Wildlife barriers: Modified jump-outs for white-tailed deer and mule deer

NDOT Research Report No. 701-18-803 TO 6 Part 1

Wildlife Vehicle Collision Reduction and Habitat Connectivity Pooled Fund Study, TPF-5(358)

REDUCE
Wildlife Vehicle Collisions

INCREASE
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IMPLEMENT
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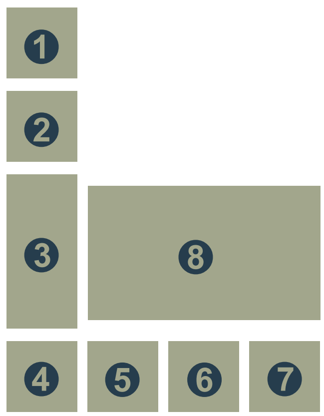

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REDUCE Wildlife Vehicle Collisions
INCREASE Habitat Connectivity
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NDOT Research Report

Report No. 701-18-803 TO 6 Part 1

TPF-5(358)
PART 1 - WILDLIFE BARRIERS: MODIFIED JUMP-OUTS FOR WHITE-TAILED DEER AND MULE DEER

September 2022

Nevada Department of Transportation
1263 South Stewart Street
Carson City, NV 89712

Contributing Partners

Alaska DOT
ARC Solutions, Inc.
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16. Abstract

The height of the jump-outs should be low enough for the target species to readily jump down to the safe side, or the habitat side, of the fence. At the same time, the jump-outs should be high enough to discourage animals that are on the habitat side of the fence from jumping up into the fenced road corridor. Previous research along US Hwy 93 North in Montana showed that only about 32% of the mule deer and about 7% of the white-tailed deer that appeared on top of the jump-outs, jumped down to safety. For this project, 10 of the jump-outs along US Hwy 93 North were lowered in height and provided with a bar on top. The height of the bars (made from rebar) and their setback from the vertical face of the jump-outs was adjustable and the researchers applied 4 different treatments: 2 different heights (18 and 15 inches) and 3 different setbacks (4, 12, and 15 inches). The overall effectiveness of the lowered jump-outs in allowing white-tailed deer to jump down, regardless of the height and setback of the bar, was only just above 5% (no improvement). For mule deer the effectiveness of the lowered jump-outs in allowing them to jump down, regardless of the height and setback of the bar, was about 64% (this was double the effectiveness of non-modified jump-outs).

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Modified jump-outs for white-tailed deer and mule deer

Prepared for

Nevada Department of Transportation

1263 South Stewart Street

Carson City, NV 89712

For the following larger project:

Wildlife Vehicle Collision (WVC) Reduction and Habitat Connectivity

Task 1 – Cost Effective Solutions

Transportation Pooled-Fund Project TPF-5(358)

(Administered by the Nevada Department of Transportation)

Prepared by:

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30 September 2022

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DISCLAIMER

This is report submitted by the Contractor. The opinions and conclusions expressed or implied herein are those of the Contractor. They are not necessarily those of the Nevada Department of Transportation or other Pooled Fund sponsors.

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SUMMARY

Wildlife "jump-outs" or "escape ramps" are widely used to allow large wild mammals, especially ungulates, to escape fenced road corridors. Most wildlife jump-outs or escape ramps are hills that are positioned in the fenced road corridor and allow animals to walk up the slope and an opening in the fence. The height of the jump-outs should be low enough for the target species to readily jump down to the safe side, or the habitat side, of the fence. At the same time, the jump-outs should be high enough to discourage animals that are on the habitat side of the fence from jumping up into the fenced road corridor. This implies that finding an optimum height for the target species is important. However, there is very little information available on the appropriate height of jump-outs for different species. A further complication occurs when there are multiple target species in an area, each with their own jumping or climbing capabilities.

The US Hwy 93 North reconstruction project (2004-2010) on the Flathead Indian Reservation in northwest Montana included wildlife crossing structures, wildlife fences, and wildlife jump-outs. Previous research on 10 of these wildlife jump-outs (between 1.75-2.04 m (5.7-6.7 ft) high) showed that only about 32% of the mule deer and about 7% of the white-tailed deer that appeared on top of the jump-outs, jumped down to safety. In the spring of 2021, these same 10 jump-outs were lowered in height and provided with a bar on top. These jump-outs were in areas frequented by predominantly white-tailed deer (6 jump-outs in the Evaro area) and mule deer (4 jump-outs in the Ravalli Hill area). The 10 jump-outs received the following modifications:

- Lower height to exactly 5 ft (1.52 m).
- The soil that was removed from the top was deposited at the bottom of the jump-outs to level the landing area.
- Removal of tall vegetation on top and on the road-facing slopes of jump-outs, and the landing area.
- Adding a bar on top of the jump-out above the ground level. The "bars" were made from rebar. The height of the bars and setback from the vertical face of the jump-outs was adjustable and the researchers applied 4 different treatments:
  - 18 inches high, 4 inches setback.
  - 18 inches high, 12 inches setback
  - 18 inches high, 15 inches setback
  - 15 inches high, 12 inches setback

The overall effectiveness of the lowered jump-outs in allowing white-tailed deer to jump down, regardless of the height and setback of the bar, was only just above 5% (no improvement). On the other hand, no white-tailed deer jumped up into the fenced road corridor. For mule deer the effectiveness of the lowered jump-outs in allowing them to jump down, regardless of the height and setback of the bar, was about 64% (this was double the effectiveness of non-modified jump-outs). Of the mule deer that were present at the bottom of the jump-outs, just under 7% jumped up into the fenced road corridor.

Regardless of how close the animals came to the face of the jump-out, and regardless of the treatment, white-tailed deer barely jumped down (10% or less) to the habitat side of the fence.

No white-tailed deer jumped up into the fenced road corridor for any of the treatments. Regardless of how close the animals came to the face of the jump-out, and regardless of the treatment, mule deer jumped down much more readily (17.7-100.0%) than white-tailed deer. The treatment with a height of 18 inches and a setback of 15 inches had 80.4% of all mule deer that were observed within the right-of-way jump down to the habitat side of the jump-outs. At the same time, this treatment allowed 14.7% of the mule deer that were observed on the habitat side of the jump-out to jump up into the fenced road corridor. By doubling the effectiveness of the jump-outs for mule deer, 26 (52/2) more mule deer escaped from the fenced road corridor, while "only" 5 more mule deer entered the fenced road corridor, resulting in a "net benefit" of 21 mule deer which were no longer in danger of being hit by traffic.

While the modified jump-outs about doubled the effectiveness in allowing mule deer to escape the fenced road corridor, there was no improvement for white-tailed deer. Further modifications of the bar with a lower height and greater setback are warranted for white-tailed deer. It may also be that a jump-out height of 5 ft (1.52 m) is still too high for white-tailed deer, regardless of the presence, height, and setback of a bar.

