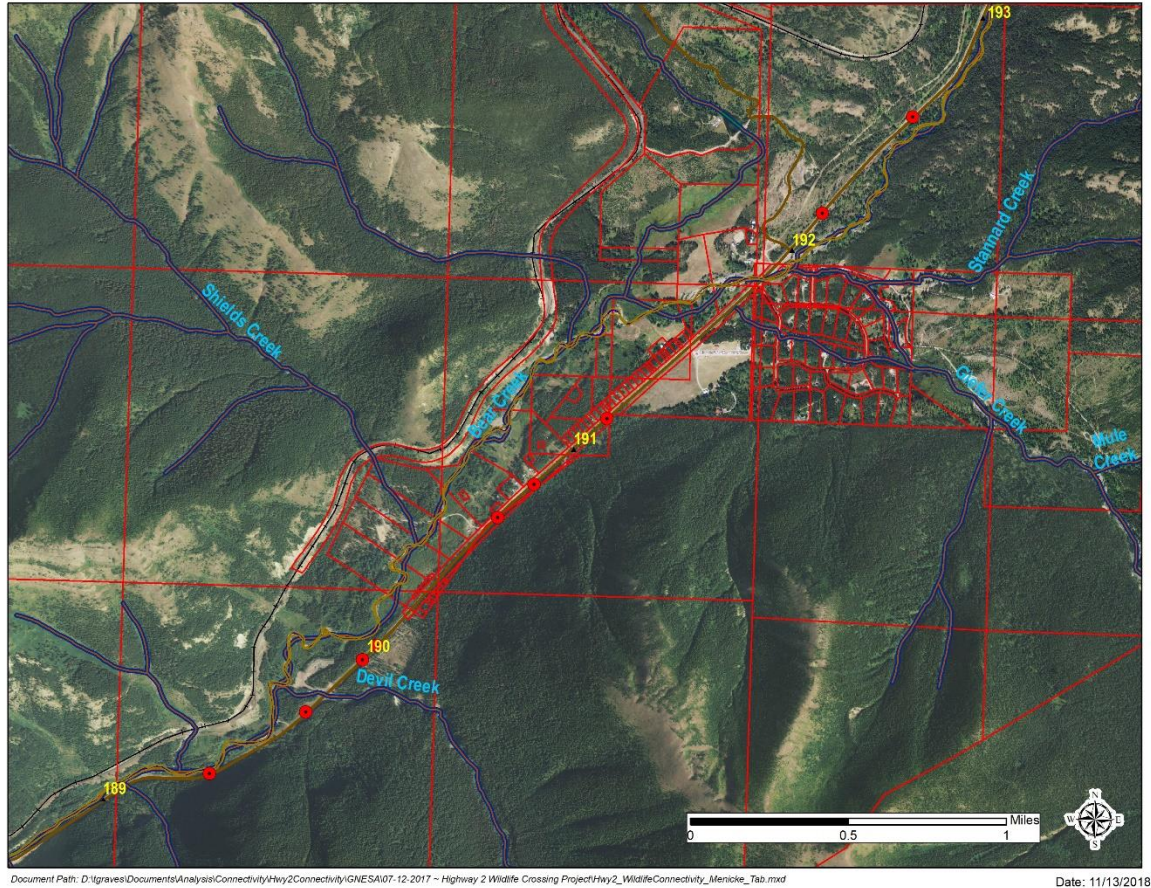


Figure 15. NAIP imagery with the Montana Cadastral property ownership outlines (red), wildlife trails (red with dark dots), US2 (brown) and streams (blue). Note that Giefer Creek is near the Bridge over Bear Creek 2, depicted in Figure 11 from Roesch (2010).

MP 197-197.2

Holdhusen (2016) identified this stretch at the west end of Marias Pass as an important crossing area, with a large network of wildlife trails clustered together. The trails are stacked up near a small tract of private land with a business that has intermittently operated as a restaurant and resort over the last decade. A small riparian area likely serves to funnel animals to this crossing area. This area is also near a section of railroad used for swapping engines that runs near Bear Creek. On the east side of the corridor animals would encounter the Pike Creek Road and a utility line cut.

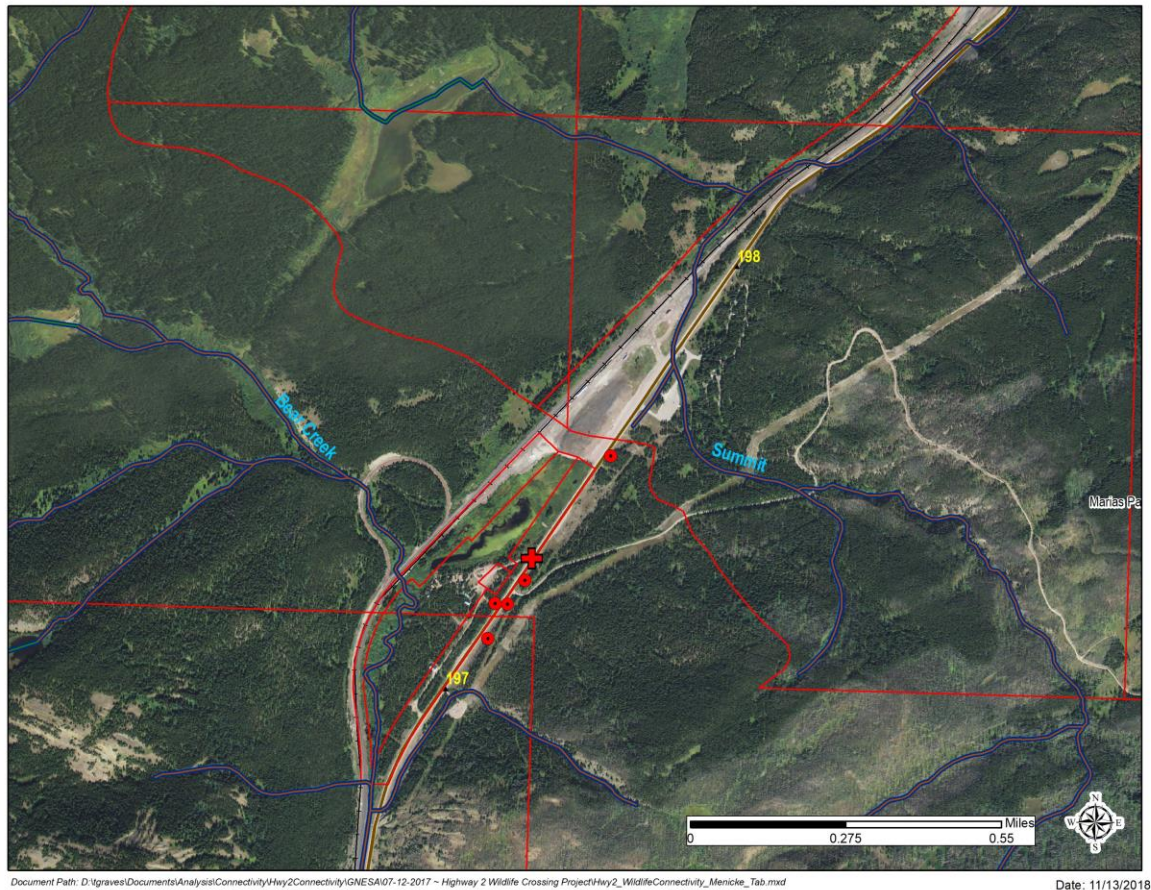


Figure 16. NAIP imagery with the Montana Cadastral property ownership outlines (red), wildlife trails (red with dark dots), US2 (brown) and streams (blue).