1 INTRODUCTION

Historically, one-way escape gates have been implemented to allow large wild mammals, especially ungulates, to escape fenced road corridors (see review in Huijser et al. 2015). However, one-way gates are now rarely implemented because of low effectiveness in allowing animals to escape the fenced road corridor, animal intrusions into the fenced road corridor, and injuries and death of animals using the one-way gates (see review in Huijser et al. 2015). Wildlife "jump-outs" or "escape ramps" are now widely used instead. Most wildlife jump-outs or escape ramps are hills that are positioned in the fenced road corridor and allow animals to walk up the slope and an opening in the fence. The hill can be constructed out of soil or rocks, and in some cases the rocks are placed in gabion baskets. The height of the jump-outs should be low enough for the target species to readily jump down to the safe side, or the habitat side, of the fence. At the same time, the jump-outs should be high enough to discourage animals that are on the habitat side of the fence from jumping up into the fenced road corridor. This implies that finding an optimum height for the target species is important. However, there is very little information available on the appropriate height of jump-outs for different species. A further complication occurs when there are multiple target species in an area, each with their own jumping or climbing capabilities (e.g., Gagnon et al. 2020).

The face for wildlife-jump-outs has been made out of wooden planks, concrete walls, gabion baskets, or stacked interlocking concrete blocks. In some cases, metal sheeting has been attached to the face to reduce the likelihood of bears climbing up the wall into the fenced road corridor (Huijser et al. 2008). A flat and clear landing area, free of branches and debris, is recommended. Loose sand, rather than compacted soil or rocks at the bottom of jump-outs may also facilitate use and safe landings for the animals. The opening in the fence on top of the jump-out, should also be clear of branches and vegetation (Gagnon et al. 2020). The slope of a jump-out may affect jump-out use and investigating the effectiveness of a slope flatter than 3:1 is recommended (Kintsch et al. 2021). Others also recommended a more gradual approach (4:1) to the top of the jump-out (Gagnon et al. 2020). Jump-outs can also be integrated into the existing roadbed, especially near underpasses where there may be a drop-off. In those situations, no earthen mounts are required. The wildlife fence can also be lowered to 1.2-1.5 m (4-5 ft) if the fence is positioned on a steep slope angling down away from the road AZDOT 2013a, b). This construction is referred to as a "slope-jump" (AZDOT 2013a, b). It is unclear whether short sections of fence, perpendicular to the fence line, increase use of jump-outs.

In North America, the height for wildlife jump-outs that have been constructed for large mammals, particularly ungulates, varies between 1.5-3.0 m (5-10 ft) (Huijser et al. 2015). Wildlife jump-outs that were about 1.5 m (5 ft) high appear to be used much more readily (about 7.9-11.0 times more) by mule deer (*Odocoileus hemionus*) than one-way gates (Bissonette & Hammer 2000). Wildlife jump-outs that were between 1.75-2.04 m (5.7-6.7 ft) high were used by about 32% of the mule deer that appeared on top of the jump-outs but very few (7%) of white-tailed deer (*O. virginianus*) that were present on top of the jump-outs jumped down to safety (Huijser et al. 2016). Jump-outs heights between 5.4-7.3 ft (1.65-2.24 m) were only used by 10% of the mule deer and 23% of the elk (*Cervus canadensis*) that had walked up the jump-outs (Kintsch et al. 2021). Others have set the height at 2.0 m (6.6 ft) in combination with a horizontal plank that stuck out from the edge (Siepel et al. 2013). However, these jump-outs did not function well for mule deer, and it was suggested to remove either the horizontal plank or reduce the height of the jump-outs (Siepel et al. 2013). A height of 2.0 m (6.6 ft) resulted in very low use by mule deer; only 6% of the animals on top of the jump-outs jumped down to the safe side of the fence (Jensen et al. 2018). A height of about 1.50-1.68 m (5-5.5 ft) seems advisable for white-tailed deer and mule deer (review in Huijser et al. 2015). Recommended wildlife jump-out height for elk is 6 ft (1.83 m) (Gagnon et al. 2020).

A jump-out can be made to appear higher for animals that may be interested in jumping up into the fenced road corridor and lower for animals that may be interested in jumping down to the safe side of the wildlife fence. The area in front of the “vertical face,” on the safe side or habitat side of the fence, may be dug out in an area up to 1.5-1.8 m (5-6 ft) from the face (AZDOT 2013a, b). Naturally the pit should extend along the entire vertical face of the jump-out, plus an additional buffer zone of perhaps 3 ft (0.91 m). The soil may be deposited on the “landing pad” which may start 1.5-1.8 m (5-6 ft) from the vertical face. Similarly, the top of the jump-out can be made to appear higher by adding soil on top of the jump-out starting about 2.4 m (8 ft) away from the edge of the top of the jump-out (AZDOT 2013a, b). Alternatively, a metal bar or wooden plank may be attached about 46 cm (18 inches) close to the edge of the jump-out (Siemers et al. 2013, Gagnon et al. 2020). This still allows animals that are on top of the jump-out to step over or crawl under the barrier before jumping down. Animals wanting to jump up would also have to clear the bar or plank as there is insufficient space to land in front of the barrier.

In this study we investigate the effectiveness of modifications to existing jump-outs. Existing jump-outs varying in height between 1.75-2.04 m (5.7-6.7 ft) were lowered to 1.52 m (5 ft) and provided with a bar on top that varied in height and setback (i.e., distance to the face of the jump-out). We investigated potential increase in desired use (i.e., jumping down) and undesired use (i.e. jumping up) for white-tailed deer and mule deer with different configurations of the bar.

2 METHODS

2.1 Study Area

US Highway 93 North (hereafter referred to as "US Hwy 93 North") is located between Evaro and Polson on the Flathead Indian Reservation in northwest Montana, USA. The study area is a mixed-use landscape, including forested hills, upland natural grasslands, riparian zones along rivers, wetlands, pastures, cropland and mixed housing densities. County and local roads cross through the landscape in the areas adjacent to US Hwy 93 North. Major mountain ranges include the Mission Mountains to the east and the Rattlesnake Mountains to the south-east. US Hwy 93 North is a major highway that connects Interstate-90 and Missoula to the Flathead Valley with Kalispell and Glacier National Park as major destinations. Average Annual Daily Traffic was 6,700-7,600 vehicles between 2010-2015 (Huijser et al. 2016).

The US Hwy 93 North reconstruction project (2004-2010) on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56 mile (90 km) long road section included the installation of wildlife crossing structures at 39 locations and approximately 8.7 miles (14 km) of road with wildlife exclusion fences (8 ft (2.4 m) tall) on both sides of the highway (Huijser et al. 2016). Long fenced road sections also had jump-outs or escape ramps installed. The longest sections with contiguous mitigation measures are in the Evaro, Ravalli Curves, and Ravalli Hill areas (Figure 1).