MP 199.8-200

Holdhusen (2016) identified this stretch with many clustered trails and large numbers of wildlife occurrences as detected with remote cameras. However, she noted that the railroad is quite near US2 so infrastructure would need to span both the highway and the railroad. To the west the creek that crosses near there is bordered by open meadows conducive to easy movement for wildlife. The cover is relatively close to the road here compared to the land on either side of the wildlife trail cluster.

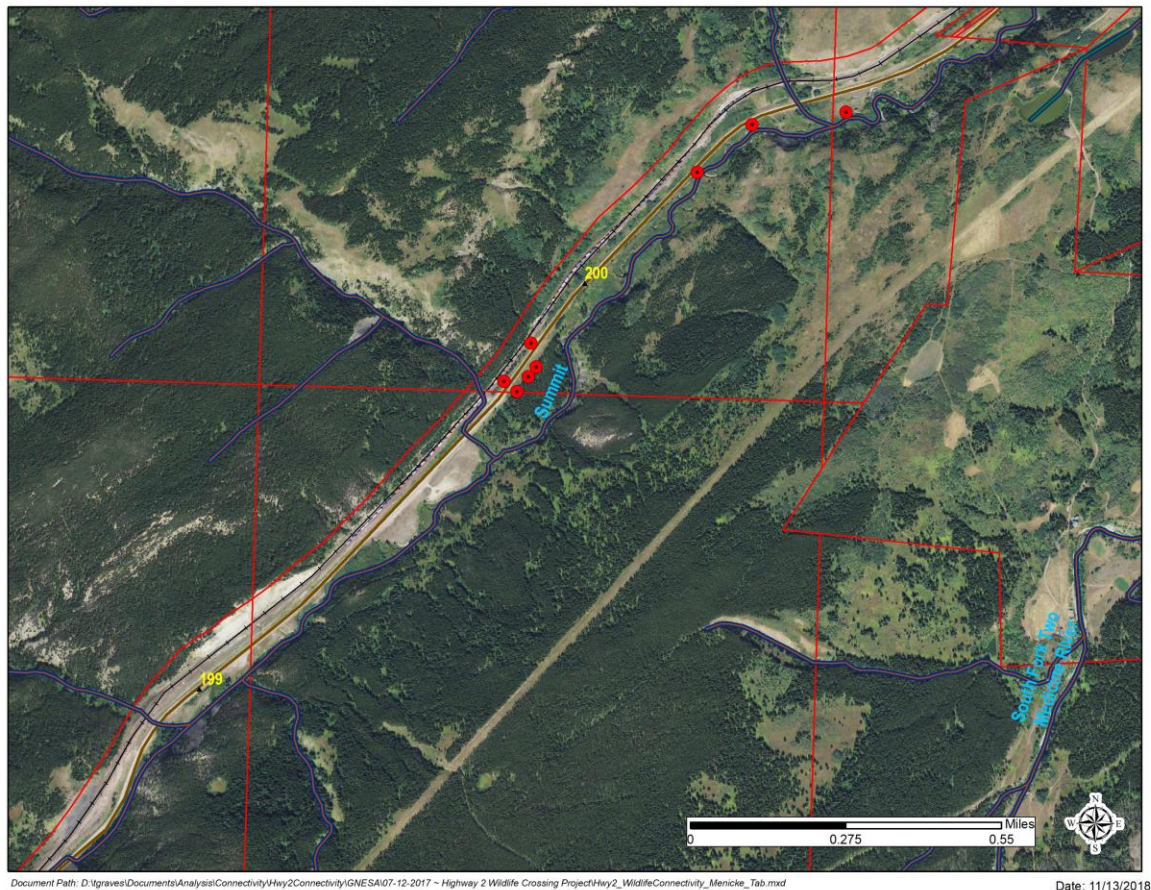


Figure 17 Figure 16. NAIP imagery with the Montana Cadastral property ownership outlines (red), wildlife trails (red with dark dots), US2 (brown) and streams (blue).

Research Needs and Framework

Through this process the interagency group identified many research needs and an overall framework for the next steps to meet the short term goal of identifying highway crossing structure locations. These are all considered priorities. Some of the items on this list will likely be easily achieved with existing agency resources, whereas others will need targeted funding and resources. This report will also serve as a resource for other connectivity planning efforts.

Local species-specific data

We have very little fine scale data for nearly any species in the corridor and very little knowledge of which species are currently satisfactorily connected at demographic or genetic levels. The exceptions are grizzly bears, black bears, and bighorn sheep. Due to the grizzly bear's threatened status and potential role as an umbrella species for conservation, substantial research on that species exists. GPS collar data for grizzly bears prior to 2002 have been analyzed to assess crossing locations east of Essex, MT (Waller and Servheen 2005). Grizzly and black bear genetic data and modern grizzly bear GPS collar data have not been analyzed with the goal of informing crossing structure placement (e.g., Royle et al. 2013; Graves et al. 2014). MT Fish Wildlife and Parks researchers will evaluate the potential to add a 'geofence' around this study area that will switch current grizzly bear collars to record more frequent locations to improve the resolution of data collected for these objectives. Similarly, while bighorn sheep GPS collar and genetic data exist within the park and even within the corridor, estimates of resistance to forest or other landscape features have not been completed. USGS researchers will look for opportunities to analyze grizzly and black bear genetic data, as well as all bighorn data for the purposes of connectivity planning. Glacier National Park and USGS are working with Colorado State University on a mountain goat project that will include goats near the Goat Lick crossing. Other species-specific data would be useful. Currently, we have very limited knowledge of whether or where local ungulate populations are primarily migrants or residents. The degree of site fidelity and thus resilience to changes in any migratory routes is also unknown.

Challenges to obtaining a reasonable sample size of collared animals to inform connectivity planning include 1) a large study area, 2) large populations of many species of interest, 3) alignment of multiple potential barriers (highway, railroad, river, topographic, buildings/roads development, high recreational activity areas), and 4) high cost, challenging logistics, and large time requirement of collaring relatively rare or wide-ranging animals such as lynx or wolverine. Therefore, many in the interagency group felt that collaring efforts should focus first on common animals (e.g., deer and elk) and it may be most efficient to focus these efforts where there are multiple information needs for the species of interest or the ability to target fine-scale information where other information suggests a broad region is being used. It may also be more cost-efficient, particularly for rare and wide-ranging species, to conduct a mapping effort targeting local observations of wildlife crossing events. This would update an earlier assessment conducted in the initial GNESEA work, but would have increased outreach objectives, and would focus on the highway as well as the railroad.

Highway specific data

While substantial information exists to inform crossing structure placement, the interagency group identified several additional useful pieces of information. First, given the high expense of crossing structures, maps of realistic options for crossing structure locations may help with prioritization because

mitigation in those areas may be more achievable. In addition, that information could help focus efforts to understand and assess fine-scale animal movements. For example, if there are 10 great locations from an engineering perspective, targeted collaring efforts or camera trapping could provide information on the species and frequencies of crossing at current times. This could be compared across those possible locations or be otherwise used in stratified approaches to inform prioritization of mitigation efforts. Also, while maps of culverts exist, some of the attributes appear to have errors. An update of this information source would be helpful, especially given the association between wildlife trails and culverts.

A map and assessment of wildlife trails adjacent to US2 between Highway 206 and West Glacier would be useful, especially given the high level of carcasses and collisions in that area and the rapid pace of current development there.

The interagency group also identified 2 ways to potentially improve animal carcass records. The first involves learning whether and how carcasses retrieved for use of meat are uploaded to other carcass and collision databases. The second improvement would be to have agency staff who collect carcasses for use in wildlife trapping ensure that they also record carcass dates and locations.