2.2 Effectiveness of Existing, Non-Modified, Jump-outs

Between 2008-2015, 52 jump-outs or escape ramps were monitored using tracking beds on top and on the bottom of the jump-outs (Huijser et al. 2016) (Figure 2 and 3). Most of these jump-outs were about 6-7 ft (1.83-2.13 m) high) and had a width (i.e., gap in the fence) of about 5 m (15 ft)). Only 13.84% of the deer that were tracked on top (white-tailed deer and mule deer combined) were estimated to have jumped down. None of the deer that passed by on the habitat side of the jump-out were estimated to have jumped up into the fenced road corridor (Huijser et al. 2016). More detailed monitoring with wildlife cameras (2014-2016) of 10 of these jump-outs (varying in height 1.75-2.04 m (5.7-6.7 ft)) showed that only 6.88% of the white-tailed deer and 32.35% of the mule deer detected on the top of the jump-outs jumped down to the safe side of the fence (Huijser et al. 2016). None of the deer that passed by on the habitat side of the jump-outs were observed jumping up into the fenced road corridor (Huijser et al. 2016). Note that "a deer" may eventually jump-down, but especially white-tailed are not likely to do so on their first attempt and the deer spend more time inside the fenced road corridor than most would consider desirable. Alternatively, a deer escapes the fenced road corridor at a wildlife guard at an access road, or where the fenced road corridor ends (at a fence-end).

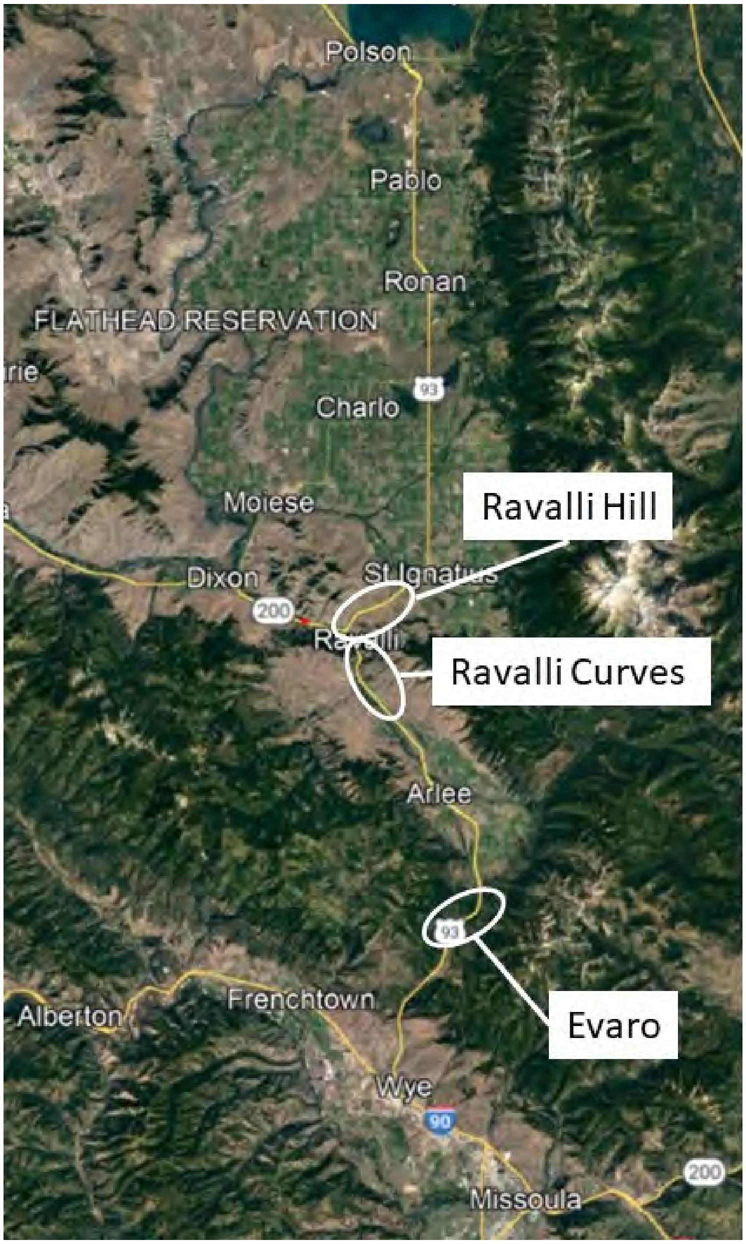

Figure 1: US Hwy 93 North between Evaro and Polson, with the longest sections of mitigated road (Evaro, Ravalli Curves, and Ravalli Hill).

Figure 2: An unmodified jump-out in the Evaro area. The mount allows the animals to walk up to an opening in the fence, with a drop of around 6 ft (1.83 m) to the habitat side of the jump-out.

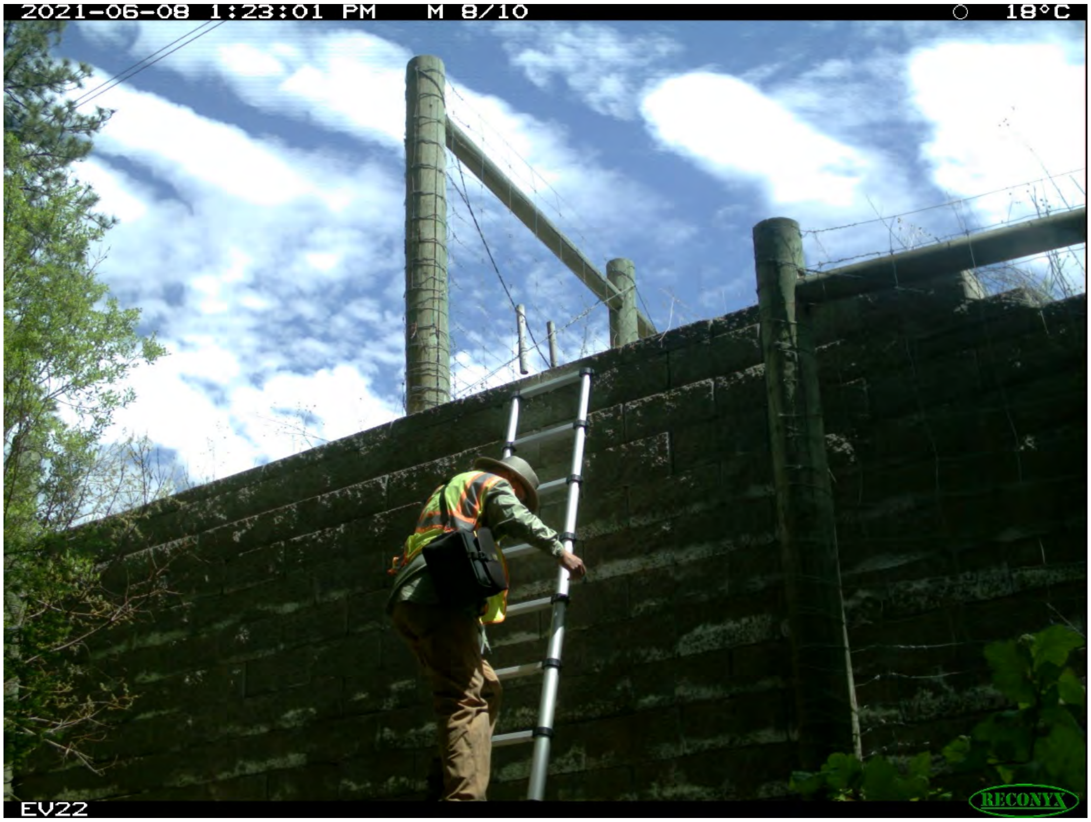

Figure 3: Some of the unmodified jump-outs are extremely high.

2.3 Modifications to the Jump-outs

The same 10 jump-outs that were monitored with trail cameras between 2014-2016 were lowered in height and provided with a bar on top in the spring of 2021 (Table 1). These jump-outs were in areas frequented by predominantly white-tailed deer (6 jump-outs in the Evaro area) and mule deer (4 jump-outs in the Ravalli Hill area) (Figures 2 and 3, Appendix). The 10 jump-outs received the following modifications:

- Lower height to exactly 5 ft (1.52 m). This was accomplished by removing soil from the top and removing one or multiple rows of the concrete blocks from the face (the wall) (Figure 4). The top blocks are 3 inches (7.6 cm) tall, and the standard blocks are 7 inches (17.8 cm) tall. The jump-outs in the Ravalli Hill area were lowered on 21 April 2021. The jump-outs in the Evaro area were lowered on 4 May 2021.
- The soil that was removed from the top was deposited at the bottom of the jump-outs to level the landing area up to about 6-7 ft (2 m) out from the vertical face of the jump-outs. This resulted in a consistent height of 5 ft (1.52 m) for vertical face of the jump-outs.
- Removal of tall vegetation on top and on the road-facing slopes of jump-outs, and the landing area.
- Adding a bar on top of the jump-out above the ground level.

A prototype of the “bar” was made from treated lumber (“2x2” inch (5x5 cm) and “4x4” inch (10x10 cm)) (Figure 5). The 4x4 inch (10x10 cm) posts sat on the top of the concrete blocks. More permanent “bars” were made from rebar (grade 60, 1/2-inch (1.25 cm) diameter) (Figure 6). The rebar was bent into giant “staples” that measured 60 inches (152 cm) horizontal and 42-inch (1.07 m) legs. The 42-inch legs allowed the “staples” to go deep into the soil of the mount for stability, and they also allowed for height adjustments (higher or lower above the ground on top). L-shaped 36-inch (91 cm) swing arms (with 42-inch legs) were used to connect the bar to the fence posts at each side of the jump-out (Figures 7-9). The legs of the “staples” and L-shape corner elements were connected with metal wire twisted around both legs to increase rigidity.

Table 1: The “original” height of the ten jump-outs selected for this project. EV=Evaro, HH= Ravalli Hill.

		Dominant deer species in the area	Original Height		Modified height	
Area	ID#		ft	cm	ft	cm
EV	14	White-tailed deer	6' 8.5"	204	5' 0"	152
EV	17	White-tailed deer	6' 0"	183	5' 0"	152
EV	19	White-tailed deer	6' 8"	203	5' 0"	152
EV	20	White-tailed deer	6' 0"	183	5' 0"	152
EV	21	White-tailed deer	6' 1.5"	187	5' 0"	152
EV	23	White-tailed deer	5' 6"	168	5' 0"	152
RH	26	Mule deer	5' 11"	180	5' 0"	152
RH	27	Mule deer	6' 0"	183	5' 0"	152
RH	28	Mule deer	5' 9"	175	5' 0"	152
RH	29	Mule deer	5' 11"	180	5' 0"	152

Figure 4: The Montana Department of Transportation assisted with the lowering of 10 jump-outs. After removing concrete blocks of the face, soil from the top was deposited at the bottom for the landing area.

Figure 5: The prototype for the "bar" made from "2x2" inch and "4x4" inch treated lumber.

Figure 6: Several of the "staples" (60-inch horizontal, 42-inch legs) the L-shaped corner elements (36-inch swing arms, 42-inch legs).

Figure 7: The rebar installed with the L-shaped corner elements connected to the fence post.

Figure 8: The L-shaped corner elements were connected to the fence posts with brackets and screws.

Figure 9: The legs of the "staples" and L-shaped corner elements were connected with metal wire.

2.4 Experimental Treatment of Bar Height and Setback

The top of the wooden prototype of the bar was 18 inches (46 cm) above the surface of the jump-out and had 4 inches (10 cm) setback from the wall (Figure 10). The bars made from rebar were initially also 18 inches above the surface of the jump-out. However, they had to be positioned behind the concrete blocks that formed the wall and therefore they had an initial setback of 12 inches (30 cm) (Figure 11). Based on the initial results with the prototype, 4 inches setback appeared to be insufficient to allow the deer to step over the bar with their front legs and take advantage of the low height of the jump-out (Figure 12). Because the deer jumped the bar going down the effective height for the animals jumping down was 5 ft (1.52 m) plus an additional 18 inches (46 cm): 6½ ft (1.98 m) total height. Additional data from the rebar design (height 18 inches, setback 12 inches) showed an increase in mule deer jumping down compared to the wooden prototype, but the performance was still marginal and similar to the use of the unmodified jump-outs; less than 10% of the white-tailed deer and only 30-40% of the mule deer that were recorded on top of the jump outs jumped down. Therefore, further modifications were initiated to the bars. The height was reduced, and the setback was increased in 3-inch increments (Figure 13, Table 2).

Figure 10: The wooden prototype had a setback of 4 inches (10 cm).

Figure 11: The rebar had a minimum setback of 12 inches (30 cm) as the legs had to be positioned behind the concrete blocks of the face of the jump-out.

Figure 12: A mule deer jumps down the jump-out with the prototype (height 18 inches, setback 4 inches). The animal starts the jump from behind the bar and does not step over the bar first before jumping down.