Maps of river depth, width, and speed of the Middle Fork of the Flathead would be useful for expert or data driven circuit theory approaches to connectivity planning. This kind of information may also be useful for planning for potential oil spills given the adjacent railroad in many places, supplementing existing coarse level information. Alternatively a model of ‘crossability’ would be useful. This might be obtained via interviews with locals or a targeted request to rafting companies, National Park Service, US Forest Service personnel, or other river users. Updated information on wildlife crossings of the railroad is needed to address it as a potential barrier.

Given the complexity of the highway corridor and likely interactions between multiple variables influencing the locations of wildlife trails and collisions, additional information and analysis on the multivariate interactions among these variables would likely be useful in prioritizing wildlife crossing structures. We conducted a relatively cursory assessment. Additional analyses on the characteristics of forest and land cover, the relative use of wildlife trails, identification of places of high collisions near wildlife trail clusters, and additional temporal assessments of carcass and collision locations may also be useful.

Research Framework

The interagency group agreed that a prioritization approach using circuit theory based analysis (Dickson et al. 2018), incorporating expert opinion where necessary, models for our species in similar ecosystems where appropriate, and data where possible, in combination with targeted data collection for validation purposes would likely be the most efficient way to work together to develop a science-based prioritization of crossing structure locations and further understand the highest research priorities. We found a prior research study that supported this integrative approach (Boyle et al. 2017), and highlighted that combining data types and approaches can address the challenges of working across the multiple scales important to a wide range of wildlife species.

Additional analyses of existing data are low-hanging fruit and much of the additional map needs may be easily collectable through technicians and students. Similarly, validation of crossing areas defined in regional efforts, especially for species of conservation concern will be highly useful (e.g., existing wolverine and lynx models).

We also note that many questions remain about how to best mitigate highway impacts for different species and in different contexts (e.g., summary in Rytwinski et al. 2015). Thus, research focused on understanding these kinds of questions can contribute to improved mitigation efforts in the future.

Potential funding sources

The interagency group identified the following potential funding sources:

- Non-federal e.g., Wilburforce; WCS/Doris Duke CC Adaptation; Vital ground; GNPC
- Crown Manager Partnership; probably supportive of low-hanging fruit analyses and workshops for circuitscape weights, and similar low-cost efforts
- Funding specific to each agency
- Interns (MDOT, UM, NSF-GRIP graduate student fellows for USGS, Jerry O’Neil)
- MDOT or FHWA
- Federal infrastructure bills

Management

Intersection of research and management

Currently, the process to incorporate feedback from wildlife managers occurs through the wildlife accommodation process (e.g., NEPA) and U.S. Fish and Wildlife Service consultation on threatened and endangered species. This often occurs very late in the process of developing engineering plans. Where possible it will be highly useful for wildlife biologists and highway engineers to engage in discussion early in road projects.

Interim wildlife highway crossing priorities

While this interagency group’s initial goals did not include the identification of specific management actions, this process identified several interim priorities for highway repairs and reconstruction to support wildlife connectivity.

First, given the association between wildlife trails and streams and between wildlife trails and culverts, where possible, culvert upsizing would likely improve connectivity for many wildlife species. Culverts are sometimes damaged by avalanches or other problems and therefore might be replaced in a relatively short time span with limited planning. As preformed larger culverts often exist, this will likely be a relatively low-cost and highly feasible option for achieving connectivity objectives in this area.

Second, our review of the previously identified locations did not find any contra-indications to their development as priority crossing areas, aside from the Geifer Creek subdivision. While this interagency group did not feel confident that these areas alone would be sufficient for achieving long-term connectivity goals, they represent reasonable options for mitigation structures if funding is available before a more complete prioritization process can be completed.

Third, we noted that the highest number of carcasses and collisions occurred in the stretch between Badrock Canyon and Columbia Falls. Participants noted that this likely serves as an important crossing area for other species as well. This was a shared area of concern.

This interagency group agrees that aquatic species, plants, and ecological processes are also important to consider, but this set of workshops did not review that literature given the expertise of participants and the funding available for this initial review.

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