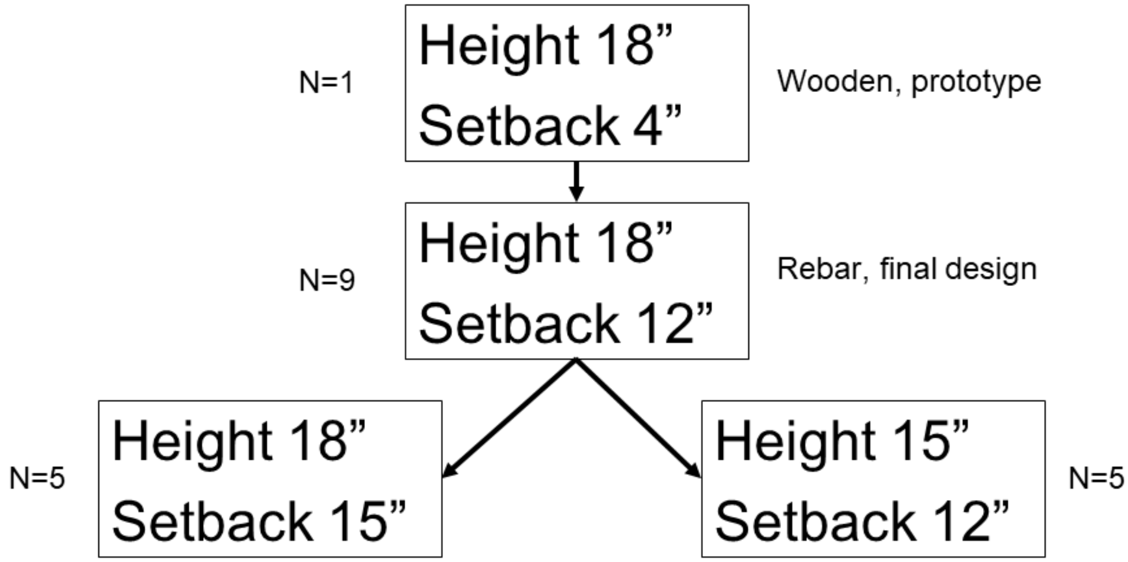

Figure 13: The treatments (height, setback) and the sample sizes (N) distributed over the 10 jump-outs that were lowered.

Table 2: The height and setbacks of the bar for ten jump-outs. EV=Evaro, RH= Ravalli Hill.

Area	ID#	Material	Period		Dimensions (inches)	
			Start	End	Height	Setback
EV	14	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	15	12
EV	17	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	18	15
EV	19	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	15	12
EV	20	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	15	12
EV	21	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	18	15
EV	23	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	18	15
RH	26	Wood	26 Apr 21	26 Aug 21	18	4
		Rebar	26 Aug 21	24 Apr 22	18	15
RH	27	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	15	12
RH	28	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	15	12
RH	29	Rebar	18 May 21	26 Aug 21	18	12
		Rebar	26 Aug 21	24 Apr 22	18	15

2.5 Research Cameras and Data Analyses

All 10 jump-outs had research cameras (Reconyx PC900 HyperFire) installed on 28 May 2021. The cameras were typically positioned on the habitat (safe) side of the fence, looking at the face of the jump-outs. This allowed the researchers to observe animals that appeared on the top of the jump-out and see animals that passed by on the safe side of the jump-out (Figures 14 and 15). In some cases, a camera needed to be installed on one of the fence posts at the edges of the jump-out because of the topography, vegetation, or land ownership. In all cases, a clear view of potential animals on top of the jump-outs was prioritized over a clear view of potential animals on the habitat side of the jump-out. The researchers analyzed the images from the cameras. The researchers identified the species, evaluated whether the animals came within 2 m (6.6 ft) of the face of the jump-out (on top and at the bottom of the jump-outs), noted if they showed interest in jumping up or down, and evaluated whether the animals ultimately jumped up or down. The researchers observed and counted the behavior of individual animals, regardless of whether they occurred in a group. Of the deer that jumped down to the habitat side of the jump-outs, the researchers also noted if the deer first stepped over the bar, and if so, with how many legs.

Figure 14: The typical view of the cameras allowing the researchers to see animals both on top and at the bottom of the jump-outs. Mule deer contemplates jumping down to the habitat side of the fence.

Figure 15: The typical view of the cameras allowing the researchers to see animals both on top and at the bottom of the jump-outs. Mule deer contemplates jumping up into the fenced road corridor.

3 RESULTS

3.1 Species Abundance

White-tailed deer and mule deer were the most frequently observed wild large mammal species at the jump-outs (Table 3). These numbers include all observations, regardless of whether the animals jumped up or down the jump outs.

Table 3: The abundance of individual species observed at the jump-outs, either on top or at the bottom, excluding human researchers, height, and setbacks of the bar for the jump-outs.

Species	Total individuals observed (N)	Individuals observed per treatment (N) Height - Setback			
		18" - 4"	18" - 12"	18" - 15"	15" - 12"
White-tailed deer	341	1	176	36	128
Cattle domesticated	212	11	140	10	51
Mule deer	153	27	31	89	6
Domesticated cat	55		32	13	10
Bird spp.	55			1	54
Black bear	37	4	8	18	7
Coyote	23		7	10	6
Bobcat	22	2	1	18	1
Human on foot	20			1	19
Red squirrel	20		3	2	15
Western striped skunk	16		5	9	2
Chipmunk spp.	7		2		5
Elk	7		5		2
Mountain lion	6	1		5	
Snowshoe hare	6		1	1	4
Deer unknown species	5		4		1
Domesticated dog	4		4		
Unknown species	4		2		2
Cottontail mountain	2		2		
Red fox	2				2
Unknown ungulate	2				2
Hare unknown	1				1
Human with bicycle	1				1
Moose	1		1		
Raccoon	1			1	
Wolf	1		1		

3.2 Jumping Behavior of all Species (Raccoon and Larger), Regardless of Bar Treatment

The overall effectiveness of the lowered jump-outs in allowing white-tailed deer to jump down, regardless of the height and setback of the bar, was only just above 5% (Table 4). On the other hand, no white-tailed deer jumped up into the fenced road corridor. For mule deer the effectiveness of the lowered jump-outs in allowing them to jump down, regardless of the height and setback of the bar, was about 64% (Table 4). Of the mule deer that were present at the bottom of the jump-outs, just under 7% jumped up into the fenced road corridor.

Besides the two deer species, other mammal species greater or equal to a raccoon were also evaluated for their behavior at the jump-outs (Table 4, Figures 16-20). However, due to small sample sizes no distinction was made between the different treatments for the bar. Black bear, bobcat, elk, mountain lion and wolf usually jump down to the safe side of the jump-out (>50%), whereas coyote and red fox occasionally jump down (≤50%). Bobcat and mountain lion always jumped up (100%), whereas black bear occasionally climbed up the face into the fenced right-of-way (12.5%), and coyote, elk, and moose were never observed jumping up.

Table 4: The overall effectiveness of the lowered jump-outs in allowing species to jump down (desired behavior) and jump up (undesired behavior).

Species	Total	Jump down (N)	Jump up (N)	In r-o-w[*1] (N)	In Habitat (N)		Jump down (%)	Jump up (%)
White-tailed deer	341	4	0	73	268		5.48	0.00
Mule deer	153	52	5	81	72		64.20	6.94
Bear black	37	14	2	21	16		66.67	12.50
Coyote	23	4	0	19	4		21.05	0.00
Bobcat	21	10	5	16	5		62.50	100.00
Elk	7	1	0	1	6		100.00	0.00
Mountain lion	6	3	3	3	3		100.00	100.00
Red fox	2	1	0	2	0		50.00	N/A
Moose	1	0	0	0	1		N/A	0.00
Raccoon	1	0	0	1	0		0.00	N/A
Wolf	1	1	0	1	0		100.00	N/A

[*1] Right-of-way

Figure 16: Some black bears first stepped over the bar; others crawled under.

Figure 17: Black bears typically jumped down (desired behavior) headfirst.

Figure 18: A bobcat jumps down to the habitat side of the jump-out (desired behavior).

Figure 19: An elk contemplates jumping up into the fenced road corridor.

Figure 20: A mountain lion jumps down to the habitat side of the jump-out (desired behavior).

3.3 Effectiveness Jump-outs for all Recorded Deer

Regardless of how close the animals came to the face of the jump-out, and regardless of the treatment, white-tailed deer barely jumped down (10% or less) to the habitat side of the fence (Figure 21). No white-tailed deer jumped up into the fenced road corridor for any of the treatments. Regardless of how close the animals came to the face of the jump-out, and regardless of the treatment, mule deer jumped down much more readily (17.7-100.0%) than white-tailed deer (Figure 22). The treatment with a height of 18 inches and a setback of 15 inches had 80.4% of all mule deer that were observed within the right-of-way jump down to the habitat side of the jump-outs (Figure 23). At the same time, this treatment allowed 14.7% of the mule deer that were observed on the habitat side of the jump-out to jump up into the fenced road corridor (Figure 24). While the treatment with a height of 15 inches and a setback of 12 inches also seemed to perform well, it suffered from low sample size.

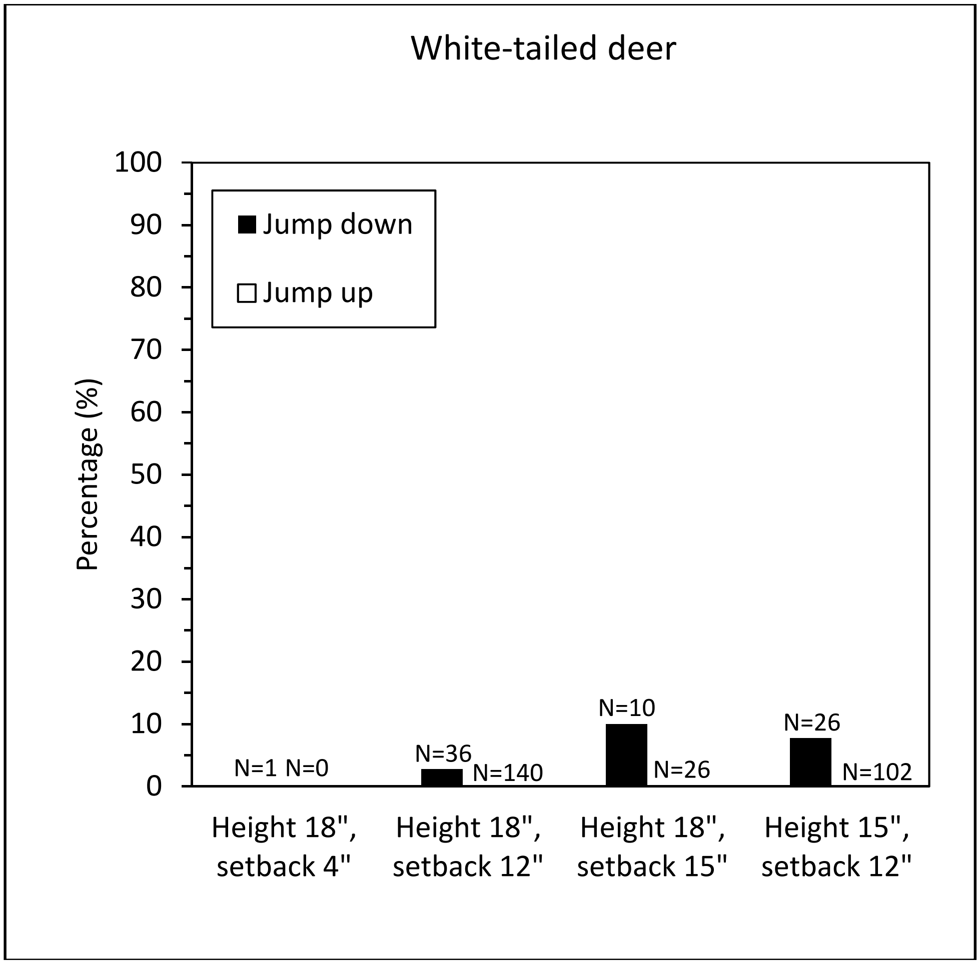

Figure 21: The percentage of white-tailed deer that jumped down (desired behavior) and that jumped up (undesired behavior) for the different treatments. N is the sample size for each treatment.

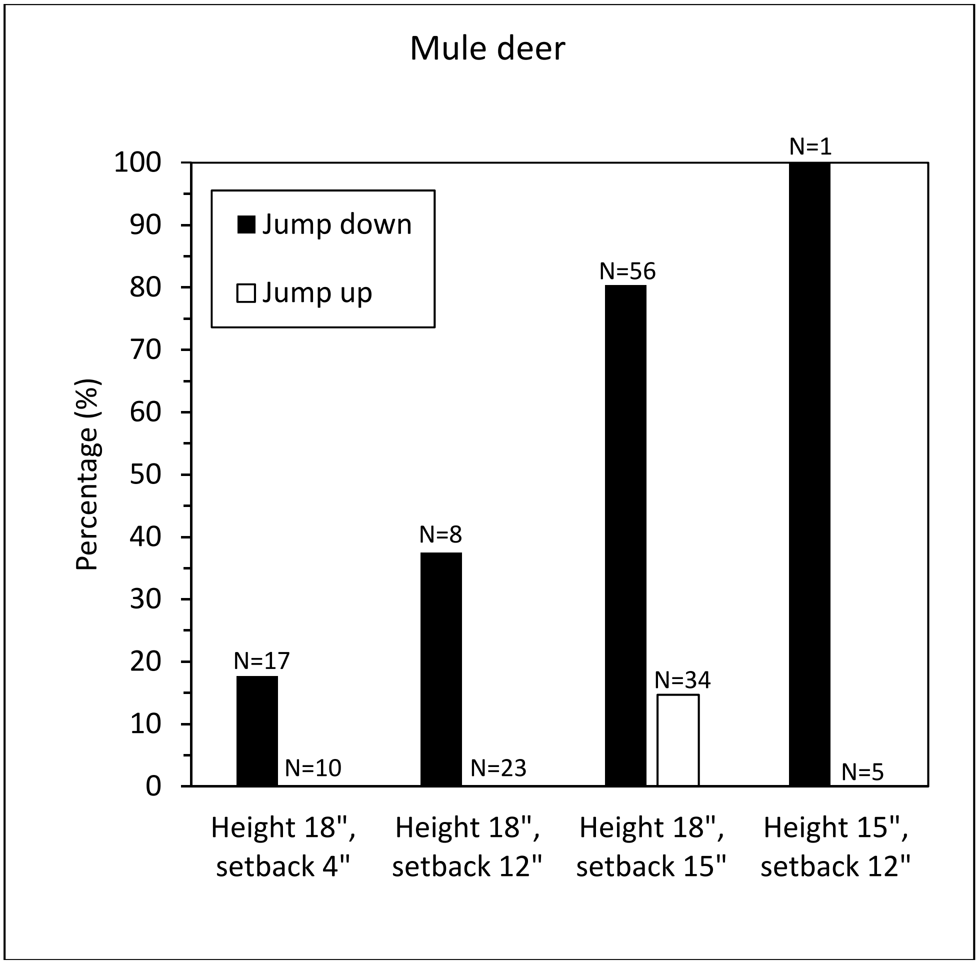

Figure 22: The percentage of mule deer that jumped down (desired behavior) and that jumped up (undesired behavior) for the different treatments. N is the sample size for each treatment.

Figure 23: A mule deer jumps down to the habitat side of the jump-out (desired behavior).

Figure 24: A mule deer jumps up into the fenced road corridor, clearing the bar (undesired behavior).

3.4 Effectiveness Jump-outs for Deer that Came within 2 m of the Jump-outs

There were only 24 white-tailed deer observed within the fenced right-of-way that did not come within 2 m of the face of the jump-out; 10 in the treatment “height 18 inches and setback 12 inches”, 4 in the treatment “height 18 inches, setback 15 inches”, and 10 in the treatment “height 15 inches, setback 12 inches”. This changed the respective results for these treatments to 3.9% (N=26), 16.7% (N=6), and 12.5% (N=16). There were 16 white-tailed deer observed on the habitat side of the jump-outs that did not come within 2 m of the face of the jump-out; 9 in the treatment “height 18 inches and setback 12 inches”, 3 in the treatment “height 18 inches, setback 15 inches”, and 4 in the treatment “height 15 inches, setback 12 inches”. This changed the respective results for these treatments to 0% (N=131), 0% (N=23) and 0% (N=98).

There were only 3 mule deer observed within the fenced right-of-way that did not come within 2 m of the face of the jump-out; 1 in the treatment “height 18 inches and setback 4 inches”, and 2 in the treatment “height 18 inches, setback 15 inches”. This changed the respective results for these treatments to 11.8% (N=16) and 83.3% (N=54). There were 9 mule deer observed on the habitat side of the jump-outs that did not come within 2 m of the face of the jump-out; 1 in the treatment “height 18 inches and setback 4 inches”, 5 in the treatment “height 18 inches and setback 12 inches”, and 3 in the treatment “height 18 inches, setback 15 inches”. This changed the respective results for these treatments to 0% (N=9), 0% (N=18) and 16.1% (N=31).

3.5 Deer Behavior when Jumping Down

There was only 1 white-tailed deer for which the images showed if and with how many legs the animal first stepped over the bar before jumping down (Table 5). However, the white-tailed deer for which this behavior was recorded, first stepped over the bar with 2 legs (the front legs). Mule deer jumped down through jumping over the bar (without first stepping over it) as well as through first stepping over the bar with one or more legs (Table 5). However, most of the mule deer that jumped down stepped over the bar with at least 1 leg, most often 2 legs (front legs), before jumping down (Figure 25). One mule deer stepped over with all 4 legs before jumping down. The jump-outs with the greatest setback (15 inches) received most of the successful jump downs and most of the mule deer that jumped down stepped over the bar with their two front legs before jumping down.

Table 5: The number of deer that successfully jumped down to the habitat side and with how many legs they first stepped over the bar, if any.

Species	Step over bar	Individuals observed per treatment (N) Height - Setback			
		18 - 4	18 - 12	18 - 15	15 -12
White-tailed deer	no step over				
	step over, 1 leg				
	step over, 2 legs		1		
	step over, 3 legs				
	step over, 4 legs				
Mule deer	no step over	3	1	12	1
	step over, 1 leg			4	
	step over, 2 legs		2	26	
	step over, 3 legs				
	step over, 4 legs			1	

Figure 25: A mule deer steps over the bar with both its front legs before jumping down (desired behavior).

4 DISCUSSION

Overall, the jump-outs that were lowered to a height of 5 ft (1.52 m) did not improve the effectiveness for white-tailed deer jumping down (unmodified jump-outs 6.88% vs. lowered jump-outs 5.48%) (Huijser et al. 2016). On the other hand, the probability of collisions also did not increase as no white-tailed deer were observed jumping up into the fenced road corridor (unmodified jump-outs 0.00% vs. lowered jump-outs 0.00% (Huijser et al. 2016). Overall, the jump-outs that were lowered to a height of 5 ft (1.52 m) about doubled the effectiveness for mule deer jumping down (unmodified jump-outs 32.35% vs. lowered jump-outs 64.20%) (Huijser et al. 2016). However, more mule deer jumped up into the fenced road corridor (unmodified jump-outs 0.00% vs. lowered jump-outs 6.94%) (Huijser et al. 2016). Nonetheless the balance of the modified jump-outs was positive; 52 mule deer jumped down (desired behavior) and 5 mule deer jumped up (undesired behavior). In other words, by doubling the effectiveness of the jump-outs for mule deer, 26 (52/2) more mule deer escaped from the fenced road corridor, while “only” 5 more mule deer entered the fenced road corridor, resulting in a “net benefit” of 21 mule deer which were no longer in danger of being hit by traffic.

The height and setback of the bar did influence the likelihood of mule deer jumping down to the habitat side of the fence. The treatment with a height of 18 inches and a setback of 15 inches had 80.4% of all mule deer that were observed in the fenced road corridor jump down (83.3% when the analysis was restricted to mule deer that came within 2 m (6.6 ft) of the vertical face of the jump-out). Further investigation showed that a setback of 15 inches had more of the mule deer place their front legs over the bar before jumping down. Apparently, a greater setback of the bar improved the performance of the jump-outs in allowing mule deer to escape the fenced road corridor.

5 CONCLUSION

The modified jump-outs about doubled the effectiveness in allowing mule deer to escape the fenced road corridor. However, there was no improvement for white-tailed deer. Further modifications of the bar with a lower height and greater setback are warranted for white-tailed deer. It may also be that a jump-out height of 5 ft (1.52 m) is still too high for white-tailed deer, regardless of the presence, height, and setback of a bar.

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8 APPENDIX

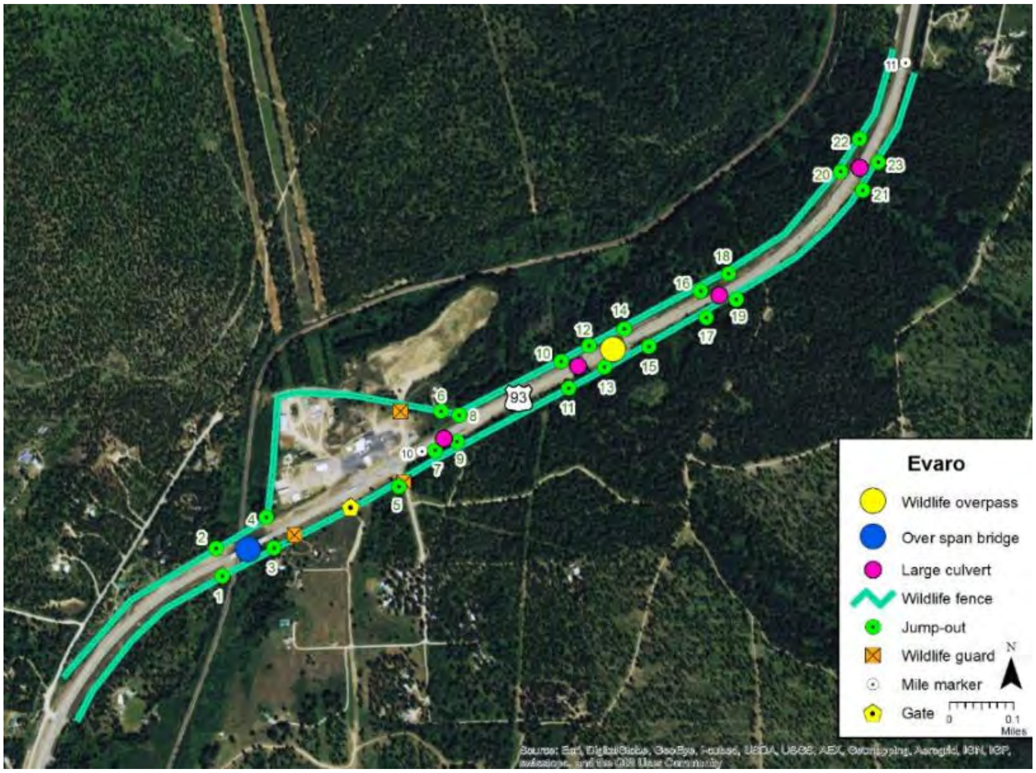

Figure 26: Location of the jump-outs in the Evaro area (green circles and associated ID#).

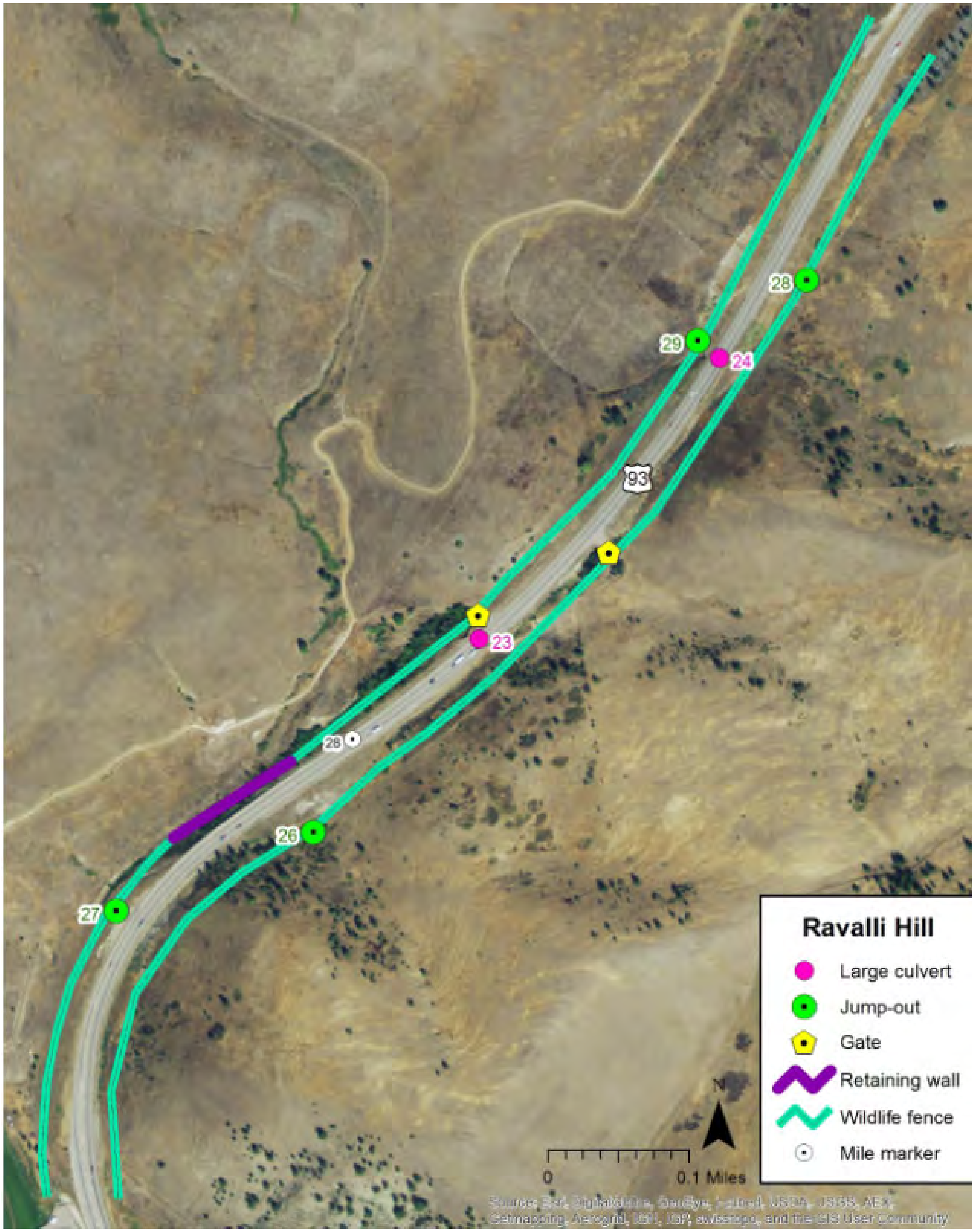

Figure 27: Location of the jump-outs in the Ravalli Hill area (green circles and associated ID#).

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